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Environmental Assessment of the Alaskan Continental Shelf

Final Reports of Principal Investigators

Volume 5. Biological Studies

Outer Continental Shelf Environmental Assessment Program

Boulder, Colorado

March 1979

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration

U.S. DEPARTMENT OF INTERIOR
Bureau of Land Management

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U.S. DEPARTMENT OF COMMERCE
Juanita M. Kreps, Secretary

National Oceanic and Atmospheric Administration
Richard A. Frank, Administrator

The facts, conclusions and issues appearing in these reports are based on interim results of an Alaskan environmental studies program managed by the Outer Continental Shelf Environmental Assessment Program (OCSEAP) of the National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce, and primarily funded by the Bureau of Land Management (BLM), U.S. Department of Interior, through interagency agreement.

DISCLAIMER

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ASSESSMENT OF AVAILABLE LITERATURE ON EFFECTS OF OIL POLLUTION ON BIOTA IN ARCTIC AND SUBARCTIC WATERS

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PETROLEUM IN MARINE ENVIRONMENTS AND ORGANISMS INDIGENOUS TO THE ARCTIC AND SUBARCTIC

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This is the third and final section of a three section final report. Sections I and II were published as follows:

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INTRODUCTION

The material included in this volume comprises Section III of the Literature Review commitment under OCSEAP Research Unit 75. The objectives were: review of the available literature as described in Task Element C1: (a) on toxicity of crude oils and crude oil components (including heavy metals), and (b) on the composition and toxicity of formation waters, various drilling muds, and their components: Compare these toxicities on the basis of species, life stage, temperature exposure, water source, oil source, geographic source of organism, and presence of heavy metals.

The subjects included in this section encompass the potential sources and levels of trace metals in the marine environment and their potential biological effects in relation to petroleum drilling and transport operations in arctic and subarctic environments. Four metals--cadmium, lead, chromium, and nickel--were chosen for detailed study in relation to their biological effects on organisms. The rationale for this choice was based on the metal compositions of petroleums, the respective metal toxicities, and other considerations. (See Chapter by Clark and Brown).

Section III represents the efforts of eight specialists on the staff of the Environmental Conservation Division of the Northwest and Alaska Fisheries Center. The extent of coverage and the emphasis and interpretation of findings are uniquely the authors.

In submitting this document, appreciation is again extended to the individuals acknowledged in Section I.

Donald C. Malins
Principal Investigator

SECTION III

POTENTIAL IMPACT OF TRACE METALS FROM PETROLEUM DRILLING AND TRANSPORT OPERATIONS ON ARCTIC AND SUBARCTIC MARINE ENVIRONMENTS: SOURCES, LEVELS AND BIOLOGICAL EFFECTS

LEVELS AND SOURCES OF CRITICAL TRACE METALS IN THE MARINE ENVIRONMENT

by

Robert C. Clark, Jr.
Environmental Conservation Division

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INTRODUCTION

Over 80 elements have been identified and quantified in seawater and at least 60 of them have been found in some crude petroleums or in the associated production waters. Pollutants produced by industrial technology contain a broad spectrum of heavy metals and other inorganic materials. The rapid advances of technology have resulted in steady increases in the drilling for and the transportation of crude oil and in the development of an enormous petrochemical industry capable of producing thousands of by-product or waste substances. Petrochemical wastes include both organic and inorganic substances. The gamut of these industrial wastes eventually makes its way into the environment with the majority ending up in some compartment of the marine environment [1].

NATURE OF CERTAIN ELEMENTS IN THE ENVIRONMENT

Some of the elements in petroleum are also found in seawater where they range in concentration from a few percent to parts per trillion (10^{-9}). The ecological aspects, or effects, of these elements may range from beneficial (essential) to detrimental (toxic). Any assessment of the biological effects of trace metals from petroleum on the marine environment must consider the levels of these elements in petroleum, drilling chemicals, and production (brine) waters; the levels naturally present in seawater; the chemical form of the metals; and the reactivity and toxicity of the chemical forms of the metals.

Table 1 summarizes the known information about the elements found in seawater and in petroleum and its production waters. Concentration units are given in micrograms per liter of solution (approximately parts per billion, 10^{-9} or ppb). Data on concentrations of the elements in seawater and on the principal chemical form (species) were taken mainly from the National Academy of Sciences publication Marine Chemistry [2], the text, Introduction to Marine Chemistry, by Riley and Chester [3], and the recent comprehensive review of minor elements in seawater by Brewer [108].

The principal chemical form of the element found in seawater can be an important factor in an element's effect on the marine biota. The lethal concentration of some toxic elements varies with the valency states of the elements (chromium in the +3 or +6) or with their chemical forms (methyl mercury is more toxic than mercuric chloride). Table 1 [column titled "Principal and (% free)"] also contains an estimate of the percentage of the chemical form present in the undissociated state in seawater. Some of the compounds may be present in the solvated states; others may consist of ion-pairs which result from a purely electrostatic attraction between oppositely charged ions, such as $MgSO_4^{\circ}$ (11% of magnesium occurs in seawater as this ion-pair), $MgHCO_3^{+}$ (1%), $MgCO_3^{\circ}$ (0.3%) [4].

An element may be present in seawater only at low levels for one or both of two reasons. First, it may be very reactive in the marine environment so that its removal by biological or sedimentary means is rapid. Secondly, the source materials may contain low levels of the element. Thus aluminum, a major constituent in igneous rocks, is a minor element in seawater because of its high reactivity. One estimate of the relative reactivity of elements can be obtained on the basis of their residence times in seawater. Elements with long residence times--the lower atomic number alkali metals and alkaline earths (excluding beryllium)--are characterized by the low reactivity of their ions. Those with short residence times (less than 1,000 years: Be, Al, Fe, La, Ce, Pr, Nd, Sm, Eu, Cd, Dy, Ho, Er, Yb, Lu, Nb, Pb and Th) display a high chemical (or biochemical) reactivity in the marine environment [5].

Data on the concentrations of the various elements in crude petroleum (Table 1) were collected from a number of sources [6,9,12,15,16, 18,19,21-24,26,27,31,33,35,37,40]; however, the compilation should not be construed to be an exhaustive survey. The wide ranges of some of the reported values demonstrates the chemical variability of petroleum. In some cases only maximum values were available. Data on the elemental content in production waters were taken from papers describing a limited number of crude oils or ground waters associated with petroleum production regions often from restricted geographic localities [7,13,14,17,20,24]. In these papers, data on the concentrations of elements in crude oil and production/ground waters were given as range of values to indicate the variability within the materials and to provide a basis of comparison. Ordinarily, however, the mean values for levels of the elements would tend to approach the lower limit of the range of values.

Most of the data in the column on permissible discharge levels for receiving waters in Table 1 were taken from the 1973 issue of Proposed Criteria for Water Quality [10] prepared by the United States Environmental Protection Agency; updated values taken from the 1975 Annual Report of the Council on Environmental Quality [11] were incorporated where applicable. Other values were taken from listings relating to quality of public water supply intake or livestock water supply, both dealing with fresh water [8]. The remaining data represent the lowest fresh water biological effect levels and were estimated at one to two orders of magnitude below the level permitted by regulation [8]. These values represent the upper limits of discharge of the various elements necessary to protect marine life. Some of the elements listed in Table 1 are considered essential to some marine organisms and, for the purpose of this discussion, were considered as non-toxic (NT) at levels of one to two orders of magnitude of that found in seawater. Nevertheless, at very high levels in the marine environment these elements could be toxic to some marine organisms; at low levels, nutritional deficiencies might occur. In either case, even these apparently non-toxic elements may have an impact on the marine environment.

BIOCONCENTRATION OF TRACE ELEMENTS

Living cells take up elements from solution against a concentration gradient. The assimilation of trace elements by marine organisms was reviewed by Bowen [41]; he characterized the biochemical relationships of the elements as follows:

(1) Chlorine is definitely rejected.

(2) Sodium, magnesium, bromine, fluorine, and sulfur are concentrated to a level of unity with the environment.

(3) Other elements, except the inert gases, are more strongly concentrated in living tissue than in seawater.

(4) The affinity by oxidation state of the cations by organisms is ranked in decreasing order as: 4+ and 3+ elements > 2+ transition metals > 2+ Group IIA metals > 1+ Group I metals.

(5) The affinity of plankton for various elements is: Fe > Al > Ti > Cr; Si > Ga; and Zn > Pb > Cu > Mn > Co > Ni > Cd.

(6) The affinity of brown algae for various elements is: Fe > La > Cr > Ga > Ti > Al > Si; Pb > Mn > Zn; Cd > Co > Ni.

(7) In general, the high molecular weight elements in a particular group of the periodic table are taken up more strongly than the low molecular weight elements.

(8) The affinity for anions increases with increasing ionic charge; organisms of lower phylogenic order usually concentrate trace elements more strongly than do organisms of the higher orders.

The ability to concentrate a particular element or group of elements may be characteristic for a particular family of organisms, or even to a particular species [3].

CLASSIFICATION OF TRACE ELEMENTS

Table 1 lists 81 elements present in detectable amounts in seawater, over 60 of these elements have been found in one or more crude oils or associated production/ground waters. Since the primary discussion of this section deals with trace metals, we can eliminate sixteen elements from Table 1 that are non-metals or occur in concentrations greater than one part per million (10^{-6}; ppm). These are hydrogen, boron, carbon, oxygen, fluorine, sodium, magnesium, silicon, sulfur, chlorine, potassium, calcium, selenium, bromine, iodine, and strontium. In addition to the metallic elements originally present in crude petroleum, several others can often be introduced by drilling muds (bentonite weighted with barite and hematite) and chemicals used in recovering the oil from the earth. These elements include sodium, magnesium, aluminum, calcium, iron, and barium salts in the form of bicarbonate, chloride, silicate, and sulfate [16].

The inert gases (helium, neon, argon, krypton, xenon, and radon) can also be eliminated because they are biologically inert. The nutritive elements, nitrogen and phosphorus, as well as the rare earth metals from lanthanum through tantalum can be eliminated. Further, it is possible to ignore beryllium, yttrium, niobium, rhodium, indium, rhenium, thallium, bismuth, polonium, radium, thorium, and protactinium since these elements occur at insignificant levels of less than 0.1 ppb in seawater or in most crude petroleum [42].

Another factor to be considered is the potential toxicity level which has been estimated and presented in the column on permissible discharge levels in Table 1. Some elements at trace concentration levels are toxic; for example, mercury exhibits toxic effects on both animals and plants at concentrations well below 1 ppm. On the other hand, other trace metals are considered essential for at least some plants and animals. For instance, vanadium is an essential nutrient for animals [102,103]. Other essential elements or micronutrients include manganese, cobalt, iron, molybdenum, and zinc. Zinc is an essential micronutrient for some marine species, and may be highly concentrated in biological material [42]. Yet oysters may be adversely affected by high levels of zinc; and, levels as low as 10 ppm can reduce the rate of photosynthesis of kelp [43]. Vanadium (and nickel) may be found in petroleum since it is frequently used to characterize crude oils [31]; however, consideration of this feature is beyond the scope of this discussion.

Toxicity data on a variety of freshwater or marine organisms for several elements which have been found in at least a few crude oils in the sub-ppm range (scandium, gallium, and germanium) were unavailable so these elements cannot be discussed. In addition, several more elements in the ppb range in some petroleums are found at or below recommended permissible discharge levels (zirconium, gold, and uranium) so these elements can also be eliminated.

At this point we are left with seventeen trace metals still to be considered (Li,Al,Ti,Cr,Ni,Cu,As,Rb,Ag,Cd,Sn,Sb,Cs,Ba,W,Hg, and Pb). Titanium can be eliminated since the apparent level of toxicity is above the levels found in production waters; only one reference to titanium values in crude oil was found in the literature. Lithium is not considered for similar reasons; it has been found in production/ground waters in the range of 0.1 to 100 ppm (mean 26 ppm) in a western Canada sedimentary basin [7]. No quantitative analyses for silver or tungsten in crude oils or associated production waters were found in the literature so these two metals cannot be considered further.

The physiological function of aluminum is not well understood [42] and the apparent levels in crude petroleum are within an order of magnitude or less for the proposed permissible discharge level into seawater [10]. It is a reactive element as indicated by its short residence time in seawater [5]. Aluminum is not considered to be a potentially damaging trace metal with regard to future arctic and subarctic petroleum activities.

Smith, Ferguson, and Carson [27] found that the arsenic content of crude petroleum ranged from 46 to 1,100 ppb with a mean of 263 ppb; Hitchon, Filby, and Shah [22] analyzed 80 Canadian crude oils; nine of the samples has less than the detectable level of arsenic (<2 ppb) and the remaining 71 showed an average of 111 ppb. Hence, the levels in crude petroleum are within an order of magnitude of the proposed total permissible discharge level of 50 ppb, and thus this element does not appear to warrant further discussion.

The lowest reported level of rubidium affecting a freshwater organism [8] is of the same order of magnitude as the maximum level reported in production/ground waters (Table 1). Such a level is considerably above the mean level of rubidium in production/ground waters (1,200 ppb) [7], or in seawater (120 ppb), or in crude petroleum (10-720 ppb). Therefore, this element was eliminated from further discussion.

The maximum level of tin in crude oils [19] appears to be below the lowest level required to produce a biological effect in freshwater organisms [8]. Insufficient information is available on cesium, an alkali earth metal, to relate its level in petroleum (an order of magnitude greater than in seawater) to toxicity data. The maximum level of barium reported for crude oil was less than the proposed permissible discharge level; hence, tin, cesium, and barium will also be eliminated.

Antimony appears to occur in petroleum at the same levels as the proposed permissible discharge levels for receiving marine waters, although the maximum reported value found in petroleum was considerably greater [9]. Few of the salts of antimony are soluble so the possibility that large concentrations will appear in the marine environment is not very great. Nevertheless, it has been considered a potential toxicant because of its toxicity to humans [1]. Relative to future arctic and subarctic petroleum development activities further discussion of this element does not appear warranted.

We now have six trace metals, namely, chromium, nickel, copper, cadmium, mercury, and lead, which occur in petroleum at trace levels and are toxic to at least some marine organisms at such levels. In view of their potential impact on the arctic and subarctic marine environments and organisms, these metals will be considered in the following discussion.

CRITICAL TRACE METALS IN PETROLEUM

COPPER AND MERCURY

An enormous amount of information has been published concerning the toxicity of copper and its salts to marine organisms [1]. Although the levels in production/ground waters in oil producing regions are higher than the proposed permissible discharge levels, they are within an order of magnitude. The levels of copper in crude petroleum tend to be considerably higher (mean of 1.3 ppm) [27] than the permissible discharge level.

The environmental impact of mercury is the subject of numerous reviews and monographs [44-46]. It is probably present in seawater as $HgCl_4^{-2}$ and $HgCl_2^{\circ}$ ion pairs at about 0.03 μg/l. The mercury content of offshore petroleum production waste water discharges is of the same order of magnitude or less [14]. However, the levels of mercury in crude petroleum range over three orders of magnitude, with a median value of 3.2 ppm [27]. Hitchon, Filby, and Shah [22] analyzed 88 western Canadian crude oils and found that 39 of the oils had a mercury content greater than the detection limit of 2 ppb with an average concentration of 51 ppb and a maximum value of 399 ppb. Filby [26] found levels of 1.49 and 21.2 ppb in two California crude oils and 139 ppb in a Venezuela crude oil. The greatest concentration of mercury occurred in the highest molecular weight fraction of the asphaltenes, probably as organometallic compounds but not as porphyrin complexes. Obviously, the source of the crude oil is an important factor, but in all cases the levels in crude oil were considerably above the levels found in seawater or those proposed for permissible discharges to marine waters.

For further information on the effects of copper and mercury on the marine environment, the reader is referred to the considerable body of literature listed in several of the review articles [2,44-46]. The discussion of trace metals associated with arctic and subarctic petroleum activities will, therefore, describe only the remaining four metals which, by and large, have had a less-well described coverage: chromium, nickel, cadmium, and lead. A review of the methods of analytical measurement of trace metal constituents in the marine environment by neutron activation analysis and by spectrophotometric techniques has been described by Bertine, Carpenter, Cutshall, Robertson, and Windom [47].

CHROMIUM

Levels

Chromium can exist in various forms, as chromous ion (Cr^{+2}), as chromic ion (Cr^{+3}), as chromite ion (CrO_3^{-3} or CrO_2^{-}), as chromate ion (CrO_4^{-2}), and as dichromate ion ($Cr_2O_7^{-2}$). In seawater the principal forms appear to be the CrO_4^{-2} and Cr^{+3} ions. In 1965, Chester [48] reviewed the literature with regard to the chromium content of marine sediments. Chromium should exist in oxygenated seawater as the CrO_4^{-2} ion based on oxidation-reduction theory, but it appears to be partly present in the +3 oxidation state, presumably as the hydroxide complexes [3].

Chromium is a moderately reactive element (residence time of 6,000 years) and occurs in seawater (0.04-0.5 μg/l) at levels considerably lower than those in crude petroleum (typical range 1.4 to 640 μg/l, maximum value reported was 3,000) or in production/ground water (from less than 1 to 34 μg/l, with a mean of 10 μg/l [17]). The United States Environmental Protection Agency has proposed a permissible discharge level for receiving waters of 100 μg/l due to the sensitivity of lower stages of aquatic life to chromium and to the accumulation of chromium by organisms in all trophic levels. Concentration factors of 1,600 in benthic algae, 2,300 in phytoplankton, 1,900 in zooplankton, 440 in the soft parts of molluscs, 100 in crustacean muscle, and 70 in fish flesh have been reported [10].

Sources

Chromic acid and chromates are used in the electroplating, dying, tanning, and other chemical industries and as corrosion inhibitors in industrial water cooling systems. Potassium chromic sulfate, $KCr(SO_4)_2$ $12H_2O$ (chrome alum), and chromic chloride, $CrCl_3 \cdot 6H_2O$, are added to the fluids used in the drilling for petroleum. These trivalent chromium salts cross link with the xanthan gum polysaccharide polymers of the drilling fluids, thereby increasing viscosity and efficiency. Chromium content can be as much as 140 ppm. Three chromium lignosulfonate compounds, ferrochrome lignosulfonate, chrome lignosulfonate, and chrome modified sodium lignosulfonate, are also used in drilling fluid formations. The lignosulfonates are by-products of the sulfide pulping of wood lignin. They are used to alter the viscosity, to thin (as a deflocculant), and to serve as a filtration control agent in drilling fluids. The nature of the complexes is not fully understood, but it appears that the hexavalent chromium salts might be strongly complexed with the organic lignosulfonate molecule such that the hexavalent chromium is not readily ionizable [49].

Hexavalent chromium as sodium chromate, $Na_2CrO_4 \cdot 10H_2O$ and sodium dichromate, $Na_2Cr_2O_7 \cdot 2H_2O$, are added to drilling fluids to inhibit corrosion (300 to 400 ppm Cr^{+6} in total fluid) and to prevent high temperature gellation (50 to 200 ppm).

Chromium is added as salts to some greases and tends to be concentrated in the high-boiling asphaltenic fraction during refining. Asphalt contains 0.5 to 3.6 ppm [27]; crude oil, 0.0014 to 3.0 ppm; and a heavy fuel oil, 0.093 ppm [37]. Table 2 gives the chromium content in different oils.

The sediments of the nearshore and deep sea areas of both the Atlantic and Pacific Oceans contain about the same level of chromium (80-100 ppm) [48]. The global average chromium concentration in seawater ranged from 0.04 to 0.5 ppb. The chromium content of the bottom sediments (particles smaller than 63 μm in diameter from the heavily-industrialized estuary of the Delaware River ranged from 33,000 to 447,000 ppb (dry weight) [51].

Falk and Lawrence [52] found exchangeable (leachable with 1-N ammonium acetate) chromium ion content of 0.3 ppm in the dried sludge material collected at the bottom of an arctic oil well drilling rig sump and a total chromium content of 22.0 ppm after digestion with *aqua regia*. Modern drilling operations employ a rotary system which requires circulation of a drilling fluid or mud to remove cuttings from the borehole. This fluid is pumped from the surface through the drill pipe and bit, and then is returned to the surface through the drill pipe annulus between the borehole and the drill string. Flow of the mixture of formation gas, oil, and production water (often a brine) into the borehole is blocked by the hydrostatic pressure fluid column that is sufficient to counterbalance or exceed the formation pressure. Drill cuttings and rock chips, after being brought to the surface, are screened from the drilling fluid by shakers located on the drilling platform and are directed toward the sump. In addition to cuttings and associated drilling fluid, other substances may be diverted toward the sump; these include rig washing compounds, waste lubricants and oils, coolants, and domestic wastes [52]. Should this sump leak or be allowed to discharge into arctic or subarctic ground, estuarine or marine waters, toxic contaminants could escape.

Chromium in crude petroleum may be associated with the high molecular weight asphaltene fraction according to Filby [26]. The ratio of concentration of chromium in the _n_-pentane-insoluble asphaltenes to that in a Tertiary California crude oil was nearly 12 to 1; there was slight concentration of chromium in the resin fraction (methanol insoluble and _n_-pentane soluble). Chromium also shows increasing concentration with increasing molecular weight of the asphaltene fraction, indicating that it is associated with the larger asphaltene molecules (4,000 to 22,000 molecular weight range by gel permeation chromatography). Filby [26] concluded that chromium existed in this California crude oil as an oil-soluble, non-porphyrin association probably incorporated into the high molecular weight asphaltene sheet structure through complexing at "holes" bordered by atoms of nitrogen, sulfur, or oxygen. The origin of the chromium in the asphaltenes may have involved complexing from an aqueous or solid phase during maturation of the petroleum in the source rocks or during migration to the reservoir rocks.

NICKEL

Levels

Although most nickel compounds are only midly toxic at low levels to either marine animals or humans, they are, even at small concentrations, highly toxic to plants [53]. Nickel exists as Ni^{+2} in seawater and is found at levels from 0.18 to 0.7 μg/l. In crude petroleum, levels from 0.027 to 345 ppm (mean about 166 ppm) [27] and in production/ground waters from less than 0.001 to nearly 0.4 ppm (mean 0.025 ppm in the western Canada sedimentary basin) [7] have been reported. The proposed level for marine permissible discharges is about 0.1 ppm [10]; the levels in crude petroleums are considerably greater than this proposed permissible level. Nickel is one of the two principal trace metals used in characterizing crude petroleums.

Certain trace metals, including nickel, appear to be enriched in the top 100 to 150 micrometers of seawater. Duce and coworkers [54] found that iron, copper, lead, and nickel are concentrated in the sea surface microlayer with respect to levels found in the underlying bulk seawater. Organic acids, proteinaceous material, and other surface-active organic substances may provide complexing sites for many trace elements and thus can be responsible for the transport and concentration of these materials at the ocean surface. The nickel content of the particulate matter (defined as that material passing through a 0.45 μm membrane filter) from a heavy frothy surface slick was 11 μg/l, about 50 times the nickel content of particulate material collected 20 cm below the surface. A second sample from a less pronounced slick had 13 μg/l, with an enrichment factor of 6.2. In both cases the nickel was associated with what was described as the "inorganic phase (insoluble in chloroform but soluble in diethyldithiocarbamic acid in methyl isobutyl ketone at a pH of 3).

Sources

The primary source of nickel in petroleum is probably the nickel contained in the crude oil. Nickel can occur as (1) porphyrin complexes (molecular weights less than 1,000) which are thought to have been derived from chlorophyll (or hemoglobin) thus indicating biogenic origin for petroleum, and from (2) non-porphyrin associations in the asphaltenic components (resins and asphaltenes: molecular weights greater than 4,000) of crude petroleum, either occupying sites bounded by heteroatoms (nitrogen, sulfur, or oxygen) or present in metalloporphyrins strongly associated by π-π bonding to the asphaltene aromatic sheets. Filby [26] found that 66% of the nickel in a California crude oil was as nickel porphyrins and 34% was as non-porphyrin nickel. The origin of the non-porphyrin nickel is not known, although Hitchon, Filby, and Shah [22] concluded that the nickel content was controlled by maturation processes of the crude petroleum rather than by migration processes.

Nelson [60] listed the nickel content of 197 crude oils from around the world. The nickel content of crude petroleums can vary over several orders of magnitude (Table 3).

Nickel is retained in the distillation bottoms that remain after fractional distillation in a refinery. The gas-oil fraction, which is the last distillate fraction of crude oil that is taken off the distillation column, is the feed stock for the catalytic crackers. Nickel contained in this gas-oil fraction can poison the cracking catalysts; hence, it is one of the better studied metals in petroleum. Nickel is sometimes added as cyclopentadienylnickel complexes to lubricants as antiwear agents, to minimize carbon deposits, and to improve lubrication and combustion.

Nickel appears to be strongly concentrated in deep sea sediments relative to both igneous rocks on land or nearshore sediments according to a 1965 review of the literature by Chester [48]. Trace metals introduced into the oceans from stream, rivers, and coastal pollution will be removed from solution mainly in the nearshore and outer continental shelf regions because the geochemical processes which bring about the removal of nickel are more effective in these nearshore environments. A discussion of the marine geochemistry of nickel based on the results of four GEOSEC profiles from the Atlantic and Pacific Oceans was presented by Sclater, Boyle, and Edmond [29].

CADMIUM

Levels

Cadmium exists in seawater as $CdCl_2$ and $CdCl^+$ ion pairs or Cd^{+2} ions and occurs at levels of 0.02 to 0.7 µg/l. Crude oil contains from 0.2 to 29 µg/l (0.002 to 0.029 ppm) cadmium and the effluent from a number of crude oil offshore production units contained essentially less than 0.050 ppm cadmium [14]. The Council on Environmental Quality [11] recommends a maximum permissible receiving water level of 10 µg/l (0.010 ppm). Cadmium acts synergistically with other substances to increase toxicity. For example, cadmium concentrations of 30 µg/l in combination with 150 µg/l of zinc from galvanized screening caused mortality of salmon fry [8]. Ordinarily, salmon fry will tolerate such levels when exposed to ions of the single element. Cadmium, like mercury, can form organic compounds which might be highly toxic or might lead to mutagenic or teratogenic effects.

Cadmium concentration factors of 1,000 in fish muscle, 3,000 in marine plants, and up to 29,600 in certain marine animals have been reported [10].

Sources

Friberg, Piscator, and Nordberg [55] presented an overview of cadmium in the environment in 1971. In 1973, Preston [56] provided a general review of cadmium in the marine environment--the inputs, distribution, seawater concentrations, concentrations in biota and sediment, and concentration factors--with particular reference to British waters. He concluded that the major potential pollution problems from cadmium probably exist in inshore waters where the primary sources of cadmium are river input, effluent discharges, sewage sludge dumping, and nearshore aerial fallout in the vicinity of industrial facilities. $CdCl^+$ is the predominant form of cadmium in seawater; the number of ions paired with sulfate and hydroxyl groups are insignificant [3]. Eaton, in 1976, reviewed the state of knowledge of the marine geochemistry of cadmium.

Cadmium has been found at levels of 0.13 ppm by ammonium acetate leaching (exchangeable ionic form) out of a total cadmium content of 0.5 ppm in the dried sludge of an arctic oil drilling rig sump [52]. Cadmium is not used extensively in petroleum development operations although it is added to some lubricants such as steam turbine oils where the dithiophosphates are used [27].

Cadmium levels appears to be several orders of magnitude lower than nickel levels in crude petroleum and the reported range varies by nearly three orders of magnitude (Table 4). It would appear that the cadmium is associated with the higher-boiling asphaltene fraction based on the high levels found in Alberta asphaltenes and in residual fuel oil.

LEAD

Levels

Lead probably exists as $PbCO_3$, $Pb(CO_3)_2^{-2}$, $Pb(OH)^+$, $PbCl_3^-$, $PbCl^+$, and Pb^{+2} and occurs at levels from 0.02 to 0.4 µg/l in seawater. It is reactive (400-year residence time) and occurs in crude petroleum ordinarily at a level from 0.5 to 430 µg/l with a maximum of 2,000 µg/l [19]. The Council on Environmental Quality recommends a maximum permissible level in receiving marine waters of 50 µg/l, which is below the levels found in some crude oils. Lead is a slow-acting cumulative poison and susceptibility among various marine species varies greatly [1]. Certain marine plants have the ability to concentrate lead up to 40,000 above background level and certain animals up to 2,000 times [58].

Lead appears to be enriched in the surface film on the sea but to no greater extent than nickel. Duce and coworkers [54] found lead contents of 1.4 and 1.5 µg/l in the particulate matter of two 100-150 µm thick slicks from Narragansett Bay compared to 0.24 and 0.28 µg/l in the particulate matter of samples collected 20 cm beneath the slicks. Chester in 1965 [48] published a survey of the occurrence and geochemistry of lead in deep sea and nearshore sedimentary environments.

Sources

Falk and Lawrence [52] found on two different sampling dates a month apart total lead concentrations in an arctic slope drilling rig sump of 6.3 and 66 ppm (dried sludge) of which 0.2 and 4.1 ppm were ammonium acetate-leachables (exchangeable ions). In the overlying water the respective dissolved lead contents were 0.038 and 0.10 ppm; a nearby uncontaminated river water content was about 0.006 ppm. Lead is not intentionally added during petroleum development activities although lead naphthenates are added to lubricants, greases, and gear oil [27]. Tetramethyl lead is an antiknock additive in gasolines. The concentrations in refined products all appear to be as great as or greater than those reported for several representative crude oils (Table 5).

CRITICAL TRACE METALS IN THE AQUATIC ENVIRONMENT

A representative sampling of reported concentrations of the four critical trace metals in a number of aquatic organisms (whole and specific organs) is given in Table 6. Data in Table 7 permit a comparison of the levels of these four trace metals in different marine sedimentary regimes. Table 9 is a summary of the levels of the trace elements in the various compartments in the marine environment.

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TABLE 1

Elements in seawater and in crude oil and associated production waters[a]

Chemical element		Occurrence in seawater			Reported ranges in crude oils	Reported ranges in production waters	Permissible levels in waters receiving discharges	Nature of the element; or biological function in seawater
Name	Symbol	Concentration range (μg/1)	Principal form and (% free)	Residence time (years)	(μg/1)	(μg/1)	(μg/1)[b]	
Hydrogen	H	1.1×10^8	H_2O	NA[c]	as H_2O	as H_2O	NT[d]	Major component
Helium	He	$(5-7) \times 10^{-3}$	He (gas)	--	8.9	--[e]	NT	Inert gas
Lithium	Li	170-180	Li^+ (99%)	2.3×10^6	--	10^2-10^5	7,200 (LiCl)[f]	--
Beryllium	Be	$(0.6-5) \times 10^{-3}$	$BeOH^+$	150	Trace	--	1,500	--
Boron	B	$(4.5-4.6) \times 10^4$	$B(OH)_3$, $B(OH)_4^-$	1.3×10^7	$(7.2-104) \times 10^3$	$(1.3-478) \times 10^3$	NT	Major component
Carbon	C	2.8×10^4	HCO_3^- (69%), $CO_3^=$ (9%)	NA	2.5×10^4 as C in CO_2	$(18-7,700) \times 10^3$ as HCO_3^-	NT	Major component
		2×10^2	Organic	NA	as crude oil	as crude oil		
Nitrogen	N	1.5×10^4 6.7×10^2	N_2 (gas) NO_3^-, NO_2^-, NH_4^+ Organic	NA	2.8×10^3 as N_2 9.5×10^5 (0.01-0.9%)	$(16-28) \times 10^3$-NH_4^+ 0-310 as NO_3^-	NT <2,600[f]	Major component
Oxygen	O	8.8×10^8 6.0×10^3 1.8×10^6	H_2O O_2 (gas) $SO_4^=$	NA	as H_2O 3.4×10^4 in CO_2 (<2% in total oil)	as H_2O -- --	NT	Major component
Fluorine	F	$(1.3-1.4) \times 10^3$	F^-, MgF^+	5.2×10^5	--	--	1,500	Major component
Neon	Ne	0.12	Ne (gas)	--	--	--	NT	Inert gas
Sodium	Na	1.1×10^7	Na^+ (99%)	6.8×10^7	$0.5-2.8 \times 10^4$	$1.3-1.3 \times 10^3$	NT	Major component
Magnesium	Mg	$(1.27-1.35) \times 10^6$	Mg^{+2} (87%)	1.2×10^7	$34-1.2 \times 10^3$ (max. 8×10^3)	$2 \times 10^3-6 \times 10^6$	NT	Major component

[a] Values based on data from references 6-40; 100.
[b] 1973 proposed criteria for receiving water for protection of marine life; references 10-11.
[c] NA = not applicable.
[d] NT = not considered toxic at concentration ranges found.
[e] -- = no data available.
[f] No marine effects data; lowest reported freshwater effect; reference 8.
[g] No marine effects data; proposed criteria for public water supply or livestock water supply (freshwater); reference 10.

TABLE 1 (cont'd)

Aluminum	Al	1-5	$Al(OH)_4^-$	100	$24-2.1\times10^3$	--	1,500	--
Silicon	Si	2×10^6	$Si(OH)_4, Si(OH)_3^-$	1.8×10^4	$(3-10)\times10^3$	$4\times10^2-1.8\times10^5$	NT	Major component
Phosphorus	P	60-90	$HPO_4^{=}, PO_4^{-3}, H_2PO_4^-$	1.8×10^5	(max. 9.8×10^4)	0-100 as PO_4^{-3}	100	Nutrient
Sulphur	S	$(9.0-9.3)\times10^5$	$SO_4^{=}$ (54%), $NaSO_4^-$	NA	(.001-5.5)%	$(2-4{,}800)\times10^3$	10 as H_2S	Major component
Chlorine	Cl	1.9×10^7	Cl^- (99%)	1×10^8	$1.1\times10^3-10^6$	$6\times10^3-1.9\times10^5$	NT	Major component
Argon	Ar	4.3-600	Ar (gas)	--	in natural gas	$(0.3-1.8)\times10^{-4}$	NT	Inert gas
Potassium	K	$(3.8-4.2)\times10^5$	K^+ (99%)	7×10^6	$(3.9-77)\times10^2$	$2\times10^3-8.8\times10^6$	NT	Major component
Calcium	Ca	$(4.1-4.2)\times10^5$	Ca^{+2} (91%)	1×10^6	$(1.7-100)\times10^2$ (max. 1.92×10^5)	$3\times10^3-3.9\times10^7$	NT	Major component
Scandium	Sc	$(0.6-4)\times10^{-3}$	$Sc(OH)_3$	4×10^4	0.27-199	--	--	--
Titanium	Ti	1	$Ti(OH)_4$	1.3×10^4	0.4-230	<10	4,000[f]	--
Vanadium	V	1-2.5	$H_2VO_4^-, HVO_4^{=}$	8×10^4	$24-1.3\times10^6$	<1	NT	Micronutrient
Chromium	Cr	$(0.4-5)\times10^{-1}$ (max. 1.5)	$Cr(OH)_3, CrO_4^{=}, Cr^{+3}$	6×10^3	1.4-690 (max. 3×10^3)	<1-34	100	--
Manganese	Mn	0.2-10 (oxic) 100-450 (anoxic)	Mn^{+2}, $MnCl^+$	1.4×10^3	$0.14-3.8\times10^3$ (max. 6×10^3)	$20-5.2\times10^4$	100	Micronutrient
Iron	Fe	2-10	$Fe(OH)_2^+$, $Fe(OH)_4^-$	140-200	$20-1.2\times10^5$	$10-8.7\times10^4$	300	Micronutrient
Cobalt	Co	$(0.3-4)\times10^{-1}$	Co^{+2}	3×10^4	$1.3-1.4\times10^4$	<5-29	1,000[g]	Micronutrient
Nickel	Ni	$(1-7)\times10^{-1}$ (max. 22.9)	Ni^{+2}	9×10^4	$27-3.4\times10^5$	<1-390	100	--
Copper	Cu	0.5-15	$CuCO_3, CuOH^+$	2×10^4	$3.5-6.3\times10^3$	<1-490	50	Micronutrient
Zinc	Zn	0.5-10	$ZnOH^+, Zn^{+2}, ZnCO_3$	2×10^4	$3.5-1.6\times10^5$	$30-2.7\times10^4$	100	Micronutrient
Gallium	Ga	$(2-3)\times10^{-2}$	$Ga(OH)_4^-$	1×10^4	11-810	0-6.0	--	--
Germanium	Ge	$(6-7)\times10^{-2}$	$Ge(OH)_4$	7.0×10^3	(max. 100)	0.3-8.5	--	--
Arsenic	As	2-3.7	$HAsO_4^{-2}$, $H_2AsO_3^-$	5×10^4	$2-2\times10^3$	--	50	--
Selenium	Se	$(0.9-4)\times10^{-1}$	$SeO_3^{=}$	2×10^4	$9-1.4\times10^3$	--	10	--
Bromine	Br	$(6.7-6.8)\times10^4$	Br^-	1×10^8	$72-2.2\times10^3$ (max. 1.25×10^4)	$(<1-1.1)\times10^6$	10^5 (Br) 100 (Br_2)	Major component

TABLE 1 (cont'd)

Krypton	Kr	$(2-3)x10^{-1}$	Kr (gas)	--	--	--	NT	Inert gas
Rubidium	Rb	120	Rb^{+} (99%)	$4x10^{6}$	10-720	$10-1.9x10^{4}$	$1.4x10^{4}$[f]	--
Strontium	Sr	$(8.0-8.5)x10^{3}$	Sr^{+2}	$4x10^{6}$	0.35-250	$(<1-1,300)x10^{3}$	NT	Major component
Yttrium	Y	$(0.01-3)x10^{-1}$	$Y(OH)_3$	$7.5x10^{3}$	Trace	$(1.9-4.7)x10^{-2}$	--	--
Zirconium	Zr	$3x10^{-2}$	$Zr(OH)_4$	--	2.4-9.8	<10	$1.4x10^{4}$[f]	--
Niobium	Nb	$1x10^{-2}$	--	300	--	--	--	--
Molybdenum	Mo	10	$MoO_4^{=}$	$2x10^{5}$	$1.0-7.3x10^{3}$	--	NT	Micronutrient
Rhodium	Rh	$(7-11)x10^{-3}$	--	--	--	--	--	--
Silver	Ag	$(0.02-3)x10^{-1}$	$AgCl_2^{-}, AgCl_3^{=}$	$4x10^{4}$	Trace	--	0.5	--
Cadmium	Cd	$(0.2-7)x10^{-1}$ (max. 20.5)	$CdCl_2, CdCl^{-}, Cd^{+2}$	$(1-50)x10^{4}$	0.2-29 (max. 50)	50	10	--
Indium	In	$(0.1-4)x10^{-3}$	$In(OH)_2^{+}$	--	(max. 0.1)	--	--	--
Tin	Sn	$(0.2-8)x10^{-1}$	$SnO(OH)_3^{-}$	$1.0x10^{5}$	0.005-190 (max. $1.3x10^{4}$)	1-12	$2.5x10^{4}$ ($SnCl_2$)	--
Antimony	Sb	$(2-5)x10^{-1}$	$Sb(OH)_6^{-}$	$7x10^{3}$	6-300 (max. $1.1x10^{4}$)	--	200	--
Iodine	I	60	IO_3^{-}, I^{-}	$4x10^{5}$	$10-9x10^{3}$	$(9-1,560)x10^{2}$	$2.8x10^{4}$ (I_2)[f]	--
Xenon	Xe	$(0.5-1)x10^{-1}$	Xe (gas)	--	--	--	--	Inert gas
Cesium	Cs	$(3-5)x10^{-1}$	Cs^{+} (99%)	$6x10^{5}$	4-68	200-870	--	--
Barium	Ba	4-20	Ba^{+2}	$4x10^{4}$	0.2-308	--	$1x10^{3}$	--
Lanthanum	La	$(3-12)x10^{-3}$	$La(OH)_3, La^{+3}$	440-600	0.03-39	$(21-32)x10^{-2}$	150	Rare earth
Cerium	Ce	$(1.0-5)x10^{-3}$	$Ce(OH)_3, Ce^{+3}$	80	Trace	$(19-20)x10^{-2}$	140	Rare earth
Praeseodymium	Pr	$(6-26)x10^{-4}$	$Pr(OH)_3, Pr^{+3}$	320	--	$(2.3-25)x10^{-3}$	--	Rare earth
Neodymium	Nd	$(28-92)x10^{-4}$	$Nd(OH)_3, Nd^{+3}$	270	Trace	$(32-42)x10^{-2}$	--	Rare earth
Samarium	Sm	$(5-17)x10^{-4}$	$Sm(OH)_3, Sm^{+3}$	180	(max. 0.78)	$(25-42)x10^{-2}$	--	Rare earth
Europium	Eu	$(1-4.6)x10^{-4}$	$Eu(OH)_3, Eu^{+3}$	300	0.6-23.2	--	--	Rare earth

TABLE 1 (cont'd)

Gadolinium	Gd	$(7-24)x10^{-4}$	$Gd(OH)_3, Gd^{+3}$	260	--	$(23-40)x10^{-2}$	--	Rare earth
Terbium	Tb	$1x10^{-4}$	$Tb(OH)_3, Tb^{+3}$	--	--	--	--	Rare earth
Dysprosium	Dy	$(9-29)x10^{-4}$	$Dy(OH)_3, Dy^{+3}$	460	Trace	--	--	Rare earth
Holmium	Ho	$(2-8.8)x10^{-4}$	$Ho(OH)_3, Ho^{+3}$	530	--	--	--	Rare earth
Erbium	Er	$(9-24)x10^{-4}$	$Er(OH)_3, Er^{+3}$	690	--	$(13-22)x10^{-2}$	--	Rare earth
Thulium	Tm	$(2-5.2)x10^{-2}$	$Tm(OH)_3, Tm^{+3}$	$1.8x10^3$	--	--	--	Rare earth
Ytterbium	Yb	$(8-20)x10^{-4}$	$Yb(OH)_3, Yb^{+3}$	530	--	$(6.7-11)x10^{-2}$	--	Rare earth
Lutetium	Lu	$(1-4.8)x10^{-4}$	$Lu(OH)_3, Lu^{+3}$	450	--	--	--	Rare earth
Hafnium	Hf	$<8x10^{-3}$	--	--	--	--	--	--
Tantalum	Ta	$(2-20)x10^{-3}$	--	--	--	--	--	--
Tungsten	W	0.12	$WO_4^{=}$	$1.2x10^5$	--	--	$1.1-10^{5}$ f	--
Rhenium	Re	$8x10^{-3}$	ReO_4^-	--	(max. 200)	--	--	--
Gold	Au	0.004-3.4	$AuCl_2^+$	$2x10^5$	0.024-3.0	--	400 f	--
Mercury	Hg	$(0.2-2)x10^{-1}$	$HgCl_4^{=}$, $HgCl_2$	$8x10^4$	$23-3x10^4$	<0.5	1	--
Thallium	Tl	$1x10^{-2}$	Tl^+	--	--	0-4.2	100	--
Lead	Pb	$(2-40)x10^{-2}$ (max. 14)	$PbCl_3^-, PbCl^+$ $PbOH^+$, Pb^{+2} $PbCO_3, Pb(CO_3)_2^{=}$	$4x10^2$	0.5-430 (max. $2x10^3$)	--	50	--
Bismuth	Bi	$2x10^{-2}$	$BiO^+, Bi(OH)_2^+$	$4.5x10^4$	Trace	--	--	--
Polonium	Po	$2x10^{-11}$	$PoO_3^{=}, PoO(OH)_2^{\circ}$?	--	--	--	--	--
Radon	Rn	$6x10^{-13}$	Rn (gas)	--	--	--	NT	Inert gas
Radium	Ra	$7-10x10^{-8}$	Ra^{+2}	--	--	--	--	--
Thorium	Th	$1x10^{-2}$	$Th(OH)_4$	200-350	--	--	$(4-8)x10^{2}$ f	--
Protactinium	Pa	$5x10^{-8}$	--	--	--	--	--	--
Uranium	U	3.2	$UO_2(CO_3)_3^{-4}$	$3x10^6$	0.01-434	--	500	--

TABLE 2

Chromium content of petroleum and refined products

Crude oil or refined product	Number of samples	Chromium content[a]	Reference
<u>Crude oils</u>			
Russian - Oligocene	8	1.4 - 250	15
Louisiana	1	1.6	21
Libyan	3	1.9 - 15	21
	1	2.3	37
Californian	5	7.9 - 17	21
- Tertiary	2	630 - 690	26
In porphyrins	(57.5%)	300	26
In resins	(37.5%)	894	26
In asphaltenes	(4.99%)	7,540	26
Wyoming	1	8.7	21
Italian	4	23 - 150	98
Canadian	1	40	16
Colorado	1	80	16
Alberta mean	42	93	22
maximum		1,680	22
Arabian	1	160	16
Venezuelan	2	380 - 430	26, 37
Boscan	1	1,110	16
World crude oils -			
mean	-[b]	8	27
maximum	-	3,000	19
range	-	1.6 - 17	27
<u>Refined products</u>			
Used jet engine oils	16	1,100 - 2,800	50
Used reciprocating engine oils	5	1,700 - 10,000	50
Heavy fuel oil	1	93	37
Asphalt	-	500 - 3,600	27

[a] ng/g ≃ μg/l ≃ ppb

[b] - = not known

TABLE 3

Nickel content of petroleum and refined products

Crude oil or refined products		Number of samples	Nickel content[a]	Reference
Crude oils				
New Mexico - Cretaceous		1	24	31
Italian		4	<100 - 3,000	98
total crude oil	(100%)	1	59,100	98
oily components	(70.9%)		700	98
resins	(11.1%)		108,000	98
carbenes & asphaltenes	(18.0%)		259,000	98
Oklahoma - Pennsylvania & Ordovician		2	198 - 18,000	31
Russian - Oligocene		3	280 - 4,060	15
Colorado		1	400	16
		2	680 - 1,440	31
Alberta - Cretaceous		1	609	37
Kansas - Pennsylvania & Ordovician		3	900 - 8,070	31
Canadian		1	1,600	16
Arkansas - Cretaceous & Jurassic		2	1,900 - 9,200	31
South Louisiana		1	2,200	59
Utah - Tertiary		1	2,700	31
Arabian		1	5,300	16
Kuwait		1	7,700	59
Sumatran		1	8,000	16
Wyoming		11	650 - 22,000	31
Alberta		69	<100 - 74,000	22
Montana - Mississippian		1	12,000	31
California - Midway		1	31,000	16
Libyan		3	49,000 - 105,000	21
California - Tertiary		1	93,500	26
In porphyrin fraction	(57.5%)		7,210	26
In resin fraction	(37.5%)		147,000	26
In asphaltene fraction	(4.99%)		852,000	26
Venezuelan		1	112,000	16
Boscan		1	117,000	37
Wyoming		1	113,000	21
California		5	138,000 - 264,000	21

TABLE 3 (cont'd)

Crude oil or refined product	Number of samples	Nickel content	Reference
World crude oils			
mean	-[b]	166,000	27
range	-	49,000 - 340,000	27
range	197	27 - 150,000	60
Louisiana	1	345,000	21
Refined products			
Used jet engine oils	16	560 - 2,500	50
Used reciprocating engine oils	5	670 - 2,500	50
No. 2 fuel oil	1	500	59
Residual fuel oil	1	37,000	21
Bunker C fuel oil	1	89,000	59
Fuel oils, undefined	100	1,000 - 1,000,000	101
Asphalt	4	86,000 - 104,000	27, 98
Italian	1	136,000	98
Oily components (46.2%)		1,300	98
Resins (19.6%)		122,000	98
Carbenes & asphaltenes (34.2%)		326,000	98

[a] ng/g ≃ μg/l ≃ ppb

[b] - = not known

TABLE 4

Cadmium content of petroleum and refined products

Crude oil or refined product	Number of samples	Cadmium content[a]	Reference
Crude oils			
Alaskan	1	0.20, 0.32	37
Louisiana	1	0.35, 0.39	37
South Louisiana	1	<5 - 15	61
Utah	1	0.50, 0.60	37
California - Tertiary	-[b]	<0.5	37
California - Tertiary	1	3.83, 40.9	37
Nigeria	1	1.22, 1.77	37
Nigeria	1	<5	61
Alberta - Upper Devonian	1	9.6, 9.9	37
Alberta - Upper Devonian	1	25.2, 29.1	37
Alberta - Asphaltene fraction	1	208, 241	37
Asphaltene fraction	1	1,520, 1,700	37
Sumatra - Miocene	1	16.8, 17.5	37
Arabian Light	1	<5 - 22	61
Refined products			
Gasoline	-	10 - 50	27
	1	<1 - 2	61
	7	10 - 40	101
Jet fuel	1	<2	61
No. 2 fuel oil	1	<2	61
Residual fuel oil	1	930, 4,660	37

[a] ng/g ≈ μg/l ≈ ppb

[b] - = Not known

TABLE 5

Lead content of petroleum and refined products

Crude oil or refined product	Number of samples	Lead content[a]	Reference
<u>Crude</u> <u>oils</u>			
Russian crude - Oligocene	5	0.5 - 430	15
Venezuela crude	2	170 - 310	99
World crude oil - range	-[b]	17.0 - 310	27
- maximum	-	2,000	9
<u>Refined</u> <u>products</u>			
Gas turbine fuels	-	<20 - 2,000	27
Aviation turbine fuels	-	<50 - 3,000	27
Kerosines	-	0 - 3,000	27
Burner fuel oils	-	0 - 3,500	27
Diesel oils	-	<10 - 5,000	27
Gasolines	7	10,000 - 1,000,000	101
- Regular	1	727,000	99
- Low-lead	1	123,000	99
Bunker C fuel oil	-	2,000	99
Residual fuel oil	-	1,510	37
Lubricating oils			
- Jet engine	3	3,700 - 11,000	99
- Used jet engine	16	0.5 - 88	50
- Used reciprocating engine	5	0 - 4,800	50

[a] ng/g ≃ μg/l ≃ ppb

[b] - = Not known

TABLE 6

Critical trace metals in representative marine organisms

Marine Organism Species	Source	Concentrations in ppm (dry weight) Chromium	Nickel	Cadmium	Lead	Reference
Algae						
Fucus vesiculosus	Bristol Channel-U.K.	---[a]	10.5-29.6	3.8-25.6	---	62
	Bristol Channel-U.K.	---	---	2-75	ND[b]-19	63
	Severn Estuary-U.K.	---	---	15-220	ND-8.5	64
	English Channel-U.K.	---	3.4-18.0	0.5-20.8	2.2-4.2	30
	Western Irish Sea-U.K.	---	2.9-9.5	0.5-1.5	1.4-7.7	30
	Eastern Irish Sea-U.K.	---	5.0-9.8	0.5-3.0	0.6-9.0	30
	Western Scotland-U.K.	---	1.8-8.4	0.9-2.1	0.5-4.3	30
	North Sea-U.K.	---	2.9-10.9	0.6-2.1	2.3-5.7	30
	North Sea-U.K.	---	3.2-17	0.5-2.7	3.1-10	30
Porphyra umbilicalis	Western Irish Sea-U.K.	---	0.2-9.6	0.10-0.97	0.8-10.5	30
	Eastern Irish Sea-U.K.	---	0.6-9.7	0.05-0.87	1.1-10.5	30
Ulva lactuca	North Sea-U.K.	---	1.4-5.9	0.27-0.76	0.8-7.3	28
Sargassum sp.	Poole Harbour-U.K.	---	8-33	1.0-4.8	16-66	36
Spartina alterniflora	Caribbean Sea	ND[b]	3.9-7.9	1.3-5.2	ND-22.4	25
	Eastern U.S.	---	---	0.5	5.3	65
Radiolarians	Oregon offshore-U.S.	---	3.0-9.7	0.4-1.1	4.3-27.7	66
	Monterey Bay-U.S.	---	4.2	6.3	8.7	66
Mixed phytoplankton	Monterey Bay-U.S.	<0.4	1.60	1.65	1.22	66
	Eastern U.S.	---	---	2.1	18	65
Sponges	Caribbean Sea	0.7-1.3	27.6-4,000	2.6-12.9	ND	25
	Gulf of Mexico	---	---	4.3	0.30	67
Coelenterates						
Cyanea capillata	Continental Shelf, New York	0.6	0.6	300	3.8	72
	Land-locked fjord	1.3	30	---	27	72
Ctenophora						
Beröe cucumis	Continental Shelf, New York	<0.7	<0.7	<350	4.2	72
Sea anemones						
Tealia felina	Irish Sea-U.K.	0.37	3.3	0.66	2.6	68
Alcyonium digitatum	Irish Sea-U.K.	<0.41	17	4.1	24	68
Unidentified species	Oregon coast-U.S.	---	---	0.11	1.5	69
Brachiopods	Oregon coast-U.S.	---	---	2.0	28	69
Chaetognaths (arrow worms)						
Sagitta elegans	Continental Shelf, New York	<0.2	104	<100	65	72

[a] --- = No data available.
[b] ND - Not detected.
[c] Wet weight.

TABLE 6 (continued)

Marine Organism Species	Source	Concentrations in ppm (dry weight) Chromium	Nickel	Cadmium	Lead	Reference
Mixed zooplankton	Caribbean Sea	1.3-40	6.1-23.8	2.6-10.4	16.6-66.6	25
	Gulf of Mexico	ND	10.5	2.6	ND	25
	Gulf of Mexico	---	---	1.8-7.4	3.2-500	67
	Oregon coast-U.S.	---	---	1.74	42	69
	Monterey Bay-U.S.	<0.4	3.06	4.84	4.77	66
	Open Pacific Ocean	---	3.2-13.2	1.9-16.0	1.5-18.0	66
	Caribbean Sea (0.5 m)	---	33	5	39	71
	" " (100 m)	---	61	6	52	71
	" " (150 m)	---	20	4	max. 1,060	71
	" " (200 m)	---	25	4	110	71
	" " (500 m)	---	22	4	75	71
	" " (all depths)	---	42	5	49	71
Mixed plankton	Northeast Atlantic	---	---	<0.03-175	<0.2-373	70
	Western Atlantic	---	---	0.4-24	2-250	65
	Clyde Sea-U.K.	---	---	0.31-6.00	<1.2-3,040	70
	North Sea-U.K.	---	---	1.59-8.50	<3.1-1,000	70
Micro plankton	Hawaii	---	11.5	1.6	29.4	66
Mixed copepods	Eastern U.S.	---	---	0.9-3.1	4-97	65
Centropages typicus & *C. hametus*	Continental Shelf, New York	60	13	<100	300	72
Calanus finmarchicus	Continental Shelf, New York	---	25-29	<180	30-100	72
Mixed euphausiids	Oregon coast-U.S.	---	---	1.05-1.22	444-497	69
	Oregon-Washington coast-U.S.	<0.09-0.27	---	0.33-2.8	<7	73
Euphausiia krohnii	Continental Shelf, New York	<0.2	1.1	<100	3.7	72
Euphausiia pacifica	Oregon coast-U.S.	---	---	0.94-2.22	4.4-14	69
Shrimp	Gulf of Mexico	ND	3.9-5.3	0.7-0.9	ND	25
	Gulf of Mexico	---	---	0.04-0.05	0.09-0.10	67
sand	Oregon coast-U.S.	---	---	0.78	1.6	69
Calathea	Oregon coast-U.S.	---	---	0.64-0.99	16-17	69
Pink - whole	Washington-Oregon coast-U.S.	0.12-0.28	---	0.20	<2	73
- tail muscle	" "	<0.1	---	0.54-1.0	<2	73
- internal organs	" "	1.2	---	---	<2	73
- shell	" "	<0.2	---	---	---	73
- eggs	" "	<0.1	---	---	<5	73
Pandalus jordanii	Oregon coast-U.S.	---	---	0.18-0.96	1.3-3.5	69
Penaeus setiferus	Eastern U.S.	---	---	<0.1-0.5	<2.0	65
Crangon vulgaris	Severn Estuary-U.K.	---	---	125	34	74
	Milford Haven-U.K.	---	---	4.9	56	74
	Bristol Channel-U.K.	---	1.0	0.4	8.0	75
Penaeus japonicus	Bristol Channel-U.K.	---	2.0	1.2	8.0	75

TABLE 6 (continued)

Marine Organism: Species	Source	Concentrations in ppm (dry weight): Chromium	Nickel	Cadmium	Lead	Reference
Lobsters						
Panulirus argus	Florida-U.S.	---	---	2.4	<1.0	65
Homarus americanus	Maine-U.S.	---	---	<0.1-0.5	<1.0-5.6	65
Crabs						
Callinectes sapidus (blue)	Eastern U.S.	---	---	0.2-0.6	<0.5-21	65
Libnia sp. (spider)	" "	---	---	0.4-0.6	<0.5-6.9	65
Menippe mercenaria (stone)	" "	---	---	1.0	1.3	65
Unidentified	Caribbean	ND	7.9-9.2	1.9-2.3	44.3-50.0	25
Limpets						
Patella vulgata - shell	Irish Sea-U.K.	---	0.54	2.0	46	76
- whole	Irish Sea-U.K.	---	2.5	31	32	76
	Bristol Channel-U.K.	---	---	9-500	ND-27	63
	Bristol Channel-U.K.	---	12.3	145	---	75
	Severn Estuary-U.K.	---	---	30-550	3.0-9.5	64
	Western Irish Sea-U.K.	---	3.1-24	2.8-35	3.5-85	30
	Eastern Irish Sea-U.K.	---	4.5-9.9	3.8-23	5.4-12.5	30
	North Sea-U.K.	---	4.5-14	2.9-7.1	1.5-9.3	28
Acmaea digitalis - shell	Central California-U.S.	<5.7	---	<2.5-6.2	<9.0-108	77
- tissue	Central California-U.S.	7.1-24.2	---	6.7-12.1	7.5-931	77
Abalone						
Haliotis rufescens - gills	Northern California	0.58-0.62	80-92	8.4-8.5	<0.1	79
	Central California	1.1	69	13	<0.1	79
	Long Beach Harbor	4.0	111	3.5	<0.1	79
	Southern California	1.8	103	20	<0.1	79
- mantle	Northern California	0.0-1.8	26-43	6.0-6.2	<0.1	79
	Central California	2.9	19	5.1	<0.1	79
	Long Beach Harbor	13	56	2.8	<0.1	79
	Southern California	3.4	43	13	<0.1	79
- digestive gland	Northern California	1.4-5.3	2.6-11	184-252	9-33	79
	Central California	3.2	6.2	1,160	18	79
	Long Beach Harbor	13	2.5	258	41	79
	Southern California	2.0	2.5	967	19	79
- foot	Northern California	---	0.7-1.6	0.17-0.24	<0.1	79
	Central California	---	0.6	0.31	<0.1	79
	Long Beach Harbor	---	1.6	0.23	<0.1	79
	Southern California	---	0.2	0.53	<0.1	79
Snails						
Polinices duplicatus	Eastern U.S.	---	---	0.1-0.3	0.5-2.9	65
Thais emarginata - shell	Central California	<5.7-10.5	---	<2.5-3.3	<9.0	77
- tissue	" "	<1.5	---	13.5	<2.2	77
Tegula funebralis - shell	" "	<5.7-15.8	---	<2.5-9.7	<9.0	77
- tissue	" "	<1.5-12.2	---	<1.0-4.8	<2.2-9.8	77
Nucella lapillus - shell	" "	---	0.25	1.64	0.45	76
- whole	" "	---	2.4	73	4.9	76
	Severn Estuary-U.K.	---	---	62-425	5.0-27	64
	Bristol Channel-U.K.	---	---	31-725	ND-38	63

TABLE 6 (continued)

Marine Organism Species	Source	Concentrations in ppm (dry weight) Chromium	Nickel	Cadmium	Lead	Reference
Snails						
Buccinum undatum - shell	Irish Sea-U.K.	---	0.12	0.048	0.45	76
- whole	Irish Sea-U.K.	---	0.60	2.2	5.4	76
Busycon sp.	Eastern U.S.	---	---	0.1-0.3	2.0	65
Liparis liparis	Severn Estuary-U.K.	---	---	13.7-16.8	25.8-29.9	74
Littorina littorea	Bristol Channel-U.K.	---	---	8-75	ND-19	63
	Severn Estuary-U.K.	---	---	15-210	0.1-3.0	64
Crepidula fornicata - shell	Irish Sea-U.K.	---	1.6	2.4	0.42	76
- whole	Irish Sea-U.K.	2.0	850	3.9	3.9	76
Mussels						
Mytilus edulis	Bristol Channel-U.K.	---	---	4-60	ND-30	63
	Poole Harbor-U.K.	---	5-12	3.7-65.4	7-19	36
- shell	Irish Sea-U.K.	---	2.1	0.95	0.40	76
- shell	New Zealand	<3	<2	<20	<5	78
- whole,	Irish Sea-U.K.	1.5	3.7	5.1	9.1	76
soft parts	New Zealand	16	7	<10	12	78
- muscle	"	<3	<2	<20	<5	78
- gut, digestive gland	"	<3,29	32,42	<20	26, 69	78
- mantle, gills	"	<3,10	<2,8	<20	<5,36	78
- gonad, foot	"	<3	<2,5	<20	<5,7	78
- shell	Central California	<5.7	---	<2.5-5.8	<9.0-21.2	77
- soft tissue	Central California	<1.5-7.6	---	3.1-6.8	<2.2-7.9	77
Mytilus galloprovincialis	Mediterranean	0.5-28.8	0.9-14.1	0.4-5.9	2.7-117	80
Mytilus californianus - shell	Central California	<5.7-14.1	---	<2.5-9.2	<9.0-19.4	77
- soft tissue	" "	<1.5-7.8	---	2.0-4.9	<2.2-23.4	77
- digestive gland	Southern California (islands)	0.8-5.4	6-20	---	2.0-12	81
- digestive gland	Southern California (mainland)	1.8-14	3.3-14	---	7.1-38	81
Modiolus modiolus - shell	Irish Sea-U.K.	---	0.20	0.03	1.9	76
- whole, soft parts	" "	0.14	9.4, 133	4.5, 7.1	23, 42	76
- muscle	" "	0.20	2.0	2.8	7.5	76
- gut, digestive gland	" "	0.19	0.59	4.2	22	76
- mantle, gills	" "	0.15	3.2	7.0	18	76
- gonad	" "	0.20	1.2	4.6	24	76
Choromytilus meridionalis - whole	South Africa	1.4	2-3	1-8	2-4	82
Scallops						
Pecten maximus - shell, upper	Irish Sea-U.K.	---	1.2	0.04	0.62	76
- shell, lower	" "	---	2.4	0.04	0.60	76
- whole, soft parts	" "	---	49	13	8.3	76
- whole, soft parts	English Channel-U.K.	1.3	0.73	32.5	2.0	83
- muscle	Irish Sea-U.K.	---	1.7	1.9	17	76
- muscle	English Channel-U.K.	0.65	0.4	2.2	0.21	83
- gut, digestive	Irish Sea-U.K.	1.8	0.96	96	1.7	76
- gut, digestive	English Channel-U.K.	8.1	3.55	321	3.90	83

TABLE 6 (continued)

Marine Organism Species	Source	Concentrations in ppm (dry weight) Chromium	Nickel	Cadmium	Lead	Reference
Scallops						
- mantle, gills (unwashed)	Irish Sea-U.K.	---	0.30	17	2.8	76
- mantle, gills (washed)	Irish Sea-U.K.	0.76	0.82	3.1	1.5	76
- mantle, gills	English Channel-U.K.	0.40, 0.74	---	0.71, 0.84		83
- gonad (unwashed)	Irish Sea-U.K.	---	0.44	2.5	31	76
- gonad (washed)	Irish Sea-U.K.	0.45	1.5	2.5	0.40	76
- gonad, foot	English Channel-U.K.	---	0.26	---	1.68	83
- kidney	English Channel-U.K.	3.9	22.9	79	159	83
Chlamys opercularis - shell	Irish Sea-U.K.	---	0.18, 0.69	0.13, 0.04	1.7, 0.64	76
- whole, soft parts	English Channel-U.K.	2.2	1.56	5.5	12.0	83
- muscle	" "	---	0.17	---	0.55	83
- gut, digestive	" "	4.7	4.24	27	10.2	83
- mantle, gills	" "	---	0.60, 1.57	---	1.02, 2.12	83
- gonad, foot	" "	---	0.63	---	2.47	83
- kidney	" "	6.6	78.2	41	827	83
Pecten novae-zelandiae - shell	New Zealand	<3	<2	<20	<5	78
- whole, soft parts	" "	10	6	249	16	78
- muscle	" "	<3	<2	<20	<5	78
- gut, digestive	New Zealand	8, 24	2, 52	2,000, <20	8, 28	78
- mantle, gills	" "	<3, 145	<2, 68	<20	<5, 52	78
- gonad, foot	" "	<3, 8	<2, 22	<20	78, 14	78
- kidney	" "	17	106	<20	137	78
Cockles						
Cerastoderma edule	Poole Harbour-U.K.	---	35-174	1.5-16.9	5-14	36
Cardium edule - shell	Irish Sea-U.K.	---	0.11	0.34	0.44	76
- soft tissue	" "	---	7.9	1.5	0.76	76
Glycymeris glycymeris - shell	" "	---	0.16	0.03	0.60	76
- soft tissue	" "	---	1.4	3.3	3.5	76
Clams						
Mercenaria mercenaria - shell	" "	0.37	2.4	0.80	0.43	76
- soft tissue	" "	0.79	11	2.1	18	76
- soft tissue	Eastern U.S.	---	---	0.2-1.2	0.5-11	65
Protothaca staminea - shell	Central California-U.S.	<5.7	---	2.9	<9.0	77
- soft tissue	" "	<1.5	---	5.7	5.2	77
Tapes semidecussata - shell	" "	10.3	---	9.6	<9.0	77
- soft tissue	" "	10.3	---	9.6	<2.2	77
Oysters						
Crassostrea gigas - whole	South Africa	---	1	9	1	82
- whole	South Africa	---	1.6	3.7	---	84
	Poole Harbour-U.K.	---	3	4.6	6	36
	Bristol Channel-U.K.	---	3.8-6.5	17-43	15-17	75
	Menai Strait-U.K.	---	2-5	4-6	7-12	75
	Washington coast-U.S.	---	0.2	5.7	0.2	75
Crassostrea virginica - adults	Connecticut-U.S.	---	---	15.6-28.1	<4.2-7.1	85
- eggs	Connecticut-U.S.	---	---	<1.6	<10	85
	Eastern U.S.	---	---	1.0-7.7	2.0-13	65
Crassostrea margaritacea	South Africa	---	1.6	2.5	---	84

TABLE 6 (continued)

Marine Organism Species	Source	Concentrations in ppm (dry weight) Chromium	Nickel	Cadmium	Lead	Reference
Oysters						
Ostrea edulis	Poole Harbour-U.K.	---	2-5	5.9-53.7	5-8	36
	South Africa	---	1.7	3.1	---	84
Ostrea sinuata - shell	New Zealand	<3	<2	<20	<5	78
- soft parts	" "	3	2	35	10	78
- muscle	" "	<3	<2, 8	<20, 97	<5	78
- gut, digestive gland	" "	<3	12	61	<5	78
- mantle, gills	" "	<3	<2	207, <20	<5	78
- kidney	" "	<3	<2	118	<5	78
- heart	" "	9	2	154	15	78
Unidentified species	Delaware Bay, oyster reef	<100	<100	---	---	51
	Delaware Bay, estuaries	<100	<100	---	---	51
	Texas	---	---	7.04	0.98	67
Squid	Oregon coast	---	---	3.2-20	3.1-5.0	69
	Gulf of Mexico	---	---	0.02-0.37	0.05	67
Loliguncula brevis	Eastern U.S.	---	---	0.5-0.7	2.0-6.4	65
Ommastrephes illicebrosa	Continental Shelf-New York	<0.07	<0.07	≈40	0.39	72
Octopus	Gulf of Mexico	---	---	1.05	0.05	67
Starfish						
Asterias rubens - whole tissue	Irish Sea-U.K.	---	1.5	3.7	2.3	68
- oral skin	" "	---	0.72	1.7	1.1	68
- aboral skin	" "	---	0.68	3.6	1.1	68
- pyloris caeca	" "	---	4.1	8.7	4.0	68
- gonads	" "	---	2.4	1.5	0.5	68
Solaster papposus	" "	---	2.3, 4.0	5.3, 4.5	5.2, 6.8	68
Porania pulvillus	" "	---	<0.28	9.4	<0.50	68
Henricia sanguinolenta	" "	0.46	3.7	3.5	<0.53	68
Ophiuroid, unidentified	" "	<0.58	3.0	1.7	<0.67	68
Pteropods						
Limacina retroversa	Continental Shelf-New York	<0.6	1.3	<320	128	72
Clione limacina	Continental Shelf-New York	---	1.3	<170	22	72
Sea urchins						
Echinus esculentus - oral shell	Irish Sea-U.K.	---	<0.23	0.67	<0.62	68
- aboral shell	" "	---	<0.14	0.30	<0.62	68
- Aristotle's lantern	" "	---	<0.13	0.20	<0.62	68
- spines	" "	---	1.6	0.66	<0.58	68
- intestines	" "	---	<0.77	8.9	<3.0	68
- gonads	" "	---	7.7	0.65	<0.68	68
Spatangus purpureus - test, spines	" "	---	<0.12	0.14	<0.54	68
- gonads	" "	---	1.4	1.1	<0.84	68
Holothurians	Oregon coast	---	---	0.43-0.69	3.9-5.3	69
	Oregon-Washington coast	<0.06	---	---	<2	73
	Gulf of Mexico	---	---	0.17	0.60	67
Tunicates	Oregon coast	---	---	3.5	29-36	69
Salpa fusiformis	Continental Shelf-New York	<0.8	50	<400	2	72
Mixed benthos	Caribbean Sea	0.7-5.9	2.6-4,000	0.4-55.3	ND-28.3	25
Neuston	Hawaii	---	27.3	4.7	196.0	66

TABLE 6 (continued)

Marine Organism: Species	Source	Concentrations in ppm (dry weight): Chromium	Nickel	Cadmium	Lead	Reference
Fish						
Mixed fish	Gulf of Mexico	---	---	<0.01-0.20	<0.05-0.72	67
	Caribbean Sea	ND	0.7-7.9	0.4-42.0	ND-50.7	25
	Gulf of Mexico	ND	2.6-6.6	0.4-27.5	ND	25
	Eastern U.S.	---	---	<0.1-3.2	<0.5-7.0	65
Salmon - muscle	Alaska	---	---	<0.06-0.21	<0.5	86
- liver	"	---	---	1.52-6.65	<1.1	86
- kidney	"	---	---	2.13-10.29	<2.9	86
Flounder (Platichthyes flesus)	Severn Estuary-U.K.	---	---	3.4-7.3	13.9-29.2	74
Flatfish	Oregon coast	---	---	0.05-0.15	0.91-2.7	69
Halibut	" "	---	---	0.041	7.7	69
Sole	" "	---	---	0.02-0.17	0.7-9.3	69
	Washington-Oregon coast	<0.1	---	0.36-0.66	<2	73
Rockfish	Oregon coast	---	---	0.02	0.98	69
	Washington-Oregon coast	0.06	---	0.25	<0.6	73
Herring	Oregon coast	---	---	0.04	1.3	69
Anchovy	Oregon coast	---	---	0.04	1.2	69
	Washington-Oregon coast	<0.06	---	---	<2	73
Hake	Oregon coast	---	---	0.045-0.081	0.85-1.2	69
Myctophids	Oregon coast	---	---	0.062-0.34	0.9-298	69
	Washington-Oregon coast	<0.05-0.08	---	0.20-5.2	---	73
Viper fish	Oregon coast	---	---	0.12-0.90	4.5-470	69
Rat tail	Oregon coast	---	---	0.08	0.54-1.0	69
- muscle	Washington-Oregon coast	<0.1	---	0.43	<3	73
- kidney	" " "	<0.1	---	---	<3	73
- liver	" " "	<0.08	---	37.8	<2	73
Eelpout	" " "	<0.03	---	1.4	<3	73
	Oregon coast	---	---	0.26-0.40	4.4-5.4	69
Grouper	Florida Strait	---	---	0.01-0.45	<0.05-0.16	67
	Gulf of Mexico	---	---	<0.01-0.13	<0.05-0.52	67
Flying fish	Caribbean Sea	ND-2.6	1.3-13.2	0.3-1.3	ND-36.5	25
Sand goby (Pomatoschistus minutus)	Severn Estuary-U.K.	---	---	3.2	17.6	74
River lamprey (Lampetra fluviatilus)	" "	---	---	0.5	6.0	74
Brook lamprey (Lampetra planeri)	" "	---	---	0.23-1.25	8.6-12.0	74
Anoplopoma fimbria	Oregon coast	---	---	0.04-0.083	0.82-13	69
Sharks						
Mixed sharks	Eastern U.S.	---	---	<0.1-5.0	<0.5-10.2	65
Dogfish (Squalus suckleyi)	Oregon coast	---	---	0.02-0.19	0.26-2.2	69
(Squalus acanthius)	Eastern U.S.	---	---	0.2-3.7	<1.0-2.7	65
Dolphin (Tursiops truncatus)	Eastern U.S.	---	---	<0.2-2.6	<2.0-43	65
Ducks	Eastern U.S.	---	---	<0.1-0.9	<0.5-3.7	65
Herring gull eggs	Bristol Channel-U.K.	---	---	0.06[c]	<0.1[c]	87
	Devon-U.K.	---	---	0.03[c]	0.16[c]	87
Lesser black backed gull	Bristol Channel-U.K.	---	---	0.06[c]	<0.1[c]	87

TABLE 7

Critical trace metals in marine sediments

Location	Concentration in ppm (dry weight)				Reference
	Chromium	Nickel	Cadmium	Lead	
Poole Harbour, U.K.	---[a]	2 - 67	<1 - 12	5 - 190	36
Tidal estuary and River Blyth, U.K.					
Total organic fraction	1 - 75	5 - 240	0.3 - 12	1 - 400	88
Humic fraction	1 - 5	33 - 100	0.5 - 2	13 - 58	88
Asphaltic fraction	0.6 - 29	18 - 230	0.3 - 15	1 - 110	88
Less polar fraction	0.5 - 2	1 - 160	0.2 - 4	1 - 38	88
More polar fraction	0.5 - 1	0.5 - 110	0.7 - 2	0.5 - 7	88
Bristol Channel, U.K.	---	43	2	190	75
Severn Estuary, U.K.	---	---	1.6 - 4.7	130 - 200	64
Solway Firth, U.K.	12 - 80	10 - 85	ND[b] - 40	ND - 76	89
Firth of Clyde, U.K.	38 - 106	19 - 62	0 - 4	48 - 134	89
Port Phillip Bay, Australia - surface	---	---	0.15 - 9.9	4.6 - 183	90
- 40 cm	---	---	0.04 - 2.3	1.8 - 74	90
Tasman Bay, New Zealand	307	219	<20	<5	78
South Africa	---	4 - 10	0.4 - 1.4	9 - 32	82
Mangrove Lake, Bermuda - surface	---	6	0.6	20	91
- core	---	7	0.8	<0.2	91
Gulf of Paria, Trinidad - river delta sand	14 - 38	9.2 - 23	---	3.6 - 20	92
- platform sands	15 - 53	8.9 - 21	---	4.0 - 81	92
- clays	59 - 99	22 - 34	---	13 - 32	92
- non-detrital	0.4 - 3.3	1.3 - 10	---	0.1 - 1.5	92
- detrital	11.7 - 96.5	7.6 - 28.7	---	3.9-31.9	92
Caribbean Sea - deep water	7.1 - 49.5	15.3 - 39.6	1.9 - 4.8	12.5 - 50.0	28
- nearshore (coral and sand)	4.0 - 9.2	21.0 - 31.6	2.6 - 3.4	ND - 50.5	28
Nearshore marine sediments, worldwide	100	55	---	20	3
Deepsea clay sediments, worldwide	77 - 90	225 - 290	0.42	80 - 160	3, 48
Deepsea carbonate sediments, worldwide	11	30	0.01	9	3
Saanich Inlet, Canada	43 - 98	10 - 37	---	ND - 34	93
Haro Strait, Canada-U.S.	51	14	---	---	93
New York Bight, Eastern U.S. - no dumping	6	3 - 8	---	12 - 14	94
- dumping	2 - 310	3 - 37	---	25 - 370	94
Shell reefs, Delaware Bay - <63 μm	33 - 447	175 - 3,600	0.5 - 11.3	20 - 1,083	51
Oyster reefs, Delaware Bay - <63 μm	103 - 187	320 - 512	1.0 - 2.0	31 - 118	51
Tidal estuaries, Delaware Bay - <63 μm	56 - 200	178 - 695	0.5 - 8.7	33 - 687	51
Card Sound, Florida	---	<2	0.07	1	91
Turkey Point, Florida	---	25	0.2	3	91

[a] --- = No data available.
[b] ND = Not detected.

TABLE 8

Critical trace metal concentrations in seawater in μg/l

Location	Chromium	Nickel	Cadmium	Lead	Reference
Bristol Channel, U.K. - particulate	---[a]	---	0.5-6.5	59-237	75
- dissolved	---	---	1.0-1.3	1	75
Severn Estuary, U.K.	---	---	0.1-5.8	0.3-2.5	64
- dissolved, surface	---	6.4	7.7	1.5	95
Poole Harbour, U.K. - dissolved	---	3-79	0.7-20.5	<1-8	36
English Channel, U.K.	---	0.22-1.3	<0.01-0.38	<0.05-1.1	30
Irish Sea, U.K. - Western - coastal	---	0.22-1.2	<0.01-0.52	<0.05-1.2	30
- inshore	---	0.9-3.1	0.03-1.43	0.9-2.9	30
- Eastern - coastal	---	0.3-22.9	<0.01-0.62	<0.05-1.0	30
- inshore	---	1.3-9.8	0.15-1.14	0.6-2.4	30
Scotland, U.K. - Western coast	---	0.36-0.79	<0.01-0.18	<0.05	30
North Sea, U.K. - dissolved	---	0.1-6.0	0.1-6.2	---	28
- dissolved	---	0.16-0.51	0.29-0.60	<0.05-0.8	30
- surface - dissolved	---	0.3-5.4	<0.1-1.6	---	28
- bottom - dissolved	---	0.5-2.9	0.1-0.5	---	28
- surface - particulate	---	0.1-1.3	<0.1-0.3	---	28
- bottom - particulate	---	0.1-1.4	0.1-0.4	---	28
Northeast Atlantic - surface - dissolved	---	0.29-0.66	<0.01-0.41	0.02	95
Caribbean Sea - western - surface	0.25-1.0	0.2-1.4	0.005-0.47	1.0-14	28
- western - 1,000 m	1.5	0.3-1.4	0.09-0.16	1.0-4.0	28
- eastern - surface	0.21-0.62	0.5-2.0	0.13-0.69	3.0-6.9	28
- eastern - 1,000 m	0.21	1.1	0.30	3.1	28
Pacific and Atlantic GEOSEC Sections (13)	---	0.18-0.80	---	---	28
Narragansett Bay, R.I. - 20 cm - particulate	---	0.2-2.1	---	0.24-0.25	27
- organic	---	0.48-1.8	---	0.27-0.36	27
- inorganic	---	14-16	---	2.7-3.7	27
- surface film - particulate	---	11-13	---	1.4-1.5	27
- organic	---	4.9-5.0	---	1.0-1.4	27
- inorganic	---	11-21	---	1.7-6.1	27

[a] --- = No data available.

TABLE 9

Summary of critical trace metal concentration ranges in various compartments in the marine environment[a]

Compartment	Chromium	Nickel	Cadmium	Lead	Reference
River waters	0.001	---[b]	---	---	47
Seawater[c]	0.04-0.5	0.1-0.7	0.02-0.7	0.02-0.4	Table 1
	0.21-1.5	0.1-79	<0.01-20	<0.05-237	Table 8
Marine organisms	<0.02-1	---	<0.1-10	---	47
	<0.1-40	<0.2-4,000	<0.03-725	<0.2-3,040	Table 6
Surface marine sediments	10-200	---	205	10-200	47
	0.4-100	1-300	0.04-40	1-200	Table 7
Street surface contaminants-U.S. - residental	24-325	0-120	0-8.8	230-5,700	96
- industrial	74-760	1.0-120	0-11	65-10,000	96
- commercial	63-430	6.0-170	0-25	0-10,000	96
Airborne particles-Hawaii[d]	<1	<1	---	3.0	97
Urban air[d] - range	10-300	1-400	2-400	100-8,000	73
- best estimate average	40	30	20	1,000	73

[a] ppm ≃ μg/g ≃ mg/l
[b] No data available
[c] μg/l
[d] ng/m^3

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INTRODUCTION

The toxicity of heavy metals to marine organisms has not been as widely studied as has the toxicity of heavy metals to freshwater fishes. However, in this review we are primarily interested in the toxic effects on marine species and more specifically of the effect on arctic and subarctic species. The metals that are being considered are four important metals associated with the production of petroleum: cadmium, chromium, nickel, and lead.

It has been established that trace amounts of various metals including nickel and chromium are important in activating enzyme systems of marine organisms, whereas excessive amounts may completely upset the enzyme systems [1]. Some metals such as cadmium and lead act as enzyme inhibitors or are toxic to enzyme systems. Cadmium, which may be concentrated in marine organisms, especially molluscs, may also act synergistically with other substances to increase toxicity. In addition to being toxic to enzyme systems, lead also forms a precipitate on the gills, especially in freshwater fish, decreasing permeability of the tissue to dissolved oxygen. However, comparatively little is known of the modes of toxicity of these metals.

Bryan [2] pointed out that the form of a metal in seawater is important in determining its toxicity; the stability of the form present and the ease of dissociation control the absorption by the marine organism. He also noted the following factors as important in influencing the toxicity of heavy metals to aquatic organisms: (1) form of the metal in water, in solution or as suspended particulate matter; (2) presence of other metals or poisons that are antagonistic, additive, or synergistic; (3) conditions that influence the physiology of the organisms and form of the metal such as salinity, temperature, dissolved oxygen, pH, and light; and (4) condition of organisms such as life-history stage, size, activity, and acclimation.

Heavy metals in solution in seawater affect marine organisms mainly by absorption. Absorption may occur across the general body surfaces and through special structures such as gills, and in teleosts, which ingest seawater; absorption also takes place across the walls of the gut. Of the four metals under consideration, cadmium may remain in aerated seawater in the greatest concentrations (4-1,000 ppm), followed by nickel (20-450 ppm), lead (0.3-0.9 ppm), and chromium (high) (Krauskopf [3] as reported by Bryan [2]). The concentration of these four metals in coastal seawater is such that nickel (0.004 ppm) is the most abundant followed by lead (0.001 ppm), chromium (0.0004 ppm), and cadmium (0.0006 ppm) [2].

The concentration of a metal lethal to a marine organism depends on the metal and the organism. Generally, of the four metals under consideration, cadmium is the most toxic followed in order by lead, chromium, and nickel. Mercury, silver, and copper are generally considered to be the most toxic of the major metals; cadmium, zinc, and lead are considered to be of intermediate toxicity; and chromium, nickel, and cobalt are considered to be the least toxic. This order may vary from organism to organism, and the susceptibility of different organisms to a particular metal may vary greatly.

The following sections treat the toxicity of each of the four metals briefly and include a tabulation of reported toxicity by phyla for each.

CADMIUM

Cadmium is the most toxic of the four metals and has been studied more extensively than the others. Table 1 reveals considerable uniformity in the 96 hour LC_{50} values for the various species of a phyla. Also the data obtained by various researchers are in good agreement. The range of 96 hour

LC_{50} values for adult Annelida was only 7.5-12.5 mg/l, for Mollusca 3.8-25.0 mg/l, for Chordata 21.0-78.0 mg/l, and for Arthropoda, where the widest variations occurred, 0.32->100 mg/l. Even this last range is small compared to that obtained for petroleum toxicants which are much less stable.

Numerous factors have a bearing on the toxicity of a metal to a particular organism. This especially seems to be true of cadmium. Jones [4] studied the synergistic effects of salinity and temperature on the toxicity of cadmium to isopods and concluded that a decrease in salinity increases mortality and reduced LT_{50} values, whereas an increase in temperature increases toxicity of cadmium. This same relationship of increased toxicity of cadmium with increased temperature and decreased salinity was also observed by O'Hara [5] in studies of the fiddler crab. Collier et al. [6] established an LC_{50} of 4.9 ppm cadmium for the mud crab, but was unable to relate oxygen consumption rates of whole animals to the concentration of cadmium. Oxygen consumption rates of gill tissue, however, decreased as cadmium concentration increased. Voyer's [7] studies of cadmium toxicity to the mummichog showed that resistance to acute poisoning was not influenced by reductions in dissolved oxygen levels to 4 mg/l at salinities of 10 to 32 ^{o}/oo, which findings contrasted to those of others working with heavy metals and freshwater fish. Eisler [8] studied the toxicity of cadmium to a wide range of marine organisms and concluded that teleosts were more resistant to cadmium than all marine invertebrates studied except the mussel. However, he questioned the adequacy of the 96 hour test period and pointed out that a 264 hour exposure of mummichog to 0.1 mg/l Cd^{2+} produced residues of cadmium no different from controls. This concentration (0.1 mg/l Cd^{2+}) was one five-hundredths of the TL_{50} (96 hour) value; and Eisler stated that if this factor (1/500) is applied to toxicity data for sand shrimp or hermit crab, cadmium concentrations in excess of 0.00058 mg/l could be potentially hazardous to those species. It should be noted that sand shrimp and hermit crab are the most sensitive species listed in Table 1.

Both Rosenthal and Sperling [9] and Von Westernhagen [10] studied the effect of cadmium on incubating herring eggs. Rosenthal and Sperling found no viable hatch occurring at concentrations of 5.0 ppm of cadmium and drastic reductions at 1.0 ppm. Von Westernhagen found little difference in hatching rates with salinities of 5-25 $^{o}/oo$ and cadmium concentrations of 0-1.0 ppm. However, at high salinities (25 $^{o}/oo$ and 35 $^{o}/oo$) there was a greater survival rate at high cadmium levels (5.0 ppm) than at low salinities (16 $^{o}/oo$ and 5 $^{o}/oo$). Low salinity (5 $^{o}/oo$) drastically reduced viable hatch at 0.5 ppm cadmium.

The toxicity of cadmium to marine organisms has been well established and physical factors, temperature and salinity have an important influence on this toxicity. Although the 96 hour TL_{50} values may seem high compared to those for some other toxins, Eisler [8] pointed out that levels as low as 0.1 mg/l Cd^{2+} in the medium are potentially harmful to mummichogs and other marine species. The Environmental Protection Agency [11] indicated that this concentration (0.1 mg/l) of cadmium in the marine environment constituted a hazard.

LEAD

Although lead is generally listed as being the second most toxic of the four metals being considered, few studies are available on the effect of lead on marine organisms. Lead is toxic to most enzyme systems, but comparatively little is known of its biochemical role in marine organisms [1]. Dilling et al. [12] stated that lead in the colloidal form does not kill plaice but does retard growth. Lead, under conditions of acute poisoning, precipitates protein on gill filaments reducing the permeability of the tissue to dissolved oxygen, and eventually causes death of the organism.

The relative toxicity of lead to marine organisms is not fixed and varies with the organism. It was the least toxic of six metals tested by Brown and Ahsanullah [13] on a marine worm (Ophryotrocha) and brine shrimp (Artemia). It was less toxic than mercury, copper, zinc, cadmium, or iron. In tests on the American oyster, Calabrese et al. [14] found lead less toxic than nickel; LC_{50} value for nickel was 1.18 ppm and for lead was 2.45 ppm. The Environmental Protection Agency [11] noted the paucity of information on the toxicity of lead especially to marine organisms. Table 2 reveals the range of toxicity to the phyla represented as: 96 hour LC_{50} for Annelida is 1.2-100.0 mg/1 and for Mollusca is 0.48-25.0 mg/1.

Aronson [15] stated that there is no evidence that lead constitutes a health problem to fish in natural waters of the United States. Although he admitted there was little evidence on which to base such a conclusion, he did point out that lead washed into waterways is probably precipitated and that there is no evidence that lead precipitated to the bottom of natural waters is harmful to fish. He may have been referring mainly to freshwater conditions. Jackim [16], on the other hand, demonstrated important decreases in enzyme activity of killifish (Fundulus heteroclitus) and winter flounder (Pseudopleuronectes americanus) exposed to 10 mg/1 Pb^{2+} for periods up to two weeks. The Environmental Protection Agency [11] concluded that, on the basis of available information, concentrations of lead equal to or exceeding 0.05 mg/1 constitute a hazard in the marine environment.

CHROMIUM AND NICKEL

Chromium and nickel are important in activating enzyme systems as are other heavy metals; however, their value is incompletely understood [1].

The hexavalent form of chromium is more readily taken up by the bodies of some marine organisms than the trivalent form and is, therefore, generally more toxic. Raymont and Shields [17] established the threshold level of a Nereis worm for the hexavalent chromium at just below 1.0 ppm. Oshida et al. [18] studied another polychaete worm, Neanthes arenaceodentata, and established the 96 hour LC_{50} for trivalent chromium could not be established. Long-term exposure of the worm to the hexavalent chromium at 0.100 mg/l halted reproduction. Calabrese et al. [14] found that chromium is one of the least toxic metals to the embryos of the American oyster (LC_{50} of 10.3 ppm). Studies of the yelloweye mullet by Negilski [19] established the 96 hour LC_{50} for hexavalent chromium at 31 mg/l. Table 3 shows that most of the work on chromium has been done with Annelida and Mollusca. The 96 hour LC_{50} for Annelida range from about 1 to 12.0 mg/l, and for Mollusca from about 3 to 35.0 mg/l.

Little information is available on the toxicity of nickel to marine organisms (Table 4). Rehwolt et al. [20] studied the toxicity of heavy metals to Hudson River fish and found that nickel was less toxic than copper or zinc for all species except the American eel. Calabrese and Nelson [21] found that nickel was next to the least toxic of five metals tested on the hard clam.

SUMMARY

Trace amounts of heavy metals may either activate or inhibit enzyme systems of marine organisms. Excessive amounts may be toxic and some metals may act synergistically with other substances to increase toxicity. Others may form precipitates that physically block oxygen exchange. Numerous factors influence the toxicity of a metal in relation to a particular organism including: the form of the metal in water, the presence of other substances, factors influencing the physiology of the organism, and the state of the organism.

Cadmium, lead, chromium, and nickel are the metals associated with petroleum oil production that may be the most detrimental to the marine environment. Cadmium may remain in seawater in the greatest concentrations followed by nickel, lead, and chromium; however in coastal seawater they usually occur in the following order of abundance: nickel, lead, chromium, and cadmium. Cadmium is generally believed to be the most toxic with lead, chromium, and nickel in decreasing order of toxicity.

Cadmium has received the most study. The 96 hour LC_{50} for the various phyla studied ranged from 0.32 to 100 mg/l. Decreasing salinity and increasing temperature increase the toxicity of cadmium. Teleosts are apparently more tolerant of cadmium than are most marine invertebrates. Short-term exposures indicate rather high LC_{50} values (4-100 mg/l) but long-term exposures of 0.1 mg/l are believed to be potentially harmful to the environment.

Although lead is generally believed to be the second most toxic of the four metals under consideration, the available information demonstrates wide variability from organism-to-organism. The information on toxicity of lead to marine organisms is especially sparse; nevertheless, the Environmental Protection Agency concluded that concentrations of lead equal to or exceeding 0.05 mg/l are a hazard to the marine environment.

Chromium and nickel are important in activating enzyme systems. The hexavalent form of chromium is generally more toxic than the trivalent form. Work on Annelida and Mollusca indicate the 96 hour LC_{50} is about 1 to 12 mg/l and 3 to 35 mg/l, respectively. Little information is available on the toxicity of nickel to marine animals.

PROSPECTUS

Little is actually known of the concentrations and durations of exposure of each of the four metals that marine organisms may be subjected to in arctic and subarctic oil producing operations. Also, little is known of the short-term toxic effects of these metals for a wide range of marine organisms. Therefore, studies are needed to determine realistic concentrations and durations of exposure for each of the metals under consideration, as well as the short-term toxic effects of these exposures on a wide range of arctic and subarctic marine organisms. Until this information is available, predictions on the effect of these metals resulting from the production of petroleum will be little more than guess work.

Cadmium is the most toxic of the four and will cause serious short-term effects if it occurs in concentrations of much above 5 mg/l for older Mollusca and Annelida, and much above 20 mg/l for Chordata. Arthropods seem to have a much wider range of tolerance. It seems doubtful that concentrations of these magnitudes would exist for any length of time except in very localized instances. Similar conclusions would seem justified in the case of the other three metals; concentrations high enough to cause disastrous short-term mortality are not likely to occur except briefly in very localized areas. Although rather high concentrations of these metals may cause little or no discernible effect on adult organisms after short exposure, reproduction may be inhibited and developing stages damaged by prolonged exposure to very low concentrations. This is probably the area of greatest potential damage to the marine biota and one of the areas of study that should be emphasized.

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Table 1

Toxicity of cadmium to marine organisms

Organism	Form of cadmium tested	Test parameters	Concentration of cadmium in mg/l (ppm)	Reference
ECHINODERMATA				
Asterias forbesii Starfish	$CdCl_2 \cdot 2\frac{1}{2}H_2O$	Seawater 20°C; salinity 20 °/oo		Eisler (1971) [8]
		96 hr LC_{50}	0.82	
MOLLUSCA				
Mya arenaria Soft-shell clam	$CdCl_2 \cdot 2\frac{1}{2}H_2O$	Seawater 20°C; salinity 20 °/oo		Eisler (1971) [8]
		96 hr LC_{50}	2.2	
Urosalpinx cinerea Oyster drill		96 hr LC_{50}	6.6	
Nassarius obsoletus Mud snail		96 hr LC_{50}	10.5	
Mytilus edulis Mussel		96 hr LC_{50}	25.0	
Mytilus edulis Mussel	$CdCl_2$	Static bioassay; seawater; 100 ml vol.; 17°C		Martin et al. (1974) [28]
		7 day LC_{50}	2.5	
Crassostrea virginica American oyster	$Cd(NO_3)_2$	Flow through bioassay; seawater; 20°C; salinity 31 °/oo 20 week exposure Mortality (%)[1]		Shuster and Pringle (1969) [29]
		84	0.1	
		100	0.2	

Table 1 (cont'd)

Toxicity of cadmium to marine organisms

Organism	Form of cadmium tested	Test parameters	Concentration of cadmium in mg/l (ppm)	Reference
Crassostrea virginica American oyster (Embryos)	$CdCl_2 \cdot 2\frac{1}{2}H_2O$	48 hr LC_{50}	3.80	Calabrese et al. (1973) [21]
Crassostrea virginica American oyster	$Cd(NO_3)_2$	Flow through bioassay; seawater; 2.5 l/min 20°C; salinity 30 °/oo Mortality started at 4-8 weeks; 100% mortality at 13-17 weeks	0.2	Shuster and Pringle (1969) [29]
ANNELIDA				
Capitella capitata Polychaete (Adults)	$CdCl_2$	96 hr LC_{50} 28 day LC_{50}	7.5 0.7	Reish et al. (1975) as reported by Oshida et al. (1976) [30-18]
(Trochophore larvae)		96 hr LC_{50}	0.22	
Neanthes arenaceodentata Polychaete (Adults)		96 hr LC_{50} 28 day LC_{50}	12.0 3.0	
(Juveniles)		96 hr LC_{50} 28 day LC_{50}	12.5 3.0	
Nereis virens Sand worm	$CdCl_2 \cdot 2\frac{1}{2}H_2$	Seawater 20°C; salinity 20°/oo 96 hr LC_{50}	11.0	Eisler (1971) [8]

Table 1

Toxicity of cadmium to marine organisms

Organism	Form of cadmium tested	Test parameters	Concentration of cadmium in mg/l (ppm)	Reference
Ophryotrocha labrenica Polychaete	$CdSO_4$	Static bioassay; seawater; 3 l. tanks; 20°C; media renewed every 4 days		Brown and Ahsanullah (1971) [13]
		Time to 50% mortality		
		410 hr	1.0 2/	
		96 hr LC_{50}	8.0 2/	
ARTHROPODA				
Eurypanopeus depressus Mud Crab	$CdCl_2 \cdot 2\frac{1}{2}H_2O$	Static bioassay; Synthetic sea water; 3 l. medium in 1 gal jar, 21°C: salinity 25‰ Ph 7; 1 g crabs		Collier et al. (1973) [6]
		72 hr LC	1.0	
		72 hr LC_{50}	4.9	
		72 hr LC_{100}	11.0	
Idothea balthica Isopod	$3CdSO_4 \cdot 8H_2O$	Static bioassay; seawater		Jones (1975) [4]

Static bioassay; seawater (Idothea balthica):

sea-water 3/ %	mort. %	hrs to mean mortality	Concentration of cadmium in mg/l (ppm)
	5°C		
40	100	<24	20
60	100	38	20
80	100	56	20
100	95	67	20
40	100	34	10
60	80	72	10
80	60	99	10
100	50	>120	10

Table 1 (cont'd)

Toxicity of cadmium to marine organisms

Organism	Form of cadmium tested	Test parameters			Concentration of cadmium in mg/l (ppm)	Reference
Idothea balthica Isopod	$3CdSO_4 \cdot 8H_2O$	10°C				
		40	100	<24	20	
		60	100	24		
		40	100	<24	10	
		60	95	42		
		5°C				
Idothea emarginata Isopod		40	100	<24	20	
		60	100	24		
		80	100	58		
		100	100	70		
		40	100	<24	10	
		60	80	72		
		80	60	108		
		100	50	120		
		5°C				
Idothea neglecta Isopod		40	100	30	20	
		60	100	37		
		80	100	49		
		100	100	69		
		40	100	26	10	
		60	90	64		
		80	70	86		
		100	65	95		
		10°C				
		40	100	<24	20	
		60	100	33		
		80	100	54		
		100	100	57		
		40	100	26	10	
		60	100	52		
		80	95	61		
		100	65	108		

Table 1 (cont'd)

Toxicity of cadmium to marine organisms

Organism	Form of cadmium tested	Test parameters			Concentration of cadmium in mg/l (ppm)	Reference
		5°C				
Jaera albifrons Isopod	$3CdSO_4 \cdot 8H_2O$	1	100	27		
		10	50	112	20	
		100	35	>120		
		1	95	46		
		10	40	>120	10	
		100	15	>120		
		10°C				
		1	100	<24		
		10	95	50	20	
		100	65	94		
		1	100	29		
		10	90	72	10	
		100	40	120		
		5°C				
Jaera nordninni Isopod		1	90	36		
		10	65	100	10	
		100	20	>120		
		10°C				
		1	100	29		
		10	95	38	20	
		100	70	90		
		1	100	30		
		10	65	102	10	
		100	50	116		

Table 1 (cont'd)

Toxicity of cadmium to marine organisms

Organism	Form of cadmium tested	Test parameters	Concentration of cadmium in mg/l (ppm)	Reference
Crangon septemspinosa Sand shrimp	$CdCl_2 \cdot 2\frac{1}{2}H_2O$	Seawater; 20°C; salinity 20‰ 96 hr LC_{50}	0.32	Eisler (1971) [8]
Pagurus longicarpus Hermit crab		96 hr LC_{50}	0.32	
Palaemonetes vulgaris Grass shrimp		96 hr LC_{50}	0.42	
Carcinus maenus Green crab		96 hr LC_{50}	4.1	
Uca pugilator Fiddler crab	$CdCl_2 \cdot 2\frac{1}{2}H_2O$	Seawater 30°C; salinity 10‰		O'Hara (1973) [5]
		240 hr LC_{50}	2.9	
		96 hr LC_{50} Salinity ‰ — Temp. °C		
		10 — 30	6.8	
		10 — 20	32.2	
		20 — 30	10.4	
		20 — 20	46.6	
		30 — 30	23.3	
		30 — 20	37.0	
Artemia sp. Brine Shrimp	$CdSO_4$	Static bioassay; seawater 500 ml beakers; 24°C aerated; .05 g Farex added alternate days; SW renewed every 4 days.		Brown and Ahsanullah (1971) [13]
		Time (hr) to 50% mortality 240 hrs.	1.0 2/	
		96 hr LC_{50}	100 2/	

Table 1 (coht'd)

Toxicity of cadmium to marine organisms

Organism	Form of cadmium tested	Test paramenters	Concentration of cadmium in mg/l (ppm)	Reference
CHORDATA				
Fundulus heteroclitus Mummichog	$CdCl_2$	Pathological changes in 12-20 hr	50	Gardner & Yevich (1970) [22]
Fundulus heteroclitus Mummichog	$CdCl_2 + CuCl_2 + ZnCl_2$	Synthetic seawater; 20°C salinity 2 ‰	4/	Eisler & Gardner (1973) [23]
		Static bioassay; seawater 10.1; 19.5°C; salinity 34‰; pH 7.9 dissolved O_2 > 80%; aeration; perspex tanks.		Negilski (1976) [19]
Aldrichetta forsteri Yellow-eye mullet (Juvenile)	$CdCl_2$	168 hr LC_{50}	16 5/	
Atherinasoma microstoma Small-mouthed hardyhead (Pre-adult)		168 hr LC_{50}	21 5/	
Pimephales promelas Fathead minnow	$CdCl_2$	Chronic bioassay 6/		Pickering & Gast (1972) [24]
		No effect on survival, growth, reproduction	4.5-37	
		decreased survival of embryos	57	
Salmo gairdneri Rainbow trout	$CdCl_2$	Mortality in 7 hr	11.2	
		96 hr - 50% mortality 7/	1.12	Bilinski & Jones (1973) [25]

Table 1 (cont'd)

Toxicity of cadmium to marine organisms

Organism	Form of cadmium tested	Test paramenters	Concentration of cadmium in mg/1, (ppm)	Reference
Fundulus heteroclitus Mummichog	$CdCl_2$	20°C, salinity 30°/₀₀, pH 7.8, DO 7 mg/l Lesions in intestine after 1 hr & kidney after 8 hr Severe eosinophilia	50	Gardner & Yevich (1969) [26]
Fundulus heteroclitus Mummichog	$CdCl_2 \cdot 2\frac{1}{2}H_2O$	Static bioassay; seawater 4 l. glass jar, 3 l. test solution 96 hr LC_{50}		Voyer (1975) [7]

Sal. °/₀₀	Temp. °C	DO mg/l 8/	Concen. mg/l
10	18.2	4.1	63
10	18.2	5.8	73
10	18.2	9.1	73
20	17.9	4.2	114
20	17.9	5.9	92
20	17.9	8.8	78
32	19.8	3.6	29
32	19.8	5.0	31
32	19.8	7.5	30

Organism	Form of cadmium tested	Test paramenters	Concentration of cadmium in mg/1, (ppm)	Reference
Fundulus majalis Striped killifish	$CdCl_2 \cdot 2\frac{1}{2}H_2O$	20°C, salinity 20°/₀₀ 96 hr LC_{50}	21.0	Eisler (1971) [8]
Cyprinodon variegatus Sheepshead minnow		96 hr LC_{50}	50.0	
Fundulus heteroclitus Mummichog		96 hr LC_{50}	55.0 9/	

Table 1 (cont'd)

Toxicity of cadmium to marine organisms

Organism	Form of cadmium tested	Test parameters		Concentration of cadmium in mg/l (ppm)	Reference
Clupea harengus Herring (Eggs)	$CdCl_2$	Static bioassay, seawater 10°C; 2 l. aerated pH 7.53-8.10 incubation jars.			Von Westernhagen et al. (1974) [10]
		Hatching rate	Salinity °/₀₀		
		Not significantly altered	5	0.1	
			16	0.5	
			32	1.0	
		Unaffected	32	0.0	
			25	0.1	
			16	0.5	
		1% of normal	5	0.5	
		16% of normal	16	1.0	
		0% of normal	5	5.0	
		0% of normal	32	5.0	
Clupea harengus Herring (Eggs)	Cd Salt not specified	Static bioassay, seawater 1.5 l. container; 10°C; Salinity 16°/₀₀, continuously aerated; solution change			Rosenthal & Sperling (1973) [9]
		viable hatch (%)	16.3	1.0	
			82.7	0.1	
			93.0	0.0 (control)	
			0.0	5.0	

Table 1

Toxicity of cadmium to marine organisms

Organism	Form of cadmium tested	Test parameters	Concentration of cadmium in mg/l (ppm)	Reference
Salmo gairdneri Rainbow trout	Cd Salt not known	Flow-through bioassay, hard water. 10/		Ball (1967) [27]
		Linear relation between survival & concentration	1-64	
		Little change in survival	0.01 and 1.0	
		7 day TLm	0.008 - 0.01	

1/ 50% mortality reached by 12th week.
2/ taken from graph.
3/ 100% salinity = 34‰.
4/ Concentrations of Cd^{2+} not ordinarily lethel exerted a negative effect on survival of fish intoxicated by salts of Cu, Zn, or both.
5/ Generally mullet and hardyhead are more sensitive to acute effects of Cd than are other marine fish for which information is available.
6/ Freshwater
7/ Those surviving 96 hr gill oxidative activity inhibited 50%
8/ Resistance to acute Cd poisoning not influenced by reductions in dissolved O_2 levels to about 4 mg/l at 10-32‰.
9/ More susceptible at 20°C than 5°C and at 5 ‰ than at 15, 25, or 35‰ salinity.
10/ Similar results in soft water.

Table 2

Toxicity of lead to marine organisms

Organism	Form of lead tested	Test parameters	Concentration of lead in ml/l (ppm)	Reference
MOLLUSCA				
Mytilus edulis Mussel	$Pb(CH_3COO)_2$	Static bioassay; seawater; 100 ml vol.; 17°C 7 day LC 50	 >25.0	Martin et al. (1974) [28]
Mytilus edulis Mussel	Pb Salt not specified in abstract	LT_{50}(median lethal time) 218 day 150 day 129 day 105 day	 Control 0.5 1.0 5.0	Schultz-Baldes (1972) [32]
Mercenaria merceneria Quahog (Embryos)	$Pb(NO_3)_2$	Synthetic seawater; 26°C; salinity 25°/∞ 48 hr LC 50	 0.78	Calabrese and Nelson (1974) [21]
Crassostrea virginica American oyster (Embryo)	$Pb(NO_3)_2$	48 hr LC 50	2.45	Calabrese et al. (1973) [14]
ANNELIDA				
Capitella capitata Polychaete (Adults) (Trochaphore)	$Pb(C_2H_3O_2)_2 \cdot 3H_2O$	96 hr LC 50 28 day LC 50 96 hr LC 50	6.8 1.0 1.2	Reish et al. (1975) as reported by Oshida et al. (1976) [30,18]
Neanthes arenaceodentata Polychaete (Adults) (Juveniles)		96 hr LC 50 28 day LC 50 96 hr LC 50 28 day LC 50	>10.0 3.2 >7.5 2.5	

Table 2 (cont'd)

Toxicity of lead to marine organisms

Organism	Form of lead tested	Test parameters			Concentration of lead in ml/l (ppm)	Reference
Ophryotrocha labronica Polychaete	$Pb(NO_3)_2$	Static bioassay; seawater; 3 l; 20°C; replaced every 4 days				Brown and Ahsanullah (1971) [13]
		Time (hr) to 50% mortality				
		600+ hr (50% mortality not reached)			1.0	
		96 hr LC 50			~100	
Tubificid Worms	Form of lead not given in abstract	pH 6.5 24 hr TLm			49.0	Whitley (1968) [31]
ARTHROPODA			5°C			Jones (1975) [4]
		Salinity[1/] (%)	Mort. %	hrs to mean mort.		
Jaera albifrons Isopod	$Pb(NO_3)_2$	1	100	<24		
		10	30	>120	10 & 20	
		100	0	>120		
Jaera nordmanni Isopod		1	100	28		
		10	20	>120	20	
		100	5	>120		
		1	95	36		
		10	15	>120	10	
		100	0	>120		
Artemia sp. Brine shrimp	$Pb(NO_3)_2$	Static bioassay; seawater; 500 ml vol.; 24°C; aerated; 0.05 g Farex added alternate days; media renewed every 4 days				Brown and Ahsanullah (1971) [13]
		Time (hr) to 50% mortality				
		576 hr			1.0	
		96 hr LC 50			>100[2/]	

Table 2 (cont'd)

Toxicity of lead to marine organisms

Organism	Form of lead tested	Test parameters	Concentration of lead in ml/l (ppm)	Reference
CHORDATA				
Salmo gairdneri Rainbow trout	Form of lead used not stated in abstract	Alkalinity 243.1 mg/l		Davies and Earhart (1973) [34]
		Total lead 96 hr LC 50	471	
		Dissolved lead 96 hr LC 50	1.38	
		Alkalinity 26.4 mg/l 18 day LC 50	140	
Salmo gairdneri Rainbow trout	$Pb(NO_3)_2$	48 hr TLm 3/	1-3	Kariya (1969) [35]
Pleuronectes platessa Plaice	$Pb(NO_3)_2$	Seawater Lead in colloidal form does not kill young 4/		Dilling et al. (1926) [12]

1/ 100% salinity = 34‰.
2/ Taken from graph.
3/ Hard water resulted in reduction of toxicity. Freshwater.
4/ Growth retarded while in lead medium.

Table 3

Toxicity of chromium to marine organisms

Organism	Form of chromium tested	Test parameters	Concentration of Chromium in mg/l (ppm)	Reference
ENCHINODERMATA				
Anthocidaris crassipina Urchin		24 hr test for normal development from eggs to pluteus		Okubo & Okubo (1965) as reported by Oshida et al. (1976) [36,18]
	$Cr_2(SO_4)_3$	Not affected	3.2	
		Affected	10.0	
	$K_2Cr_2O_7$	Not affected	3.2	
		Affected	10.0	
Hemicentrotus pulcheurimus Urchin		72 hr test for normal development from eggs to pluteus		
	$Cr_2(SO_4)_3$	Not affected	--	
		Affected	1.0	
	$K_2Cr_2O_7$	Not affected	3.2	
		Affected	10.0	
MOLLUSCA				
Mytilus edulis Mussel	CrO_3	Static bioassay: seawater 100 ml vol.; 17°C		Martin et al. (1974) [28]
		7 day LC_{50}	5.0	
Mytilus edulis Mussel		48 hr test for normal development from eggs to straight-hinged larvae		Okubo & Okubo (1965) as reported by Oshida et al. (1976) [36]
	$Cr_2(SO_4)_3$	Not affected	3.2	
		Affected	10.0	
	$K_2Cr_2O_4$	Not affected	3.2	
		Affected	10.0	

Table 3 (cont'd)

Toxicity of chromium to marine organisms

Organism	Form of chromium tested	Test parameters	Concentration of chromium in mg/l (ppm)	Reference
<u>Crassostrea gigas</u> Oyster		24 hr test for normal development from eggs to straight-hinged larvae		Okubo & Okubo (1965) as reported by Oshida et al. (1976) [36]
	$K_2Cr_2O_4$	Not affected	3.2	
		Affected	10.0	
<u>Crassostrea virginica</u> American oyster	$Cr(NO_3)_3 \cdot 7\frac{1}{2}H_2O$	Flow-through bioassay; seawater; 20°C; salinity 31‰		Shuster & Pringle (1969) [29]
		20 wk exposure - 6% mort.	0.05	
		" -14% mort.	0.1	
<u>Crassostrea virginica</u> American oyster	$CrCl_3 \cdot 6H_2O$	48 hr LC_{50}	10.3	Calabrese et al. (1973) [14]
<u>Rangia cuneata</u> Brackish water clam	$K_2Cr_2O_4$	96 hr LC_{50}		Olson & Howel (1973) as reported by Oshida et al. (1976) [37]
		Salinity (‰) = 1.0	0.21	
		" = 5.5	14.0	
		" = 22.0	35.0	

Table 3 (cont'd)

Toxicity of chromium to marine organisms

Organism	Form of chromium tested	Test parameters	Concentration of chromium in mg/l (ppm)	Reference
ANNELIDA				Reish et al. (1974) as reported by Oshida et al. (1976) [30,18]
Capitella capitata Polychaete (Adult)	CrO_3	96 hr LC_{50} 28 day LC_{50}	5.0 0.28	
(Trochophore larva)		96 hr LC_{50}	8.0	
Neanthes arenaceodentata Polychaete (Adult)		96 hr LC_{50} 28 day LC_{50}	>1.0 0.55	
(Juvenile)		96 hr LC_{50} 28 day LC_{50}	>1.0 0.7	
Neanthes arenaceodentata Polychaete (Juvenile)	$K_2Cr_2O_4$	96 hr LC_{50} 7 day LC_{50} 59 day LC_{50} Reduction in brood	2.2-4.3 1.44-1.89 0.20 0.05-0.0125	Oshida et al. (1976) [18]
	$CrCl_3$	7 day-<5% mortality 293 day no detrimental effects	12.5 50.4	
Neanthes arenaceodentata Polychaete	$K_2Cr_2O_7$	96 hr LC_{50} 7 day LC_{50}	3.0-4.0 1.4-1.7	Mearns (1974) as reported by Oshida et al. (1976) [39]
Nereis virens Polychaete	$Na_2CrO_4 \cdot 10H_2O$	5 wk (no mortality) 3 wk LC_{50}	0.5 1.0	Raymont & Shields (1963) [17]

Table 3 (cont'd)

Toxicity of chromium to marine organisms

Organism	Form of chromium tested	Test parameters	Concentration of chromium in mg/l (ppm)	Reference
ARTHROPODA				Okubo & Okubo (1965) as reported by Oshida et al. (1976) [36,18]
Artemia salina Brine shrimp (Eggs)	$Cr_2(SO_4)_3$	24 hr LC_{50}	40	
	K_2CrO_4	"	70	
Sesarma hematocheir Crab (Zoea)	$Cr_2(SO_4)_3$	"	56	
	K_2CrO_4	"	200	
Balanus amphitrite albicostatus Barnacle (Adult)	$Cr_2(SO_4)_3$	1 hr test for cessation of cirri movement	3.2	
CHORDATA				
Aldrichetta forsteri Yellow-eye mullet (Juvenile)	Cr prepared from- $Cr(NO_3)_3 \cdot 7\frac{1}{2}H_2O$	Static bioassay; seawater 10.1 vol., 19.5°C; salinity 34‰; pH 7.9; 80% aeration		Negilski (1976) [38]
	$CrCl_3$	96 hr LC_{50}	53 1/	
	$K_2Cr_2O_7$	"	24	
Salmo gairdneri Rainbow trout	K_2CrO_4 $K_2Cr_2O_7$	Static bioassay; freshwater threshold concentration	30	Grindley (1948) [38]

1/ Generally mullet are more sensitive to acute effects of Cr than other marine fish for which information is available.

Table 4

Toxicity of nickel to marine organisms

Organism	Form of nickel tested	Test parameters	Concentration of nickel in ml/l (ppm)	Reference
MOLLUSCA				
Mercenaria mercenaria Quahog (Embryos)	$NiCl_2 \cdot 6H_2O$	Static bioassay; synthetic seawater; 25°C; 25‰		Calabrese and Nelson (1974) [21]
		48 hr LC_{50}	0.31	
Crassostrea virginica American oyster (Embryo)	$NiCl_2 \cdot 6H_2O$	48 hr LC_{50}	1.18	Calabrese et al. (1973) [14]
CHORDATA				
Pimephales promelas Fathead minnow	Form of nickel tested not given in abstract	Chronic bioassay		Pickering (1974) [40]
		No effect on survival, growth, or reproduction	<0.38	
		Significant reduction in number of eggs and hatch	0.73	

PATHOLOGY OF ARCTIC AND SUBARCTIC MARINE SPECIES AND EXPOSURE TO TRACE METALS ASSOCIATED WITH PETROLEUM

by

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INTRODUCTION

There is little published information on pathological effects resulting from exposure of arctic and subarctic marine vertebrates and invertebrates to petroleum-associated trace metals (defined as primarily cadmium, chromium, nickel, and lead for this review). There is some published information, however, on pathological effects of these and other trace metals on other species, which by inference may be applicable to the above animals. In this short review we will present examples of studies on trace metals implicated in neoplasia, immunosuppression, and in alterations in cellular and subcellular structure. Whether similar effects actually do or can occur in arctic marine species mostly remains to be demonstrated.

NEOPLASIA

Certain compounds containing beryllium, cadmium, chromium, cobalt, iron, lead, nickel, selenium, zinc, and titanium are carcinogenic for experimental animals if administered by respiratory or parenteral routes [1]. There is little evidence, however, that trace metals in foods cause tumors in experimental animals [1]. Exceptions are dietary selenium [2,3] and lead [4,5], which have caused malignant changes in rats, mice, or hamsters when fed at high, toxic levels. Failure to produce tumors following oral administration of cadmium [6], titanium [6], chromium [6], nickel [6], and zinc and tin [7] to mice has been reported.

IMMUNOSUPPRESSION

Compounds containing certain potentially petroleum-related metals have been found to be immunosuppressive. Koller et al. [8] reported a remarkable decrease in antibody forming cells in mice exposed to 3 ppm cadmium in drinking water for 70 days and Koller and Kovacic [9] found a decrease in antibody formation in mice exposed to lead (13.75-1,375 ppm as lead acetate in deionized water for 56 days).

Cook et al. [10] reported that intravenous administration of cadmium acetate (0.60 mg/100 g) and lead acetate (2.00 mg/100 g) enhanced the susceptibility of rats to intravenous challenge with *Escherichia coli* by approximately a thousand-fold. It appeared that the effect was mediated by increased susceptibility to endotoxin, since equivalent vulnerability of metal-treated rats to exposure to killed *E. coli* occurrred.

Hemphill et al. [11] reported that mice treated with subclinical doses of lead nitrate (100 ug/l or 250 ug/l per day) for 30 days were more susceptible to challenge with *Salmonella typhimurium*.

Trejo et al. [12] found that a single injection of lead acetate (5.0 mg) had no effect on antibody production of rats but that it did impair phagocytic activity and significantly reduced the ability of liver and spleen to detoxify endotoxin.

Jones et al. [13] found that the effects of metals on immune responses depend on dose and time of administration in relation to antigen. For example, cadmium chloride (0.6 mg/kg Cd^{2+} at 5 days/week) injected into rats beginning 14 days before antigen enhanced both primary and secondary antibody responses. If the metal treatment was initiated one week before antigen, the primary immune response was delayed and the secondary response depressed. It was postulated that cadmium may be involved in a number of physiological processes in cells or may affect cell permeability.

Koller et al. [14] reported that a single dose of lead (4 mg) administered orally or intraperitoneally to mice stimulated formation of IgM antibody. Conversely, lead by either route of administration significantly reduced IgG antibody formation. Cadmium (0.15 mg), on the other hand, caused an increase in IgM antibody formation when injected intraperitoneally, a slight decrease of IgM when given orally, a reduced IgG antibody response when given orally, and an increased IgG antibody response when given intraperitoneally. Subclinical doses of lead in drinking water (2,500 ppm lead acetate over 10 weeks), cadmium (300 ppm cadmium chloride over 10 weeks), or mercury (10 ppm mercuric chloride over 10 weeks) suppressed immunocompetence of rabbits [15], but various subclinical dietary doses of lead had no effect on immunocompetence of chickens [16].

Nickel affected interferon synthesis of cells in tissue cultures whereas iron, chromium, and cadmium had no effect [17,18].

Robohm and Nitkowski [19] have reported that exposure of a fish, the cunner, *Tautogolabrus adspersus*, to 3 to 24 ppm Cd^{2+} in artificial seawater had no demonstrable effect on the ability of the fish to produce antibody. Exposure to 12 ppm cadmium increased the rates of bacterial uptake in phagocytes of the liver and spleen but significantly decreased the rates of bacterial killing within cells, probably increasing susceptibility of the fish to disease.

Therefore, it appears that effects of at least certain trace metals on immune responses vary markedly depending on dose and time of administration in relation to antigen and on route of metal administration. These factors must be considered as well as the species in designing suitable laboratory experiments for evaluating trace metal effects on disease resistance of arctic and subarctic marine animals.

CELLULAR AND SUBCELLULAR PATHOLOGICAL ALTERATIONS

Trace metals associated with petroleum hydrocarbons are among the more toxic metals known to affect marine and other organisms [20]. More is known about the effects of cadmium on the morphology of fish and mammals than about lead, nickel, or chromium; the effects of all four metals, but predominantly cadmium, on testis and ovaries, the central nervous system, gills, intestine, liver, and kidney will be discussed.

The toxicity of cadmium to humans [21] and mammals [22] has been recognized for some time; the primary site of damage is the testis. Testicular atrophy occurred in rats and mice injected subcutaneously with 0.02 mM cadmium chloride per kg of body weight involving destruction of both the seminiferous epithelium and interstitial tissue. However, no regeneration of spermogenic epithelium was evident as long as 133 days after the last cadmium injection [21]. Within 20 days after cadmium exposure, new blood vessels were formed and later, new Leydig cells were observed and there was gradually recovery in endocrine function.

The reproductive tissues of fish can also be affected by exposure to trace metals. Seven days after a 24-hour exposure to 25 ppm cadmium in the water, brook trout, <u>Salvelinus fontinalis</u>, developed haemorrhagic necrosis of the testis. Androgen production was disturbed but the primordial germ cells were not changed [23]. Testicular damage also occurred in goldfish after five interperitoneal injections of 10 mg cadmium chloride per kg of body weight. The number of primary germ cells decreased as the seminiferous tubules became depleted and were replaced by collagen fibrils [24]. In the same study, but with female goldfish, the ovaries maintained histological integrity but decreased both in the number of mature oocytes and in relative weight. In addition, lead may affect gonadal tissue. Sexual maturation was retarded in newborn guppies, Lebistes reticulatus, exposed to 2 ppm lead nitrate or 1.25 ppm lead [25].

There were toxic effects of cadmium on the central nervous system in 190 g Sprague-Dawley rats injected subcutaneously with 5.5 mg/ml cadmium chloride. Some ganglionic cells were lysed and others had pyknotic nuclei; massive hemorrhages also occurred in the ganglionic tissues [26]. In a subsequent experiments, young rats and rabbits had damaged central nervous systems after receiving cadmium chloride in the first few days after birth; both nerve fibers and cells were destroyed [27].

Effects of cadmium on other tissues did not involve hemorrhagic lesions. The cells of target organs appeared to be directly damaged by cadmium. In fresh water, the gills of Fundulus heteroclitus were damaged after the fish were exposed for 64 hours to 28 mg cadmium per liter. The mucous epithelium sloughed and necrotic tissues were evident on both the lamellae and filaments [28]. In 20 ^{o}/oo salinity and at cadmium levels "considered to be acutely toxic" [29], F. heteroclitus responded with an excessive production of mucus from the gill. The gill epithelium was destroyed in four species of fish, including rainbow trout, exposed to both nickel and cadmium and the fish suffocated [30]. Lead contamination of other species of fish produced a similar response [31,32].

Apparently, the salinity of the water is a factor in the toxic action of cadmium on fish: F. heteroclitus treated with cadmium in seawater were more resistant to poisoning [33] than when exposed to fresh water [28]. In addition, the intestine, rather than the gills, showed damaged mucous cells and a swollen epithelium after a one-hour exposure to 50 ppm cadmium chloride, and, after 48 hours, the submucosa was edematous. Some hypertrophied and necrotic areas were observed in the gills of these fish but not all the filaments were affected and not to the extent reported in fresh water exposures [34]. The differences in osmoregulatory mechanisms in fresh and marine fishes may explain the differences in gill and intestinal damage: in freshwater fishes there is a flow of water into the fish through the gills and oral tissues with minimal ingestion. However, in the marine environment, fish swallow water to compensate for the dehydrating effects of the surroundings [28].

After entry to internal tissues, cadmium can be accumulated in both kidney and liver. Overall, histological integrity was maintained in the livers of goldfish injected intraperitoneally with ten doses of 20 mg/l cadmium, but occasional focal granulomas developed. The kidneys of the same fish had an abundant invasion of macrophages which aggregated at some sites and formed granulomas [24].

Newman [35] found that the kidney structure changed in five of six cunners, Tautogolabrus adspersus, which were exposed to 48 ppm cadmium chloride ($CdCl_2 \cdot 2\text{-}1/2\ H_2O$) in seawater. There was diffuse and focal necrosis in the kidney tubules, and, in one cunner, the necrosis had progressed to form lesions. The proximal segment of the tubule was most affected; however, the glomeruli were not damaged. After a year's exposure to 5 mg/l of cadmium in seawater (20 ^{o}/oo salinity), no lesions were found in the liver and kidney tissue of Fundulus [29].

The blood spaces of the kidney of the cunner treated with 48 ppm cadmium chloride in seawater had large numbers of immature thrombocytes. In addition, changes in circulating blood cells occurred: the numbers of thrombocytes and lymphocytes decreased and the percentage of neutrophils increased [35]. Similar changes in the percentage of neutrophils and lymphocytes occurred in rabbits fed food containing 160 ppm cadmium for 200 days. Each rabbit consumed 14.9 mg cadmium per kg of body weight per day [36]. Thrombocyte, neutrophil and basophil levels changed in white perch, Morone americana, and hogchokers, Trinectes maculatus, exposed to Baltimore Harbor water for 7-30 days [37]. The water contained at least six heavy metals, among them cadmium and chromium.

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METABOLISM OF TRACE METALS: BIOACCUMULATION AND BIOTRANSFORMATION IN MARINE ORGANISMS

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CADMIUM

Little relevant information exists on plankton and invertebrates in relation to the uptake, distribution, and discharge of cadmium. Moreover, much of the available information relates to the uptake of this metal with respect to levels existing in the marine environment. Studies with plankton support the view that these organisms are capable of concentrating cadmium from the marine environment to produce tissue levels many-fold greater than exposure levels.

ASSIMILATION AND DISCHARGE

Plankton and Invertebrates

Fassett [1] reported that plankton and brown algae concentrate cadmium from seawater about 900 times. Moreover, Sparling [2] showed that blue-green algae accumulate cadmium in the range of 0.5 to 10 mg/l- levels substantially in excess of those in surrounding water. Cossa [3], in studies of the uptake of cadmium by the marine diatom, Phaeodactylum tricornutum, also found that cadmium levels were substantially magnified in these organisms over levels present in surrounding water. Interestingly, when cadmium was chelated with EDTA, uptake was negligible, suggesting that the chemical form of cadmium may be a critical factor in the degree of accumulation. Cossa [3] observed that two opposing phenomena appear to be responsible for the acquisition of cadmium by phytoplankton from the marine environment: adsorption of cadmium on the cell walls and the gradual elution (desorption) by external metabolites. Morris and Bale [4] studied the accumulation of cadmium by *Fucus vesiculosus* in the Bristol Bay Channel. These workers compared levels of cadmium in surrounding waters to those present in *F. vesiculosus* from six different geographic locations (Table 1). The findings clearly show that ambient levels of dissolved cadmium largely dictate the degree of magnification in *F. vesiculosus* over a wide range of concentrations. Data of Morris and Bale [4] (Table 2) may be compared with data obtained by other workers (Table 3) in studies with the accumulation of cadmium in *F. vesiculosus*. For example, Table 3 shows a comparison of inferred mean ambient dissolved cadmium at Portis Head from *F. vesiculosus* content. Although different analytical procedures were used in the studies just described, the data strongly imply that cadmium is actively sequestered by *F. vesiculosus* and is substantially magnified in tissues over concentrations present in the marine environment. This tendency is depicted in Figure 1 which summarizes data on the cadmium content of *F. vesiculosus* from coastal sites in the Bristol Channel. The data indicate that cadmium can reach 80 ppm in the tissues of *F. vesiculosus* in this geographic region. Although cadmium accumulates to a substantial degree in exposed marine plankton, it is not always found in detectable amounts in these organisms. For example, Nickless et al. [5] found detectable levels of cadmium in only one squid, Ommastrephes illecebrosa, of 10 species of zooplankton. The tendency of seaweeds to accumulate cadmium (and other metals) from the marine environment has been attributed to the presence of alginates in the cell walls and intercellular spaces that act as ion exchange materials having a strong affinity for divalent metals. In alginates extracted from Laminarea digitata, this affinity for divalent metals decreases in the order: Pb, Cd, Ba, Sr, Ca, Co, Ni, Zn, Mn, and Mg.

Bryan [6] studied adaptation of the polychaete, Nereis diversicolor (marine worm), to estuarine sediments containing high concentrations of cadmium. Comparisons were made of the concentrations of cadmium in sediments from estuaries of 26 rivers which drain metal-mining areas of southwest England. Concentrations of cadmium in sediments varied by a factor of 46, from about 0.2 to 9.3 μg/g; concentrations in worms varied by a factor of 45, from 0.08 to 3.6 μg/g. Figure 2 shows a direct relationship between concentrations of cadmium in whole Nereis and total concentrations in sediments. Thus, it appears that high percentages of cadmium may accumulate in marine worms from sediments rich in this element.

Yager and Harry [7] studied the uptake of heavy metal ions by Taphius glabratus, a snail host of Shistosoma mansoni. These workers found that cadmium tends to concentrate in liver, kidney, oviduct, and sections of the intestine.

Riley and Segar [8] studied the distribution of cadmium in seven echinoderms and two coelenterates. This trace metal was concentrated in the digestive parts of the organisms, less so in the gonads, and least so in the skeletal tissues.

The influence of several parameters on cadmium uptake was emphasized with crustacea. The uptake of cadmium from seawater by the blue crab, *Callinectes sapidus*, varied substantially in relation to salinity, temperature, and exposure levels. The rates of uptake were the greatest at low salinities and high temperatures. The main sites of localization of cadmium were the gill, hepatopancreas, and carapace. When low concentrations of cadmium occurred in the seawater for extended periods (0.11 ppm for 8 days and 0.2 ppm for 27 days), cadmium accumulations greater than background levels did not occur in the crab. The work of Hutcheson [9] serves to emphasize the great importance of environmental parameters in influencing the degree of uptake of cadmium into marine crustacea. Hutcheson emphasizes that interactions of multiple environmental factors must be considered in evaluating the biological influences of cadmium on marine organisms. Eisler [10] reported that mummichogs, *Fundulus heteroclitus*, were more susceptible to cadmium at 20°C than at 5°C and at 5 °/oo salinity than at 15, 25, or 35 °/oo salinity. The author observed that concentrations as low as 100 ppb of Cd^{+2} in the medium is potentially harmful to mummichogs and that mummichogs with whole body residues in the excess of 86 ppm (μg/g dry weight) will expire within five weeks.

Pringle et al. [11] determined the concentration of cadmium in the tissues of estuarine molluscs. The data showed that the tendency to accumulate cadmium from the environment varied widely with species; also, the rate of uptake and level of uptake were directly related to the exposure time and concentration of the metal in the water.

Shuster and Pringle [12] studied the accumulations of cadmium by the American oysters, Crassostrea virginica. During experimental periods, ambient seawater was maintained at a flow rate of 2.5 l/min and at $20 \pm 1^{\circ}C$; the salinity was 30 ± 2 $^{o}/oo$. The oysters were exposed to cadmium salts at concentrations of 0.1 and 0.2 mg/l over a 20-week study period. The test animals were emaciated and lost pigmentation of the mantle edge and coloration of digestive diverticulae. Moreover, these animals did not show much shell growth and eventually suffered high mortality. The animals exposed to 200 ppb of cadmium sustained high mortality between the fourth and eighth week of exposure.

Brooks and Rumsby [13] studied the uptake of cadmium by the oyster, Ostrea sinuata. Specimens were maintained for 100 hours in filtered seawater and an additional number was treated for the same period with filtered seawater containing 50 mg/l of cadmium. Substantial amounts of cadmium accumulated in the gills, viscera, and heart of the oyster. These findings were confirmed in radiometric experiments involving the uptake of cadmium from seawater. These studies indicated that, although the rate of uptake of cadmium by oysters was relatively slow, accumulation of the metal in organs was appreciable. Fractionation factors for the various organs, or varying cadmium concentrations in seawater, were similar in profile for all organs examined and indicated cessation of uptake at cadmium levels between 40 and 140 mg/kg. It was concluded that the uptake of cadmium was related to non-selective absorption, probably by coordination to organic ligands. Data supporting this hypothesis were obtained in radiometric studies on the oyster; the protein-bound cadmium content of the heart probably did not exceed one-fourth of the total amount of cadmium accumulated.

Ferrell et al. [14] demonstrated by spectrometry that cadmium accumulates in the shell of the oyster, _C. virginica_, to levels considerably above those in the seawater. Preliminary studies on oysters from different geographic regions did not indicate that large differences in their ability to accumulate cadmium existed. Ferrell and coworkers pointed out that the accumulation of cadmium in shells may arise from ingestion of algae enriched with cadmium and of various soluble complexes containing cadmium. The chemical form of cadmium in the environment may be a critical factor in the nature and degree of accumulation in bivalves. Brooks and Rumsby [15] studied the biogeochemistry of cadmium uptake by three species of New Zealand bivalves. Analyses were performed on sediment, on the whole animals (excluding shells), on the shells, and on individual dissected organs. Each of three species of bivalves accumulated cadmium to levels above that in the marine environment.

Segar et al. [16] studied the accumulation of cadmium in the shells and entire soft parts of 11 species of molluscs from the Irish Sea and of one species from a fresh-water source. Considerable enrichment of cadmium occurred in the soft parts of the organisms; the highest concentrations were found in the digestive organs and gills and the lowest concentrations in the shells.

Huggett et al. [17] studied the uptake and distribution of cadmium in oysters, _C. virginica_, with respect to various salinity regimes in Chesapeake Bay, Maryland. The data indicated that regimes of low salinity could be potentially more dangerous to oysters than those of high salinity.

Eisler et al. [18] studied the uptake of cadmium into a number of marine invertebrates. Oysters, _C. virginica_; subadult lobsters, _Homarus americanus_; and scallops, _Aquipecten irradians_, were immersed for 21 days in flowing seawater containing 10 μg/l Cd as $CdCl_2 \cdot 2\text{-}1/2\ H_2O$. Cadmium residues in whole animals and selected tissues were substantially higher in exposed animals than in control animals. The tail muscle of lobsters, adductor muscle of scallop, and the whole tissue of the oyster contained more cadmium per unit weight than did the appropriate control by 25%, 19%, and 352%, respectively (Table 4).

Recently, Frazier [19] carried out a series of experiments designed to determine relationships between the concentration of cadmium and other metals in the soft tissues of oyster, _C. virginica_, and sediments. He also investigated seasonal differences in the rate of metal uptake by the oyster soft tissues. The data [19] revealed that the increase in the metal concentrations in the soft tissues of the test animals over the levels found in the controls reflected the pattern of metal contamination in the sediments. Further, uptake of cadmium (Fig. 3) was seasonally dependent, with rapid uptake occurring during the summer and fall.

Bryan [20] studied the occurrence and seasonal variation of cadmium in the scallops, Pecten maximus and Chlamys opercularis, from the English Channel. There were considerable variations in the concentrations of cadmium in the animals examined. The concentrations of cadmium in P. maximus were higher than those in C. opercularis. The authors observed that, despite problems from individual and seasonal variations, kidneys and digestive glands of scallops appeared to have a potential as biological indicators of cadmium and other trace metal contamination.

O'Hara [21] studied the uptake of cadmium by fiddler crabs, Uca pugilator, exposed to temperature and salinity stress. The crabs were collected from an unpolluted estuary near Georgetown, South Carolina. After acclimatization to each level of salinity, the animals were subjected to 1 μC of ^{109}Cd and 10 μg/l (10 ppb) Cd^{++} as $CdCl_2$. Temperatures of 3°, 10°, and 25°C at two levels of salinity (10 and 30%) of the media were employed. The cadmium contents of gill and hepatopancreas were determined after periods of 24, 48, and 72 hours. Under each temperature regime, the crabs held in low-salinity water accumulated more cadmium than the crabs held in high-salinity water. Maximum accumulations of cadmium occurred in the crabs held at highest temperature and lower salinity; totals for gill and hepatopancreas were 65 and 74 mg/g at 24 hours, 98 and 198 mg/g at 48 hours, and 92 and 200 mg/g at 72 hours, respectively (Table 5). O'Hara [21] attempted to assay the total body burden of cadmium in the gills and hepatopancreas of the fiddler crabs. The results indicated that the body burden increased over time in all temperature-salinity regimes tested, reaching 17.44 μg at 33°C and 10 ‰. The translocation of cadmium from gills to hepatopancreas was most pronounced at high temperatures, as shown by the percent of metal in each tissue.

Marine Fish

Greig et al. [22] studied the uptake of cadmium into organs and tissues of the cunner, *Tautogolabrus adspersus*. The animals were exposed to 3, 6, 12, 24, and 48 ppm of cadmium in artificial seawater for four days. Average levels of accumulated cadmium were 8.2 times higher in liver than in gills. However, in the experiment employing 48 ppm cadmium, the livers of the cunner averaged 195 ppm as compared to 3.55 ppm for the gills (Table 6).

In a depuration study, the cunner were exposed to 24 ppm of cadmium in seawater for four days. Half of the animals were placed subsequently in clean flowing seawater for one month and the other half were immediately sacrificed to determine initial cadmium residues. A substantial decline in cadmium concentrations was found in the gills and blood of animals held in clean seawater for one month, in comparison to those sacrificed immediately after exposure to cadmium. The data obtained on the livers showed no particular trend; the livers of fish maintained in clean seawater for one month contained anywhere from 5 to 155 ppm of cadmium. These values may be compared to 30 to 170 ppm for livers from eight fish sacrificed immediately after exposure to cadmium. Apparently the fish lost very little of the accumulated cadmium during depuration (Table 7; Figs. 4,5).

Gilmartin and Revelante [23] determined the concentration of cadmium in the tissues and the whole of the northern Adriatic anchovy, *Engraulis encrasicholus*, and the sardine, *Sardinia pilchardus* (Table 8). During a seven-month fishing season, it was found that cadmium occurred in highest concentrations in the skin, gills, and liver. Cadmium levels in tissues of both species ranged from less than 0.1 to 1.4 μg/g wet weight. No significant differences existed between the cadmium contents in the two species, except that anchovy liver had a consistently higher level of cadmium than the other tissues. Table 9 contains data on the mean concentrations of various metals, including cadmium, in *Engraulis mordax* from Monterey Bay, California, and in *Engraulis encrasicholus* from the Adriatic Sea off Rovinj, Yugoslavia.

Von Westernhagen and Dethlefsen [24] investigated the combined effects of cadmium level and salinity on development and survival of flounder eggs (Fig. 6). The accumulation of cadmium by flounder eggs during embryogenesis under various test conditions is shown in Figure 6. Cadmium uptake during the first three hours after fertilization was quite rapid. Generally, the cadmium level in the eggs reached a maximum by the third day and then, in most cases, tended to decrease somewhat to the end of the test period of 10 days. Eggs incubated in 16 $^{o}/oo$ artificial seawater had the highest initial concentration of cadmium, whereas the eggs reared in 24, 32, and 42 $^{o}/oo$ contained consecutively smaller concentrations of cadmium. Eggs fertilized in uncontaminated water (25 $^{o}/oo$) and transferred into the contaminated media 30 minutes later had only slightly lower cadmium values than those eggs in comparable trials at 25 $^{o}/oo$. Newly hatched larvae contain very little cadmium. Low values for both control and contaminated larvae indicated that cadmium accumulation during incubation occurred primarily in the chorion. It was suggested that the accumulation of cadmium in eggs took place at cell surfaces due to the formation of complexes with anions present. This assumption would account for the fact that, after initial uptake, eggs did not accumulate further cadmium during the course of the experiments. These findings are in contrast to those found in fish larvae (Dethlefsen, von Westernhagen, and Rosenthal [25], unpublished data) and other marine organisms [10,18,26,27]. It was suggested that the chorion, which binds a substantial amount of cadmium, acts as a protective agent against contaminants such as the heavy metals [28].

Dethlefsen, von Westernhagen, and Rosenthal [29] studied the accumulation of cadmium in newly hatched flounder, Pleuronectes flesus, and herring, Clupea harengus, larvae arising from eggs incubated in water containing 0.05 to 5.0 ppm cadmium. Levels of cadmium accumulating in the larvae varied from 0.7 to 2.3 ng/0.1 mg dry weight. The levels of cadmium in herring and flounder larvae generally increased with increasing exposure time.

Blood and Grant [30] determined the levels of cadmium in the tissues of the fish, Lepomis macrochirus, by flameless atomic absorption spectroscopy. Liver, gills, gut, and heart accumulated 5.6, 4.7, 3.6, and 4.5 ppm of cadmium, respectively, after one week of exposure of the fish to 3 ppm of $CdCl_2$.

Eisler [27] studied the radiocadmium exchange with seawater by killifish, F. heteroclitus. Viscera were the main repository of radiocadmium during uptake over a 25-day period. Especially high concentrations of radiocadmium appeared in the gastrointestinal tract and lesser levels in the liver. A post-treatment interval of 180 days in cadmium-free seawater resulted in about 90% loss of whole body cadmium. This tendency to lose cadmium did not appear dependent to a marked degree upon the level of stable Cd^{++} present in the aquatic environment during exposure.

Havre et al. [31] determined cadmium levels in fish from a coastal area in southern Norway. The cadmium concentrations were considered to be low, varying from 0.03 to 0.012 μg/g wet weight in cod, from 0.02 to 0.029 μg/g in whiting, and from 0.003 to 0.033 μg/g in herring. Evidence was presented to suggest that cadmium accumulates to a greater degree in fat fish than in lean fish. Windom et al. [32] studied the accumulation of cadmium, arsenic, copper, zinc, and mercury in 35 species of North Atlantic finfish, Chondrichthys and Osteichthys, and found that there are slight differences in metal levels between offshore and inshore species of finfish in the North Atlantic. The authors believe that some variations in metal concentrations that do exist in different species appear to be related to size and hence are probably physiologically controlled.

BIOCHEMICAL INTERACTIONS

Cadmium is considered to be a relatively rare element in the biosphere; yet its high toxicity, primarily documented with terrestrial animals, has led to a number of studies relating to the biochemical and physiological alterations brought about by this element in aquatic and terrestrial animals. Cadmium forms complexes with amino acids and peptides; it is often concentrated in tissues in the form of metallothionein. Vallee and Ulmer [33] reviewed in detail a number of enzyme systems which are either inhibited or enhanced by cadmium. It is known that cadmium ions can, in vitro and in vivo systems, completely uncouple phosphorylation reactions associated with the oxidation of succinate or citrate in rat liver mitochondria. In addition, this element appears to alter the physical properties of DNA. Just a few examples are given below to illustrate the widespread involvement of cadmium in altering a host of biochemical and physiological systems.

Biesinger and Christensen [34] studied the effects of cadmium on the metabolism of Daphnia magna. Exposure of the D. magna to 0.17 μg/l of cadmium ion over a three-week period resulted in alterations in total protein and glutamicoxaloacetic transaminase activity; moreover, alterations in the metal-ATP complex also occurred.

The work of Albright and coworkers [35] revealed that $CdCl_2 \cdot 2.5H_2O$ altered glucose metabolism in the heterotrophic microflora of a natural water system. In invertebrates, such as the mud snail (unknown species), cadmium was found to elevate oxygen consumption. Interestingly, the combination of cadmium with copper resulted in a lower oxygen consumption rate than when either metal was employed alone [36].

May and Brown [37] found that cadmium affects the uricolytic enzyme from *Sabellid* polychaetes. A 6×10^{-7} M solution of $CdCl_2$ inhibited allantoinase from whole *Eudistylia vancouveri*. O'Hara [38], in studies of the effect of salinity on the toxicity of cadmium to the fiddler crab, *U. pugilator*, observed that there was a clear relationship of high susceptibility to cadmium in a low-salinity water. The relationship may be due to the interaction between cadmium and a variety of salts in normal seawater. An alternative possibility is that the direction of the osmotic gradient in the higher salinities may reduce the rate of entry of the metal into the marine organism.

Collier et al. [39] studied alterations in the uptake of oxygen through the gills in the mud crab, *Eurypanopeus depressus*, in response to cadmium exposure. The degree of oxygen uptake by the gills was severely reduced on exposure of the organism to between 3 and 11 ppm of cadmium in the ambient water. Interestingly, the reduction in oxygen uptake was positively correlated with survival of the mud crab (Fig. 7). The findings of Collier et al. [39] suggest that cadmium is in some way interfering with normal osmoregulatory processes in the mud crab. In studies with estuarine crabs, *Carcinus maenas* and *Cancer irroratus*, Thurberg et al. [40] showed that cadmium elevated the serum of *C. maenas* above its normal hyperosmotic state and reduced the rate of oxygen consumption in both species. This study further pointed to the fact that cadmium is influential in altering the osmoregulatory processes of aquatic crustacea.

Frazier [19] reported that shells of oysters from areas contaminated with metals, such as cadmium, zinc, copper, manganese, or iron were significantly thinner (16%) than the shells of animals from non-contaminated areas.

Begenisich and Lynch [41] studied the effects of cadmium ions on voltage-clamped squid axons. One effect of cadmium was to reversibly depolarize axons by 20 to 30 mV. It was suggested that cadmium alters the gating structure of the ionic channels, presumably by binding to the protein constituents. Casterline and Yip [42] provided some interesting insight into the binding of cadmium with macromolecules in the oyster (species not given). Table 10 gives the cadmium content of homogenate, nucleii, mitochondria, microsomes, and supernatant; the values are compared with those of the rat kidney and soybean. Cadmium was found to be primarily associated with proteins in the 105,000 g supernatant fraction. Specifically, cadmium in oysters, as well as in rat organs, was principally bound to proteins of 9,200 to 13,800 molecular weight units. Figure 8 illustrates the protein and cadmium distribution pattern in oysters as determined by gel filtration chromatography. The study by Casterline and Yip [42] suggested that the tendency for oysters and other marine organisms to accumulate high levels of cadmium in relation to environmental levels may be attributed to the formation of stable protein complexes.

Jackim [43] determined enzyme responses to metals, including cadmium, in fish. The enzymes studied were xanthene oxidase, acid phosphatase, alkaline phosphatase, catalase, sodium-potassium ATPase, and magnesium ATPase. Figure 9 shows the influence of the direct addition of 10^{-5} M of cadmium, copper, lead, and silver on the enzyme preparations *in vitro*. Also shown is the influence of metals on several enzymes of surviving animals after a 96-hour exposure. Consistent relationships were not apparent between the direct *in vitro* effects of the metal on enzymes and the effect of exposing the animal (*in vivo*) to metal. Generally, the effect on the enzymes is inhibitory. Figures 10 and 11 show the effect of cadmium and other metals on ribonuclease activity measured at pH 7.8 and pH 5. It is notable that pH 5 favors a much greater change in ribonuclease activity than does pH 7.8. The author pointed out that other factors, such as toxicant concentrations, salinity, and temperature, influence the time course of the responses (Figs. 10,11). The degree of enzyme inhibition resulting from *in vitro* addition of metal salts to enzyme preparations was discussed by Jackim [44] in a later paper (Table 11). The enzyme activity from 10 fish surviving 96-hour TLm concentrations of the toxic metals is given in Table 12. Changes in ribonuclease activity of fish exposed to cadmium are presented in Figure 12. The author suggested that the results of their study indicate that liver enzyme activities are a useful index of sublethal exposure of fish to toxic metals. Decreases in catalase activity and RNAase activity were consistent throughout the experiment.

Gould and Karolus [45] studied the effects of cadmium on the cunner, T. adspersus. After exposure of cunner to 3 ppm and 24 ppm of cadmium for 96 hours, aspartate aminotransferase activity of the liver was 71% and 50%, respectively, of the activity in livers of control fish. Also, in a study of nicotinimide adenine dinucleotide reductase activity in liver, it was found that 10 times more magnesium was required for activation of the enzyme in the experimental group than in the control group. The authors presented preliminary evidence to suggest that in cunner exposed to cadmium a significant degree of metal-protein complexing occurs in serum.

Gardner and Yevitch [46] examined the hematological response of an estuarine teleost to cadmium. In this study a number of changes were observed in blood morphology. Interestingly, however, no significant differences existed in hematocrits between animals exposed to 50 ppm cadmium for 24 and 48 hours and a control group.

Hiltibran [47] studied the effects of cadmium and other metals on oxygen and phosphate metabolism of bluegill liver mitochondria. In studying the hydrolysis of adenosine triphosphate (ATP) by freshly prepared mitochondria from the liver of the bluegill, it was found that low levels of cadmium and zinc enhanced the hydrolysis of ATP more than the same levels of manganese or calcium. Data relating to the effects of cadmium ions and other metal ions on the hydrolysis of ATP in bluegill liver are given in Table 13. In addition, Tables 14 and 15 give data on the effects of cadmium and other metals on succinic oxidase and α-ketoglutaric oxidase, respectively. The findings suggest that low levels of cadmium (3.3×10^{-3} μM/ml) severely interrupt energy production by blocking oxygen uptake. This phenomenon may explain at least one mechanism for the toxic action of cadmium on aquatic fish.

FOOD WEB RELATIONSHIPS

Very little information is available on the transport and biomagnification of cadmium in marine ecosystems of the arctic and subarctic regions. Despite the paucity of information, however, several papers pinpoint certain relations among geological deposits, the water column, and marine biota, that are of interest in the present review. Kerfoot [48] employed an experimental flowing marine microcosm for the evaluation of the chronic accumulation of cadmiun and other metals released into coastal waters. Cadmium was introduced into seawater flowing through compartments filled with representative samples of sediment and marine life. In determining the material balance of cadmium introduced into the microcosm, it was found that 15% of this metal was removed by sediment and biota. A major portion of the retained cadmium was incorporated into sediment (62%) and oysters (33.9%). Interestingly, however, the greatest enrichment occurred in algae, shrimp, and sand worms. It seems likely that oysters and sediments serve as reservoirs for cadmium in the marine environment. It is of interest to note from a comparative point of view that deep-burrowing earthworms had a more substantial effect on cadmium distribution in soils than shallow-burrowing species. Van Hook and colleagues [49] stressed the pH, the chemical form of the element, and antagonisms and synergisms of other ions as important factors in determining the ultimate fate of cadmium in the ecosystem. A detailed study was conducted by Fowler and Benayoun [50] on the role of mussels, *Mytilus galloprovincialis*, and benthic shrimp, *Lysmata seticaudata*, in the cycling of cadmium in the marine environment. Results of experiments on the accumulation of radioactive cadmium indicated that steady state between water and organisms was not reached after two months. Bioconcentration factors at this time were 130 and 600 in whole mussels and shrimp, respectively. Concentration factors based on use of stable cadmium were several times higher, suggesting that equilibrium between radioactive cadmium and stable cadmium in the organisms was incomplete. In mussels, the highest concentrations of radioactive cadmium were in the viscera but significant amounts also occurred in muscle, mantle, gills, and shell. In shrimp, the highest levels of radioactive cadmium were also found in viscera and substantial amounts in decreasing levels in the exoskeleton, muscle, and eyes. Ambient temperature was a factor in the accumulation of cadmium in the shrimp, but not in the mussels. Cadmium accumulation was directly proportional to the content of cadmium in seawater; however, the accumulation did not appear to be affected by variations in zinc levels in surrounding medium. During depuration, the shrimp tended to lose cadmium at a faster rate at higher temperatures; however, differences in rates were not significant over a two-month period. Shrimp maintained in a flowing seawater aquarium retained about 55% of the original radioactive cadmium body burden after eight months. The biological half-life, based on a seven-month period, was 378 days.

The relatively slow loss of radioactive cadmium from mussels was not affected by the levels of zinc in the tissues or by the levels in surrounding seawater. Mussels, held under natural conditions at a field station, lost significantly less radioactive cadmium than a similar group held in a laboratory flowing seawater system during the first three months of depuration; thereafter, however, animals fluxed cadmium four times faster than a comparable laboratory group. It was concluded that fluxing of cadmium by mussels and shrimp is a relatively slow process; such animals exposed to cadmium in the water column may retain a significant fraction of the accumulated metal for a relatively long period of time.

Several factors appear to influence the transport of cadmium in ecosystems. Martin [51] demonstrated that cadmium is adsorbed to copepod exoskeletons. Concentrations of cadmium and other metals in samples of surface zooplankton were compared with those of 12 samples collected at 100 or more meters deep. Substantial binding of cadmium to exoskeleton of the copepods was attributed to the large total surface area which is available for chemical reactions. Because copepods are the most abundant multicellular animals in the world, it was suggested that the binding of cadmium and other metals to their exoskeletons may be an important transport mechanism of cadmium in marine ecosystems.

Boothe and Knauer [52] studied the possible importance of fecal material in the biological amplification of trace and heavy metals, such as cadmium. The studies were conducted with brown algae, *Macrocystis pyrifera*, a primary producer, and the crab, *Pugettia producta*, a primary consumer, in a closed system. The concentration of cadmium in the resulting feces from the consumer was determined. Although the accumulation of cadmiun in feces was generally lower than that of other metals, it appeared that feces may play a significant role in the cycling of cadmium in the marine environment. The role of phytoplankton in the transport and biomagnification of cadmium is obscure; nevertheless, these organisms do concentrate this element. Interestingly, it was shown that cadmium levels decreased during peak periods of productivity in a study of an Hawaiian transect. Unfortunately, little information exists on probable complex relationships that exist between phytoplankton and other aspects of the arctic and subarctic ecosystems.

LEAD

Lead is widely distributed in the biosphere and is absorbed and accumulated in the tissues of many plants and animals in higher concentrations than either mercury or cadmium [53]. Lead also interacts with a number of enzyme systems in animals, mostly by bringing about enhanced activities (Table 16) [33]. In addition, lead interacts with amino acids and proteins, notably forming mercaptides with cysteine and less stable complexes with other amino acids. Lead alters mitochondrial structure or cellular oxidation processes in a number of terrestrial animals and interacts with phosphate groups of nucleotides and nucleic acids to form complexes. Moreover, the toxic effects of lead include anemia, due to reactions of lead with hemoglobin and erythrocytes and to the tendency of this metal to interfere with porphyrin biosynthesis. The number of reactions of Pb^{++} with membranes have been documented in terrestrial animals; associations of lead with the components of membranes bring about deleterious effects, such as decreased osmotic fragility of red cells and disruption of biomembrane architecture. These examples indicate that lead alters biochemical and physiological processes of animals in a variety of ways.

ASSIMILATION AND DISCHARGE

Plankton and Invertebrates

Several studies provide detailed information on the uptake of lead into marine plankton organisms. Unfortunately, the possible hazardous effects of lead on phytoplankton have been studied in only a limited number of species. Phytoplankton seem to have a rather high tolerance for lead [54,55]. The incorporation of lead into marine phytoplankton is important because these organisms occupy the first level of the marine food chain and may play a significant part in the distribution and biomagnification of this metal in the marine environment. Schulz-Baldes and Lewin [56] studied the uptake of lead into two marine phytoplankton, *Phaeodactylum tricornutum* or *Paltymonas subcordiformis*, exposed to lead in concentrations ranging from 0.02 to 0.08 mg/l. The authors found that despite differences in the number of cells and lead concentrations, some lead was adsorbed per cell, suggesting that the number of binding sites for each cell were limited; cells of *Phaeodactylum* become "saturated" when the lead concentration reached 11,640 μg/g (dry weight), equivalent to approximately 6.7 x 10.8 Pb atoms/cell. The addition of 2×10^{-6} M EDTA to a solution of 0.5×10^{-6} M Pb completely inhibited the accumulation of the element by Phaeodactylum, indicating that only uncomplexed lead is adsorbed. Moreover, when the lead-treated diatom cells were resuspended in a higher concentration of EDTA (10^{-2} M), a significant amount of adsorbed lead was eluted. As the pre-treatment time with lead was increased, a significant decline in the ability of the organisms to discharge this metal was noted. The findings of Schulz-Baldes and Lewin [56] indicate that lead ions are first absorbed to the cell surface and then are translocated to loci within the cell wall, to the plasma membrane, and eventually to the cytoplasm. Figures 13 to 18 depict the results obtained by Schulz-Baldes and Lewin [56]. It is important to point out that in seawater a variety of lead complexes may occur: $PbCO_3$, $PbCl^+$, $PbCl_2$, Pb^{++}, $PbCl_3^-$, and possibly $PbOH^+$. Also, the formation of complexes and chelates with organic ligands in natural seawater are likely to occur. In relation to the experiments of Schulz-Baldes and Lewin [56] on uptake of lead by marine phytoplankton, Duce et al. [57] found that in Narragansett Bay, Rhode Island, lead and other metals are concentrated in surface water films only a few molecular layers thick. They concluded that the actual enrichment factors in the films may be well over 10,000, resulting in extremely localized pollutant concentration. These findings suggest that phytoplankton organisms, under some circumstances, may sequester very high levels of lead from the marine environment.

Reilly and Roth [58] studied the accumulation of lead and other metals in 15 species of phytoplankton representing several marine classes. Organisms were harvested after 20 to 30 days and analyzed for lead and other metals. In additional series of experiments, the authors investigated the uptake of lead and other metals by four species of phytoplankton growing in media having different levels of chelated trace metals. They found that pH, salinity, and other factors are critical in governing the amount of lead sequestered by these organisms from seawater [59].

Studies on the uptake, distribution, and discharge of lead in marine invertebrates are somewhat more numerous than those with marine phytoplankton. Bryan [20] determined the presence of lead and other metals in the whole body and renal organs of the scallop, C. opercularis, from the English Channel (Table 17). The storage site for lead is the renal organs. These organs account for about 0.5% of the mass of the scallop without the shell. Pringle et al. [60] determined the amount of lead absorbed by the eastern oyster, C. virginica, after exposure to different concentrations in seawater for 49 days (Fig. 19). Generally, the concentrations of lead in the tissues were proportional to the concentrations in the water. The higher concentrations of lead appeared in the organs (hepatopancreas, gonad, and gills in decreasing order of magnitude). In a study of the brown seaweed, F. vesiculosus, concentrations of lead and other metals appeared to increase substantially with the distance of the tissue from the growing point (Fig. 20). Such changes were attributed to the continued slow accumulation of the metals, to the formation of more binding sites as the weed grows older, and possibly to contamination of all the surfaces of the plant by fine particles [60].

In considering the influence of sediments containing lead and other metals on animals, such as worms and molluscs which inhabit these sites, a study was made of the worm, N. diversicolor, from two estuarine sediments off the British coast. The data obtained for lead and other metals are given in Table 18. Relatively small concentrations of lead are sequestered by this marine worm from estuarine sediments containing from 56 to 230 $p/10^6$ dry weight. In a study of Echinus esculentus, Spatangus pureus, and Asterias rubens, Riley and Segar [8] found that lead, together with cadmium and other trace metals, is strongly concentrated in the digestive parts of organs, less so in gonads, and least so in skeletal tissues. Lead was concentrated to a substantial degree in the tissues in relation to a number of other metals. In other studies, Riley and coworkers [8] determined the distribution of the major and minor elements in a number of marine molluscs. In those animals obtained from the Irish Sea, the highest concentrations of lead, cadmium, and other metals were found in the digestive organs and gills and the lowest concentrations were found in shell.

Laboratory studies with Pb^{++} were carried out with mussels by Majori and Petronio [53]. These workers demonstrated that the mussel, M. galloprovincialis, accumulates substantial amounts of lead from the surrounding seawater.

Brooks and Rumbsy [13] substantiated the findings of other workers indicating that bivalves accumulate toxic metals, such as lead, to a significant extent from the marine environment. Analyses were performed on sediment, on the whole animals excluding shells, on the shells, and on the individual dissected organs.

Ferrell et al. [14], in studies with the oyster, C. virginica, found that the shell contained considerably higher levels of lead than did surrounding seawater. Some evidence was presented that the shells of bivalves do not accumulate as high levels of lead from the marine environment as do the soft tissues. This work provided additional data in support of the view that the levels of metal in shellfish tissue may be a good indicator of metal pollution in the marine environment.

Schultz-Baldes [61] studied, in laboratory experiments, the accumulation of lead in the common mussel, M. edulis. The mussels were maintained for 130 days in media containing different concentrations of lead. Quantitative analyses of the soft parts of this organism revealed a distinct tendency to accumulate lead. The lead content of the animals increased from a natural level of 8.4 μg Pb/g dry weight to 12,840 μg/g when held in media containing 0.5 mg/l; to 20,770 μg/g in media containing 1 mg/l; and to 39,830 μg/g in media containing 5 mg/l. Lead accumulations expressed as percent of lead in surrounding water were 10.9% at 0.5 mg/l, 9.5% at 1 mg/l, and 3.4% at 5 mg/l, respectively.

In later work, Schulz-Baldes [62] studied the uptake of lead from seawater and from food, and subsequent depuration of the mussel, M. edulis). Mussels were held for six weeks in seawater containing different concentrations of lead from 0.05 to 5.0 mg/l. The author observed a constant rate of lead uptake that was linearly dependent on the concentration of lead in the surrounding water. Moreover, the discharge of lead was linearly dependent upon the original lead concentrations in soft parts of the organism. Rates of accumulation and depuration in large mussels, shell length 45 to 55 mm with an average dry weight of 750 mg, were less than those in smaller mussels of shell length 19 to 21 mm with average dry weight of 30 mg. The author predicted that lead uptake and elimination would become non-linear if prolonged for extended periods. Lead accumulations in kidney, gills, adductor muscle, digestive gland, foot, mantle, and gonads were evaluated in two experimental series. In one series, medium-size mussels were maintained in seawater containing 0.01 mg of lead per liter. In another series the mussels were held in natural seawater and fed green algae, Dunaliella marina, containing lead of approximately 600 μg/g dry weight of tissue. The average amount of lead given to each mussel per day in both test series was approximately 2 μg. In the first series, mussels took up 25% of the total amount of lead given within 35 days. The animals exposed to lead through the diet acquired 23.5% of the lead presented. In each organ examined the lead concentration increased during the course of the experiment; however, the rates of uptake differed significantly. The kidney had the highest rate of uptake.

In considering the data presented in challenge experiments on the uptake of lead into various invertebrate forms, it should be remembered that a number of factors play an important role in the nature and extent of accumulations in these animals. Bryan [20], in a study of the concentrations of 11 trace metals in the tissues of two species of scallops from the English Channel, found that seasonal changes had a pronounced effect on the levels of lead and other metals present in these organisms. In both species, *P. maximus* and *C. opercularis*, differences existed in lead accumulations during autumn and winter months; the highest values occurred in the autumn. These changes may have been related to food supply, because accumulated levels were generally higher when phytoplankton productivity was low (autumn) and were generally lower when productivity was high (spring). Despite such seasonal factors, however, it appeared that the lead content of the kidneys and digestive glands of scallops may have potential as a biological indicator of trace metal contamination of the marine environment.

Marine Fish

The uptake, distribution, and discharge of lead by marine fish has been the subject of only a few detailed and relevant studies. Gilmartin and Revelante [23] studied the concentrations of lead and other metals in the northern Adriatic anchovy, *E. encrasicholus*, and sardine, *S. pilchardus*. The lead concentrations in sardine tissues paralleled those in anchovy tissues (Table 19). High concentrations of lead occurred in the gills and skin of both species and a tendency for higher levels in anchovy liver occurred late in the year. The lowest values observed generally occurred in muscle tissue with seasonal means ranging from non-detected to 1.2 μg/g wet weight. The tendency of the fish to accumulate lead in their skin during winter was thought to be related to wind-induced roiling of lead-containing sediments into the water column during this period. The bottom sediments of the northern Adriatic contain relatively high levels of metal pollution. Comparative data on the mean elemental concentrations in E. mordax collected from Monterey Bay, California [63] and in E. encrasicholus from Rovinj, Yugoslavia, are presented in Table 20. Lunde [64] found that both lipid and non-lipid phases of halibut, Hippoglossus hippoglossus and Thunnus Thynnus, became enriched with lead and a number of other metals from natural exposure of the fish to these contaminants in the marine environment. Petkevich [65] also found that sprat, anchovy, mackerel, and other fish accumulate lead and other metals (e.g., Ni, Cr, V, Ti, Sn, Sr) in their bones. In fact, more lead is accumulated in the bony tissue of plankton-feeding fish than in the bony tissue of benthos-feeding fish. McDermott and Young [66] conducted an intensive study of the extent of metal enhancement in flatfish obtained from contaminated and non-contaminated sediments. Estimated sediment enrichments and median concentrations (mg/kg of dry weight) of seven metals, including lead in tissues from Dover sole obtained near Palos Verdes outfalls (Station T_4-450) and from a control region in the Santa Barbara Channel are presented in Table 21. Data on levels of lead and chromium in the tissues of diseased and apparently healthy Dover sole from the Palos Verdes shelf are given in Table 22. The accumulation of lead was essentially restricted to the kidney, with diseased animals having twice as much lead as did the healthy animals. The authors state that the differences between medians for diseased and healthy specimens are significant at the 95% confidence level. The suggestion was made that the observed significant differences in the lead contents of the kidneys may be related to fin erosion disease. Lead has an affinity for epithelial tissues. In tuna, for example, this metal tends to accumulate in the skin. McDermott and Young [66] observed that in Dover sole from Palos Verdes outfall regions the skin is less slimy than in the same fish from non-contaminated regions. The authors attribute this to a possible interaction of the metal with epithelium. Such a conclusion is substantiated by the work of Varanasi et al. [67], showing that lead substantially alters the architectural properties of skin mucus from rainbow trout, *Salmo gairdneri*, as determined by ESR spectrometry.

Marine Mammals

A limited amount of data is available that suggest marine mammals accumulate high proportions of lead (as well as cadmium and arsenic) from the marine environment. The studies of Anas [68] with the northern fur seal, *Callorhinus ursinus*, and harbor seals, *Phoca vitulina*, reveal that relatively high levels of lead appear in liver, muscle, and kidney of the fur seal and in the liver of the harbor seal. The fur seals were obtained from the Pribilof Islands, Alaska, and from off the coast of Washington State. The harbor seals were taken from the waters off southern California, Oregon, and Washington, and from the Bering Sea. All of the samples, including a fetus obtained three months before birth, contained lead. The concentrations of lead were highest in the kidney (maximum of 1.8 mg/g). No correlation was obtained between lead contents in the liver or kidney and the age of the animals.

Braham [69], in a study of the California sea lion, *Zalophus californianus*, found that lead accumulated significantly in high concentrations in hard tissues, such as bone and teeth. Because comparable results are found in man, the author suggested that the large amount of information on human toxicology of lead may be useful in interpreting the influence of lead on coastal environmental communities.

BIOCHEMICAL INTERACTIONS

Although evidence to date suggests that lead accumulates to a significant extent in phytoplankton, very little information is available to provide an understanding of the biochemical and physiological effects that such accumulations bring about. Biesinger and Christensen [34] described a study involving exposure of the fresh-water organism, *D. magna*, to lead. Alterations in total protein and in glutamic oxaloacetic transaminase (GOT, L-aspartate: 2-oxoglutarate amino transferase) activity were noted. Table 23 gives the effect of three-week exposures of *D. magna* to metal chlorides on body weight, total protein, and GOT activity (expressed as mean percent deviation from control means). The data show that there was in increase in protein and GOT values in metal-exposed organisms. The reasons for the increases in total protein and GOT activity were not clear; however, it was suggested that the molecular dynamics of the animal, induction protein-forming enzymes, were changed. Such events may well cause a general increase in protein metabolism. In the study by Biesinger and Christensen [34], the nature of the metal-ligand forms present in the water was unknown. However, certain correlations between the toxicity of the metals and their physicochemical characteristics were apparent. In fact, correlations between toxicity and the solubility of metal sulfides suggested the possibility that metals may combine in vivo with the sulfhydryl groups of enzymes, thus affecting their solubility and catalytic activity. Figure 21 shows correlations between the 16% reproductive impairment concentration for D. magna of metals as pM (-log molarity) and their solubility product constants as metal sulfides (pK_{sp}), their electronegativity, and their equilibrium constants as the metal-adenosine triphosphate complex (log K_{eq}). In a study by Albright et al. [35], the effects of $PbCl_2$ and other metal chlorides were evaluated with respect to indigenous heterotrophic microflora of a natural water. The heterotrophic activity is based upon the uptake and mineralization of a radioactively-labeled metabolite (in these experiments ^{14}C-glucose) by the indigenous aquatic microbes. The data are then analyzed by Michaelis-Menten enzyme kinetic relations. The findings showed that concentrations of lead salts that resulted in death of the organism also caused erratic uptake and mineralization rates of ^{14}C-glucose. Moreover, sublethal concentrations of this metal caused a non-competitive inhibition of maximum heterotrophic activity and markedly increased the turnover time of the glucose substrate as determined by nutrient agar plate counts.

The action of lead on lobster (species unspecified) axons has been studied by Pennock and Goldman [70]. $PbCl_2$ altered the action potential of lobster axons. The lead salt was added in sub-millimolar quantities to the artificial seawater bathing the node under study. Their action on the voltage-clamp behavior reached a steady level in 30 to 90 seconds and was slightly reversible with lead. The major effect was a decrease in early peak conductance with a minimal effect on the steady-state conductance. Resting potential and leakage conductance were not affected and the time to peak of the early current increased slightly, particularly at lower voltages. Castles et al. [71] studied the bioavailability of lead in oysters. The bioavailability of lead accumulated by oysters was compared to that of inorganic lead, as lead acetate, using a 6-point bioassay. Male rats were fed a synthetic rodent diet (SRD) containing 10% freeze-dried, lead-free, oysters. These diets contained three levels of lead, either as lead acetate (47, 199, or 552 ppm) or lead-laden oysters (68, 172, or 612 ppm). Control animals were fed the SRD containing 10% dried, lead-free, oysters. Additional controls consisted of the male rats fed SRD; SRD with medium level of lead acetate (160 ppm); SRD with added Ca, Cu, Fe, Zn, Mn, and Mg in the quantities found in the oysters; and SRD fortified with a medium level of lead acetate (122 ppm). The findings revealed that lead, either as lead acetate or lead-laden oysters, suppressed erythrocyte Δ-aminolevulinic acid dehydrase activity (ALAD), increased urinary Δ-aminolevulinic acid (ALA), and increased kidney weight. Lead-laden oysters in the diet decreased their overall body burden of lead but had no marked effect in altering the lead-induced ALAD suppression. The results from the ALAD and ALA bioassay revealed interesting information on the interactions of lead with macromolecules in the oyster. Bioassay analyses suggested that lead found in freeze-dried oysters was as bioavailable and toxic as lead acetate added to control oysters. Although these findings do not directly relate to marine ecosystems, they clearly suggest the possibility that the toxicity of lead present in shellfish may be roughly comparable in toxicity to lead present in the water column.

D'Amelio et al. [72] studied the effect of lead on protein synthesis in crustaceans. These workers obtained polyribosomal profiles from the hepatopancreas of *Eriphia spinifrons* and evaluated the role of polyribosomes in protein biosynthesis. During the acclimation of crustaceans in seawater containing lead salts, polyribosomes were found to disappear from the profiles.

Studies were also conducted on blood cells in goldfish, *Carassius auratus*, including lead-induced changes in cell density, hemoglobin synthesis, and Δ-aminolevulinic acid dehydrase (ALA dehydrase) [73]. Statistical problems were encountered in attempting to evaluate alterations in cell density because of the large variability in this parameter. However, the findings indicated that hemoglobin synthesis is strongly inhibited by lead, and ALA dehydrase activity is also reduced during immersion of animals in 0.2 mg Pb^{++}/l for five days.

As mentioned earlier in our discussion, Jackim et al. [44] studied the effects of metal poisoning on five liver enzymes in the killifish, *F. heteroclitus*. The data presented in Table 11 show percent enzyme inhibition resulting from *in vitro* addition of various metal salts. Table 12 gives ranges and means of enzyme activity from 10 fish surviving a 96-hour TLm concentration of the toxic metals. The enzymes considered are alkaline phosphatase, acid phosphatase, xanthine oxidase, and catalase.

It is noteworthy that catalase showed a striking difference between control and exposed fish for all metals tested (Table 11). Also, the range of values of the experimental groups fell completely outside of the range of values for the control groups (Table 11). Such differences in results led the authors to suggest that catalase activity could be used in diagnosis of fish suffering from metal poisoning. Figure 12 shows that a number of metals, including lead, bring about substantial changes in the activity of killifish liver RNAase. Both lead and cadmium produce major changes in the liver RNAase in fish exposed to 10^{-4} M concentrations of $PbCl_2$ for periods of from approximately 48 to 96 hours. Jackim et al. [74] suggest that the changes in enzyme activities could represent initial disorders ultimately resulting in death of the fish, or that they may simply be symptoms of metabolic impairment(s).

A study [43] with F. heteroclitus was made of the effect of exposure time of $PbCl_2$ and $CdCl_2$ on the liver ribonuclease activity measured at pH 7.8. The data given in Figure 12 show that both lead and cadmium substantially affected ribonuclease activity in fish exposed for 48 to 96 hours. A change in the ionic strength of the water to pH 5 brought about substantial alterations in the effects of the lead salts on ribonuclease activity (Fig. 12); the changes in enzyme activity are very much greater at the lower pH. Jackim [74] studied temporal changes in Δ-aminolevulinic acid dehydrase activity upon exposure of F. heteroclitus to both lead and mercury (Fig. 22). The findings revealed that, of the 50 ppm of lead added to the fish tanks in the experiments described, only about 1 ppm remained in solution after one week. All fish survived the 28-day exposure with no apparent outward damage; therefore, it was suggested that activity of Δ-aminolevulinic acid dehydrase be a suitable index of sublethal lead toxicity in fish. A similar conclusion was reached with respect to Δ-aminolevulinic acid dehydrase activity of fish blood. Hodson [73] studied alterations in the activity of this enzyme in order to determine if the activities could serve as a useful indicator of harmful exposure of fish to lead. In studies with rainbow trout, *S. gairdneri*, the activity of red cell Δ-aminolevulinic acid dehydrase was depressed after exposure of the fish to lead. Concentrations of this element in water as low as 13 μg/l caused a significant inhibition of activity after only a four-week exposure period. The conditions of exposure were:

Temperature:	$11 \pm 0.9^{\circ}C$ (N=59)
Alkalinity:	90 ± 4 mg/l (N=34)
Hardness:	135 ± 2 mg/l (N=35)
Conductivity:	241 ± 0 u ohm/cm^2 (N=90)
pH:	7.7 ± 0.2 (N=81)
Oxygen:	9.8 ± 0.9 mg/l (N=85)

Figure 23 shows the inhibition of Δ-aminolevulinic acid dehydrase activity of rainbow trout, *S. gairdneri*, following exposure to lead nitrate. Values obtained for experimental animals are given in comparison to a control group. Significant differences existed in the activities of Δ-aminolevulinic acid dehydrase in relation to exposure to lead nitrate at concentrations varying from 13 μg/l to 143 μg/l. These changes were brought about in periods from 1 to 16 weeks of exposure. Jackim [74], in studying the effect of lead nitrates on fish, also examined alterations in activity of Δ-aminolevulinic acid dehydrase. The data on the ALA-D inhibition and activation versus time for *F. heteroclitus* exposed to mercury and lead salts are given in Figure 24.

Abou-Donia and Menzel [75] studied fish brain choline esterase in shiner perch, *Cymatogaster aggregata*. Acetylcholine esterase activity was inhibited by lead ions as lead nitrate. These findings suggest the possibility that lead ions accumulated by marine fish may alter the normal biochemistry of neural transmission.

Westfall [76] tested the hypothesis that the coagulation of gill mucus on exposure of fish to lead salts was due to a decrease in the permeability of the mucus to dissolved oxygen. As a result of studies with goldfish, it was concluded that precipitation of the mucus of the gills with lead nitrate does in fact decrease the permeability of the gills to dissolved oxygen. The content of dissolved oxygen had no effect on the toxicity of solutions of lactic acid, which coagulated the mucus to only a very slight extent. In the work by Varanasi et al. [67], it was found that solutions of $PbCl_2$ varying from 0.1 ppm to 1.0 ppm brought about substantial changes in the architecture of skin surface mucus of rainbow trout, *S. gairdneri*, in 24 hours. Alterations in properties of the mucus were evaluated by electron spin resonance spectrometry using a free radical probe (N, N-dimethyl-N-dodecyl-N-tempoylammonium bromide) for polar sites (Fig. 25). Exposure of the fish to aqueous $PbCl_2$ solutions revealed that the mucus accumulated 0.9 to 4.0 ppm lead. When the fish were exposed to lead and placed in metal-free water for 24 hours, the mucus released a maximum of 70% of the sequestered metal. Accumulated lead was associated with a substantial increase in the mobility of the spin probe, which was indicative of structural changes in the mucus. Despite the fact that lead was released to a considerable extent in metal-free water, the ESR data suggested that induced structural alterations had not been significantly reversed on release of the metal from the epidermal mucus. The authors suggest the possibility that "fluidization" of mucus may alter the delicate rheological properties of this medium. Such an occurrence might result in changes in hydrodynamic resistance and other vital properties of mucus.

FOOD WEB RELATIONSHIPS

As is the case with cadmium, little detailed information is available on processes involved in the transport of, or the potential for biomagnification of, lead in ecosystems. Martin [51] stressed the importance of zooplankton in the cycling of elements in the world's oceans. Such organisms, second only to phytoplankton in abundance, can transport elements in a variety of ways: by vertical migrations across mixing barriers, by incorporation of metals into fast-sinking fecal material, by molting of exoskeletons, by the transport of metals to higher trophic levels, and by the sinking of skeletal structures. Despite the obvious importance of zooplankton in the transport and biomagnification of elements, little work has been reported in relation to such processes. Martin [51] collected 22 zooplankton samples from the general area off Puerto Rico and analyzed them for lead and other trace metals. The elemental concentrations in the zooplankton are given in Table 24. The data indicate that average values for lead were higher in the deep samples. It was suggested that more of these elements had become adsorbed to copepod exoskeletons at greater depths because food-dependent molting rates were lower. Accordingly, more time would be expected to be available for elemental adsorption to take place. If such an hypothesis is proved to be correct, molted copepod exoskeletons may be important in biogeochemical marine cycles. Martin [51] hypothesized that slow-sinking exoskeletons may well be capable of taking up lead and other toxic metals by adsorption-exchange mechanisms long after leaving the living animals. The author [51] also suggested that a large surface area is provided by such structures on which important chemical reactions may take place. Concentration factors for the zooplankton were considered and relevant data are presented in Table 25. Concentration factors were lowest for magnesium, strontium, and calcium; however, values for the remaining elements were much higher, reaching 197,000 for lead.

The importance of fecal material in the transport of metals, such as cadmium and lead, has been discussed previously in this report. Boothe and Knauer [77] determined the concentrations of trace elements, such as lead, in the food of herbivorous crustaceans and in the resulting fecal material. Using Pugettia as a source of fecal material, the authors were able to collect 1.2 g wet weight of feces per day.

The pellicle surrounding the fecal pellet enabled the authors to collect, in a pure and intact form, most of the fecal material arising throughout the experimental period. Data on amounts of lead in the food and feces allowed for the calculation of concentration ratios for lead and the other elements. Table 26 gives the concentrations of various elements in _M. pyrifera_ and in the feces of _P. producta_. Table 27 gives comparisons of the average elemental concentrations in algae and feces. The findings (Table 27) show that lead is significantly concentrated in the feces. Thus, it would appear that several trace elements, including lead, can be greatly concentrated in fecal material of a primary consumer. Moreover, fecal material appears to play a major role in the trophic relationships of coastal benthic communities. Thus, this tendency to concentrate metals may exert a significant influence on levels of heavy metals in _Euphausia pacifica_ organisms and other members of detritus food chains. The authors suggested that the fate and significance of fecal materials in pelagic communities requires further detailed investigation. Obviously a number of complex factors influence the transport and biomagnification of lead in ecosystems; Aubert et al. [78] pointed out that chelation and other complexing reactions, such as those occurring with EDTA, ABS, fumic acid, and others, predictably play an important role in the transport and biomagnification of lead and other toxic metals. Unfortunately, however, little information is available at present to assess the influence of such associations on the transfer of lead through marine food webs.

CHROMIUM

Chromium has been detected in living organisms in only trace amounts and apparently has no known essential function in the physiology of either plants or animals. The principal means through which chromium enters the biosphere is the liquid and gaseous effluents of industrial plants. Chromium is toxic, especially to aquatic animals [79]. Chromium exists in the +2, +3, +5, and +6 valence states, the trivalent and hexavalent species being more stable. Krauskopf [80] has reported that chromium was present in seawater at concentrations of 0.05 μg/l and the principal state was the chromate form. Apparently, hexavalent chromium was assimilated more readily in organisms than trivalent chromium and was found to be at least a hundred times as toxic as the trivalent form.

Because radiochromium (Cr^{51}) is an important component of effluents from nuclear reactions, much attention has been given to the distribution of this component in aquatic organisms. However, analyses for radiochromium does not include assessment of total chromium present in the animals and therefore should be viewed as such. Very little information is available on the occurrence of chromium in marine ecosystems and even fewer reports exist on the rate of uptake and elimination of chromium under controlled exposure conditions. Because of this obvious lack of information, mechanisms operating in the uptake and biomagnification of chromium are not well understood.

ASSIMILATION AND DISCHARGE

We shall discuss a few field studies that give information on the levels of chromium in various marine organisms collected from known polluted areas in order to assess biomagnification factors. Hardly any studies have been reported on the levels of chromium in phytoplankton. However, Black and Mitchell [81], in their report of trace metal analyses of _Laminonia_ fronds, demonstrated that chromium was present in the range of 0.9 to 1.8 ppm. Trace elements, such as chromium, were concentrated more in the perennial stipe than in the attached frond. Biomagnification factors for chromium were in the range of 100 to 500 for different algae (Table 28). Riley and Segar [8] and Segar et al. [16] reported on the distribution of several trace elements in organs of echinoderms, coelenterates, and molluscs (Tables 29 and 30). Chromium accumulated to a larger extent in the soft parts than in the shells of molluscs and the levels in the soft parts were higher than those in the marine environment.

Brooks and Rumsby [13] reported the biomagnification factor for chromium in three species of bivalves, _O. sinuata_, _Pecten novae zelondiae_, and _M. edulis_ collected from New Zealand near Taxman Bay. The values were 20×10^4 for scallop, 6×10^4 for oyster, and 32×10^4 for mussel. The authors also examined various organs and tissue sites of the test animals. Chromium (and nickel) was found to be concentrated in the gills, visceral mass, intestine, and kidney of scallops. Interestingly, significant levels were also detected in the heart of the oysters.

Raymont and Shields [82] studied the uptake and toxicity of chromium on the marine worm, _Nereis_. It was shown that chromium was taken up (levels were not determined) by _Nereis_ kept in 1 ppm solutions of potassium chromate: the threshold toxicity was 1 ppm. Heavy mortality occurred in worms exposed to chromium in the range of 2 to 10 ppm. The tests were carried out under static bioassay conditions. Exposure of the worms to 1 ppm level of chromium for more than two weeks brought about considerable mortality. With autoradiographic techniques using Cr^{51}, the authors were able to show that gut and body walls absorbed detectable levels of this metal. Parapodial regions also showed certain concentrations of chromium. The distribution of chromium in the gut was uniform; blood vessels contained high levels of chromium. The authors suggested that chromium was transferred from the body and gut wall to the small blood vessels. No determinations were made on the rate of uptake of chromium. Raymont and Shields also determined that threshold toxicity for crab, _C. maenas_, was in the region of 40 to 60 ppm.

Chipman [83] investigated rates of uptake, accumulation, and distribution of chromium in the marine polychaete worm, _Hermione hystrix_; this worm is known [84] to have relatively high levels of chromium. In challenge studies with trivalent chromium using radioactive sodium chromate, the authors found no evidence of accumulation of chromium in the animals. However, when _Hermione_ was exposed to seawater solutions containing hexavalent Cr^{51}, the uptake was rapid, but accumulation was a slow process (Fig. 26); relatively small amounts of chromium were accumulated over a period of 19 days. The author [83] determined uptake of chromate by Hermione with respect to concentration of the metal in seawater (Table 31) and found that the uptake was directly related to the concentration of metals in water; the higher the concentration in water the larger the amount of accumulated metal. This finding led the authors to infer that the uptake of chromium was a passive process.

To determine the mode of uptake of trace metals via gill membranes, Hibiya and Oguri [85] perfused several eels, *Anguilla japonica*, with trivalent Cr^{51} in perfusion fluid. After one hour, chromium was taken up by the gills to a very small extent (0.073 ppm) in comparison to 0.74 ppm zinc, mercury, or silver. Knoll and Fromm [86] reported that hexavalent chromium (Cr^{51}) was taken up from the surrounding water mainly via the gills; it appears that the rate of uptake of trivalent Cr^{51} from the water is rather low. These results are in agreement with the findings of Chipman [83]. In other experiments, Hibiya and Oguri [85] injected radioactive Cr^{51} into the air bladder of goldfish, *C. auratus*, and examined various tissue for distribution of the metal. The highest levels were, of course, found in the air bladder, the site of injection of the metal ions (Fig. 27). The authors suggested that Cr^{51} has a strong affinity to bind to collagenous fibers of the air bladder; nevertheless, significant levels were also found in kidney and head kidney. Kraintz and Talmage [87] observed that Cr^{51} was deposited in the reticuloendothelial system of the kidney and bone marrow of scallops. Bryan [20], in his studies on seasonal variation of trace metals in scallops concentrated (Table 32) from 1,000 to 9,400 times in the tissues of the animals collected from the English Channel. The kidney and digestive glands accumulated the largest amounts of chromium.

In an experiment to determine levels of metals in feces of marine animals, Boothe and Knauer [52] fed algae, M. pyrifera, containing 2 to 9 ppm (based on dry weight) chromium to adult kelp crab, P. producta, and collected fecal material for analysis of chromium. Very little chromium was discharged in feces; the ratio of concentration of metal in feces to concentration of metal in algae was only 0.8 for chromium compared to 5.4 for lead. Because no analyses for levels of chromium in the crab were carried out, the authors were not able to determine accumulation patterns of chromium in the challenged animal.

In another study, Sather [88] exposed crab, Podophthalmus vigil, to 1 μCi Cr^{51}/l for 16 days. Figure 28 depicts the uptake of chromium by various tissues. The gill accumulated the largest amount of chromium. Interestingly, the mid-gut gland and the muscle concentrated more chromium that the blood. As these two sites are well supplied with blood, it appears that they may have more affinity for chromium than the blood. The level of chromium reached (Fig. 29) a maximum value within two to three days in gills and four to five days in blood. It would appear that gills probably regulate the amount of chromium that is absorbed by the blood. When the exposed animals were placed in metal-free water after two-day exposure, the gill lost a certain amount of chromium (Fig. 30) whereas the blood level remained relatively unaltered. The authors also studied accumulation and discharge of chromium by gills and blood of

P. vigil after intrapericardial injection of 5.3 μCi $Cr^{51}Cl_3$. The gills (Fig. 30) showed continuous increase in the levels of chromium and the blood showed a steady decrease. However, the increase of activity in the gills cannot totally be accounted for by the amount of decrease in blood; the authors suggested that other tissues may be involved. Sather [88] suggested that chromium may be bound to mucopolysaccharides and proteins of the gills. It appears (Fig. 30) that a certain amount of chromium in the gills is in "non-assimilated" or non-bound or labile form; the biological half-life of that chromium during the excretion experiment was nine to ten days. These results are in agreement with earlier work of Chipman [83] with *Nereis*. Sather [88] also showed, in a series of *in vivo* and *in vitro* experiments, that potassium cyanide (an inhibitor of carbonic anhydrase) affected the rate of uptake of chromium, indicating that regulation of the influx of the amount of chromium by gills is dependent upon oxidative phosphorylation and partially dependent upon the zinc-containing enzyme, carbonic anhydrase (Fig. 31). Tennant and Forster [90] investigated the distribution pattern of chromium in crabs, *Cancer magister*, collected from a Columbia River estuary (Fig. 32). They found that chromium was accumulated in setae, gills, and hepatopancreas. The authors inferred from these findings that both surface adsorption (on setae and gills) as well as physiological process (involving the hepatopancreas) are operative in bioaccumulation of chromium. Tennant and Forster noted that Cr^{51} is accumulated by diffusion into gill tissues of crab. There appears to be virtually no information available on the uptake and distribution of chromium in marine fish; most of the work was done on fresh water fish, such as rainbow trout [79,86]. One study was published on the Cr^{51} distribution in Pacific salmon [89]. Tennant and Forster [90] reported on the biomagnification factors for chromium (Table 33) in several marine organisms. There appeared to be no definite pattern relating trophic levels to biomagnification factors. Morozov et al. [91] determined the metal content of 12 species of South Atlantic fish. In general, the content of the metals decreased in the order: zinc, iron, strontium, copper, lead, chromium, nickel, cobalt, and cadmium. The metals were primarily present in skin, scales, and fins.

BIOCHEMICAL INTERACTIONS

Most of the literature on biochemical effects of chromium deals with fresh-water species [79]. Chromium is involved in many biochemical systems [92]. Gray and Sterling [93] noted that Cr^{6+}, as radiochromate, readily passed through erythrocyte membranes. In the red blood cell, the hexavalent form was reduced to the trivalent form before being bound to the hemoglobin molecule. The trivalent form bound to blood plasma protein more readily than the hexavalent form [93]. The site of attachment of chromium to hemoglobin is a subject of controversy. Chernoff [94] reported that the chromium was bound to the α-chains, whereas Pearson and Vertrees [95] stated that the chromium was bound to the β-chains. Grogan and Oppenheimer [96], employing paper electrophoresis and dialysis experiments on human plasma and egg albumin, postulated that chromium was electrostatically bound to the proteins because the binding energy increased as the positive charge on the molecules was increased.

Literature on the action of chromium on biochemical systems is somewhat conflicting. Meldrum and Roughton [97] reported that trivalent chromium may possibly inactivate carbonic anhydrase. However, at the pH level and buffer system employed, the possibility existed that the chromium could have been precipitated from solution and thus could have affected the nature of the results. Henry and Smith [98] reported that a dichromate concentration range from 1 to 10 μg/ml inhibited as much as 95% of the urease activity. Curran [99], working with rats, reported that chromium increased the synthesis of cholesterol and fatty acids. Schwartz and Mertz [100] discovered that trivalent chromium is an active ingredient of the glucose tolerance factor (a dietary factor required to maintain normal glucose tolerance in rats fed semipurified diets). It was reported that chromium is essential for the binding of insulin to the mitochondrial membranes of liver cells, thus extending chromium studies to the problem of diabetes mellitus.

Sather [88], in studies of chromium absorption and metabolism of *P. vigil*, reported that radiochromium was transported to tissue sites by way of the blood; electrophoretic studies of blood proteins indicated that the majority of the radiochromium was present in the saline portion of the hemolymph. Sather [88] also demonstrated, by means of *in vivo* studies, that gills of *P. vigil* regulated absorption of chromium and the regulation was dependent in part on the oxidative phosphorylation process and in part on the action of the zinc-containing enzyme, carbonic anhydrase. Further, Sather [88] noted that the flux of chromium was altered when another metal, such as iron, was present. Potassium cyanide had virtually no affect on the flux of chromium when iron was also present in seawater.

Abegg [101] found that sodium dichromate tended to increase tissue fluids of bluegill, L. macrochirus. The density of the blood of the test fish decreased noticeably in sodium dichromate solutions (930 ppm). Other workers [103] have found that metals, such as chromium and nickel, bring about death of fish by precipitating the gill secretions, thus causing asphyxiation. Jones [102] proposed that, on a ppm level, a relationship between the toxicity of metals and their solution pressure exists. For example, metals of low solution pressure (silver and copper) are more toxic because they rapidly precipitate gill secretions. Lead and cadmium are known to act in the same way but much more slowly; chromium and nickel are even less effective. Zarafenetis and Hempton [104] found that small concentrations (10 to 20 ppb) of potassium dichromate had no apparent effect on the growth rate of Chlorella pyreneidesa but had a strong inhibiting effect on the growth of Chlamydomonas reinhardi. Moreover, Upitis et al. [105] found that small concentrations (0.1 to 10 mg/l) of chromium significantly retarded the growth and productivity of Chlorella. Interestingly, addition of copper, manganese, molybdenum, iron, or zinc counteracted the toxic effects of chromium.

FOOD WEB RELATIONSHIPS

An interesting study by Baptist and Lewis [106] involved transfer of Cr^{51} and Zn^{65} through the food chain. In two separate experiments, the authors used phytoplankton Chlamysdomonas sp. for the first trophic level; brine shrimp, Artemia salina, for the second; postlarval shrimp, Micropogon undulatus and Eucinostomus sp. for the third; and mummichog, F. heteroclitus, for the fourth. In the first experiment, phytoplankton grown in Cr^{51} medium were fed to brine shrimp for 24 hours. The fish were then fed daily to the postlarval fish which, in turn, were fed daily to the mummichog. Both assimilated and non-assimilated (undigested) chromium were transferred through the food chain. The authors found in a previous experiment that organisms at each trophic level emptied their digestive tract of radioactive material within 48 hours when radioactive food was followed by non-radioactive food. To study the transfer of only assimilated metals, the workers fed radioactive food to each organism on alternate days. The authors [106] found that both Cr^{51} and Zn^{65} were transferred through the food chain and the concentration of Cr^{51} declined to some extent (Fig. 33) through the food chain.

In another experiment, the authors [106] measured the uptake of Cr^{51} by the organisms at each trophic level from water (Table 34). The munnichog and zooplankton accumulated more Cr^{51} from food than from water, but postlarval croaker accumulated more Cr^{51} from water than from food. However, Cross et al. [107] found that the amphipod, Anonyx, did not accumulate detectable levels of Cr^{51} after being fed radioactive shrimp. Moreover, Osterberg et al. [108] showed that Cr^{51} appeared to a very small extent in food chains. It should be remembered, however, that in the studies of Osterberg and coworkers [108] hexavalent Cr^{51}, which is ionized in seawater was used; whereas in the experiment of Baptist and Lewis [106] the trivalent Cr^{51}, which is present as particulate matter and is thus more easily assimilated, was used. However, the fact that all the organisms took up trivalent Cr^{51} from water is in variance with Chipman's results [83]; he found that the polychaete,

H. hystrix, was able to accumulate hexavalent chromium, but not trivalent chromium, from water. It is not possible to draw any firm conclusions from these results as to whether the food chain or the water is the principal pathway of uptake of chromium by marine organisms. Aubert et al. [109] studied in vitro transfer of copper, chromium, and mercury along the benthic trophodynamic chain (consisting of marine bacteria; the annelid, N. diversicolor; and the fish, Scorpaeno pircus; and mice). The degree of accumulation in the worm decreased in the order: Hg, Pb, Cu, Cr, and Zn. The presence of ethylenediaminetetraacetic acid (EDTA) enhanced the uptake of mercury, copper, zinc, and chromium in fish.

NICKEL

Virtually no information is available on the uptake and distribution of nickel under laboratory conditions. A few studies [8,16,102,110] showed detectable levels of nickel in various marine animals obtained from relatively polluted areas indicating that nickel, in common with other trace metals, is accumulated to a much higher level than that existing in surrounding seawater (Tables 28-30, 35-37), For example, Bryan [20] reported that bioconcentration for nickel in scallops was in the range of 240 to 4,000 (Table 32). Kidney and digestive glands of these animals accumulated relatively high concentrations of nickel. Black and Mitchell [81] reported that biological concentration factors for nickel in various algae ranged from 200 to 1,000 (Table 28). Segar and coworkers [16], in their studies on distributions of several trace metals in organs of scallops, reported that nickel was present in substantial amounts (49 ppm) in soft parts of P. maximus (Table 37).

Duce et al. [57] showed that trace elements, such as lead and nickel, are enriched 1.5 to 50 times in the top 100 to 150 μm in Narragansett Bay relative to the concentrations in water at 20 cm. Nickel was enriched in organic particulates to a great extent. The authors suggested that pollutants concentrated in the surface micro-layer of the coastal zone may easily be introduced into the atmosphere for subsequent transport to open ocean waters. With regard to these findings, it should be noted that Martin [51] examined various copepods from ocean surfaces as well as from different depths for concentration of nickel and found that, on the average, surface animals concentrated slightly less nickel than the animals from the depth of 100 to 500 meters. However, the dominant species at the surface was Undinula vulgaris; whereas the dominant organism, at 100-meter depth, was Pleuromamma xiphias. Thus, the difference in concentrations of metal may be related to species difference. Martin [51] noted that bioconcentration for nickel in copepods was 2,500 (Table 38).

Paraschiv et al. [111] reported that when 60 to 90 mg of $NiSO_4$ was added to the media containing algae, Scenedesmus guadricaudo and Chlorella vulgaris, about 10 mg/g dry weight of nickel was absorbed by by the algae. In addition, the authors [111] studied absorption of aluminum, zinc, copper, and chromium by the algae and found that aluminum and nickel showed the highest degree of absorption. In relation to these results, it is interesting to note that Upitis et al. [105] found that small concentrations (0.1 to 10 mg/l) of nickel in the medium significantly decreased growth and productivity of the algae, Chlorella.

Hardly any reports are available on accumulation of nickel in higher marine organisms. Beasley and Held [110] reported that clams, Tridacna gigas, from eastern seaboard of USA, contained radio-nickel (Ni^{63}) in kidneys together with stable nickel. Gilmartin and Revelante [23] determined levels of nickel in tissues of the northern Adriatic anchovy, E. encrasicholus, and sardine, S. pilchardus, during a seven-month period (Table 9). Nickel was concentrated mainly in the skin and gills. In contrast to other metals, such as copper and cadmium, nickel was not detected in sardine liver and was only occasionally detected in anchovy liver. The authors feel that high concentrations of nickel found in the skin and gill may have been due in part to artifacts introduced during experimental procedures.

Few studies have been reported on the biochemical effects of nickel on marine organisms. It was reported [27,103], however, that nickel (and other metals such as lead and cadmium) precipitate the gill secretions of fish causing asphyxiation and subsequent death of the animal. Schweiger [103] reported that levels as high as 2.5 ppm of nickel were not toxic to fishes such as tench, carp, rainbow trout, and brook trout. The effect of sublethal levels of nickel on marine organisms has not been reported in any detail in the literature.

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TABLE 1

Annual overall ranges of occurrence and mean ambient levels of dissolved cadmium, copper, manganese and zinc and their accumulation in Fucus vesiculosus at coastal sites of the Bristol Channel

Metal	Position	Dissolved metal: Overall range (μg/l)	Dissolved metal: Geometric mean (μg/l)	*F. vesiculosus* content (ppm dry wt)	Concentration factor (ppm, dry wt in seaweed per ug/ml dissolved metal in seawater
Cadmium	Ilfracombe	0.15- 0.38	0.27	3.82	1.4×10^4
	Mumbles	0.22- 1.77	0.59	11.3	1.9×10^4
	Porthcawl	0.29- 1.20	0.59	9.33	1.6×10^4
	Minehead	0.45- 1.28	0.75	19.2	2.6×10^4
	Barry	0.65- 1.50	1.07	15.8	1.5×10^4
	Weston	0.91- 2.01	1.34	19.5	1.5×10^4
Copper	Ilfracombe	0.11- 0.79	0.35	3.82	1.4×10^4
	Mumbles	0.22- 2.04	0.67	8.52	1.3×10^4
	Porthcawl	0.13- 1.57	0.62	10.0	1.6×10^4
	Minehead	0.27- 1.80	0.67	10.7	1.6×10^4
	Barry	0.65- 2.78	1.32	14.3	1.1×10^4
	Weston	0.57- 1.90	1.20	12.0	1.0×10^4
Manganese	Ilfracombe	0.10-15.50	1.00	38.7	3.9×10^4
	Mumbles	0.29-17.90	3.55	80.0	2.3×10^4
	Porthcawl	0.32- 1.42	0.66	85.8	1.3×10^5
	Minehead	0.10- 3.24	0.64	77.1	1.2×10^5
	Barry	0.19- 2.12	0.74	66.4	8.9×10^4
	Weston	0.10- 2.12	0.41	89.2	2.2×10^5
Zinc	Ilfracombe	3.30- 9.10	5.21	88.4	1.7×10^4
	Mumbles	6.10-50.00	15.0	262	2.0×10^4
	Porthcawl	6.00-12.50	8.48	209	2.5×10^4
	Minehead	4.50-13.90	7.47	188	2.5×10^4
	Barry	7.10-18.70	11.9	209	1.8×10^4
	Weston	7.00-15.00	11.2	202	1.8×10^4

[From Morris and Bale, 1975 (4)]

TABLE 2

Concentration factors for metals in Fucus vesiculosus (parts per million in dried seaweed per ug/ml dissolved metal in seawater)

Source	Cadmium	Copper	Manganese	Zinc
Bowen's (1966) compilation of data for brown seaweeds	3.6×10^{3}	3.7×10^{3}	2.6×10^{4}	1.4×10^{4}
Preston et al. (1972). Mean of 18 Irish Sea coastline samples	2.7×10^{3}	4.5×10^{3}	2.3×10^{4}	2.0×10^{4}
Bryan & Hummerstone (1973)		2.7×10^{4}	4.6×10^{3}	1.1×10^{4}
South-west coast estuaries		2.5×10^{4}	1.9×10^{4}	6.4×10^{4}
This work. Bristol Channel	1.5×10^{4}	1.0×10^{4}	$2.3\text{–}22 \times 10^{4}$	1.8×10^{4}

[From Morris and Bale, 1975 (4)]

TABLE 3

Comparison of inferred mean ambient dissolved cadmium and zinc at Portishead from Fucus vesiculosus content

Source	Cadmium		Zinc	
	F. vesiculosus content (ppm, dry wt)	Inferred mean dissolved metal (μg/l)	F. vesiculosus content (ppm, dry wt)	Inferred mean dissolved metal (μg/l)
Butterworth et al. (1972)	220	14.7	800	44
Fuge & James (1974)	25.6	1.7	330	18

[From Hiltibran, 1971 (47)]

TABLE 4

Cadmium in whole body and selected tissues of four marine species after immersion for 21 days in flowing sea water containing 10 ppb of cadmium (as $CdCl_2 \cdot 2\text{-}1/2H_2O$) (values in parenthesis represent percentage increases over controls)

Species	mg Cd/kg ash wt		mg Cd/kg wet wt	
	Experimental	Control	Experimental	Control
Crassostrea virginica				
whole oyster	52.1(460)	9.3	1.49(352)	0.33
Aquipecten irradians				
whole scallop[a]	82.7(143)	43.0	2.46(114)	1.15
adductor muscle	74.1(51)	49.2	1.68(19)	1.41
remainder	85.0(188)	29.5	2.74(161)	1.05
Homarus americanus				
whole lobster[a]	5.4(2)	5.3	0.72(41)	0.51
muscle	11.7(17)	10.0	0.25(25)	0.20
exoskeleton	4.4(7)	4.1	0.88(49)	0.59
gill	31.3(82)	17.2	0.87(78)	0.49
viscera	37.5(11)	33.8	1.21(0)	1.21
Fundulus heteroclitus				
whole fish	7.6(36)	5.6	0.48(45)	0.33

[a]Estimated from sum of components.

(From Eisler et al, 1972 (18)]

TABLE 5

Cadmium content in gill (G) and hepatopancreas (H) from fiddler crabs exposed to 10.0 ppm cadmium over a 72-hour period and under various temperature-salinity regimes. Values are means of concentrations in tissues of four animals ± standard error.

	24 hours			48 hours			72 hours		
Temperature-salinity regime	Total μg Cd^{++} in G and H	% in G and H	ppm Cd^{++} in G and H	Total μg Cd^{++} in G and H	% in G and H	ppm Cd^{++} in G and H	Total μg Cd^{++} in G and H	% in G and H	ppm Cd^{++} in G and H
10°C, 10‰	.78	G-68.8 H-31.2	20.8±3.3 6.8±0.8	1.03	G-55.3 H-44.7	28.1± 1.4 16.2± 0.8	1.86	G-29.9 H-70.1	25.1± 3.7 30.1± 2.2
10°C, 30‰	.39	G-69.0 H-31.0	9.1±1.1 3.6±0.8	.44	G-44.2 H-55.8	10.6± 0.9 8.8± 1.2	.75	G-38.6 H-61.4	10.2± 0.8 6.5± 2.9
25°C, 10‰	2.08	G-30.6 H-69.4	27.9±3.5 34.2±4.0	3.72	G-26.5 H-73.5	37.1± 5.6 78.3± 5.5	8.65	G-19.9 H-80.1	70.8± 8.8 133.8±30.2
25°C, 30‰	.77	G-32.9 H-67.1	10.2±1.4 14.5±2.2	1.34	G-24.3 H-75.7	12.8± 1.8 23.3± 2.4	1.85	G-20.2 H-79.8	15.5± 1.1 33.7± 6.3
33°C, 10‰	4.98	G-38.0 H-62.0	65.1±3.6 74.1±2.8	10.10	G-21.3 H-78.7	98.7±11.1 198.2±14.7	17.44	G-16.2 H-83.8	92.0±15.1 200.2±22.1
33°C, 30‰	1.67	G-22.1 H-77.9	11.2±0.7 30.8±7.0	2.50	G-22.3 H-77.7	26.5± 2.8 88.0±13.7	4.90	G-11.3 H-88.7	24.1± 3.5 77.5±13.1

[From O'Hara, 1975 (21)]

TABLE 6

Uptake of cadmium by livers and gills of cunners exposed for 96 hours at various concentrations of cadmium as $CdCl_2 \cdot 2\text{-}1/2H_2O$ in artificial seawater

Concentration of cadmium in artificial sea water (in ppm)	Concentrations of cadmium in tissues							
	ppm wet wt basis[a]				ppm dry wt basis			
		Individual experiments				Individual experiments		
	Av	1	2	3	Av	1	2	3
0	1.2	0.95	1.65	0.85	5.5	3.6	6.7	3.2
3	16.0	13.5	21.5	13.0	54.5	41.0	75.0	47.5
6	34.5	39.0	36.5	27.5	119.5	125.0	131.0	102.0
12	55.0	54.5	65.0	45.0	198.7	182.5	236.0	177.5
24	110.7	143.0	109.0	80.0	390.0	454.0	386.5	329.5
48	195.0	267.0	160.5	157.0	761.3	928.0	744.0	611.5
0	< 1.1	< 1.1	< 0.9	< 1.3	< 5.4	< 5.4	< 5.0	< 7.3
3	3.0	4.3	2.3	2.5	16.5	21.5	11.5	16.5
6	3.4	5.1	2.4	2.7	17.5	28.0	12.5	13.
12	6.3	7.5	5.8	5.6	31.8	38.5	28.0	29.
24	11.9	16.0	12.0	7.8	66.5	88.5	60.5	44.
48	33.5	43.0	27.5	30.0	171.3	226.5	135.0	152.

[a]Liver and gill tissues from 4-5 fish per exposure level were composited and analyzed in duplicate for each experiment. The values shown for individual experiments are averages of the duplicate analyses.

[From Greig et al, 1973 (22)]

TABLE 7

Clearance of cadmium from organs and tissues of cunners held in flowing natural sea water for one month after a 96-hour exposure to 24 ppm cadmium as $CdCl_2 \cdot 2\text{-}1/2H_2O$

Organ or tissue	Concentration of Cd (in ppm) immediately after exposure[a]		Concentration of Cd (in ppm) after one month in clean seawater[b]	
	Range	Av	Range	Av
TEST FISH				
Flesh	0.11 - 0.22	0.17	0.08 - 0.22	0.12
Liver	30.5 - 117.2	64.2	A[b] 62 155 B 5 11	92 10
Gill	6.2 - 10.6	8.1	2.8 4.7	3.5
Red blood cells	5.2 +8.0	6.6	A 2.8 B 0.8	2.8 0.8
Serum	5.9 +6.0	5.9	A 2.3 B 0.7	2.3 0.7
Carcass	0.9 - 6.2	4.8	2.8 - 4.2	3.5
CONTROL FISH				
Flesh	-	<0.06	-	<0.05
Liver	0.6 +0.8	0.7	-	<1.0
Gills	-	<0.4	-	<0.3
Red blood cells	-	<0.4	-	0.4
Serum	-	<0.4	-	<0.5
Carcass	0.08 + 0.10	0.09	-	0.12

[a]All test fish were exposed to 24 ppm cadmium (as $CdCl_2 \cdot 2\text{-}1/2H_2O$). Control fish were maintained in the same type artificial seawater.
[b]Liver, red blood cells, and serum labeled A came from the same fish. This was also true for samples labeled B.

[From Greig et al, 1973 (22)]

TABLE 8

Concentrations of cadmium (μg g^{-1} wet wt) in tissues of sardine and anchovy from the Adriatic Sea

Date	Skin	Gills	Muscle	Digest	Liver	Total fish
Sardine						
9 June 72	0.2	0.2	<0.1	0.1	0.2	0.11
10 July 72	0.3	0.2	<0.1	0.3	ND	0.11
17 Aug 72	0.4	0.1	ND[a]	ND	0.4	0.10
29 Sept 72	0.5	0.1	ND	ND	0.2	0.09
31 Oct 72	0.3	0.1	ND	0.1	0.1	0.10
9 Dec 72	0.5	0.2	ND	0.3	0.1	0.11
Mean	0.4	0.2	<0.1	0.1	0.2	0.1
Anchovy						
9 June 72	0.4	0.2	<0.1	0.2	0.9	0.18
10 July 72	0.3	0.3	0.1	0.4	0.5	0.13
17 Aug 72	0.5	0.3	<0.1	0.2	0.7	0.13
3 Oct 72	0.2	0.1	ND	0.2	0.5	0.09
31 Oct 72	0.4	0.2	<0.1	0.2	ND	0.12
6 Dec 72	0.6	0.1	<0.1	0.2	1.4	0.20
Mean	0.4	0.2	<0.1	0.2	0.7	0.1

[a]ND = not detected.

[From O'Hara, 1975 (21)]

TABLE 9

Mean elemental concentrations in _Engraulis mordax_ *collected from Monterey Bay, Calif (Pacific) from Knauer (1972) and* _E. encrasicholus_ *from Rovinj, Yugoslavia (Adriatic) (mercury: ng* g^{-1} *wet wt; other elements: µg* g^{-1} *wet wt)*

Element	Location	Skin	Gills	Muscle	Digest	Liver	Gonads
Mercury	Pacific	10	30	40		90	15
	Adriatic	95	45	140		295	55
Copper	Pacific	1.6	3	1.6	5	3	2
	Adriatic	2.4	0.8	0.7	2.6	3.9	
Nickel	Pacific	0.4	0.7	ND[a]	1.1	ND	ND
	Adriatic	2.5	0.7	0.3	0.8	0.3	
Silver	Pacific	0.2	0.4	0.01	0.07	ND	0.4
	Adriatic	0.3	0.2	ND	ND	ND	
Cadmium	Pacific	0.2	0.3	0.03	2.8	1	0.3
	Adriatic	0.4	0.2	<0.1	0.2	0.7	
Lead	Pacific	3	4.8	0.2	1.2	ND	0,2
	Adriatic	4.8	3.8	0.3	0.5	1.2	

[a]ND = not detected.

[From Gilmartin et al, 1975 (23)]

TABLE 10

Distribution of cadmium in tissue fractions

Tissue fraction	Cadmium content per gram tissue[a] Liver (cpm)	Kidney (cpm)	Oyster (μg)	Soybean (μg)
Homogenate	96,106	189,103	24.44	1.23
Nuclei	67	189	[b]	[b]
Mitochrondia	106	244	2.66	0.24
Microsomes	135	340		
Supernatant	90,471	153,173	21.39	0.94
% recovered in supernatant	94	81	88	76

[a]Each fraction isolated from one g of tissue.
[b]Fractions were pooled since cadmium contents in these fractions were too low.

[From Casterline and Yip, 1972 (45)]

TABLE 11

Percentage enzyme inhibition resulting from in vitro addition of metal salts

Enzyme	Molar concentration of element	% inhibition					
		Be	Cd	Cu	Pb	Hg	Ag
Alkaline phosphatase	10^{-7}	10	1	--	--	--	--
	10^{-6}	36	27	0	--	1	--
	10^{-5}	62	72	12	50	10	10
	10^{-4}	70	80	36	64	68	53
		PB	Cu	Ag	Hg	Cd	
Acid phosphatase	10^{-7}	0.1	--	--	--	--	
	10^{-6}	15	1	--	--	--	
	10^{-5}	30	30	15	2	--	
	10^{-4}	50	60	50	40	--	
	10^{-3}	75	70	76	70	--	
	10^{-2}	100	95	89.5	95	11.5	
		Cu	Hg	Ag	Pb	Cd	
Xanthine oxidase	10^{-9}	3.0	--	--	--	--	
	10^{-8}	15.1	--	--	--	--	
	10^{-7}	39.3	27.2	--	--	--	
	10^{-6}	69.6	67.2	25	1.8	--	
	10^{-5}	81.8	88.2	75	36.4	--	
	10^{-4}	100.0	100.0	100	63.4	--	
		Hg	Ag	Pb	Cd	Cu	
Catalase	10^{-6}	20	--	--	--	--	
	10^{-5}	32	27.5	4	1.4	--	
	10^{-4}	57.5	53.5	29	6.2	1	
	10^{-3}	100.0	80.0	50	14.1	12	

[From Jackim et al., 1970 (44)]

TABLE 12

Ranges and means of enzyme activity from 10 fish surviving 96-h TLm concentrations of the toxic metals. The values are of changes in optical density over the specific reaction period. All differences between the control and experimental means are significant ($P < 0.05$) except those marked with an ansterisk(*)

Enzyme	Metal	Range	Mean
Alkaline phosphatase	Control	.275-.319	.293
	Copper	.243-.361	.325*
	Mercury	.283-.350	.317
	Lead	.294-.363	.316
	Cadmium	.268-.302	.282*
	Silver	.238-.285	.259
	Beryllium	.240-.268	.251
Acid phosphatase	Control	.130-.147	.139
	Lead	.106-.112	.108
	Cadmium	.108-.117	.112
	Copper	.112-.128	.120
	Mercury	.124-.133	.129
	Silver	.135-.152	.144*
Xanthine oxidase	Control	.150-.171	.160
	Lead	.095-.115	.103
	Mercury	.101-.118	.109
	Silver	.109-.124	.117
	Cadmium	.138-.148	.143
	Copper	.190-.220	.203
Catalase	Control	.167-.185	.173
	Silver	.108-.125	.117
	Lead	.117-.126	.122
	Copper	.116-.143	.129
	Mercury	.133-.152	.140
	Cadmium	.130-.154	.143

TABLE 13

Effects of metal ions on the hydrolysis of ATP

Metal ions	Hydrolysis for given concentration (µmoles PO_4/hr/mg N)					
	0.5 µmoles/ml	1.0 µmoles/ml	5.0 µmoles/ml	10 µmoles/ml	20 µmoles/ml	30 µmoles/ml
Cadmium	92	104	67	37	--	--
Zinc	71	89	58	4	--	--
Manganese	51	60	54	24	--	--
Magnesium	20	24	28	24	--	--
Calcium	12	15	24	28	53	63

[From Hiltibran, 1971 (47)]

TABLE 14

Effects of metals on the succinic oxidase

Metal	Concentration (μmoles/ml reaction medium)	Average change	
		($\mu l O_2$/hr/mg N)	(μmoles PO_4/hr/mg N)
Cadmium	3.3×10^{-2}	(−)209	(+)28
	3.3×10^{-3}	(−)209	(+)27
	3.3×10^{-4}	(±) 37	(±)11
Calcium	1.7×10^{-1}	(−) 53	(+)48
	1.7×10^{-2}	(−) 86	(±)15
	1.7×10^{-3}	(±) 68	(±)29
Manganese	1.7	(−)105	(+)21
	1.7×10^{-1}	(±) 67	(±)10
Zinc	3.3×10^{-1}	(−)146	(+)22
	3.3×10^{-2}	(−)138	(+)17
	3.3×10^{-3}	(±) 10	(+)12
	3.3×10^{-4}	(±) 28	(±)22

[From Hiltibran, 1971 (47)]

TABLE 15

Effects of metals on the alpha-ketoglutaric oxidase

Metal	Concentration (µmoles/ml reaction medium)	Average change	
		($\mu l O_2$/hr/mg N)	(µmoles PO_4/hr/mg N)
Cadmium	1.7	(-) 71	(+)51
	0.33	(-)119	(+)21
	0.1	(±) 60	(±) 6
Calcium	1.7	(-) 84	(+)55
	1.7×10^{-1}	(±) 36	(±)11
Manganese	1.7	(-) 66	(+)58
	1.7×10^{-1}	(±) 56	(±)16
Zinc	1.0	(-) 77	(+)33
	0.1	(±) 36	(±)27

[From Hiltibran, 1971 (47)]

TABLE 16

Enzymatic activities enhanced by lead

Enzyme	Source	Reference
Alkaline phosphatase	Guinea pig urine	433
Cytochrome oxidase	Canine intestine	434
Glucose-6-P dehydrogenase	Guinea pig kidney	435
Glutamic dehydrogenase	Guinea pig serum and urine	433,436
Glutamic oxaloacetic transaminase	Sheep red cells;	437
	Guinea pig serum	436
Glutamic pyruvate transaminase	Sheep plasma and red cells	437
Lactic dehydrogenase	Guinea pig serum and kidney	435,436
Sorbital dehydrogenase	Guinea pig serum	436
Steroid 3 β-ol-dehydrogenase	Rabbit adrenal	438

[From Vallee and Ulmer, 1972 (33)]

TABLE 17

Metals in the whole body and renal organs of the scallop *Chlamys opercularis* *from the English Channel*

Metal[a]	Concentration in whole body minus shell (parts/10^6 wet mass)	Concentration in renal organs (parts 10^8 wet mass)	Proportion of total metal in renal organs (%)
Zinc	71	8582	60
Manganese	21.9	3547	81
Iron	16.4	66.4	2
Copper	2.3	240	52
Lead	1.7	148	43
Nickel	0.22	15.8	39
Cobalt	0.05	3.4	34

[a]Mean values for animals collected at six intervals during one year.

[From Bryan, 1971 (20)]

TABLE 18

Metals in Nereis diversicolor from two estuarine sediments[a]

Metal	Concentration in sediment		Mean concentration in ten *Nereis*	
	Plym Estuary (parts 10^8 dry mass)	Tamar Estuary (parts 10^8 dry mass)	Plym Estuary (wet)	Tamar Estuary (wet)
Zinc	288	528	34.0	36.0
Copper	49	407	9.0	22.0
Lead	56	230	0.7	1.1
Manganese	55	333	1.4	2.2
Iron	5693	37391	86.0	118.0

[a]Sediments and worms were digested in nitric acid and after dilution the supernatant solution was analyzed.

TABLE 19

Concentrations of lead (μg g^{-1} wt weight) in tissues of sardine and anchovy from the Adriatic Sea

Date	Skin	Gills	Muscle	Digest	Liver	Total fish
Sardine						
9 June 72	4.5	3.0	0.4	ND	ND	1.23
10 July 72	4.9	4.5	0.1	ND	ND	0.94
17 Aug 72	4.3	2.6	ND[a]	ND	ND	0.82
29 Sept 72	5.3	1.9	ND	2.2	ND	0.84
31 Oct 72	3.3	2.4	ND	0.7	ND	1.38
5 Dec 72	6.8	3.1	ND	0.3	ND	1.40
Mean	4.9	2.9	0.1	0.5	ND	1.1
Anchovy						
9 June 72	2.7	4.3	ND	ND	ND	0.99
10 July 72	5.2	3.7	ND	0.4	ND	0.99
17 Aug 72	5.7	3.9	ND	0.3	1.1	0.51
3 Oct 72	1.6	2.6	ND	1.3	1.5	0.73
31 Oct 72	7.0	3.1	1.2	0.7	3.4	1.16
6 Dec 72	6.5	3.9	0.3	0.4	11.0[b]	1.37
Mean	4.8	3.6	0.3	0.5	1.2	1.0

[a]ND = not detected
[b]Suspect value--excluded from mean.

[From Gilmartin et al, 1975 (23)]

TABLE 20

Mean elemental concentrations in Engraulis mordax collected from Monterey Bay, Calif (Pacific) from Knauer (1972) and in E. encrasicholus from Rovinj, Yugoslavia (Adriatic) (mercury: ng g^{-1} wet weight; other elements: µg g^{-1} wet weight)

Element	Location	Skin	Gills	Muscle	Digest	Liver	Gonads
Mercury	Pacific	10	30	40		90	15
	Adriatic	95	45	140		295	55
Copper	Pacific	1.6	3	1.6	5	3	2
	Adriatic	2.4	0.8	0.7	2.6	3.9	
Nickel	Pacific	0.4	0.7	ND[a]	1.1	ND	ND
	Adriatic	2.5	0.7	0.3	0.8	0.3	
Silver	Pacific	0.2	0.4	0.01	0.07	ND	0.4
	Adriatic	0.3	0.2	ND	ND	ND	
Cadmium	Pacific	0.2	0.3	0.03	2.8	1	0.3
	Adriatic	0.4	0.2	<0.1	0.2	0.7	
Lead	Pacific	3	4.8	0.2	1.2	ND	0.2
	Adriatic	4.8	3.6	0.3	0.5	1.2	

[From Knauer, 1972 (63)]

TABLE 21

Estimated sediment enrichments and median concentrations (mg/dry kg) of seven metals in tissues from Dover sole trawled near the Palos Verde outfalls (Station T_4-450) and from a control region in the Santa Barbara Channel

Trace metal	Sediments Outfall to control	Flesh		Gonads		Liver	
		Outfall	Control	Outfall	Control	Outfall	Control
Silver	3.2	0.2	0.1	<0.1	0.3	0.4	0.6
Cadmium	150	<3.0	<3.0	<3.0	<3.0	3.8	6.4
Chromium	16	<0.2	<0.2	0.4	<0.2	0.4	0.2
Copper	20	0.6	0.5	10.7	12.7	7.4	9.5
Nickel	2.4	<2.0	<2.0	<4.8	<2.0	2.6	1.4
Lead	52	1.3	<1.1	<1.0	<1.0	5.0	4.6
Zinc	12	39.4	38.0	214	233	91.8	108

[From McDermott and Young, 1974 (66)]

TABLE 22

Chromium and lead (mg/dry kg) in the tissues of diseased and apparently healthy Dover sole from the Palos Verde shelf

Tissues	Chromium	Lead
Gonads		
Diseased	<0.2	--
Healthy	0.9	--
Heart		
Diseased	<0.2	--
Healthy	0.4	--
Liver		
Diseased	0.6	--
Healthy	0.2	--
Kidney		
Diseased	0.5	6.0
Healthy	0.2	3.1

[From McDermott and Young, 1974 (66)]

TABLE 23

Effects of 3-week exposures to metal chlorides on body weight, total protein, and GOT activity of <u>*Daphnia magna*</u> *(expressed as mean percentage deviation from control means)*[a]

Metal ion	Number of experiments	Effect concentrations In M x 10^6	Effect concentrations In µg/liter	Weight/animal % Δ	Protein/animal % Δ	GOT/animal % Δ
Sodium	3	43,500	1,000,000	-18	-7	+12
Calcium	2	10,000	400,000	-29	+18	+3
Magnesium	2	10,300	250,000	-22	+40	+65
Potassium	2	2,040	79,800	+27	-5	+5
Strontium	2	1,140	99,900	-24	+15	+55
Barium	1	144	19,800	-12	0	+1
Iron	1	134	7,480	-77	+48	-13
Manganese	3	91.0	5,000	-8	+24	+100
Arsenic	4	13.3	996	-18	-15	-18
Tin	2	25.3	3,000	-23	+5	+15
Chromium	4	11.9	619	-11	-3	-4
Aluminum	2	23.0	620	-38	+3	-13
Zinc	1	2.68	175	-28	+10	+1
Nickel	2	2.13	125	-43	-9	-26
Lead	3	0.300	62	-12	+8	+15
Copper	3	0.628	40	-26	-5	-10
Platinum	2	0.318	62	-12	-13	-20
Cobalt	1	0.423	24	-15	+12	+45
Mercury	1	0.050	10	-5	-5	-19
Cadmium	1	0.0089	1	-7	+6	+15

[a]Precision (range) = +10% (weight); 8% (protein); ±5% (GOT)

[From Biesinger and Christensen, 1972 (34)]

TABLE 24

Elemental concentrations in the zooplankton. Approximate concentrations of elements per gram wet weight or dry weight can be obtained by dividing the ash weight values by 25 (wet wt:ash wt) or by 3 (dry wt:ash wt)

Exp No	Depth (m)	Lead	Zinc	Iron	Cadmium	Cobalt	Copper	Nickel (μg/g ash)	Manganese	Strontium	Calcium	Magnesium
1	Surface	110	580	3,600	21	60	200	185	-	780	85,000	60,000
2	Surface	85	1,200	3,800	21	60	110	230	-	1,060	80,000	55,000
3	Surface	95	750	4,400	23	60	270	125	-	1,560	190,000	52,000
4	Surface	25	550	2,450	21	40	145	85	-	1,280	165,000	48,000
5	Surface	370	430	2,000	27	40	215	50	-	1,500	165,000	54,000
6	Surface	ND[a]	360	3,000	16	30	40	85	-	820	75,000	42,000
7	Surface	25	360	1,700	10	45	40	65	70	350	110,000	33,000
8	Surface	35	1,120	3,500	9	50	30	55	70	940	42,000	38,000
9	Surface	280	800	2,900	7	25	50	75	ND	170	97,000	35,000
10	Surface	120	420	1,750	10	30	50	45	ND	440	90,000	40,000
11	100	-	2,700	5,400	-	20	620[b]	1,070[b]	-	-	85,000	
12	100	140	950	5,000	-	40	190	340	-	920	85,000	48,000
13	100	90	1,200	3,800	12	40	120	205	-	1,140	53,000	62,000
14	100	75	1,900	4,800	-	30	550[b]	135	-	2,100	62,000	60,000
15	100	100	1,250	5,600	18	40	220	220	-	920	58,000	60,000
16	100	410	1,600	3,400	36	50	110	85	-	2,060	175,000	50,000
17	100	150	770	3,900	-	-	180	240	-	2,400	62,000	31,000
18	100	130	840	3,000	8	45	50	150	70	290	50,000	42,000
19	100	3,200[b]	2,300	3,600	13	30	60	80	90	650	165,000	39,000
20	150	3,200[b]	2,200	4,400	11	35	60	60	100	900	170,000	43,500
21	200	330	2,400	3,200	13	35	240	75	80	380	80,000	43,500
22	500	225	3,600	4,200	12	45	90	65	100	740	215,000	29,500
Avg surface		117	657	2,900	16	44	115	100	<70	890	103,900	45,700
Avg > 99 m		183	1,809	4,200	15	37	132	150	88	1,140	105,000	46,200
Avg all samples		148	1,285	3,600	16	40	123	126	<83	1,020	104,500	46,000

[a]ND = not detected.
[b]These values were not included in the means.

[From Duce et al, 1972 (57)]

TABLE 25

Concentration factors for the zooplankton

Element	Zooplankton µg/g wet wt	Sea water µg/g	Concentration factor
Lead	5.9	0.00008	197,000
Iron	144.0	0.01	14,400
Cadmium	0.6	0.0001	6,000
Zinc	51.0	0.01	5,100
Cobalt	1.6	0.0005	3,200
Nickel	5.0	0.002	2,700
Manganese	3.3	0.002	1,650
Copper	4.9	0.003	1,650
Calcium	4,200.0	400.0	10.5
Strontium	40.8	8.0	5.1
Magnesium	1,800.0	1,350.0	1.3

[From Duce et al, 1972 (57)]

TABLE 26

Elemental concentrations in Macrocystis pyrifera and in the feces of Pugettia producta. Approximate concentrations of elements per gram dry or wet weight can be obtained by dividing the ash weight values of the algae by 1.8 (dry wt:ash wt) or by 17 (wet wt:ash wt). A and F indicate individual numbered samples of algae and feces.

Sample No.	Arsenic	Cadmium	Cobalt	Chromium	Copper (μg/g ash)	Iron	Manganese	Lead	Zinc
A 1	140	3.1	0.3	9.2	4.4	64	10.2	7.8	32
A 2	144	2.9	0.4	8.4	4.5	75	11.4	8.1	33
A 3	72	3.5	0.4	2.0	5.2	75	11.0	7.5	28
A 4	111	3.8	0.3	2.8	10.1	74	8.6	4.4	34
A 5	112	3.8	0.3	2.8	10.3	79	6.4	4.6	55
F 1/ (41.01)[a]	ND[b]	3.1	ND	7.6	21	1,650	ND	40	78
F 2/ (48.64)[a]	ND	3.2	ND	1.1	15	750	ND	29	39
F 3/ (74.75)[a]	340	ND	0.6	3.6	25	887	ND	43	77
F 4/ (124.62)[a]	193	ND	0.9	ND	60	796	ND	27	119

[a]Crab wet weight in grams.
[b]ND = not detected.

[From Boothe and Knauer, 1972 (77)]

TABLE 27

Comparison of the average elemental concentrations in algae and feces

Element	Average concentration: Algae[a]	Average concentration: Feces[a]	Theoretical maximum concentration feces[a]	Theoretical % in feces	Feces:algae concentration
Manganese	9.5 ± 1.8	ND[b]	57	NA[c]	-
Chromium	5.0 ± 3.5	4.1 ± 3.3	30	14	0.8
Cadmium	3.4 ± 0.4	3.2 -	20	16	0.9
Cobalt	0.3 ± 0.05	0.7 ± 0.2	1.8	39	2.3
Arsenic	116 ± 26	266 ± 74	696	38	2.3
Zinc	33 ± 2.2	78 ± 28	198	39	2.4
Copper	6.9 ± 2.7	30 ± 18	41	73	4.3
Lead	6.5 ± 1.6	35 ± 6.9	39	90	5.4
Iron	73 ± 5	1,021 ± 367	438	233	14.0

[a]μg/g ash weight.
[b]ND = not detected.
[c]NA = not applicable.

[From Boothe and Knauer, 1972 (77)]

TABLE 28

'Concentration factor' or ratio of trace-element content in algae (fresh weight) to trace-element content in sea water

Sample	Nickel	Chromium
Pelvetia canaliculata	700	300
Fucus spiralis	1,000	300
Ascophyllum nodosum	600	500
F. vesiculosus	900	400
F. serratus	600	100
Laminaria digitata frond, Atlantic Bridge	200	200
L. digitata stipe, Atlantic Bridge	300	230
L. digitata frond, Ardencaple Bay	200	200
L. digitata stipe, Ardencaple Bay	400	200

[From Black and Mitchell, 1952 (81)]

TABLE 29

Elemental composition of Modiolus modiolus

Sample	Shell	Entire soft parts	Entire soft parts	Mantle and gills	Muscle	Gonad	Gut and digestive gland
Dry wt (%)	--	25.0	20.8	9.1	16.7	15.4	11.1
Nickel	0.20	133	9.4	3.2	2.0	1.2	0.59
Cadmium	0.03	7.1	4.5	7.0	2.8	4.6	4.2
Lead	1.9	42	23	18	7.5	25	22
Chromium	ND[a]	ND	0.14	0.15	0.20	0.20	0.19

[a]ND = not determined. All concentrations as ppm in specimen dried at 60°C

[From Riley and Segar, 1970 (8)]

TABLE 30

Elemental composition of Pecten maximus

Sample	Entire soft parts	Muscle	Gut and digestive gland	Mantle and gills unwashed	Mantle and gills washed	Gonad unwashed	Gonad washed	Mixed shell	Upper valve shell	Lower valve shell
Dry wt (%)	28.3	ND[a]	24.3	ND	7.7	ND	21.1	--	--	--
Nickel	49	1.7	0.96	0.30	0.82	0.44	1.5	0.21	1.2	2.4
Cadmium	13	1.9	96	17	3.1	2.5	2.5	0.04	0.04	0.04
Lead	8.3	17	1.7	2.8	1.5	31	0.40	2.0	0.62	0.60
Chromium	ND	ND	1.8	ND	0.76	ND	0.45	ND	ND	ND

[a]ND = not determined. All concentrations as ppm in specimen dried at 60°C.

(From Segar et al, 1971 (16)]

TABLE 31

Uptake of chromium by Hermione in relation to the amounts added to the sea water as sodium chromate (calculated from the uptake of ^{51}Cr

Days after addition	Amount of chromium taken up in millimicrograms per gram live weight at the sea water concentrations indicated				
	0.3 µg/1	3 µg/1	10 µg/1	100 µg/1 (toxic)	500 µg/1 (toxic)
1	0.4	6	15		
2	0.7	10	24		
3	0.9			206	856
4		14	40		
5	1.1				
6		16	53	288	1139
7	1.3			326	1177
8		22	68		
9	1.7				
11		26	84	428	1436
12	2.3				
13		31	106		
14				495	1834
15	2.7	34			
19	3.6				

[From Chipman, 1966 (83)

TABLE 32

Concentration factors for stable metals

Metal ml	Concentration in seawater (µg/ml)	Concentration per g wet tissue/concentration per ml seawater: Whole animal excluding shell		Kidneys		Digestive gland	
		Pecten	Chlamys	Pecten	Chlamys	Pecten	Chlamys
Nickel	0.0003	2.4×10^2	5.6×10^2	1.0×10^4	4.0×10^4	2.7×10^3	3.1×10^3
Lead	0.00017	1.5×10^3	9.6×10^3	1.6×10^3	9.5×10^5	6.5×10^3	1.7×10^1
Cadmium	0.00006	6.8×10^4	1.1×10^4	2.6×10^5	1.6×10^5	1.5×10^6	1.2×10^5
Chromium	0.00016	1.0×10^3	1.6×10^3	4.7×10^3	9.4×10^3	1.4×10^4	7.8×10^3

[From Bryan, 1971 (20)]

TABLE 33

Concentration factors of stable zinc, chromium, and manganese in nature by groups of marine organisms

Organism	Zinc	Chromium	Manganese
Brown algae	420-1400	60	300-20,000
Sponges	30	800	3000-95,000
Scyphomedusae	1600	1600	120
Malacontracan crustaceans	9400-15,000	---	7500
Molluscs (muscle)	2600-40,000	---	---
Echinoderms	25-56	140-9000	3500-33,000
Echinoderm (muscle)	1400	---	200
Fishes	280-15,500	2000	95-126,000

[From Tennant and Forester, 1969 (90)]

TABLE 34

Comparison of food-chain transfer with uptake of seawater of ^{65}Zn and ^{51}Cr by organisms of three tropic levels. Values are based on the initial amount of each radionuclide in the phytoplankton culture medium as having a concentration of 1

Trophic level	Relative concentration			
	^{65}Zn		^{51}Cr	
	Daily feeding	Uptake from water	Daily feeding	Uptake from water
Zooplankton	168	338	73	23
Post-larval fish	115	23	6.2	8.8
Mummichog	13	3.4	9.9	1.2

[From Baptist and Lewis, 1967 (106)]

TABLE 35

Elemental composition[a] of Asterias rubens

Organ	Oral skin	Aboral skin	Pyloric caeca	Gonad
Dry wt (%)	33.3	15.8	21.1	18.9
Nickel (Ni)	0.72	0.68	4.1	2.4
Cadmium (Cd)	1.7	3.6	4.1	2.4
Lead (Pb)	1.1	1.1	4.0	0.50

[a]All concentrations as ppm in dried (60°C) specimen.

[From Riley and Segar, 1970 (8)]

TABLE 36

Elemental composition[a] of the shells of some molluscs

Molluscs	Metals		
Class, genus, and species	Nickel	Cadmium	Lead
Lamellibranchia			
Pecten maximus			
Mixed	0.21	0.04	2.0
Upper valve	1.2	0.04	0.62
Lower Valve	2.4	0.04	0.60
Chlamys opercularis	0.18	0.13	1.7
Chlamys opercularis	0.69	0.04	0.64
Glycymeris glycymeris	0.16	0.03	0.60
Modiolus modiolus	0.20	0.03	1.9
Mytilus edulis	2.1	0.95	0.40
Cardium edule	0.11	0.34	0.44
Mercenaria mercenaria	2.4	0.80	0.43
Anodonta sp.	1.2	0.43	0.60
Gastropoda			
Patella vulgata	0.54	2.0	46
Nucella lapillus	0.25	1.64	0.45
Buccinum undatum	0.12	0.048	0.45
Crepidula fornicata	1.6	2.4	0.42

[a]All concentrations as ppm in dried (60°C) specimen.

[From Segar et al., 1971 (16)]

TABLE 37

Elemental composition of the entire soft parts of some molluscs

Molluscs Class, genus, and species	Dry wt (%)	Metals Nickel	 Cadmium	 Lead	 Chromium
Lamellibranchia					
Modiolus modiolus	25	133	7.1	42	ND
Modiolus modiolus	20.8	9.4	4.5	23	0.14
Glycymeris glycymeris	ND[a]	1.4	3.3	3.5	ND
Pecten maximus	28.3	49	13	8.3	ND
Mytilus edulis	11.1	3.7	5.1	9.1	1.5
Mercenaria mercenaria	20.0	11	2.1	18	0.79
Anodonta sp.	11.9	0.35	1.2	1.2	0.84
Cardium edule	13.0	7.9	1.5	0.76	ND
Gastropoda					
Patella vulgata	17.9	2.5	31	32	ND
Nucella lapillus	ND	2.4	73	49	ND
Buccinum undatum	22.2	0.60	2.2	5.4	ND
Crepidula fornicata	15.0	850	3.9	3.9 940 0.97	2.0

[a]ND = not determined. All concentrations as ppm in the specimen dried at 60°C.

[From Segar et al., 1971 (16)]

TABLE 38

Concentration factors for the zooplankton

Element	μg/g wet zooplankton	μg/g seawater[a]	Concentration factor
Lead	5.9	0.00003	197,000
Cadmium	0.6	0.0001	6,000
Nickel	5.0	0.002	2,500

[a]Values for seawater are from Goldberg (1963)

[From Martin, 1970 (51)]

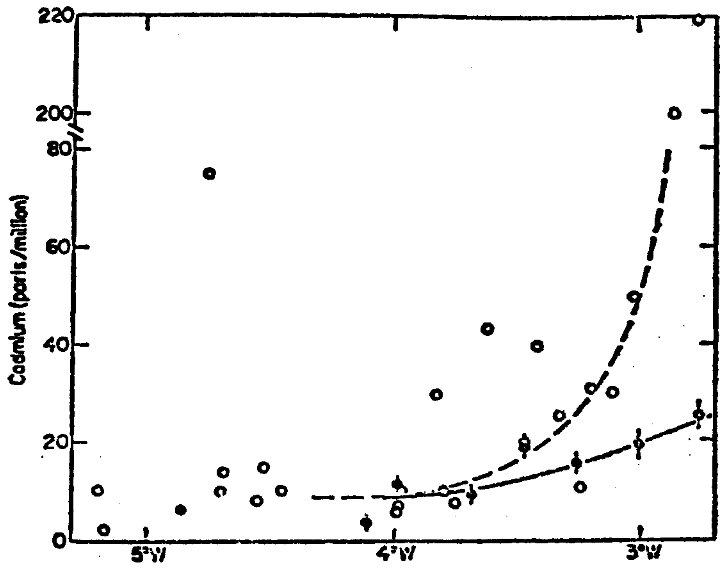

FIG. 1. Published dry weight cadmium contents of Fucus vesiculosus in the Bristol Channel plotted on a longitudinal basis. Bars on the data of Fuge and James (1974) represent analytical error (one standard deviation). (O) Data of Nickless et al. (1972) and Butterworth et al. (1972): (ϕ) data of Fuge and James (1974).

[From Morris and Bale, 1975 (4)]

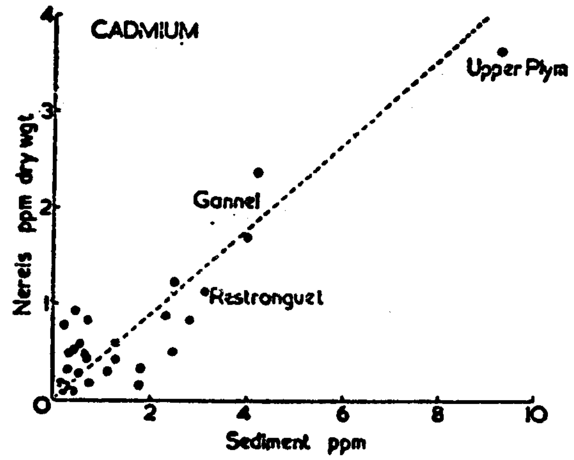

FIG. 2. Relationship between concentrations of metal in whole Nereis and total concentrations in sediments. Broken line shows direct proportionality.

[From Bryan, 1974, (6)]

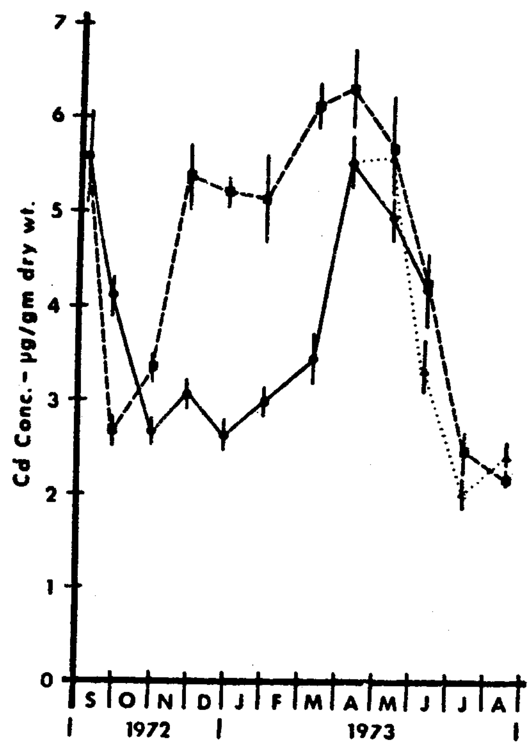

FIG. 3. Concentration of Cd in soft tissues of control and exposed oysters. Mean ± 1 standard error of the mean (n = 10). Key: ● - control, ■ - Exposed 1, ▲ - Exposed 2.

[From Frazier, 1976 (19)]

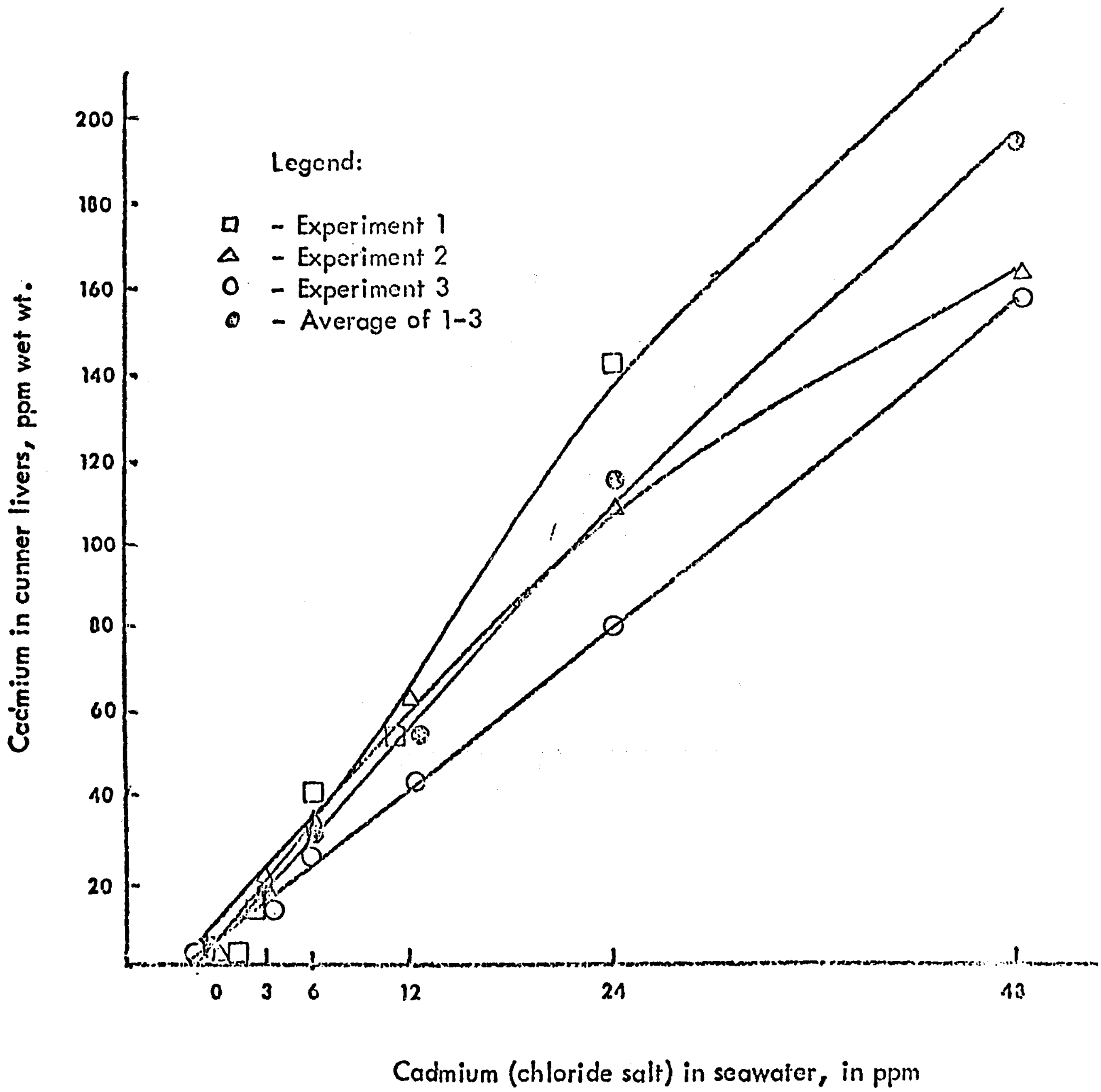

FIG. 4. Uptake of cadmium by the livers of cunner held 96 hours in various concentrations of cadmium (as cadmium chloride) in artificial seawater.

[From Greig et al., 1973 (22)]

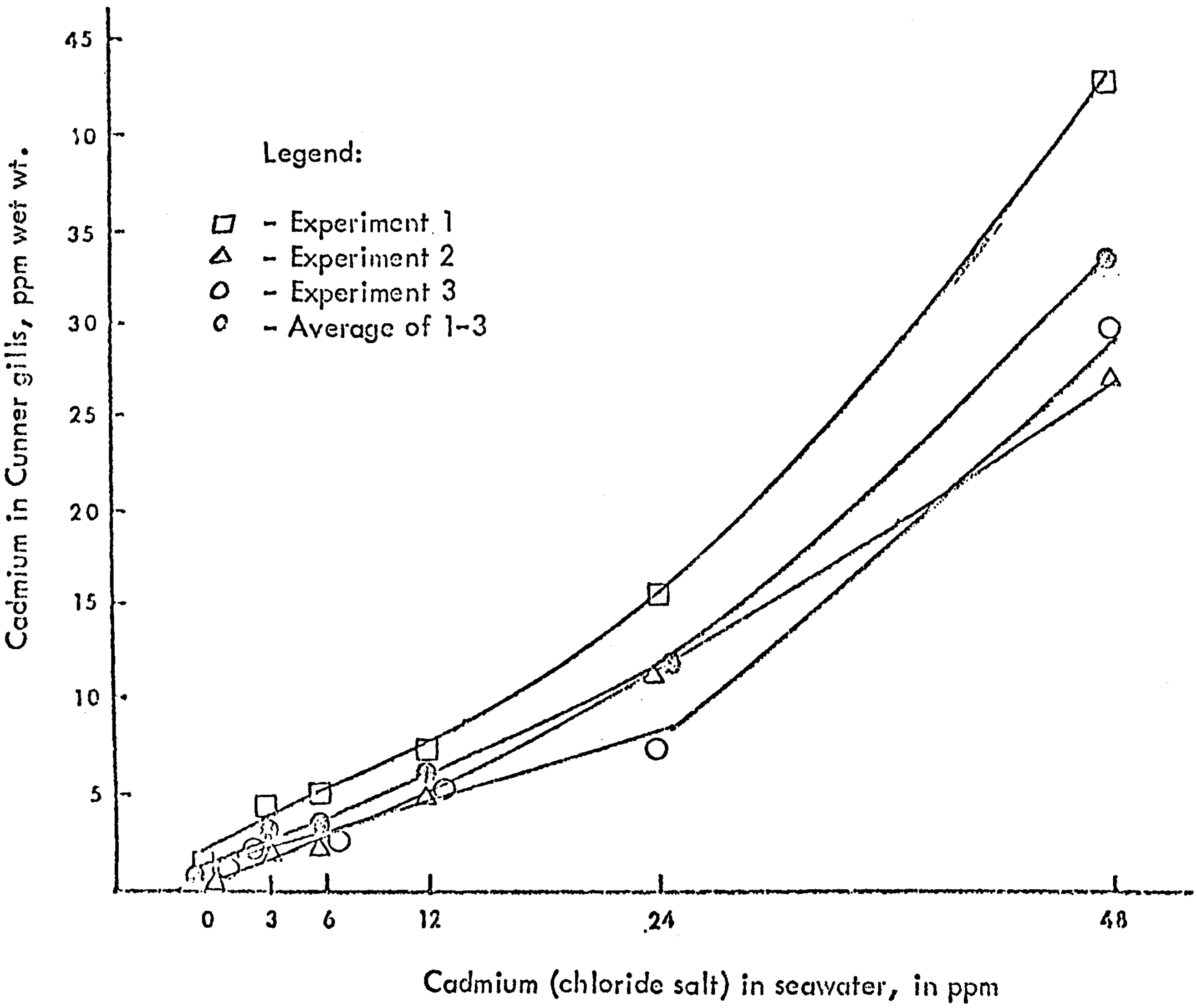

FIG. 5. Uptake of cadmium by the gills of cunner held 96 hours in various concentrations of cadmium (as cadmium chloride) in artificial seawater.

[From Greig et al., 1973 (22)]

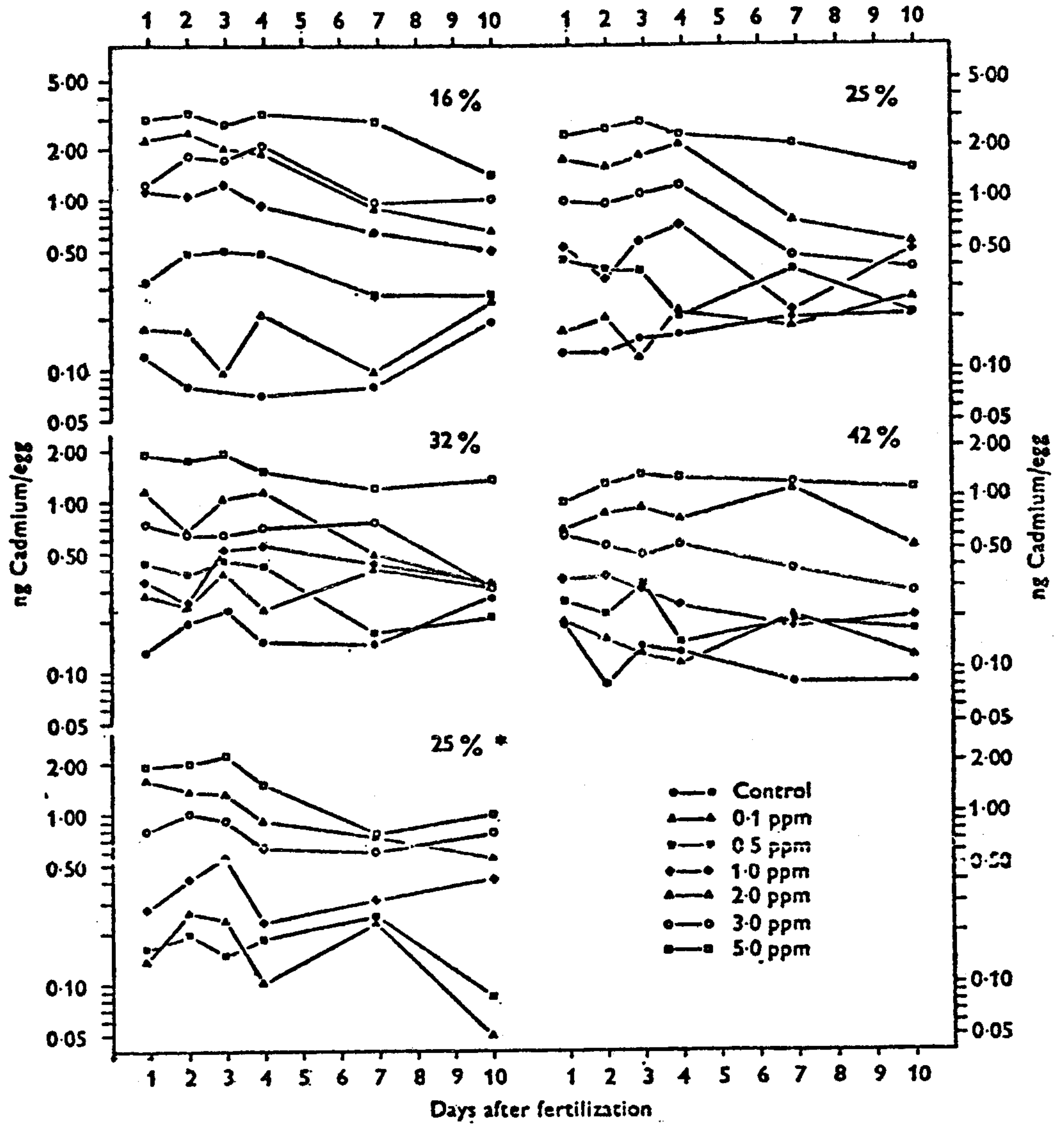

Fig. 3. Cadmium uptake of flounder eggs during embryogenesis, incubated at different salinities and Cd-concentrations. * fertilization occurred in Cd-contaminated water.

FIG. 6. Cadmium uptake of flounder eggs during embryogenesis, incubated at different salinities and Cd-concentrations. *fertilization occurred in Cd-contaminated water.

[From Westernhagen and Dethlefsen, 1975 (24)]

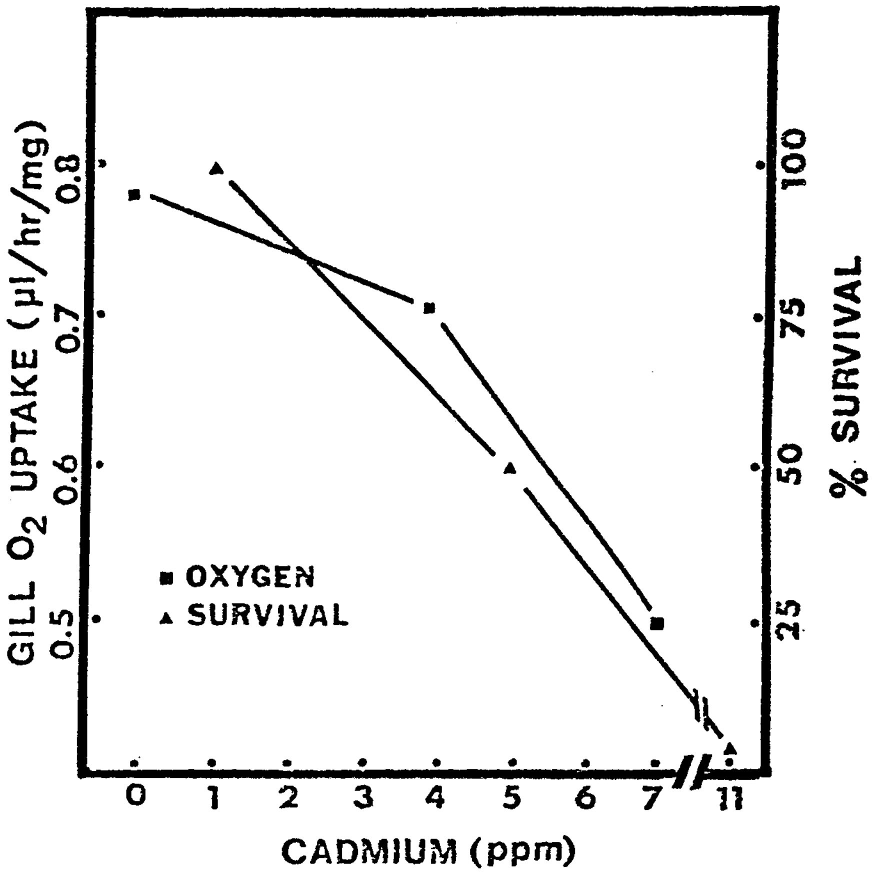

FIG. 7. Response of Eurypanopeus depressus to cadmium.

[From Collier et al., 1973 (39)]

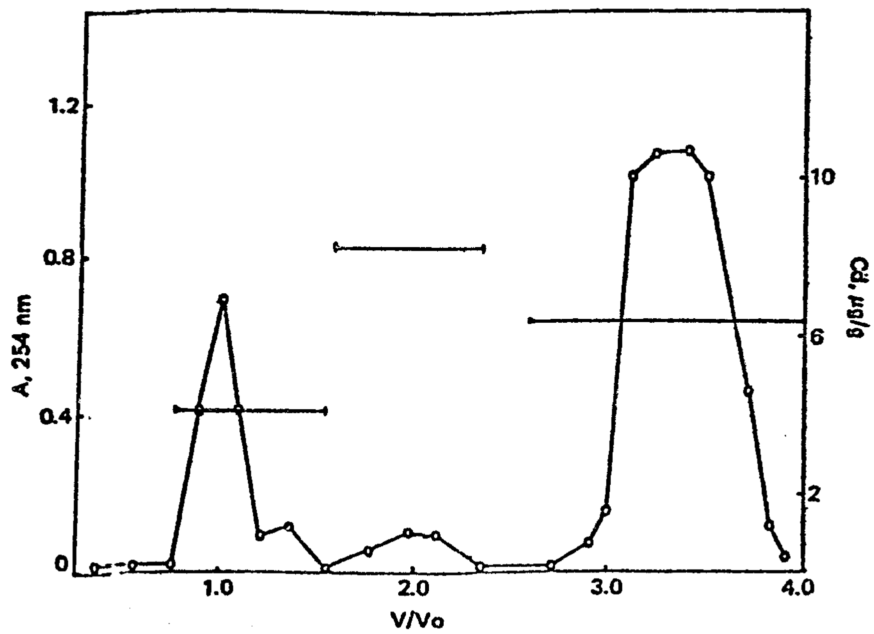

Fig. 3. Protein and cadmium distribution pattern in oyster. Gel filtration of soluble fraction on Sephadex G-75 column: o—o—o = UV; |———| = Cd. The length of the bar across each peak represents fractions that were pooled for total Cd measurement.

FIG. 8. Protein and cadmium distribution pattern in oyster. Gel filtration of soluble fraction on Sephadex G-75 column: o—o—o = UV; |———| = Cd. The length of the bar across each peak represents fractions that were pooled for total Cd measurement.

[From Casterline and Yip, 1975 (42)]

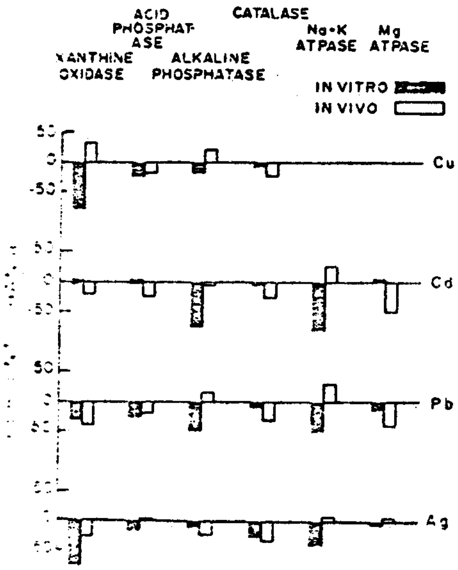

FIG. 9. Solid bars represent percent change in enzyme activity upon direct addition of 10^{-5}M metal. Line bars show the mean percent difference in enzyme activity between F. heteroclitus exposed to toxic metal for 96 hrs and control fish.

[From Jackin, 1974 (43)]

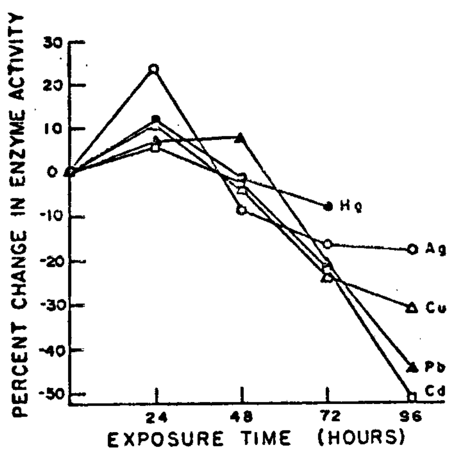

FIG. 10. Effect of fish exposure time on Fundulus heteroclitus liver ribonuclease activity measured at pH 7.8.

[From Jackim, 1974 (43)]

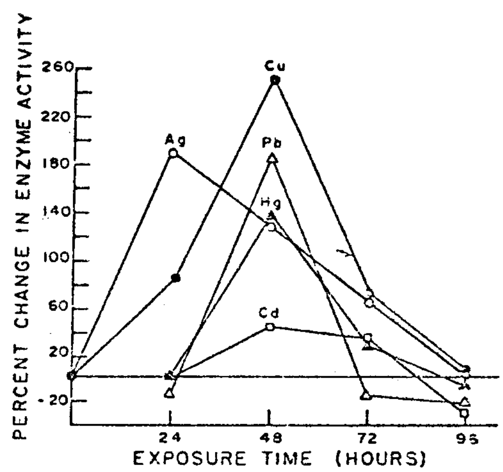

FIG. 11. Influence of fish exposure time on ribonuclease activity measured at pH 5.→

[From Jackim, 1974 (43)]

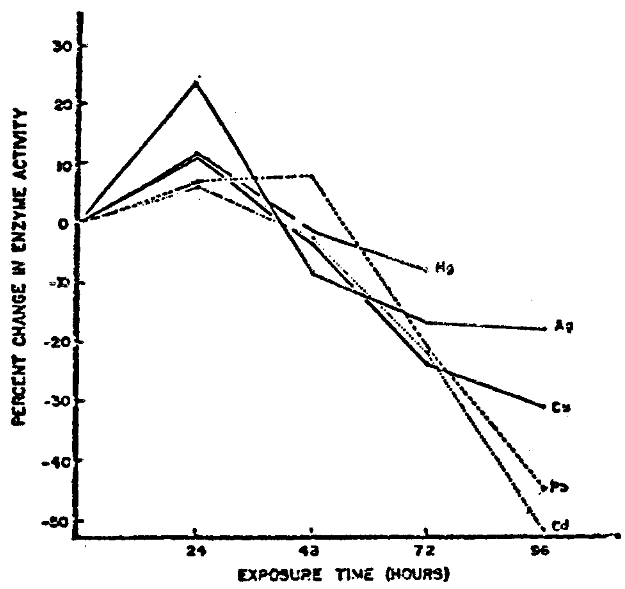

FIG. 12. Percentage changes in activity of fish liver RNAase exposed to salts of mercury, silver, copper, lead, and cadmium for various periods and assayed at pH 7.8. Each point represents the mean value for 10 fish.

[From Jackim et al., 1970 (44)]

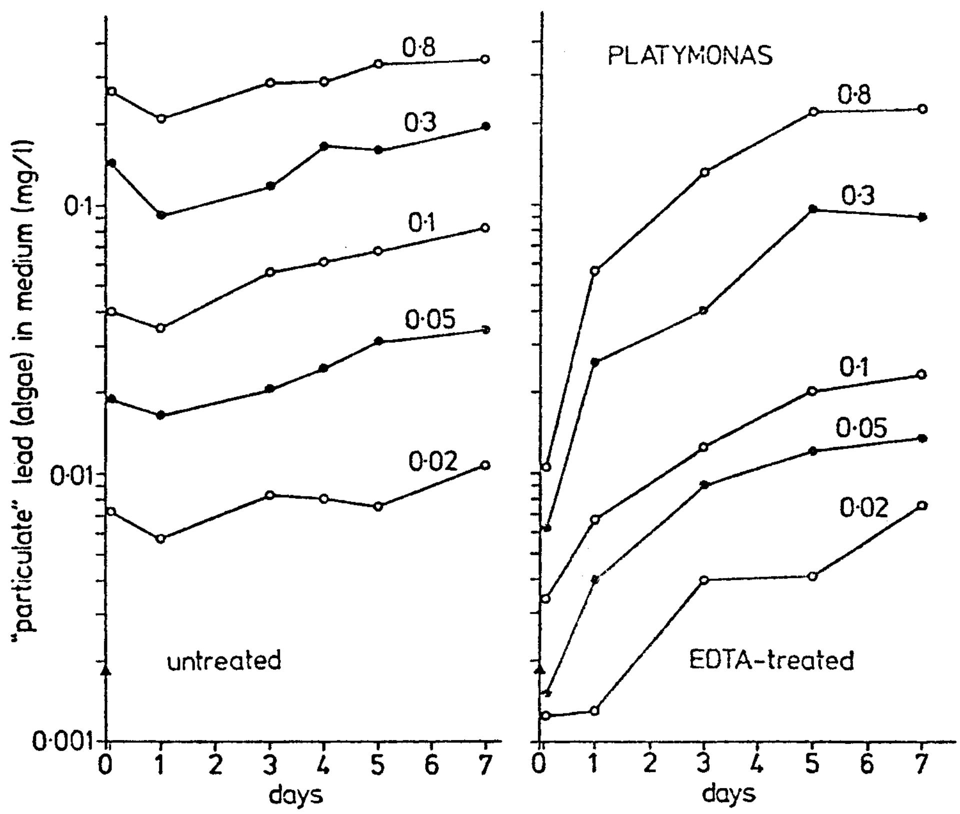

FIG. 13. Platymonus subcordiformis: lead content (= "particulate" lead, expressed as mg Pb bound to the algal cells contained in one liter of medium) of cells suspended in a medium containing Pb (0.02-0.8 mg/l) and then untreated (left) or treated with 10^{-2} M EDTA for one hour (right), as a function of time. In all figures, the black triangles indicate the natural lead content of the cells. Cell numbers per ml rose from 3.2 x 10^6 (day 0) to 4.5 x 10^6 (day 7).

[From Schulz-Baldes and Lewin, 1976 (56)]

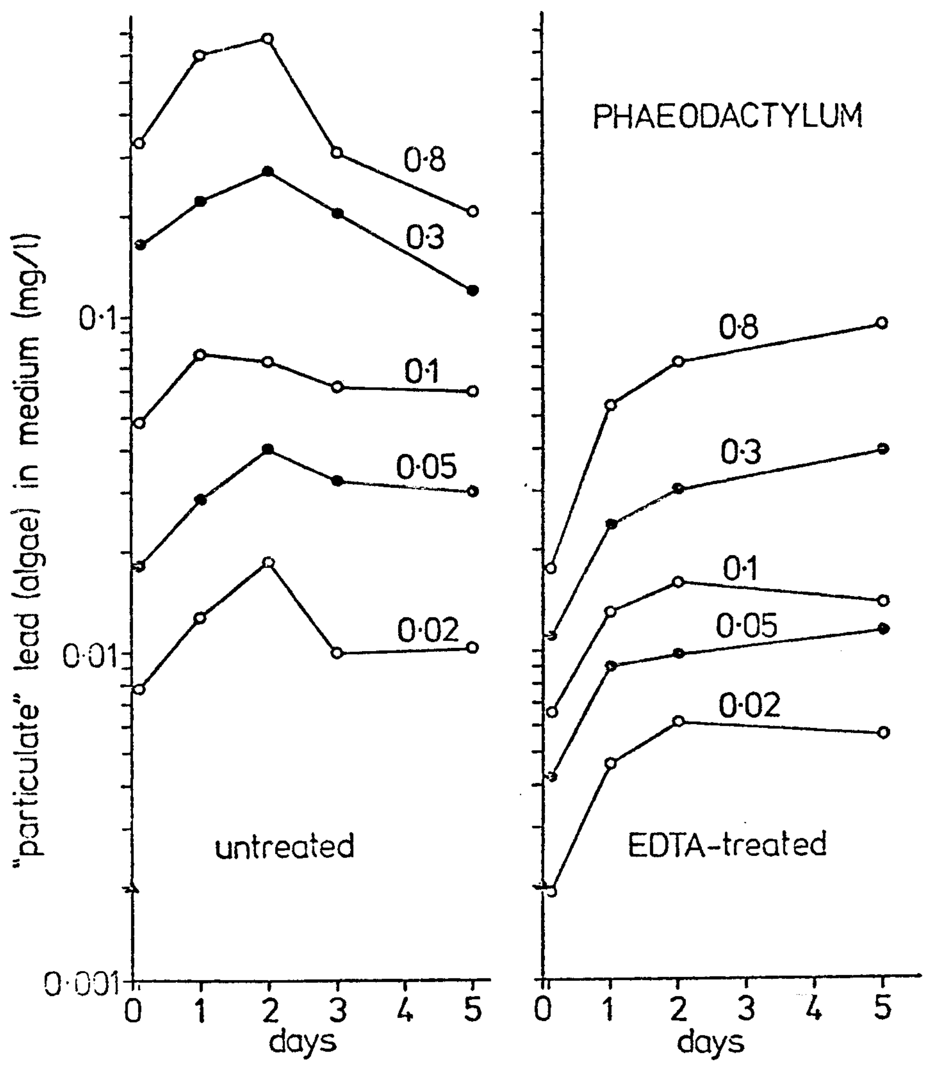

FIG. 14. Phaeodactylum tricornutum: lead content of cells, as a function of time; see legend to Figure 13. Cell numbers per ml rose from 7 x 10^6 (day 0) to 10 x 10^6 (day 5).

[From Schulz-Baldes and Lewin, 1976 (56)]

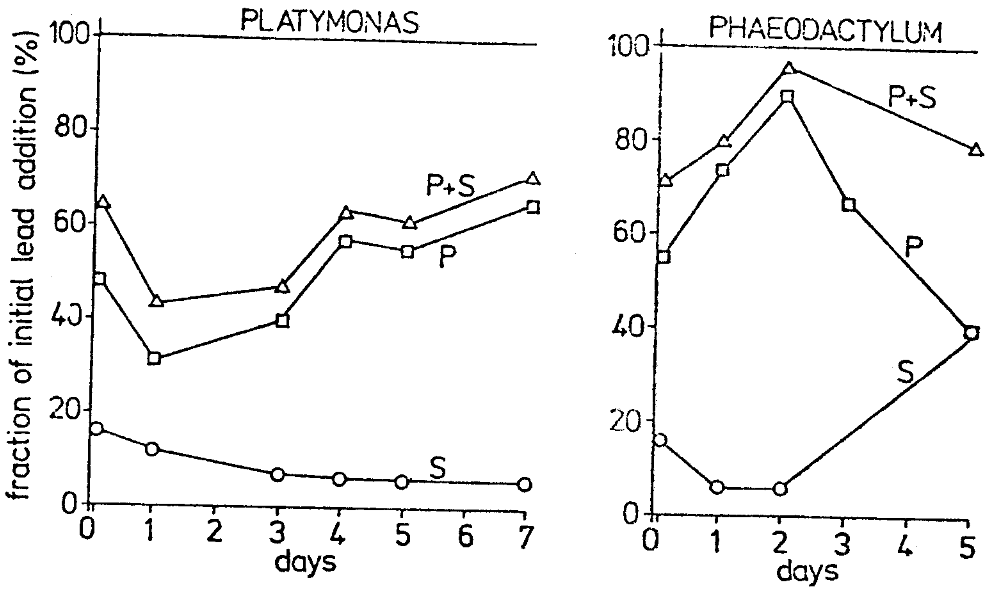

FIG. 15. Platymonus subcordiformis and Phacodactylum tricornutum: lead budget in percent of initial addition (0.3 mg Pb/l) as a function of time. S indicates soluble lead; P, "particulate" lead, i.e., lead associated with the algae; and P + S, sum of soluble and "particulate" lead.

[From Schulz-Baldes and Lewin, 1976 (56)]

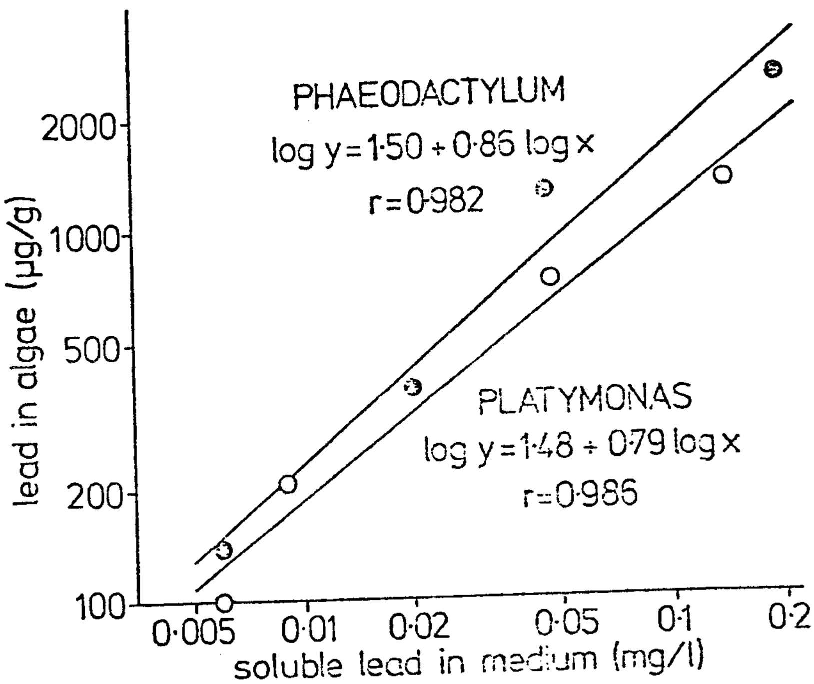

FIG. 16. Platymonus subcordiformis and Phacodactylum tricornutum: Pb adsorption isotherms after one hour of lead exposure.

[From Schulz-Baldes and Lewin, 1976 (56)]

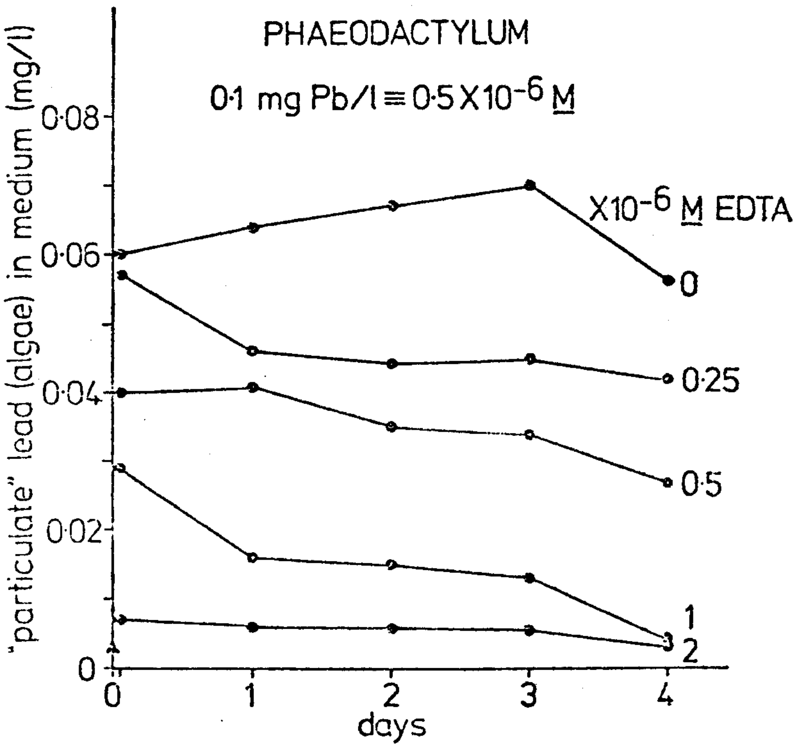

FIG. 17. Phacodactylum tricornutum: lead content of cells exposed to 0.1 mg Pb/l in the presence of 0 to 2 x 10^{-6} M EDTA, as a function of time.

[From Schulz-Baldes and Lewin, 1976 (56)]

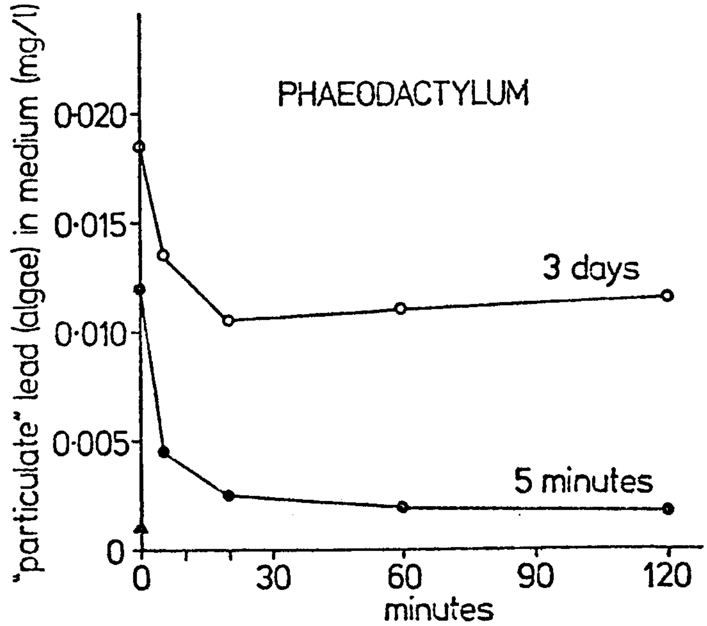

FIG. 18. Phacodactylum tricornutum: lead content of cells, previously exposed to 0.02 mg Pb/l for 5 min or 3 days, and then treated with 10^{-2} M EDTA, as a function of time.

[From Schulz-Baldes and Lewin, 1976 (56)]

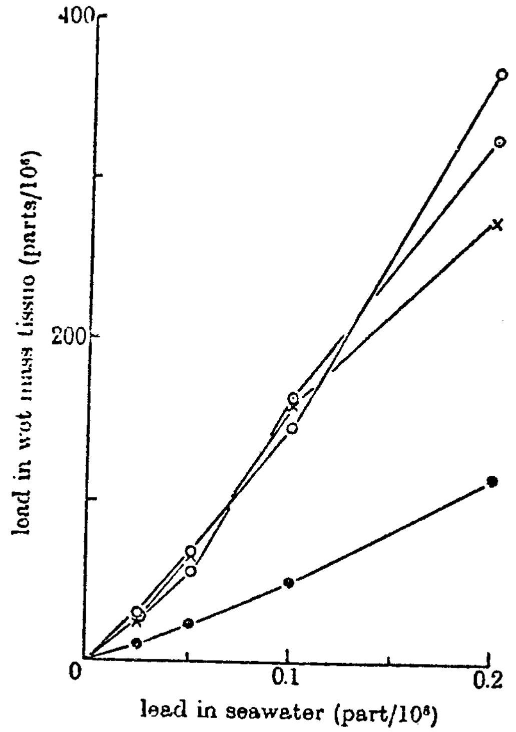

FIG. 19. Lead in the tissues of the oyster Crassostrea virginica after exposure to different concentrations in seawater for 49 days. Concentrations in : •, muscle; x, gills; ⊙, gonad; o, hepatopancreas.

[From Bryan, 1971 (20)]

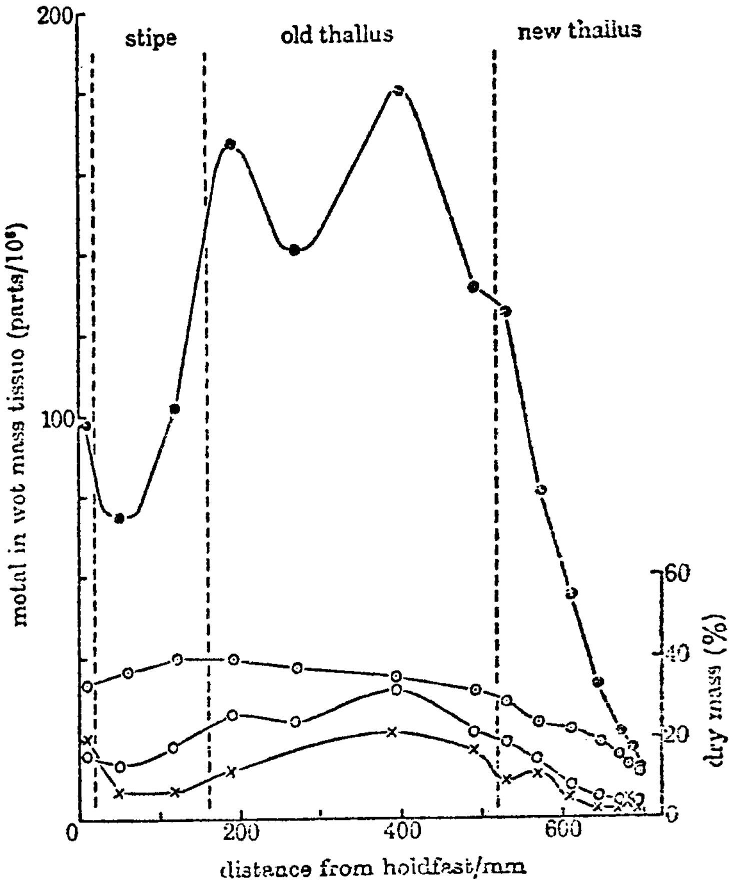

FIG. 20. Distribution of metals along the holdfast, stipe and thallus of Fucus vesiculosus from the Tamar Estuary. Concentrations of: ●, zinc; o, copper; x, lead; ⊙, percentage dry mass.

[From Bryan, 1971 (20)]

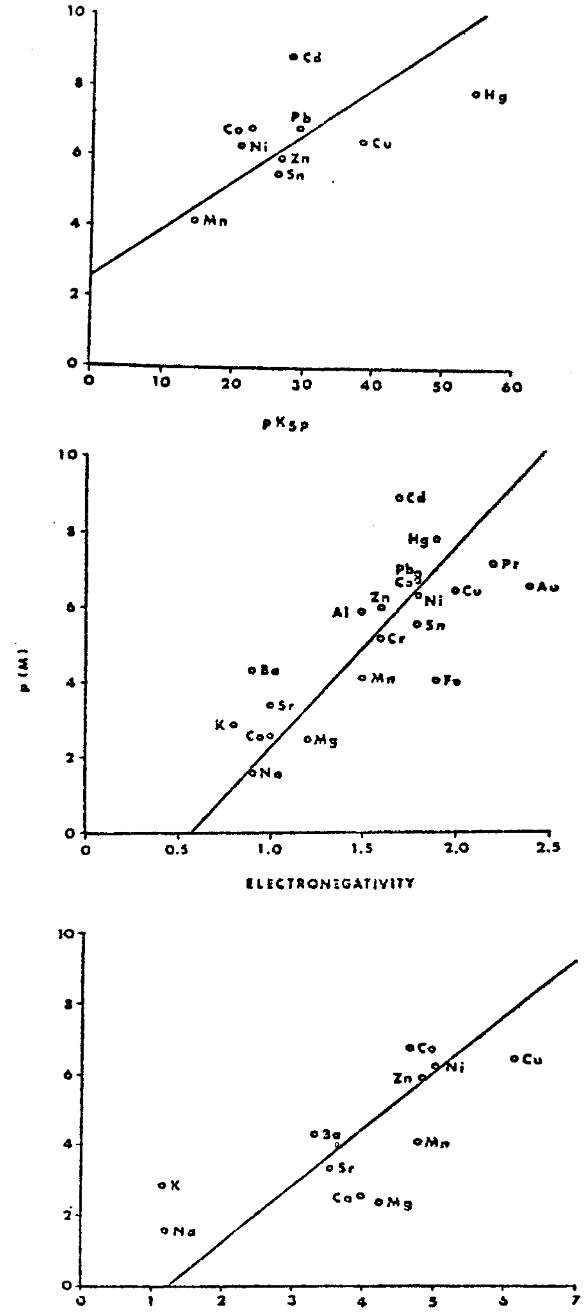

FIG. 21. Correlations between the 16% reproductive impairment concentration for <u>Daphnia</u> <u>magna</u> of metal as pM (-log molarity) and their solubility product constants as metal sulfides (pK_{sp}), their electronegativity, and their equilibrium constants as the metal-adenosine triphosphate complex (log K_{eq}). (Lines were fitted using the method of least squares.)

[From Biesinger and Christensen, 1972 (34)]

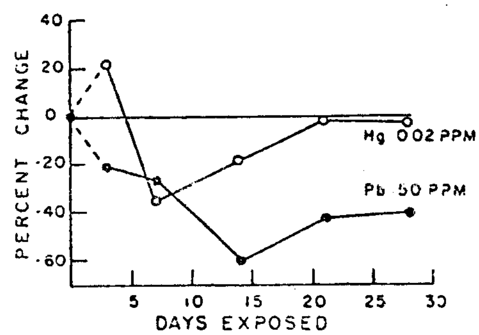

FIG 22. Temporal changes in δ-amino levulinate dehydrase activity upon exposure of fish to lead and mercury.

[From Jackim, 1974 (43)]

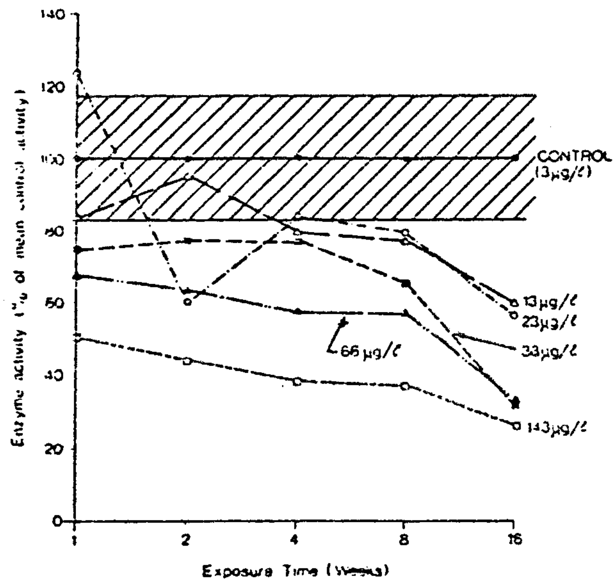

FIG. 23. Inhibition of rainbow trout (Salmo gairdneri) β-amino levulinic acid dehydratase activity by exposure to lead. The shaded area represents the minimum significant difference from control values. The numbers to the right are the lead concentrations in water.

[From Hodson, 1976 (73)]

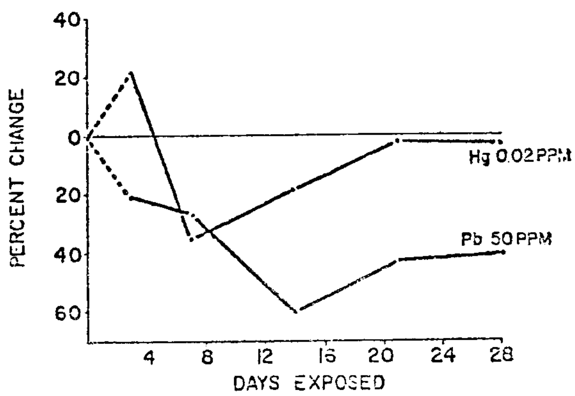

FIG. 24. ALA-D inhibition and activation vs time for mummichog (Fundulus heteroclitus) exposed to mercury and lead salts. Each point represents a value produced by three pooled livers as compared to that from three pooled control animals assayed simultaneously. The initial concentration was 50 ppm for lead and 0.02 ppm for mercury. The final concentration was 1 and 0.012 ppm, respectively.

[From Jackim, 1973 (74)]

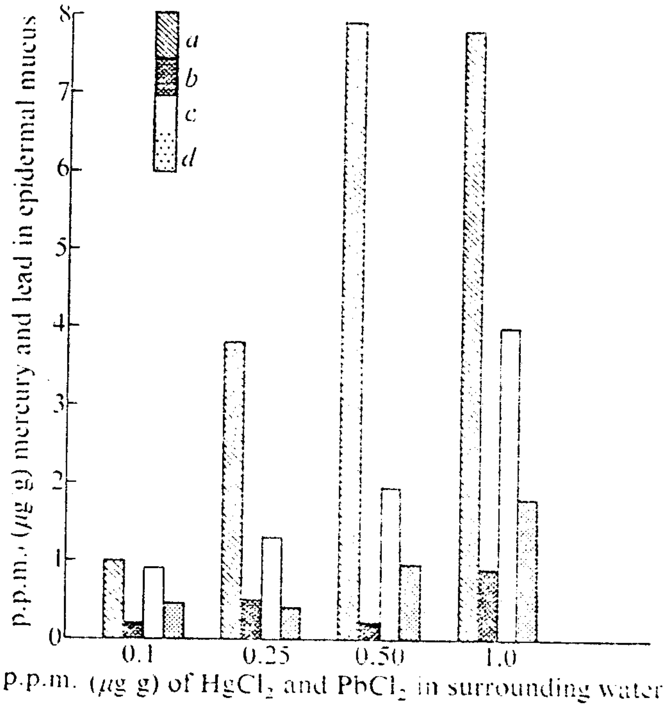

FIG. 25. Levels of mercury and lead in the epidermal mucus of rainbow trout exposed to $HgCl_2$ and $PbCl_2$ solutions. *a*, Accumulation of mercury in mucus after exposure to $HgCl_2$; *b*, concentration of mercury remaining in mucus after 24 h of depuration; *c*, accumulation of lead in mucus after exposure to $PbCl_2$; *d*, concentration of lead remaining in mucus after 24 h of depuration.

[From Varanasi et al., 1975 (67)]

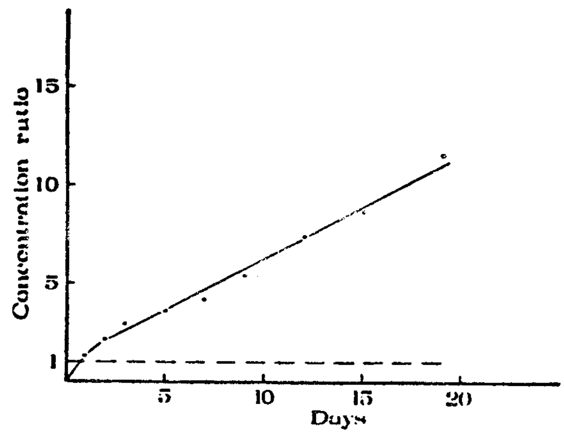

FIG. 26. Accumulation of ^{51}Cr by Hermione hystrix from sea water containing the radionuclide in the form of chromate. The accumulation at the different times of exposure is expressed as the ratio of radioactivity per gram of live worm to that of a milliliter of sea water.

[From Chipman, 1967 (83)]

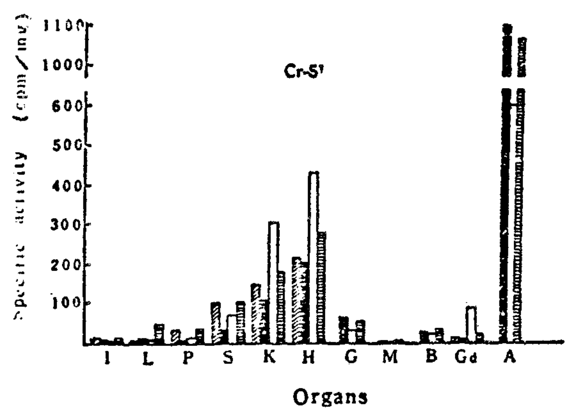

FIG. 27. Radioactivity of Cr-51 in various organs of goldfish injected with these readionuclides. I, Intestine; L, Liver; P, Pancreas; S, Spleen; K, Kidney; H, Head kidney; G, Gill; M, Muscle; B, Backbone; Gd, Gonad; and A, Air bladder.

[From Hibiya and Oguri, 1961 (85)]

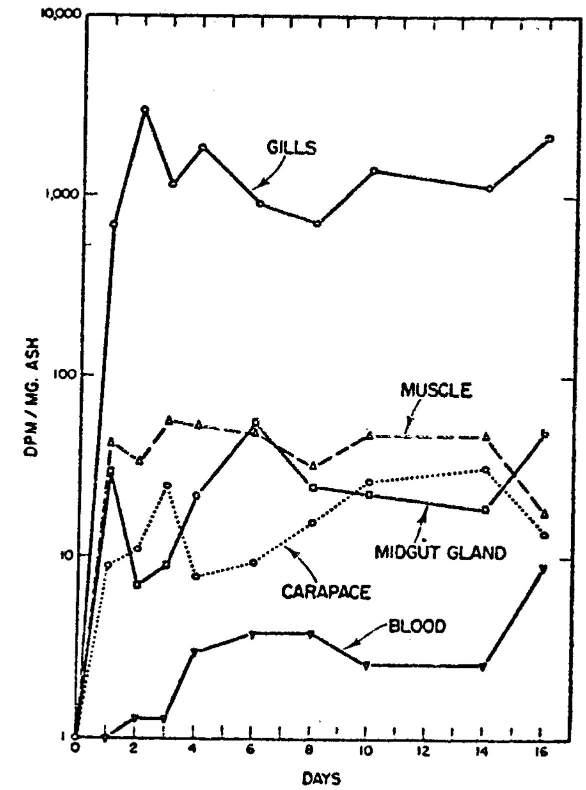

FIG. 28. Accumulation from solution of ^{51}Cr by the crab, P. vigil; radioactivities of five organs.

[From Sather, 1966 (88)]

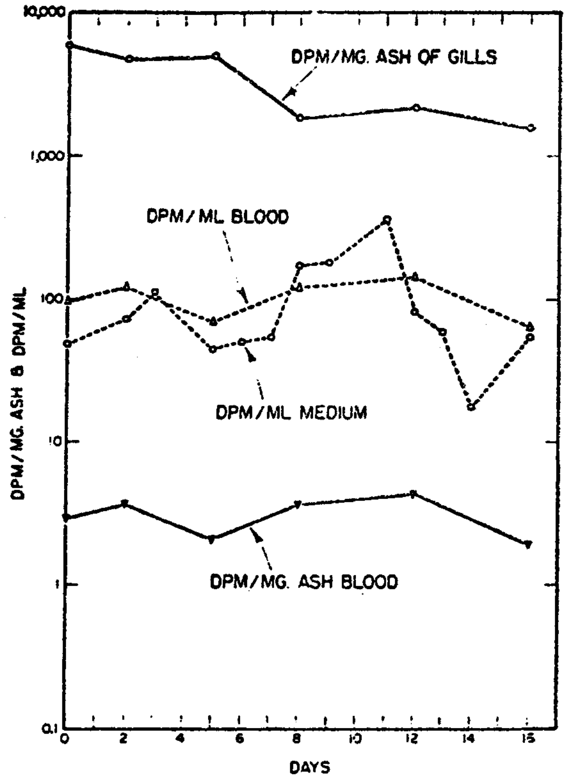

FIG. 29. ^{51}Cr activities of the gills and blood of P. vigil and medium after being placed inot "cold" (nonradioactive) sea water.

[From Sather, 1966 (88)]

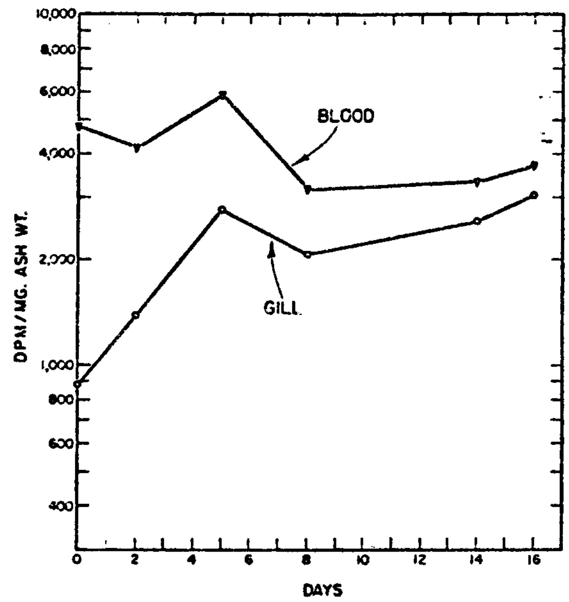

FIG. 30. Accumulation and loss of radiochromium by the gills and blood, respectively, of P. vigil after injection of 5.3 μCi $^{51}CrCl_3$.

[From Sather, 1966 (88)]

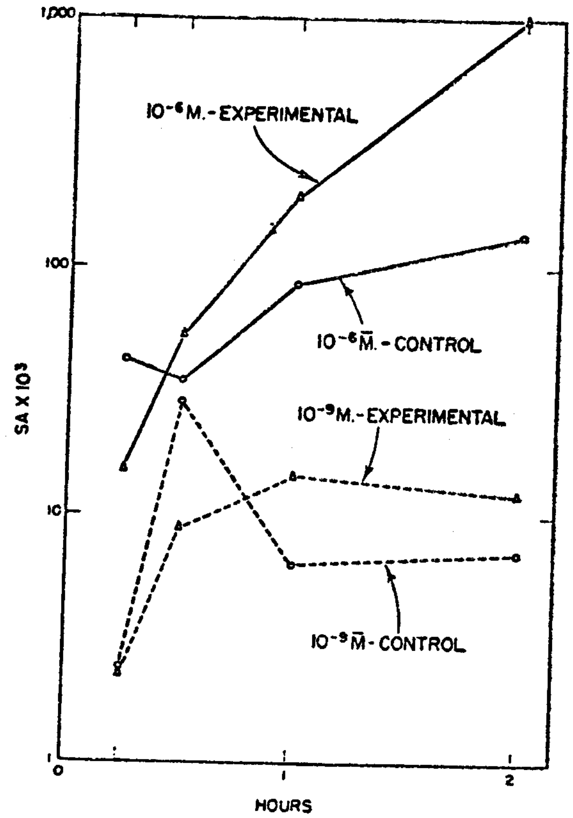

FIG. 31. Effect of two concentrations of KCN on the absorption of $^{51}CrO_4$ by isolated gills of P. vigil. Controls = without KCN. Experiments = KCN added.

[From Sather, 1966 (88)]

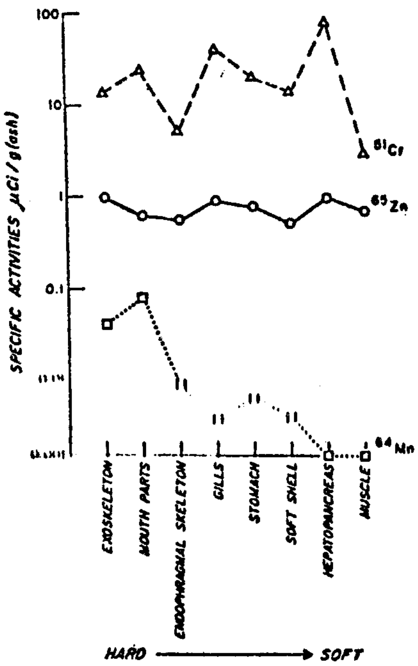

FIG. 32. Specific activities plotted as a function of tissue hardness for Columbia River crabs.

[From Tennant and Forester, 1969 (90)]

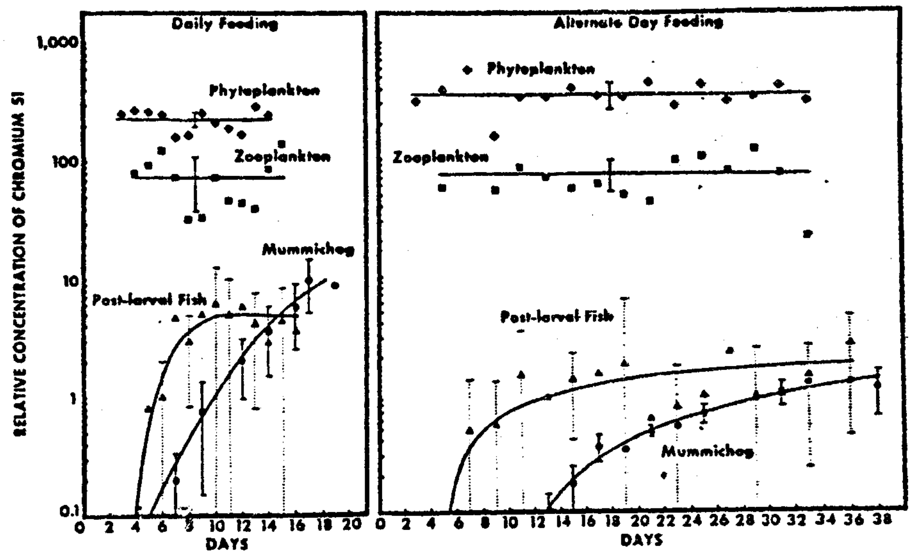

FIG. 33. Transfer of ^{51}Cr through an estuarine food chain with daily and alternate-day feeding. Concentrations were based on the initial amount of ^{51}Cr in the phytoplankton culture medium which had a value of 1. Vertical lines represent one standard deviation above and below the mean. Dotted vertical lines pertain to post-larval fish.

[From Upitis and Wollendorf, 1973 (105)]

BEHAVIORAL AND PHYSIOLOGICAL EFFECTS INDUCED BY SUBLETHAL LEVELS OF HEAVY METALS

by

William L. Reichert
Environmental Conservation Division

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INTRODUCTION

This review will cover the physiological and behavioral effects of cadmium (Cd), chromium (Cr), lead (Pb), and nickel (Ni) on marine organisms under saline conditions. At present, the vast bulk of research has focused on heavy metal toxicology in freshwater systems. Only recently has research focused on the physiological effects of heavy metals on aquatic organisms and their life cycles.

The effects of metals on physiological responses of marine organisms are dependent on the temperature and salinity of the marine environment [1,2,3]. In general, physiological effects of heavy metals increase with increasing temperature and decreasing salinity [4,5].

PHYSIOLOGICAL EFFECTS

EGG DEVELOPMENT

Rosenthal and Sperling [6] exposed Baltic herring (Clupea harengus) eggs to cadmium in seawater. They found that cadmium levels of 0.1 ppm and above reduced incubation time and viability of the hatch[1] (See Table I). At 1 ppm Cd, the viability of the hatch was down to 16% and at 5 ppm Cd the hatch was not viable. Westernhagen et al. [1] also observed that as salinity decreased cadmium became increasingly more toxic to herring egg development. The cadmium-exposed larvae were smaller than the unexposed

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[1] Viable hatch refers to those larvae that hatch without apparent morphological deformity.

but had a longer yolk sac. Westernhagen and Dethlefsen [3] in studies with Baltic flounder (Pleuronectes flesus) eggs found a similar response to cadmium with the exception that embryonic survival and viable hatch were relatively independent of salinity, except for the exposure at 16 ^{o}/oo salinity (Fig. 1). In both the Baltic flounder and Baltic herring, the amounts of cadmium found in the embryos after exposure to the highest levels were not much more than those levels found in the controls suggesting that the chorion is effective in limiting the transport of cadmium. The fact that so little metal is found in embryos might suggest that the embryos themselves are extremely sensitive to cadmium.

Embryonic activity can serve as an index of metal poisoning. Westernhagen et al. [2] observed in garpike (Belone belone L.) eggs that at cadmium concentrations of 0.5 ppm and above, both embryonic heart beat and frequency of pectoral fin movements in prelarvae were greatly reduced; however, embryonic survival and viable hatch rate were adversely affected only when cadmium levels had exceeded 1.0 ppm. Such questions may be raised as: how healthy are those larvae that appear viable when they hatch, will they have normal growth, and are the developed larvae more sensitive to cadmium than are the developing eggs? Studies with molluscs indicate similar responses to metal challenge. Calabrese et al. [7] exposed fertilized eggs of the oyster, Crassostrea virginica, to heavy metals and observed significant inhibition of embryo development. Nickel began inhibiting oyster-embryo development above 0.1 ppm and lead effects were observed above 0.50 ppm (Table 2). The authors observed some precipitation of lead and chromium on addition of lead and chromium solutions to their test media. This would suggest that the observed effects induced are from concentration levels of lead and chromium lower than is shown in the tables. In studies with the embryos of the hard clam, Mercenaria mercenaria, Calabrese and Nelson [8] concluded that lead and nickel inhibited embryo development of hard clams at significantly lower levels than for oysters. The LC_{50} for clams was 0.78 ppm Pb as against 2.45 ppm for oysters.

These studies with oysters and hard clams reflect only a portion of the life cycles of these marine animals. The larvae in the straight hinge form may be much more susceptible to the toxicant at low concentration than is the embryonic stage. Growth of the developed larvae may be retarded so that the free-swimming stage would be prolonged, thus increasing the chance of predation and dispersal away from a favorable environment for setting. The ability of the larvae to set may be hindered also.

HEMATOCRIT

Gardner and Yevich [9] exposed cunners (Fundulus heteroclitus) for up to 48 hours to 50 ppm of cadmium ion and found no significant change in hematocrit and concluded that for short-term exposures that it was not an indicator of physiological stress. In long-term studies at low levels of metal ions, however, hematocrit could become a stress indicator. Studies need to be conducted with metals such as lead and chromium, which readily interact with red cells, to establish whether hematocrit could be used as an index of metal-induced physiological stress.

OSMOREGULATION

Cadmium has been observed to affect osmoregulatory systems of marine organisms. Thurberg et al. [10] induced in the green crab, Carcinus maenas, an elevation of serum osmolality with cadmium at levels as low as 0.5 ppm whereas the cunner (F. heteroclitus) [11] in a 96-hour acute toxicity test showed a change in serum osmolality only at levels exceeding 24 ppm. The change in osmolality of cunner serum may have been due to a kidney failure [12]. The loss in ability to osmoregulate appears, in part, due to impairment of the gill function in maintaining osmotic balance [9, 13].

The osmoregulatory system of marine organisms, such as green crabs and rock crabs, may be subject to additional stress in estuarine areas where extensive changes in salinity occur daily due to tidal changes and freshwater runoff. The presence of heavy metals does alter the physiological response to the salinity changes, suggesting increased physiological stress.

OXYGEN CONSUMPTION

Thurberg [10] found in in vitro studies with gill tissues from green crabs (C. maenas) and rock crabs (Cancer irroratus) that 0.5 and 0.12 ppm Cd, respectively, significantly reduced oxygen consumption. In addition, cadmium at 0.12 ppm induced in the green crab a greater decrease in oxygen consumption at a salinity of 17% than at 32%. The teleost, F. heteroclitus, [11] showed changes in oxygen consumption above 3 ppm Cd.

Collier et al. [14] found that oxygen consumption by the mud crab, Eurypanopeus depressus, decreased rapidly with increasing concentration of cadmium. They were unable to decide, however, if the decrease was due to cadmium interference with respiration or was a reflection of the morbid state of the crab due to cadmium intoxication. The mud snail (Nassarius obsoletus) [15] increased its rate of oxygen consumption when cadium was greater than 0.5 ppm. However, copper ions do act synergistically with cadmium ions to lower oxygen consumption well below the rates for control snails (Table 3).

The gills are quite efficient in sequestering heavy metals, and relatively low levels of such metals could affect osmoregulation and oxygen consumption on a long-term basis.

PHOTOSYNTHESIS

The photosynthetic process of the giant kelp, Macrocystis pyrifera, is readily affected by heavy metals [16]. Clendenning and North [16] exposed young kelp fronds to heavy metals (Table 4) and found that photosynthesis of the fronds can be severely impaired after four days. Since the young kelp fronds are heavily screened from direct sunlight by the mature growth overhead, any exposure to metal ions could have an adverse effect on long-term productivity.

REPRODUCTION

Oshida et al. [17] found in long-term studies with the polychaete, Neanthes arenaceodentata, that after three generations (440-day study) of being exposed to 0.1 ppm Cr as chromate reproduction ceased. They also observed a reduction in brood size at levels as low as 0.0125 ppm Cr as chromate. In contrast, chromium in the trivalent state induced no observable adverse effects on N. arenaceodentata after two generations of exposure to a precipitate that was 50.4 ppm Cr^{+3}. The worms were in direct contact with the precipitate.

LIMB REGENERATION AND ECDYSIS

Crabs are capable of autotomizing injured limbs at a preformed breakage plane and subsequently regenerating them. Weis [18] found in studies with the fiddler crab (Uca pugilator) that 0.1 and 1.0 ppm Cd inhibited regeneration of limbs and since regeneration ends in a molt, ecdysis was also delayed. After 24 days at 1.0 ppm Cd, only 20% of the exposed crabs had molted, whereas 70% of the controls had. Seasonal differences were also observed and the inhibiting effect of cadmium was less during August, which is the normal time for molting, than in July. It is probable that fiddler crabs have higher titers of ecdysone and their progress toward ecdysis cannot be inhibited to the same extent. The crabs were also exposed to lead at the same levels as cadmium and no apparent effect on regeneration was observed.

If the crab should lose many limbs, any delay in regeneration and ecdysis would cause the animal to be more suseptible to predation.

BEHAVIOR

Behavioral studies with lead, cadmium, chromium and nickel are sparse under saline conditions. Weir and Hine [19] in studies with goldfish (*Carassius auratus*) using lead and mercury, found that levels well below the lethal concentration impaired response in a conditioned avoidance experiment (Table 5). While their work was performed under freshwater conditions, the implications for saline environments are clear. That is, toxic levels are not a good indicator of environmental stress. Also, it is reasonable to expect that the effect of metals on behavioral response would not be uniform on different species. Therefore, the delicate balance in predator and prey relationships could be adversely affected.

MacInnes [15] found that 0.5 ppm Cd induced stress in the mud snail (*N. obsoletus*). The snail was unable to move about, the body was extended, and the foot would not attach to anything. Such behavior could be viewed as a serious impairment in ability to forage and escape predation. Such behavioral studies would be a useful tool in assessing acceptable levels of metal pollutants in the marine environment.

CONCLUSION

Much work remains to be done with heavy metals. Of prime importance are studies involving continuous exposure to successive generations as indicated by the work of Oshida [17] on the effects of hexavalent chromium causing a decrease in reproduction by *N. arenaceodentata*. Reish [20] found that zinc ions, which are chemically similar to cadmium, induced abnormal larvae in the polychaete, *Capitella capitata*, after two generations at 50 ppb Zn, and copper will induce similar results at 10 ppb after one generation. The work on polychaetes by Oshida [17] and Reish [20] clearly show that physiological effects of low concentrations of metals, as low as 10 ppb for copper, may not be observable until one or more generations have been exposed. Thus, such findings indicate that short-term exposures do not always give satisfactory answers.

In addition to the life-cycle studies, there remains much work to be done on the sublethal effects of metals on behavioral responses, growth, disease resistance, and physiological responses under marine conditions. Also, as the work of Weis [18] points out, seasonal variations in response to heavy metal challenge should be considered.

The sparse literature on the physiological and behavioral effects of lead, cadmium, nickel and chromium presently provides insufficient background for balanced judgments relating to acceptable levels of these metals in the marine environment.

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TABLE 1

Effect of cadmium on Baltic herring eggs

Cadmium[a] (ppm) treatment of herring eggs	Time to 50% hatch (h)	Hatching rate[b] (%)	Viable hatch[c] (%)
0 (control)	361	88.9	87
0.1	332	94.6	82.7
1.0	293	84.0	16.3
5.0	254	74.8	0
10.0	-	14.4	0

[a] Cadmium as $CdCl_2 \cdot 2\text{-}1/2H_2O$

[b] Expressed as percent of eggs

[c] Expressed as percent of hatch

TABLE 2

Toxicity of heavy metals to oyster and hard clam embryos[a]

Metal as inorganic salts	LC_0[b]		LC_{50}		LC_{100}	
	Clams	Oysters	Clams	Oysters	Clams	Oysters
Cadmium chloride	--[c]	1.0	--	3.80	--	6.0
Chromium chloride	--	--	--	10.3	--	--
Nickel chloride	0.10	0.10	0.31	1.18	0.60	3.0
Lead nitrate	0.40	0.50	0.78	2.45	1.20	6.0

[a] Oyster and hard clam embryos were held at 26 ± 1°C in synthetic seawater (25 $^{o}/oo$ salinity). The concentrations are for the metallic ion added to the media at the start, producing mortality of 50% and 100% (LC_0 and LC_{100} are actual values and LC_{50} is estimated). The concentrations do not include background concentrations of the heavy metals in synthetic seawater medium. They were in ppm: Cd, 0.0045; Cr, 0.005; Ni, 0.0065; and Pb, 0.007.

[b] Exposure period is 42-48 hours.

[c] No data given.

TABLE 3

Oxygen consumption rates of the mud snail (Nassarius obsoletus) exposed to copper and cadmium individually and in combination

Metal ion treatment of mud snail		Number of tests	Oxygen consumption rate ($\mu l\ O_2$/h per g wet wt.)	
Inorganic ion	Ion concentration (ppm)		Mean	Standard error
Control	0	11	30.5	2.2
Copper	0.25	11	12.5	2.6
Cadmium	1.00	11	40.4	3.1
Copper and cadmium	0.25 and 1.00	11	6.4	3.0

TABLE 4

Inactivator of photosynthesis of kelp fronds by inorganic ions

Ion as inorganic salt	Concentration of inorganic ion causing 50% inactivator of photosynthesis of kelp fronds[a] (ppm)
Mercury	0.05
Copper	0.1
Nickel	2.0
Chromium	5.0
Chlorine (dissolved gas)	5-10
Zinc	10
Lead	--[b]

a Four-day exposure period.

b Inorganic salt was insoluble.

TABLE 5

Effect of heavy metal ions on the conditioned avoidance reaction of goldfish (Carassius auratus)

Metal ion		Fraction of 48 h LC_{50}	Fraction of 48 h LC_1
As inorganic salt	Concentration[a] (ppm)		
Sodium arsenate	0.1	1/320	1/15
Lead nitrate	0.07	1/1,570	1/857
Mercuric chloride	0.003	1/273	1/120
Selenium dioxide	0.25	1/48	1/4

[a] Lowest concentration of metal ion giving significant impairment of avoidance reaction of goldfish.

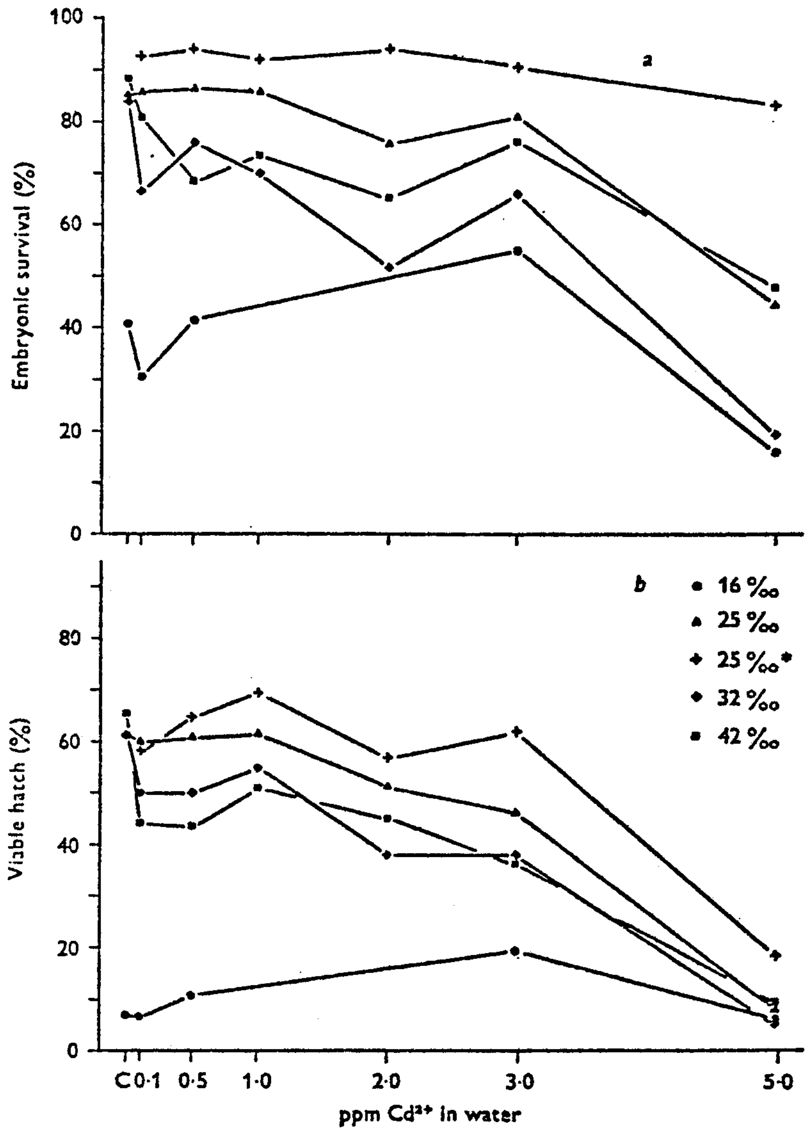

FIG. 1. Embryonic survival (a) and viable hatch (b) of flounder eggs and larvae incubated at different salinities and Cd-concentrations.
* Fertilization occurred in Cd-contaminated water.

GENERAL EFFECTS OF METALS ON THE ECOSYSTEM

by

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The effect of heavy metals particularly lead, cadmium, chromium and nickel on ecosystems has received little study. Some information is available on the rates of uptake, toxicity, and accumulation of these metals by individual species but the literature concerning community effects, food chains, and ecosystems is generally lacking. In a study of the distribution of trace metals from the disposal of sewage sludge [1], the presence of comparatively large amounts of cadmium, chromium, lead and other metals was indicated. Grossly elevated levels were restricted to a small area at the center of the disposal area. There were changes in species composition of the benthic infauna in this area. Benthic epifauna showed no changes in species composition. Increased levels of metals in this group were limited to certain species associated with the center of the disposal area. Several of the epifauna species were migratory making firm conclusions impossible with respect to accumulation of the metals. Even though the observed effects were localized and seemingly slight, it was stated that actually nothing is known of the levels necessary to induce changes in marine ecosystems.

Studies of the salt marsh have produced information on the cycling and budgets of metals in this ecosystems [2,3]. Salt marsh sediments are reduced and act as sinks for metals. The metals are picked up by the roots of the marsh vegetation and incorporated in the above-ground tissue. Half of the annual standing crop of the marsh grass is transported to deeper water by tidal flushing and thus the incorporated metals are exported to deeper water.

The salt marsh acts as a sink for lead by forming insoluble compounds. Increases in lead contamination result in increased lead burden but in little loss of the capacity of the salt marsh to retain lead. Eutrophication, in particular nitrogen increases, may increase lead export by order of magnitude amounts but this represents only a small percentage of the total lead retained in the marsh sediments. Animals associated with the marsh hold measureable amounts of lead but again these amounts are small compared to those in the sediment [2,3].

Cadmium is much more mobile in the salt marsh than lead. In areas where marshes are contaminated with 15 mg m^{-2} per year of cadmium or less, the bulk of the cadmium is retained. Losses were attributed to faunal accumulation and to tidal water. With rates of addition of cadmium greater than 15 mg m^{-2} per year, there is an export from the system probably as soluble cadmium compounds. Coincident high cadmium levels are found in the detritus and in the shellfish but are not of a magnitude to account for the loss of cadmium. Eutrophication will also increase the cadmium exported from the marsh in dead grass [2,3].

A single study of the transfer of chromium through an estuarine food chain indicates possible accumulations and points out the ecological factors that influence uptake of metals [4]. The chromium was followed through an experimental food chain of four steps including phytoplankton, brine shrimp, post-larval fish, and adult fish. The results indicate that the chromium was transferred through each level with a decline in concentration at each level. It was also shown that uptake from the food chain was more efficient than the uptake from the water. It was pointed out, however, that the transfer through food chains depends on the exposure, i.e., chronic or single, and the level of concentration reached in organisms is dependent on duration of feeding, amount of contaminated food consumed at each trophic level, time interval between feeding and being preyed upon, and the availability of the metal in the water. Ecological factors such as amount and kind of prey species available, the water temperature and salinity, and the migration of prey and consumer species into the area also influence the concentration levels.

The literature thus reveals only a very limited view of the effects of chromium, nickel, lead, and cadmium on the ecosystem. The available information deals only with cycling and budgets with no information on the effects of the metals on the ecology of the animals and resultant effects on populations and communities.

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FINAL REPORT

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MIGRATION OF BIRDS IN ALASKA MARINE HABITATS

By

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INTRODUCTION

Migration is a periodic movement with definite orientation, usually related to the annual departure from and return to an ancestral breeding ground. In birds, it is most apparent in those species which breed away from the equatorial regions of the world, including most waterfowl, shorebirds and seabirds. Migration is not to be confused with dispersal which is the movement of an immature bird from its birthplace to its first breeding place, or of older birds from the breeding place of one year to the breeding place of the next year.

The migratory process is often as varied as the species, with no two species having the same pattern and few individuals within a given population following the exact same route. There usually exist broad corridors within which birds move between summering and wintering grounds. These corridors are usually ecologically determined by such factors as landmark recognition, weather patterns, ocean currents, food sources, etc. Although most species exhibit some degree of philopatry to their wintering and breeding grounds, it is not uncommon for a species to use different migration routes in spring and fall.

The different migratory paths a species takes are, in part, determined by different migration strategies associated with the various physiological processes demanded by the different seasons. As a rule, the spring migration route is more direct and traversed more rapidly than the often longer fall route. Many species of seabirds and shorebirds, prior to their fall migrations to wintering quarters, partake of a comparatively short migration to areas away from the breeding grounds. On these staging areas, birds often undergo molt, reestablish flock integrity and build fat reserves needed for extended migrations. A staging process often occurs in spring in temporal latitudes in these same birds but is less accentuated and probably not as site specific as the fall counterpart. Different, yet, is another group of birds, the alcids, which rarely exhibit a migration in the strict sense, but instead disperse widely over the oceans following breeding.

There are over a hundred species of birds regularly occurring in Alaskan coastal habitats. The majority of these breed in Alaska, but included are several species which breed in equatorial and southern latitudes and winter in or pass through Alaskan waters during migration. In addition, several Siberian populations winter in coastal Alaskan waters, especially seaducks. Of the species breeding in Alaska, most exhibit a typical southward migration to temperate winter quarters; these include most shorebirds and several species of waterfowl. Besides this traditional type of migration, many seaducks and alcids engage in comparatively short movements from arctic and subarctic breeding grounds to wintering areas in the southern Bering Sea and the Gulf of Alaska. Wintering populations may also shift periodically between these two areas.

These varying components of avian migration systems provide for species-specific differences in both temporal and spatial distribution and abundance of populations. An understanding of these aspects as they relate to migratory bird populations in Alaskan waters is essential if we are to evaluate the potentially far-reaching effects of adverse impacts to these populations from Outer Continental Shelf mineral exploitation.

Of these impacts, direct contamination from spilled oil and alterations of marine food webs pose the greatest potential threat to marine bird communities. It is not the intent of this paper to discuss the biological implications of such events (for reviews, see e.g., Aldrich 1970, Bourne 1968, 1976, Clark 1973, and Vermeer and Vermeer 1974).

The purpose of the report (RU-340) is to summarize existing data on the timing, routes, patterns and magnitudes of bird migrations in Alaskan OCS areas and relate these events to lease area activities. Our efforts to do this were limited by the lack of migration studies over many of the Alaskan OCS areas. For areas from which we do have information, the data are generally of insufficient geographic or temporal coverage to accurately depict migratory movements.

Considering these limitations, we have prepared this report with emphasis on (1) those species which are highly vulnerable to oil contamination, e.g., seaducks and alcids, (2) areas of present or pending OCS mineral exploitation, and (3) areas which support large populations of breeding, wintering and transient marine birds.

CURRENT STATE OF KNOWLEDGE

The literature of Alaska's marine birds has recently been summarized by Bartonek and Lensink (1978). Their compilation of some 900 references through 1976 represents the most recent attempt at bringing some degree of cohesion to the published and unpublished accounts of Alaskan marine birds. Despite what appears to be an ample literature, including recent reports from OCS investigators, that portion addressing migration is wholly inadequate to develop meaningful accounts of timing and routes of migration of birds likely to be impacted from OCS activities.

Of the published literature, Gabrielson's and Lincoln's Birds of Alaska, recently updated by Kessel and Gibson (in press), summarizes the published and unpublished reports of Alaska's avifauna, and remains the best single account of the range, habits, foods, and migration of the approximately 380 species occurring within the state. Some of Gabrielson's and Lincoln's conclusions about migration were drawn from recovery of banded birds, but many of these were conjectural, being based upon their knowledge that a species was known to breed in a certain locality and that the same species (but perhaps not the same population) was known to winter in another locality. Since most ornithological investigations that they summarized were conducted from land, the migration information for some species of marine birds was fragmentary, misleading, or erroneous.

Somewhat better information on marine bird migration is found in Dement'ev and Gladkov (1951), Dement'ev et al. (1951, 1952), Palmer (1962, 1976), Shuntov (1972), Flock (1974) and Bellrose (1976). These authors generalize about patterns of migration, especially at-sea migration, and delineate the breeding and wintering areas for many species of birds found in Alaskan waters.

Only recently through OCSEAP related studies of marine birds have data become available to begin to adequately analyze migration routes and timing of migration of selected marine birds in Alaska (see e.g., Myres and Guzman 1976, 1977; Lensink and Bartonek 1976a, 1976b; Harrison 1977; Gould 1977, 1978; Arneson 1976, 1977; Gill et al. 1977, 1978; Senner 1977a, 1977b; Richardson et al. 1975). However, because of the lack of integrated design among these studies the data applicable to a migration synthesis often suffer from inadequate geographic and seasonal coverage.

STUDY AREA

This report primarily discusses migration of marine birds in Lower Cook Inlet, NE and W Gulf of Alaska, Kodiak Basin, Aleutian Shelf and Southern Alaska Peninsula, and SE Bering Sea and Bristol Bay (Figure 1). Environmental descriptions of these areas are found in USDI (1976, 1977a, 1977b) and Hood and Kelley (1974).

METHODS

No single comprehensive study has addressed the subject of marine bird migration in Alaska. Data for this report were, therefore, in part acquired through observations of bird migration, or the lack thereof, made during other research activities. Types and sources of these data include: 1) bird band recovery data provided by the Bird Banding Laboratory, Laurel, Maryland, 2) shipboard and aerial surveys (Research Unit 337), 3) site-specific studies (RU 83, 96 and 341), and 4) incidental accounts of migration available from published and unpublished literature.

The records of banded birds usually show no more than the place of banding and recovery; the route traversed between the two points is often conjectural. When banding is augmented by some form of color-marking, thereby increasing the chances of an encounter, or a banded bird is caught and released and subsequently recovered or recaptured elsewhere, then more conclusive evidence is available for determining migration pathways or dispersal movements. Contingent upon this, however, is the likelihood that someone will encounter a banded or marked bird and report the information. This has been shown to be directly related to the degree of contact a species has with humans, e.g., whether or not it is hunted or if it depends on areas close to human population centers.

For these reasons, marine birds generally have a low recovery rate ($< 0.01\%$) compared to heavily hunted duck and geese populations ($> 10\%$). Some species such as alcids are seldom, if ever, encountered after banding except on the breeding grounds. Others such as gulls are reported more regularly since they frequent fishing ports and garbage dumps along coastal areas.

Shipboard and aerial surveys were designed to determine seasonal occurrence and relative densities of seabird populations. These data are adequate to rough out migration patterns for certain species but lack of circumannual coverage in most OCS areas limits their usefulness.

Site-specific studies appear to afford the best data for assessing migration, but these are extremely limited in geographic coverage. Observations from coastal study sites during spring and fall have documented timing of migration of birds moving into and from the N Bering Sea (Dall Pt. and Cape Prince of Wales), SE Bering Sea and the Gulf of Alaska (Unimak Pass), along Bristol Bay (Cape Peirce and Nelson Lagoon) and to a lesser extent in Prince William Sound and the N Gulf of Alaska (Hinchinbrook Island). No such data exist for Lower Cook Inlet or elsewhere in the Gulf of Alaska.

RESULTS AND DISCUSSION

By identifying nesting areas and by knowing their respective species populations and breeding schedules one can begin to assess migration through and into OCS areas in Alaska. Tables 1 and 2 show minimum breeding population levels and seasonal occurrence by OCS area for some 30 species of marine birds. Combined, they represent a conservative figure of 23 million birds. Of these, approximately 15 species exhibit a true migration in the sense that they move to temperate latitudes in winter, usually following traditional routes. The remaining 15 species, comprising the majority of the breeding populations, are comparatively sedentary and winter in the inshore and pelagic waters of the Gulf of Alaska, southeastern Bering Sea and boreal waters of the East North Pacific Ocean. These populations do not migrate as such but rather disperse from colony areas and appear, superficially, to have random, widespread pelagic distributions in winter. However, it remains unclear whether these "pelagic" species have fixed dispersal or migration routes as found in most long distance migrants such as shorebirds and waterfowl.

Of the areas addressed in this report, the Bering Sea supports the greatest number of breeding seabirds, approximately 48 percent of all cataloged for Alaska. A somewhat smaller number, but greater diversity of seabirds, occurs along the Alaska Peninsula. Approximately 95 percent of these occur on the south side of the peninsula. Comparatively few species or numbers breed in the Cook Inlet region.

In addition to these numbers of breeding seabirds, most areas support an influx in summer and fall of subadults and southern hemisphere migrants who spend their nonbreeding season in Alaskan waters; chief among the latter are Sooty and Short-tailed Shearwaters, estimated at over 30 million each for their primary wintering areas, respectively, the Gulf of Alaska and the southern Bering Sea (G.A. Sanger, pers. comm). The majority of subadult birds present in Alaska each year, estimated at several million, is comprised chiefly of scoters, gulls including kittiwakes, and murres (Pat Gould, pers. comm.).

Another component of the migratory avifauna in Alaska is shorebirds. While they have so far demonstrated a low susceptibility to direct oil contamination their dependency upon rather restricted geographic areas adjacent to OCS oil and mineral lease areas warrants more attention than given to date. In the case of shorebirds, oil contamination of benthic foods might pose a greater problem than direct contamination. The majority of the Alaskan breeding populations of Dunlin and Western Sandpipers, in numbers exceeding 2 million each, rely almost exclusively on areas in the north Gulf of Alaska and along the southern Bering Sea and Bristol Bay coastlines for food during spring and fall migrations.

The following species accounts provide information on numbers, temporal and spatial occurrence and known or hypothetical migration and dispersal routes in Alaska.

The following species accounts provide information on numbers, temporal and spatial occurrence and known or hypothetical migration and dispersal routes in Alaska.

Species Accounts

Shearwaters

Two congeneric species of shearwaters occur regularly and in large numbers in Alaskan waters; the Sooty Shearwater (*Puffinus griseus*) and Short-tailed Shearwater (*P. tenuirostris*). Both species breed in the southern hemisphere during the boreal winter, and migrate to the northern hemisphere in the spring, forage heavily in summer throughout much of the Subarctic Pacific Region, and migrate to the southern hemisphere again in the boreal autumn (Sanger and Baird 1977). The at-sea migrations of both species have been described by Shuntov (1972).

Their respective entries into Alaskan waters occur from different regions of the Pacific; *tenuirostris* moves north into the Bering Sea via the eastern Pacific Ocean while *griseus* moves north along the Pacific coast of North America into the Gulf of Alaska (Shuntov 1972, Myres and Guzman 1977). Virtually nothing is known of the specifics of these species' entries into and subsequent migrations through Alaskan oceanic areas.

Generally, there is a zone of overlap in their distribution in the southern Bering Sea (Shuntov 1972), but most of the Sooty population occurs in the North Pacific proper and Gulf of Alaska while Short-tails occur primarily in Bristol Bay and the Bering Sea, north to the Bering Strait (Figure 2). In the Kodiak archipelago both are found in large numbers but their occurrence appears to be temporally segregated, *tenuirostris* present between May-June and *griseus* present during July-September (Gould 1978).

The arrival of populations of both species occurs beginning late March with subadult birds preceeding adults (Serventy 1967, Harrison 1977). Once in Alaskan waters movements of birds appear to be confined to specific regions. Generally, shearwaters concentrate on the continental shelf in the N and NW Gulf of Alaska beginning in April (Harrison 1977), with greatest densities found in waters $<$ 180 m deep during April-June. During this period Harrison had no observations of shearwaters closer than 3 km from shore or in waters shallower than 34 m. In May and June he noticed a decline in birds over the shelf and found birds concentrated inshore near the mouths of bays, especially in the Kodiak area. Myres and Guzman (1977) recorded a similar movement in this same area and Gould (1977) reported the same with densities during May-July exceeding 100 birds/km^2. Sanger et al. (1978) found August densities of Short-tails averaging 74 birds/km^2, with flocks of a few thousand still present in the Kodiak area in September. Whether these observations represent a single population or movements of several populations through the area is unknown.

The highest densities of shearwaters probably occur in the Unimak Pass area in spring and fall when populations of both species are arriving to and departing from Alaskan waters or in the interim period when interchange of populations between the Gulf of Alaska and Bering Sea probably occurs. Concentrations of over 1 million shearwaters have been recorded feeding in Unimak Pass in July and movements in excess of 25,000 birds/hour over several hours period have been recorded during April and May (FWS, unpubl. data).

Shearwaters in Bristol Bay and the eastern Bering Sea appear to be more widespread than those in the Gulf (Bartonek and Gibson 1972, Harrison 1977, Gould 1977, Myres and Guzman 1977). Large, prolonged movements (over 1000/minute over several hours) have been observed 2-5 km offshore along the north Alaska Peninsula between May - August (Gill et al. 1977). It is unknown if these movements represent portions of a single population summering in these areas or are movements of birds from elsewhere in the Bering Sea, or yet still, are birds entering Bering Sea-Bristol Bay from the Gulf of Alaska. Harrison (1977) found densities exceeding an average 100 birds/km^2 in fall along the entire north Alaska Peninsula; most of these were sighted within 60 km of shore.

Cormorants

By far the most abundant and widely distributed of the four cormorants in Alaska is the Pelagic Cormorant (*Phalacrocorax pelagicus*), which breeds on islands and coasts of the Bering Sea and North Pacific, north to Cape Thompson and south to Washington and Japan. Second in abundance is the Red-faced Cormorant (*P. urile*), restricted to the southern Bering Sea and northern Gulf of Alaska. Small numbers of the Double-crested Cormorant (*P. auritus*) breed in colonies scattered along the coasts of the southern Bering Sea and eastern North Pacific. Brandt's Cormorant (*P. penicillatus*) is only a casual breeder in southern Alaska (AOU 1957, Gabrielson and Lincoln 1959, Swartz 1966, Isleib and Kessel 1973). Discussion here will be limited to a description of the migrations of the Pelagic and Red-faced Cormorants.

Dement'ev and Gladkov (1951) have characterized the northern breeding populations of the Pelagic Cormorant as migratory, and the southern breeders as resident. Wintering areas include the Pribilof and Aleutian islands and North Pacific coastal waters (Figure 2). Migratory movements for all species of cormorants are poorly described, as they are among the first to arrive at and last to depart from the breeding cliffs.

Data for spring migration are variable and limited in geographic coverage. In April there is considerable migratory shifting of populations of the Pelagic Cormorant along the North Gulf coast (Isleib and Kessel 1973). No such northerly movements were observed in April and May through Unimak Pass in 1976, but cormorants may have been moving north farther offshore than could be observed (Nelson, FWS, unpubl. data). Within Bristol Bay, there is a late March 1977 observation of approximately 800 white-flanked cormorants (Pelagic) off Cape Seniavin (Gill, FWS, unpubl. data). Since the 1976-77 winter was a record mild one, this observation is probably not representative of the timing of cormorant migration into eastern Bristol Bay.

Elsewhere, a concentration of 10,000 cormorants (undoubtedly Pelagic) was observed on 30 April 1964 in Hagemeister Strait (King, FWS, unpubl. data). Spring migrants were observed in early May past Cape Peirce, Bristol Bay (Dick, pers. comm.) and Dall Point, Yukon Delta (Brandt 1943). Most breeders had arrived at Cape Prince of Wales (Bailey 1948) and at St. Lawrence Island (Fay and Cade 1959, Searing 1977) in late April, but not at Cape Thompson until mid-May (Swartz 1966). Variations of timing of migration may be due to seasonal differences among years, as arrival at the northern breeding sites coincides with the receding of winter ice and opening of leads (Bailey 1948, Dement'ev and Gladkov 1951).

In the fall, Pelagic Cormorants linger extendedly at the breeding cliffs, with adults still feeding "fledged" young for two to three weeks (Dement'ev and Gladkov 1951, Dick and Dick 1971). At Cape Thompson, many adults and young departed in late September and early October 1960, and the last was sighted in mid-October (Swartz 1966). Cormorants exhibited a steady, low level migration southward through Unimak Pass into the Gulf of Alaska from mid-September until late October 1976, the period monitored by Nelson (FWS, unpubl. data). Major migration occurs throughout September and October along the northern coast of the Gulf of Alaska (Isleib and Kessel 1973).

Both spring and fall movements are more restricted for the Red-faced Cormorant, which is resident throughout most of its breeding range (Dement'ev and Gladkov 1951, Gabrielson and Lincoln 1959). However, population levels during the winter are lower than those during the breeding season in both the Aleutians and northern Kodiak Island (Byrd et al. 1974, Dick, FWS, unpubl. data). As winter adults are notoriously difficult to distinguish from winter-plumaged Pelagic Cormorants (Gabrielson and Lincoln 1959), it is possible that an as yet undetected fall migration does occur along Alaska's coast. Red-faced Cormorants have only recently been identified as uncommon residents of the North Gulf Coast-Prince William Sound region (Isleib and Kessel 1973), and few winter observations have been conducted in Southeastern Alaska or among islands south of the Alaska Peninsula, potential major wintering grounds for this species.

From 7 April to 26 May 1976 a net southward movement of cormorants was recorded through Unimak Pass, with Red-faced outnumbering Pelagic Cormorants 10 to one (Nelson and Taber, FWS, unpubl. data). It is unlikely that Red-faced Cormorants move north to winter in the southern Bering Sea, because of the normally reduced winter population levels observed in the Aleutian Islands. As the 1975-76 winter was extremely mild, cormorants may have moved further north than usual; or perhaps, birds may have been moving in a local gyre far offshore, suggesting an apparent but not actual spring southward migration. Fall migration for all cormorant species that year was steadily southward through Unimak Pass during the period monitored, from mid-September to late October (Nelson, FWS, unpubl. data).

Black Brant

The Black Brant (*Branta bernicla nigricans*) breeds in Alaska and Eastern Siberia and winters along coastal Baja California, the eastern Gulf of California, and the Canadian Archepelago. Most of the breeding population (110,000 birds) is centered on the west and north coasts of Alaska and Canada (Figure 4). Breeding is usually restricted to a narrow fringe of coastal habitat.

In late winter (January-March) brant begin moving north along the Pacific coast of North America to Washington and southern British Columbia from which, around mid-April, they cross the Gulf of Alaska and proceed to Izembek Lagoon on the north Alaska Peninsula (in Palmer 1976). A small segment of the population, believed to be nonbreeding birds (Myres 1972), is known to proceed north along the British Columbia and SE Alaska coastline and stop at Copper River Delta, Prince William Sound and Kodiak Island (Isleib and Kessel 1973). These birds, in turn, also move on to Izembek Lagoon.

The breeding population remains at Izembek from mid-April until about the second or third week of May before continuing its northward flight across Bristol Bay to Cape Peirce. They make brief stops at several small lagoons including those on Nunivak Island, Nanvak Bay, and Chagvan Bay, and move north along the coast to the breeding grounds, arriving there from mid- to late May. Birds breeding in the more northern portion of the range, in Siberia and on the Beaufort Sea coast, arrive slightly later than birds utilizing the more southern area. It is unknown if the Siberian breeding population moves directly across the Bering Sea once north of Nunivak Island, or if it follows the coast to the Bering Strait before crossing.

Non-breeding birds appear to straggle northward from Izembek on a liesurely migration to molting areas. They appear at Nome, and the lagoons of the Seward Peninsula. Most birds proceed to the Teshekpuk Lake area on the Arctic Coast.

Within Alaska, the fall migration is nearly the reverse of that in spring. Postbreeding movements begin in August with adults and young using most lagoon and estuarine systems along the W and SW coast of Alaska to Cape Newenham. Then most apparently strike straight across Bristol Bay to Izembek Lagoon. By September and October virtually the entire brant population is found again on Izembek Lagoon. They remain there until about the first week of November, then migrate en masse across the East North Pacific Ocean to coastal California and Baja California (R. Jones in Palmer 1976).

Emperor Goose

The Emperor Goose (*Anser canagica*) nests along the northern and western coasts of Alaska and winters primarily along the northwestern Alaska Peninsula, eastern Aleutian Islands and throughout the Kodiak Basin (Figure 5). Spring migration from the wintering areas begins with a gradual movement to the major lagoons along the northern Alaska Peninsula. Most of the entire Alaskan breeding population (approximately 65,000 birds, in Bellrose 1976) concentrates on Izembek Lagoon, Nelson Lagoon and Port Heiden in late April and early May (Arneson 1977, Gill et all. 1978, R.D. Jones, pers. comm.). The migration from these areas to the breeding grounds occurs suddenly with most of the population departing within a 24-48 hour period. Their first landfall after leaving the Peninsula is Cape Peirce where they remain a short while at Nanvak and Chagvan Bays (J. King in Palmer 1976) before continuing north, apparently following the coast to their principal nesting areas on the Yukon-Kuskokwim Delta and beyond. That portion of the population nesting in Siberia is thought to follow the coast to approximately Dall Point before crossing the Bering Strait (Palmer 1976).

Prior to fall migration many species of waterfowl undergo a molt migration, especially subadults and unsuccessful breeding adults. Such migrations of Emperor Geese are known from Hooper Bay (Murie 1924, Jones 1972, Eisenhauer and Kirkpatrick 1977), to St. Lawrence Island (Fay and Cade 1959) and the Chukotski Peninsula (Portenko 1972).

In late August, continuing through September, successfully breeding adults and their young gradually leave the breeding areas and move south along the coast to Bristol Bay and the Alaska Peninsula. Major stopover points include Nunivak Island (Swarth 1934), Chagvan and Nanvak Bays (Petersen and Sigman 1977) and the larger lagoons along the Peninsula (R.D. Jones, pers. comm.). Fall migration is usually more prolonged than spring migration, comprised of family groups numbering usually less than 20 birds, and spread over a greater portion of the range. During late fall, small numbers of geese move to the Kodiak area and as far east as Prince William Sound (Isleib and Kessel 1973, M. Dick, FWS, unpubl. data).

Steller's Eider

The total population of Steller's Eiders (*Polysticta stelleri*) is estimated at 200,000 birds, most of which winter in Alaska and nest in

Siberia and to a lesser extent along west and north coastal Alaska (Jones 1965). They winter primarily along the southern Alaska Peninsula from Unimak Pass to Kodiak Island, some extending to Lower Cook Inlet and Kachemak Bay (Figure 6). Spring migration from the wintering area begins as a gradual movement to the north Alaska Peninsula to Bechevin Bay, Izembek Lagoon and Nelson Lagoon (Palmer 1976). Birds generally remain in the lagoons through April and into early May. Migration from Bechevin Bay and Izembek Lagoon is complete by late May and apparently proceeds along the coast (R.D. Jones, pers. comm.), until the birds reach Nelson Lagoon, from which they apparently fly north across Bristol Bay to Cape Peirce. Past Cape Peirce they probably continue north just offshore until they reach Dall Point. From Dall Point the majority of the birds probably head towards St. Lawrence Island and continue across the Bering Strait to Siberia. Most birds arrive on the breeding grounds in mid-July (Rutilevskii in Palmer 1976). A small segment of the population breeds along the north slope of Alaska. Birds en route to this area in spring apparently follow the coast, as they have been observed migrating past Point Barrow in early June (in Palmer 1976).

Details of molt migrations and fall migration are poorly known for areas other than the southern Bering Sea. However, Flock (1972) suspected a broad front migration of postbreeding males past Cape Prince of Wales in late July. Considerably south of Cape Prince of Wales, at Cape Peirce, adult males have been recorded passing south offshore from late August through September (Petersen and Sigman 1977). Adult males generally arrive at their primary molting areas on Nelson and Izembek lagoons in late August (Jones 1965, Gill et al. 1978). These areas also support large numbers of molting subadults which often preceed adult males in their arrival by several weeks. Females and young of the year probably do not leave the breeding areas until late September, and then gradually move down the coast. Females and young have been observed passing Nunivak Island during late September (C. P. Dau, pers. comm.), and arriving at Izembek Lagoon in October (Jones 1965); however, their migration is extremely variable, with birds occasionally arriving at Izembek in December (Jones 1965). There is probably a gradual departure of all birds from these areas in late fall and winter as molt is completed. By freeze-up most birds have scattered to wintering areas over inshore waters along the south side of the Alaska Peninsula.

Common Eider

The subspecies Somateria mollissima v-nigra of the Common Eider is a year round resident of Alaska, chiefly along the Arctic coast and shores of the Bering Sea, including the Aleutian Islands (Gabrielson and Lincoln 1959). The total population is unknown but probably exceeds several hundred thousand birds (in Bellrose 1976). A limited number breed and winter in the Gulf of Alaska, east to Sitka (Isleib and Kessel 1973, Bellrose 1976). Away from the breeding grounds the species frequents relatively shallow coastal waters.

The migrations of the Common Eider, as with all eider species, are poorly known, primarily because of the often complex sex and/or age segregation in flocks and their use of open water, inshore and overland migration corridors (Flock 1973, Richardson et al. 1975, Palmer 1976).

For that segment of the population breeding in the more southerly limits of the range (Bristol Bay and Gulf of Alaska) there is very little migration. From the major wintering areas in the southern Bering Sea and Bristol Bay (Gabrielson and Lincoln 1959, Lensink and Bartonek 1976b, Harrison 1977) the more migratory populations begin spring migration in April, moving along the coast past Cape Peirce to Dall Point (Figure 7). This movement probably includes a large segment of the population wintering in the Gulf of Alaska. These birds are suspected of migrating into the Bering Sea in late winter; however, the timing and routes of these movements are unknown, but probably include passage through several low areas along the Alaska Peninsula, as there are few records of Common Eiders migrating through Unimak Pass in spring. Once birds pass Dall Point on the Yukon Delta, a segment moves toward St. Lawrence Island and from there probably to breeding grounds in Siberia, while the main segment continues along the coast, some crossing the base of the Seward Peninsula to Kotzebue Sound (Flock 1973). Breeding becomes concentrated from Norton Sound, north onto the Beaufort Sea coast. Spring migration is rapid and usually non-stop, with birds arriving on the breeding grounds from mid-to late May.

Molt migration and fall migration are poorly known. Birds migrate past Point Barrow from early July until late October (Thompson and Person 1963). Adult males are usually the first to pass, followed by females and young. The fall migration is generally thought to proceed rapidly until birds are south of Point Hope. Birds then apparently begin congregating along major lagoons in Kotzebue and Norton Sounds (Harrison, FWS, unpubl. data). Numbers do not begin to build on the wintering areas (Nelson and Izembek Lagoons) until late September through November (Gill et al. 1978, R. D. Jones, pers. comm.). The timing of winter influx of Common Eiders into the Gulf of Alaska and around Kodiak is unknown, but probably commences in November.

King Eider

The King Eider's (Somateria spectabilis) range is circumpolar. It breeds abundantly along coastal arctic Canada and sparingly in similar habitat in Alaska (Gabrielson and Lincoln 1959). The North American breeding population is figured at between 1 million and 1.5 million birds of which fewer than 10,000 are thought to breed in arctic Alaska (Bartonek in Bellrose 1976). However, the King Eider migration in arctic Alaska, accounting for the majority of the North American population, is the most spectacular and well documented of any of the eider migrations (Figure 8).

Most of the western Canadian, an unknown portion of the Siberian, and all of the Alaskan breeding populations are thought to winter in the southern Bering Sea and Bristol Bay (Bellrose 1976). Minor concentrations winter throughout the Kodiak archipelago (Matt Dick, FWS, unpubl. data). Over the major wintering area birds tend to congregate in the eastern Aleutians and off the larger lagoons along the western Alaska Peninsula (R. D. Jones, pers. comm.). During mild winters large concentrations of King Eiders can be found off major lagoons farther east along the Peninsula; e.g., an estimated 300,000 were recorded off of Ugashik and Egekik Bays in March 1977 (Gill, FWS, unpubl. data) and approximately 20,000 wintered in Nelson Lagoon in 1976-77 (Gill et al. 1977). It is possible that, as the birds prepare for spring migration, such concentrations occur regularly there when ice conditions permit.

Spring migration can be characterized as orderly and proceeding at a fast rate, usually occurring during favorable winds (Bailey 1943), and completed in 3-4 weeks. Peak spring migration has been recorded during the first week of May past Cape Peirce (Petersen and Sigman 1977) and on 15 May past Dall Point, approximately 250 km to the north (Brandt 1943, Murie in Gabrielson and Lincoln 1959). Surprisingly, spring migration peaks also at Wainwright and Point Barrow in mid-May (Gabrielson and Lincoln 1959, Bellrose 1976). From Dall Point, some birds apparently fly to St. Lawrence Island en route to breeding grounds in Siberia (Fay 1961).

Breeding is hardly initiated before adult males start the return to their wintering grounds, stopping along the way to complete molt. At present, these molting areas are unknown. Migration of adult males past Point Barrow begins in July and continues through August (Thompson and Person 1963). The ratio of males to females shifts beginning mid-August (Thompson and Person 1963, Johnson 1971); females then become dominant into late September. Young birds generally migrate past Barrow during September and October.

Details of fall migration south of Point Barrow are sketchy. Concentrations of "mottled plumage" King Eiders have been observed in Eschscholtz Bay, Kotzebue Sound in late August (Harrison 1977), and C.P. Dau (pers. comm.) has recorded movements of females and young past Nunivak Island in late September. Dau's lack of observations of males during this period suggests that they do not move south until later. King Eiders did not appear at St. Lawrence Island until ice formed in December (Fay 1961). During normal ice years numbers of birds along the Alaska Peninsula usually do not begin to build until after November (R.D. Jones, pers. comm.). None had arrived at Nelson Lagoon as of 15 October 1977 (Gill et al. 1978) and only a few were present in mid-November 1976 (Gill et al. 1977). They are not reported to arrive in the eastern Aleutians (Dutch Harbor) until early December (Cahn 1947) and probably do not occur in numbers in the Gulf of Alaska and around Kodiak until this time also.

Scoters

An estimated 235,000 Black Scoters (Melanitta nigra), and several 100,000 Surf Scoters (M. perspicillata) and White-winged Scoters (M. fusca) nest in Alaska (Bellrose 1976). A large portion of these nesting populations may also winter in Alaskan waters. Migration in Alaska has been documented only for Black Scoters, and only from two sites: Nelson Lagoon (Gill et al 1978), and Cape Peirce (Petersen and Sigman 1977) (Figure 9). Spring migration of Black Scoters along the north Alaska Peninsula occurs during late April. Migration of Black Scoters does not peak at Cape Peirce until early May, suggesting that part of the population probably moves along the inshore waters of Bristol Bay, before moving north and inland to major breeding grounds on the Yukon-Kuskokwim Delta. The spring migration routes of scoters breeding in interior Alaska and along the northwest coast are even less well known. Possibly the Black Scoters that nest in the interior migrate from the Gulf of Alaska, while the ones that nest along the northwest coast migrate from the southeast Bering Sea.

The molt migration and fall migration patterns of scoters in Alaskan waters are also poorly known. Apparently breeding males and nonbreeding birds leave the nesting areas in July and August, and congregate along the coast, south from Kotzebue Sound, off the Yukon Delta and along the Alaska Peninsula (Black Scoters), to Lower Cook Inlet (Harrison 1977, Petersen and Sigman 1977, Arneson 1977, C.P. Dau, pers. comm.). The species composition of molting flocks is poorly known, but probably consists largely of Surf and Black Scoters north of the Alaska Peninsula with White-winged Scoters dispersed along the coast of the Gulf of Alaska. The species composition of molting flocks in Lower Cook Inlet is unknown.

The migration of both adult and young scoters to wintering areas is undescribed, although wintering areas in Alaska have been generally delineated. Black Scoters concentrate in Prince William Sound (Isleib and Kessel 1973), around Kodiak Island (Dick, FWS, unpubl. data), and along the Alaska Peninsula and throughout the Aleutian Islands (Bellrose 1976, R.D. Jones pers. comm.). White-winged Scoters and Surf Scoters primarily winter along the Pacific coast south of Alaska, but concentrations of 10,000's of birds have been reported in Lower Cook Inlet (Arneson 1977) and Prince William Sound (Isleib and Kessel 1973).

Shorebirds

Dunlin (Calidris alpina pacifica) and Western Sandpipers (Calidris mauri) account for approximately 80 percent of the shorebirds using intertidal areas in the Gulf of Alaska, northeast Bering Sea, and Bristol Bay. During spring migration more than 10 million Dunlin and Western Sandpipers pass through the Copper-Bering River Deltas on the north coast of the Gulf of Alaska, and the Fox River Flats at the head of Kachemak Bay in lower Cook Inlet (Figures 10 and 11) (Isleib and Kessel 1973, Senner 1977b). These numbers probably include the majority of the Alaskan breeding populations of both species (Senner 1977b). The stay of individual birds at these sites is relatively short, probably 2-3 days in spring, with most passing through during the second and third weeks of May. It is possible that a small portion of each population also stops at suitable estuarine areas along the western shore of Cook Inlet. Most, however, are thought to move west from the Copper River area and cross the base of the Alaska Peninsula. From there they move along the Bristol Bay coastline or inland to their principal breeding grounds on the Yukon-Kuskokwim Delta, north to the Seward Peninsula (Senner 1977b).

In fall, migration is preceeded by a movement of large numbers of both species directly to coastal areas along the Yukon-Kuskokwim Delta and Bristol Bay (Holmes 1971, 1972). For Western Sandpipers this movement occurs from mid-July through August and for Dunlin from late July through mid-October. During these periods both species build large fat reserves preparatory to extended fall migration. Fall migrant Western Sandpipers appear to cross the base of the Alaska Peninsula and follow the Gulf of Alaska and British Columbia coastline to their wintering quarters in temperate latitudes. Comparatively little use is made of intertidal areas along the north Gulf of Alaska in fall except by birds coming from the Alaska Peninsula (Gill et al. 1978). Probably the majority of Dunlin breeding on the Yukon-Kuskokwim Delta migrate across the base of the Alaska Peninsula, and then along or across the north Gulf of Alaska to British Columbia and farther south. They have been reported as occurring irregularly in fall on the Copper River Delta (Isleib and Kessel 1973, Stan Senner, pers. comm.). Dunlin staging on the north side of the Alaska Peninsula appear to exhibit a different migration strategy and are suspected of using a more direct overwater route across the Gulf of Alaka to their wintering quarters along the west coast of the United States and Mexoco (Gill et al. 1978).

Black-legged Kittiwake

The Pacific race of the Black-legged Kittiwake (*Rissa tridactyla pollicaris*) breeds along coastal cliffs of Siberia and Alaska and nomads in the open ocean in two major wintering areas: 1) south of the Aleutian Islands and east of Japan, an 2) along the coast from British Columbia to Baja California (Figure 12) (AOU 1957, Gabrielson and Lincoln 1959, Shuntov 1972). Some kittiwakes also winter in the Gulf of Alaska and in the southern Bering Sea in lower concentrations (Kenyon 1949, Shuntov 1972).

Migratory movements during both spring and fall are poorly understood, but appear to be gradual during both seasons. As it is still unknown where specific breeding populations winter, migratory pathways can at best be inferred by analyzing changes in distribution and abundance throughout the seasons. Migration patterns seem to differ, however, for the two major wintering areas, in the NE and NW Pacific Ocean.

The initiation of spring migration coincides with the warming of ocean waters (Shuntov 1972). On the east side of the Pacific, peak numbers occur off Monterey, California in late Febraury and early March (Ainley 1976). During late April and throughout May, kittiwakes become common migrants through Southeastern Alaska (Gabrielson and Lincoln 1959). In the Gulf of Alaska, kittiwakes begin to concentrate over waters along the outer edge of the continental shelf and slope in February and March, building in numbers in April. By May, adults have moved into breeding colonies, and are encountered only as scattered individuals except close to shore (Isleib and Kessel 1973, FWS unpubl. data).

Spring migration into the Bering Sea, in contrast with that into the Gulf of Alaska, occurs along a broad front (Shuntov 1972). Probably most of the kittiwakes breeding in colonies in the Bering Sea concentrate in the western portion of their major wintering area south of the Aleutians. Northward displacement begins in mid-March with intensive movements occurring through the straits of the eastern Aleutian ridge in April (Shuntov 1972). Once into the southern Bering Sea, further northward migration is delayed by ice. During March and April kittiwakes in this area occur mostly at the fringes and just south of the ice front (Divoky 1977), with birds moving into leads in proximity to breeding colonies (Swartz 1966). Occupation of colonies in the Bering Sea occurs in late April and May (Dement'ev et al. 1951, King and Monson 1968, Shuntov 1972, Petersen and Sigman 1977), with migration through the Bering Strait commencing in mid-May and peaking in mid-June (Bailey 1948, Flock 1972).

Fall migration also seems to be a leisurely process. Both adults and young frequent old nests until ready to migrate (Bent 1921). Adult kittiwakes undergo a complete postnuptial molt which begins at the end of the nesting period and terminates during the period of wandering, usually around mid-September (Dement'ev et al. 1951). Fall migration is sometimes, but perhaps not always, preceded by flocking of adults and young offshore from nesting cliffs or on nearby beaches (Swartz 1966, Drury 1977, Gill et al. 1977). Flocks of failed breeders and sometimes nonbreeders develop throughout the nesting period, with flocks of successful breeders and juveniles developing later as young fledge. At Cape Thompson, north of the Bering Strait, most young depart by late September, and most adults, by mid-October (Swartz 1966). To the south, at Bluff in Norton Sound (Drury 1977), postbreeding adults apparently leave gradually through September, while juveniles remain somewhat later than adults.

Fall kittiwake migration through Unimak Pass has been described as a slow but steady net movement south throughout the middle of September and into late October (Jay Nelson, FWS, unpubl. data). Generally, by October, flocks may be sighted a few hundred km south of the Aleutian ridge, but kittiwakes are still numerous throughout the Bering Sea (Shuntov 1972). Observations in the southern Bering Sea in October and November indicate that highest densities of kittiwakes are found in Bristol Bay, with immature birds predominating in all areas (FWS, unpubl. data).

In Prince William Sound the majority of kittiwakes leave colony sites from mid-August to mid-September, and are down to winter levels by

November (Isleib and Kessel 1973), by which time they are also scarce in the Gulf of Alaska (David Nysewander, pers. comm.). Migration through SE Alaska occurs from mid-August to late September (Gabrielson and Lincoln 1959); however, kittiwakes do not become abundant off Monterey Bay, California until late December, indicating a leisurely movement south along the coast (Ainley 1976).

The fall migratory pathways of Alaskan kittiwakes appear to roughly reverse those followed in spring. For the eastern Bering Sea population there is a broad and gradual movement from breeding colonies to wintering areas south of the Aleutians, while populations from the Gulf of Alaska are thought to have a more narrowly channeled movement along the continental shelf on the east side of the Pacific to their wintering areas south of British Columbia.

Murres

Two species of murres breed and winter in Alaskan waters, the Common Murre (Uria aalge) and the Thick-billed Murre (U. lomvia). They occur in approximately equal numbers on their major breeding grounds in Bristol Bay and the northern Bering Sea (Table 1, Figure 13). Both species breed along the southern Alaska Peninsula and throughout the Kodiak Basin and Gulf of Alaska; however, the Common Murre is the more abundant and widespread of the two (Gabrielson and Lincoln 1959).

Apparently, only breeding populations in the Chukchi and northern Bering Seas partake of a well-defined migration to and from the breeding grounds. The more southerly populations, especially those breeding in the Gulf of Alaska and in the Bering Sea south of winter ice advance, are thought to move randomly from colonies and assume a pelagic existence in winter, usually over the continental shelf, with some birds moving into the protected waters of SE Alaska (Gabrielson and Lincoln 1959). In the southern Bering Sea, winter populations associated with the ice edge have been described as being the greatest densities of any throughout the murres' winter range (Shuntov 1972, Divoky 1977), and are probably comprised chiefly of birds breeding throughout the Bering Sea. There is, however, a substantial population of Bering Sea breeders which do not winter in the area but migrate through Unimak Pass into the Gulf of Alaska each fall (FWS, unpubl. data).

The return spring migration through Unimak Pass into the Bering Sea commences in late March and peaks in late April, but continues into May. Clinal variations in nesting chronologies of birds breeding in western Alaska probably account for the prolonged spring migration through the pass. This movement has been described as sporadic, and occurring at the rate of approximately 500 birds per hour during normal migrations, but with as many as 12,000 birds per hour having been recorded (Jay Nelson, FWS, unpubl. data).

Autumn migration through Unimak Pass is also quite protracted, extending from late July through October. Peak movements have been recorded during the last week of August and again during the middle of

October (FWS, unpubl. data). These observations were made during different years and, therefore, might not reflect the true chronology of migration through Unimak Pass. It is possible, however, that the earlier peak is comprised of murres from the Pribilof Islands and Cape Newenham colonies which nest earlier than those at colonies in the northern Bering and Chukchi Seas (Petersen and Sigman 1977, Drury 1977, Hunt 1977). The more northern breeders might, in turn, comprise the mid-October migraton.

Tufted Puffin

The Tufted Puffin (*Lunda cirrhata*) is an abundant breeding alcid in Alaskan waters (Table 1, Figure 14), but like most alcids it partakes of no well-defined migration. Instead, it disperses over the open ocean, usually off the continental shelf following breeding (Shuntov 1972). The return to the colonies in spring has been described as a "broad front migration" (Kuroda 1955, Shuntov 1972), and apparently does not include subadults. Juveniles probably spend their first and second years at sea (Kuroda 1955).

Tufted Puffins begin arriving at colony areas in the Gulf of Alaska in late March but usually remain at sea in water deeper than 200 m (Harrison 1977, Wiens et al. 1977). By April, most birds have moved to inshore waters around their respective colonies, and by May most are on colonies with few remaining at sea. While on the colonies birds feed over the continental shelf, seldom straying beyond (Harrison 1977, Gould 1977, 1978). Postbreeding dispersal usually occurs beginning mid-September. There is some indication that following breeding, birds immediately resume a pelagic existence and do not linger over inshore waters near the colonies. By November birds are seldom found over the continental shelf.

CONCLUSIONS

At present, the data do not exist to adequately depict the migrations of most marine birds in Alaska. Exceptions probably include some of the intensively hunted and managed species and populations of waterfowl. For most others, however, knowledge of that segment of their annual cycle between breeding seasons is incomplete. It is generally during this time, especially in fall, that many species of shorebirds and waterfowl become dependent upon coastal areas throughout Alaska for staging, molting and premigratory fattening.

From the available data, we have generalized timing and routes of migration for those species (alcids and seaducks) which have demonstrated a high susceptibility to oil contamination. In addition, we have discussed migration for species (shorebirds) which have, to date, shown little susceptibility to oil contamination but which depend on habitats most likely to be adversely affected by nearshore oil related impacts. Alteration of avian food resources in littoral areas, especially those used for staging and/or molting by waterfowl as well as shorebirds, could affect entire populations with, as yet, unknown consequences to the species' population as a whole.

The available data also indicate the importance, as major migration thoroughfares, of areas such as Cape Peirce and Unimak Pass. While much of the information presented in the species accounts is based on data collected from these two areas and consequently tends to highlight their importance to migratory birds, other similar key areas undoubtedly exist. Studies from such areas would greatly supplement the existing data and allow for a more complete understanding of the phenomenon of migration in Alaska.

As we now understand it, migration of most species occurs over and/or along inshore waters throughout coastal Alaska. This is especially true of scoters and eiders which, in addition, spend most of the winter on such waters. For most scoter and eider species, the southern Bering Sea and southern Bristol Bay are the most important wintering areas. The Steller's Eider is an exception since most winter along the southern Alaska Peninsula and around Kodiak Island. Minor numbers of King and Common Eiders and significant numbers of Black and White-winged Scoters winter in the Gulf of Alaska. The migrations of all of these seaducks generally take them along inshore waters where they occasionally congregate on lagoons and off the mouths of major drainages, especially along the north coast of the Alaska Peninsula. Northward migrations from the Peninsula are usually rapid and follow the coast or edge of shore-fast ice to Dall Point and Cape Prince of Wales where birds breeding in Siberia usually cross the Bering Strait. Fall migration often commences in early July for most adult males, followed by females and young through September. Most congregate again on lagoons to molt before moving to wintering areas, which are often along inshore waters adjacent or proximate to the molting area.

Shorebirds, generally, are quite restricted in their use of coastal areas in spring. However, for areas such as the Copper-Bering River Delta in the north Gulf of Alaska where almost the entire Alaska breeding population of certain species congregates each spring, a major oil spill affecting littoral areas could be devastating. Fall migration for most shorebirds is usually quite prolonged and involves considerable use of intertidal areas along western Alaska and Bristol Bay. Use of many of these areas is traditional for species such as Bar-tailed Godwits and Whimbrels, and often the majority of an entire breeding population occurs on a single area each fall.

The migrations of most alcids and cliff-nesters are poorly known, primarily because of their tendency to disperse randomly from colony areas following breeding. In light of OCS mineral exploitation, this tendency is probably beneficial to most populations in Alaska in that it reduces concentrations over shelf waters and the potential for a large segment of any one population to be affected by a major oil spill. These birds are probably most vulnerable during summer because of their association with and dependence upon inshore and nearshore waters around colonies. An exception, however, is cormorants, which rely heavily upon coastal waters during both summer and winter.

In synthesizing data for this report we found several areas of coastal Alaska from which little if any information on migration has been collected. Among these are almost all of SE Alaska, especially within the Alexander Archipelago; the southern Alaska Peninsula; the Aleutian Islands; eastern Bristol Bay; and segments of western coastal Alaska between major promontories. Many of these segments encompass several 100 km of coastline and include ideal locales from which to monitor migration. They also, undoubtedly, include critical molting and staging areas used during migration. Studies of these areas would significantly add to an understanding of the importance of coastal areas to migratory birds in Alaska.

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TABLE 1. Estimated Numbers of Seabirds Breeding Within OCS Regions in Alaska.

SPECIES	Region[1/]									
	GA	PWS	CI	KB	APS	AI	SBS	NBS	AO	TOTAL
Northern Fulmar	150	40		20	464,500	456,090	70,700	400,000		1,391,500
Fork-tailed Storm Petrel	92,700	5,000		300,000	152,300	901,000				1,451,000
Leach's Storm Petrel	729,400	400			13,600	1,100,200				1,843,600
Cormorant	112	790	672	9,167	18,872	87,048	2,503			119,164
Double-crested Cormorant	178	565	248	949	309		1,514			3,763
Pelagic Cormorant	4,940	257	1,262	3,900	511	18,366	16,050	50,789	366	96,441
Red-faced Cormorant	124	924	342	3,128	17,622	6,822	7,536			36,498
Harlequin Duck	22			75	74	288	185	298		942
Common Eider		250	1,203	2	487	351	155	10,036	78,042	90,526
Bald Eagle	46	20	18	54	52	59	4			253
Black Oystercatcher	116	51	37	459	145	41				849
Glaucous Gull								13,478	1,856	15,334
Glaucous-winged Gull	9,200	8,386	60,024	39,767	103,843	14,381	9,400	26		245,027
Mew Gull	125	149	60	1,411	300	10			20	2,075
Black-legged Kittiwake	100,594	76,350	31,357	160,671	499,739	89,104	484,310	314,863	44,055	1,801,043
Red-legged Kittiwake						16,322	222,200			238,522
Arctic Tern	1,392	2,182	86	5,819	1,020	669	500	14	621	12,303
Aleutian Tern	150			920	430	32	700	35	58	2,325
Murre	5,851			94,610	1,113,101	216,243	309,110	528,670	25,825	2,293,410
Common Murre	10,436	53,100	6,050	91,730	27,000	9,050	1,265,800	1,140,600	151,260	2,755,026
Thick-billed Murre				300	2,800	50,548	1,610,000	1,086,840	164,060	2,914,548
Black Guillemot								1	208	209
Pigeon Guillemot	977	1,312	67	1,866	22,966	6,901	1,591	4,509		40,189
Ancient Murrelet	60,000			2	35,500	120				95,622
Cassin's Auklet	67,740				23,000					90,740
Parakeet Auklet	426	999		1,356	86,610	60,134	186,485	180,160		516,170
Crested Auklet					42,550	218,118	34,100	756,540		1,051,308
Least Auklet					8	972,060	273,000	2,210,060		3,455,128
Whiskered Auklet						3,000				3,000
Rhinoceros Auklet	109,496			1,000	842					111,338
Horned Puffin	914	11,944	7,253	18,722	506,343	36,674	36,463	140,655	18,389	777,357
Tufted Puffin	95,742	60,640	15,886	401,145	1,095,642	218,564	94,410	16,346	97	1,998,472
other										
Total	1,290,831	1,223,359	124,565	1,137,073	4,230,166	4,482,195	4,626,716	6,853,920	484,857	23,453,682

1/Region: GA - Gulf of Alaska; PWS - Prince William Sound; CI - Cook Inlet; KB - Kodiak Basin; APS - Alaska Peninsula South; AI - Aleutian Islands; SBS - Southern Bering Sea; NBS - Northern Bering Sea; AO - Arctic Ocean.

Numbers taken from: Sowls, A. L., *et al*. (in press). Catalog of Alaskan Seabird Colonies. USFWS, Office of Biological Services, Coastal Ecosystems, Alaska.

Table 2. Seasonal occurrence of selected species of marine birds within OCS regions in Alaska.

SPECIES	SEASONAL OCCURRENCE BY REGION 1/								
	CA	PWS	CI	KB	APS	AI	SBS	NBS	AO
Northern Fulmar	S S F W	- - - -	- - - -	S S F W	S S F W	S S F W	s S F w	s S f -	s s f -
Shearwaters	S S F -	- - - -	- s f -	S S F -	S S F -	s S F -	s S F -	- s F -	- s f -
Pelagic Cormorant	S S F W	S S F W	s s f w	S S F W	S S F W	s s f w	S S F W	s s f -	- - f -
Black Brant	s - - -	s - - -	s - - -	s - - -	S - F -	- - - -	S - F -	S S F -	s s f -
Emperor Goose	- - - -	- - - -	- - - -	s - f w	S - F W	S - F W	S S F W	S S F -	s s f -
Oldsquaw	s s f w	s s f w	s s f W	s - f W	s - f W	s s f W	S S F W	S S F w	S S F -
Steller's Eider	- - - -	- - - -	- - - w	s - f W	S s F W	s - f w	S s F W	S S F -	s S f -
Common Eider	- - - -	- - - -	s s f w	s s f w	s s f w	s s f W	S S F W	S S F w	S S F -
King Eider	- - - w	- - - w	- - - w	s - f w	s - f W	s - f W	S s F W	S S F w	S S F -
White-winged Scoter	S S F W	S S F W	S - F W	S - F W	S - F W	s - f W	s - f -	- - - -	- - - -
Black Scoter	s - f w	s - f w	s s f w	s - f w	s - f w	s - f w	S S F W	s S f -	- - - -
Dunlin	S s F w	S s F w	s s f w	- - - -	- - f -	- - f -	s S F -	S S F -	S S F -
Western Sandpiper	S S f -	S S f -	S s f -	- s f -	s s f -	- - - -	- S f -	S S - -	- - - -
Glaucous-winged Gull	S S F W	S S F W	s s f w	S S F W	S S F W	S S F W	S S F W	S S F -	- - - -
Black-legged Kittiwake	S S F W	S S F W	s s f w	S S F W	S S F W	S S F W	S S F W	S S F -	s s f -
Arctic Tern	S S f -	S S - -	s s - -	S S f -	S S f -	s s - -	s s f -	s s - -	- s - -
Aleutian Tern	s s - -	s s - -	s s - -	S S f -	S S f -	s s - -	s s - -	s s - -	- s - -
Murres	s s f W	s s f w	s s f w	s s f W	s S f W	s s f w	S S F W	s S f w	s s f -
Pigeon Guillemot	s s f w	s s f w	s s f w	s s f w	S S F W	S S F W	s s f w	s s f -	- - - -
Parakeet Auklet	s s f w	s s f -	s s f -	s s f w	S S F w	S S F w	S S F w	S S F -	- - f -
Crested Auklet	- - - -	- - - -	- - - -	- - F W	S S F W	S S F W	S S F W	S S F -	- - f -
Least Auklet	- - - -	- - - -	- - - -	- - - -	s s f w	S S F W	S S F W	S S F -	- - f -
Horned Puffin	s s f w	s s f -	s s f -	s s f w	S S F w	s s f w	s s f w	S S F -	s s f -
Tufted Puffin	s s f W	s s f -	s s f -	S S F W	S S F W	S S F w	S S F -	s s f -	s s f -

1/ Region: GA - Gulf of Alaska; PWS - Prince William Sound; CI - Cook Inlet; KB - Kodiak Basin; APS - Alaska Peninsula South; AI - Aleutian Islands; SBS - Southern Bering Sea; NBS - Northern Bering Sea; AO - Arctic Ocean.

Season: S - Spring (March - May); S - Summer (June - August); F - Fall (September - November); W - Winter (December - February).

Abundance: Capital letter - major abundance; small letter - minor abundance; dash - absence or uncommon occurrence.

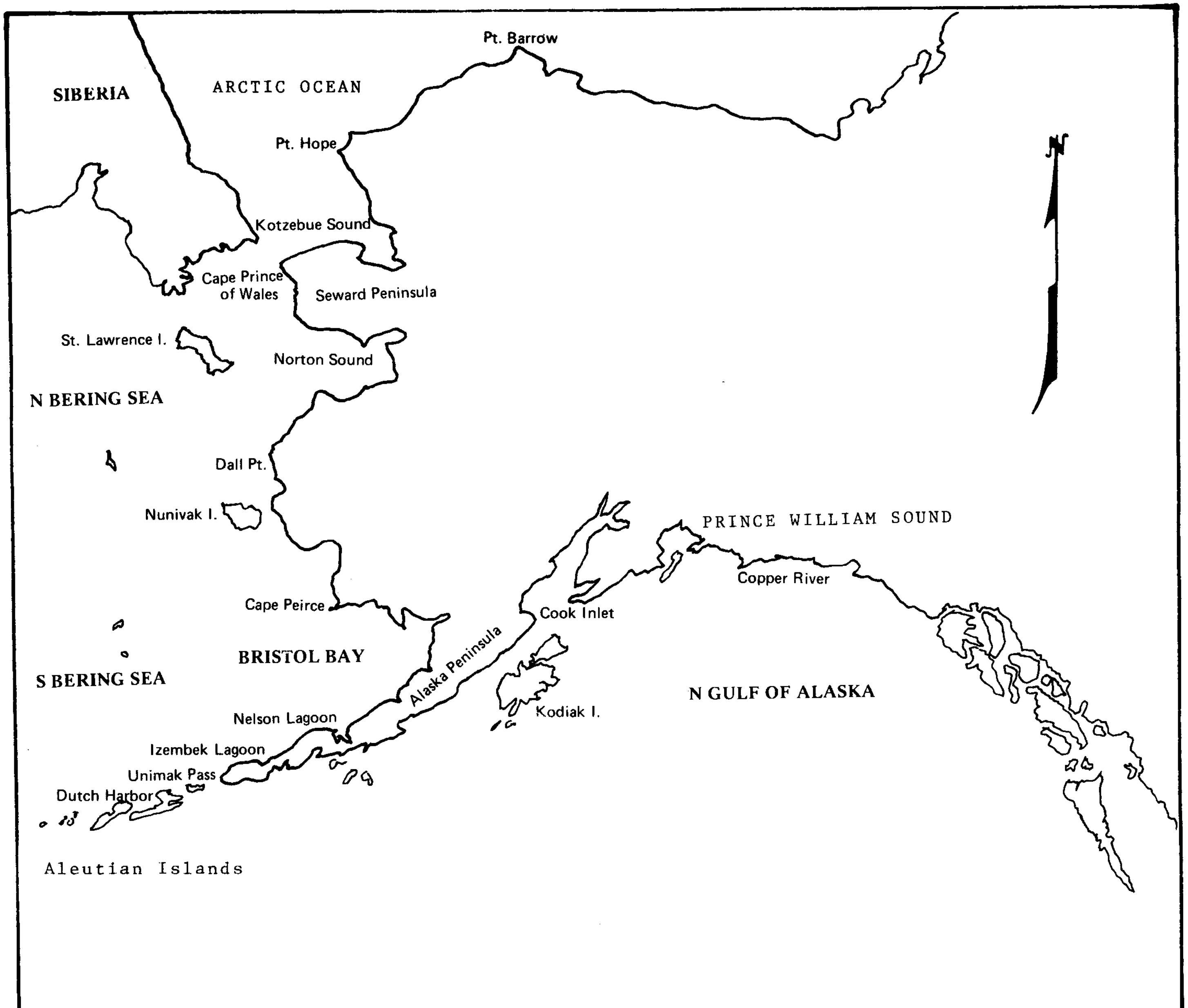


FIGURE I. THE STUDY AREA SHOWING REGIONS OF THE CONTINENTAL SHELF OF ALASKA.

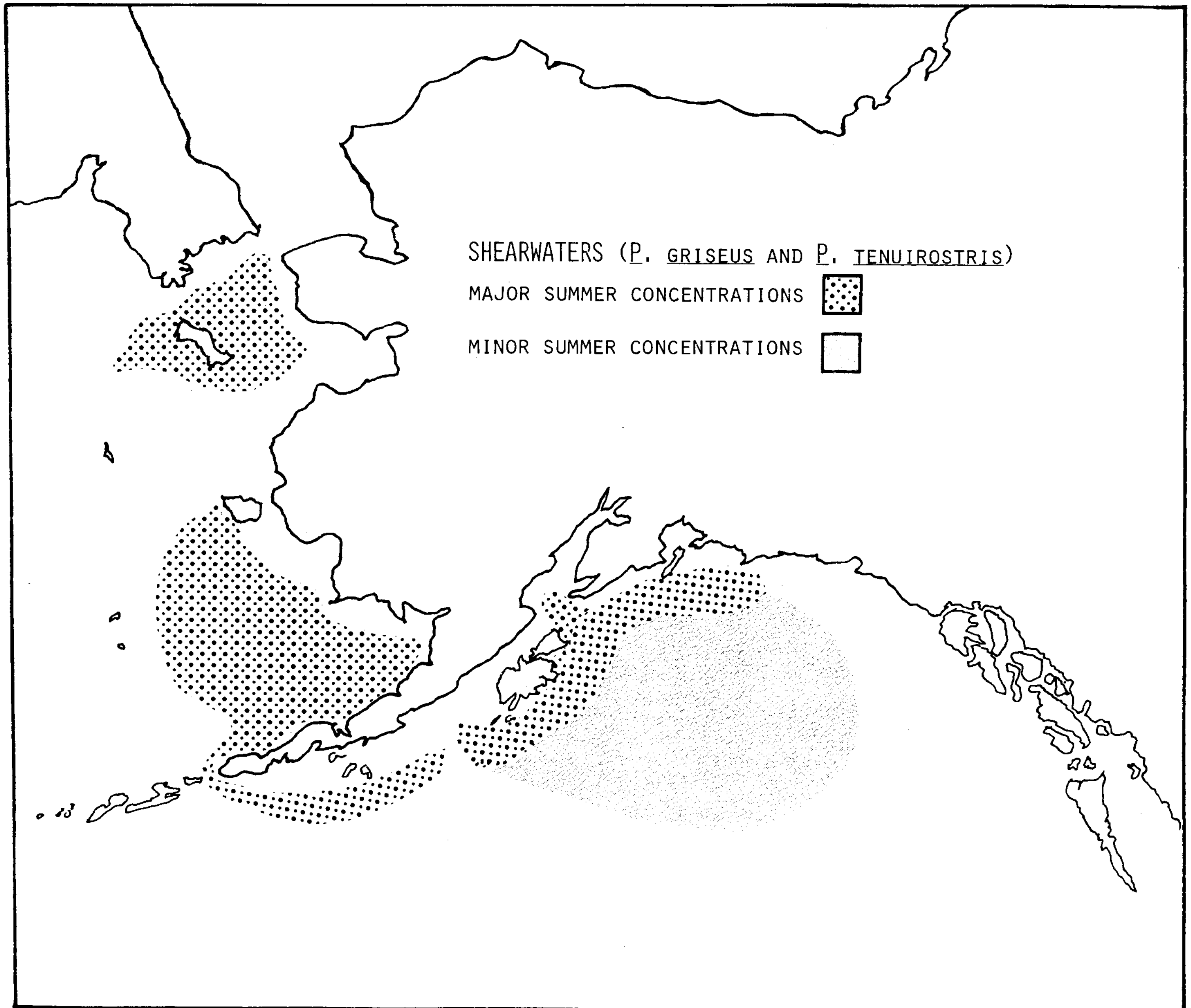


FIGURE 2. THE DISTRIBUTION OF SHEARWATERS IN ALASKA WATERS DURING SUMMER.

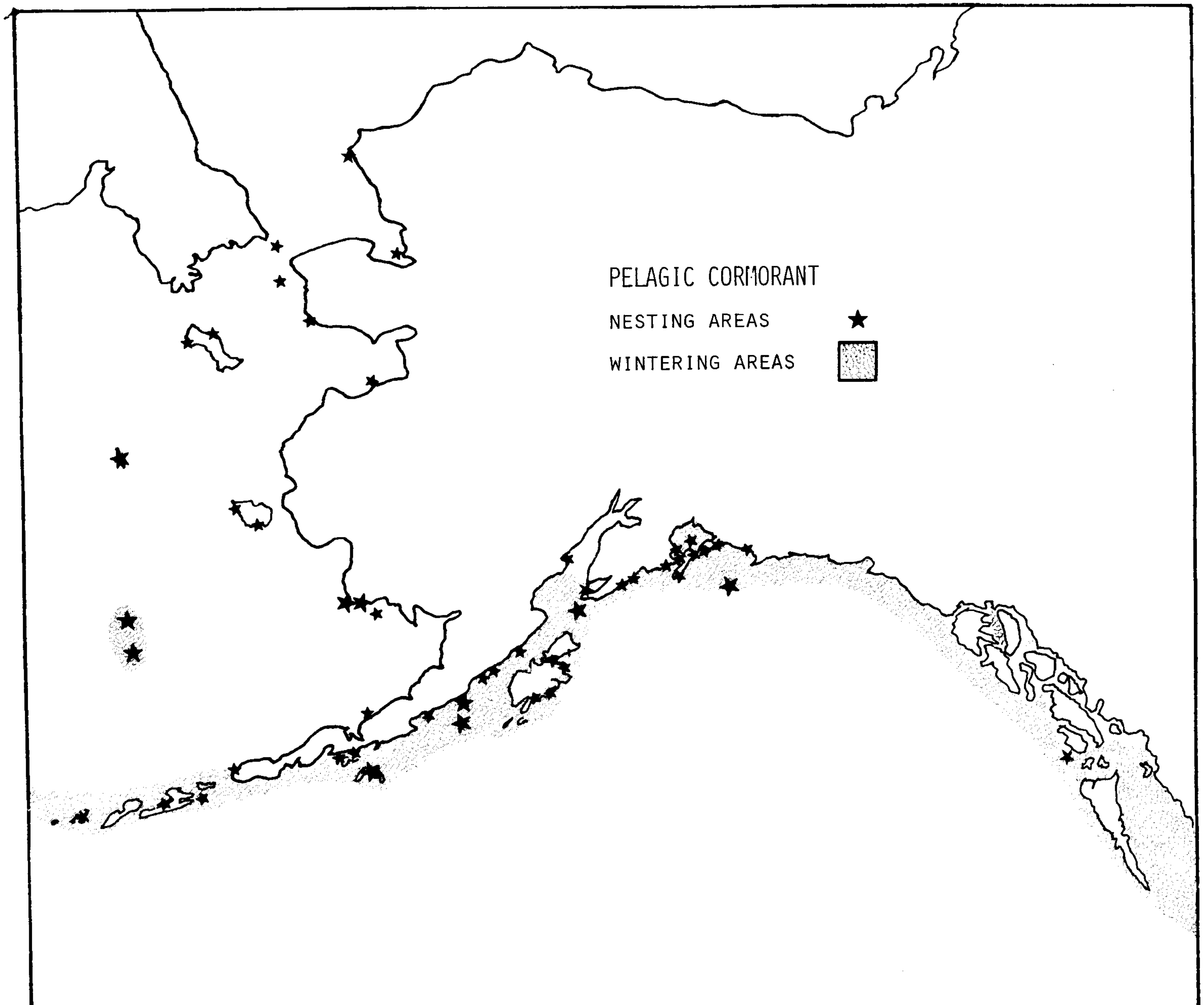


FIGURE 3. BREEDING AND WINTER DISTRIBUTION OF PELAGIC CORMORANTS IN ALASKA.

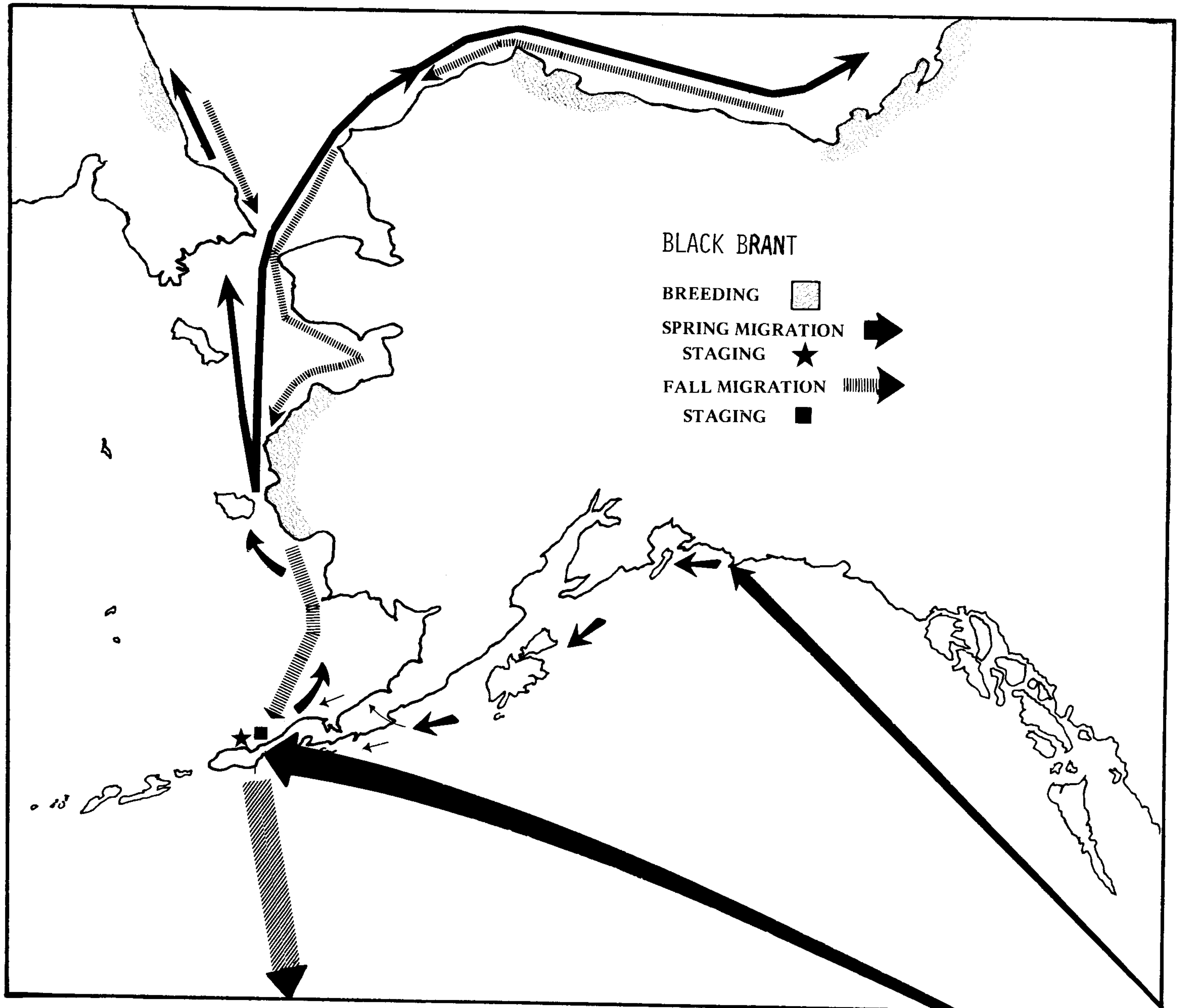


FIGURE 4. THE MIGRATIONS OF BLACK BRANT IN ALASKA.

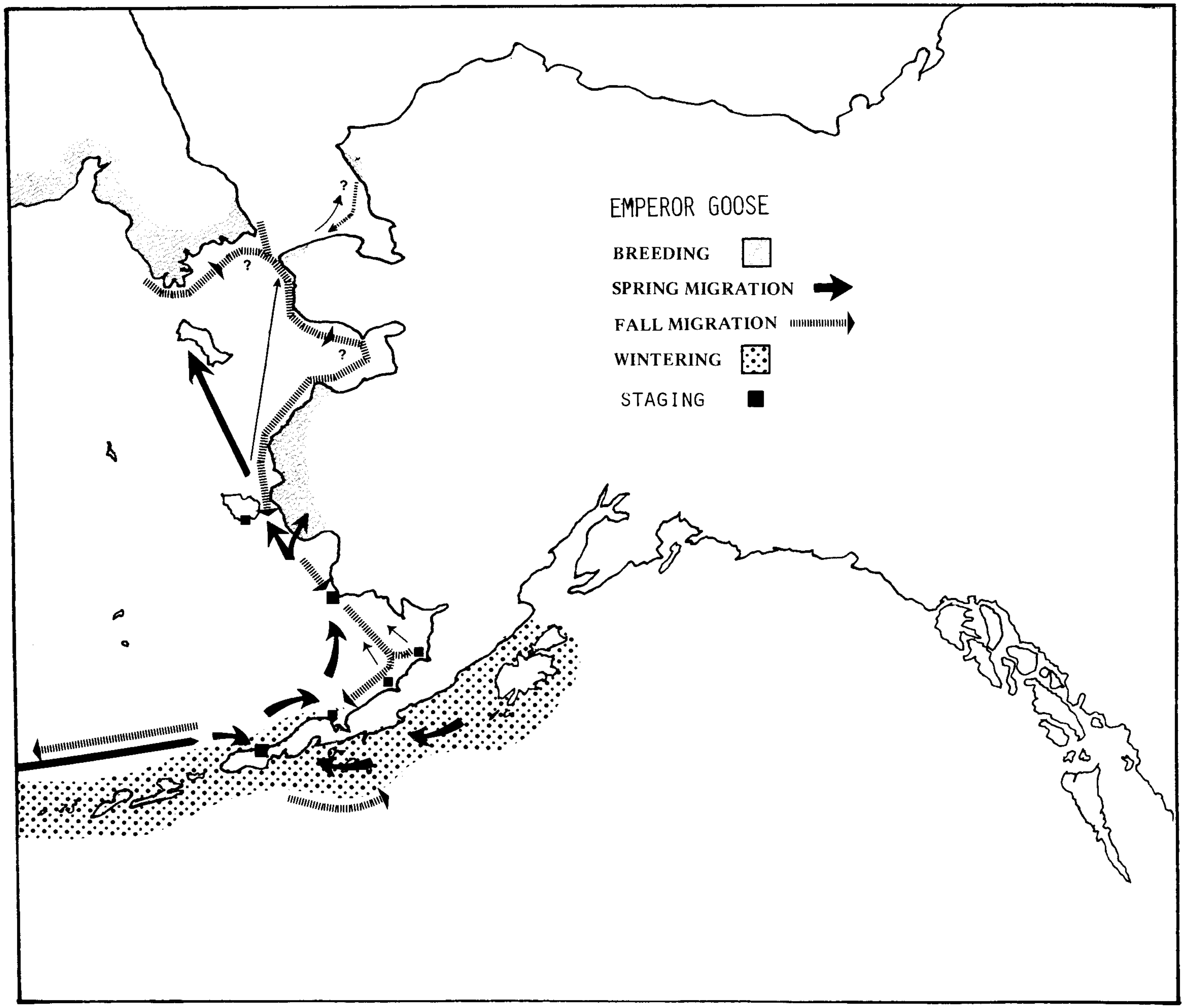
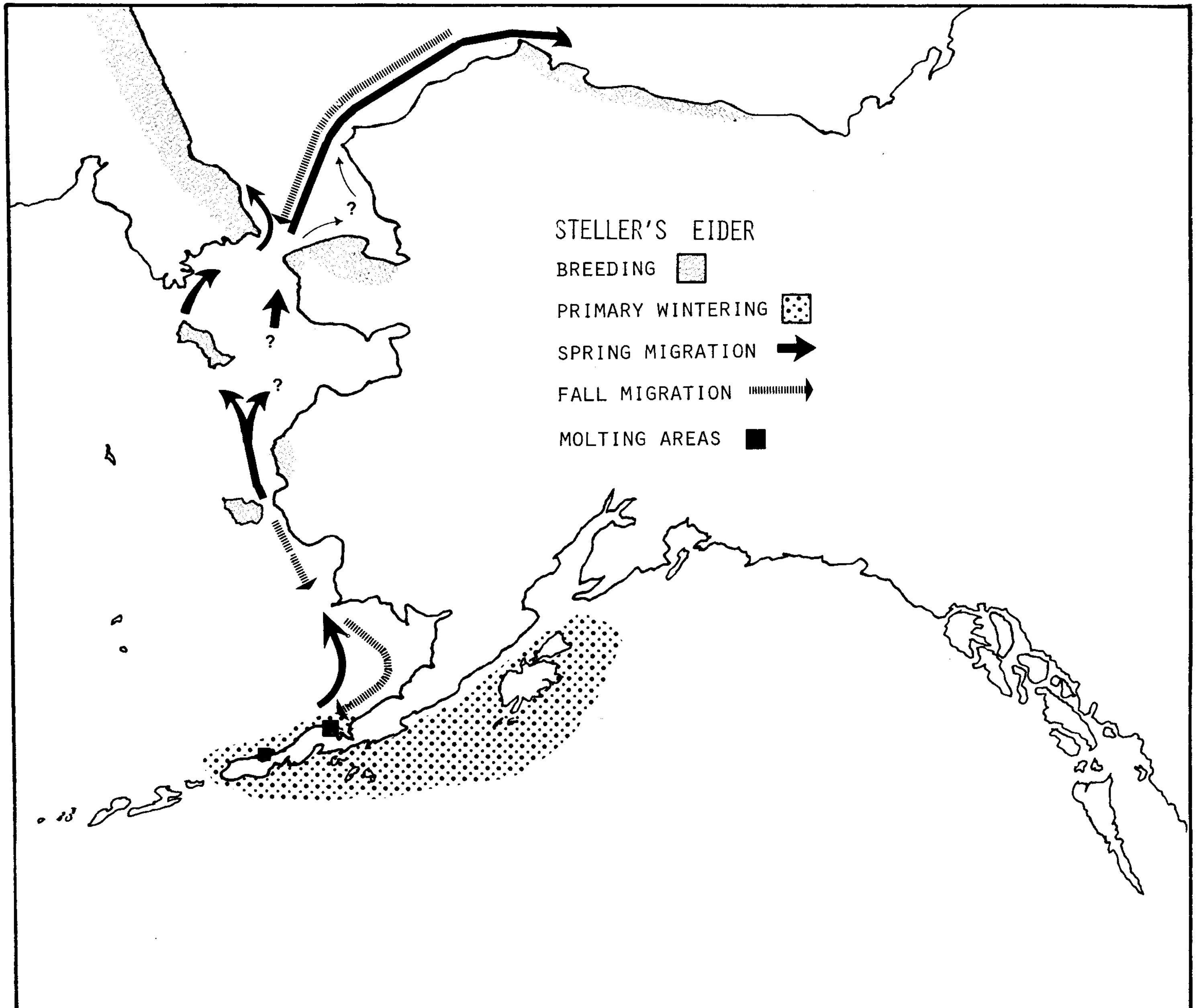


FIGURE 5. THE MIGRATIONS OF EMPEROR GEESE IN ALASKA.



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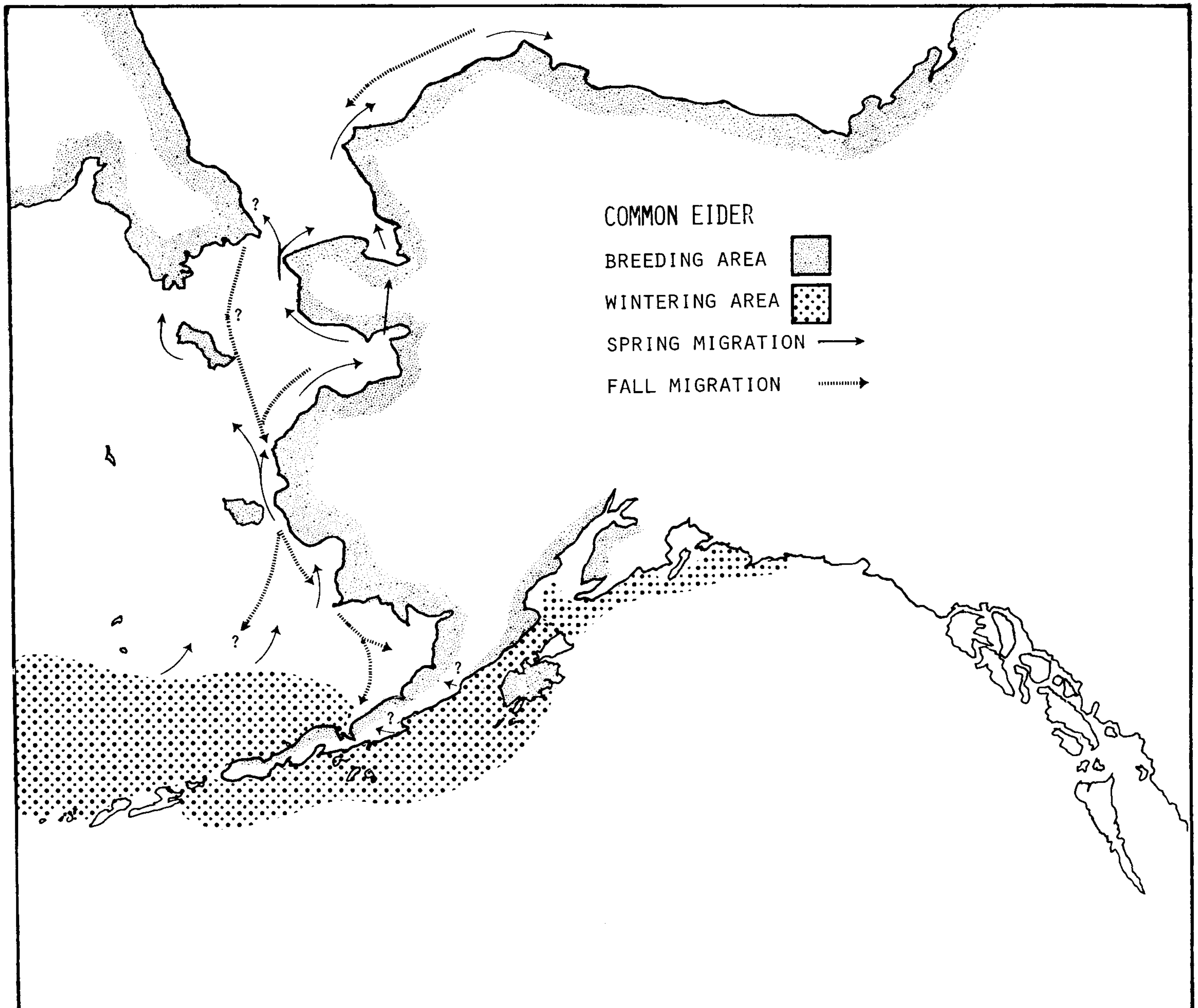

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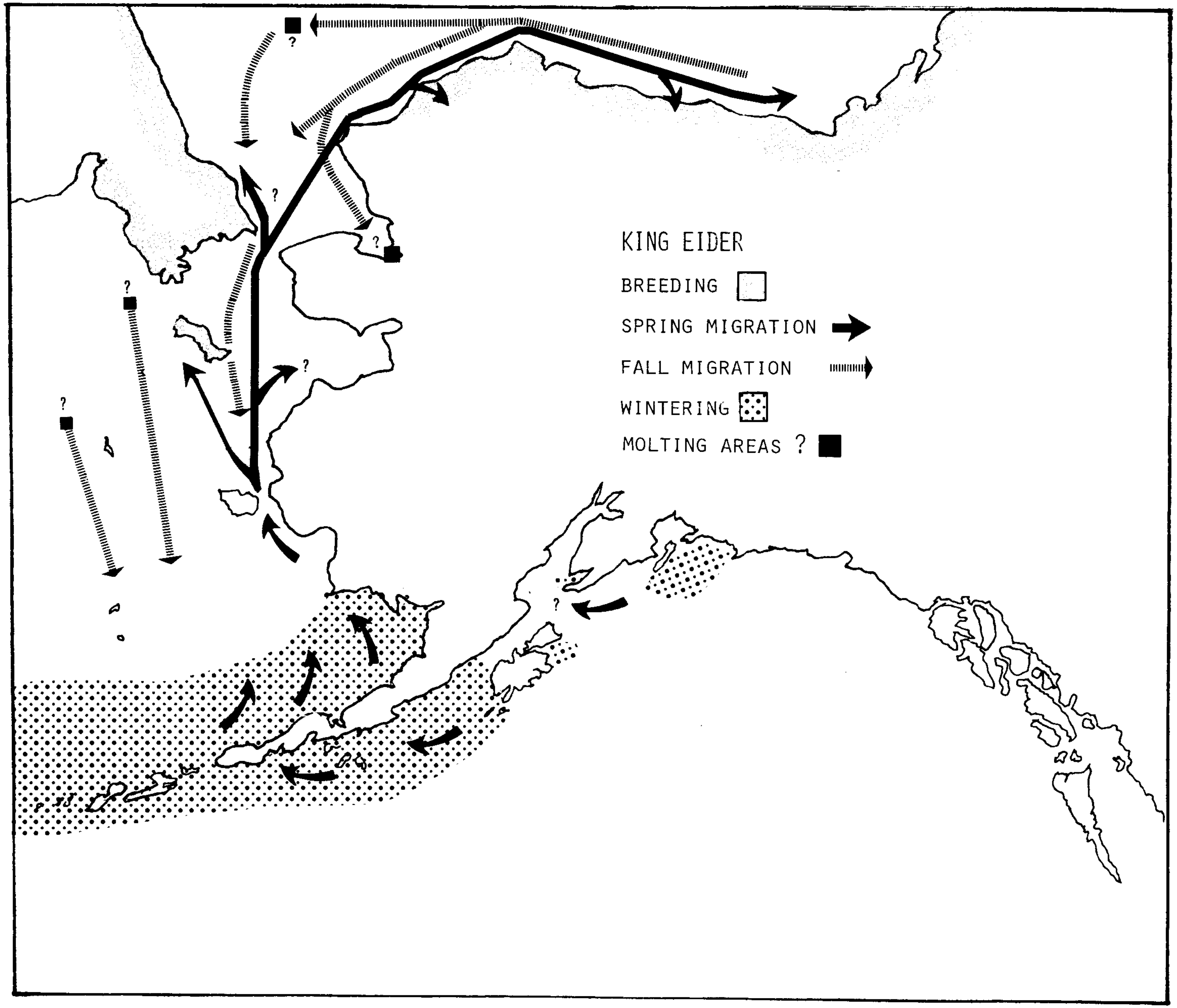

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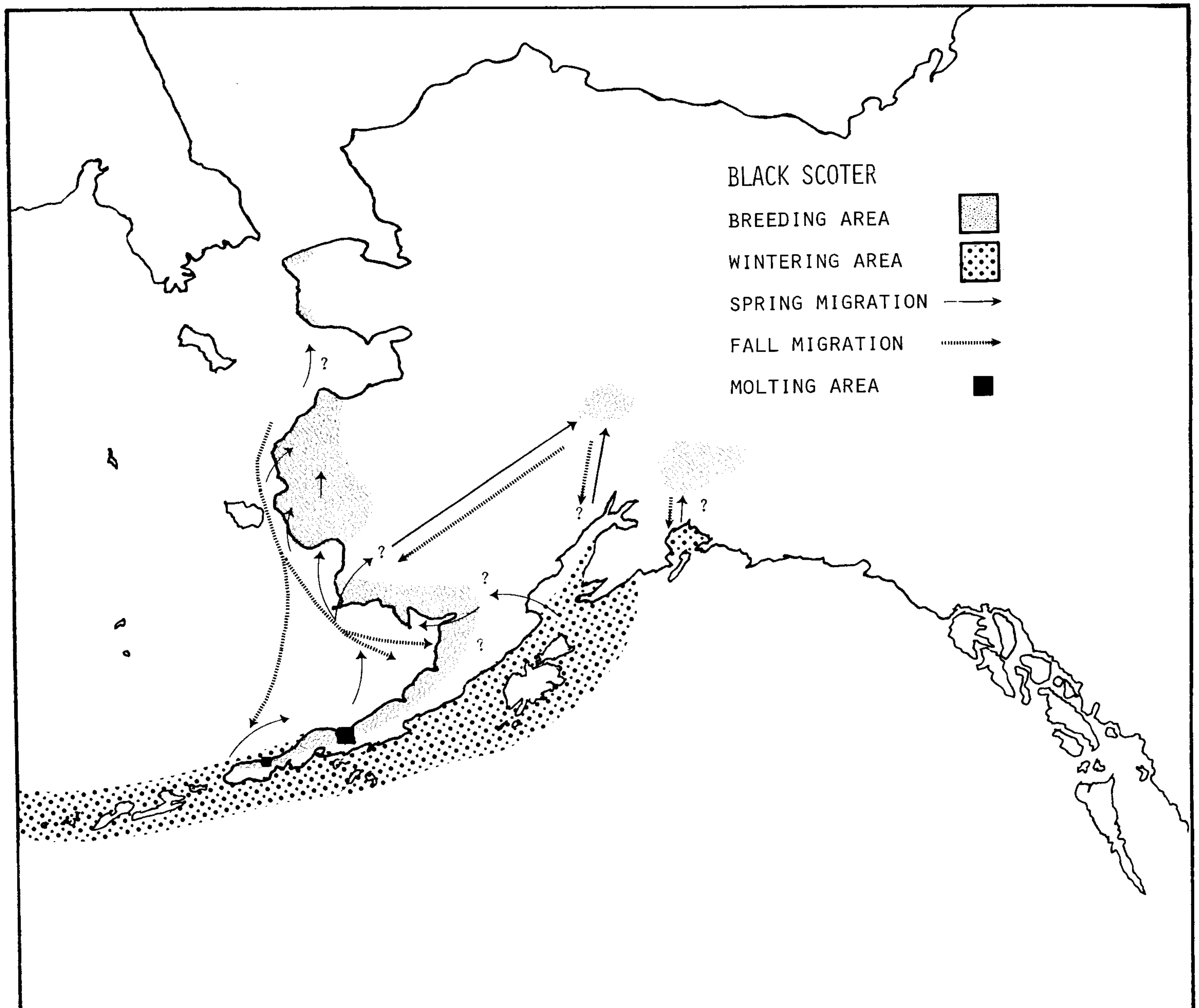

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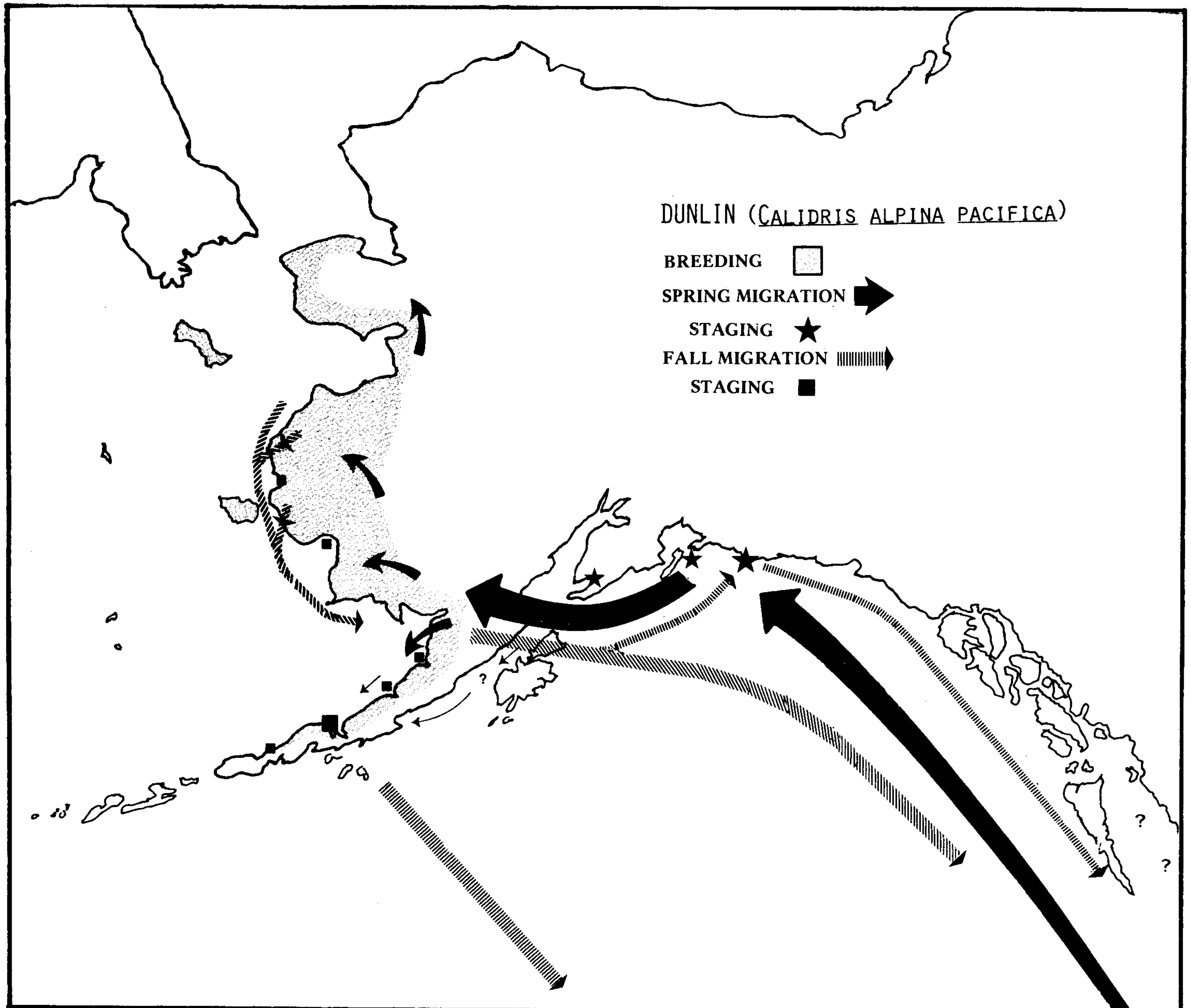

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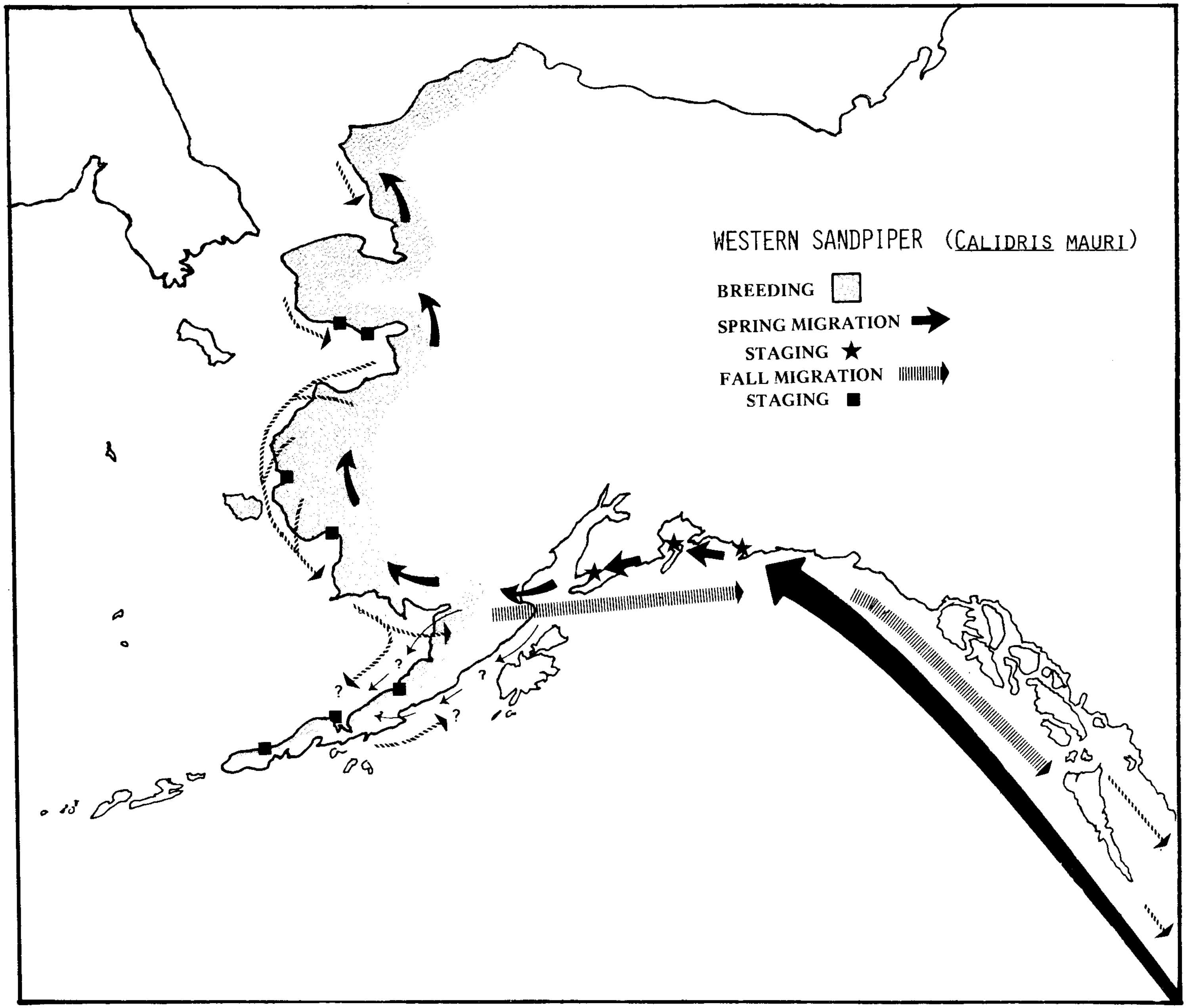

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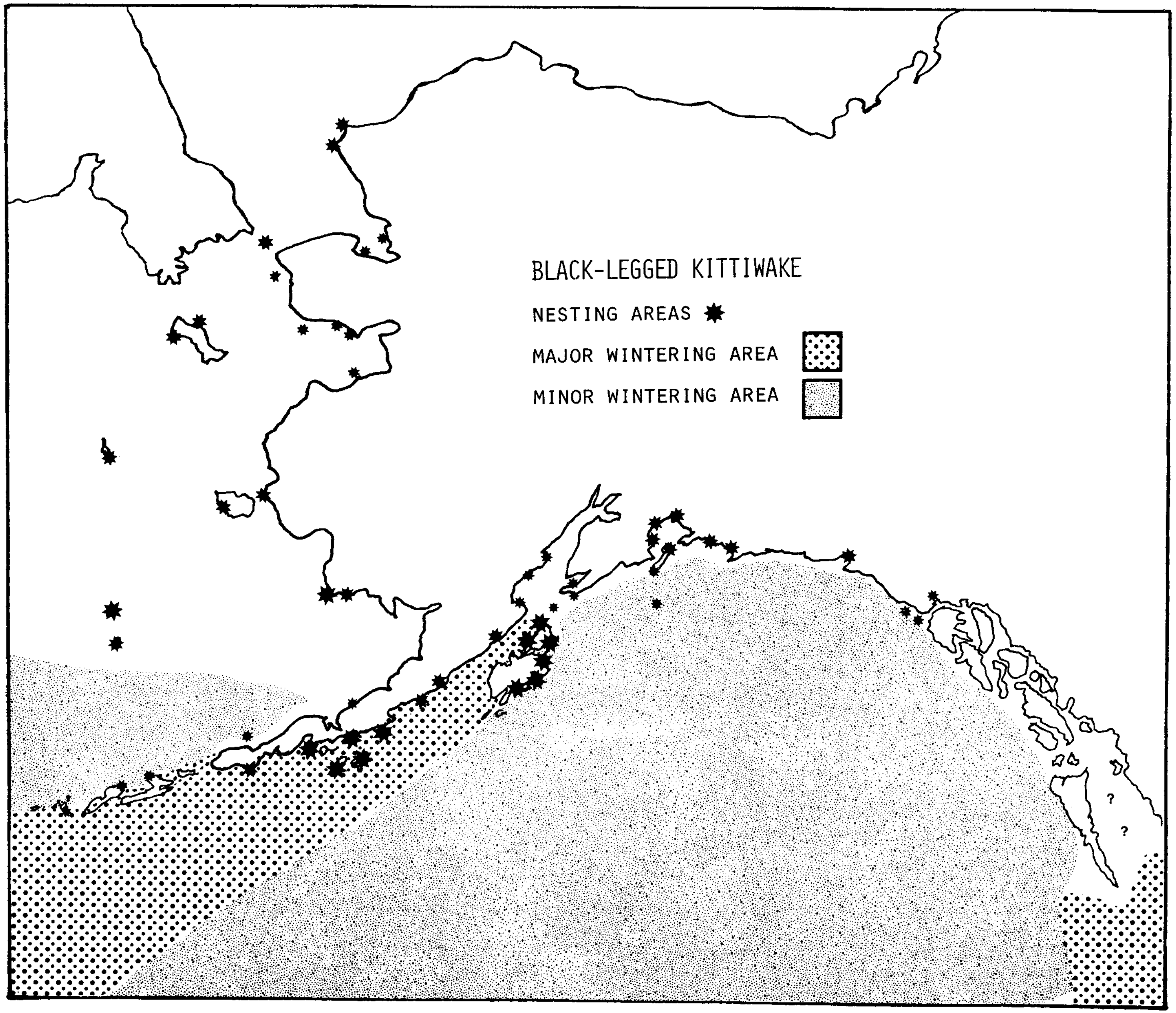

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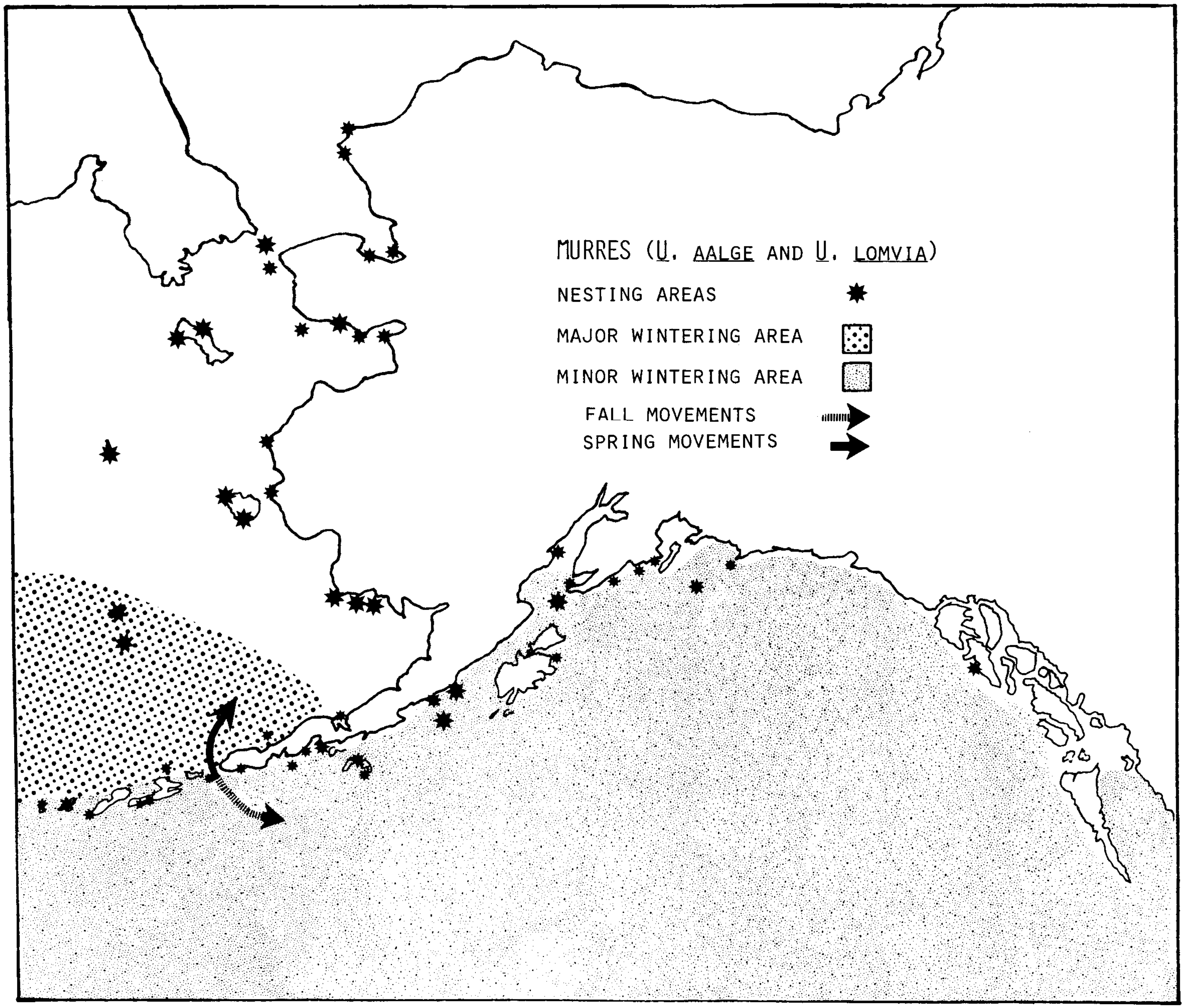

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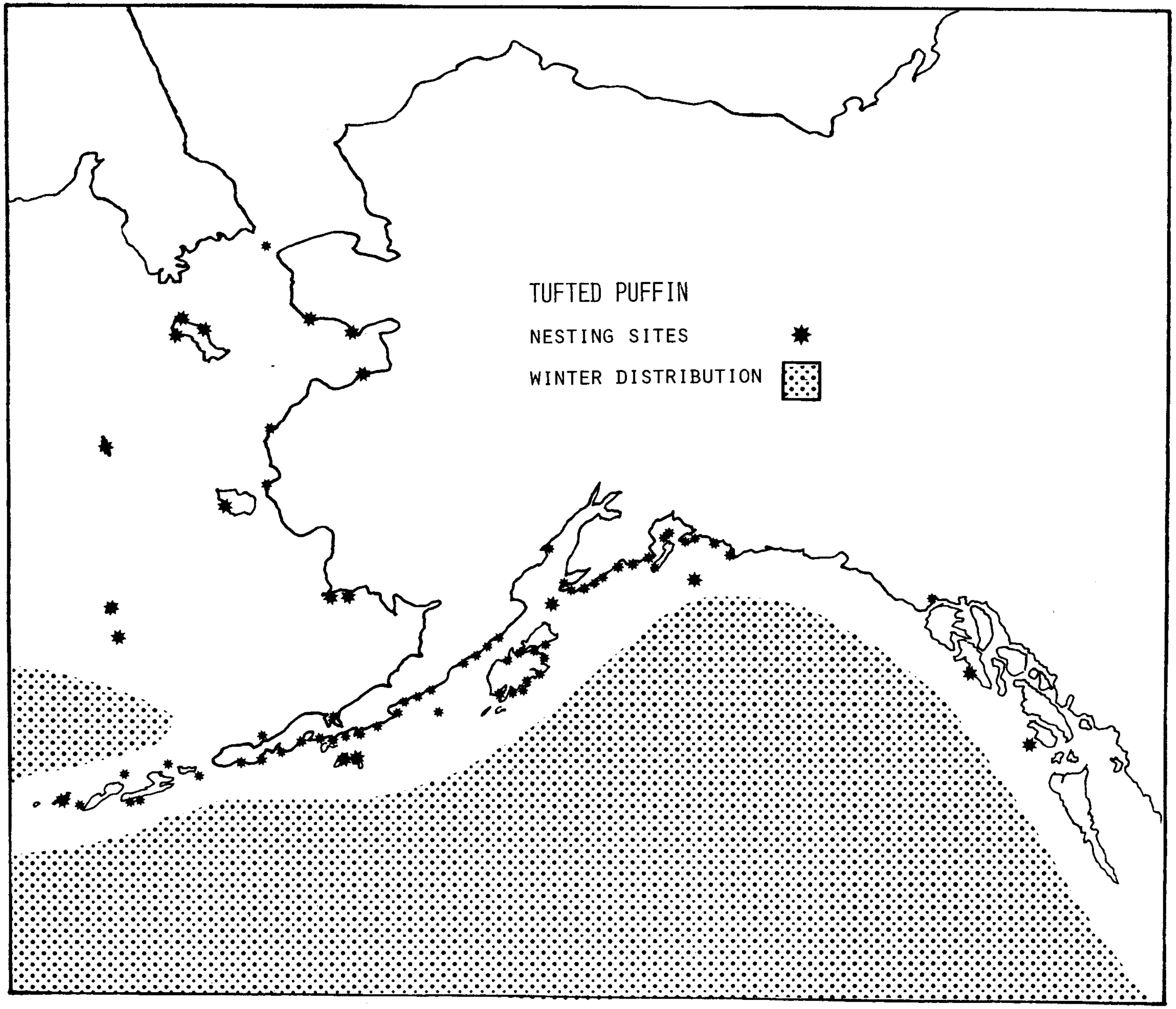

FIGURE 14. THE BREEDING AND WINTER DISTRIBUTION OF TUFTED PUFFINS IN ALASKA.

FINAL REPORT

Contract #03-5-022--56
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Avian Community Ecology at Two Sites on Espenberg Peninsula in Kotzebue Sound, Alaska

Principal Investigator: P. G. Mickelson

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Fairbanks, Alaska 99701

30 September 1978

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ACKNOWLEDGEMENTS

We thank the NANA Corporation for permitting us to spend three beautiful summers on Cape Espenberg. Our neighbors, the Fred Goodhope family of Espenberg, were particularly helpful and friendly. Logistical support and aerial survey work were chartered through Maxson Aviation, Kotzebue, Alaska. Their flight service was excellent and unanticipated mail stops were greatly appreciated. Steve Long served as our field assistant for two summers; Dena Matkin worked with us for one summer. Without their dedicated assistance, our data would have been far less complete. John Wright kindly provided comparative data and split air charters with us. The Frank M. Chapman Memorial Fund provided partial financial assistance for our return visit to the Cape in 1978. The personnel of the OCS Arctic Project Office, especially Dave Norton, Ted Fleischer, and Dave Kennedy, gave us frequent and much appreciated assistance and encouragement when problems arose. Mary Kunz and Theresa Gilstrap took on the immense task of typing this report and we are very grateful for their efforts. Finally, we thank Brina Kessel and Dan Gibson for suggesting Cape Espenberg as a study site.

I. SUMMARY OF OBJECTIVES, CONCLUSIONS, AND IMPLICATIONS WITH RESPECT TO OCS OIL AND GAS DEVELOPMENT

Cape Espenberg is a 1.5 km wide peninsula, jutting 13 km into the western edge of Kotzebue Sound in western Alaska. It is comprised of a series of sand dune ridges, interspersed with numerous ponds and marshes. Prevailing winds are westerly during summer and currents, which sweep nearshore at Espenberg, come from the west. Thus, large oil spills on Chukchi Sea waters north of the Bering Strait to Kotzebue Sound are likely to be deposited on the beaches of Cape Espenberg.

The main objectives of this study are to: 1) determine the seasonal abundance and habitat use by birds on the Cape, 2) determine the productivity of birds on the Cape, 3) determine the availability and use of some avian foods, especially marine invertebrates, 4) determine the seasonal abundance and distribution of birds along coastal southern Kotzebue Sound and the importance of the Cape to the birds of this entire area, 5) determine the use of the Cape by sea mammals, and 6) establish guidelines for future biological monitoring.

During 1976 and 1977, 85 species of birds were recorded on the Cape. Six species, Pintail, Common Eider, Dunlin, Semipalmated Sandpiper, Western Sandpiper, and Northern Phalarope, could be found in numbers in the thousands at any one time. Most of the species used marine habitats at some time during the summer, and many used these habitats extensively. The mudflats attracted the densest concentrations of staging and migrant birds. Beginning in late July, thousands of ducks and shorebirds congregated on the mudflats to feed. Migrant shorebirds were still abundant in late September.

The mosaic marsh of Cape Espenberg provides ideal nesting habitat for large concentrations of waterbirds. Although small in total area (22.1 km^2), the Cape supports several hundred each of nesting loons, larids and songbirds, and several thousand each of nesting ducks and shorebirds. An estimated 14,000-16,000 chicks were produced here each summer. During our flights along 221 km of coastal southern Kotzebue Sound, we saw no marsh areas comparable in area or quality to that of Cape Espenberg.

Predation was the most important factor influencing avian production on Cape Espenberg. Red Foxes (1976) and Arctic Foxes (1977) were the most important predators. They destroyed a large percentage of waterfowl nests in the two years when they were common. Glaucous Gulls and Parasitic Jaegers took a smaller percentage of eggs and young. Arctic Ground Squirrel populations were high enough each year to serve as a partial buffer to fox predation on birds. However, microtine populations were low in 1976 and virtually non-existent in 1977. The dense concentrations of waterfowl nests probably provide a buffer to predation of shorebird eggs. Renesting also appeared important in reducing the effects of predation.

Although some subsistence activities by Natives currently take place on the Cape, the affects on the local breeding population of birds are minimal. We documented losses of eggs and young birds to trampling by reindeer. Losses were small, primarily because reindeer did not arrive until the end of the incubation period.

Each summer at Cape Espenberg was phenologically different: 1976 was late, 1977 was normal, and 1978 was early. These differences affected avian production primarily by changing the length of the nesting period. In 1976, the nesting period was abbreviated and renesting attempts were limited; renesting was much more prevalent in 1977 and 1978. Clutch sizes were little affected by phenological differences.

Most young birds were raised in the marsh. However, Common Eider and Emperor Goose broods moved to marine environments almost immediately after hatching. Here they fed in the shallows, sloughs, and mudflats.

Invertebrate species diversity in the intertidal zone on Cape Espenberg was low (19 species). Even so, these organisms were often abundant enough to be extremely important food items for birds. Intertidal invertebrates were most abundant in the chemically reduced muds in the western and southern sections of Espenberg Bay. At low tide, the greatest biomass was found at the water's edge. Inter-year variation in waterbird food items was significant. Seasonal sampling indicated rapid growth in juvenile amphipods and isopods. The clam population within the sampling area changed drastically from 1976 to 1977.

Of the 34 nesting species on the Cape, 13 species were very dependent on marine food sources during part or all of the nesting and brood rearing period, while 16 other nesting species used marine food sources at least occasionally during this period. In addition, thousands of staging and migrant ducks and shorebirds fed on marine invertebrates on the mudflats. These birds fed primarily upon small clams (Mollusca:Pelecypods), isopods (Arthropoda:Crustacea), and shoreflies (Arthropoda:Insecta:Diptera). The importance of these food items varied between years, dependant upon abundance.

We located several sections of coastline in southern Kotzebue Sound that support large concentrations of birds (>30 birds/linear km): Cape Deceit, Sullivan Bluffs, Nugnugaluktuk/Pish River Delta, Kiwalik Lagoon, coastal section "C", and Espenberg Bay. Birds numbers along southern Kotzebue Sound peaked during September in 1977.

We did not observe marine mammals hauling out on the beaches of the Cape. During the breakup of the sea ice as many as hundreds of seals were observed resting on the ice within a kilometer of the Cape. A few seals were observed swimming in the nearshore waters throughout the summer. They may congregate off the tip of the Cape in the fall.

Oil contamination of nearshore waters poses a threat to bird populations throughout the summer. Oil in leads in the ice may affect spring migrants which often concentrate in the limited open water of leads. Numerous birds rely upon marine organisms throughout the summer and would be subjected to oil contamination while foraging at sea. Beginning in July, post-breeding shorebirds concentrate on mudflats prior to or during migration. They are susceptible to oiling from July through September. Birds may also be indirectly, but profoundly, affected by oil contamination through the loss of food resources.

The beach of Cape Espenberg is a likely site of sand extraction for petroleum development-related activities. Such an activity during summer may produce sufficient turbidity to lower the feeding efficiency of birds around the site, as well as downcurrent. Concomitant noise may lower the productivity of some nesting birds, although this subject is poorly understood. More importantly, sand extraction may endanger the integrity of the cape, through subsequent erosion of the dunes, and jeopardize marsh habitat.

We have begun baseline monitoring of breeding and migrant bird populations, avian productivity, the occurrence of beached birds and mammals, and the abundance and distribution of intertidal invertebrates.

II. INTRODUCTION

Justification

Cape Espenberg was chosen as our study area primarily for two reasons. First, it is highly susceptible to oil spills. Currents sweep easterly along the outside coast and especially at the Cape. Prevailing winds come onshore from across open waters of the Chukchi Sea during July through September. Thus large oil spills on Chukchi Sea waters north of Bering Strait to Kotzebue Sound most likely will be deposited along the beach of Cape Espenberg. Second, Cape Espenberg hosts a large variety of breeding and staging birds. Especially high nesting densities of Red-throated Loons, Common Eiders, Glaucous Gulls, Semipalmated Sandpipers, Dunlins, Northern Phalaropes, and Lapland Longspurs were reported by Kessel and Gibson (1974).

For these reasons, we set out to determine 1) distribution, abundance, and habitat utilization of nesting, molting, rearing and migrating birds; and 2) factors affecting the distribution and abundance of birds--especially phenology, predators, and food availability in the intertidal mudflats. Furthermore, through an extensive banding program and intensive observation of several nesting species, we wanted to gather information on the breeding ecology of several key species. We hoped that recaptures of banded juvenile birds would permit determination of growth rate, and reveal fidelity to Cape Espenberg.

Objectives

1. To determine phenology of events from spring arrival through departure of birds,
2. to determine the distribution and abundance of birds and their predators,
3. to describe habitat utilization of birds and their predators during migration, the nesting season, and the brood rearing season,
4. to estimate production of all avian species nesting on Cape Espenberg and to evaluate factors affecting production,
5. to determine the abundance of small mammals which are utilized by avian and mammalian predators,
6. to describe availability of food and utilization by shorebirds,
7. to determine distribution and abundance of sea mammals,
8. to provide recommendations to lesson the impact of developments on the avian community and avian habitat at Cape Espenberg,

9. to establish baseline study plots to evaluate the impact of developments on the avian community and avian habitat at Cape Espenberg, and
10. to assess bird use of coastal habitats in southern Kotzebue Sound by flying aerial surveys at regular intervals.

Relevance to Problems of Petroleum Development

This study will provide baseline data on bird numbers and seasonal habitat use patterns. We also determined nesting densities, nesting success, and clutch size for the most common species. In addition, we were able to evaluate habitat use and bird numbers along coastal southern Kotzebue Sound. These data have shown us that Espenberg is atypically rich in nesting waterbirds and that most of these birds depend upon the marine environment at some time during the breeding season. Food studies suggest that some birds forage on whatever invertebrates are abundant in the nearshore waters and that their reproductive success may be closely tied to the productivity of those waters. Perturbations that lower the densities of marine prey items may directly and adversely affect avian productivity.

III. CURRENT STATE OF KNOWLEDGE

The current state of knowledge of bird numbers and distribution along coastal Seward Peninsula is limited. Data comparable to those we collected in 1976, 1977, and (to a limited extent) 1978 at Cape Espenberg are available from Norton Bay (Shields and Peyton 1978), Wales (Connors 1978), and Shishmaref Inlet (Noble and Wright 1977). Connors (1978) also conducted studies at Cape Krusenstern and Barrow. Comparative data on nesting shorebirds and passerines from Cape Thompson are available from Williamson et al. (1966). Data on birds (Kessel and Gibson 1974) and mammals (Melchior 1974) were collected on Cape Espenberg during two brief visits by biologists contracted by the National Park Service in 1973.

Prior to OCSEAP-sponsored studies on the Seward Peninsula, beginning in 1976, information on concentrations of coastally nesting and post-breeding waterbirds was virtually non-existent. We now have a much better feel for important sections of the coast. Data collected during the course of these studies clearly demonstrate that a very high percentage of the bird species of the area use marine habitats, at least occasionally.

IV. STUDY AREA

The Espenberg Peninsula lies 60 km southwest of Kotzebue, Alaska (Fig. 1). Our study area was confined mainly to Cape Espenberg, which is a 1.5 km wide peninsula jutting 13 km into the western edge of Kotzebue Sound. Cape Espenberg is a series of sand dune beach ridges interspersed with numerous ponds and marsh and tussock habitat (Fig. 2).

The vegetation of the Cape has been characterized as "coastal meadows-dwarf shrub tundra mosaic" by Anderson et al. (1974). The sand dunes are colonized first by *Elymus arenarius* (plant names according to Hulten 1968) and *Honckenya peploides*. Mid-successional species on dune ridges include: *Potentilla villosa*, *Lathyrus maritimus*, *Calamagrostis purpurascens*, *Stellaria*

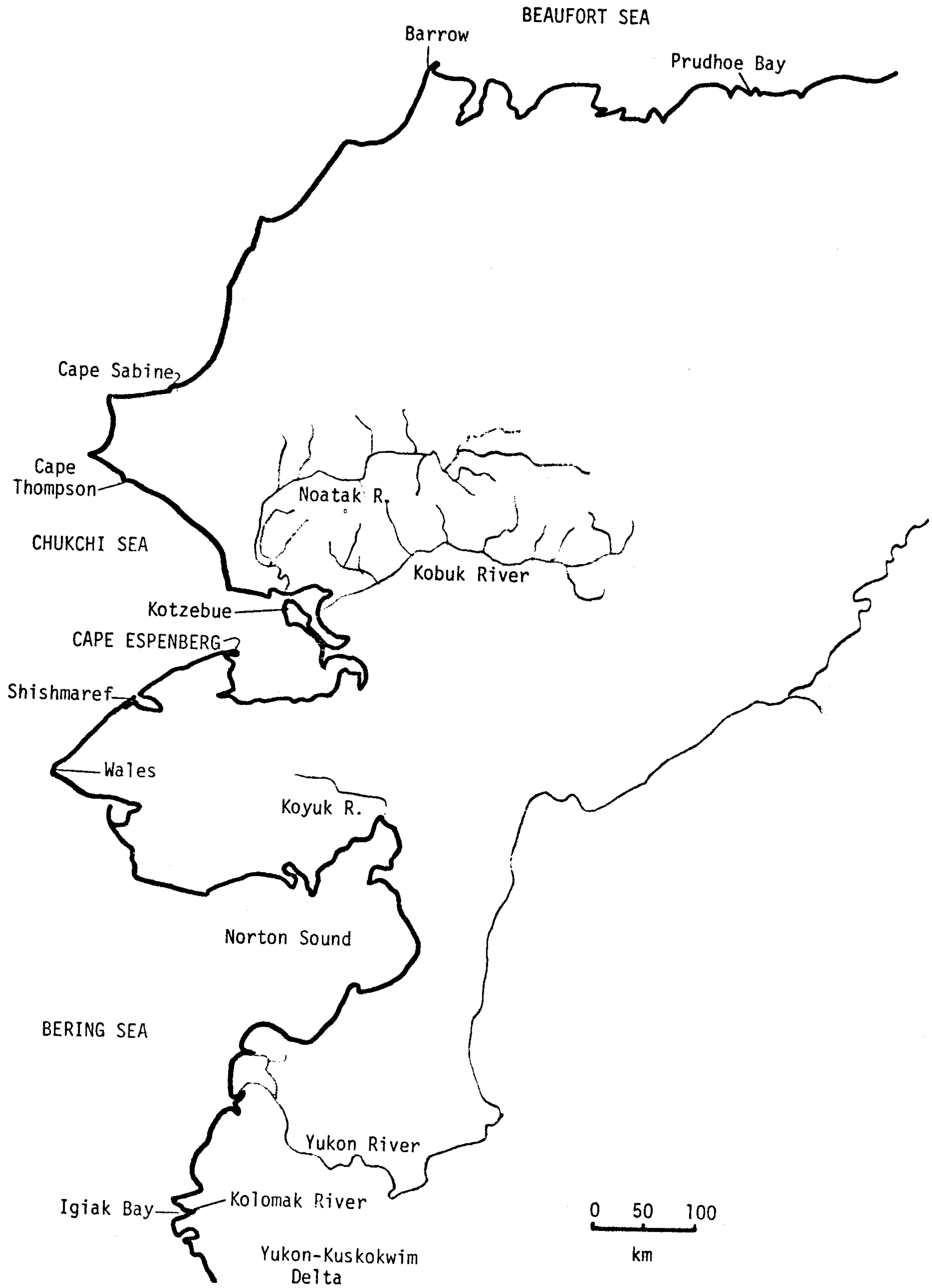

Figure 1. Location of study area, Cape Espenberg, Alaska.

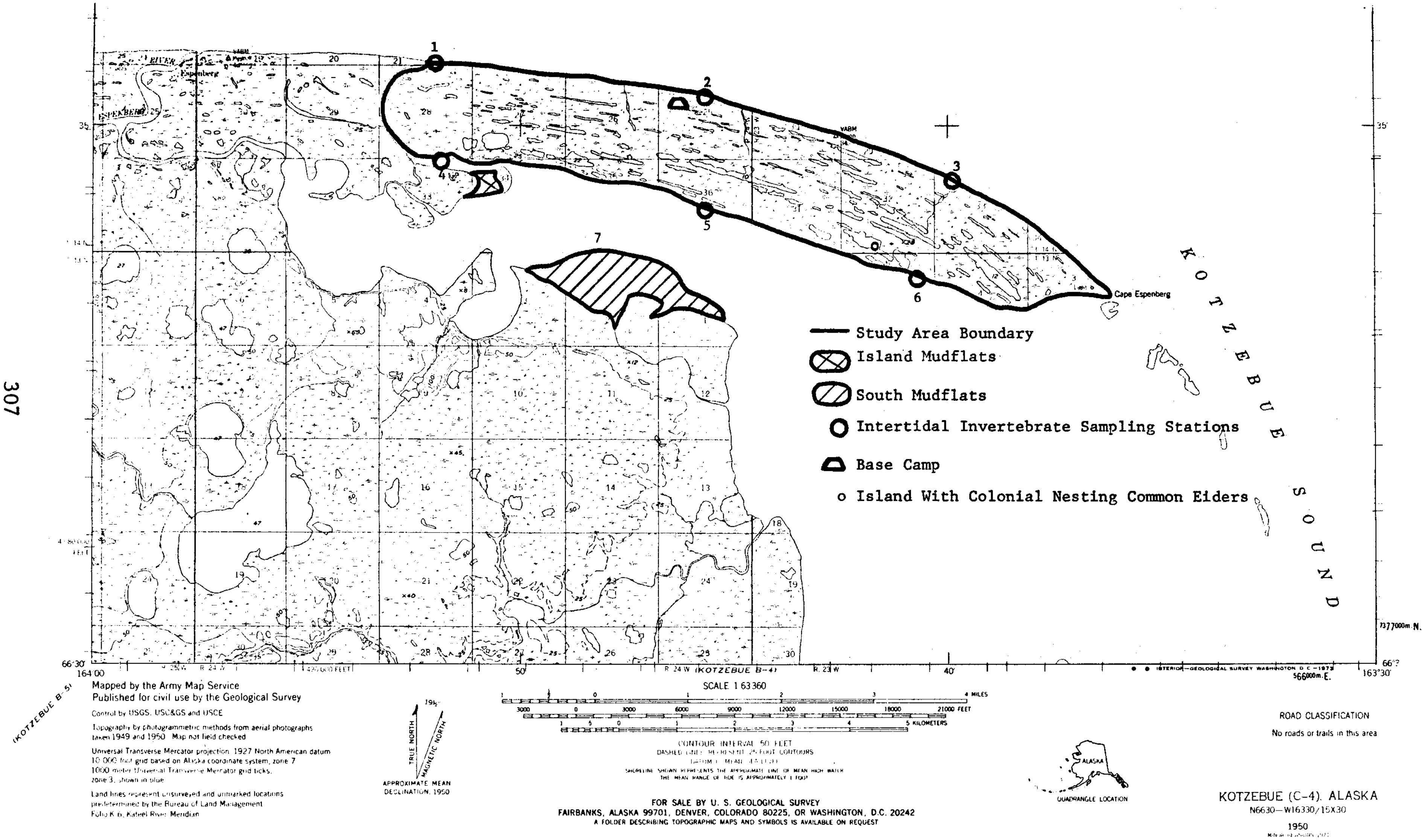

Figure 2. Locations of study area, island mudflats, south mudflats, intertidal sampling stations, camp, and island with colonial nesting Common Eiders.

sp., Chrysanthemum arcticum, Artemesia Tilesii, Pedicularis spp., and several other grasses and forbs. Depressions between sand dunes often have small stands of dwarf Salix spp. and shallow ponds are typically surrounded by Juncus spp. and Carex spp. The dunes rise to a maximum of 10 m.

Tundra ridges are dominated by lichens, Potentilla villosa, Silene acaulis, Empetrum nigrum, Vaccinium vitis-idaea, Betula nana, and Salix glauca. Ledum palustre, Arctostaphylos alpina, Andromeda polifolia, Oxytropis Maydelliana, Cassiope tetragona, Pedicularis spp., Carex spp., Rubus chamaemorus. Other species also occur on these tundra ridges.

Approximately 1 to 2 m below these tundra ridges are areas of tussocks and marsh, with a mosaic of vegetation. Characteristic types include: dry and wet tussocks, cotton grass-sedge marsh, sedge meadow, and sedge-saltgrass meadow. The tussock areas include the following dominant species: Eriophorum angustifolium, Ledum palustre, Carex bigelowii, Vaccinium uliginosum, and Betula nana. Other species included: Rubus chamaemorus, Cassiope tetragona, Empetrum nigrum, and several grass and forb species. The tussocks are only moderately developed.

Cottongrass-sedge marshes are dominated by Eriophorum angustifolium, E. russeolum, and Carex aquatilis. Other species include Betula nana, Andromeda polifolia, Arctostaphylos alpina, Vaccinium vitis-idaea, V. uliginosum, Ledum palustre and Cassiope tetragona. Hummocks and broken ridges occur in many of the marsh areas.

Sedge meadow consists of Carex aquatilis as the dominant species, and the following species: Eriophorum angustifolium, E. russeolum, Pedicularis sudetica, Betula nana, and Salix sp.

Sedge-saltgrass meadow dominates a few sites along the inner (south) coast. Puccinellia phryganodes, and Carex spp. dominate these sites. Other species include: Stellaria humifusa, Potentilla Egedii, Saussurea nuda, and Chrysanthemum arcticum.

Emergent and submersed aquatic vegetation vary with pond depth and location. Some ponds amongst the outer sand dunes lack submersed species, but do contain Juncus and Carex species. Ponds in marshy areas contain Arctophila fulva, Potentilla palustris, Menyanthes trifoliata, Hippuris vulgaris and Ranunculus sp.

During the nesting season, our efforts were directed mainly to six nesting plots and four census transects (Fig. 3). In addition, the South Mudflats area was censused regularly in 1977. These study areas are discussed under Methods.

Aerial surveys were flown in 1977 and 1978 from the western edge of Espenberg Bay, south and eastward to the eastern edge of the mouth of Kiwalik Lagoon, near Candle, Alaska. The survey route followed the coastline and entered river mouths as far as salt water intrusion, as indicated by saltmarsh vegetation (Figs. 4 and 5). To make survey results more meaningful, the survey route was divided into 16 coastal sections, each with certain habitat features (Figs. 4 and 5). Major coastal habitats include 1) saltmarsh mudflats (sections A,C,E,M,P), 2) saltmarsh (section G), 3)eroding tundra bluffs/gravel beach (sections B and D), 4) non-eroding

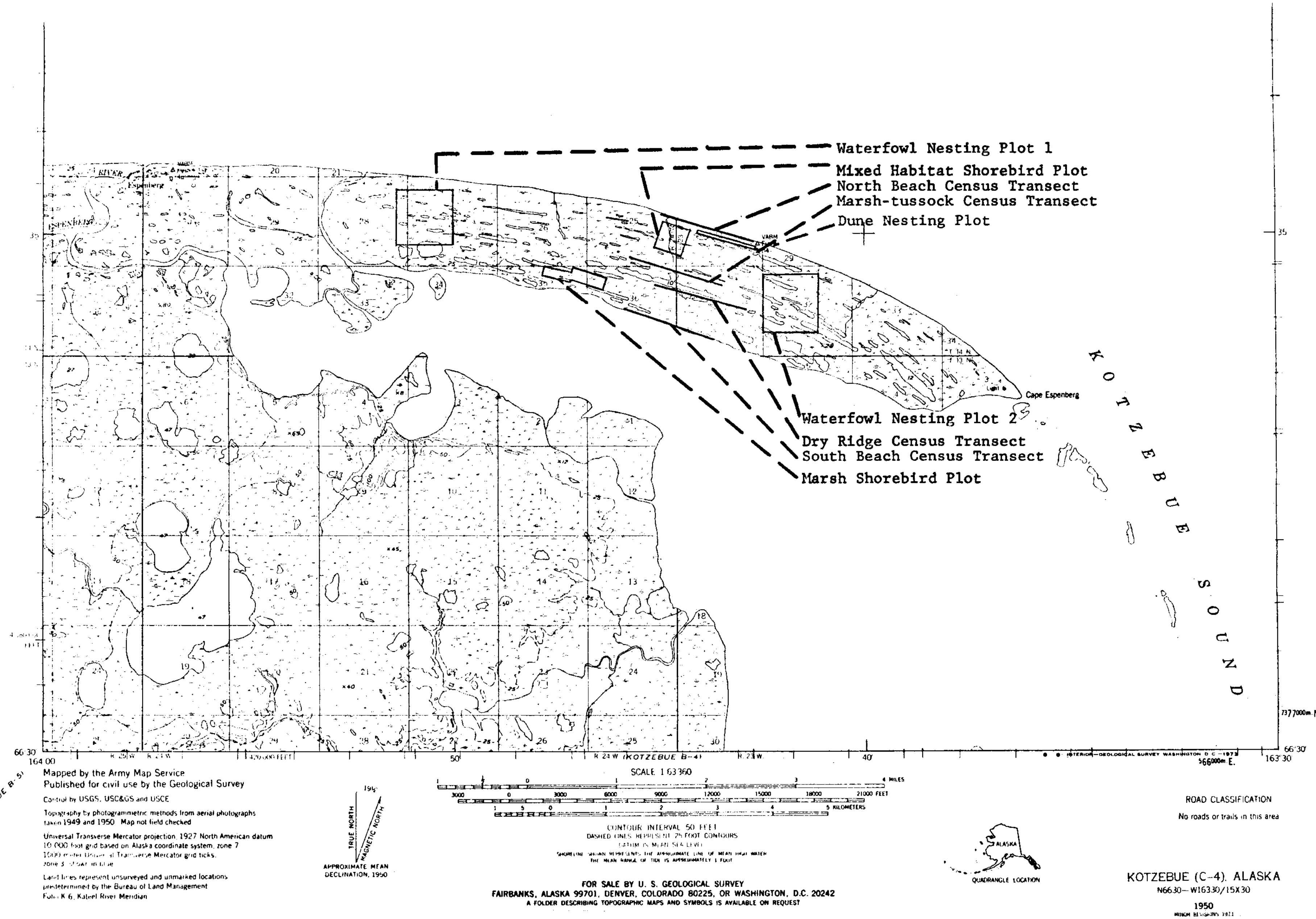

Figure 3. Locations of nesting plots and census transects.

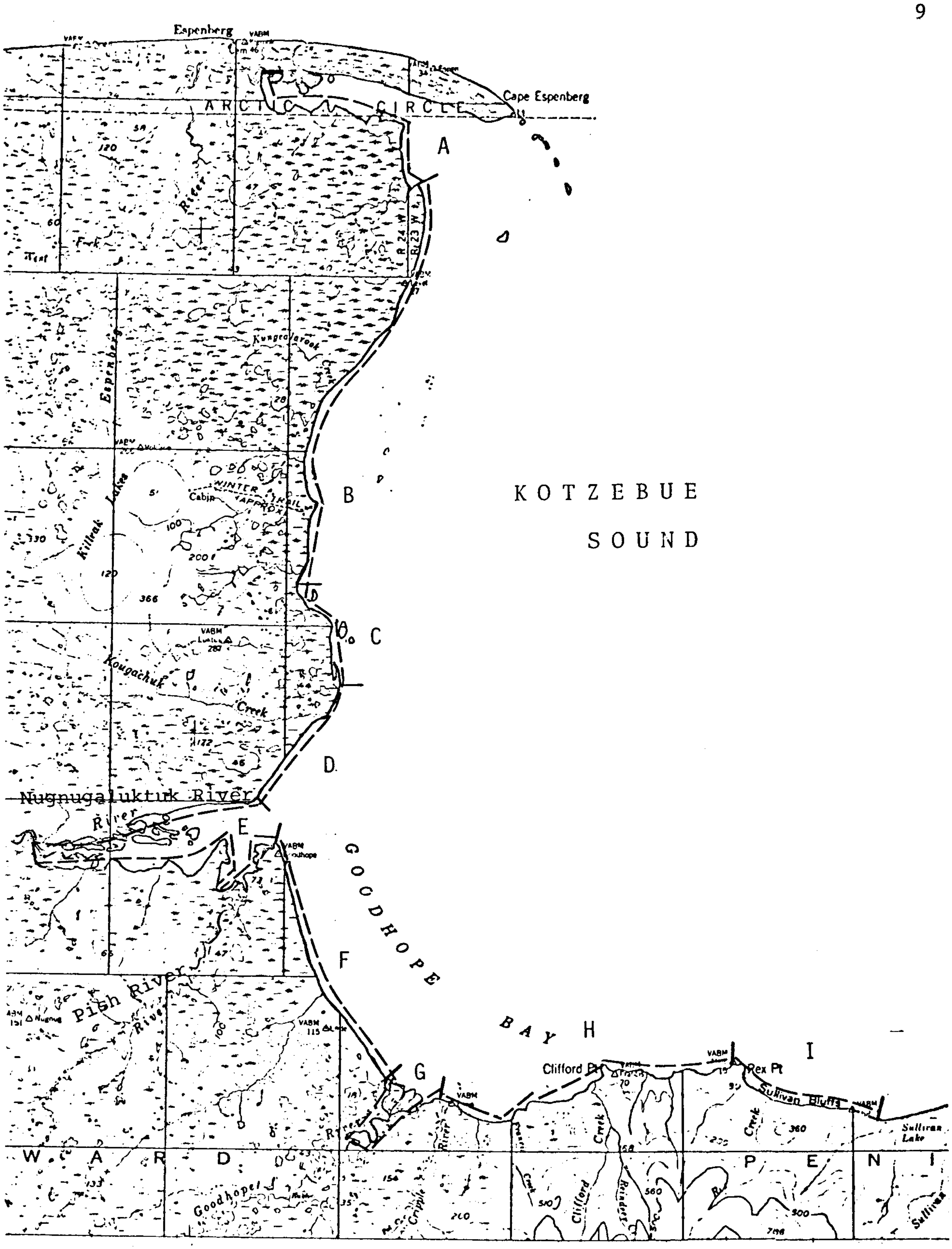

Figure 4. Route of western part of aerial surveys, southern Kotzebue Sound, Alaska.

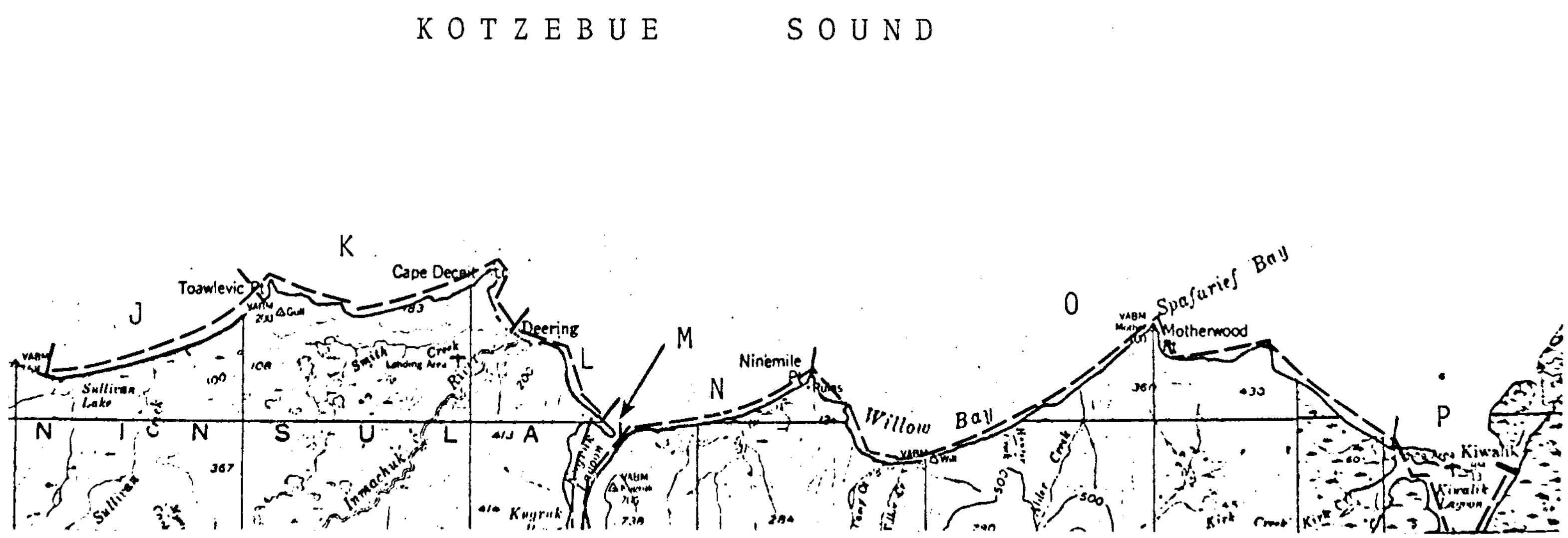

Figure 5. Route of eastern part of aerial surveys, southern Kotzebue Sound, Alaska.

tundra bluffs/gravel or rocky beach (sections F, H, L), and 5) rocky bluffs/rocky beach (sections I, K, N).

A few hiking trips were taken to Espenberg and along the Espenberg River. In 1977, Schamel and Long hiked a 13 km section of coast south of the Cape, near Kungealarook Creek. Fred Goodhope, Jr., a resident of Espenberg and Shishmaref, kindly took us by boat to several islands south of the Cape and to the mouth of the Nugnugaluktuk River.

V. METHODS

Bird Census Transects and Daily Bird Observations

Four bird census transects (each 50 m x 2000 m) were established on the Cape (Fig. 3). The transects were marked with numbered wooden stakes at 50 m intervals. Each transect was located in a homogeneous habitat type, as follows 1) north beach, 2) marsh-tussocks, 3) dry ridge, and 4) south beach. Beach transects included 25 m on both sides of the water's edge. Transects were walked once each week. Usually, two observers walked two transects each on the same day. An observer walked a transect at a speed of approximately 50 m/1.5 min. Time-of-day was kept constant (morning to mid-day). Tide levels and weather conditions were recorded, as well as species, number, location, habitat, and activity of all birds sighted.

To supplement the transect data, a list was kept each day of all the bird species observed by all investigators and the relative abundance of each species. Since the transects were done only once each week, the daily bird lists helped to pinpoint arrival and departure dates and to delineate long-term trends of relative abundance.

Espenberg Bay Mudflats Surveys

We discovered a large mudflat at the south edge of Espenberg Bay in 1976. This area (3.0 km^2), and smaller mudflats on the Cape, were used by large numbers of migrant waterfowl and shorebirds. Estimates of bird numbers on these mudflats were made on several occasions.

In 1977, estimates of bird numbers on the mudflats were obtained regularly, using a 20-30x spotting scope from the south coast of the Cape. Except during late July and early August, when smoke from nearby tundra fires obscured the mudflats, counts were conducted at least three times weekly.

Beached Carcass Surveys

The north beach was searched from the slough in section 21 to the tip of the Cape for dead birds and mammals (Fig. 2). Species, extent of decay, and amount of oil on the plumage were recorded. The census was conducted on foot about once per week in 1976 and less frequently in 1977.

Aerial Surveys

Aerial surveys of coastal southern Kotzebue Sound were conducted from June-September 1977 and June-July 1978. Surveys were flown in a Maule fixed-wing aircraft at an altitude of 30-40 m, a ground speed of about 54 m/sec (120 mph), and 300 m seaward of the coast. Most surveys involved three observers; two observers estimated bird numbers within 300-400 m of either side of the plane, while the third observer called out landmarks. Bird numbers were estimated within 400 m on the sea side of the plane, while birds within 300 m on the land side were estimated. Bird numbers for each coastal section were recorded using tape recorders. After 15 July, 1976, we avoided the seabird nesting cliffs at Sullivan Bluffs and Cape Deceit.

The amount of coastline in each coastal section was estimated from a U.S.G.S. map, by use of a map measurer.

Waterfowl Nesting Plots

Two one-square-kilometer study plots, located in sections 27 and 28 (plot 1) and 32 (plot 2), T14N, R24W Kateel River Meridian were established in 1976 (Fig. 3). In 1977, approximately 17 ha on the southern side of plot 2 was ommitted due to time constraints. Consequently, the study plot was 1 km^2 in 1976 as opposed to approximately 0.83 km^2 in 1977. Probably few birds nested in the excluded area. In 1976, only five nests were found in this area: Red-throated Loon (2 nests), Common Eider (2 nests), and Dunlin (1 nest). From 1976 data on the excluded area, it is doubtful if many waterfowl nests were omitted from the plot in 1977. Despite the size discrepancy between the two years, the number of nests in the plot, by species, should be comparable.

Each plot was systematically searched for waterfowl nests. Plot 1 was searched with a 50 m rope. With one person at either end of the rope and another positioned at the 25 m mark, the investigators walked easterly, and then westerly covering a 50 m wide swath. When a bird was flushed, the immediate area was searched for a nest. Each nest was assigned a number and the date, species, number of eggs, and location recorded. Nests were marked by tongue depressors inscribed with all the above information except location.

The search of plot 2 was conducted without a rope. Instead, two or three people, positioned 7-12 m apart, walked abreast until the plot was covered. Nests were marked and the same information collected as for plot 1.

Nests in both plots were visited repeatedly during incubation. During each visit, investigators recorded the number of eggs, stage of incubation, date of hatch, and number of eggs hatched. The percent cover of plant species within a 0.5 m radius of the nest bowl center was determined for many of the nests in each plot.

Waterfowl Plot 3 was located on a small island (ca. 10 m x 100 m) in one of the larger ponds on the Cape. The island supported a dense concentration of Common Eiders. The island was searched on several occasions both summers and most nests were located. The standard nest site and fate information were recorded.

In order to minimize the effects of human disturbance on the nesting waterfowl, very little searching for nests in the waterfowl plots was conducted during the egg-laying period. Thus, some nests that were destroyed before incubation began were probably missed, especially if no obvious signs of their presence were left, such as abundant fresh down or freshly destroyed eggshells. We estimate that we found 80% of the waterfowl nests in the waterfowl plots.

In 1977 a new study plot (8.2 ha) was located in the dunes on the north side of the Cape. The entire area was thoroughly searched for nests on June 7 and 8. One to three investigators walked repeatedly through the plot and watched for displaying males or flushing adults. When a nest was found the species, number of eggs and/or young, and general location were recorded. Because this plot was only searched for two days in early June we do not have density data for the entire breeding season. The results give an indication of the species that nest in this habitat and their relative abundance.

Waterfowl broods were counted whenever encountered and the habitat and location were recorded.

Shorebird Nesting Plots

Two 0.25 km^2 shorebird nesting plots were selected (Fig. 3): one in uniform marsh habitat and one in mixed habitat including dunes, dry ridges, tussock tundra, a fresh-water slough, and marsh. A grid system was set up in both plots using wooden stakes marked with coordinate numbers. In the marsh plot, stakes were 50 m apart, while in the mixed habitat plot, they were 100 m apart. These stakes increased the ease and accuracy of 1) relocating nests, 2) mapping nest locations within each plot, 3) recording the movements of banded adults and broods, and 4) developing vegetation-habitat maps of the plots.

Throughout the nesting season, these plots were regularly searched for nests of all birds. Nesting shorebirds were recognized by their behavior and observed until the nest location was revealed. We attempted to color-band adult shorebirds at all known nests so that breeding pairs from unlocated nests could be identified and their nests found. In addition, both plots were systematically searched for nests once each summer by three people dragging a 25 m rope over the entire area and searching areas from which birds flushed. Because of our intensive searching and banding effort throughout the nesting season, we estimate that we found 90% of all nests in the shorebird nesting plots. All nests were assigned numbers and marked with tongue depressors to aid in relocating them. Nests were visited at least once weekly. As hatching time approached, nests were visited at 2-day intervals. Nesting success was determined by 1) the presence of chicks in the nest bowl, 2) the presence of shell fragments in a nest that was hatching during an earlier visit, or 3) the sighting of a banded adult with young. At each nest we recorded 1) general habitat type, 2) distance to nearest water, 3) type of nearest water, 4) height above water, 5) distance to nearest hummock and ridge (if nest located on a hummock), 6) percent cover of plant species, 7) percent cover over the nest, and 8) distance to two grid stakes. The grid stake distance was used to plot nest locations on a map and this map used to determine distance to nearest neighbor and nearest conspecific nest. Inter-nest distances were measured in the field when nests were close together (less than 10 m). A general vegetation-habitat map was prepared for both shorebirds plots for 1) comparison with nest distribution, 2) estimation of the percentage of various habitat types, and 3) a ground-truth for the aerial photography. Percent cover of plant species at nest sites was determined within a 15 cm radius of the nest for shorebird, Arctic Tern, and Sabine's Gull nests. A 50 cm radius area was used for waterfowl, Willow Ptarmigan, Sandhill Crane, and Glaucous Gull nests.

Chicks of shorebirds, Sabine's Gulls, and Arctic Terns that hatched in the study area were banded, weighed, and measured at the nest whenever possible. Banded chicks were recaptured at irregular intervals. They were weighed and measured to determine growth rates. We recorded the location and habitat of all recaptured chicks.

Banding, Tagging, and Marking

Nesting shorebirds were nest-trapped, weighed, measured, and banded. Adult Red and Northern phalaropes were also captured with a hoop net and banded (Schamel and Tracy 1977). Each bird was banded with a standard aluminum U.S.F.W.S. band and three color bands. Bands were placed above the tarsal joint of each leg. This reduces the overwinter fading of color bands and corrosion of aluminum bands. The following colors were used: red, yellow, blue, and green. Chicks were captured at nests and opportunistically. Each chick was banded with an aluminum band and a single color band, coded for hatching year. The following color code was used for chicks: Semipalmated Sandpiper - - red (1976), green (1977); Western Sandpiper - - yellow (1976), blue (1977); and Dunlin, Ruddy Turnstone, Northern Phalarope, and Red Phalarope - - green (1976), yellow (1977). Adult Arctic Terns were banded above the tarsal joint with aluminum on the left and a single green color band on the right. Arctic Tern chicks were banded above the tarsal joint with aluminum bands only. Sabine's Gull chicks were similarly banded. Glaucous Gull chicks were banded below the tarsal joint with aluminum bands only.

Nesting Parasitic Jaegers were nest-trapped and banded with aluminum bands. They were also color-marked with pink dye. Young Emperor Geese were web-tagged at nests with size 1 monel fingerling fish tags. Several nesting Glaucous Gulls were color-marked with dye by placing cotton soaked with dye in their nests. Location, habitat, and activities of color-marked birds were recorded whenever the birds were encountered.

Sticky Boards

Relative insect abundance was monitored both summers from June through late August or September using sticky boards (10 cm x 50 cm masonite boards coated with Stikem Special). Five sticky boards were used. They were located 50 m apart along one north-south stake line in the Marsh Shorebird Plot. Insects on boards were counted and the boards re-set at three-day intervals. A wire mesh canopy, placed over each board, prevented birds from removing insects or becoming entangled.

Intertidal Invertebrate Collection

In 1976, a total of 115 intertidal invertebrate samples were collected from six locations on the Cape, three along the sea coast and three along the bay (Fig. 2). Twenty samples were taken at each of five sampling areas: five replicates each from 1) 2 cm deep water (substation A), 2) the water's edge (substation B), 3) mid-way from the water's edge to the summer high tide mark (substation C), and 4) the summer high tide mark (substation D). The sixth sampling area was located near a salt marsh and only 15 samples were taken. The high tide mark here was on the tundra and no samples were taken from it. An additional 10 samples were taken from the Espenberg Bay mudflats (Fig. 2). These were taken from the water and water's edge only.

The intensive intertidal sampling initiated in 1976 was repeated in mid-August 1977 at all six stations on the Cape, plus the mudflats station. In mid-July and mid-September 1977, station 2 along the Chukchi coast, stations 4 and 5 on the bay coast, and the mudflats were sampled less intensively. Five replicate samples were taken 1) in 2 cm deep water and 2) at the water's edge. Additional samples were collected from the center of the mudflats in mid-July, near an area of intensive feeding by shorebirds.

Sampling was accomplished by means of a 10 cm x 20 cm metal frame and a garden trowel. Mud was collected to a depth of 4 cm. Samples were screened in the field, placed in Whirl-paks or glass vials, and preserved with 10% buffered formalin. The samples were screened using a 1 mm mesh screen, sorted, and identified at the Marine Sorting Center, University of Alaska. Wet weights were determined to the nearest 0.001 g, using a top-loading Mettler balance.

Shorebird Stomach Analysis

In 1976, 13 shorebirds were collected for stomach analysis (9 Dunlin, 3 Western Sandpipers, and 1 Sanderling); 10 shorebirds were collected in 1977 (8 Dunlin and 2 Sanderlings). Except for the Sanderlings, birds were observed for 15 minutes prior to collection. All birds were weighed and measured. Sex was determined by dissection. Stomachs were either immediately removed from each bird and placed in 10% buffered formalin or induced with formalin, using an eye dropper and plunger. The esophagus-proventriculus-stomach of each bird was examined at the Marine Sorting Center, University of Alaska.

Predator Distribution and Numbers

The entire Cape area was systematically searched for fox dens. The search was made by a varying number of persons walking abreast within view of each other and searching all available denning habitat. The location of each den site was marked on a map and the following information was recorded 1) general habitat, 2) distance to and type of nearest water, 3) vegetation, 4) slope and degrees of view, and 5) number of holes. We determined which den sites were active each summer and the number of pups present. All observations of foxes were recorded, accompanied by a description of the animal, the location, and its behavior.

Between mid-June and early July each summer, the entire Cape was searched for Glaucous Gull colonies. The searches were conducted using a spotting scope and binoculars from a series of high dunes running the length of the Cape. Colony locations were recorded on a map and the approximate number of nests in each colony was estimated. The laying and hatching dates, clutch sizes, and nest fates for three small Glaucous Gull colonies (total of 30-38 nests) near the Shorebird Marsh Plot were recorded each summer. During 1977, all the ponds on the Cape were visited and the number and sizes of all Glaucous Gull chicks present were recorded.

Each summer, an attempt was made to locate most of the Parasitic Jaeger nests on the Cape. The location, clutch size, and fate of each nest was recorded.

Systematic Predator Observations

From 21 June-17 July 1977 systematic predator observations were made in the Shorebird Marsh Plot. A blind was set up on a dune along the south boundary of the plot. On 20 evenings an observer sat in the blind and used binoculars and a spotting scope to observe predator activities in the plot. Most observation periods began at 1800 and lasted 4 hours. However, fog, strong winds, and other research obligations caused some variation in the time and lengths of the observation periods. A total of 75 hours of observations were made. During this time the following information was recorded: 1) the species of each predator observed, 2) the length of time each predator was in the plot, 3) the movements and activities of each predator while it was in the plot, 4) the numbers, types, and locations of eggs and chicks taken by each predator, and 5) the behavioral responses of the nesting birds to the predators.

Predator Pellet and Scat Collection

Glaucous Gull nest sites (29 in 1976, 34 in 1977) near the Shorebird Marsh Plot were selected as gull pellet collection sites. All pellets in the vicinity of these nests were collected twice monthly (at the middle and end of each month). Collections were made from June through mid-September. "Pellets" included both requrgitated items and feces, as it was often difficult to distinguish between these. Carcasses, eggshells, and other remains of items brought to the nest were also collected and each counted as a "pellet," but such items made up only 1% of all pellets. On a few occasions too many pellets were present to collect all of them. In these cases, the major food items in the pellets that were not collected were identified in the field and the presence of trace items were estimated from their presence in the pellets that were collected during the same period, at the same nest, and with the same major food item contents. The pellets examined in the field and not collected comprised only 17% of all the pellets.

Fox scats were collected at all active den sites in 1976. At two dens, collections were made in late July and again in mid-September. This provided seasonal food habit information. There were no active dens at which to collect scats in 1977.

A few pellets from Parasitic Jaegers and Snowy Owls were collected opportunistically.

Food items in each pellet and scat were identified in the lab. The percent of the volume of each pellet or scat that each food item comprised was estimated.

Small Mammal Trapline

To determine species present and relative abundance of alternative prey for foxes and avian predators, small mammals were trapped in and near the shorebird nesting plots using Sherman live traps during mid-July to mid-August. Traps were set in lines. Each line consisted of 20 traps, located 25 m apart, placed at microtine runways, holes, or natural runways if these were present. Traps were baited with peanut butter and checked at 6-8 hour intervals. The following information was collected for each captured animal: 1) species, 2) age, 3) sex, 4) weight, and 5) body and tail measurements. Animals were marked for later identification and released. Each summer, 80 trap-days were completed in each of four habitats: *Elymus*-dunes, dwarf shrub-dunes, sedge-pond edge, and moist ridge. In marsh habitat, 160 trap-days were completed. Additional trapping was conducted at various locations where microtine activity was suspected. (One trap-day is equal to one trap set for 24 hr.)

Vegetation and Habitat Mapping

A series of aerial photographs were taken in 1976 and used to produce a habitat map for the Cape. In 1977, this map was extensively refined and verified through ground-truth work. The map was used to estimate the amount of each type of habitat on the Cape. The map is not reproduced in this report because of the difficulty and resultant great expense of reproducing a map illustrating 14 finely interspersed habitats. For those interested the map may be obtained from the authors or from the OCS Arctic Project Office.

Plant Phenology and Floristics

Flowering plants were collected, pressed, and identified. Dates of flowering were recorded by several of the investigators.

Incidental Observations

Observations were made opportunistically on 1) the presence of marine mammals on the ice and in the ocean near the Cape, 2) the numbers of reindeer on the Cape and their effects on breeding birds, and 3) subsistence activities of Natives on the Cape.

VI. and VII. RESULTS AND DISCUSSION

Avian Occurrence, Abundance, and Habitat Use

Occurrence

During 1976 (4 June-15 September) and 1977 (19 May-30 September), 85 bird species were recorded on Cape Espenberg (Table 1). Of these, 34 nested on the Cape, 11 were spring migrants, 14 occurred during summer as non-breeders, 19 were fall migrants, and 6 were migrants both

Table 1. Birds observed at Cape Espenberg, 1976 and 1977.

Species	Year[1]	Nesting Status[2] 76	77
Yellow-billed Loon (Gavia adamsii)	6,7	pn	n
Arctic Loon (Gavia arctica)	6,7	n	n
Red-throated Loon (Gavia stellata)	6,7	cn	cn
Red-necked Grebe (Podiceps grisegena)	7	-	o
Whistling Swan (Olor columbianus)	6,7	o	o
Canada Goose (Branta canadensis)	6,7	un	pn
Black Brant (Branta bernicla nigricans)	6,7	un	un
Emperor Goose (Philacte canagica)	6,7	n	n
White-fronted Goose (Anser albifrons)	7	-	o
Snow Goose (Chen caerulescens)	6,7	o	o
Mallard (Anas platyrhynchos)	6,7	o	o
Pintail (Anas acuta)	6,7	o	n
Green-winged Teal (Anas crecca)	6,7	un	un
American Widgeon (Anas crecca)	6,7	o	o
Northern Shoveler (Anas clypeata)	7	-	un
Redhead (Aythya americana)	7	-	o
Canvasback (Aythya valisineria)	7	-	o
Greater Scaup (Aythya marila)	6,7	n	n
Oldsquaw (Clangula hyemalis)	6,7	n	n
Common Eider (Somateria mollissima)	6,7	cn	cn
King Eider (Somateria spectabilis)	6,7	un	un
Spectacled Eider (Somateria fischeri)	6,7	un	un
White-winged Scoter (Melanitta deglandi)	7	-	o
Surf Scoter (Malanitta perspicillata)	6,7	o	o
Black Scoter (Melanitta nigra)	7	-	o
Red-breasted Merganser (Mergus serrator)	6,7	o	o
Goshawk (Accipiter gentilis)	6,7	o	o
Rough-legged Hawk (Buteo lagopus)	6	o	-
Marsh Hawk (Circus cyaneus)	6,7	o	o
Peregrine Falcon (Falco peregrinus)	7	-	o
Willow Ptarmigan (Lagopus lagopus)	6,7	n	n
Sandhill Crane (Grus canadensis)	6,7	cn	cn
American Golden Plover (Pluvialis dominica)	6,7	o	un
Black-bellied Plover (Pluvialis squatarola)	6,7	o	un
Ruddy Turnstone (Arenaria interpres)	6,7	n	n
Black Turnstone (Arenaria melanocephala)	6,7	un	un
Common Snipe (Capella gallinago)	6,7	o	o
Whimbrel (Numenius phaeopus)	6,7	o	o
Bristle-thighed Curlew (Numenius tahitiensis)	6,7	o	o

Table 1. Birds observed at Cape Espenberg, 1976 and 1977. (Continued)

Species	Year[1]	Nesting Status[2] 76	77
Red Knot (Calidris canutus)	6,7	o	o
Sharp-tailed Sandpiper (Calidris acuminata)	6,7	o	o
Pectoral Sandpiper (Calidris melanotos)	6,7	pn	un
Baird's Sandpiper (Calidris bairdii)	6,7	o	o
Curlew Sandpiper (Calidris ferruginea)	6	o	-
Dunlin (Calidris alpina)	6,7	n	n
Semipalmated Sandpiper (Calidris pusilla)	6,7	cn	cn
Western Sandpiper (Calidris mauri)	6,7	cn	cn
Sanderling (Calidris alba)	6,7	o	o
Long-billed Dowitcher (Limnodromus scolopaceus)	6,7	n	n
Bar-tailed Godwit (Limosa lapponica)	6,7	o	o
Hudsonian Godwit (Limosa haemastica)	6,7	o	o
Red Phalarope (Phalaropus fulicarius)	6,7	n	n
Northern Phalarope (Phalaropus lobatus)	6,7	cn	cn
Pomarine Jaeger (Stercorarius pomarinus)	6,7	o	o
Parasitic Jaeger (Stercorarius parasiticus)	6,7	cn	cn
Long-tailed Jaeger (Stercorarius longicaudus)	6,7	o	o
Glaucous Gull (Larus hyperboreus)	6,7	cn	cn
Mew Gull (Larus canus)	6,7	o	o
Black-legged Kittiwake (Rissa tridactyla)	6,7	o	o
Sabine's Gull (Xema sabini)	6,7	n	n
Arctic Tern (Sterna paradisaea)	6,7	n	n
Aleutian Tern (Sterna aleutica)	6,7	o	o
Common Murre (Uria aalge)	6,7	o	o
Thick-billed Murre (Uria lomvia)	6,7	o	o
Horned Puffin (Fratercula corniculata)	6	o	-
Tufted Puffin (Lunda cirrhata)	6,7	o	o
Snowy Owl (Nyctea scandiaca)	6,7	o	o
Short-eared Owl (Asio flammeus)	6,7	o	o
Say's Phoebe (Sayornis saya)	7	-	o
Horned Lark (Eromophila alpestris)	7	-	o
Tree Swallow (Iridoprocne bicolor)	7	-	o
Bank Swallow (Riparia riparia)	7	-	o
Cliff Swallow (Petrochelidon pyrrhonota)	7	-	o
Common Raven (Corvus corax)	6,7	o	o
Wheatear (Oenanthe oenanthe)	6,7	o	o

Table 1. Birds observed at Cape Espenberg, 1976 and 1977. (Continued)

Species	Year[1]	Nesting Status[2] 76	Nesting Status[2] 77
Arctic Warbler (*Phylloscopus borealis*)	6,7	o	o
Yellow Wagtail (*Motacilla flava*)	6,7	o	o
Orange-crowned Warbler (*Vermivora celata*)	7	-	o
Redpoll (*Acanthis* sp.)	6,7	un	o
White-winged Crossbill (*Loxia leucoptera*)	7	-	o
Savannah Sparrow (*Passerculus sandwichensis*)	6,7	un	un
Dark-eyed Junco (*Junco hyemalis*)	7	-	o
White-crowned Sparrow (*Zonotrichia leucophrys*)	6,7	o	o
Lapland Longspur (*Calcarius lapponicus*)	6,7	n	n
Snow Bunting (*Plectrophenax nivalis*)	7	-	o

[1]Year observed: "6" = 1976, "7" = 1977.

[2]cn = common nesting; n = moderate nesting; un = uncommon nesting; pn = probable nesting, but no nests or broods seen; o = not nesting.

in spring and fall. We added 40 species to the Cape Espenberg checklist reported by Kessel and Gibson (1974) for 3-5 July and 4-6 September 1973.

As noted by Kessel and Gibson (1974), Cape Espenberg, on the Seward Peninsula, lies in the nearctic region. However, at Cape Espenberg there were several bird species not of nearctic origin and affinities. Species can be holarctic--regularly occurring in the arctic and north temperature zone of North American and Eurasia; palearctic--with Eurasian affinities; nearctic--with North American affinities, and beringian--differentiated in the Bering Sea during previous interglacial (land bridge connections between Siberia and Alaska) and glacial periods (Fay and Cade 1959:73). Birds are categorized as such in Table 2. It is important to note that palearctic species, for instance, may use Cape Espenberg as a staging area. Even though these species breed elsewhere, Cape Espenberg or adjacent habitat may be an important staging area during their migrations.

Compared with adjacent areas along the western coast of Alaska, Cape Espenberg has a lower avian diversity (Table 3). This can be explained by a lack of two key habitats: nesting cliffs for seabirds, and willow thickets for passerines.

Abundance

Estimates of avian abundance on Cape Espenberg were derived by several methods. Nesting densities were determined from six nesting plots. Rough estimates of overall abundance can be made from the daily bird observations (Tables 4 and 5). These estimates show seasonal trends and are useful for comparison. Quantitative data were collected at weekly intervals on census transects through four major habitat types on the Cape. Estimates of birds using the South Mudflats were obtained on an irregular basis in 1976 and regularly in 1977. Because of the lack of total coverage of Cape Espenberg and the mosaic of habitat types, we are unable to provide estimates of bird numbers more accurate than orders of magnitude (Table 6).

Six species occurred in the 1000s at any one time: Pintail, Common Eider, Dunlin, Semipalmated Sandpiper, Western Sandpiper, and Northern Phalarope. All of these species nested on Cape Espenberg, but numbers of Pintails and sandpipers were enhanced substantially by arrival of fall migrants which staged primarily in the bay south of Cape Espenberg.

Besides these very abundant species, 100 or more pairs nesting on Cape Espenberg were recorded for: Red-throated Loons, Oldsquaws, Red Phalaropes, Glaucous Gulls, Arctic Terns and Lapland Longspurs. A more detailed summary, analysis, and comparison with other areas will be presented under the section on Avian Production.

In a following section, numbers of birds in Espenberg Bay are compared with other areas of southern Kotzebue Sound using data from several aerial surveys, conducted in 1977 and 1978.

Habitat Use

Tables 6 and 7 provide general information on habitat use on the

Table 2. Cape Espenberg avian species with Palearctic or Beringian affinities, or breeding grounds.[1]

Palearctic	Beringian
Goshawk	Yellow-billed Loon
Red Knot	Black Brant
Sharp-tailed Sandpiper	Emperor Goose
Curlew Sandpiper	Common Eider
Bar-tailed Godwit	Spectacled Eider
Arctic Warbler	King Eider
	Black Turnstone
	Bristle-thighed Curlew
	Pectoral Sandpiper
	Dunlin
	Western Sandpiper
	Long-billed Dowitcher
	Glaucous Gull
	Black-legged Kittiwake
	Aleutian Tern
	Common Murre
	Thick-billed Murre
	Horned Puffin
	Yellow Wagtail
	Laplang Longspur

[1]Modified from Kessel and Gibson 1974.

Table 3. Comparison of avian species recorded at Cape Espenberg with adjacent areas.

Species	Cape Espenberg (66°N)	Barrow[2] (71°N)	Prudhoe[3] Bay (70°N)	Cape[4] Sabine (68°N)	Cape[5] Thompson (68°N)	Shishmaref Inlet[6] Seward Peninsula (66°N)	Inglutalik River, Norton Bay[7] (64°N)	Igiak Bay[8] (61°N)
Breeding[1]	34	35	25	55	65	39	32	59
Non-breeding	51	116	47	35	55	39	71	31
Total	85	151	72	90	120	78	103	90

[1]Includes those species nesting or suspected of nesting.
[2]Pitelka 1974.
[3]Bergman et al 1977.
[4]Childs 1969.
[5]Williamson et al 1966.
[6]Noble and Wright 1977.
[7]Shields and Peyton 1978.
[8]Eisenhauer 1976.

Table 4. Daily bird observations, 4 June to 12 September 1976, Cape Espenberg, Alaska (These data are not a reliable indicator of short term changes in daily abundance of avian species, but do illustrate dates of first and last observations and longer-term changes in relative abundance).

JUNE

	4*	5*	6*	7*	8*	9*	10*	11*	12*	13*	14*	15*	16*	17	18	19	20	21	22	23
Yellow-billed Loon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1+	1	1	-	-	-
Arctic Loon	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1+	1	3	2	3	2
Red-throated Loon	10+	10+	6	11+	3	9	-	-	-	1+	-	1	8	1	1+	8	15	-	15	15
Whistling Swan	2	-	2	5	4	-	-	-	-	-	-	2	-	1+	-	1	4	-	7	2
Canada Goose	-	-	-	-	-	-	2	-	-	-	-	-	-	1+	1+	-	-	-	-	-
Black Brant	-	-	-	19	2	-	-	-	-	-	-	-	-	-	-	30	20	-	3	-
Emperor Goose	-	-	-	10	5	2	5	-	-	4	6	4	3	1+	1+	18	18	-	10	10
Snow Goose	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1+	-	15	-	-	-
Mallard	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pintail	-	-	-	9+	-	7	5	-	-	1+	4	-	17	1+	1+	3	20+	-	4	-
Green-winged Teal	-	-	-	4	-	-	-	-	-	-	-	-	-	-	1+	-	-	-	-	1
American Widgeon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Greater Scaup	-	1+	4	10	2	-	2	-	-	1+	-	1	-	1+	1+	4	10	-	2	2
Oldsquaw	-	4	2	7	20	-	-	-	-	4+	1	12+	7	1+	6	20+	-	-	4	4
Common Eider	-	10+	2+	19	14+	-	8	1	1	-	2	26+	38	1+	1+	25	60+	-	20+	20+
King Eider	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
Spectacled Eider	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Eider sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Surf Scoter	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Red-breasted Merganser	-	-	-	2	1	-	-	-	-	-	3	-	1	-	1+	4	35+	-	6	-
Goshawk	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rough-legged Hawk	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Marsh Hawk	-	-	-	-	-	-	-	-	-	-	-	9+	-	1+	-	-	-	-	-	-
Willow Ptarmigan	-	1	-	5	1	-	-	-	-	3	-	2	2	1+	1+	3	2	-	1	2
Sandhill Crane	3+	2+	1+	6	-	3	2	-	-	1+	-	-	8	1+	1+	3	6	-	5	2
American Golden Plover	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-
Black-bellied Plover	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1+	-	1	-	-	-
Ruddy Turnstone	-	-	-	3	-	-	-	-	-	-	-	2+	-	-	1+	1	5	-	1	1
Black Turnstone	-	-	-	1	-	-	-	-	-	-	-	2+	-	1+	1+	-	2	-	2	-
Semipalmated Sandpiper	-	5+	2+	2	6	1	2	2	4	3+	2	10+	2	1+	1+	45+	45+	-	35	35+
Western Sandpiper	-	-	-	2	6	-	-	-	1	3+	-	-	1	1+	1+	40	40	-	30	-
Baird's Sandpiper	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1+	-	-	-	-	-
Pectoral Sandpiper	-	-	-	1	-	-	1	1	-	3	-	1	2	1+	1+	30	30	-	20	10
Sharp-tailed Sandpiper	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dunlin	-	-	-	1	-	3	1	-	1	1+	-	10+	5	1+	1+	6	12	-	6	-
Curlew Sandpiper	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Knot	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sanderling	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Long-billed Dowitcher	-	-	-	-	2	3	3	-	1	-	-	-	-	1+	1+	6	12	-	6	-
Bar-tailed Godwit	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hudsonian Godwit	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Whimbrel	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1+	-	2	-	1	-
Bristle-thighed Curlew	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Common Snipe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-

*data incomplete

Table 4. Continued

JUNE

	4*	5*	6*	7*	8*	9*	10*	11*	12*	13*	14*	15*	16*	17	18	19	20	21	22	23
Red Phalarope	-	1+	-	21	-	2	-	-	16	7+	1	7+	4	1+	1+	20	30	-	10	-
Northern Phalarope	6+	1+	-	22	4	3	1	-	3	9+	3	6+	10	1+	1+	20	20+	-	5	5
Unidentified Small Shorebirds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified Medium Sized Shorebirds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified Large Shorebirds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pomarine Jaeger	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Parasitic Jaeger	-	-	-	4	-	-	-	-	-	-	2	-	5	1+	1+	15	15	-	6	4
Long-tailed Jaeger	-	-	2	1	1	-	-	-	1	4	1	-	-	1+	1+	7	5	-		5
Glaucous Gull	-	-	-	110	82	-	-	4	4	-	10+	70	70+	1+	1+	75	75+	-	50+	50+
Mew Gull	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Black-legged Kittiwake	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1+	4	5	6	25	5
Sabine's Gull	-	1	-	-	-	1	-	1	1	-	4	5+	2	1+	1+	2	20	-	2	4
Arctic Tern	-	-	-	2+	-	-	2	-	-	-	-	-	11	1+	1+	10	20	-	7	3
Aleutian Tern	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Common Murre	-	-	-	-	-	-	-	-	-	-	-	-	-	1+	1+	-	-	80 -	-	-
Thick-billed Murre	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Murre sp.	-	-	-	200	235	-	-	-	15	-	6	-	-	-	-	-	-	-	-	-
Horned Puffin	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tufted Puffin	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Puffin sp.	-	-	-	-	-	-	-	-	-	-	-	1	-	1+	-	-	2	-	-	-
Snowy Owl	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Short-eared Owl	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1+	-	-	-	-	-
Common Raven	-	-	-	-	2	-	-	-	2	-	-	-	-	1+	1+	-	1	-	2	-
Wheatear	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arctic Warbler	-	-	-	-	-	-	-	-	1	-	-	-	-	1+	-	-	-	-	-	-
Yellow Wagtail	-	-	-	-	-	-	-	-	-	-	-	-	-	1+	1+	1 -	1	-	1	-
Redpoll sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	1+	1+	-	5	-	10	-
Savannah Sparrow	-	-	-	1	-	-	-	-	1+	-	-	-	-	-	-	-	-	-	-	-
White-crowned Sparrow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lapland Longspur	-	5+	2+	2	2+	1	-	-	1+	5	1	-	-	1+	1+	16	16+	-	20	20

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Table 4. Continued

	JUNE							JULY											
	24	25	26	27	28	29	30	1	2	3	4	5	6	7	8	9	10	11	12
Yellow-billed Loon	-	-	-	-	2	3	2	2	1	-	-	1	-	2	-	1	2	2	2
Arctic Loon	-	6	3	3	4	4	2	4	4	-	-	4	-	-	2	1	4	4	6
Red-throated Loon	15	15	15	15	15	15	15	15	15	-	50+	15	15	15	15	15	15	10	15
Whistling Swan	-	-	1	-	1	-	-	-	-	-	-	3	-	-	-	-	3	-	-
Canada Goose	-	1	2	5	2	-	-	-	1	-	-	-	-	-	-	-	-	-	7
Black Brant	15	-	-	-	-	-	-	-	-	-	2	9	2	4	-	-	1	-	-
Emperor Goose	8	3	21	15+	13	8	-	10	12	-	12	5	8	10	30	8	13	-	12
Snow Goose	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mallard	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pintail	15	5	7	1	3	3	-	8	4	-	2	2	1	3	-	1	5	3	-
Green-winged Teal	-	-	1	2	-	-	2	-	-	-	-	-	-	1	-	2	-	-	1
American Widgeon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Greater Scaup	2	4	6	12	2	6	2	2	3	-	-	2	2	11	2	-	7	2	2
Oldsquaw	5	2	8	20+	4	4	6	6	10	-	20	12	12	15	30+	15	30	10	15
Common Eider	20+	60+	100+	100+	20+	20+	20+	20+	20+	-	50	100	100	50	300	20+	20+	50	50+
King Eider	-	-	-	-	-	-	-	-	-	-	-	1	-	5	1	-	-	-	1
Spectacled Eider	-	1	-	1	-	-	-	-	-	-	-	-	-	-3	6	-	-	12	-
Eider sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Surf Scoter	-	-	-	-	-	-	-	--	-	-	-	-	-	-	-	-	5	-	90
Red-breasted Merganser	-	-	10	-	4	4	2	-	7	-	2	10	-	6	15	1	5	3	2
Goshawk	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rough-legged Hawk	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Marsh Hawk	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Willow Ptarmigan	3	3	2	3	2	2	3	1	1	-	2	12	1	-	-	-	-	1	7
Sandhill Crane	3	6	10+	10+	6	12	4	6	10	-	10	4	2	12	8	-	18	33	8
American Golden Plover	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Black-bellied Plover	-	-	-	1	-	-	-	1	1	-	-	1	-	1	-	-	-	6	-
Ruddy Turnstone	2	8	10	12	8	5	2	4	6	-	1	5	1	5	6	4	3	-	3
Black Turnstone	5	3	2	2	-	-	-	1	3	-	-	3	-	-	6	-	2	5	2
Semipalmated Sandpiper	20+	20+	20+	20+	20+	20+	20+	20+	20+	-	20+	20+	20+	10	20+	-	15+	15+	15+
Western Sandpiper	20+	20+	20+	20+	20+	20+	20+	20+	20+	-	20+	20+	20+	-	20+	-	1	15+	15+
Baird's Sandpiper	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pectoral Sandpiper	2	3	5	4	-	-	1	1	3	-	-	3	-	-	1	-	-	-	25
Sharp-tailed Sandpiper	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dunlin	5	5+	5+	5+	5	5	10	10+	15	-	3	10+	5	8	10+	5	5	3	15+
Curlew Sandpiper	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Knot	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sanderling	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Long-billed Dowitcher	10+	10+	10+	10+	4	2	5	1	4	-	2	8	3	4	10	5	3	4	4
Bar-tailed Godwit	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Hudsonian Godwit	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Godwit sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Whimbrel	3	4	5	2	-	-	5	-	1	-	2	-	3	6	2	-	26	6	15
Bristle-thighed Curlew	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	2
Common Snipe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

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Table 4. Continued

	JUNE							JULY											
	24	25	26	27	28	29	30	1	2	3	4	5	6	7	8	9	10	11	12
Red Phalarope	2^+	20^+	20^+	20^+	45	25	20^+	20^+	20^+	-	10^+	10^+	3	11	10^+	5	5	5	25^+
Northern Phalarope	5	20^+	15^+	15^+	25	20	20^+	20^+	15	-	5	15^+	3	12	20^+	15	20	5	30^+
Unidentified Small Shorebirds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified Medium Sized Shorebirds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified Large Shorebirds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pomarine Jaeger	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Parasitic Jaeger	5	15	20^+	20^+	10	12	12	12	12	-	5	4	3	12	16	8	9	3	6
Long-tailed Jaeger	8	3	6	8	7	6	2	1	1	-	10	5	5	2	4	5	2	8	5
Glaucous Gull	20^+	20^+	20^+	20^+	20^+	20^+	20^+	20^+	20^+	-	20^+	20^+	20^+	20^+	20^+	20^+	20^+	20^+	20^+
Mew Gull	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Black-legged Kittiwake	-	2	20	10	35	10^+	-	-	10	-	1	5	2	-	4	-	7	20	13
Sabine's Gull	4	20^+	20^+	20^+	3	2	4	2	4	-	2	20^+	5	15	20^+	20	20	10	30^+
Arctic Tern	10	20^+	20^+	30^+	55	30	20	25	25	-	8	6	15	50	30^+	12	40	10	30^+
Aleutian Tern	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Common Murre	-	3	2	-	-	60	-	-	-	-	-	-	-	-	-	-	-	10	10
Thick-billed Murre	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Murre sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Horned Puffin	-	-	-	-	-	-	-	-	10	-	-	1	7	1	15	1	1	-	-
Tufted Puffin	-	-	-	-	-	-	-	-	-	-	-	-	40	-	-	-	-	-	-
Puffin sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Snowy Owl	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Short-eared Owl	-	-	-	1	1	1	1	-	-	-	-	-	-	-	-	1	1	-	2
Common Raven	1	-	2	10	-	-	-	-	-	-	-	-	-	-	-	1	-	7	3
Wheatear	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arctic Warbler	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yellow Wagtail	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Redpoll sp.	-	5	15^+	5	-	-	18	-	4	-	2	-	-	-	-	2	-	-	2
Savannah Sparrow	-	8	-	-	-	-	7	2	10	-	3	6	4	3	9	2	6	5^+	5^+
White-crowned Sparrow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lapland Longspur	15^+	15^+	15^+	15^+	15^+	15^+	15^+	15^+	15^+	-	15^+	15^+	15^+	15^+	25^+	20	15	10	20^+

Table 4. Continued

JULY

	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Yellow-billed Loon	-	3	-	2	1	3	2	-	2	3	1	1	-	-	1	-	-	2	-
Arctic Loon	3	1	4	-	5	-	7	2	-	4	1	3	-	6	6	-	2	6	3
Red-throated Loon	15	50	30	30	23	2	35	10	17	45	10	35	25	16	35	9	100	95	150
Whistling Swan	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Canada Goose	-	-	-	-	-	-	-	-	-	8	-	-	-	-	-	-	-	-	-
Black Brant	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Emperor Goose	-	6	-	-	-	-	-	-	-	4	-	2	-	-	-	-	-	-	-
Snow Goose	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mallard	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pintail	2	4	2	2	1	2	3	-	-	2	10	10	2	55	81	-	4	19	30
Green-winged Teal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
American Widgeon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Greater Scaup	-	4	4	1	-	-	2	-	-	1	-	1	-	-	-	-	-	-	2
Oldsquaw	15+	70	40	80	30	20+	90	20	30	55	75	40	13	56	45	40	3	35	32
Common Eider	20+	175	195	65	125	15+	155	5	25	70	100	61	6	98	70	10	4	45	30
King Eider	-	1	-	-	-	-	-	-	-	-	-	2	1	1	1	1	-	-	1
Spectacled Eider	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eider sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Surf Scoter	-	-	4	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Red-breasted Merganser	24	-	3	2	1	-	11	-	-	-	-	2	1	1	1	-	-	8	-
Goshawk	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rough-legged Hawk	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Marsh Hawk	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Willow Ptarmigan	-	-	20	2	3	15	1	3	-	5	-	15	-	14	18	10	-	-	5
Sandhill Crane	2	28	18	9	15	-	24	5	10	47	4	15	10	34	20	8	7	11	13
American Golden Plover	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Black-bellied Plover	-	3	3	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-
Ruddy Turnstone	4	5	2	7	3	3	8	3	2	3	2	10	1	-	7	1	1	2	1
Black Turnstone	-	2	1	4	-	-	3	-	-	2	6	-	-	2	-	-	-	-	3
Semipalmated Sandpiper	15+	20+	30+	30+	25	25	25	20	20	35	25	25	3	15	11	15	10	60	85
Western Sandpiper	15+	20+	30+	30+	25	25	25	20	20	35	25	25	-	20	11	15	-	20	15
Baird's Sandpiper	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pectoral Sandpiper	-	7	3	30	14	7	7	1	-	-	-	1	-	1	10	1	-	6	9
Sharp-tailed Sandpiper	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dunlin	15+	20+	20+	25+	25+	25+	85	20	20	175	60	60	-	50	25	30	-	25	20
Curlew Sandpiper	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Knot	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sanderling	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Long-billed Dowitcher	4	88	7	6	4	10	6	6	3	8	4	7	-	5	11	14	-	28	12
Bar-tailed Godwit	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hudsonian Godwit	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Godwit sp.	-	-	2	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Whimbrel	19	15	21	15	23	8	5	3	5	16	8	2	-	-	1	10	-	-	15
Common Snipe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 4. Continued

JULY

	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Red Phalarope	25+	25+	25+	25+	20+	20	15	15	15	15	35	30	-	8	8	6	-	5	10
Northern Phalarope	30+	25+	25+	25+	25+	25	25	20	20	45	25	60	-	40	27	27	2	20	22
Unidentified Small Shorebirds	-	-	-	-	-	300	-	-	-	-	-	-	-	-	-	-	30	-	-
Unidentified Medium Sized Shorebirds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified Large Shorebirds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pomarine Jaeger	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Parasitic Jaeger	6	11	6	12	15	6	20	6	6	14	9	14	4	9	24	7	3	11	10
Long-tailed Jaeger	4	4	2	-	2	2	2	2	5	-	-	3	-	1	-	-	-	3	3
Glaucous Gull	20+	20+	140	110	120	16	150	15	40	930	50	75	550+	470	200	25	50	300	560
Mew Gull	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Black-legged Kittiwake	-	45	35	10	8	-	45	8	25	-	20	19	43	60	7	3	18	60	41
Sabine's Gull	30+	50+	40	40	40	40	40	40	40	50	70	70	-	40	30	30	3	35	35
Arctic Tern	30+	30+	85	85	45+	45+	75	35	37	45	60	40	78	170	150	35	26	135	160
Aleutian Tern	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Common Murre	-	20	120	10	42	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thick-billed Murre	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Murre sp.	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Horned Puffin	-	9	1	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tufted Puffin	20	-	-	1	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-
Puffin sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Snowy Owl	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Short-eared Owl	-	-	-	-	1	-	2	-	-	-	-	1	1	1	1	-	-	1	2
Common Raven	-	-	-	1	1	1	4	-	1	-	-	-	-	-	-	-	-	-	-
Wheatear	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arctic Warbler	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yellow Wagtail	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Redpoll sp.	-	-	1	3	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Savannah Sparrow	-	10	2	3	3	3	-	1	1	6	1	1	-	4	-	-	-	1	5
White-crowned Sparrow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lapland Longspur	20+	25	25	25	10+	15	20	15	5	33	11	17	18	11	17	9	1	12	19

Table 4. Continued

AUGUST

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Yellow-billed Loon	2	-	2	4	-	-	-	-	-	-	2	-	-	-	-	1	-	2	2	-
Arctic Loon	2	6	4	5	1	1	3	3	-	-	12	2	1	-	1	12	7	17	2	3
Red-throated Loon	45	180	120	150	30	30	108	15	36	4	68	65	25	-	3	105	18	56	65	10
Whistling Swan	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Canada Goose	-	-	-	8	-	-	-	-	-	-	5	-	-	-	-	11	-	-	36	1+
Black Brant	-	-	-	19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	-
Emperor Goose	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
Snow Goose	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mallard	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Pintail	330	500	130	410	400	10	48	42	76	-	85	-	11	-	1	15	45	11	17	3
Green-winged Teal	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	2	-	-	-
American Widgeon	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Greater Scaup	-	-	8	8	-	-	5	2	1	-	15	-	-	-	-	-	-	-	-	2
Oldsquaw	12	23	27	27	-	3	1	5	40	-	25	13	-	-	-	19	-	8	8	-
Common Eider	15	26	100	70	54	35	47	5	14	-	7	-	-	-	10	-	-	-	2	-
King Eider	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Spectacled Eider	-	-	-	3	-	-	10	-	-	-	-	-	-	-	-	-	-	-	6	-
Eider sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-
Surf Scoter	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Red-breasted Merganser	2	-	1	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Goshawk	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	-
Rough-legged Hawk	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Marsh Hawk	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-
Willow Ptarmigan	-	16	1	5	-	-	-	9	4	-	-	-	-	-	-	-	-	-	2	-
Sandhill Crane	8	24	22	22	6	10	16	10	11	2	20	8	3	-	2	31	10	14	36	2
American Golden Plover	-	-	2	1	-	1	-	2	2	-	4	3	-	-	1	3	25	25	33	10
Black-bellied Plover	1	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-
Ruddy Turnstone	1	1	2	1	1	1	2	-	-	4	2	-	1	1	-	-	-	-	-	-
Black Turnstone	-	-	-	-	-	-	2	-	-	-	4	9	-	-	-	3	1	10	3	-
Semipalmated Sandpiper	20	17	20	2	6	2	5	1	-	-	11	-	-	-	-	-	-	-	-	-
Western Sandpiper	9	27	65	140	70	30	50	5	50	11	62	30	4	-	10	50	16	10	5	-
Baird's Sandpiper	1	-	-	-	-	-	1	-	-	-	2	-	-	-	-	-	-	-	-	-
Pectoral Sandpiper	-	1	2	2	-	15	10	3	35	1	60	45	20	-	10	400	160	60	53	20
Sharp-tailed Sandpiper	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dunlin	6	20	26	225	5	20	40	40	100	-	100	20	3	-	-	80	100	50	1200	7
Curlew Sandpiper	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Knot	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
Sanderling	-	-	-	-	-	-	-	-	-	-	8	20	30	-	7	23	15	10	-	-
Long-billed Dowitcher	-	6	4	5	-	2	1	-	1	-	-	-	1	-	3	1	13	5	11	1
Bar-tailed Godwit	-	-	3	6	-	3	-	1	-	1	-	12	-	-	-	10	8	10	15	-
Hudsonian Godwit	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-
Godwit sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Whimbrel	4	2	-	3	7	1	2	1	1	1	3	3	7	-	-	4	25	-	7	-
Bristle-thighed Curlew	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Common Snipe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-

Table 4. Continued

AUGUST

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Red Phalarope	-	1	1	3	-	-	-	-	1	-	-	1	-	-	1	1	-	-	2	-
Northern Phalarope	11	28	18	55	2	10	20	2	15	-	17	8	-	-	2	8	10	8	3	1
Unidentified Small Shorebirds	-	-	1900	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified Medium Sized Shorebirds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified Large Shorebirds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pomarine Jaeger	-	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Parasitic Jaeger	10	14	7	10	3	8	9	4	5	-	10	3	6	-	2	9	6	8	10	-
Long-tailed Jaeger	-	1	3	-	-	1	-	1	1	-	-	-	-	-	-	1	-	1	-	-
Glaucous Gull	225	70	500+	210	35	25	480	300	140	28	260+	90	50	-	15	80	70	-	170	20
Mew Gull	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Black-legged Kittiwake	12	30	6	9	-	3	75	45	11	-	23	-	-	-	5	2	30	11	97	-
Sabine's Gull	1	20	15	15	-	7	6	-	1	-	1	-	-	-	-	-	-	1	1	-
Arctic Tern	40	86	45	130	26	31	215	60	35	10	60	45	14	-	15	30	40	28	12	5
Aleutian Tern	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Common Murre	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Murre sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Horned Puffin	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tufted Puffin	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Puffin sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Snowy Owl	-	1	1	1	-	1	4	1	2	-	3	1	1	-	-	2	2	-	3	1
Short-eared Owl	-	-	2	2	-	-	-	2	2	-	1	1	1	-	1	4	1	-	-	-
Common Raven	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	12	-	-	-
Wheatear	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Arctic Warbler	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yellow Wagtail	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Redpoll sp.	-	50	-	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-
Savannah Sparrow	-	9	4	2	-	-	-	10	-	-	-	-	-	-	-	1	-	-	-	-
White-crowned Sparrow	-	1	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-
Lapland Longspur	13	80	35	95	10	20	50	60	150	-	85	50	50	-	5	140	140	55	40	20

Table 4. Continued

AUGUST

	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	8
Yellow-billed Loon	-	-	-	-	1	1	-	1	1	-	-	1	-	-	-	-	-	1	1
Arctic Loon	2	3	2	2	2	14	-	1	9	17	6	6	5	-	1	2	15	25	15
Red-throated Loon	30	100	41	35	20	40	17	5	23	35	10	10	5	-	6	1	-	3	-
Whistling Swan	-	-	-	3	1	-	1	4	-	-	1		5	-	3	-	-	-	-
Canada Goose	22	27	18	29	14	42	-	70	27+	30	16	-	70	-	-	-	150	240	20
Black Brant	-	-	-	-	-	-	17	18	6	17	25	26	-	-	1	-	-	-	-
Emperor Goose	-	-	-	-	-	-	-	-	-	-	30	31	23	-	10	-	-	15	5
Snow Goose	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mallard	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pintail	3	6	4	24	12	5	3	2	6	10	13	13	13	-	-	-	4	7	-
Green-winged Teal	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-
American Widgeon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Greater Scaup	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oldsquaw	5	2	-	5	-	3	6	5	-	-	-	-	2	-	-	-	-	2	-
Common Eider	42	6	-	35	-	-	-	-	-	-	-	-	-	-	18	-	-	30	20
King Eider	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Spectacled Eider	3	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	10	-
Eider sp.	-	-	-	25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Surf Scoter	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Red-breasted Merganser	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Goshawk	1	3	2	1	-	-	1	-	-	2	-	1	-	-	-	-	-	-	-
Rough-legged Hawk	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Marsh Hawk	1	1	2	1	1	1	1	2	1	1	2	1			1		1		
Willow Ptarmigan	-	-	-	-	8	6	-	-	13	-	1	-	-	-	-	-	9	12	-
Sandhill Crane	7	15	10	19	12	28	2	5	10	6	10	20	20	-	5	2	7	18	2
American Golden Plover	21	20	40	30	30	30	10	60	50	80	80	50	60	-	-	5	15	40	15
Black-bellied Plover	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ruddy Turnstone	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Black Turnstone	2	2	6	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-
Semipalmated Sandpiper	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Western Sandpiper	10	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Baird's Sandpiper	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pectoral Sandpiper	23	80	60	117	60	60	50	35	50	30	20	8	5	-	15	7	-	22	5
Sharp-tailed Sandpiper	-	-	-	1	-	-	-	4	25	29	45	35	20	-	10	-	1	10	-
Dunlin	300	1206	12	70	20	161	30	-	12	35	50	250	350	-	60	20	20	150	20
Curlew Sandpiper	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Knot	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sanderling	31	35	16	17	-	21	11	10	-	-	-	5	20	-	9	-	-	4	-
Long-billed Dowitcher	9	6	12	3	10	3	1	14	26	45	22	8	1	-	6	2	2	4	-
Bar-tailed Godwit	6	-	-	9	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hudsonian Godwit	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Godwit sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Whimbrel	-	-	12	-	20	25	1	-	1	-	-	-	-	-	-	-	-	-	-
Bristle-thighed Curlew	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Common Snipe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 4. Continued

	AUGUST											SEPTEMBER							
	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	8
Red Phalarope	1	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Northern Phalarope	20	3	1	1	-	2	-	2	-	-	-	-	-	-	-	-	-	1	-
Unidentified Small Shorebirds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified Medium Sized Shorebirds	-	-	-	-	-	-	-	-	20	-	-	-	-	-	-	-	-	-	-
Unidentified Large Shorebirds	-	-	-	-	-	-	-	-	25	-	-	-	-	-	-	-	-	-	-
Pomarine Jaeger	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Parasitic Jaeger	10	8	6	12	8	8	4	2	6	4	8	8	8	-	-	-	3	-	-
Long-tailed Jaeger	-	-	1	-	-	1	-	-	1	-	-	2	-	-	-	-	-	-	-
Glaucous Gull	290	175	30	105	20	70	37	28	30	13	15	20	120	-	450	5	10	100	10
Mew Gull	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Black-legged Kittiwake	26	112	6	86	-	73	20	-	-	-	-	-	-	-	1	-	-	-	-
Sabine's Gull	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-
Arctic Tern	65	22	5	2	-	7	-	-	-	-	-	-	-	-	4	-	-	-	-
Aleutian Tern	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-
Common Murre	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thick-billed Murre	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Murre sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Horned Puffin	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tufted Puffin	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Puffin sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Snowy Owl	2	2	2	1	2	3	1	1	2	3	3	3	3	-	-	-	-	1	-
Short-eared Owl	1	1	-	2	1	-	-	-	-	1	1	-	-	-	-	-	-	-	-
Common Raven	-	-	2	2	-	1	1	1	-	-	-	1	-	-	-	-	-	-	-
Wheatear	-	-	5	-	1	6	3	3	-	-	-	-	-	-	-	-	-	-	-
Arctic Warbler	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yellow Wagtail	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Redpoll sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Savannah Sparrow	-	-	1	1	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-
White-crowned Sparrow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lapland Longspur	31	50	20	40	20	20	10	5	25	25	15	10	10	-	3	1	-	25	-

Table 4. Continued

SEPTEMBER

	9	10	11	12
Yellow-billed Loon	-	1	3	6
Arctic Loon	9	20	15	13
Red-throated Loon	-	10	-	-
Whistling Swan	10	-	-	-
Canada Goose	75	-	-	-
Black Brant	-	-	25	-
Emperor Goose	20	30	50	80
Snow Goose	-	-	-	-
Mallard	-	-	-	-
Pintail	-	1	1	10
Green-winged Teal	-	-	-	2
American Widgeon	-	-	-	-
Greater Scaup	-	-	-	2
Oldsquaw	-	1	-	1
Common Eider	6	-	-	15
King Eider	-	-	-	-
Spectacled Eider	-	-	-	-
Eider sp.	-	-	-	-
Surf Scoter	-	-	-	-
Red-breasted Merganser	-	-	-	-
Goshawk	-	-	1	1
Rough-legged Hawk	-	-	-	-
Marsh Hawk	-	1	-	-
Willow Ptarmigan	-	-	1	45
Sandhill Crane	-	5	2	9
American Golden Plover	10	15	15	20
Black-bellied Plover	-	-	-	-
Ruddy Turnstone	-	-	-	-
Black Turnstone	-	-	-	-
Semipalmated Sandpiper	-	-	-	-
Western Sandpiper	-	-	-	-
Baird's Sandpiper	-	-	-	-
Pectoral Sandpiper	2	20	25	10
Sharp-tailed Sandpiper	2	-	3	2
Dunlin	10	25	50	150
Curlew Sandpiper	-	-	-	-
Knot	-	-	-	-
Sanderling	-	3	-	1
Long-billed Dowitcher	-	1	3	7
Bar-tailed Godwit	-	-	-	-
Hudsonian Godwit	-	-	-	-
Godwit sp.	-	-	-	-
Whimbrel	-	-	-	-
Bristle-thighed Curlew	-	-	-	-
Common Snipe	-	-	-	-

Table 4. Continued

SEPTEMBER

	9	10	11	12	13	14
Red Phalarope	-	-	-	-	-	-
Northern Phalarope	-	-	-	-	-	-
Unidentified Small Shorebirds	-	-	-	-	-	-
Unidentified Medium Sized Shorebirds	-	-	-	-	-	-
Pomarine Jaeger	-	-	-	-	-	-
Parasitic Jaeger	-	-	-	-	-	-
Glaucous Gull	-	125	-	20	150	-
Mew Gull	-	-	-	-	-	-
Black-legged Kittiwake	-	-	-	3	-	-
Sabine's Gull	-	-	-	-	-	-
Arctic Tern	-	-	-	7	-	-
Aleutian Tern	-	-	-	-	-	-
Thick-billed Murre	-	-	-	-	-	-
Murre sp.	-	-	-	-	-	-
Horned Puffin	-	-	-	-	-	-
Tufted Puffin	-	-	-	-	-	-
Puffin sp.	-	-	-	-	-	-
Snowy Owl	-	1	2	2	-	-
Short-eared Owl	-	-	-	-	-	-
Common Raven	-	-	-	-	-	-
Wheatear	-	-	-	-	-	-
Arctic Warbler	-	-	-	-	-	-
Yellow Wagtail	-	-	-	-	-	-
Redpoll sp.	-	-	-	-	-	-
Savannah Sparrow	-	-	-	-	-	-
White-crowned Sparrow	-	-	-	-	-	-
Lapland Longspur	-	-	-	15	5	-
Common Murre	-	-	-	-	-	-

Table 5. Daily bird observations, 19 May to 24 September 1977, Cape Espenberg, Alaska. (These data are not a reliable indicator of short term changes in daily abundance of avian species, but do illustrate dates of first and last observations and longer-term changes in relative abundance).

	MAY													JUNE													
	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Yellow-billed Loon	-	-	-	-	-	-	-	-	-	-	1	-	2	1	1	1	2	5	2	2	2	2	2	1	2	-	1
Arctic Loon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	6	8	2	2	4	6	6	3	4	2	4
Red-throated Loon	-	-	-	-	-	-	3	1	5	35	20	35	60	70	55	30	65	40	55	24	25	55	70	25	65	20	25
Red-necked Grebe	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Whisting Swan	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	1	10	6	6	-	-	4	-	4	2	-
Canada Goose	-	3	-	2	-	-	-	-	1	3	7	1	2	3	2	-	2	5	4	5	8	5	3	2	2	2	2
Black Brant	-	-	-	-	-	-	-	-	-	-	-	-	50	2	2	10	2	20	6	-	26	31	16	10	6	-	-
Emperor Goose	-	-	-	-	-	-	-	-	-	-	2	2	2	2	-	2	14	38	9	8	6	18	6	12	12	6	13
White-fronted Goose	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Snow Goose	-	-	-	-	-	-	-	-	-	-	-	-	4	-	17	13	-	13	-	-	-	-	-	-	-	-	-
Mallard	2	2	2	4	2	2	2	4	6	10	10	11	15	4	10	10	12	12	10	2	-	-	-	2	2	2	-
Pintail	50	50	50	50	50	50	50	15	30	60	120	100	120	70	70	16	120	125	105	50	40	90	90	60	50	15	30
Green-winged Teal	-	-	-	-	-	2	-	4	-	2	2	-	8	2	2	2	4	2	7	4	5	-	-	-	2	1	1
American Wigeon	-	-	-	-	-	-	-	-	-	-	-	15	-	2	-	5	-	-	-	-	-	-	-	-	-	-	-
Northern Shoveler	-	-	3	3	3	3	3	3	-	1	16	1	12	2	2	2	6	4	2	-	-	-	-	-	-	-	-
Redhead	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Canvasback	-	-	-	-	-	2	2	4	-	-	-	1	2	-	2	-	-	2	4	-	8	4	1	-	-	-	-
Greater Scaup	2	2	2	2	2	2	2	4	4	7	12	8	27	12	8	4	12	14	12	16	16	14	14	8	6	6	15
Oldsquaw	-	-	-	-	-	-	-	-	-	6	25	15	25	8	25	20	50	110	40	35	25	40	40	30	30	10	15
Common Eider	-	-	-	4	-	-	2	-	2	14	45	35	20	20	35	20	85	100	55	60	100	70	30	45	180	130	40
King Eider	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	-	-
Spectacled Eider	-	-	-	-	-	-	-	-	-	-	-	-	2	2	3	-	-	4	-	-	-	2	-	-	-	-	-
White-winged Scoter	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Surf Scoter	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Black Scoter	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	1	-	-
Red-breasted Merganser	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	4	6	2	-	-	-	-
Goshawk	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Marsh Hawk	-	1	1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Peregrine Falcon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Willow Ptarmigan	-	-	-	15	-	-	5	1	6	8	10	8	30	3	7	9	18	8	11	7	8	9	3	6	8	1	5
Sandhill Crane	-	10	10	10	10	10	10	-	10	15	20	17	30	16	21	9	19	23	17	6	9	17	4	5	15	4	9
American Golden Plover	-	-	-	3	-	-	2	-	1	-	1	2	3	4	-	-	4	4	1	4	1	1	1	-	1	-	2
Black-bellied Plover	-	-	-	1	-	-	1	1	-	-	1	-	-	1	1	-	2	-	-	-	-	-	2	2	-	-	-
Ruddy Turnstone	3	3	3	3	3	3	7	3	3	12	6	4	7	6	5	3	8	14	10	7	6	4	5	4	9	1	6
Black Turnstone	-	-	-	2	-	-	1	1	2	5	3	8	7	6	5	-	6	20	2	4	1	-	-	-	2	-	2
Common Snipe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Whimbrel	2	2	2	2	2	2	2	2	-	1	-	-	20	1	1	-	-	-	1	2	1	2	2	-	-	-	-
Bristle-thighed Curlew	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Red Knot	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sharp-tailed Sandpiper	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pectoral Sandpiper	-	-	1	5	-	-	-	4	-	15	3	1	4	1	4	4	-	-	1	-	-	1	-	-	-	-	2

Table 5. Continued

	MAY													JUNE													
	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Baird's Sandpiper	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Dunlin	10	10	10	15	10	10	10	-	15	15	55	30	50	13	30	35	35	45	25	25	15	20	13	30	30	4	20
Semipalmated Sandpiper	10	10	10	30	10	10	15	7	20	30	55	25	50	25	25	20	35	70	25	45	30	40	20	40	55	10	40
Western Sandpiper	10	10	10	30	10	10	15	2	8	15	20	10	13	7	12	15	30	50	30	30	15	35	20	20	20	8	25
Sanderling	-	-	-	-	-	-	-	3	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Long-billed Dowitcher	3	3	3	3	3	3	3	1	8	6	25	7	25	9	10	8	11	10	8	10	9	6	7	8	13	7	10
Bar-tailed Godwit	-	-	-	-	-	-	-	-	-	-	2	-	2	-	-	-	-	3	-	-	-	1	-	1	-	-	-
Hudsonian Godwit	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Red Phalarope	-	-	-	-	-	-	-	-	3	-	30	40	70	15	30	12	50	35	30	25	15	70	20	30	50	7	25
Northern Phalarope	-	-	5	2	2	2	2	1	2	5	15	10	45	15	25	10	40	60	35	35	30	55	40	40	45	8	25
Unidentified Small Shorebirds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified Medium Shorebirds	-	-	-	-	-	-	-	-	-	-	-	20	-	-	-	-	-	-	-	15	-	-	-	-	-	-	-
Unidentified Large Shorebirds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pomarine Jaeger	-	-	-	3	-	-	-	-	-	14	2	-	4	1	8	-	6	9	-	1	1	-	-	-	-	1	-
Parasitic Jaeger	-	-	1	2	2	2	2	-	10	25	18	5	35	25	20	18	28	35	27	20	25	43	27	23	23	8	16
Long-tailed Jaeger	2	-	-	-	-	-	-	4	1	2	3	3	10	2	1	4	1	-	-	1	1	5	6	2	2	-	-
Glaucous Gull	20	20	20	20	20	20	20	8	25	50	120	75	110	70	65	60	100	160	110	75	50	105	115	110	180	50	110
Mew Gull	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-
Black-legged Kittiwake	-	-	-	-	-	-	-	-	-	80	2	1	13	20	2	-	20	24	6	20	60	80	50	10	30	10	5
Sabine's Gull	-	-	-	-	-	-	-	-	8	8	13	1	2	18	22	15	35	40	14	20	18	30	18	20	20	5	20
Arctic Tern	-	-	-	-	-	-	-	-	-	-	2	3	17	16	20	12	35	60	40	40	25	35	35	30	55	5	30
Aleutian Tern	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Murre sp.	-	-	-	-	-	-	-	-	-	-	-	-	85	-	25	-	-	-	-	-	-	-	-	-	-	-	-
Tufted Puffin	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Snowy Owl	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Short-eared Owl	1	1	1	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Say's Phoebe	-	-	1	1	1	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Horned Lark	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Tree Swallow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	1	-	-	-	-	-
Bank Swallow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-
Cliff Swallow	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	1	-	-	-	-	-	-
Common Raven	-	2	2	1	2	1	1	2	1	3	1	1	-	-	-	-	-	2	-	1	-	2	1	1	2	2	2
Wheatear	-	-	-	-	-	1	1	-	1	1	-	1	-	-	-	-	-	-	-	-	3	2	-	-	-	-	-
Arctic Warbler	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	3	2	-	-
Yellow Wagtail	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	6	4	2	3	-	-	-	-
Orange-crowned Warbler	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-
Redpoll sp.	-	-	-	3	-	-	-	5	-	-	7	2	3	1	-	1	-	4	2	2	11	-	5	-	4	2	2
White-winged Crossbill	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Savannah Sparrow	2	2	2	2	2	2	2	5	-	4	7	2	9	7	3	8	-	17	4	4	6	8	12	12	14	4	7
Dark-eyed Junco	-	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
White-crowned Sparrow	-	3	3	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lapland Longspur	10	10	10	10	10	10	10	8	20	25	60	30	50	35	35	20	60	35	45	40	35	65	35	35	50	10	35
Snow Bunting	-	-	-	2	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 5. Continued

JUNE																JULY										
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	5	6	7	8	9	10	11
Yellow-billed Loon	-	-	3	1	1	-	-	-	2	-	-	-	1	1	-	-	-	-	-	-	-	-	3	-	2	1	1
Arctic Loon	-	-	8	8	4	6	6	2	6	2	2	-	7	4	3	2	6	5	6	2	7	5	7	4	6	4	8
Red-throated Loon	15	35	75	45	35	30	30	30	30	29	10	12	30	15	25	15	35	30	35	20	100	30	40	30	80	50	45
Red-necked Grebe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Whistling Swan	4	1	6	2	2	-	-	1	-	19	-	-	4	-	-	-	-	-	-	-	-	-	-	-	4	-	-
Canada Goose	-	-	3	2	-	6	-	-	-	-	-	-	-	-	-	-	2	-	-	-	6	3	-	-	-	-	-
Black Brant	16	8	5	25	1	-	-	-	10	-	-	-	-	-	11	-	-	-	-	-	-	-	10	-	-	-	8
Emperor Goose	3	2	22	18	25	15	14	13	9	10	-	5	22	2	7	2	12	6	9	-	16	3	20	10	14	3	-
White-fronted Goose	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Snow Goose	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mallard	6	-	5	2	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	-	-	1	1
Pintail	8	30	120	50	50	30	60	30	25	60	5	15	35	12	90	10	20	40	50	95	70	14	2	20	40	10	5
Green-winged Teal	1	6	7	3	-	4	-	1	-	-	-	2	2	-	-	-	-	2	-	-	-	2	1	-	-	-	4
American Wigeon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Northern Shoveler	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Redhead	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Canvasback	2	-	3	-	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Greater Scaup	3	10	20	13	8	11	12	10	7	-	1	1	3	-	2	1	1	2	-	-	2	6	5	1	1	-	2
Oldsquaw	10	25	40	30	30	35	30	30	25	20	5	5	40	15	30	20	25	45	45	20	45	30	40	35	35	30	35
Common Eider	30	50	115	135	145	65	100	60	40	60	10	20	95	25	60	30	80	130	85	30	60	35	95	235	290	450	90
King Eider	-	-	1	1	-	-	-	-	1	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1
Spectacled Eider	-	1	1	0	-	-	-	-	-	2	-	-	1	1	-	-	-	-	-	-	1	-	6	-	-	1	-
White-winged Scoter	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-
Surf Scoter	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20	-	-	-	-
Black Scoter	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Red-breasted Merganser	-	-	-	3	6	3	10	3	3	-	-	-	-	-	1	-	-	-	-	-	2	10	14	1	6	22	3
Goshawk	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-
Marsh Hawk	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Peregrine Falcon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Willow Ptarmigan	2	6	11	9	6	5	4	2	2	3	-	3	4	-	8	-	14	3	8	-	3	1	15	2	4	16	2
Sandhill Crane	-	8	18	20	20	11	10	8	14	12	4	5	25	6	16	6	14	18	16	8	30	14	25	14	30	20	16
American Golden Plover	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	1	-	1	1	-	-	-	-
Black-bellied Plover	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	2	-	-	-	-	-	2
Ruddy Turnstone	3	10	14	5	8	8	4	4	6	3	-	-	7	4	9	2	4	8	9	2	8	4	12	2	8	30	5
Black Turnstone	-	-	-	6	-	-	-	3	2	2	-	-	10	2	2	-	2	-	2	1	5	1	-	1	10	1	-
Common Snipe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Whimbrel	-	-	-	-	-	-	-	-	-	-	-	-	8	-	-	-	2	1	-	-	-	-	-	-	-	-	-
Bristle-thighed Curlew	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Red Knot	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sharp-tailed Sandpiper	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pectoral Sandpiper	1	3	9	6	6	1	-	3	2	2	-	3	6	2	2	3	10	15	18	20	240	10	20	11	15	41	10
Baird's Sandpiper	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dunlin	8	25	50	45	45	30	15	20	30	30	15	25	45	15	25	15	35	25	35	20	45	25	25	20	50	35	16
Semipalmated Sandpiper	10	40	80	45	50	40	30	30	35	40	15	16	55	25	40	25	40	40	40	30	40	35	35	25	30	25	35

Table 5. Continued

	JUNE																JULY										
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	5	6	7	8	9	10	11
Western Sandpiper	10	20	35	25	35	30	20	25	30	30	5	6	40	25	35	20	30	30	30	20	25	20	20	15	21	10	12
Sanderling	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Long-billed Dowitcher	4	4	10	8	15	8	6	6	10	8	2	2	9	4	6	4	8	8	8	6	6	9	9	10	30	40	6
Bar-tailed Godwit	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Hudsonian Godwit	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Red Phalarope	15	12	20	18	25	30	25	25	30	25	10	10	40	15	20	20	40	35	33	25	25	20	20	10	25	15	15
Northern Phalarope	12	20	50	55	50	50	40	35	45	40	15	20	50	25	35	30	50	35	40	30	60	35	50	30	50	35	25
Unidentified Small Shorebirds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20	-
Unidentified Medium Shorebirds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified Large Shorebirds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-
Pomarine Jaeger	-	4	-	1	2	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Parasitic Jaeger	6	15	38	37	40	20	14	16	24	21	10	14	19	10	18	12	20	18	20	10	45	17	30	18	26	28	4
Long-tailed Jaeger	-	3	3	2	4	1	-	1	2	-	2	-	13	1	5	2	4	2	3	-	-	-	-	-	2	2	10
Glaucous Gull	40	140	350	300	210	180	80	80	80	90	25	65	180	40	215	70	265	190	190	120	290	90	155	170	200	170	65
New Gull	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Black-legged Kittiwake	20	20	120	160	90	25	10	10	8	-	2	-	2	-	-	-	11	3	-	-	-	1	2	-	-	-	6
Sabine's Gull	4	20	25	23	30	15	16	16	20	20	-	-	16	15	25	15	16	30	16	15	35	26	25	20	30	35	25
Arctic Tern	20	50	20	90	50	30	30	40	40	35	5	10	85	25	90	30	120	55	70	40	115	32	55	65	80	75	35
Aleutian Tern	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Murre sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50	-	-	-	10	-	-
Tufted Puffin	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Snowy Owl	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Short-eared Owl	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Say's Phoebe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Horned Lark	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tree Swallow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bank Swallow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cliff Swallow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Common Raven	1	4	3	-	1	1	1	-	1	-	1	-	2	-	3	-	-	-	-	-	-	1	1	-	-	2	-
Wheatear	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arctic Warbler	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yellow Wagtail	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Orange-crowned Warbler	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Redpoll sp.	-	-	2	-	-	4	-	1	1	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	3	1	-
White-winged Crossbill	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Savannah Sparrow	7	10	10	12	10	6	5	-	4	2	4	7	10	3	2	-	8	8	10	-	15	3	15	2	6	6	3
Dark-eyed Junco	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
White-crowned Sparrow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lapland Longspur	10	30	55	55	60	30	20	35	35	30	10	20	40	15	30	15	30	30	35	20	55	25	35	25	30	30	15
Snow Bunting	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 5. Continued

	JULY																				AUGUST						
	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7
Yellow-billed Loon	1	-	-	-	-	1	1	2	3	1	3	2	3	1	2	-	-	2	-	2	-	-	-	-	8	8	-
Arctic Loon	-	10	10	8	9	8	10	7	7	4	4	5	7	4	9	6	10	7	3	6	-	3	5	6	12	18	6
Red-throated Loon	15	40	75	-	60	50	50	100	40	50	25	20	85	55	145	20	-	90	25	50	-	20	130	65	100	85	50
Red-necked Grebe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Whistling Swan	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Canada Goose	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Black Brant	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Emperor Goose	-	-	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
White-fronted Goose	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Snow Goose	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mallard	-	2	-	-	-	-	-	-	-	-	-	-	-	2	-	-	2	-	2	-	-	3	-	-	7	15	-
Pintail	5	14	8	-	14	80	50	20	8	10	2	5	280	35	60	100	15	55	45	80	-	50	70	80	145	150	65
Green-winged Teal	-	3	1	-	-	-	-	-	-	-	-	-	-	-	-	2	4	-	2	-	-	16	25	-	75	60	6
American Wigeon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Northern Shoveler	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Redhead	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Canvasback	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Greater Scaup	-	1	10	-	-	-	2	14	1	-	1	-	-	3	8	-	1	-	1	6	-	-	4	11	18	20	13
Oldsquaw	10	40	40	-	25	30	30	35	16	12	13	16	45	13	13	40	45	-	20	5	3	13	45	15	55	40	9
Common Eider	270	60	50	-	170	210	260	75	30	25	10	20	90	40	100	150	30	40	35	40	-	25	50	18	60	45	9
King Eider	-	-	1	-	-	1	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Spectacled Eider	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
White-winged Scoter	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Surf Scoter	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Black Scoter	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Red-breasted Merganser	-	-	8	-	8	1	1	40	3	-	-	-	1	3	-	-	-	1	-	-	-	-	-	-	-	-	-
Goshawk	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Marsh Hawk	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Peregrine Falcon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Willow Ptarmigan	-	1	2	-	6	6	1	1	-	22	7	2	8	1	9	-	-	2	13	10	-	10	2	3	5	13	2
Sandhill Crane	6	16	20	-	30	40	30	20	20	12	5	9	16	14	25	10	9	10	12	20	-	16	25	14	20	30	25
American Golden Plover	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	45	17	30	40
Black-bellied Plover	-	-	-	-	2	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	15
Ruddy Turnstone	1	9	10	-	11	8	14	11	5	4	1	1	9	1	-	2	-	-	-	3	-	3	3	3	11	7	6
Black Turnstone	-	-	-	-	-	-	3	1	-	-	-	-	-	5	4	-	1	-	2	-	-	2	11	-	1	-	3
Common Snipe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
Whimbrel	1	1	4	-	7	-	-	-	-	-	-	-	2	1	-	2	-	-	-	-	-	-	-	-	2	-	-
Bristle-thighed Curlew	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Red Knot	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	-	-	2
Sharp-tailed Sandpiper	-	-	-	-	-	-	-	-	1	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pectoral Sandpiper	-	15	105	-	40	65	30	60	20	20	10	15	30	1	45	50	-	25	15	60	-	20	35	35	80	100	85
Baird's Sandpiper	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-
Dunlin	6	25	25	-	50	90	1500	140	85	40	50	40	80	5	30	300	2	5	11	35	-	90	40	80	550	15	115
Semipalmated Sandpiper	2	25	20	-	30	25	25	50	25	15	15	20	50	5	25	30	-	15	7	3	-	-	-	4	10	1	-

Table 5. Continued

	JULY																				AUGUST						
	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7
Western Sandpiper	4	15	11	-	20	25	45	55	20	12	10	8	35	4	25	100	10	30	5	12	-	15	9	20	50	8	25
Sanderling	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2	-	-	-	-	-	-	-	-	-	-	-
Long-billed Dowitcher	-	20	8	-	11	12	7	75	8	6	15	2	6	15	5	45	1	5	6	12	-	5	7	6	21	13	8
Bar-tailed Godwit	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hudsonian Godwit	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Red Phalarope	1	20	25	-	14	30	12	8	14	6	5	5	8	2	4	8	2	1	1	1	-	-	-	2	3	-	-
Northern Phalarope	12	35	35	-	35	40	150	40	20	12	8	12	30	10	70	100	10	25	12	20	-	25	50	20	55	45	17
Unidentified Small Shorebirds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified Medium Shorebirds	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified Large Shorebirds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pomarine Jaeger	-	4	1	-	3	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Parasitic Jaeger	8	22	14	-	20	22	27	21	10	10	8	18	23	12	13	10	2	10	11	12	-	12	20	16	35	35	20
Long-tailed Jaeger	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Glaucous Gull	50	115	65	-	100	120	100	240	90	40	20	25	100	80	190	230	35	120	85	100	-	75	155	140	200	215	160
New Gull	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Black-legged Kittiwake	1	3	3	-	1	1	2	6	-	-	-	-	-	16	11	55	50	8	35	7	-	13	25	2	65	20	7
Sabine's Gull	2	20	30	-	45	30	25	20	40	25	20	20	25	1	8	1	1	20	11	15	-	12	16	3	12	14	3
Arctic Tern	30	35	40	-	85	90	65	260	40	20	20	20.	45	40	70	150	70	45	130	50	-	60	90	35	85	110	80
Aleutian Tern	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Murre sp.	-	-	-	-	-	-	-	-	-	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tufted Puffin	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Snowy Owl	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Short-eared Owl	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Say's Phoebe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Horned Lark	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tree Swallow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bank Swallow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cliff Swallow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Common Raven	-	1	-	-	-	-	-	-	1	-	2	1	-	1	-	-	-	-	-	-	-	-	-	-	-	2	-
Wheatear	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arctic Warbler	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yellow Wagtail	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	2	4	14	1	15	1
Orange-crowned Warbler	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Redpoll sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
White-winged Crossbill	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Savannah Sparrow	3	12	9	-	5	6	8	6	6	2	1	1	-	3	-	-	2	-	-	1	-	4	3	6	11	11	-
Dark-eyed Junco	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
White-crowned Sparrow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lapland Lonspur	8	25	30	-	25	40	40	35	25	12	10	12	25	45	45	30	15	30	13	110	-	45	60	80	110	130	120
Snow Bunting	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 5. Continued

	AUGUST																								SEPTEMBER		
	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3
Yellow-billed Loon	1	1	-	1	-	1	-	-	1	-	-	1	-	3	1	1	-	-	1	-	2	-	-	3	-	2	1
Arctic Loon	-	-	5	4	-	5	3	10	10	2	6	6	8	11	13	7	3	3	5	15	7	7	11	-	-	-	9
Red-throated Loon	30	40	45	25	8	20	45	-	40	15	40	25	35	46	40	45	40	12	60	25	60	20	15	20	-	8	15
Red-necked Grebe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Whistling Swan	-	-	-	-	-	-	-	-	2	-	-	5	-	-	-	-	-	-	-	-	-	2	6	-	-	-	-
Canada Goose	-	-	-	-	-	-	-	-	-	-	-	-	-	20	20	-	-	-	-	-	30	6	50	12	-	-	-
Black Brant	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18	3	-	16	40	80	-	-	-	45
Emperor Goose	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	-	20	40	-	5	45
White-fronted Goose	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Snow Goose	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18	-	-	-	-	-	-
Mallard	-	-	2	2	-	-	-	-	-	-	2	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-
Pintail	30	5	30	16	4	50	50	-	25	20	60	100	40	35	20	30	35	6	20	15	45	20	20	30	-	3	10
Green-winged Teal	10	3	8	8	-	1	-	6	4	2	6	5	4	9	6	2	4	4	5	5	8	-	-	4	-	-	8
American Wigeon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Northern Shoveler	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Redhead	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Canvasback	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Greater Scaup	13	12	13	13	7	-	-	-	6	6	-	6	-	-	9	-	6	-	6	6	-	-	8	-	-	6	6
Oldsquaw	5	3	3	5	1	4	1	-	-	-	15	-	-	-	-	-	-	-	3	7	8	-	-	2	-	3	3
Common Eider	7	27	-	2	-	4	1	1	1	1	10	1	-	10	-	-	1	-	-	2	-	-	-	-	-	-	-
King Eider	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Spectacled Eider	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
White-winged Scoter	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Surf Scoter	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Black Scoter	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Red-breasted Merganser	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Goshawk	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	2	-	-	1
Marsh Hawk	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	1	-	1	-	-	-
Peregrine Falcon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Willow Ptarmigan	1	-	10	2	-	1	3	8	13	-	4	-	8	20	8	-	10	-	8	-	9	10	6	20	-	-	4
Sandhill Crane	15	2	18	13	6	8	14	6	12	6	25	12	17	25	18	18	13	4	14	13	35	10	10	15	-	10	19
American Golden Plover	20	9	40	25	5	70	75	35	70	20	30	50	30	60	20	30	20	15	25	80	125	60	40	50	-	45	120
Black-bellied Plover	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ruddy Turnstone	3	9	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Black Turnstone	-	15	-	-	-	-	4	-	-	6	6	-	-	6	-	8	3	-	-	1	-	-	-	-	-	-	-
Common Snipe	-	-	1	-	-	-	-	-	1	1	-	1	1	1	-	1	-	-	1	-	-	-	-	-	-	-	-
Whimbrel	-	-	10	7	-	30	15	17	13	-	35	25	60	20	1	1	9	-	35	3	9	-	2	7	-	-	-
Bristle-thighed Curlew	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Red Knot	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	2	-	-	-	-	-	-	-	-
Sharp-tailed Sandpiper	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Pectoral Sandpiper	50	10	40	35	12	45	50	20	45	10	20	25	30	50	20	40	35	10	20	20	60	30	30	20	-	10	-
Baird's Sandpiper	-	3	-	-	-	-	-	-	-	1	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dunlin	55	65	40	30	-	40	30	-	45	10	30	25	25	150	20	6	45	10	15	10	100	10	30	55	-	-	20
Semipalmated Sandpiper	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 5 Continued

	AUGUST																								SEPTEMBER		
	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3
Western Sandpiper	1	-	8	6	-	-	-	-	-	-	10	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sanderling	-	-	1	7	-	-	4	-	3	15	6	5	1	6	1	25	1	-	4	3	15	6	-	1	2	-	2
Long-billed Dowitcher	5	-	12	8	1	6	-	2	20	1	3	2	1	1	1	2	1	-	1	20	35	2	15	25	-	10	25
Bar-tailed Godwit	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	2	-	-	-
Hudsonian Godwit	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Red Phalarope	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Northern Phalarope	8	-	2	6	2	1	-	-	2	2	50	5	1	1	-	-	-	-	-	-	2	-	3	2	-	-	2
Unidentified Small Shorebirds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified Medium Shorebirds	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60	-	-	-	-	-	-	-	-
Unidentified Large Shorebirds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pomarine Jaeger	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Parasitic Jaeger	18	13	16	12	6	8	12	7	11	4	18	11	16	20	17	16	15	8	13	13	22	10	10	12	-	4	4
Long-tailed Jaeger	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10
Glaucous Gull	70	100	70	70	35	30	80	30	90	100	140	80	50	60	90	110	85	25	60	100	115	50	50	40	-	35	80
Mew Gull	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Black-legged Kittiwake	-	10	8	10	-	4	8	-	4	60	110	-	-	15	20	30	-	5	-	-	-	-	-	-	-	-	-
Sabine's Gull	4	3	-	3	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arctic Tern	40	90	35	50	10	20	30	4	28	50	50	20	35	30	15	10	8	8	8	5	5	-	15	3	-	-	-
Aleutian Tern	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Murre sp.	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tufted Puffin	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Snowy Owl	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	1	-	-	-
Short-eared Owl	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Say's Phoebe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Horned Lark	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tree Swallow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bank Swallow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cliff Swallow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Common Raven	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	-	3	-	-	1	2	3	1	1	-	2	-
Wheatear	-	-	-	6	3	3	-	1	-	-	-	-	-	-	-	-	2	-	-	-	2	-	-	-	-	-	-
Arctic Warbler	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yellow Wagtail	-	2	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Orange-crowned Warbler	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Redpoll sp.	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
White-winged Crossbill	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Savannah Sparrow	3	-	5	3	5	-	2	3	6	2	4	3	1	1	-	-	2	-	3	-	-	-	-	-	-	-	-
Dark-eyed Junco	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
White-crowned Sparrow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lapland Longspur	55	90	40	25	15	-	50	60	65	30	30	35	35	45	30	50	60	20	40	25	40	20	15	20	-	-	12
Snow Bunting	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 5. Continued

SEPTEMBER

	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Yellow-billed Loon	1	-	-	2	1	2	6	1	1	1	2	-	1	1	4	3	2	-	-	-	2
Arctic Loon	12	-	-	7	7	10	4	10	6	3	14	-	8	5	10	5	3	2	15	-	4
Red-throated Loon	20	-	-	12	18	35	13	4	-	1	4	-	5	-	2	2	-	-	-	-	-
Red-necked Grebe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Whistling Swan	6	-	-	-	2	-	-	8	-	-	2	-	6	-	8	-	-	6	11	-	15
Canada Goose	200	-	-	-	31	18	10	9	50	13	35	-	-	-	-	-	-	-	-	-	-
Black Brant	-	-	-	50	-	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Emperor Goose	80	-	-	30	65	40	20	40	25	12	55	-	55	5	50	10	4	-	7	-	-
White-fronted Goose	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Snow Goose	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mallard	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pintail	10	-	-	2	-	10	20	10	-	-	10	-	10	-	3	1	-	20	10	-	2
Green-winged Teal	4	-	-	2	5	2	5	4	7	-	3	-	2	1	2	6	-	7	-	2	-
American Wigeon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Northern Shoveler	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Redhead	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Canvasback	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Greater Scaup	12	-	-	6	6	8	8	10	2	-	-	-	-	-	4	-	-	-	-	-	3
Oldsquaw	3	-	-	3	3	7	3	-	-	-	17	-	6	-	6	-	-	7	-	-	7
Common Eider	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1
King Eider	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Spectacled Eider	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
White-winged Scoter	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Surf Scoter	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Black Scoter	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Red-breasted Merganser	-	-	-	30	170	-	14	1	-	-	-	-	-	-	2	2	-	-	18	-	8
Goshawk	3	-	-	2	-	1	1	-	-	1	1	-	-	-	2	-	-	1	-	-	-
Marsh Hawk	-	-	-	-	2	-	-	-	1	2	-	-	-	-	-	-	-	-	-	-	-
Peregrine Falcon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Willow Ptarmigan	7	-	-	-	-	9	-	-	-	-	12	-	-	-	-	-	-	-	-	1	-
Sandhill Crane	30	-	-	5	15	20	13	30	2	-	14	-	-	-	-	-	-	-	-	-	-
American Golden Plover	70	-	-	1	12	100	25	40	15	5	20	-	4	4	30	10	5	15	-	-	20
Black-bellied Plover	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ruddy Turnstone	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Black Turnstone	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Common Snipe	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Whimbrel	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bristle-thighed Curlew	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Red Knot	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sharp-tailed Sandpiper	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Pectoral Sandpiper	-	-	-	-	-	20	20	2	1	-	-	-	1	-	1	-	-	-	-	-	-
Baird's Sandpiper	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dunlin	70	-	-	50	20	20	150	50	10	10	55	-	5	30	150	20	20	60	70	20	120
Semipalmated Sandpiper	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 5. Continued

SEPTEMBER

	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Western Sandpiper	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sanderling	1	-	-	-	-	-	9	4	-	-	-	-	-	-	2	2	2	6	2	2	10
Long-billed Dowitcher	45	-	5	-	2	1	-	30	-	-	20	-	1	-	2	-	-	-	-	-	-
Bar-tailed Godwit	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hudsonian Godwit	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Red Phalarope	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-
Northern Phalarope	-	-	-	1	-	-	-	-	-	-	-	-	1	-	6	-	-	19	35	-	250
Unidentified Small Shorebirds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified Medium Shorebirds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified Large Shorebirds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pomarine Jaeger	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Parasitic Jaeger	4	-	-	7	4	4	1	1	-	1	1	-	-	-	1	-	-	-	-	-	-
Long-tailed Jaeger	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Glaucous Gull	95	-	-	145	200	40	220	65	50	50	30	-	170	20	220	15	16	70	50	50	220
Mew Gull	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Black-legged Kittiwake	-	20	-	5	-	-	20	100	-	250	40	-	-	-	2	-	-	-	-	-	-
Sabine's Gull	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arctic Tern	16	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aleutian Tern	-	-	-	-	-	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Murre sp.	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tufted Puffin	-	-	-	-	-	-	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Snowy Owl	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-
Short-eared Owl	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Say's Phoebe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Horned Lark	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tree Swallow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bank Swallow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cliff Swallow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Common Raven	-	-	-	-	1	1	-	3	-	2	-	-	2	-	-	-	-	-	-	-	-
Wheatear	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arctic Warbler	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yellow Wagtail	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Orange-crowned Warbler	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Redpoll sp.	-	-	-	-	-	-	-	-	-	-	-	-	15	-	100	-	-	-	-	-	-
White-winged Crossbill	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Savannah Sparrow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dark-eyed Junco	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
White-crowned Sparrow	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lapland Longspur	17	-	-	-	10	5	4	6	2	3	5	-	2	-	2	-	-	1	1	-	-
Snow Bunting	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	6	13	250

Table 6. Productivity, occurrence, and habitat use of birds, 1976-1977, Cape Espenberg, Alaska.

Species	Estimated Number of Chicks Produced[1] 1976	1977	OCCURRENCE[2] Spring[3]	Summer[3]	Fall[3]	Nearshore Coastal Waters[4]	Bay Waters[4]	Outer Beach Tideflats[4]	Inner Beach Mudflats[4]	Sandy Outer Beach[4]	Driftwood Along Coast[4]	Driftwood Along Bay[4]	TOTAL NEARSHORE[4]	Outer Sand Dune[4]	Tundra Ridge[4]	Marsh and Tussocks[4]	TOTAL ONSHORE[4]
Yellow-billed Loon	-	4	10s	10s	1s	1s	10s	-	-	-	-	-	10s	-	-	10s	10s
Arctic Loon	12	20	10s	10s	10s	10s	10s	-	-	-	-	-	10s	-	-	10s	10s
Red-throated Loon	60	125	100s	100s	100s	10s	100s	-	-	-	-	-	100s	10s	-	100s	100s
Whistling Swan	-	-	10s	1s	1s	-	1s	-	-	-	-	-	1s	-	-	10s	10s
Canada Goose	10	6	1s	1s	100s	100s	-	-	-	-	-	-	100s	-	10s	10s	~100
Black Brant	-	-	10s	10s	10s	10s	-	-	-	-	-	-	10s	-	1s	1s	1s
Emperor Goose	70	70	10s	10s	100s	100s	10s	-	10s	-	-	-	100s	-	10s	10s	10s
Snow Goose	-	-	10s	-	10s	-	-	-	-	-	-	-	-	-	-	10s	10s
Mallard	-	-	10s	1s	1s	-	-	-	-	-	-	-	-	-	-	10s	10s
Pintail	5	-	100s	10s	1000s	-	-	-	1000s	-	-	-	1000s	-	-	100s	100s
Green-winged Teal	-	-	1s	1s	1s	-	-	-	-	-	-	-	-	-	-	1s	1s
American Wigeon	-	-	10	-	1s	-	-	-	-	-	-	-	-	-	-	1s	1s
Northern Shoveler	-	-	1s	1s	1s	-	-	-	-	-	-	-	-	-	-	1s	1s
Canvasback	-	-	1s	1s	-	-	-	-	-	-	-	-	-	-	-	1s	1s
Greater Scaup	100	150	10s	10s	10s	-	-	-	-	-	-	-	-	-	-	10s	10s
Oldsquaw	350	250	100s	100s	10s	10s	10s	-	-	-	-	-	100s	-	10s	100s	100s
Common Eider	3000	3500	1000s	1000s	10s	100s	100s	100s	100s	100s	-	-	1000s	10s	10s	1000s	1000s
King Eider	-	-	10s	10s	10s	1s	1s	1s	1s	-	-	-	10s	-	-	10s	10s
Spectacled Eider	40	40	10s	10s	10s	-	10s	-	10s	-	-	-	10s	-	-	10s	10s
Surf Scoter	-	-	-	100s	-	100s	-	-	-	-	-	-	100s	-	-	-	-
Red-breasted Merganser	-	-	10s	10s	1s	10s	-	-	-	-	-	-	10s	-	-	10s	10s
Goshawk	-	-	-	-	1s	-	-	-	-	-	-	-	-	1s	-	-	1s
Marsh Hawk	-	-	1s	-	1s	-	-	-	-	-	-	-	-	-	-	1s	1s
Willow Ptarmigan	200	200	10s	~100	10s	-	-	-	-	-	-	1s	1s	10s	10s	10s	10s

Table 6. Continued

Species	Estimated Number of Chicks Produced[1] 1976	1977	OCCURRENCE[2] Spring[3]	Summer[3]	Fall[3]	Nearshore Coastal Waters[4]	Bay Waters[4]	Outer Beach Tideflats[4]	Inner Beach Mudflats[4]	Sandy Outer Beach[4]	Driftwood Along Coast[4]	Driftwood Along Bay[4]	TOTAL NEARSHORE[4]	Outer Sand Dune[4]	Tundra Ridge[4]	Marsh and Tussocks[4]	TOTAL ONSHORE[4]
Sandhill Crane	25	30	10s	10s	10s	-	1s	1s	1s	1s	1s	1s	10s	10s	10s	10s	10s
American Golden Plover	-	-	1s	1s	10s	-	-	-	10	-	-	-	10	-	10s	10s	10s
Black-bellied Plover	-	4	1s	1s	1s	-	-	-	1s	-	-	-	1s	-	1s	1s	1s
Ruddy Turnstone	80	80	10s	~100	10s	-	-	1s	1s	1s	1s	1s	10	-	~100	-	10s
Black Turnstone	40	40	1s	10s	10	-	-	1s	10	10	10	1s	10	-	1s	1s	1s
Common Snipe	-	-	-	1s	1s	-	-	-	-	-	-	-	-	1s	-	1s	1s
Whimbrel	-	-	1s	10s	10s	-	-	10s	10s	-	-	-	10s	10s	10s	10s	10s
Bristle-thighed Curlew	-	-	-	1s	1s	-	-	1s	1s	-	-	-	1s	-	1s	1s	1s
Red Knot	-	-	-	-	1s	-	-	1s	1s	-	-	-	1s	-	-	-	-
Sharp-tailed Sandpiper	-	-	-	-	10s	-	-	-	1s	-	-	-	1s	-	-	10s	10s
Pectoral Sandpiper	-	16	1s	10s	100s	-	-	1s	1s	-	-	-	1s	-	-	100s	100s
Baird's Sandpiper	-	-	-	1s	1s	-	-	1s	1s	-	-	1s	1s	-	-	1s	1s
Dunlin	1000	800	100s	~1000	1000s	-	-	10s	1000s	10s	100s	100s	1000s	-	100s	~1000	1000s
Semipalmated Sandpiper	2000	1500	100s	1000s	1000s	-	-	10s	1000s	10s	10s	100s	1000s	100s	100s	~1000	100s
Western Sandpiper	900	1500	100s	~1000	1000s	-	-	10s	1000s	10s	10s	10s	1000s	-	100s	~1000	100s
Sanderling	-	-	-	-	10s	-	1s	10s	10s	10s	10s	10s	10s	-	-	-	-
Long-billed Dowitcher	200	250	10s	100s	10s	-	-	-	10s	-	-	-	10s	-	-	100s	10s
Bar-tailed Godwit	-		-	-	1s	-	-	1s	1s	-	-	-	1s	-	-	1s	1s
Hudsonian Godwit	-	-	-	-	1s	-	-	-	-	-	-	-	-	-	-	1s	1s
Red Phalarope	1500	1500	100s	~1000	10s	10s	100s	10s	100s	-	-	-	100s	-	-	~1000	100s
Northern Phalarope	3000	3000	1000s	1000s	1000s	10s	100s	10s	100s	-	-	-	100s	10s	-	1000s	1000s
Pomarine Jaeger	-	-	1s	1s	-	1s	-	-	-	-	-	-	1s	-	-	-	-
Parasitic Jaeger	34	34	10s	10s	10s	10	10	10	10	-	-	-	10s	-	10s	10s	10s
Long-tailed Jaeger	-	-	10s	10s	10s	-	-	-	-	-	-	-	-	-	10s	1s	10s
Glaucous Gull	500	600	100s	100s	100s	100s	100s	100s	100s	10s	10s	10s	100s	10s	10s	100s	100s
Mew Gull	-	-	-	-	1s	1s	1s	-	-	-	-	-	1s	-	-	-	-
Black-legged Kittiwake	-	-	10s	10s	10s	10s	10s	1s	-	-	-	-	10s	-	-	-	-

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Table 6. Continued

Species	Estimated Numbers of Chicks Produced[1] 1976	1977	OCCURRENCE[2] Spring[3]	Summer[3]	Fall[3]	Nearshore Coastal Waters[4]	Bay Waters[4]	Outer Beach Tideflats[4]	Inner Beach Mudflats[4]	Sandy Outer Beach[4]	Driftwood Along Coast[4]	Driftwood Along Bay[4]	TOTAL NEARSHORE[4]	Outer Sand Dune[4]	Tundra Ridge[4]	Marsh and Tussocks[4]	TOTAL ONSHORE[4]
Sabine's Gull	70	60	10s	~100	1s	10s	10s	10s	1s	-	-	-	10s	-	-	~100	10s
Arctic Tern	350	250	100s	100s	10s	100s	100s	100s	100s	10s	10s	10s	100s	1s	10s	100s	100s
Aleutian Tern	-	-	-	-	1s	1s	-	-	-	-	-	-	1s	-	-	-	-
Common Murre	-	-	10s	10s	10s	10s	-	-	-	-	-	-	10s	-	-	-	-
Thick-billed Murre	-	-	10s	10s	10s	10s	-	-	-	-	-	-	10s	-	-	-	-
Horned Puffin	-	-	1s	1s	-	1s	-	-	-	-	-	-	1s	-	-	-	-
Tufted Puffin	-	-	10s	10s	-	10s	-	-	-	-	-	-	10s	-	-	-	-
Snowy Owl	-	-	-	-	1s	-	-	-	-	-	-	-	-	-	1s	1s	1s
Short-eared Owl	-	-	1s	1s	1s	-	-	-	-	-	-	-	-	1s	1s	1s	1s
Say's Phoebe	-	-	1s	-	1s	-	-	-	-	-	-	-	-	1s	1s	-	1s
Tree Swallow	-	-	-	1s	-	-	-	-	-	-	-	-	-	1s	-	-	1s
Bank Swallow	-	-	-	1s	-	-	-	-	-	-	-	-	-	1s	-	-	1s
Common Raven	-	-	1s	1s	1s	-	-	-	-	1s	-	-	1s	-	1s	-	1s
Wheatear	-	-	1s	-	1s	-	-	-	-	-	-	-	-	-	1s	-	1s
Arctic Warbler	-	-	1s	-	1s	-	-	-	-	-	-	-	-	-	1s	-	1s
Yellow Wagtail	-	-	1s	-	1s	-	-	-	-	-	-	-	-	-	1s	-	1s
Redpoll sp.	5	-	10s	10s	10s	-	-	-	-	-	-	-	-	-	10s	-	10s
Savannah Sparrow	200	250	10s	100s	10s	-	-	-	-	-	-	-	-	-	10s	~100	10s
White-crowned Sparrow	-	-	1s	-	1s	-	-	-	-	-	-	-	-	-	1s	-	1s
Lapland Longspur	1000	1600	100s	100s	100s	-	-	10s	10s	10s	100s	10s	100s	10s	100s	100s	100s
Snow Bunting	-	-	1s	-	100s	-	-	-	-	10s	100s	-	100s	100s	-	-	100s

[1] We estimated the number of chicks hatched on the Cape from our data on nesting densities, clutch sizes, hatching, success, and amounts of different types of habitat. We could not estimate the number of fledglings because of a lack of good data on fledging success for most species.

[2] Estimated maximum number of birds present at any one time (not cumulative).

[3] Spring:arrival; Summer:nest construction, egg laying, incubation, hatching, brood rearing; Fall:post-breeding. Calendar dates for these seasonal events will vary for each bird species.

[4] Estimated maximum number of birds present at any one time during the season of peak use.

Table 7. Avian habitat utilization for Cape Espenberg, 1976 and 1977.

Species N = Nest Site B = Feeding Site during Breeding Season R = Brood-rearing Resting Site F = Brood-rearing Feeding Site M = Migration Resting Site S = Migration Feeding Site	Nearshore Coastal Waters	Bay Waters	Outer Beach Tideflats	Inner Beach Mudflats	Sandy Outer Beach	Driftwood Along Shore	Outer Sand Dune	Tundra Ridge	Marsh and Tussocks	Sedge-Saltgrass Meadow
Yellow-billed Loon	-	BMS	-	-	-	-	-	-	NRM	-
Arctic Loon	BRFMS	BRFMS	-	-	-	-	-	-	NBRFMS	-
Red-throated Loon	BRFMS	BRFMS	-	-	-	-	-	-	NRFM	-
Whistling Swan	-	M	-	-	-	-	-	M	MS	-
Canada Goose	-	-	-	MS	-	-	-	RM	NBRFM	BRFMS
Black Brant	-	RFMS	-	BRFMS	-	-	-	BRFMS	NBRFMS	BRFMS
Emperor Goose	-	RFMS	-	BRFMS	-	-	-	MS	NBMS	MS
Snow Goose	-	-	-	-	-	-	-	-	-	-
Mallard	-	-	-	-	-	-	-	-	MS	-
Pintail	-	BMS	-	MS	-	-	NRFMS	N	NBRFMS	MS
Green-winged Teal	-	-	-	-	-	-	NMS	-	NBRFMS	-
American Wigeon	-	-	-	-	-	-	-	-	MS	-
Northern Shoveler	-	-	-	-	-	-	-	-	MS	-
Canvasback	-	-	-	-	-	-	-	-	MS	-
Greater Scaup	-	-	-	-	-	-	RFMS	-	NBRFMS	-
Oldsquaw	BMS	BMS	M	-	-	N	NRFMS	N	NBRFMS	-
Common Eider	BRFMS	BRFMS	RM	RFMS	-	-	NRF	M	NBRFMS	-
King Eider	BMS	BMS	-	MS	-	-	-	-	NBMS	-
Spectacled Eider	BMS	BRFMS	M	RFMS	-	-	-	-	NBRFMS	-
Surf Scoter	MS	-	-	-	-	-	-	-	-	-
Red-breasted Merganser	MS	MS	-	-	-	-	-	-	MS	-
Goshawk	-	-	-	-	-	-	M	-	M	-
Marsh Hawk	-	-	-	-	-	-	-	-	MS	-
Willow Ptarmigan	-	-	-	-	-	FS	BRFMS	NBRFMS	NBRFMS	-

Table 7. Continued

Species N = Nest Site B = Feeding Site during Breeding Season R = Brood-rearing Resting Site F = Brood-rearing Feeding Site M = Migration Resting Site S = Migration Feeding Site	Nearshore Coastal Waters	Bay Waters	Outer Beach Tideflats	Inner Beach Mudflats	Sandy Outer Beach	Driftwood Along Shore	Outer Sand Dune	Tundra Ridge	Marsh and Tussocks	Sedge-Saltgrass Meadow
Sandhill Crane	-	BS	BFS	BFS	BF	BFS	BRFMS	BRFMS	NBRFMS	BFS
American Golden Plover	-	-	-	S	-	-	-	MS	NMS	MS
Black-bellied Plover	-	-	-	S	-	-	-	NMS	F	MS
Ruddy Turnstone	-	-	BRFMS	BRFMS	BRFMS	BRFMS	-	NBRF	-	-
Black Turnstone	-	-	MS	MS	MS	MS	-	N	NBRFMS	BRFMS
Common Snipe	-	-	-	-	-	-	MS		MS	-
Whimbrel	-	-	MS	MS	-	-	MS	MS	MS	-
Bristle-thighed Curlew	-	-	MS	MS	-	-	-	MS	MS	-
Red Knot	-	-	MS	MS	-	-	-	-	-	-
Sharp-tailed Sandpiper	-	-	-	MS	-	-	-	-	MS	-
Pectoral Sandpiper	-	-	MS	MS	-	-	-	-	NBRFMS	MS
Baird's Sandpiper	-	-	MS	MS	-	MS	-	-	-	MS
Dunlin	-	-	MS	MS	MS	MS	-	M	NBRFMS	RFMS
Semipalmated Sandpiper	-	-	BMS	BMS	MS	MS	NB	NBRFMS	NBRFMS	RFMS
Western Sandpiper	-	-	MS	BMS	MS	MS	-	NBRFMS	NBRFMS	RFMS
Sanderling	-	-	MS	MS	MS	MS	-	-	-	-
Long-billed Dowitcher	-	-	-	MS	-	-	-	-	NBRFMS	RFMS
Bar-tailed Godwit	-	-	MS	MS	-	-	-	-	MS	-
Hudsonian Godwit	-	-	-	-	-	-	-	-	MS	-
Red Phalarope	MS	MS	MS	MS	-	-	-	-	NBRFMS	MS
Northern Phalarope	MS	MS	MS	MS	-	-	NBRFMS	-	NBRFMS	MS
Pomarine Jaeger	S	-	-	-	-	-	-	-	-	-
Parasitic Jaeger	S	S	MS	MS	M	-	-	NBRMS	NBRFMS	NBRFMS
Long-tailed Jaeger	S	-	-	-	-	-	-	MS	MS	-

Table 7. Continued

Species N = Nest Site B = Feeding Site during Breeding Season R = Brood-rearing Resting Site F = Brood-rearing Feeding Site M = Migration Resting Site S = Migration Feeding Site	Nearshore Coastal Waters	Bay Waters	Outer Beach Tideflats	Inner Beach Mudflats	Sandy Outer Beach	Driftwood Along Shore	Outer Sand Dune	Tundra Ridge	Marsh and Tussocks	Sedge-Saltgrass Meadow
Glaucous Gull	BRFMS	BRFMS	BRFMS	BRFMS	BRFMS	BRFMS	RM	RM	NBRFMS	NRF
Mew Gull	S	S	-	-	-	-	-	-	-	-
Black-legged Kittiwake	BMS	S	M	-	-	-	-	-	-	-
Sabine's Gull	BS	BS	BS	BS	-	-	-	-	NBRF	-
Arctic Tern	BS	BS	BRFMS	BRFMS	RFM	NRM	R	NR	NBRF	NRF
Aleutian Tern	S	-	-	-	-	-	-	-	-	-
Common Murre	MS	-	-	-	-	-	-	-	-	-
Thick-billed Murre	MS	-	-	-	-	-	-	-	-	-
Horned Puffin	MS	-	-	-	-	-	-	-	-	-
Tufted Puffin	MS	-	-	-	-	-	-	-	-	-
Snowy Owl	-	-	-	-	-	-	MS	MS	MS	-
Short-eared Owl	-	-	-	-	-	-	MS	MS	MS	-
Say's Phoebe	-	-	-	-	-	-	MS	MS	-	-
Tree Swallow	-	-	-	-	-	-	MS	-	-	-
Bank Swallow	-	-	-	-	-	-	MS	-	-	-
Common Raven	-	-	-	-	-	-	MS	MS	-	-
Wheatear	-	-	-	-	-	-	-	MS	-	-
Arctic Warbler	-	-	-	-	-	-	MS	MS	-	-
Yellow Wagtail	-	-	-	-	-	-	MS	MS	-	-
Redpoll sp.	-	-	-	-	-	NB	MS	-	-	-
Savannah Sparrow	-	-	-	-	-	-	-	BRFMS	NBRFMS	-
White-crowned Sparrow	-	-	-	-	-	-	MS	MS	-	-
Lapland Longspur	-	-	MS	BMS	MS	BRFMS	NBRFMS	NBRFMS	NBRFMS	MS
Snow Bunting	-	-	-	-	MS	MS	MS	MS	MS	-

Cape, with an emphasis on the littoral habitats.

Nearshore coastal waters refer to the Chukchi Sea up to 2 km north of Cape Espenberg. This habitat was ice-bound until 18 July 1976. Leads were present by mid-June. In 1977, nearly all the ice was gone by 3 July. Bay waters include those to the south of Cape Espenberg, in Kotzebue Sound, and will be designated as Espenberg Bay. These waters are shallow, generally less than 70 cm, but are deeper during periods of high tides and winds from the east and south. Generally, both the nearshore coastal waters of the Chukchi Sea and waters of Espenberg Bay are calm while the ice pack is present, and during calm weather. Once the ice disintegrates, wave action is common. Relatively calm waters occur on the lee side of Cape Espenberg unless winds exceed 25 knots.

The outer beach tideflat is a narrow zone between high and low tides, which generally fluctuate no more than 30 cm (USGS map). Since the sandy beach is on a moderate gradient, this intertidal zone is only a few meters wide. Where small streams enter the coast, a tideflat of up to 4 m may be exposed at low tide. The outer beach tideflat is sandy and subject to much wave action during storms, after the ice has disintegrated. Hence it harbors a lower diversity and generally less food for birds compared with the inner beach tideflats.

In contrast, the inner beach tideflats of Espenberg Bay are richer in invertebrates because they are composed of mud and are influenced less by storms. The mudflats are on a low gradient and may extend for 20 m or more, depending on tides and winds in Espenberg Bay.

One large slough serves as the west boundary of our Cape Espenberg study area (Fig. 2). This slough is tidal to only a minor extent. In 1976 and 1977 its north mouth was plugged by sand, most likely deposited by storms. According to Fred Goodhope, Jr., this slough is open most years.

The sandy outer beach is that zone from the high tide mark to the vegetated dunes on the north side of Cape Espenberg. It consists of almost pure sand, however debris does wash ashore. Based on the accumulation of drift wood, prevailing winds, and plant succession, the outer beach is building northward. Hence there is an unstable intertidal area which is being buried constantly. Data on sediment transport and deposition is being collected by OCSEAP investigator Jan Cannon (pers. comm.).

Driftwood accumulates along the storm zone of the outer sandy beach and to a much lesser extent on the beach along Espenberg Bay. These accumulations of logs, limbs, and litter provide shelter for such pioneering plants as *Honckenya peploides* and *Elymus arenarius*.

The outer sand dunes, tundra ridges, marsh and tussock habitats have been described under Description of the Study Area.

Of the nearshore habitats, coastal waters, bay waters, and inner beach mudflats receive the most use by birds (Tables 6 and 7). This is to be expected, since 16 species are considered to be marine and many other species feed at sea or on intertidal mudflats. In spring many of these birds are initially dependent upon open leads which are the only feeding and/or resting sites available until ice melts in ponds and marshes. Coastal and bay waters continue to serve as feeding and resting sites at least through late September. Once ice disintegrates and/or is carried off by currents and wind (mid or late June), the mudflats of Espenberg Bay have even greater use. Geese, dabbling ducks, and occasional shorebirds feed and rest on the mudflats during the breeding and brood-rearing season.

The sandy outer beach and the driftwood zone around Cape Espenberg were used predominately by resting shorebirds, gulls, terns, and Lapland Longspurs (Tables 6 and 7). Sandhill Cranes, some shorebirds and Lapland Longspurs foraged in these areas. Ruddy Turnstones set up territories around beached walrus carcasses where they fed on fly pupae. Glaucous Gulls fed on the remains of walrus and other mammal and bird carcasses washed ashore. Only Arctic Terns, at least one Oldsquaw, and one Redpoll were known to nest in the driftwood zone.

Outer sand dunes were least used by birds (Tables 6 and 7). Of the few species using sand dunes, most roosted on them. Willow Ptarmigan, Whimbrels, Bristle-thighed Curlews, Sandhill Cranes and Glaucous Gulls fed on insects and berries on the dunes. Lapland Longspurs, Semiplamated Sandpipers, and a few waterfowl (Table 24) nested amongst beachgrass of the outer sand dunes.

In contrast, greater use was made of tundra ridges for nest sites. At least 11 species nested on tundra ridges (Table 7). Geese, some shorebirds, Long-tailed Jaegers, and passerines fed on berries and/or insects available on the tundra. Tundra ridges and associated sand dunes and blowouts also were used as den sites for Red Foxes and Arctic Ground Squirrels.

Marsh and tussock habitats was utilized by 30 out of 34 nesting species (Table 7). Marshes provided a variety of nesting habitats including: hummocks, peninsulas, islands, and a mosaic of water and land. Hummocks, and islands often were selected by eiders, gulls, and terns as nesting sites. These sites were less accessible to foxes, thus were more secure from predation and more likely to be successful.

One island in the large lake in southwest section 32 (Fig. 3) was the site of a colony of nesting Common Eiders and Arctic Terns. This island was 10 x 100 m and vegetated with various forbs, grasses, sedges, and dwarf willows. A maximum of 272 Common Eider nests was counted in 1976. In 1977, 323 eider nests were counted.

Other aggregations in marshes were recorded for nesting Common Eiders, Glaucous Gulls, Sabine's Gulls, and Arctic Terns. These species preferred to nest on islands or peninsulas at ponds and lakes or on hummocks in the marsh. High densities of nesting Red and Northern Phalaropes also were found in marshes. Marshes served as feeding sites for most non-pelagic species. Nesting shorebirds, and later their young, fed extensively in marsh habitat.

Sedge-saltgrass meadows served as feeding and resting sites for geese and some insectivorous shorebirds (Table 7). The total area of these meadows was very small and use was minimal. We did see goose dung and cropped sedges, which indicate previous use of this habitat. Judging from observations on the Yukon-Kuskokwim Delta (Mickelson 1975), we expected greater use by geese and brant. However, most of these birds left the study area after nest termination.

Additional information on occurrence, abundance, and habitat use is given in the following sections.

Bird Census Transects

The results from the census transects and daily bird observations are discussed by species below.

Arctic Loons. Arctic Loons nest on the edges of medium-sized, deep lakes on the Cape. These lakes thaw after the shallow ponds, but before the largest and deepest lakes. Primarily due to unavailable habitat, Arctic Loons were not noted on the Cape until early June (Figs. 6, 7 and 8). Most Arctic Loons observed on the transects were flying. Feeding was noted only on the sea transect, although much feeding occurred on nesting and brood-rearing lakes, off the transects. In both years, maximum numbers of these birds were noted in mid-September, close to the time when fledging should occur.

Red-throated Loons. Red-throated Loons arrived in late May 1977 and remained in the area through mid-September (Figs. 9, 10, and 11 and Table 5). Since they can use small, shallow ponds for nesting, they arrived and nested earlier than Arctic Loons. Red-throated Loons fed both at sea and in Espenberg Bay (Figs. 10 and 11). Most young probably fledged by 1 September, after which time Red-throated Loon numbers on the Cape decreased rapidly. Young loons probably deserted the Cape after gaining flight ability.

Emperor Geese. Emperor Geese arrived on the Cape in late May and were present through late September (Figs. 12, 13 and 14). They were notably absent from transects during July. During this time, adults and young were seldom seen on the Cape. Instead, they frequented brackish sloughs and saltmarsh/mudflat areas (our observations from aerial surveys). Beginning in late August/early September, these geese became common, as they migrated through the area. They fed in bay waters and on sedge-saltgrass meadows at this time.

Pintails. As noted elsewhere in this report (see Aerial Surveys), drought-displaced Pintails were numerous everywhere in Alaska in 1977, including Cape Espenberg. Figures 15, 16 and 17 show the increase in Pintail numbers over 1976 dramatically. Numbers of these ducks diminished substantially in late August. Pintails were found in all habitats in May and early June. Associating in small groups at pond and lake edges, they underwent the molt of flight feathers in early August. Pintails also fed extensively on Espenberg Bay mudflats (Fig. 17 and Tables 8 and 9).

Oldsquaws. Oldsquaws arrived on the Cape in late May 1977 and at least a few were seen through late September (Figs. 18, 19 and 20 and Table 5). They were most common on transects during the early part of the summer; few were observed on the transects after hatching of nests.

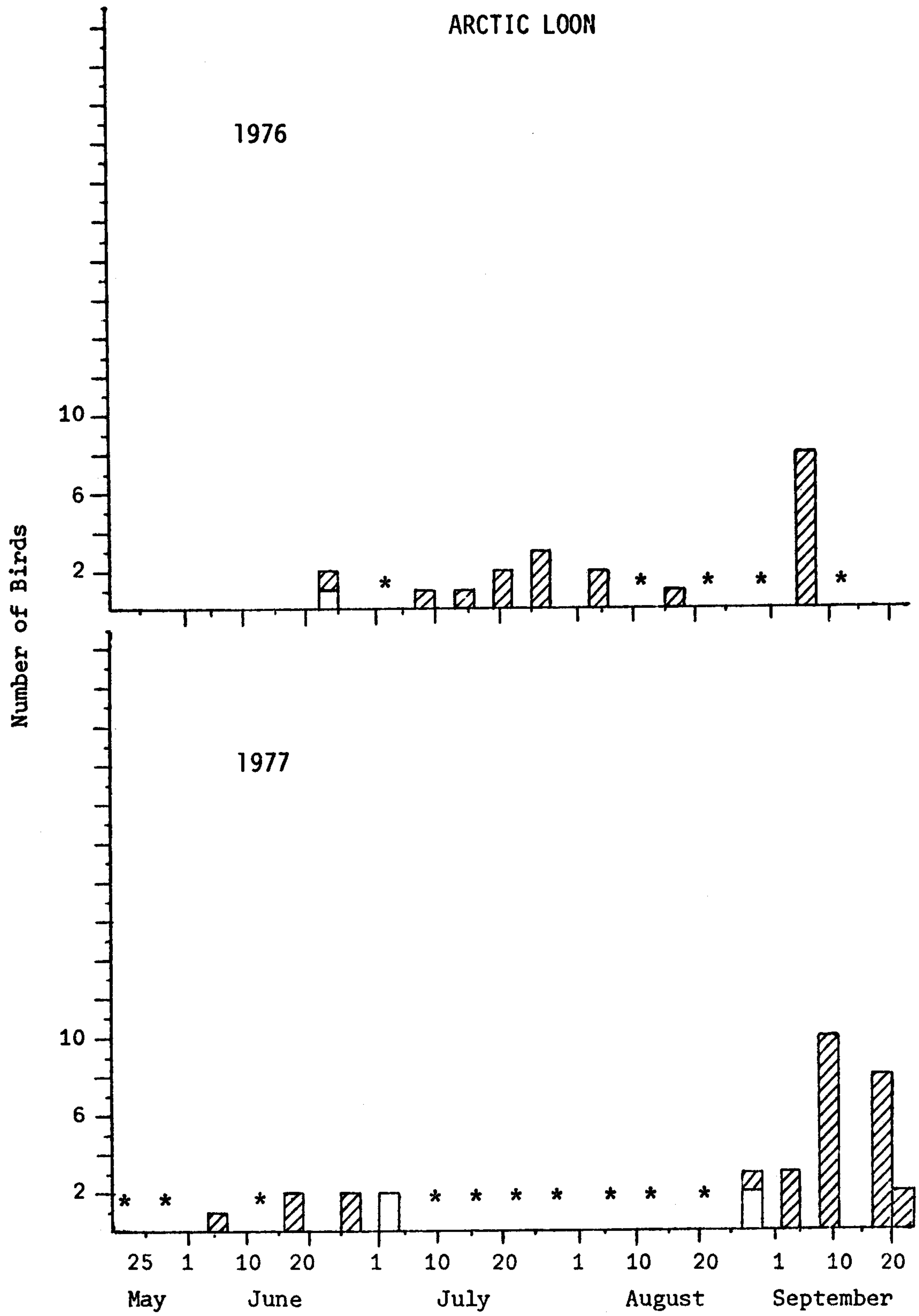

Figure 6. Summary of numbers of Arctic Loons on the census transects, 1976-1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

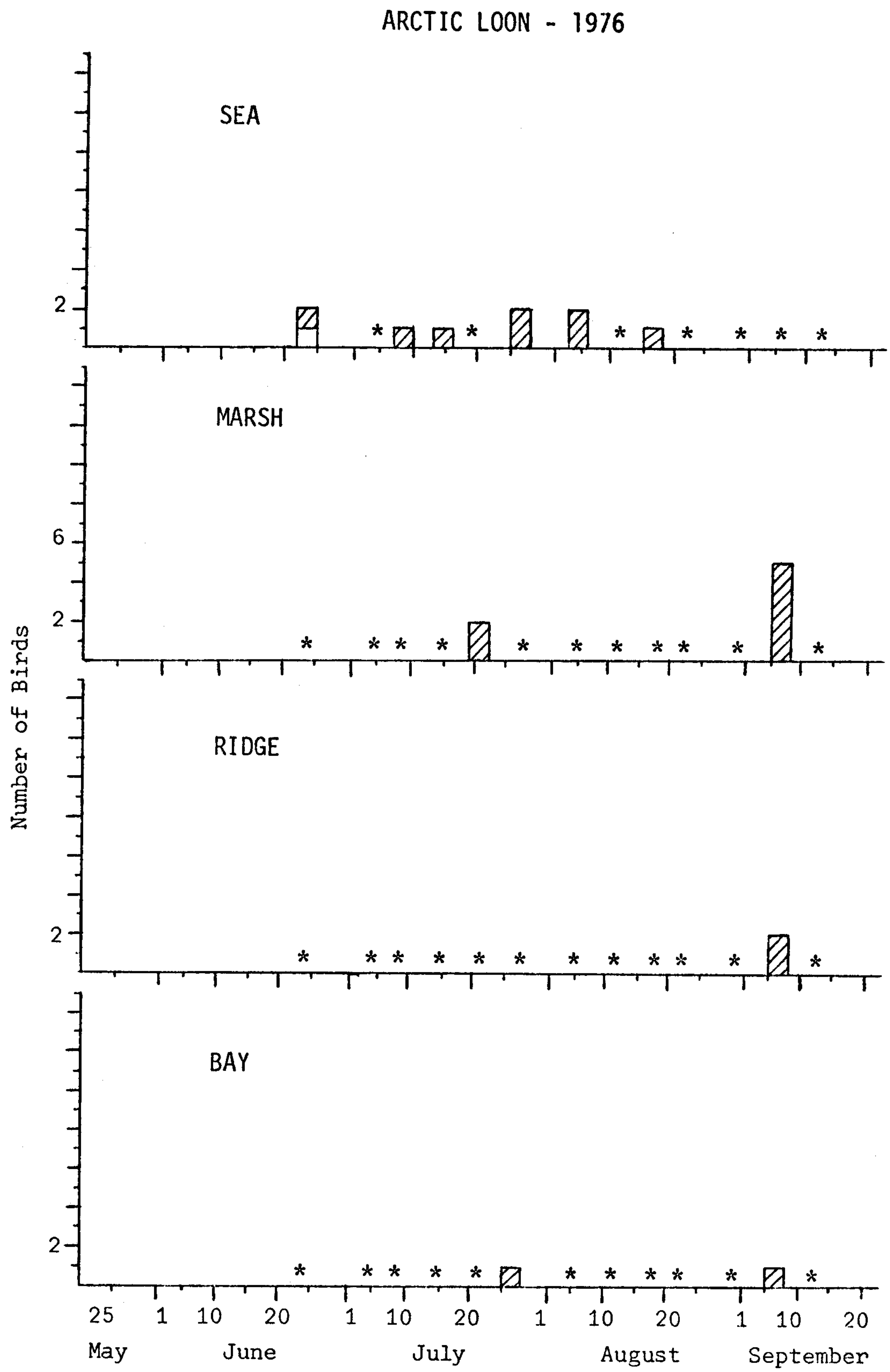

Figure 7. Numbers and distribution of Arctic Loons on the census transects, 1976, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

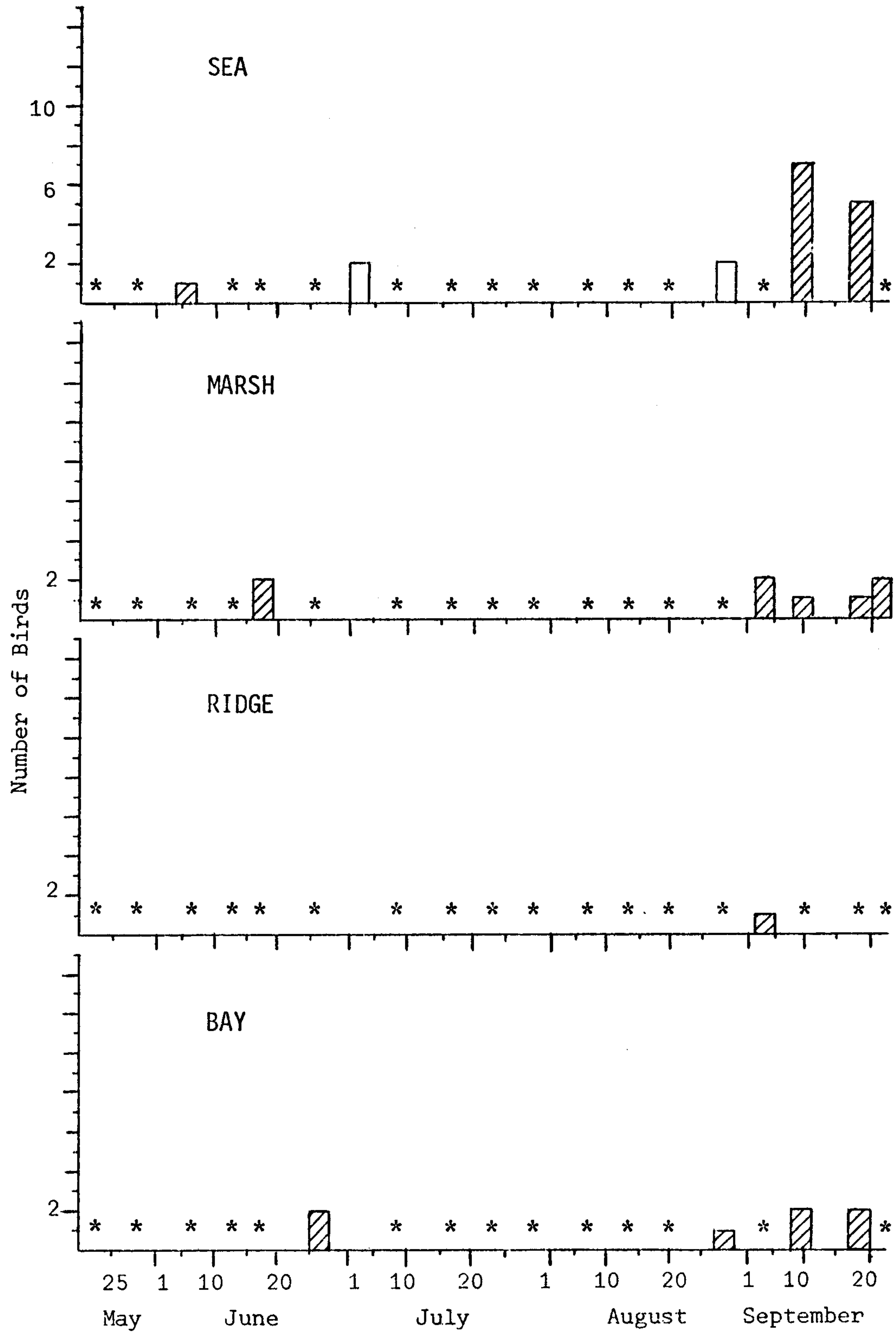

Figure 8. Numbers and distribution of Arctic Loons on the census transects, 1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

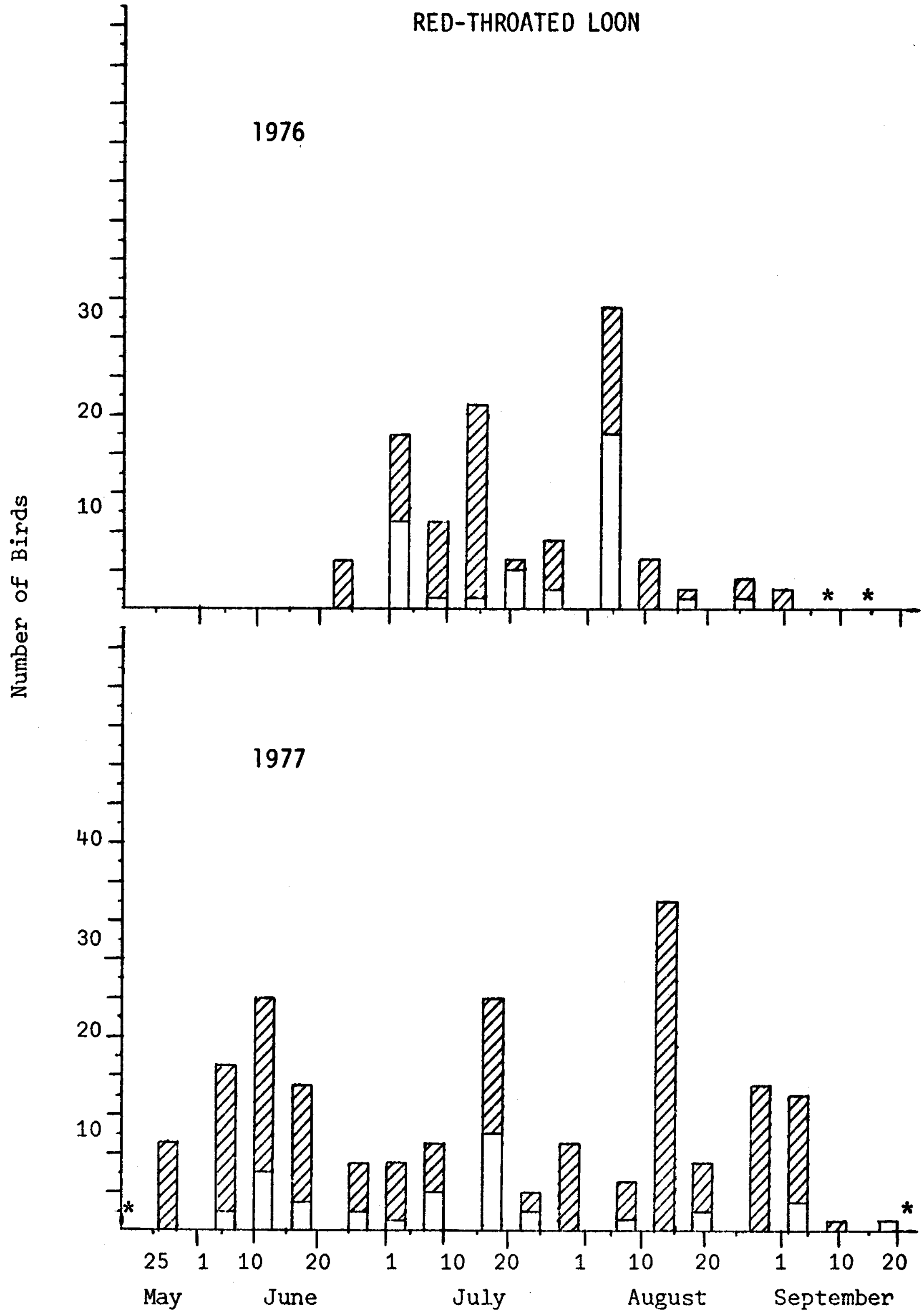

Figure 9. Summary of numbers of Red-Throated Loons on the census transects, 1976-1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

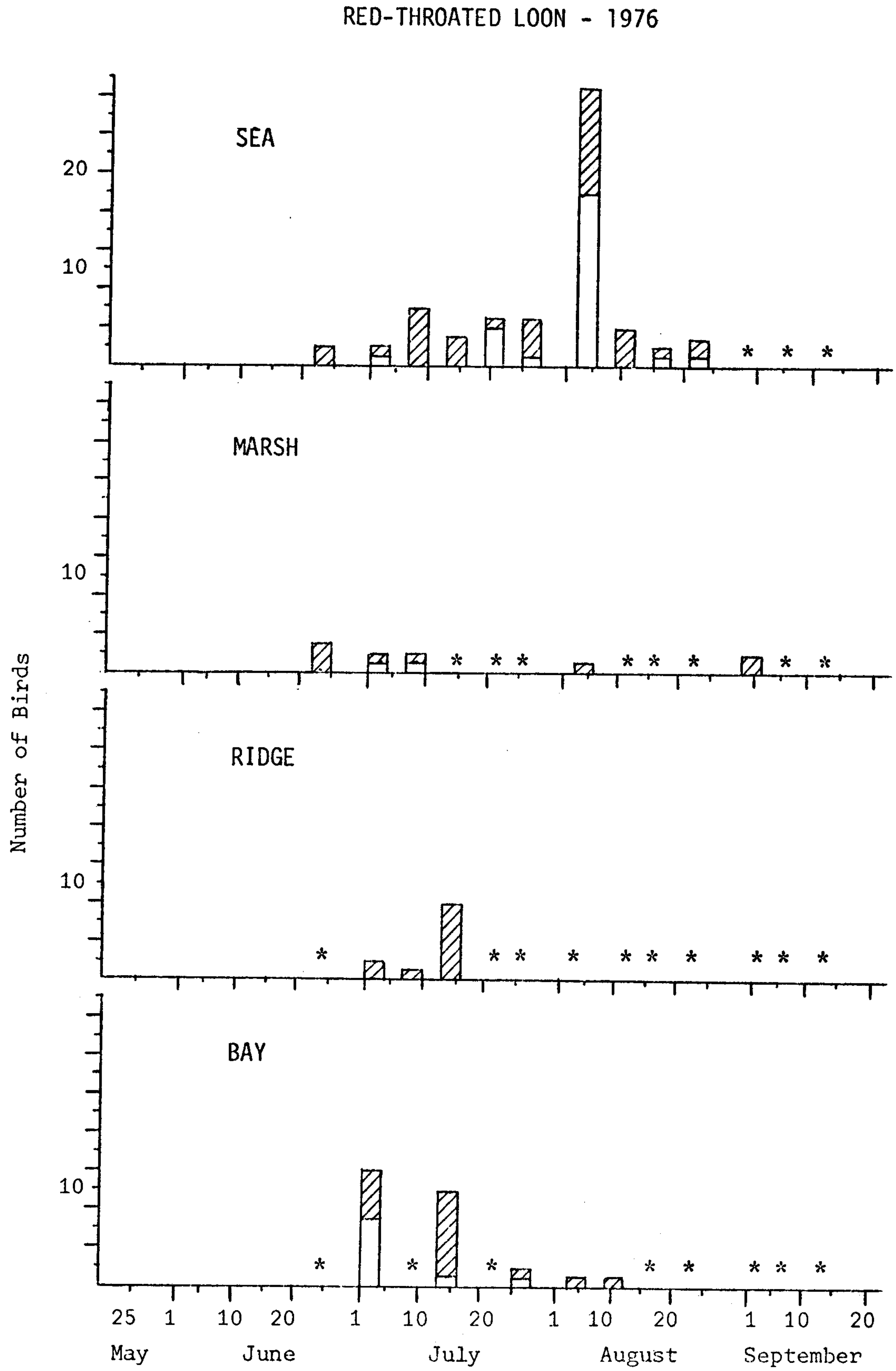

Figure 10. Numbers and distribution of Red-Throated Loons on the census transects, 1976, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

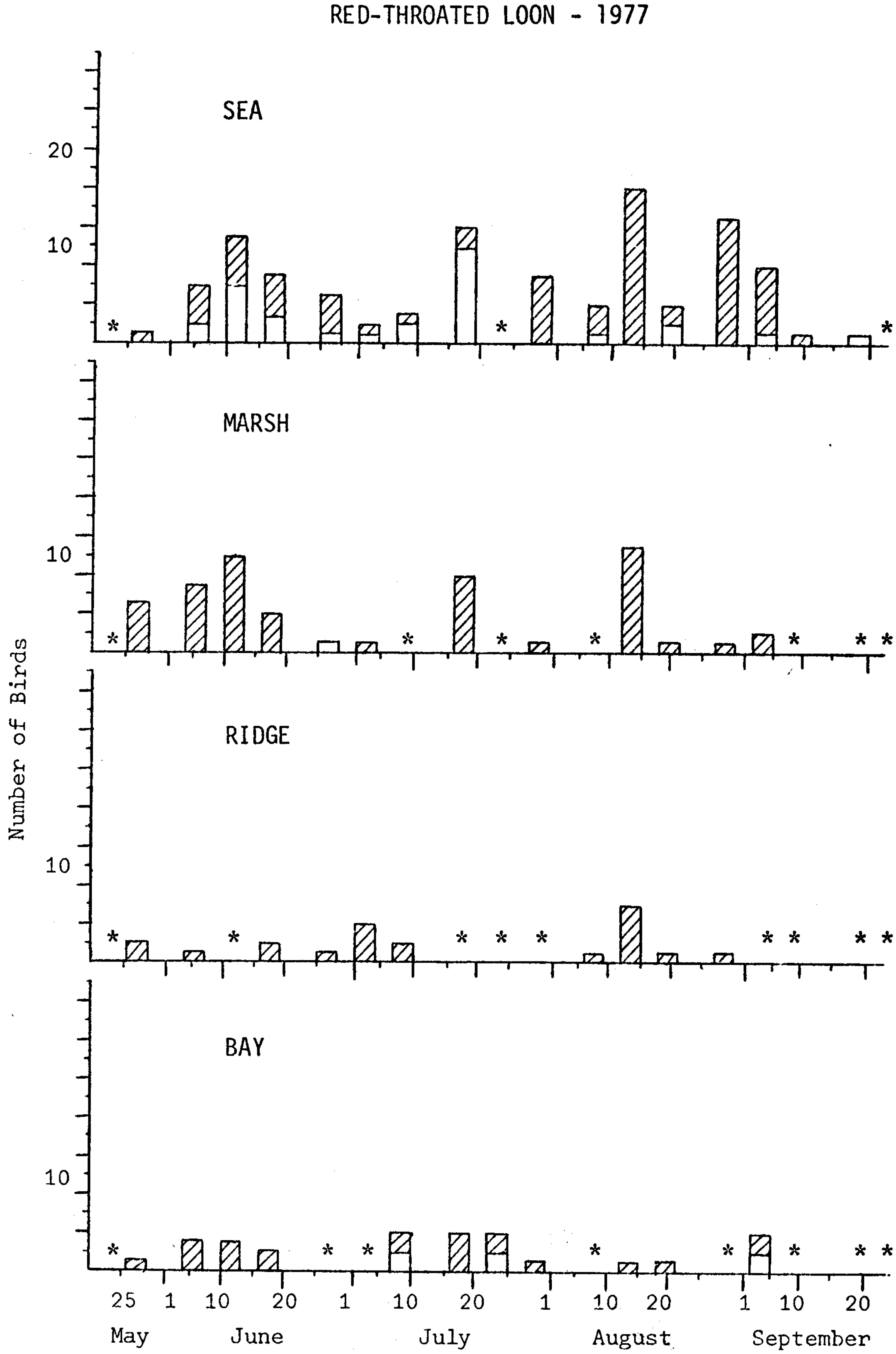

Figure 11. Numbers and distribution of Red-Throated Loons on the census transects, 1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

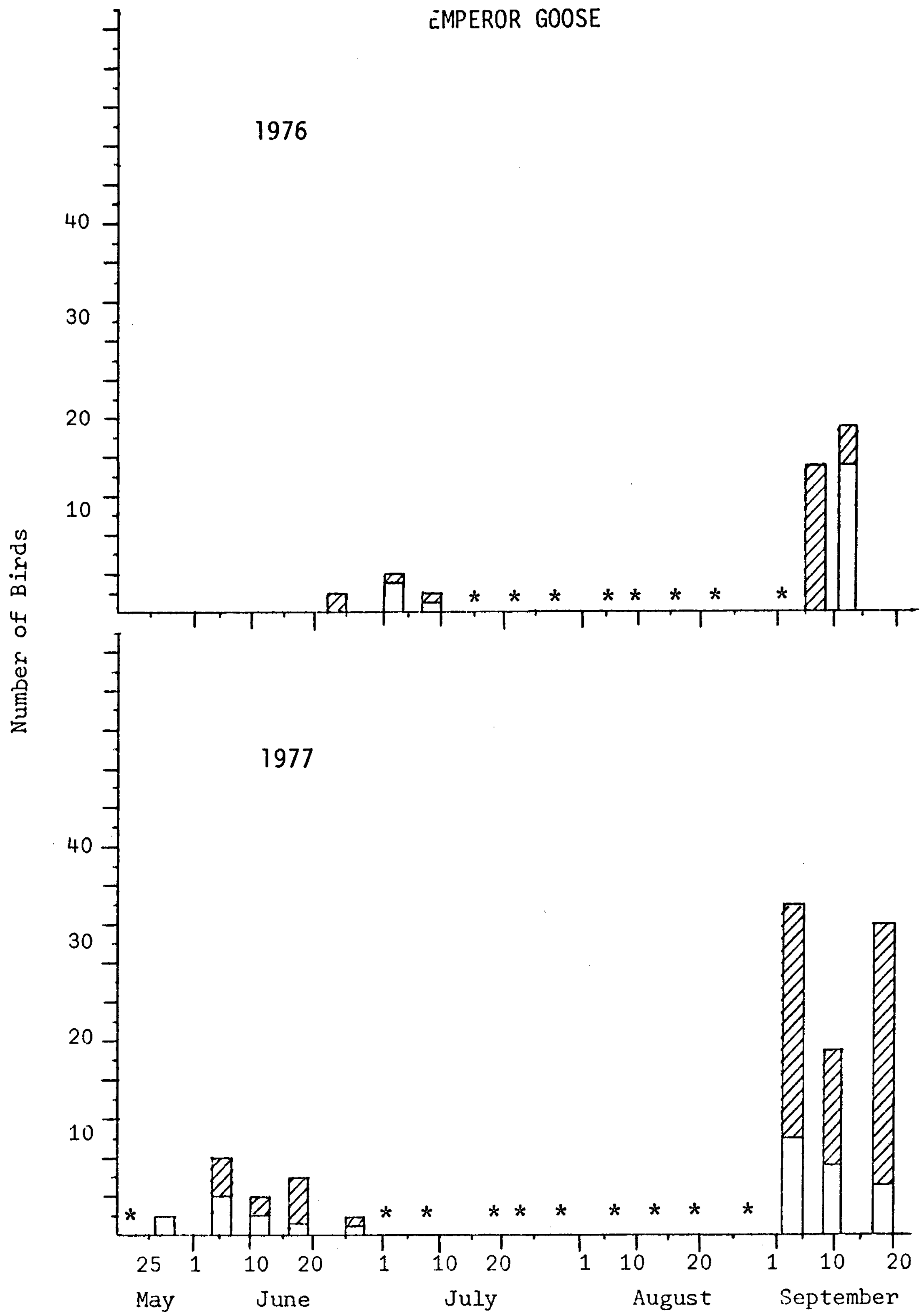

Figure 12. Summary of numbers of Emperor Geese on the census transects, 1976-1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

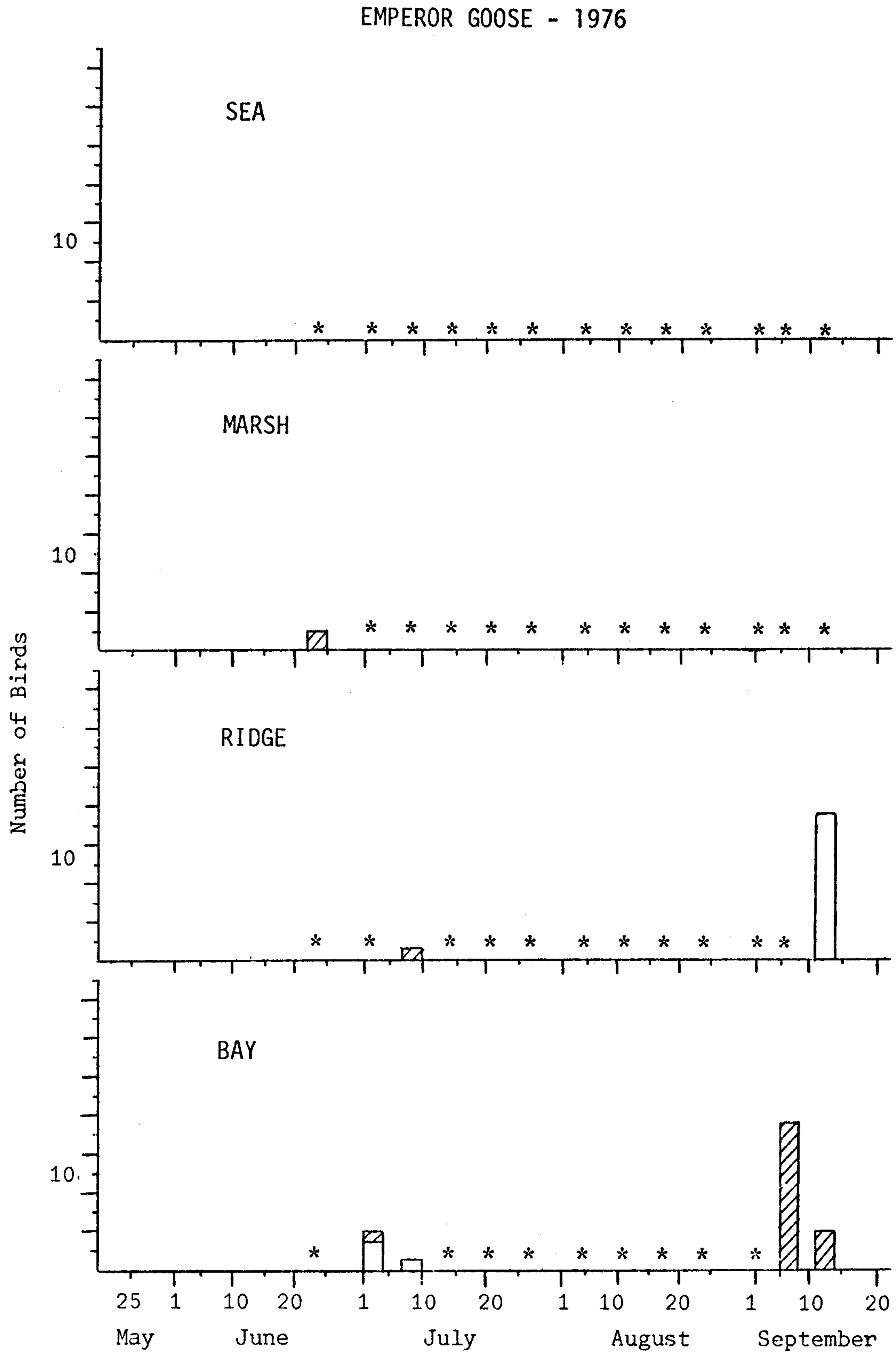

Figure 13. Numbers and distribution of Emperor Geese on the census transects, 1976, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

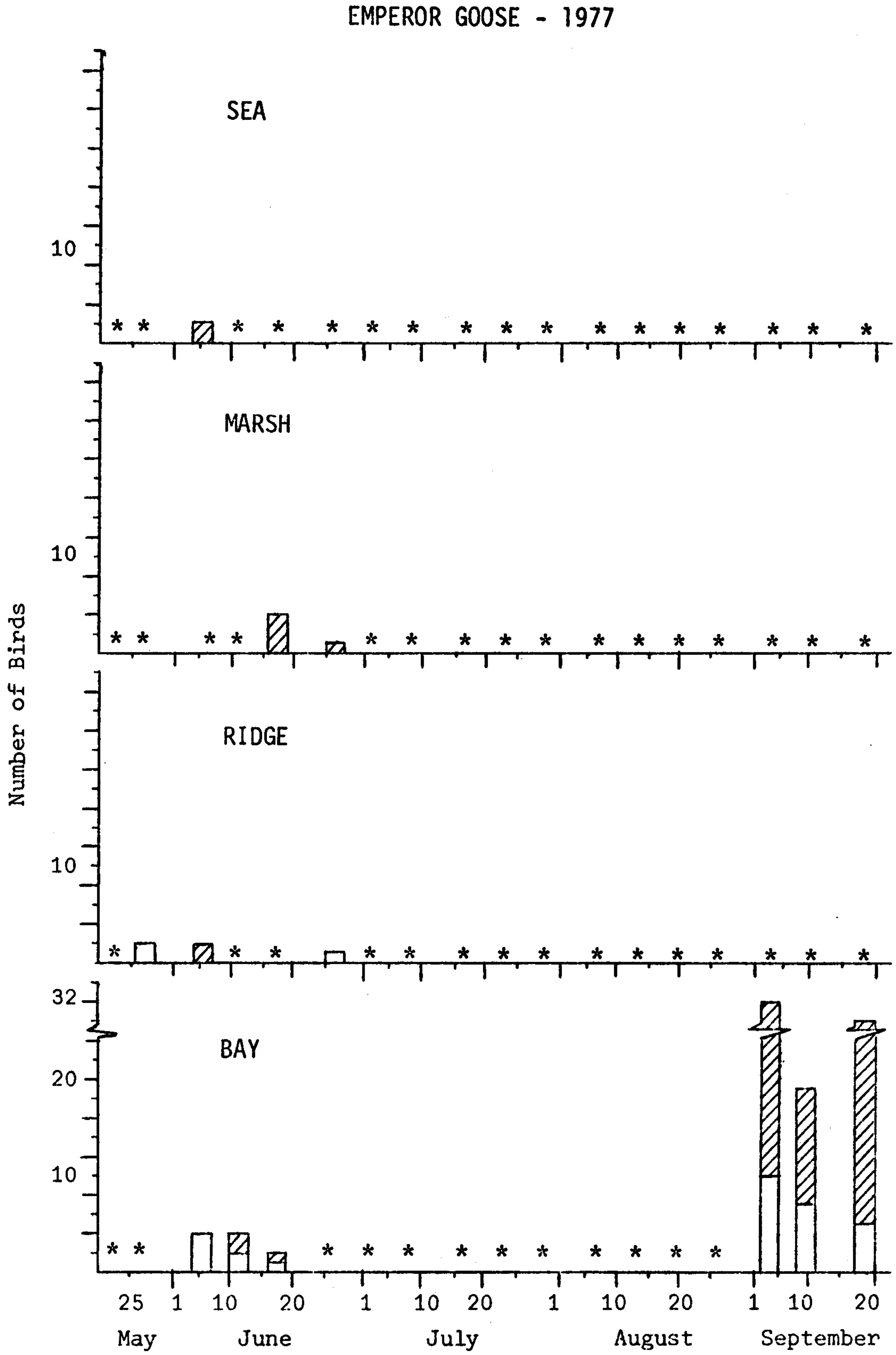

Figure 14. Numbers and distribution of Emperor Geese on the census transects, 1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

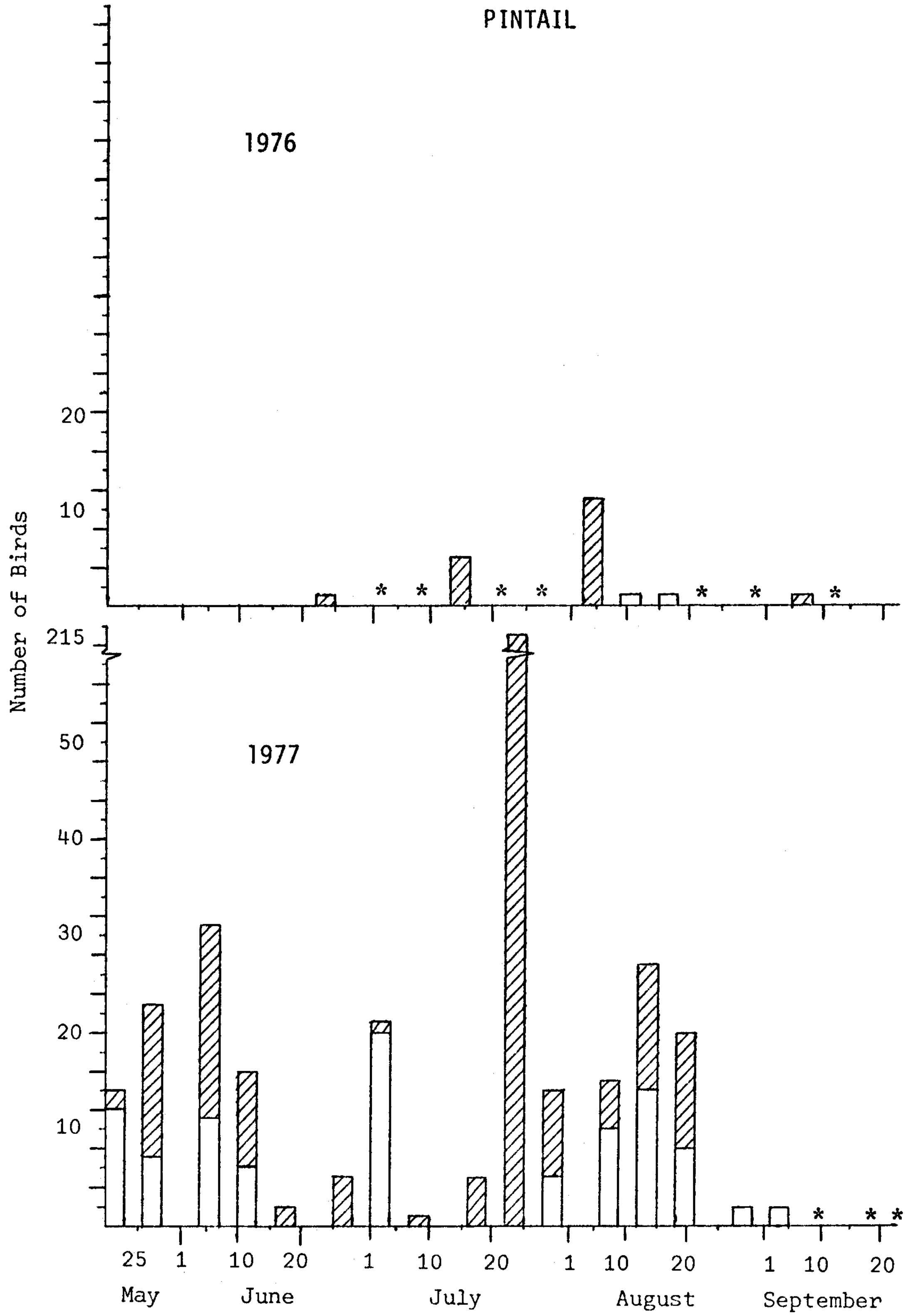

Figure 15. Summary of numbers of Pintails on the census transects, 1976-1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

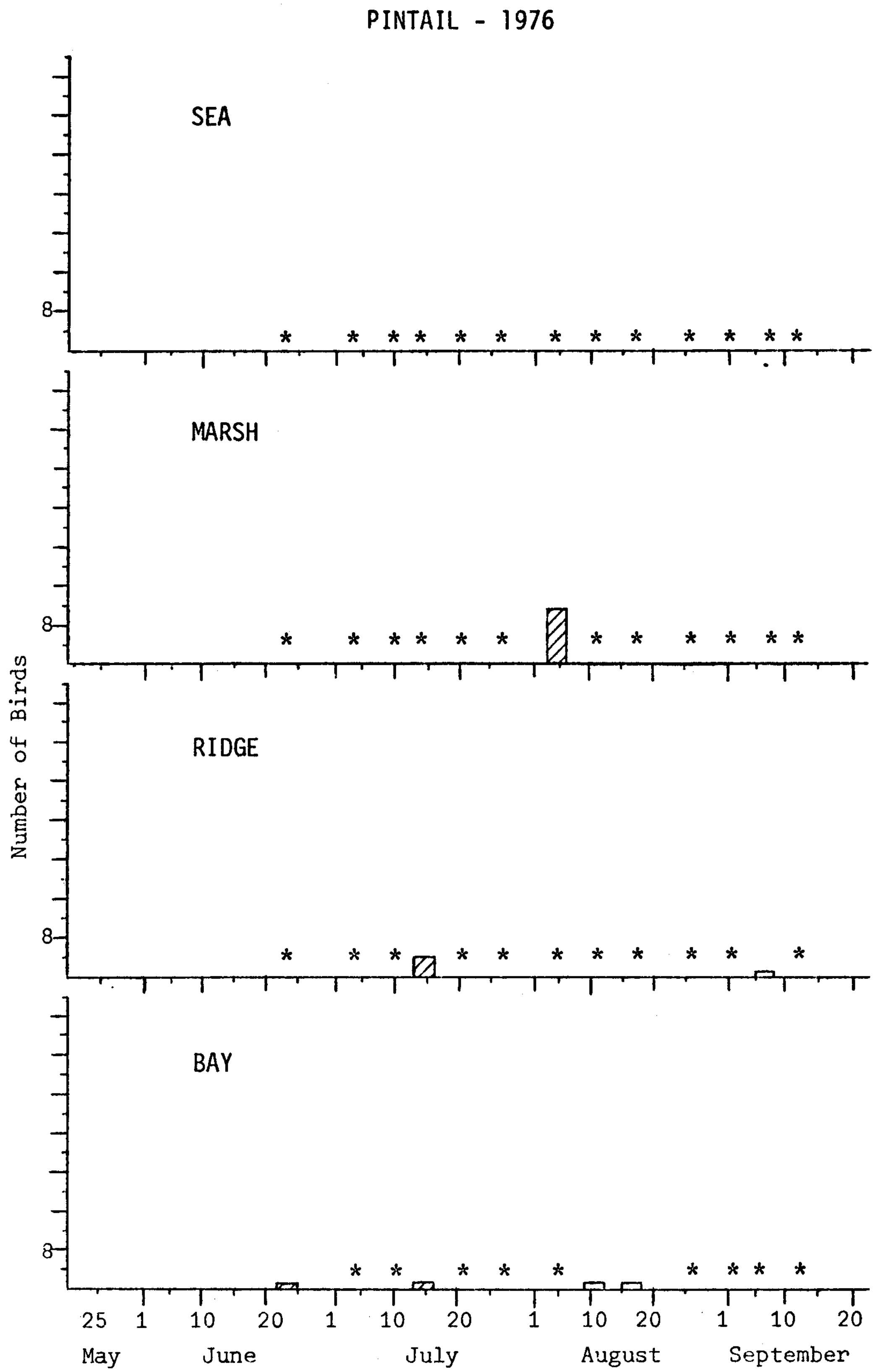

Figure 16. Numbers and distribution of Pintails on the census transects, 1976, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

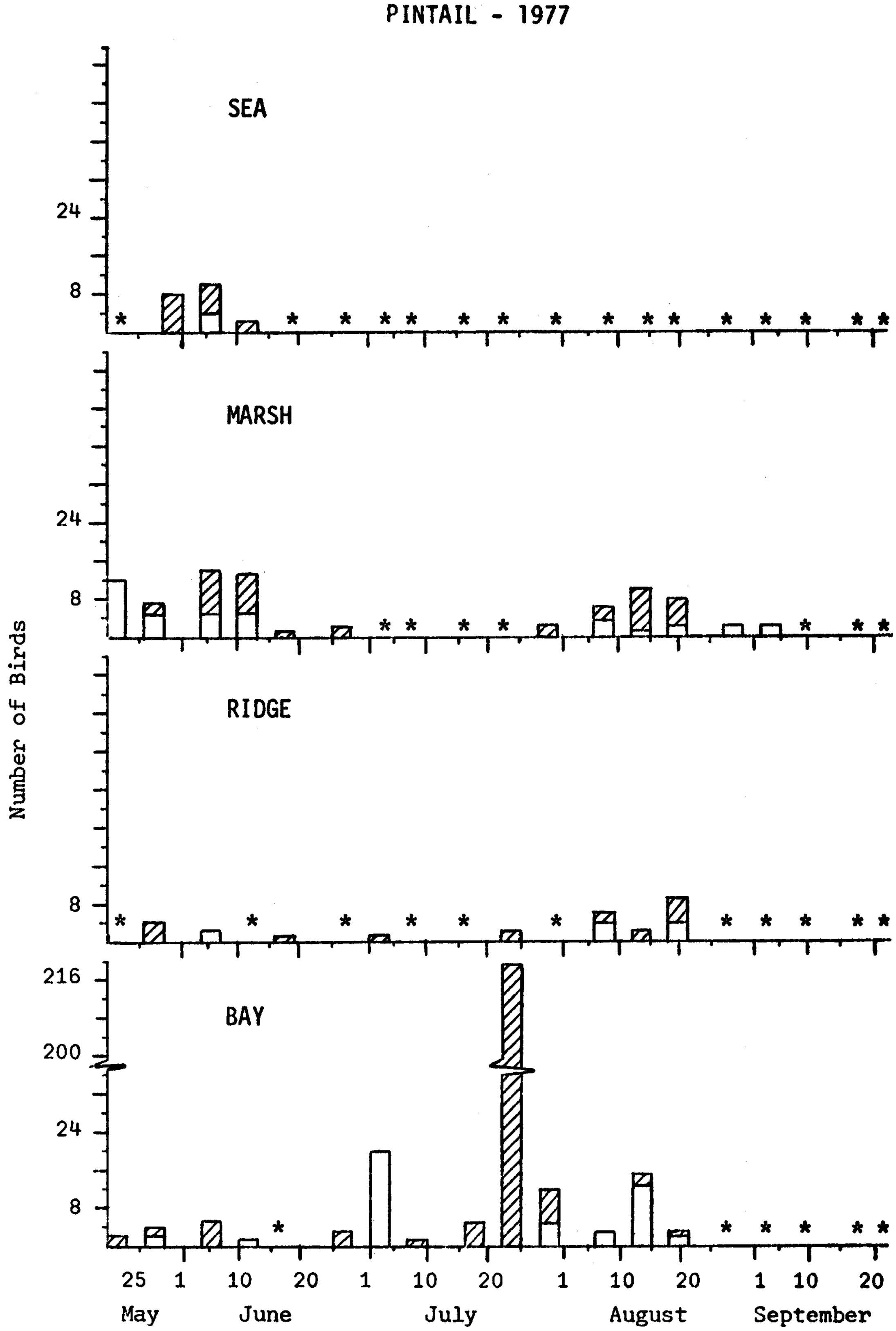

Figure 17. Numbers and distribution of Pintails on the census transects, 1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

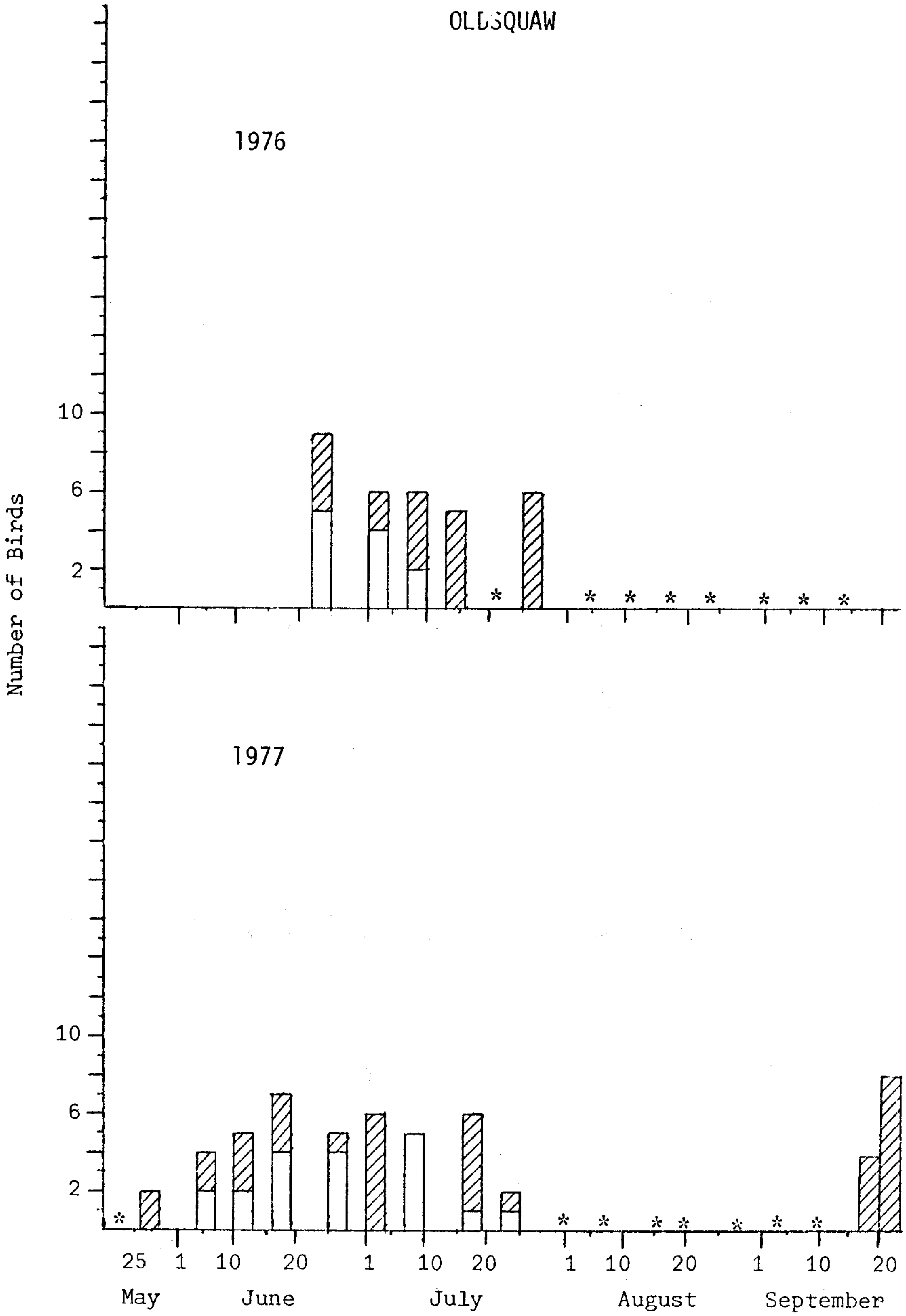

Figure 18. Summary of numbers of Oldsquaws on the census transects, 1976-1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

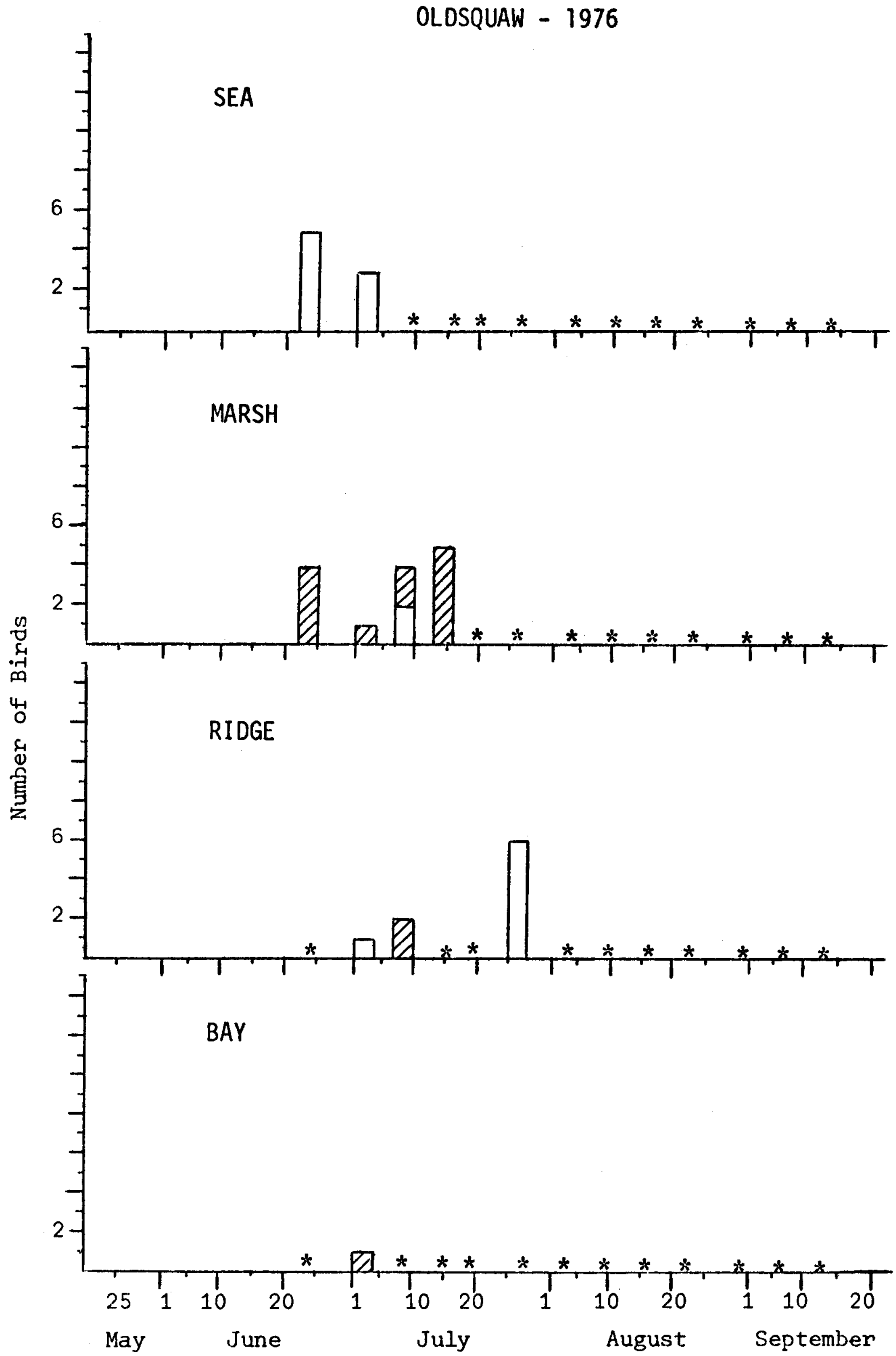

Figure 19. Numbers and distribution of Oldsquaws on the census transects, 1976, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

OLDSQUAW - 1977

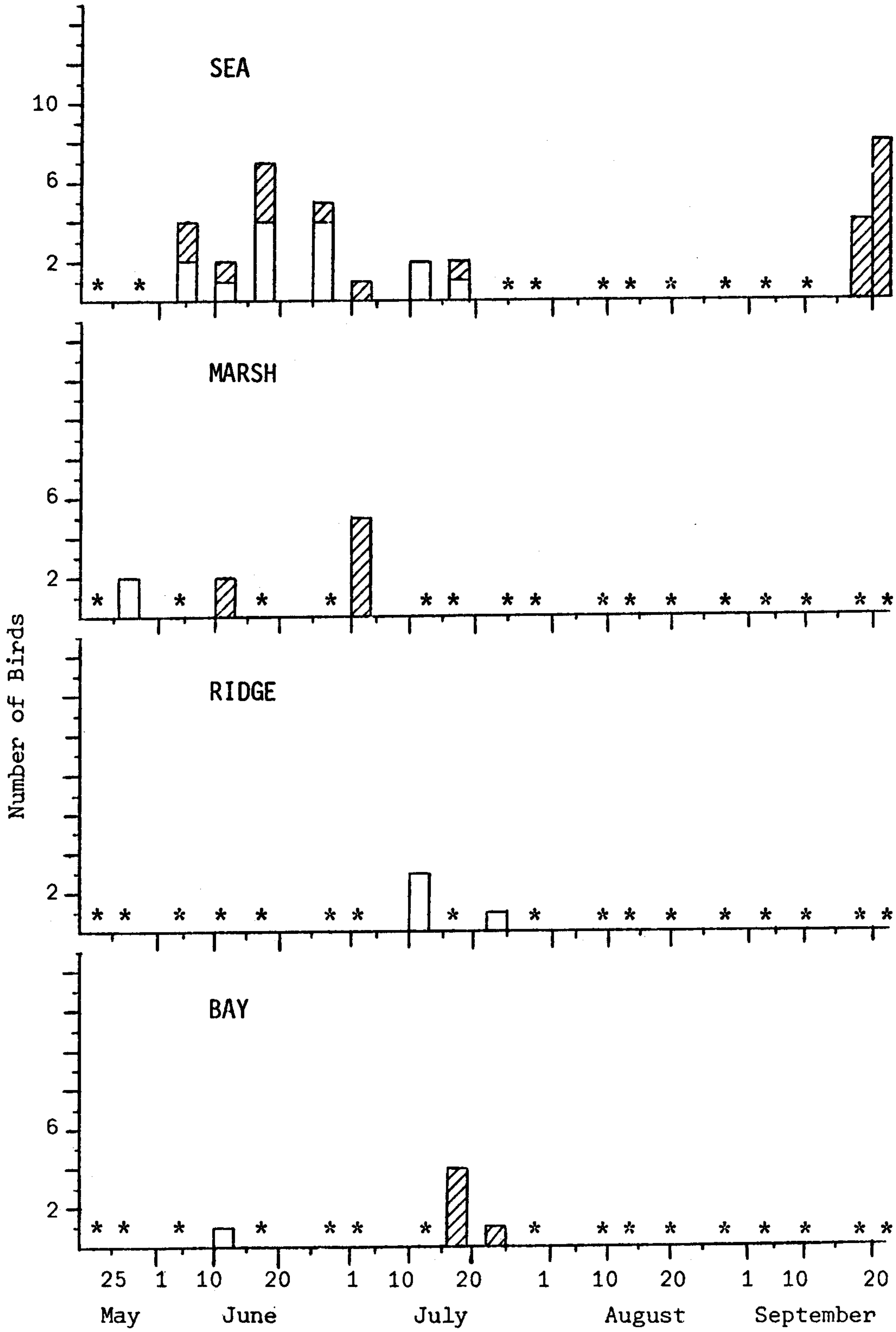

Figure 20. Numbers and distribution of Oldsquaws on the census transects, 1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

Occasional broods and creches of broods were observed on small ponds and sloughs on the Cape in August. On the transects, Oldsquaws most frequently fed at sea, although a few were observed feeding in the bay and marsh; the ridge transect provided loafing sites for birds that probably had failed in nesting attempts.

Common Eiders. Common Eiders were observed from late May through late September in 1977 (Figs. 21, 22 and 23). In both years, eider numbers on the transects peaked in late June/early July. This corresponds primarily with the peak of incubation and the flocking of non-nesting and/or failed-nesting eiders on the Cape. As nests hatched, females led young to brackish or salt water, and eider numbers decreased. The noticeable increase in the numbers of eiders on the transects from 1976 to 1977 may be partially due to (1) a small increase in the number of nesting eiders (Table 22) and (2) a slight increase in nest predation. Increased predation would lead to larger post-breeding flocks.

Sandhill Cranes. Cranes were common from our arrival in mid-May through mid-September in 1977 (Figs. 24, 25 and 26). Numbers peaked in both 1976 and 1977 in early September (late summer migration), which is consistent with both the aerial surveys (Table 19) and counts on the mudflats (Table 9). Cranes regularly fed in all habitats on the Cape, including the beach along the sea coast. However, they were most common in marsh areas.

Golden Plovers. Only one Golden Plover nest was found during the two years of study. Fall migrant young-of-the-year were regularly observed on transects from mid-August through late September (Figs. 27, 28 and 29). These birds were most common on tundra transects, particularly marsh. However, a few were regularly seen on bay mudflats, where some feeding was noted. Golden Plovers were noticeably absent from the Chukchi coast transect. The numerical decline in mid-September may be either the end of fall migration or just a temporary lag. Our results are similar to those of Connors (1978) at Wales and Cape Krusenstern in 1977.

Ruddy Turnstones. Ruddy Turnstones were present in small numbers from mid-May through mid-August (Figs. 30, 31 and 32). In May, they were most common along the Chukchi coast, where they fed along the ice edge and in the flotsam. Adults continued to feed along the Chukchi coast during the nesting period and used both coasts (as well as dunes and ridges) during the brood-rearing period. Connors (1978) also reported a few Ruddy Turnstones in littoral habitats at Wales and Krusenstern.

Black Turnstones. Black Turnstones were less common than Ruddy Turnstones (Figs. 33, 34 and 35). They fed along both coasts in August, prior to their departure. Food items were taken primarily from flotsam, although some birds were observed feeding at the water's edge.

Sharp-tailed Sandpipers. Sharp-tailed Sandpipers were common migrants from late August through mid-September 1976 (Table 4). They were most frequently observed in marsh habitats, often in mixed flocks with Pectoral Sandpipers. In 1977, however, very few Sharp-tailed Sandpipers were observed (Table 5), although we regularly examined flocks of Pectorals. Net movement of these migrants was east-

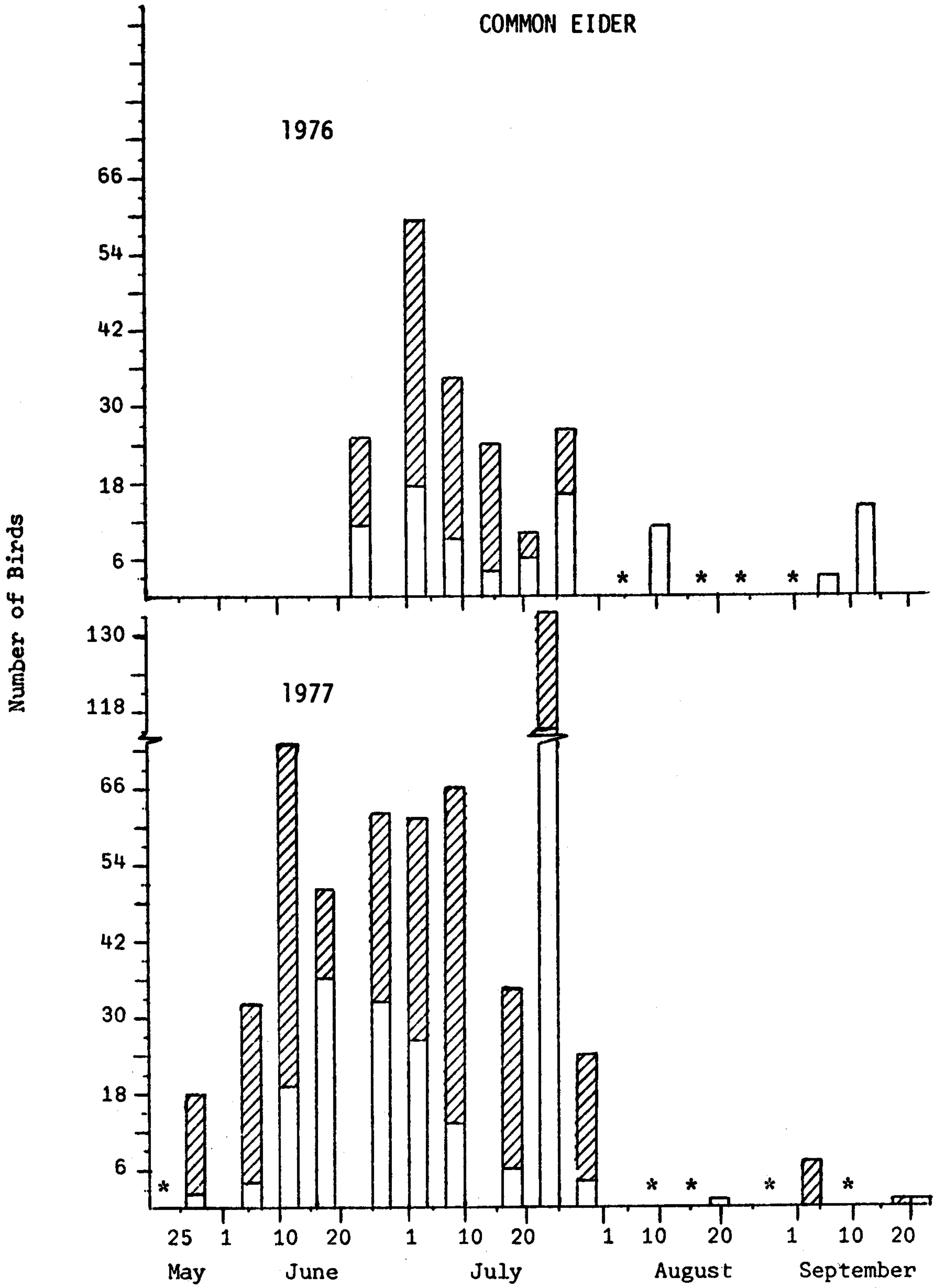

Figure 21. Summary of numbers of Common Eiders on the census transects, 1976-1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

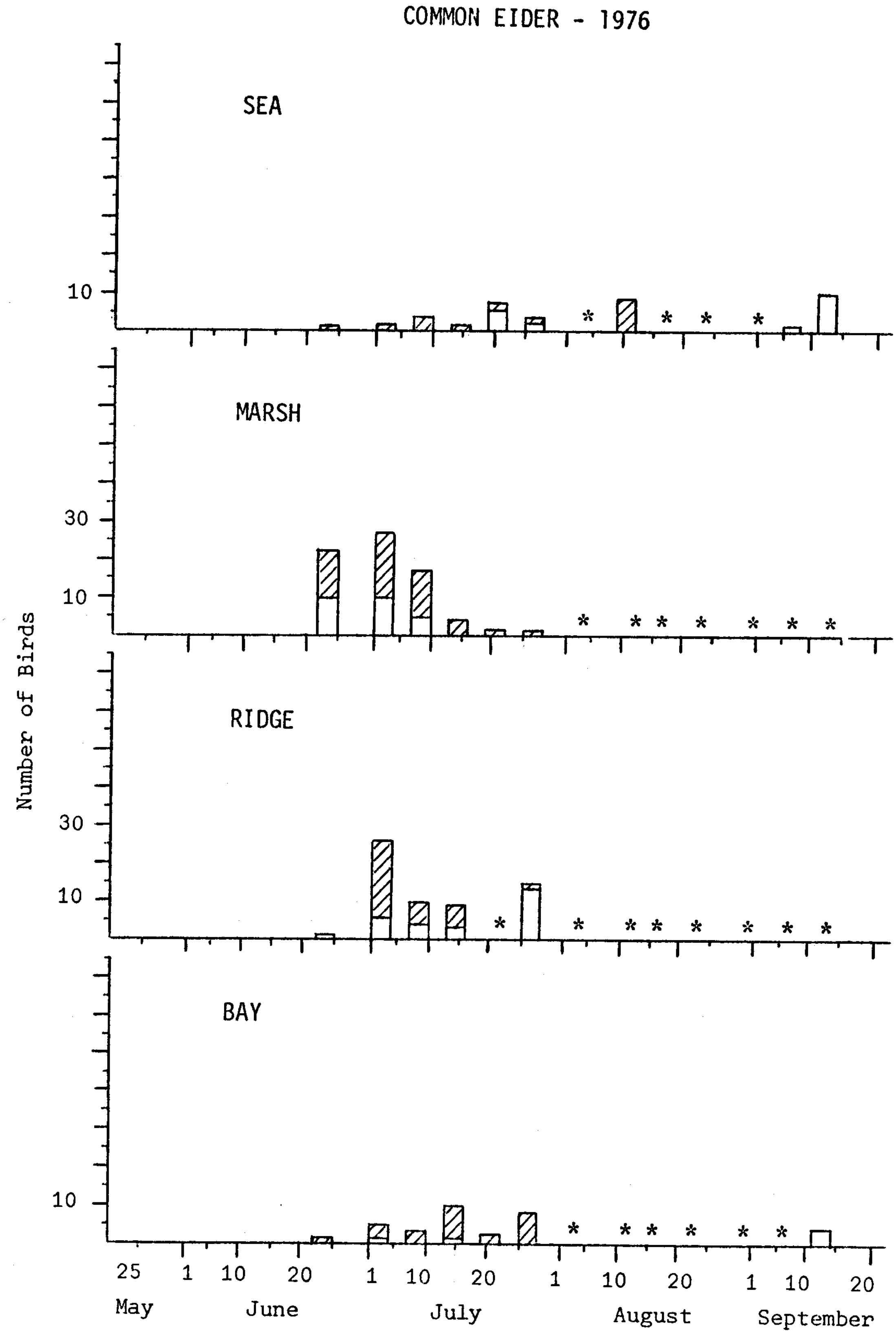

Figure 22. Numbers and distribution of Common Eiders on the census transects, 1976, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

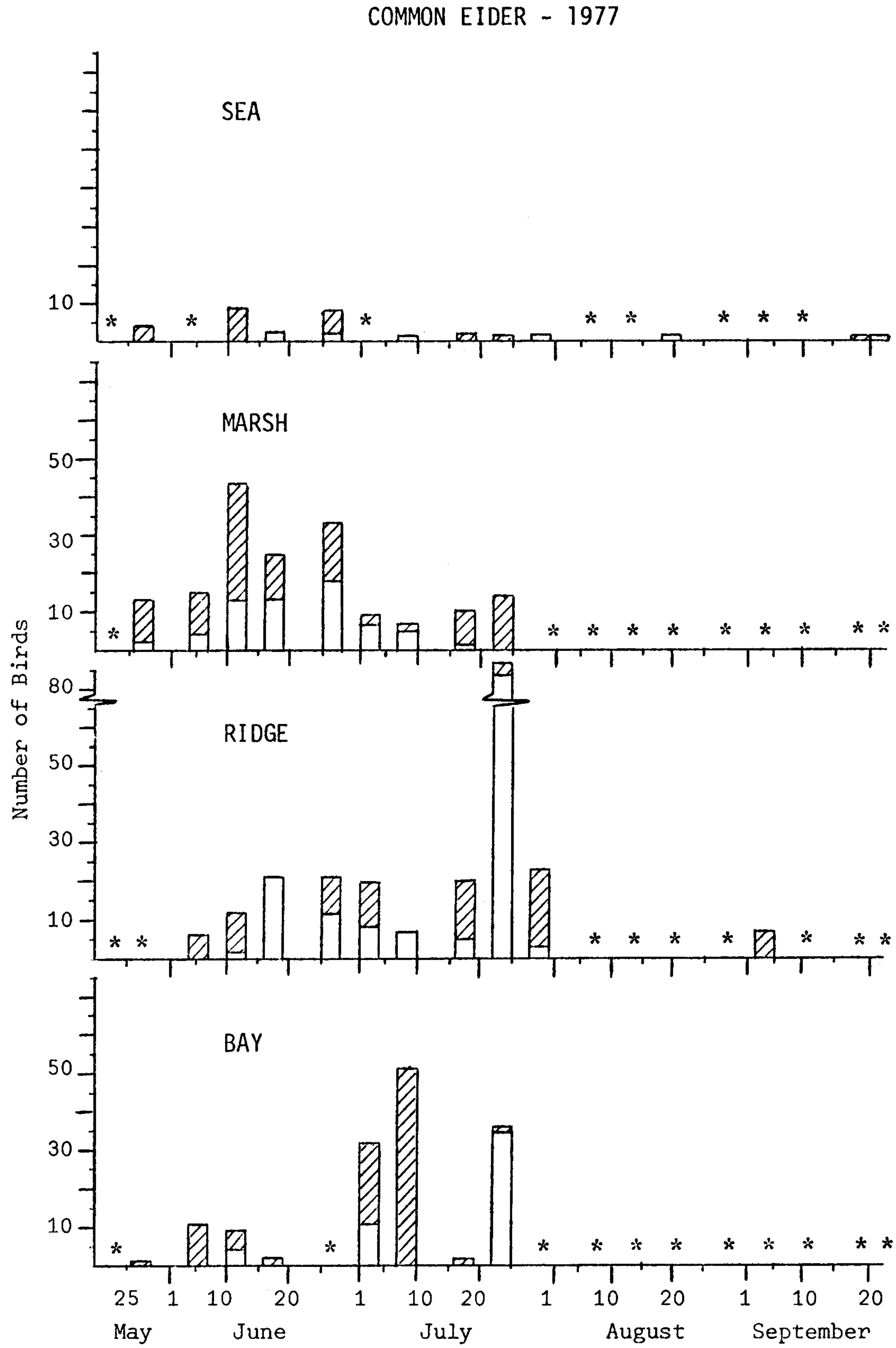

Figure 23. Numbers and distribution of Common Eiders on the census transects, 1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

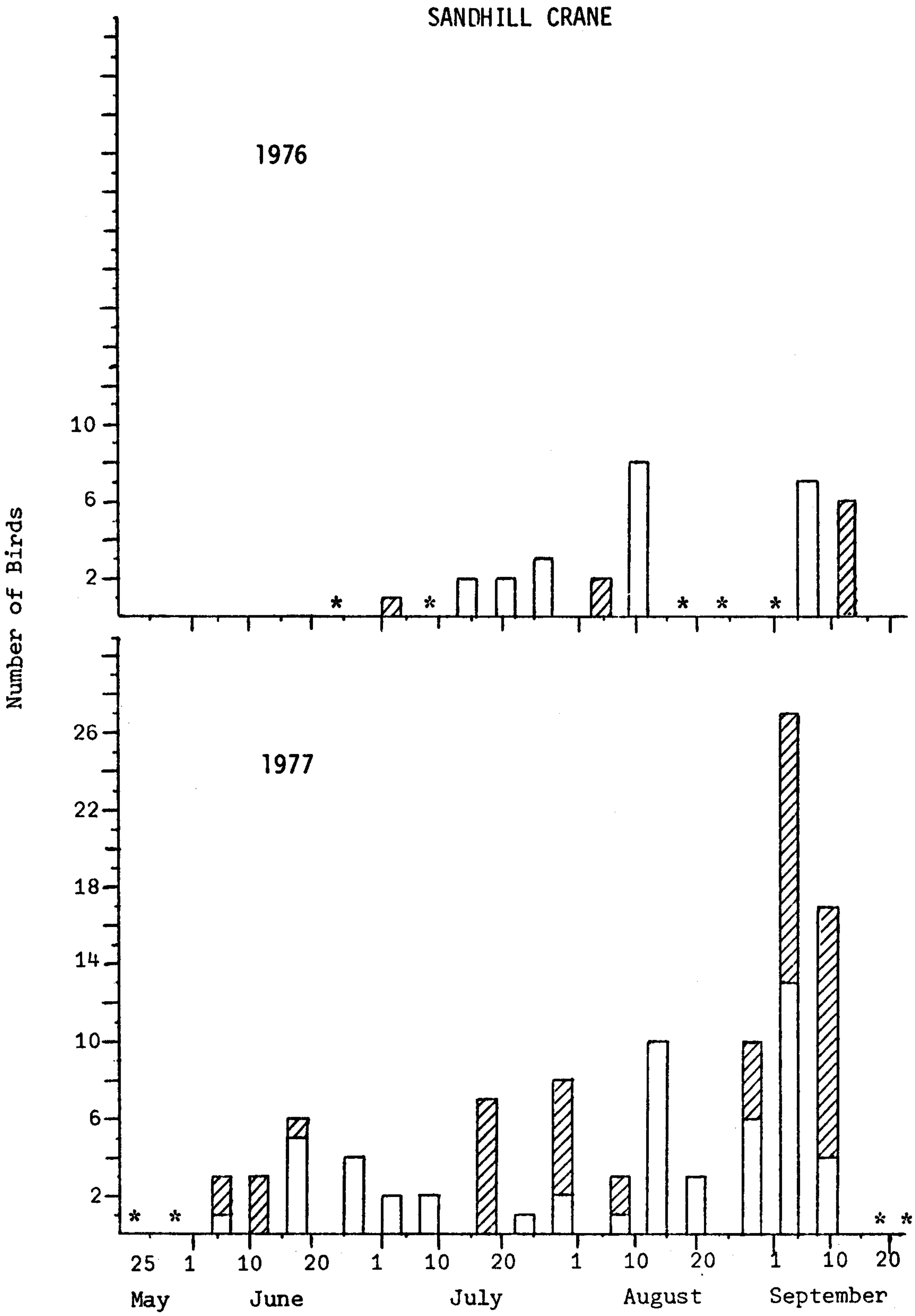

Figure 24. Summary of numbers of Sandhill Cranes on the census transects, 1976-1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

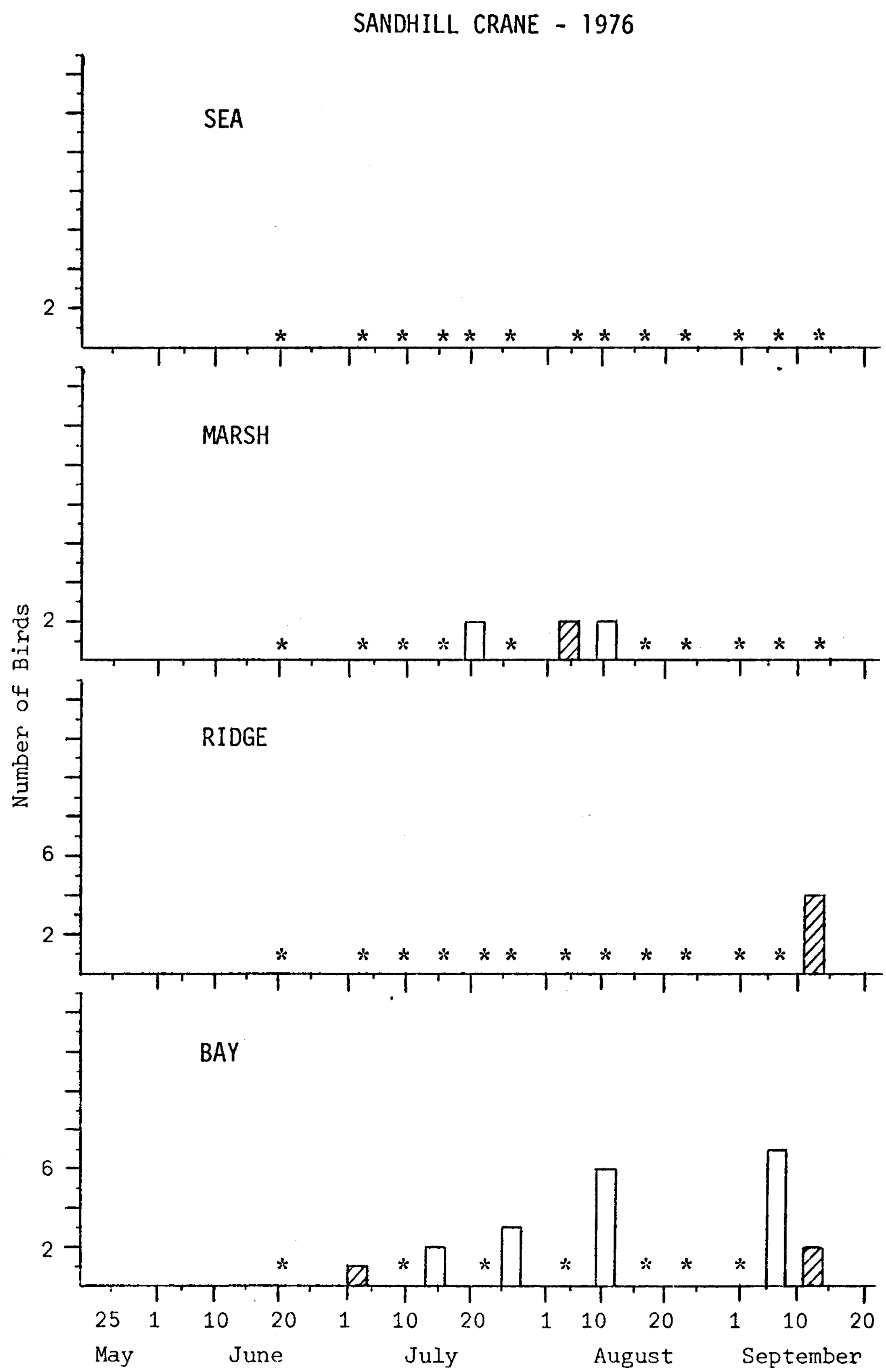

Figure 25. Numbers and distribution of Sandhill Cranes on the census transects, 1976, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

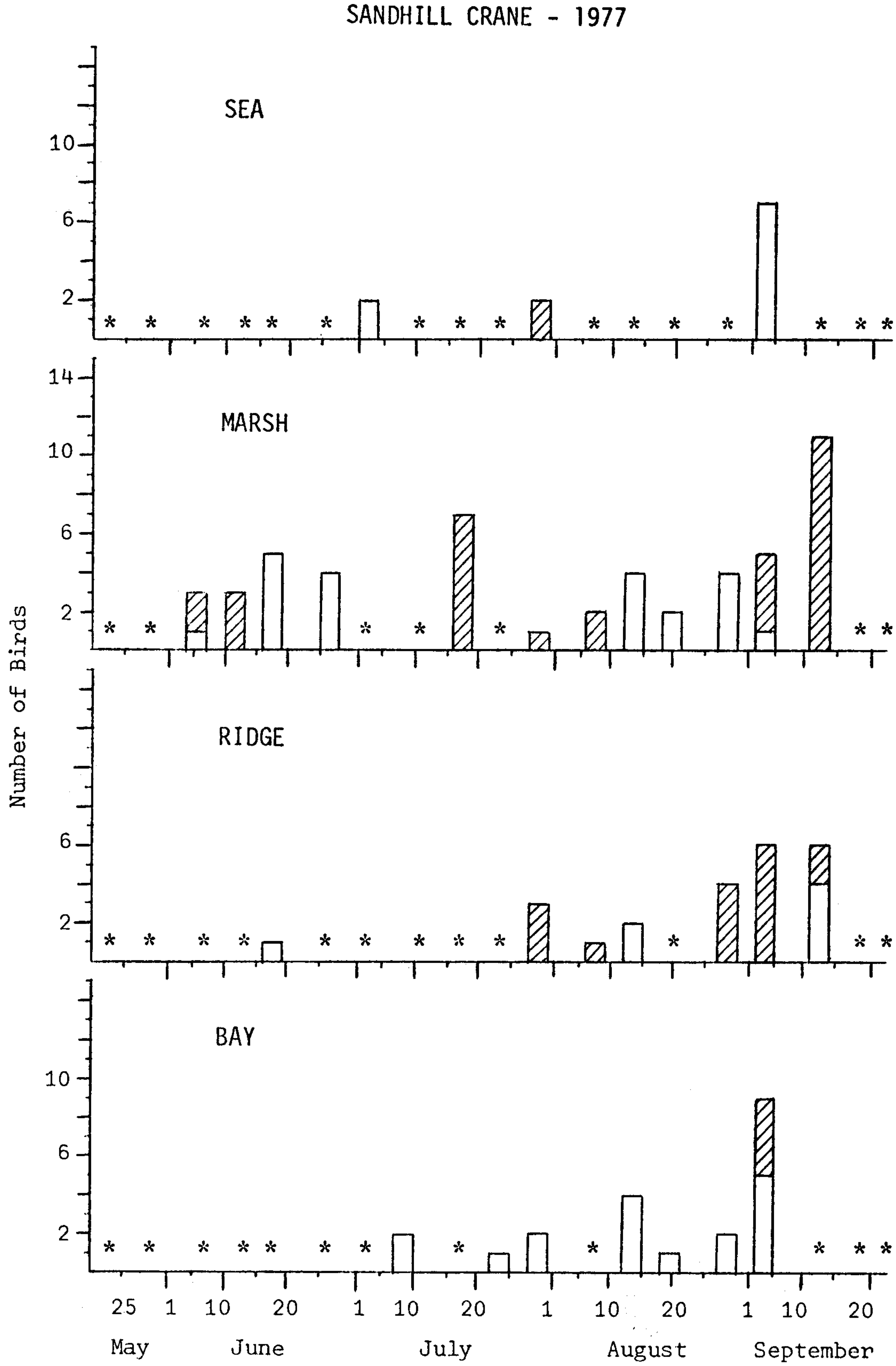

Figure 26. Numbers and distribution of Sandhill Cranes on the census transects, 1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

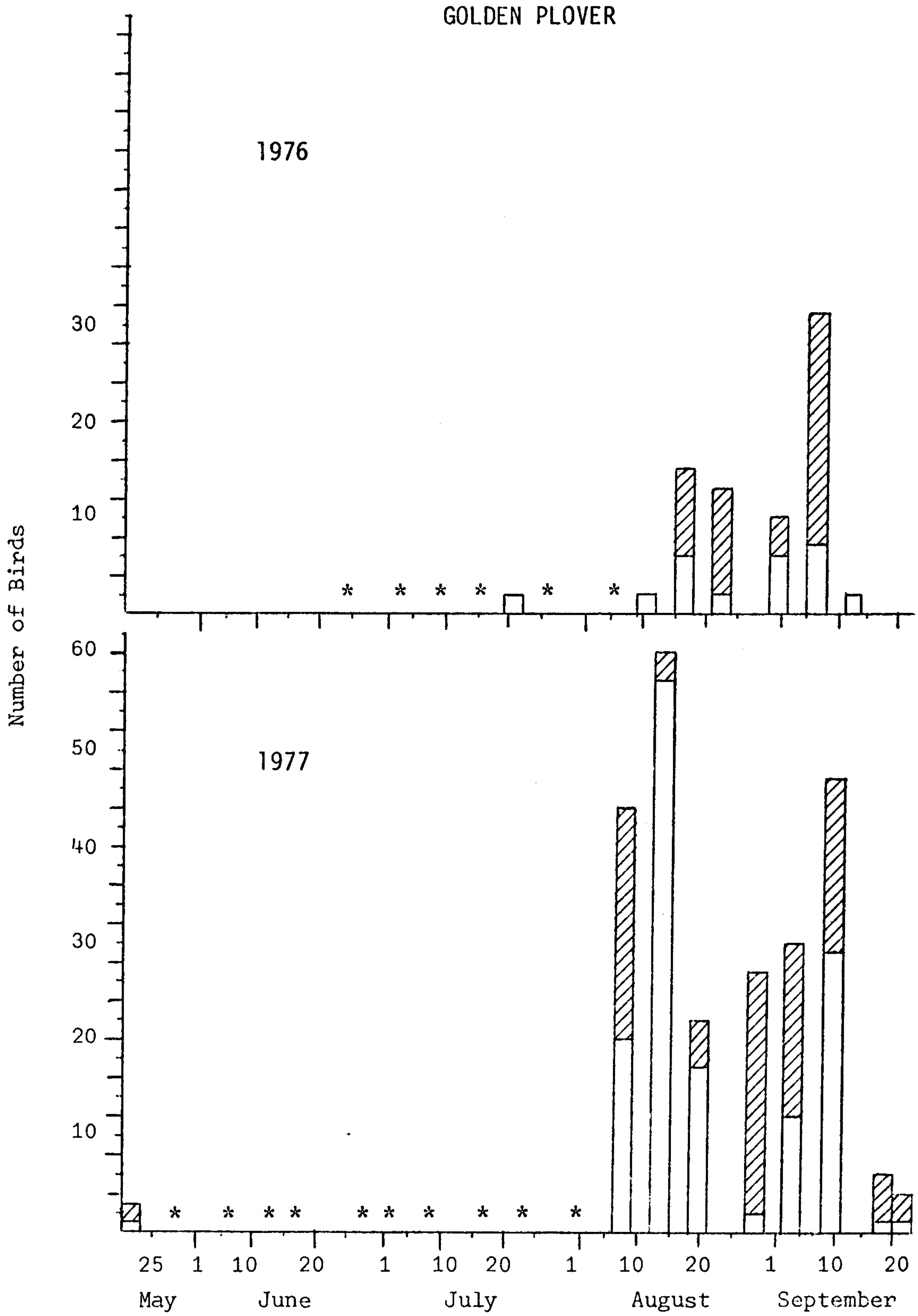

Figure 27. Summary of numbers of Golden Plovers on the census transects, 1976-1977, Cape Espenberg Alaska (unshaded = on ground or water, shaded = flying, * = not present).

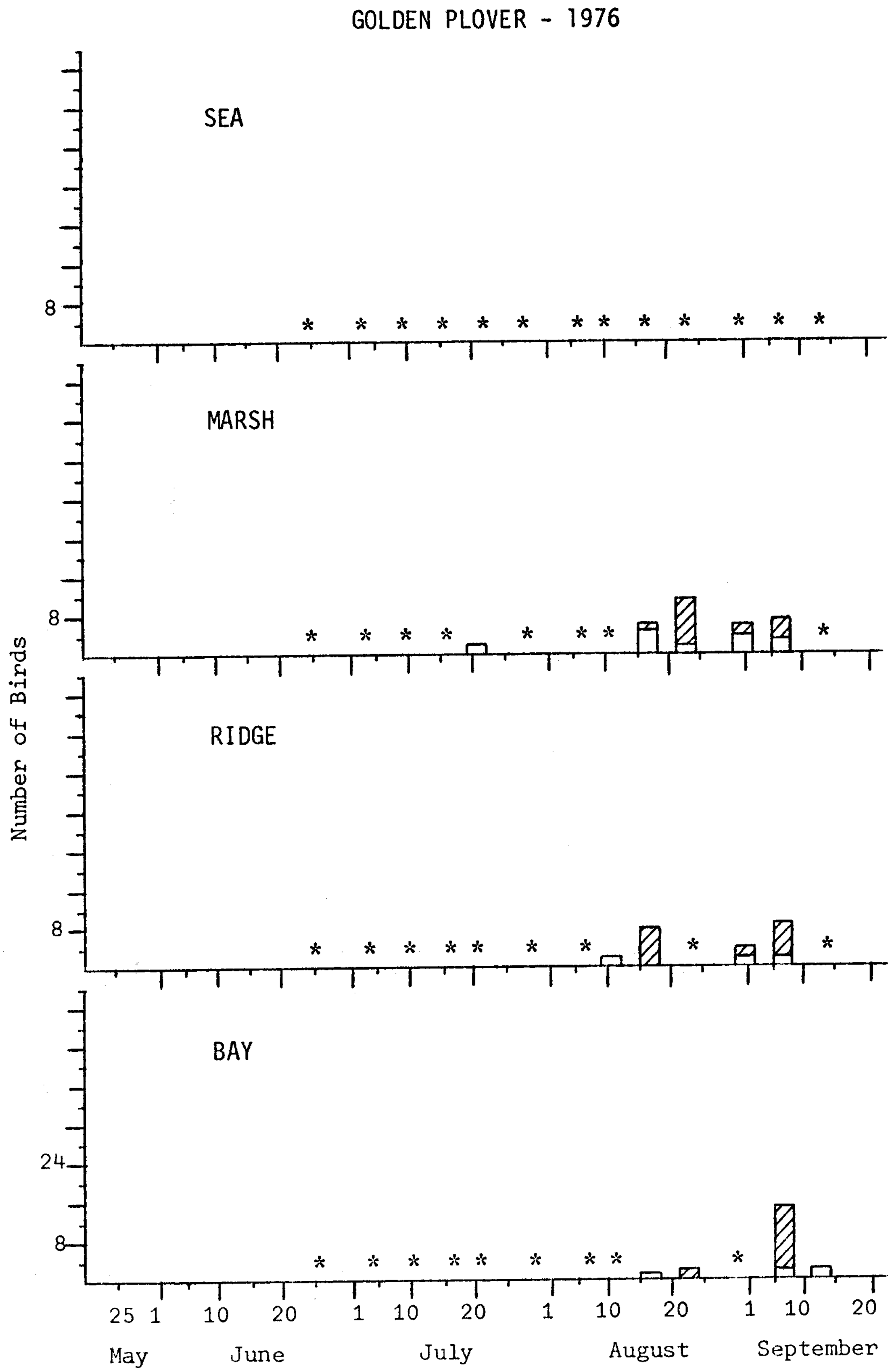

Figure 28. Numbers and distribution of Golden Plovers on the census transects, 1976, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

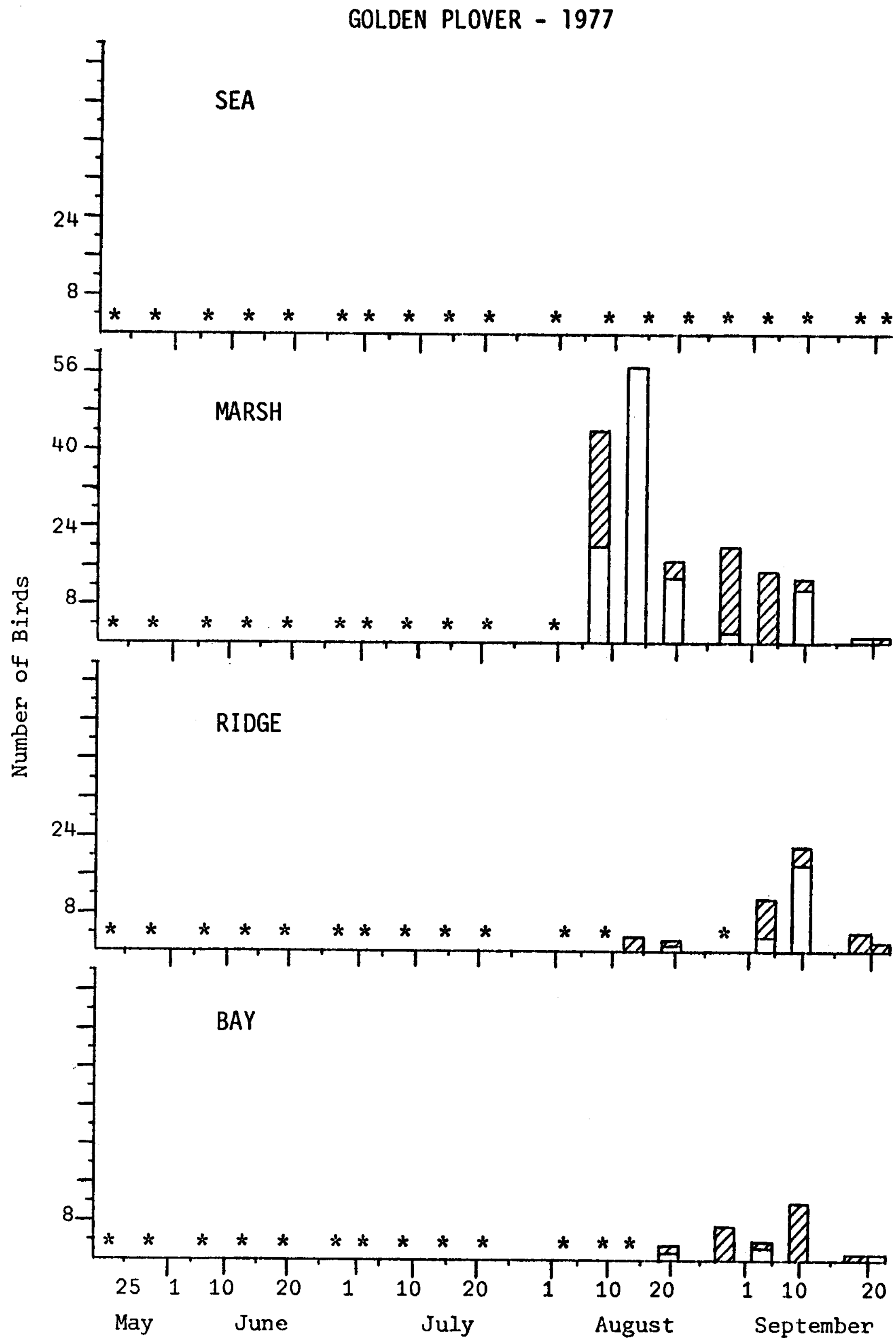

Figure 29. Numbers and distribution of Golden Plovers on the census transects, 1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

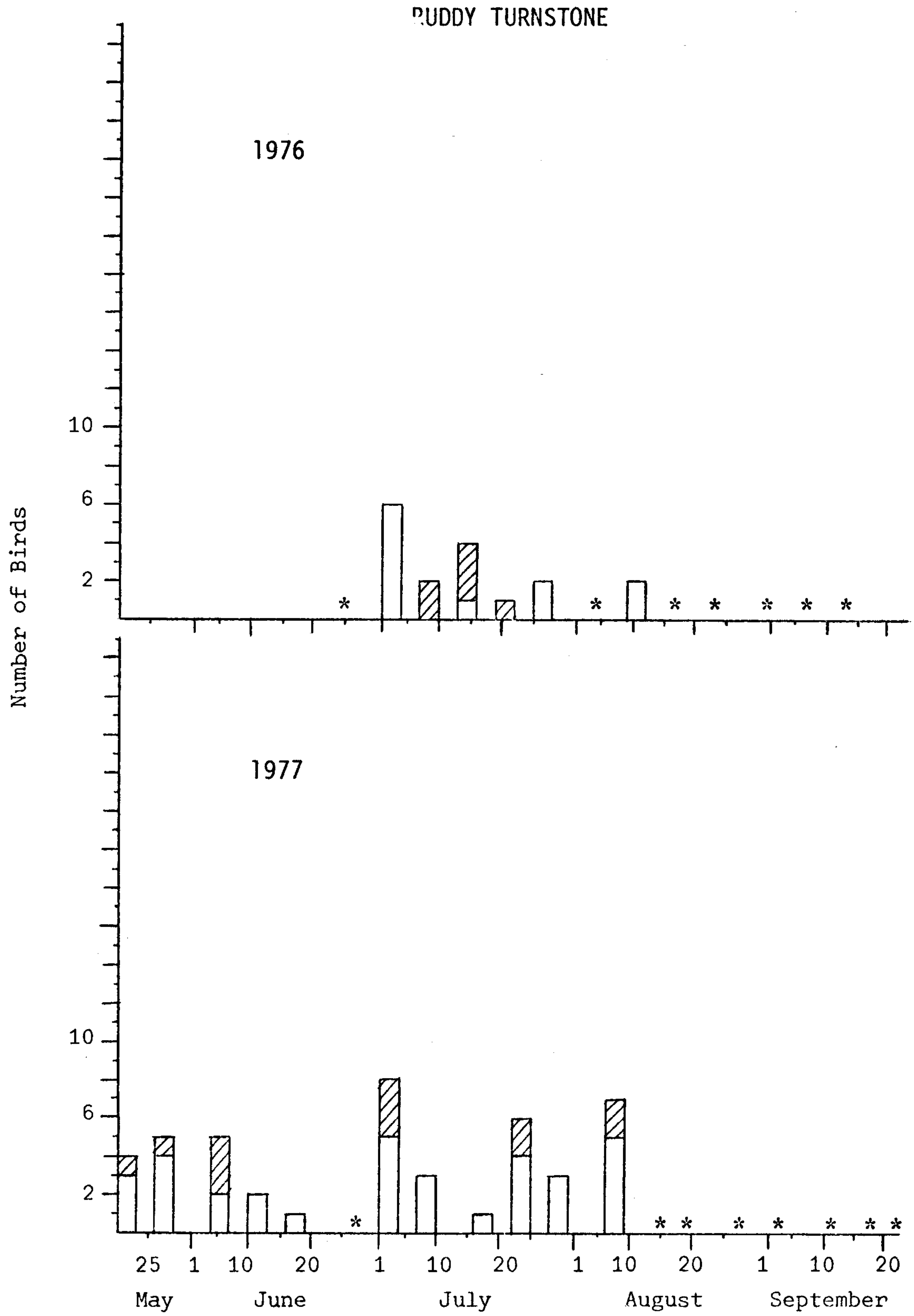

Figure 30. Summary of numbers of Ruddy Turnstones on the census transects, 1976-1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

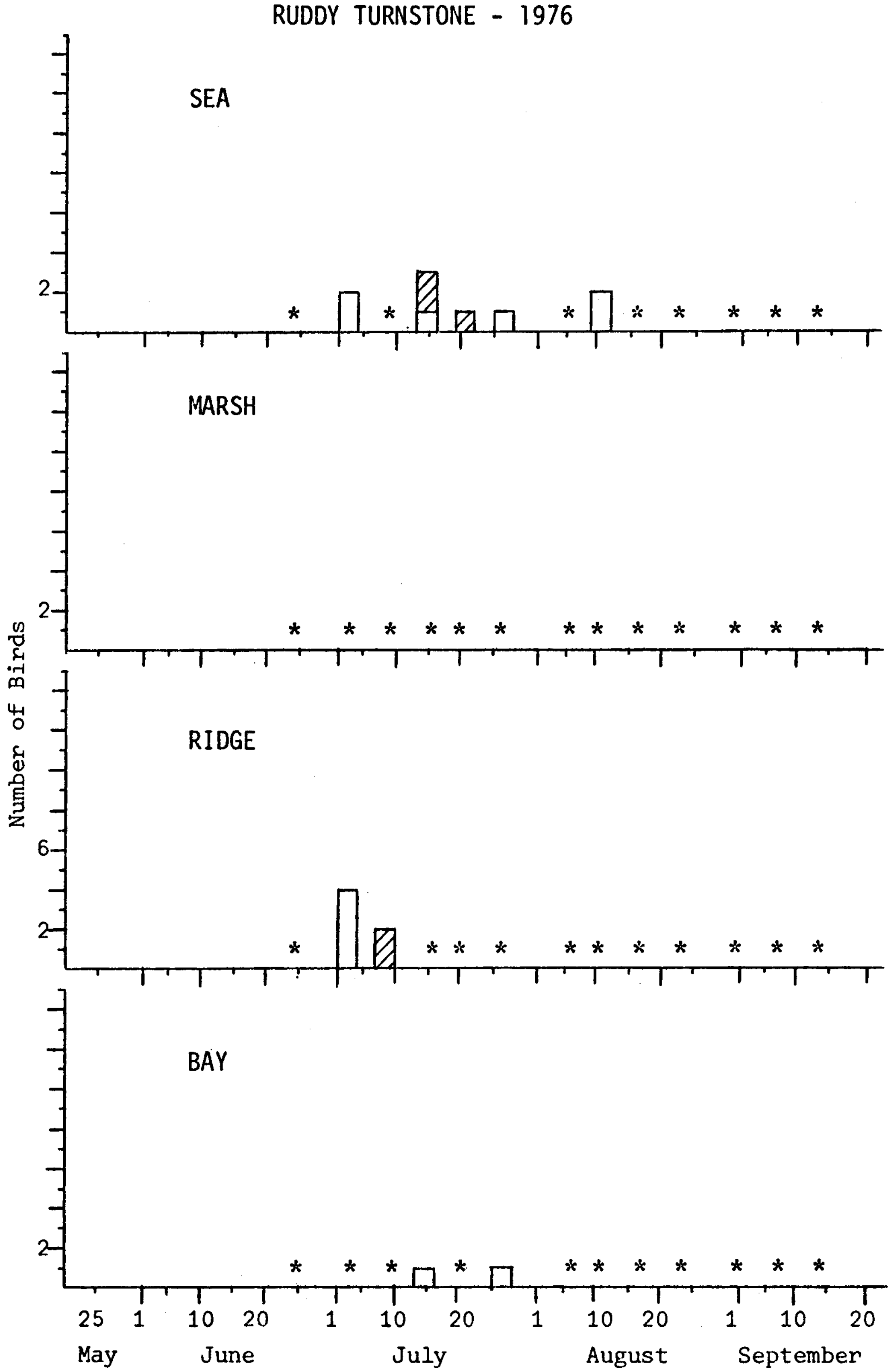

Figure 31. Numbers and distribution of Ruddy Turnstones on the census transects, 1976, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

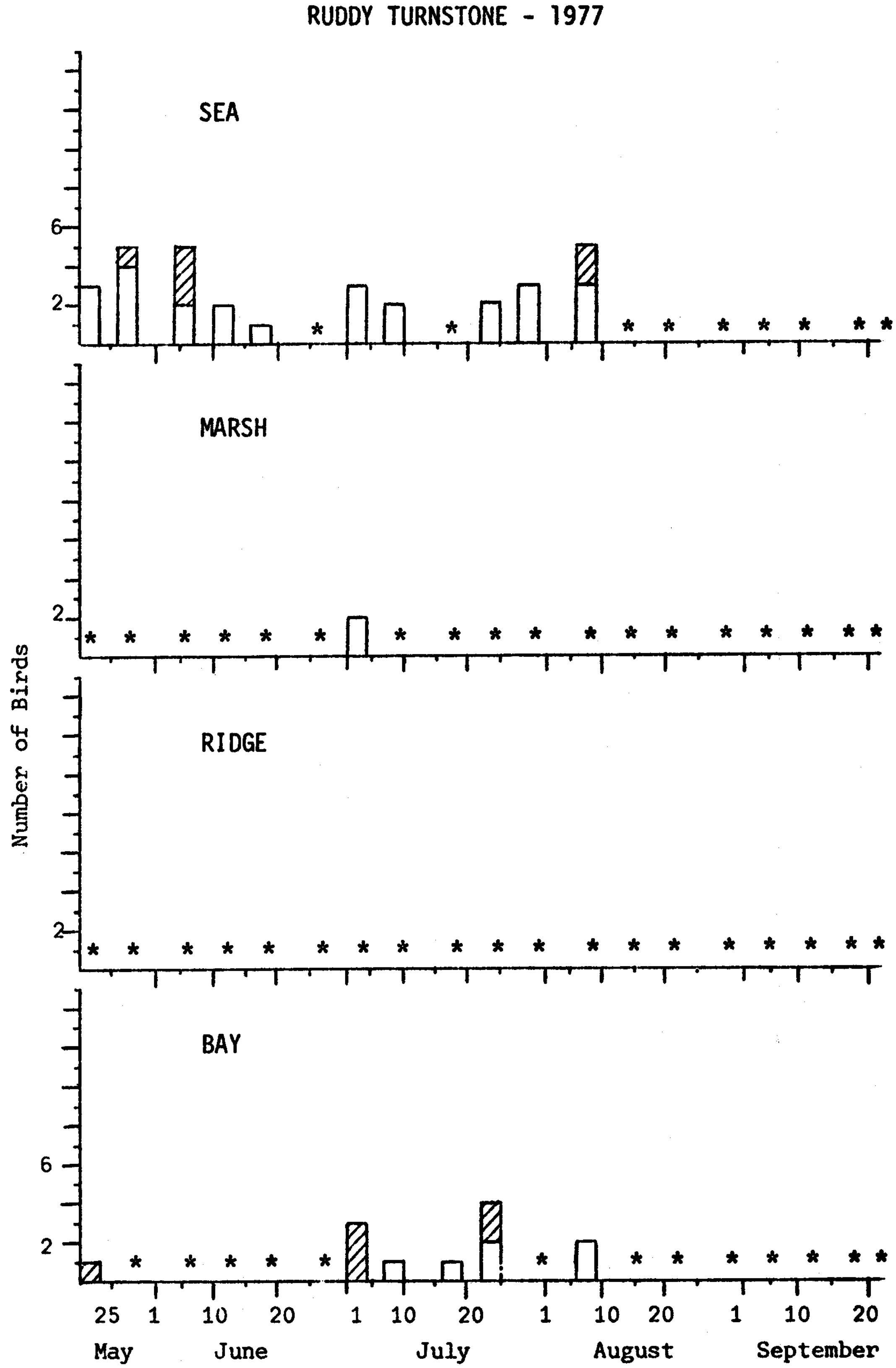

Figure 32. Numbers and distribution of Ruddy Turnstones on the census transects, 1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * - not present).

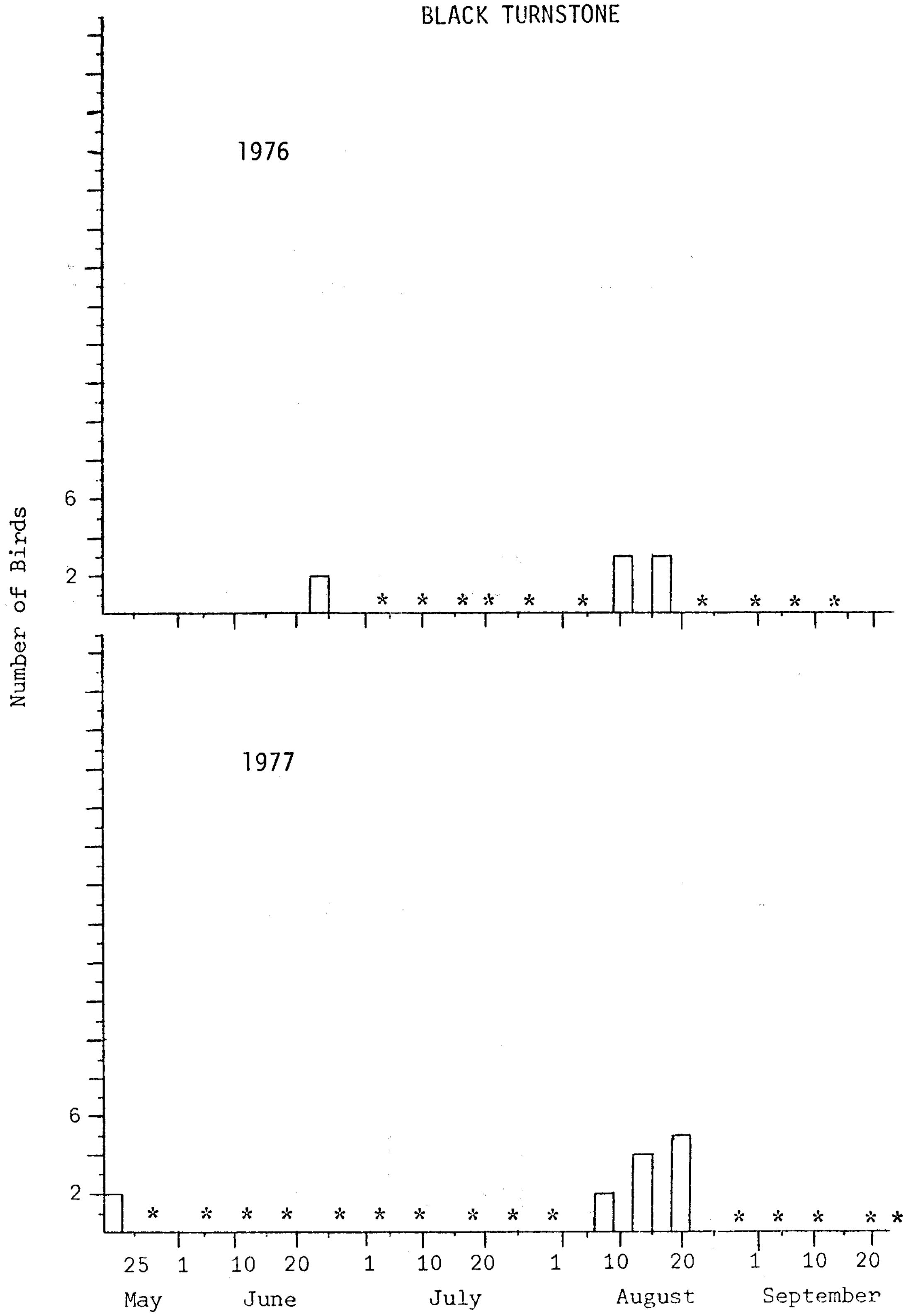

Figure 33. Summary of numbers of Black Turnstones on the census transects, 1976-1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

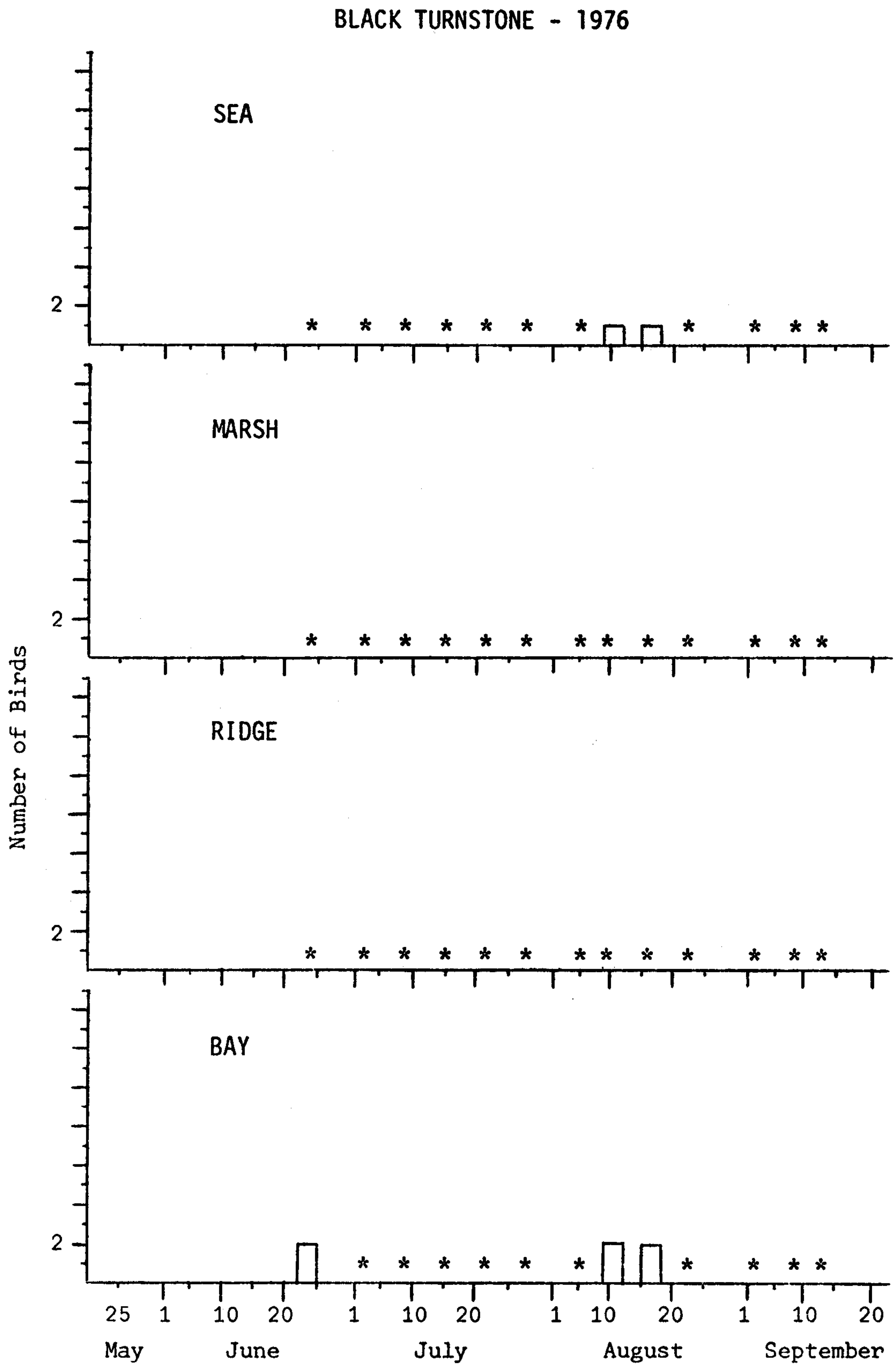

Figure 34. Numbers and distribution of Black Turnstones on the census transects, 1976, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

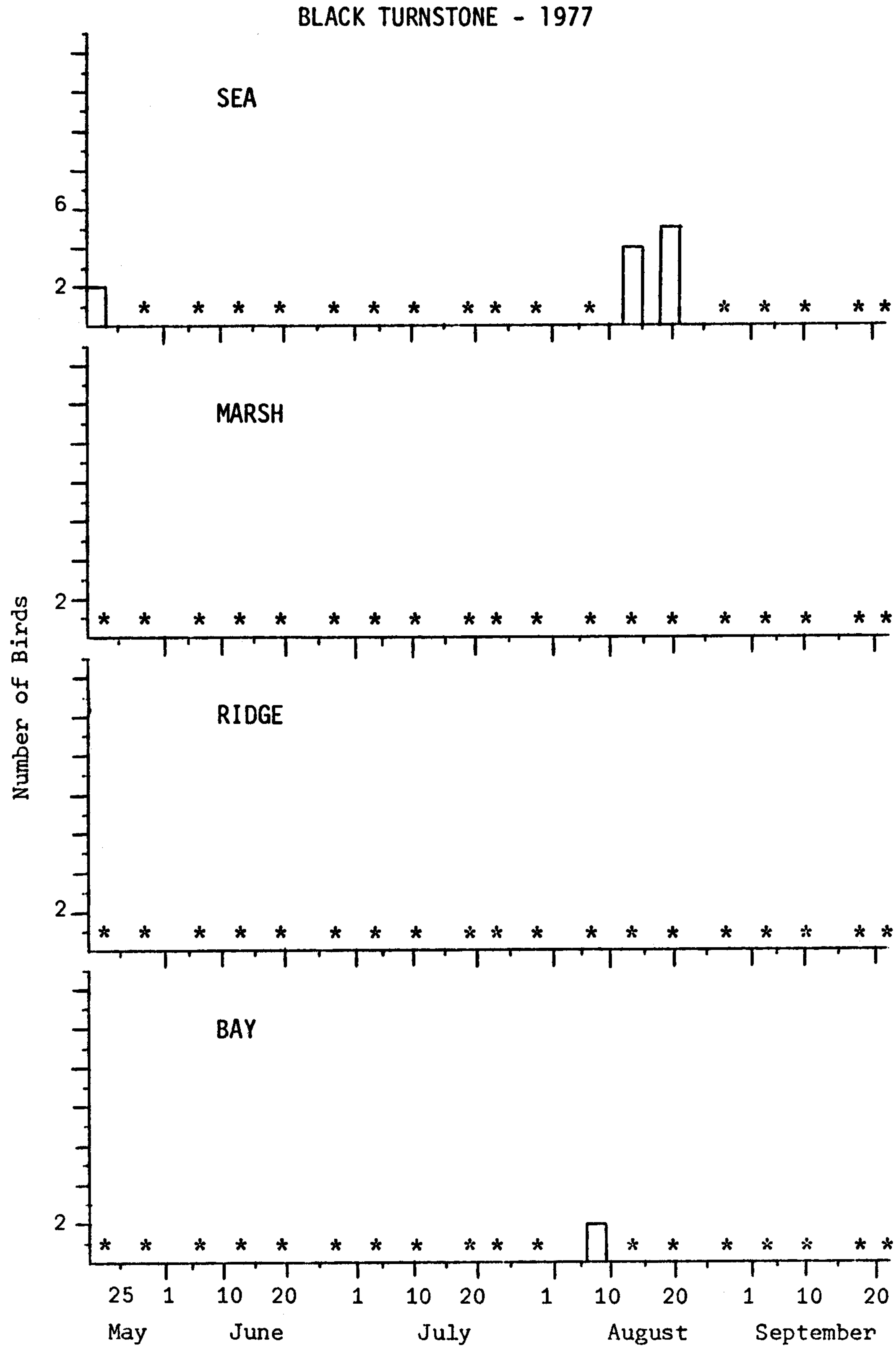

Figure 35. Numbers and distribution of Black Turnstones on the census transects, 1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

ward. The large flocks of eastbound Sharp-tails noted in late August at Wales in 1977 (Connors 1978) must have traveled across the Seward Peninsula south of the Cape. Although we observed only a few Sharp-tails in 1977, as did Connors (1978) at Krusenstern, this species was briefly abundant in late August in Norton Bay (Shields and Peyton 1978).

Pectoral Sandpipers. Pectoral Sandpipers were present, at least in low numbers, from early June through mid-September (Figs. 36, 37 and 38). Only a few nests of this species were found, all in 1977. Late-summer migrants were common during both summers. However, in 1977, migrant Pectoral Sandpipers were abundant by mid-July, about 3 weeks earlier than in 1976. Numbers decreased by early September both summers. These birds were most common in marsh habitat, where they fed and rested. Pectorals occasionally fed along the bay coast on the transects and some were observed feeding on the South Mudflats. All flocks of late-summer migrant Pectorals were eastbound. Migrant Pectoral and Sharp-tailed Sandpipers probably came from Siberian nesting grounds (Gabrielson and Lincoln 1959). Peak densities of migrant Pectorals (ca. 1.0 bird/ha) and the seasonal numerical and habitat distributional trends at the Cape match more closely Barrow data than those data reported from Wales and Krusenstern (Connors 1978). At the latter sites, more birds were observed on littoral transects than on the tundra; in addition, typical densities were less than 0.4 birds/ha.

Dunlins. Dunlins were present during our entire stay at Cape Espenberg. Their numbers varied little through early August, the beginning of fall migration (Figs. 39, 40 and 41). Only migrant (both spring and fall) Dunlins fed along the Chukchi coast. They were most common in this habitat during high tides in fall when mudflats in Espenberg Bay were not available for foraging. They fed primarily along the flotsam line and at the edges of tide pools. Fall migrants were most common on the marsh and bay transects; they fed extensively in both habitats. The largest numbers of migrant Dunlins fed on the South Mudflats (Table 9). Dunlins fed on ridges and in the marsh during the nesting period. Densities of fall migrant Dunlins were greater on the Cape (ca. 2.0 birds/ha) than reported by Connors(1978) for Krusenstern (0.6 birds/ha), and only slightly greater than most counts at Wales (1.8 birds/ha). The pattern of numerical increase in August and September was similar to that reported from Barrow (Connors 1978).

Semipalmated Sandpipers. Semipalmated Sandpipers were present from mid-May through early August (Figs. 42, 43 and 44). They were regularly seen on all transects. The large number observed on the bay transect in late June 1976 corresponds to an influx of ice and its associated fauna. Densities of Semipalmated Sandpipers on transects on the Cape (ca. 0.5 birds/ha) were similar to Krusenstern (Connors 1978), although littoral use was much less on the Cape. The birds vacated the Krusenstern to Norton Bay region by early August (this study, Connors 1978, Shields and Peyton 1978). Migrant birds were more numerous on the South Mudflats than on littoral transects on the Cape.

Western Sandpipers. Western Sandpipers remained on the Cape about 10 days longer than did Semipalmated Sandpipers (Figs. 45, 46 and 47).

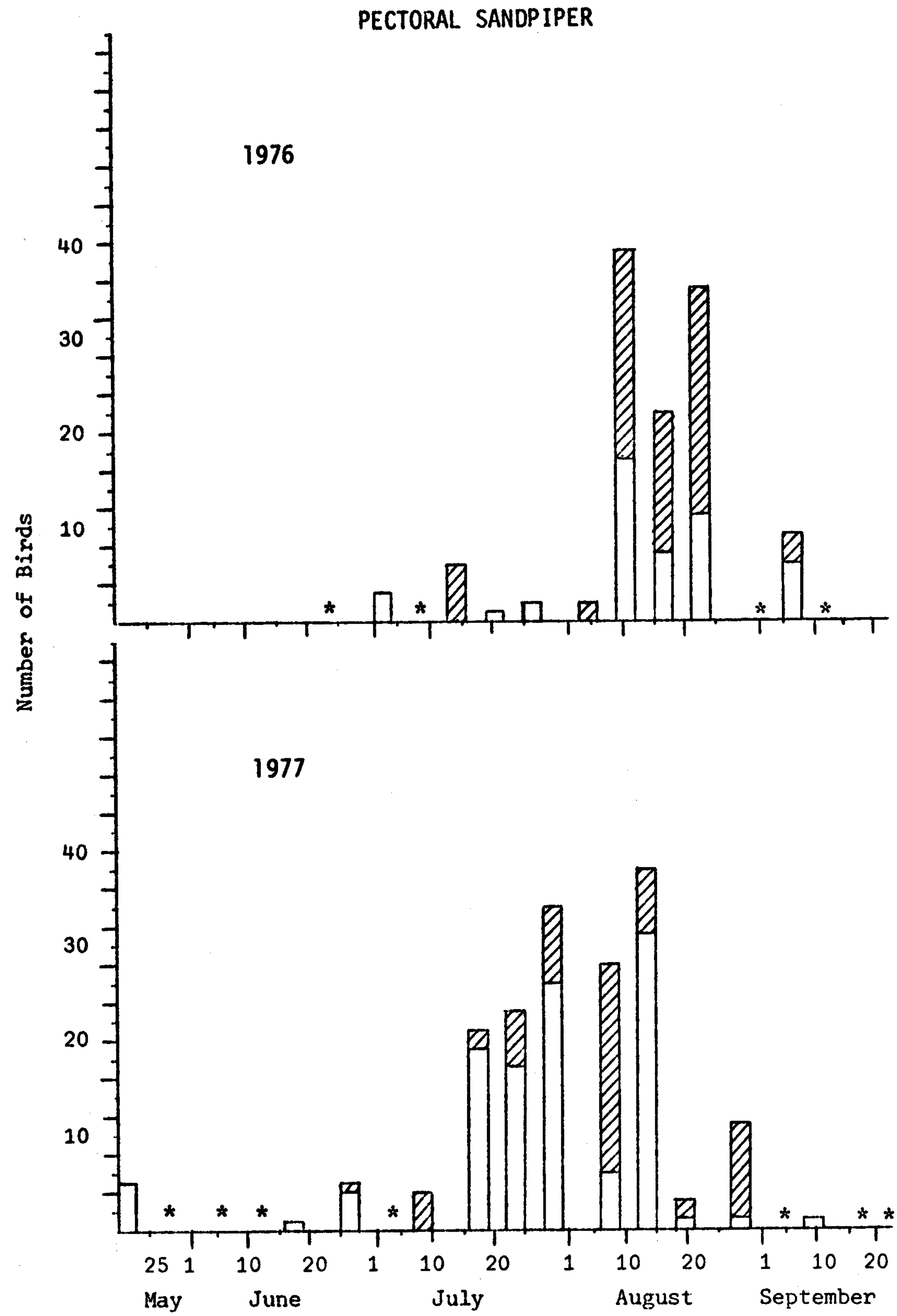

Figure 36. Summary of numbers of Pectoral Sandpipers on the census transects, 1976-1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

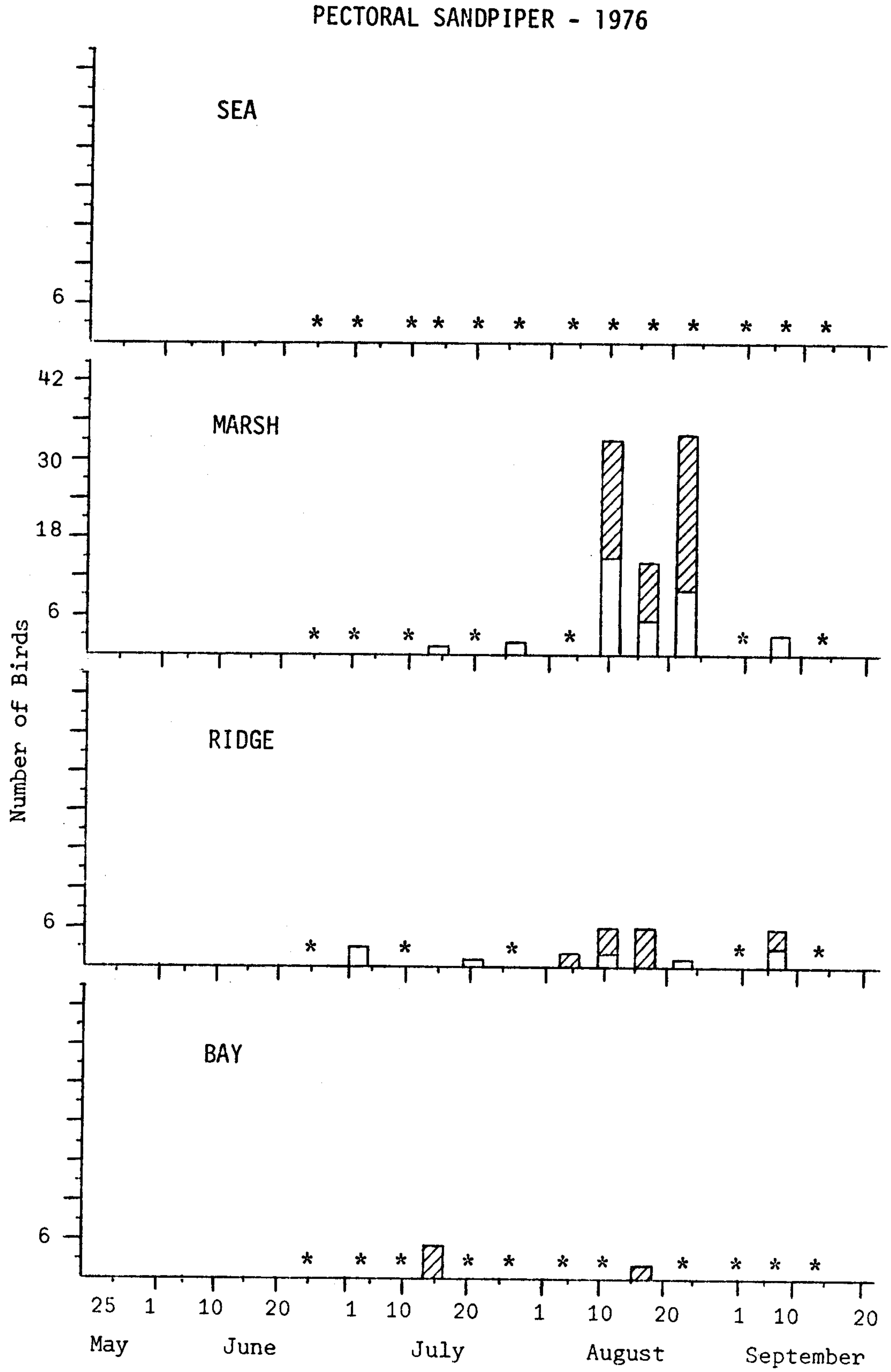

Figure 37. Numbers and distribution of Pectoral Sandpipers on the census transects, 1976, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

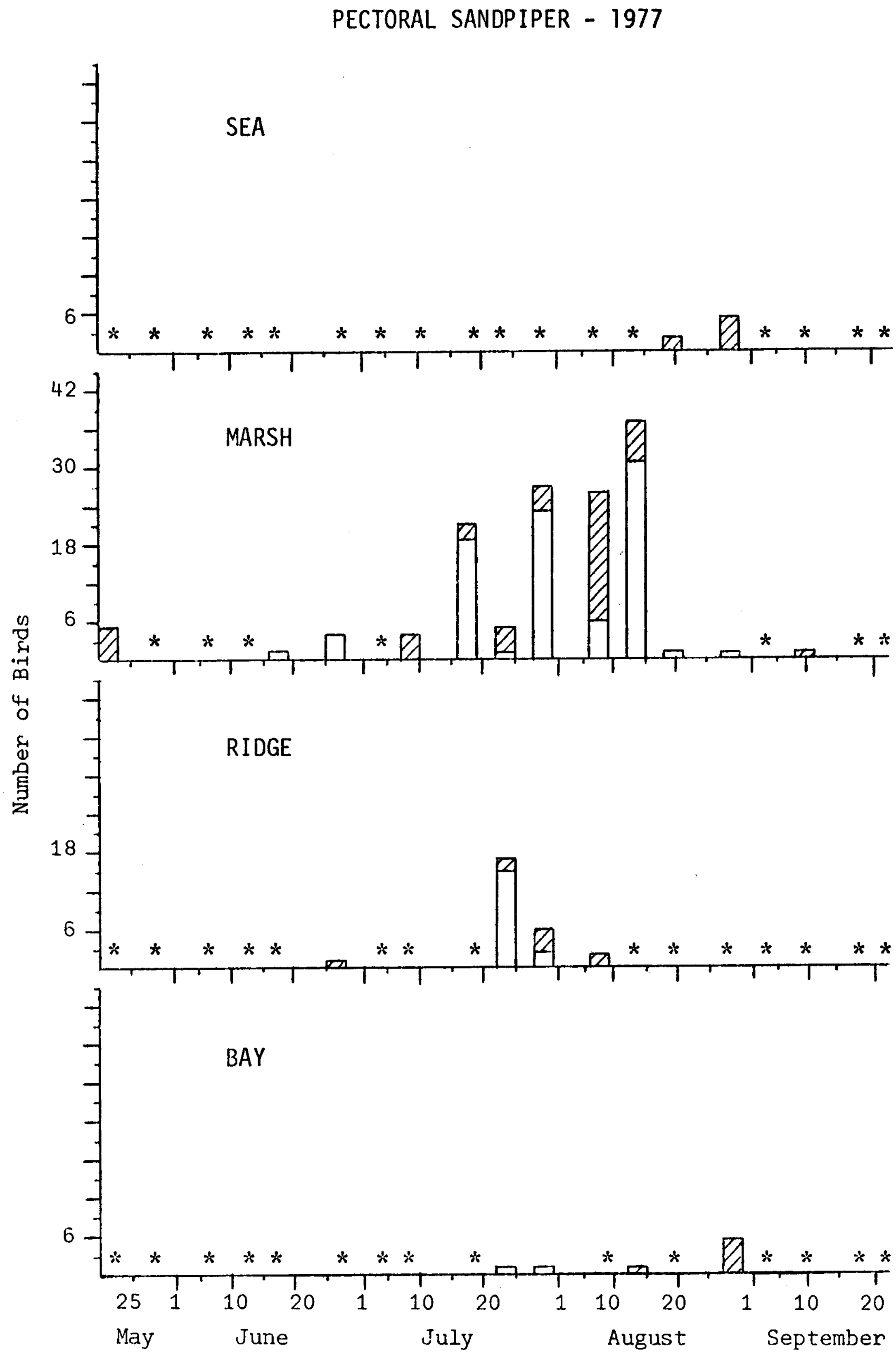

Figure 38. Numbers and distribution of Pectoral Sandpipers on the census transects, 1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

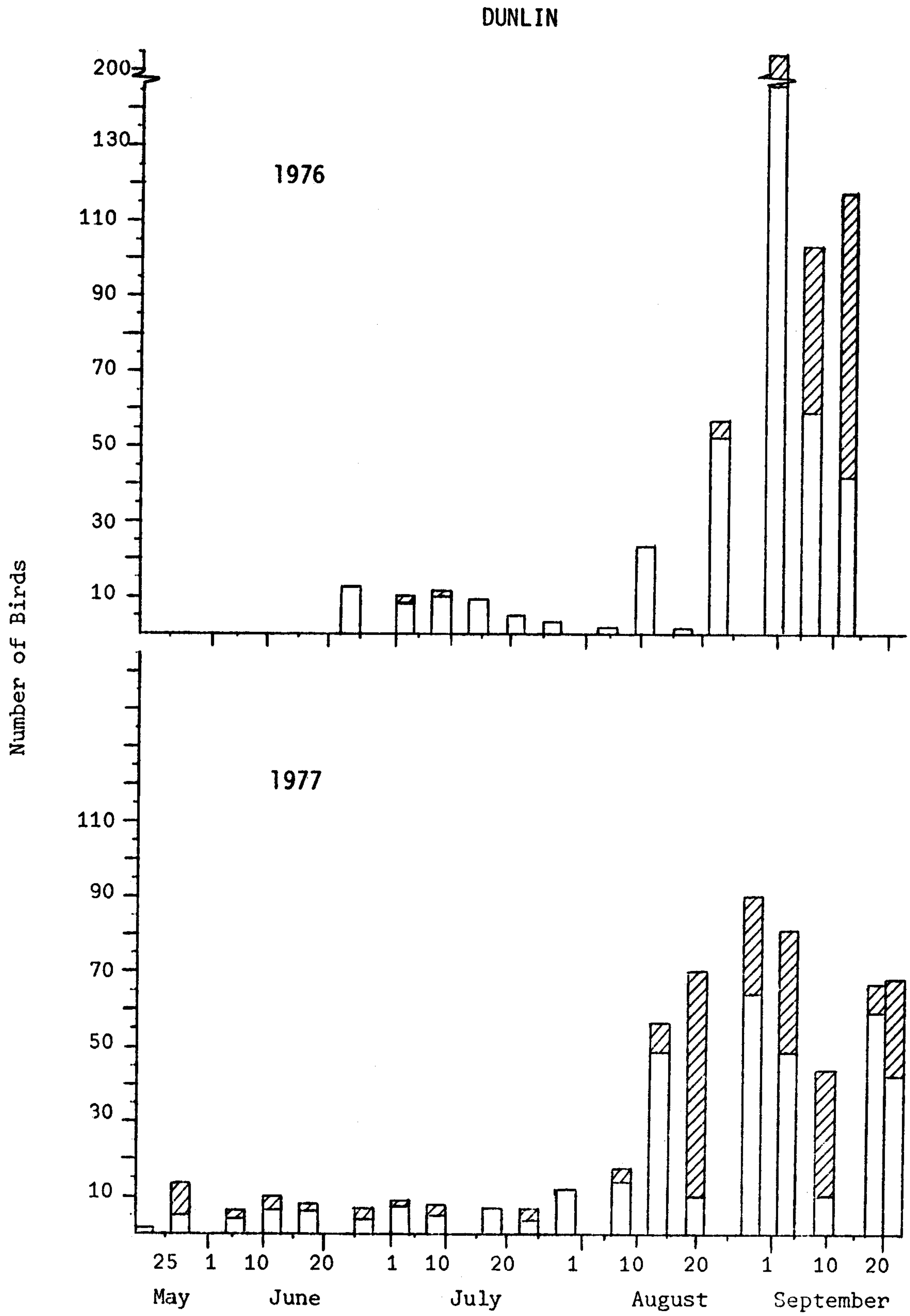

Figure 39. Summary of numbers of Dunlins on the census transects, 1976-1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

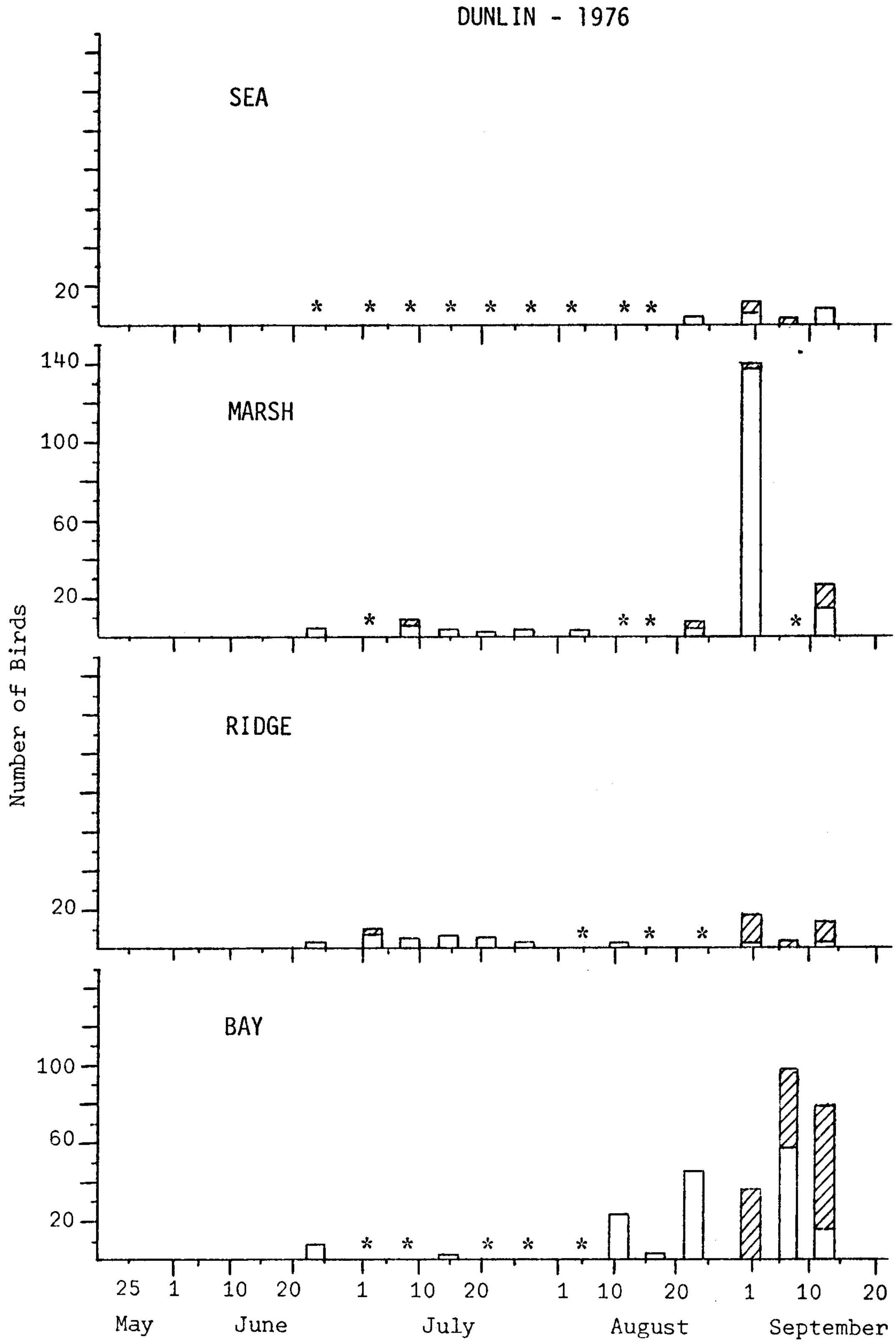

Figure 40. Numbers and distribution of Dunlins on the census transects, 1976, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

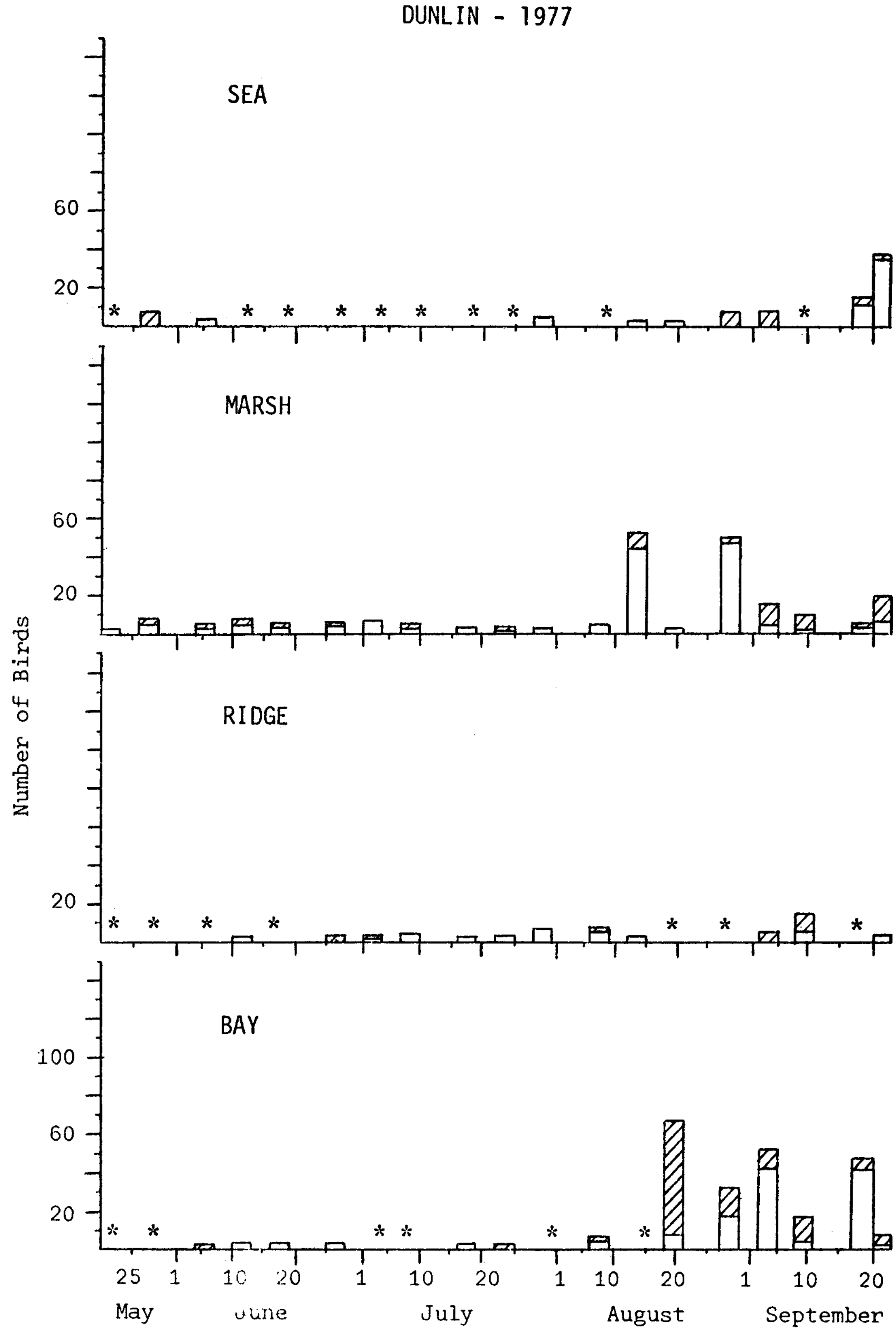

Figure 41. Numbers and distribution of Dunlins on the census transects, 1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

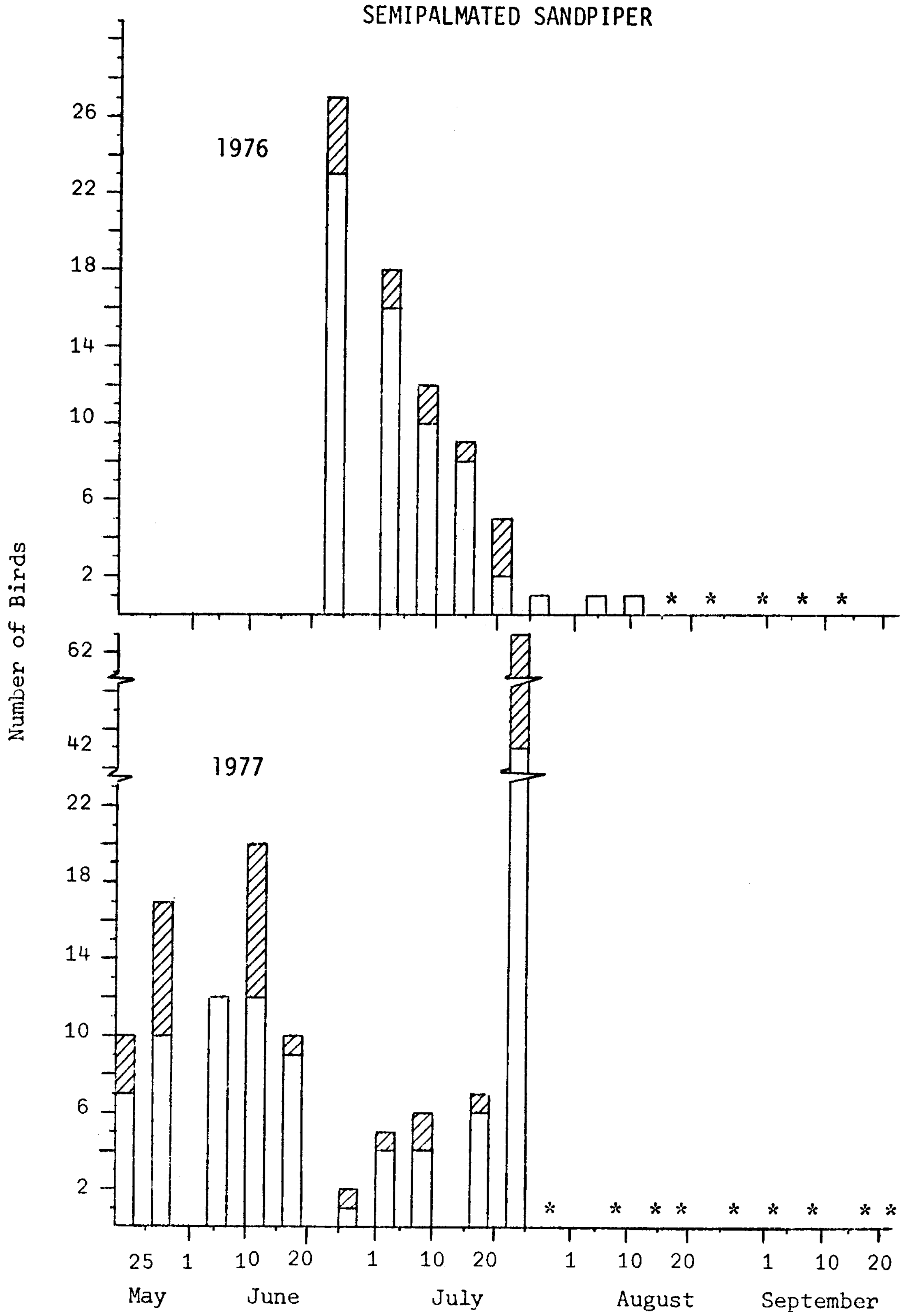

Figure 42. Summary of numbers of Semipalmated Sandpipers on the census transects, 1976-1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

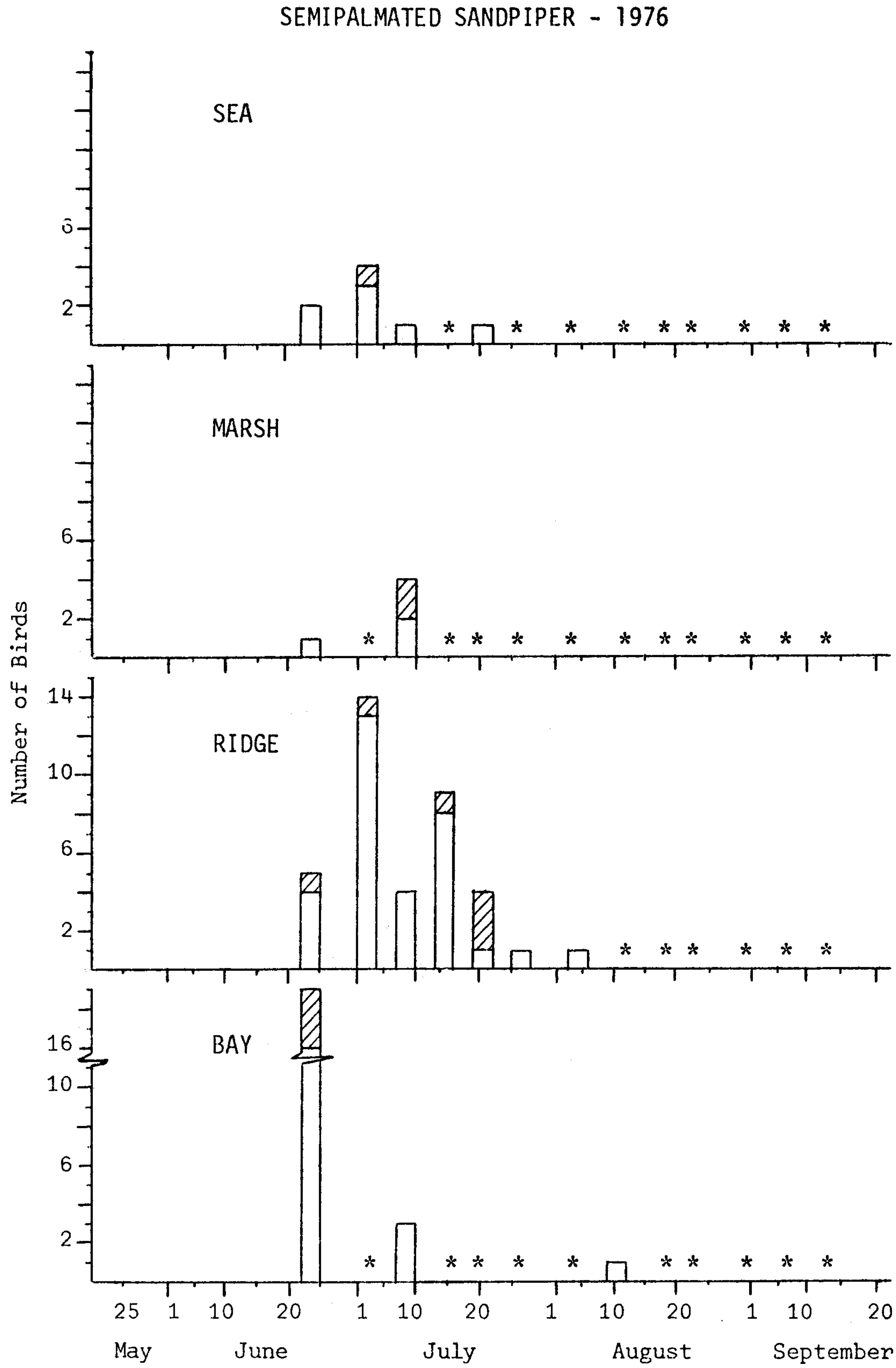

Figure 43. Numbers and distribution of Semipalmated Sandpipers on the census transects, 1976, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

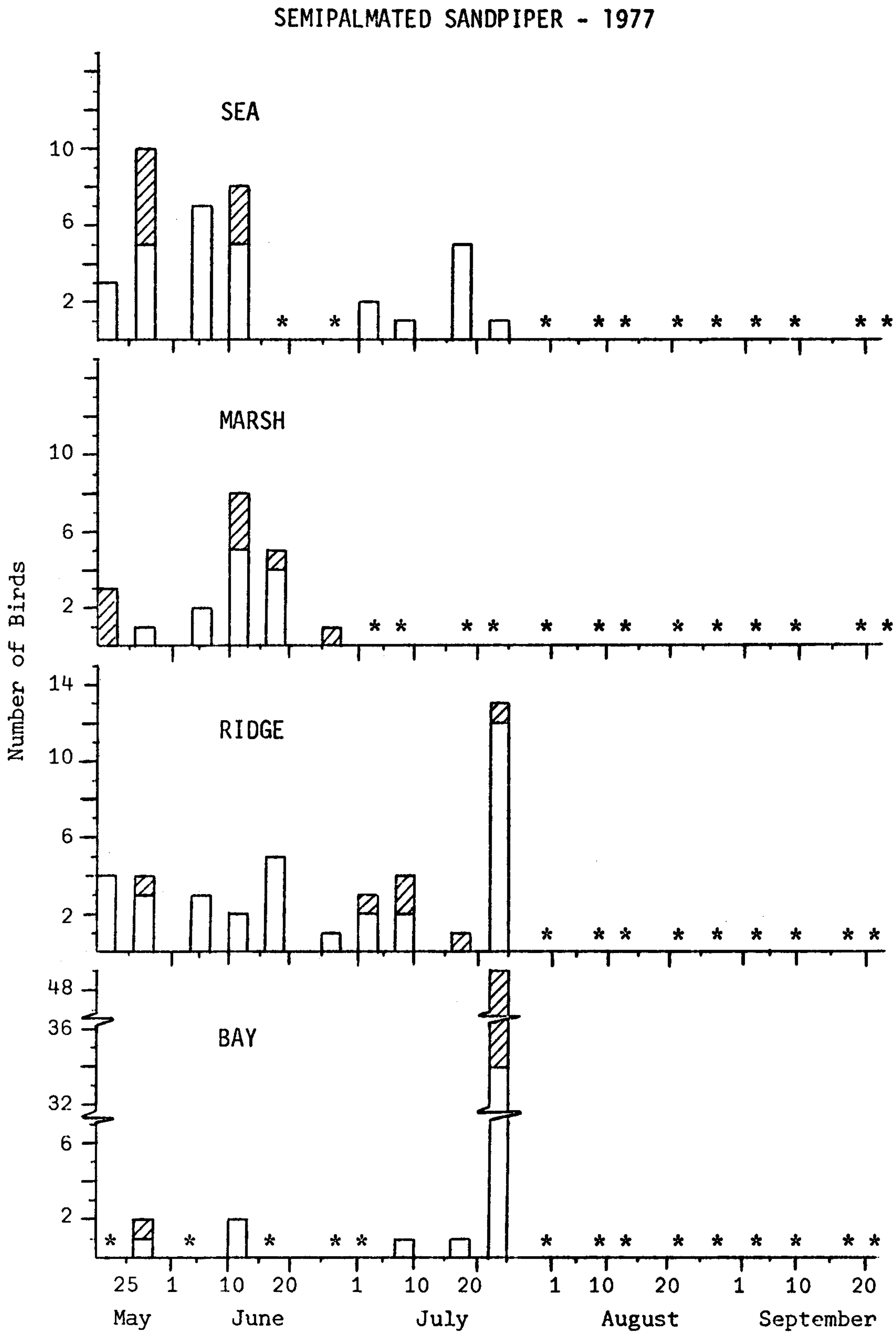

Figure 44. Numbers and distribution of Semipalmated Sandpipers on the census transects, 1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

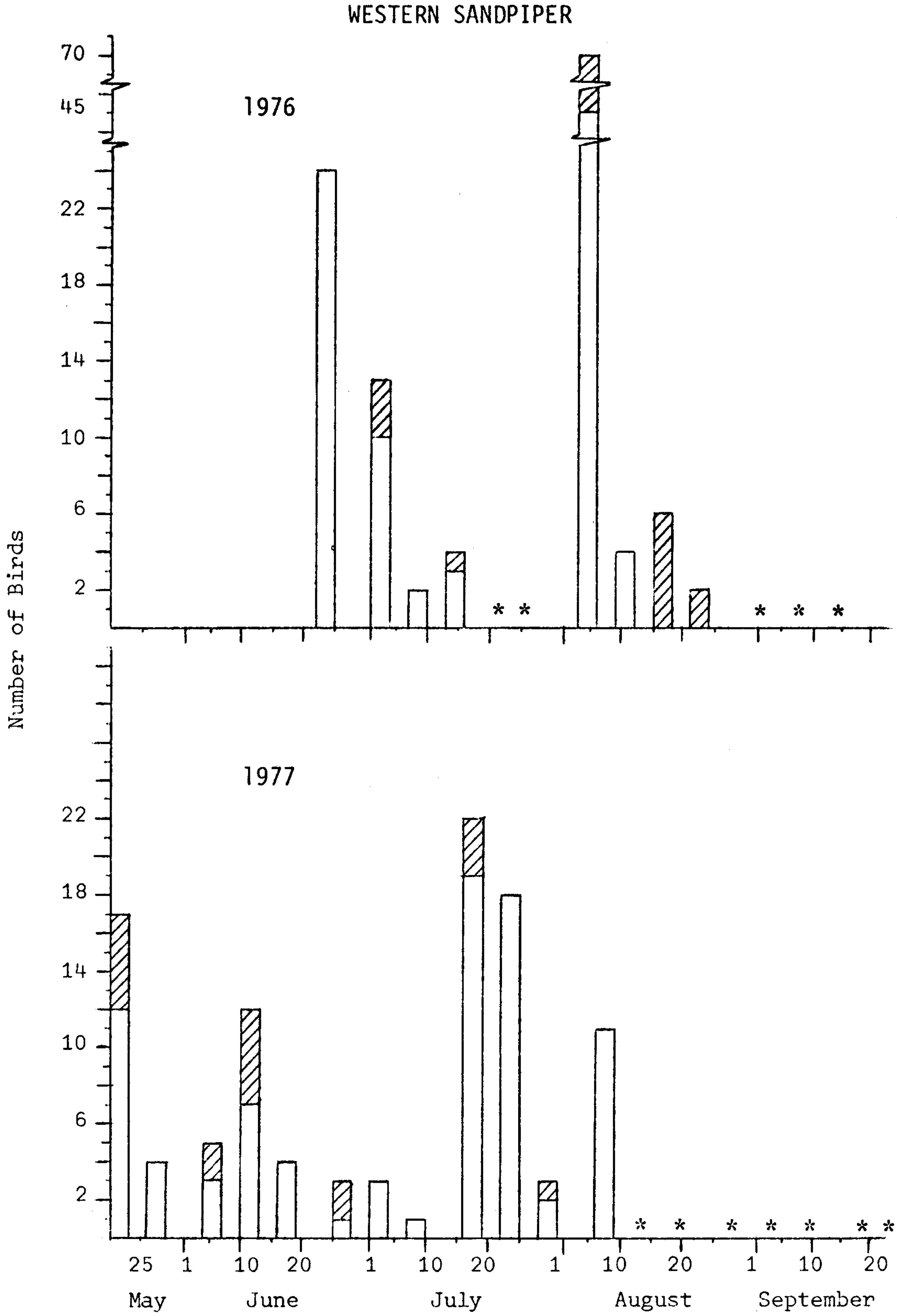

Figure 45. Summary of numbers of Western Sandpipers on the census transects, 1976-1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

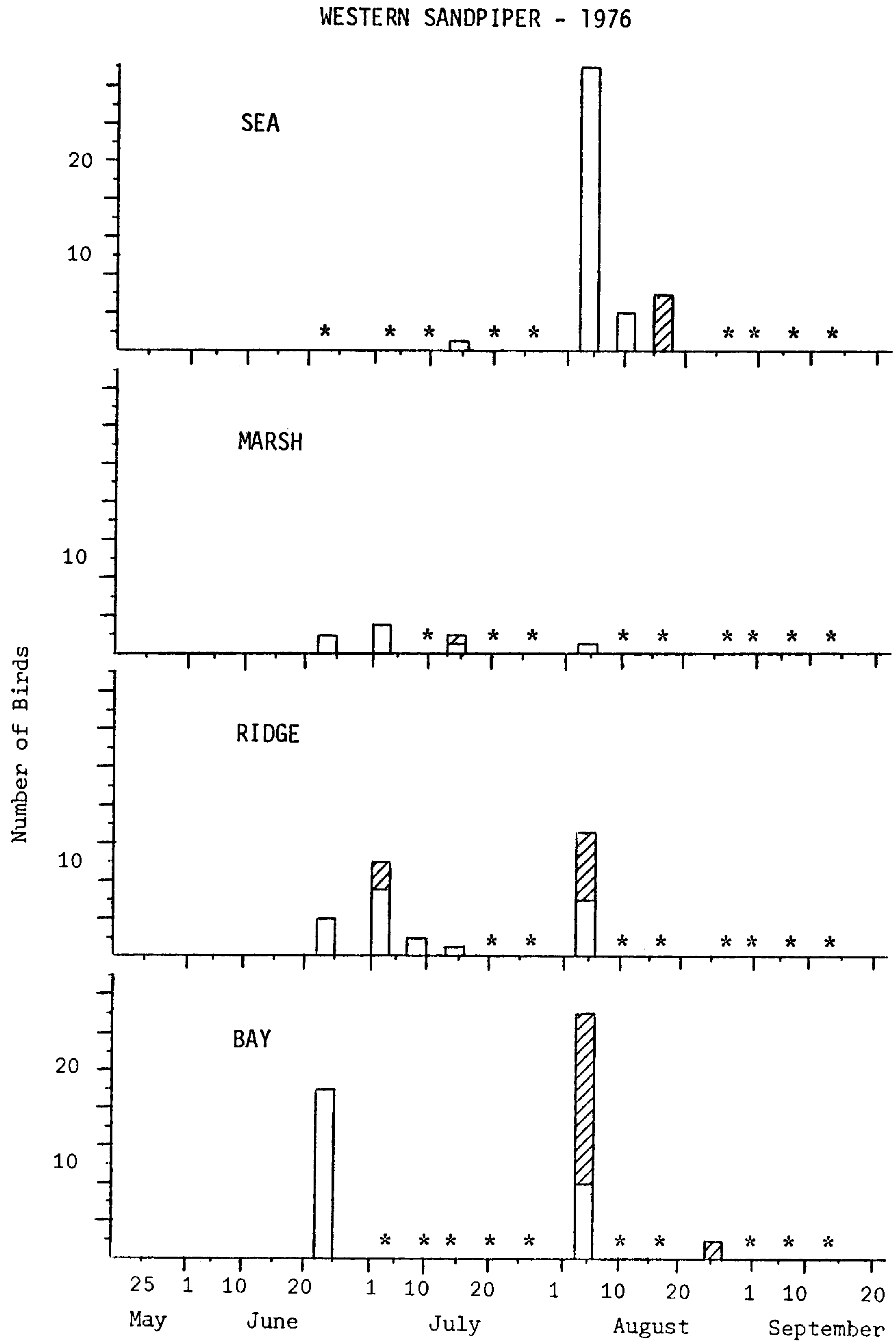

Figure 46. Numbers and distribution of Western Sandpipers on the census transects, 1976, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

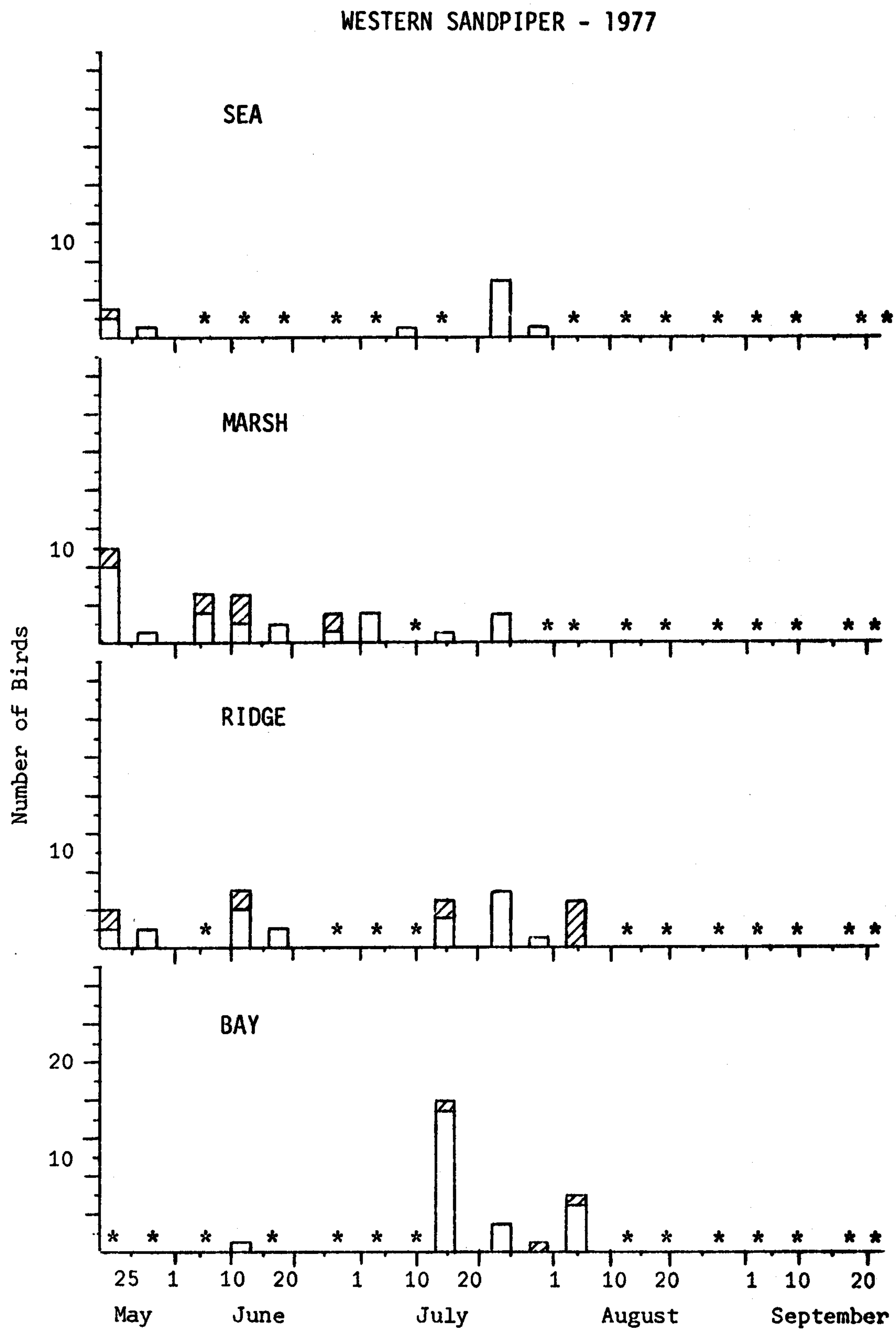

Figure 47. Numbers and distribution of Western Sandpipers on the census transects, 1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

They used habitats similar to Semipalmated Sandpipers. In 1976, fall migration started in early August and continued for about 3 weeks. The pattern was similar in 1977, but occurred about 2 weeks earlier. Fall migrants were common along both coasts, as well as on tundra areas. Seasonal trends were similar to those reported from Wales and Krusenstern (Connors 1978). Migrant birds were more numerous on the South Mudflats than on the Cape littoral transects.

Sanderlings. Except for a few adults in mid-July, Sanderlings did not appear on the transects until mid-August (Figs. 48, 49 and 50). This occurred both summers. August birds were all juveniles and were all westbound. They were found primarily along the sea coast, where they fed on amphipods at the water's edge and dead insects in the flotsam. Sanderlings were still present on the Cape in late September. Densities in the littoral zone (ca. 0.3 birds/ha) were similar to Barrow (Connors 1978). Few Sanderlings were observed at Wales and Krusenstern (Connors 1978).

Long-billed Dowitchers. Dowitchers were observed on the Cape throughout the entire field season. During the breeding period, they nested and fed in marsh habitat. They were most numerous in early September, still feeding primarily in marshes (Figs. 51, 52 and 53). Dowitchers were occasionally observed feeding on mudflats in Espenberg Bay. The brief fall migrant peak (ca. 1.0 bird/ha) was similar to the pattern observed at Wales (Connors 1978) and Norton Bay (Shields and Peyton 1978). Large numbers of migrants were last noted in early September at Wales and Krusenstern, 10 September at the Cape, and 14 September at Norton Bay, suggesting a quick movement southward.

Red Phalaropes. Red Phalaropes showed little inter-year variation over the two years of this study (Figs. 54, 55 and 56). These birds were most frequently observed in the marsh, where they fed and nested in June and early July. In mid-June, an influx of adults (that would probably soon nest) was noted along the Chukchi coast. By late July, most Red Phalaropes had departed from the area. The large number of birds observed in the bay in late June 1976 corresponds to an influx of ice and its associated fauna. The absence of large numbers of juvenile Red Phalaropes in nearshore waters in late summer contrasts sharply with Beaufort Sea studies, where these birds are quite numerous in August (Connors 1978, Johnson 1978). The absence of late summer migrant phalaropes from Espenberg may be the typical situation. Swartz (1967) did not find Red Phalaropes in the Kotzebue Sound area in August 1960. The distribution of these birds in the southern Chukchi Sea reported by Swartz (1967) suggests that they move directly from the Cape Thompson area to the Bering Strait, bypassing Kotzebue Sound. Seasonal, habitat, and density trends were similar to those noted at Wales and Krusenstern (Connors 1978).

Northern Phalaropes. With one major exception, Northern Phalaropes showed the same basic seasonal and distributional patterns as Red Phalaropes (Figs. 57, 58 and 59). The exception is the large number of birds observed along the Chukchi coast in late September 1977. They were sighted just after a storm passed through the area and may have been driven shoreward by high winds. Regardless of how these phalaropes arrived at Cape Espenberg, their presence in late September was un-

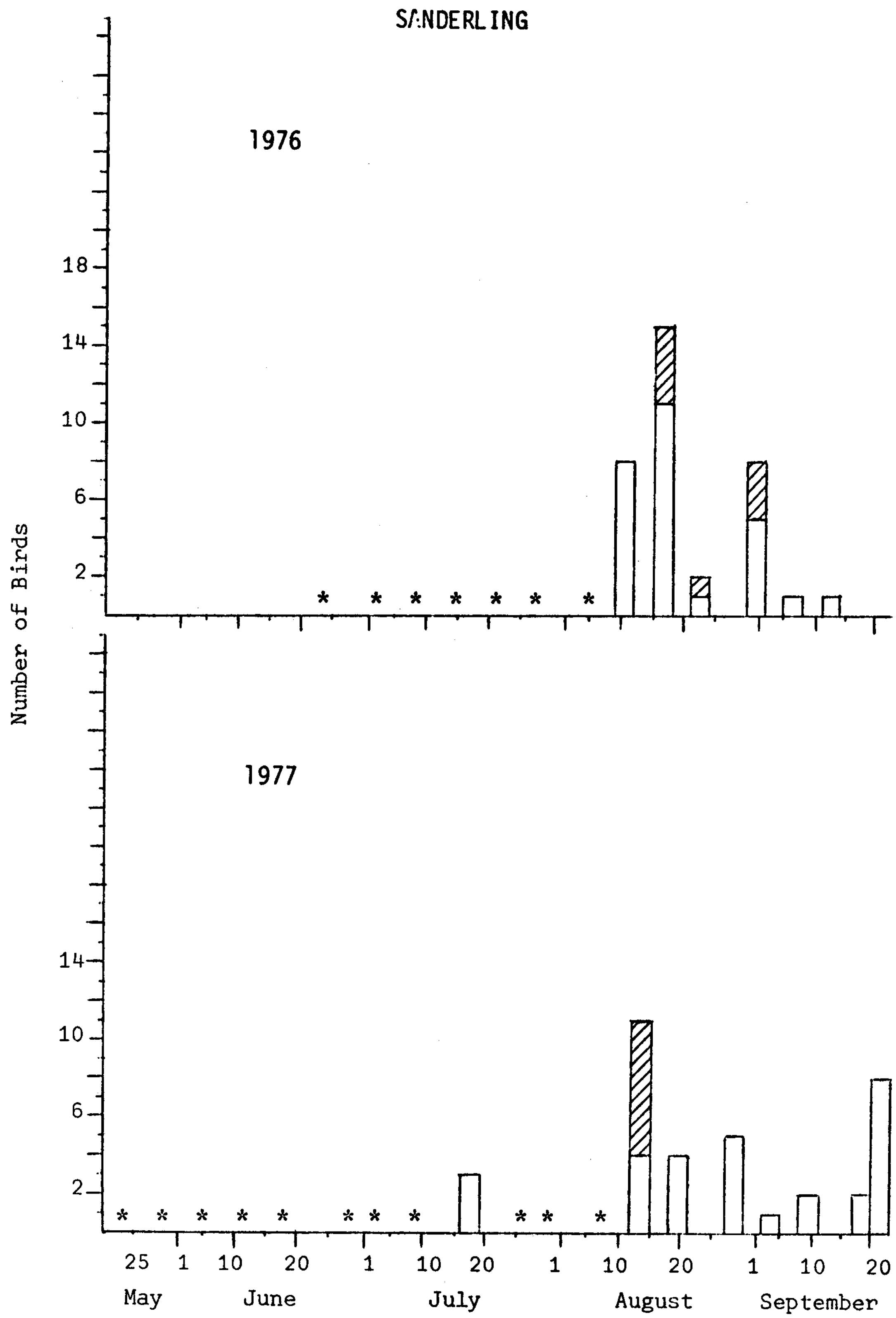

Figure 48. Summary of numbers of Sanderlings on the census transects, 1976-1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

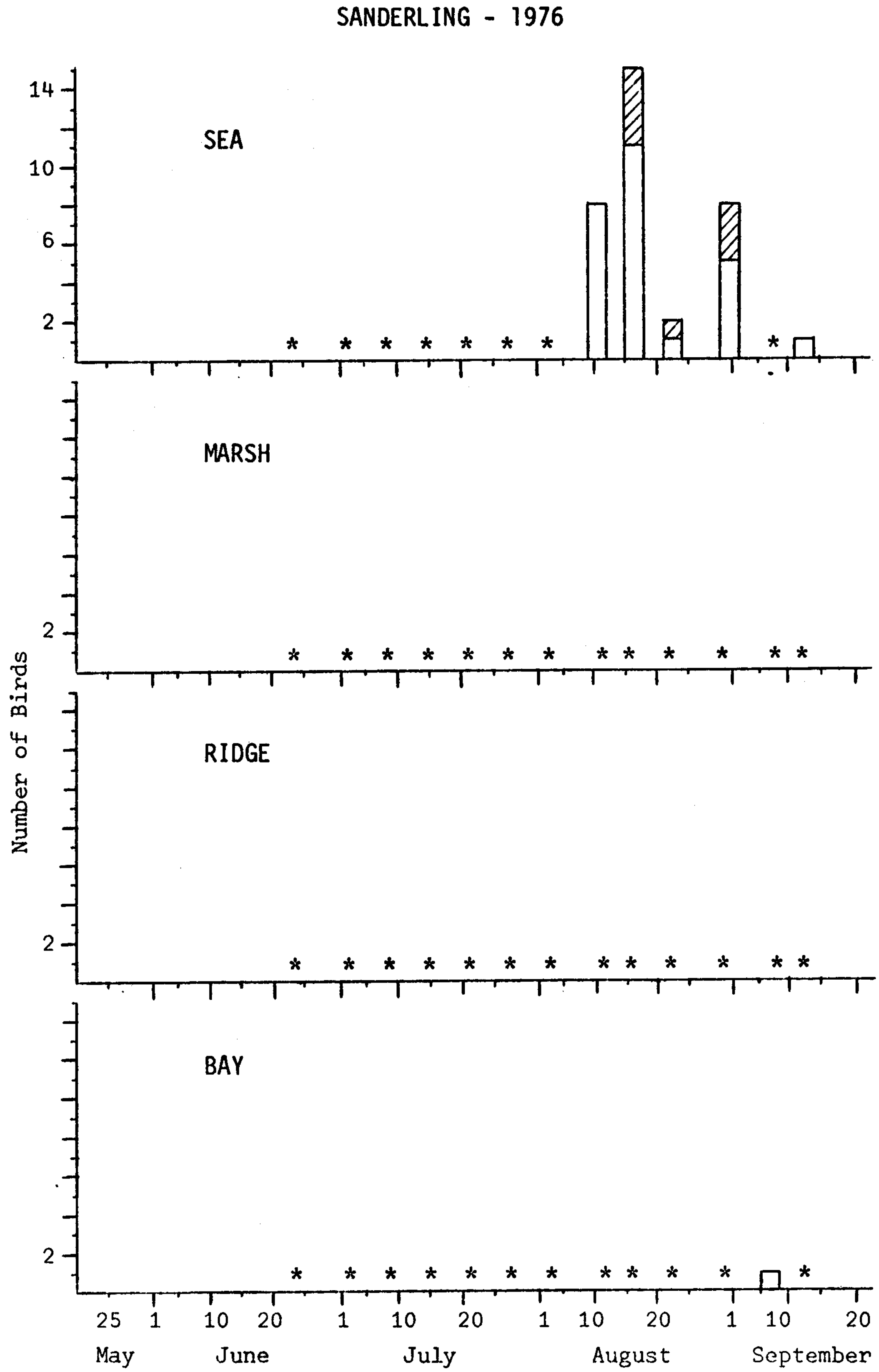

Figure 49. Numbers and distribution of Sanderlings on the census transects, 1976, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

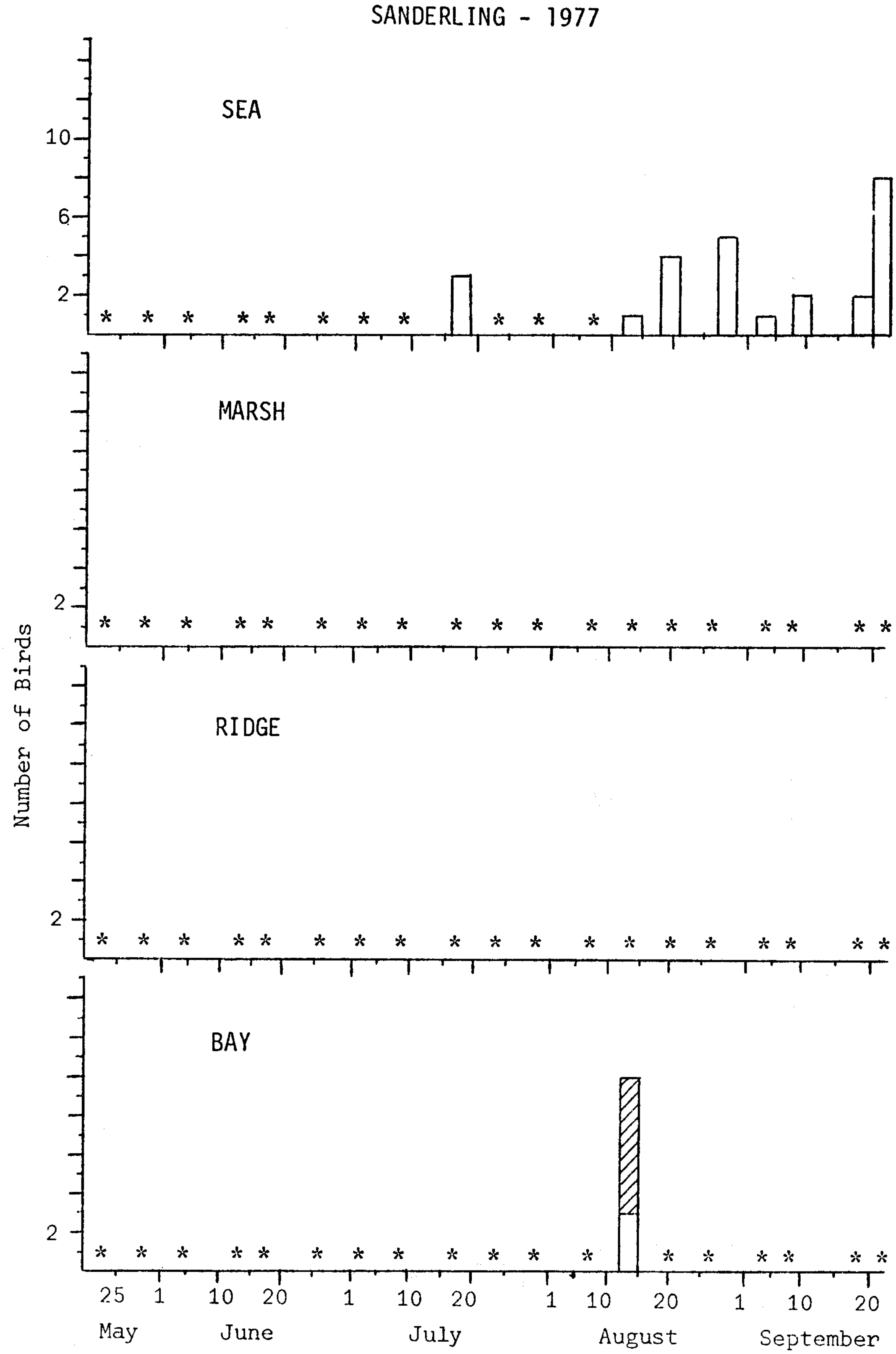

Figure 50. Numbers and distribution of Sanderlings on the census transects, 1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

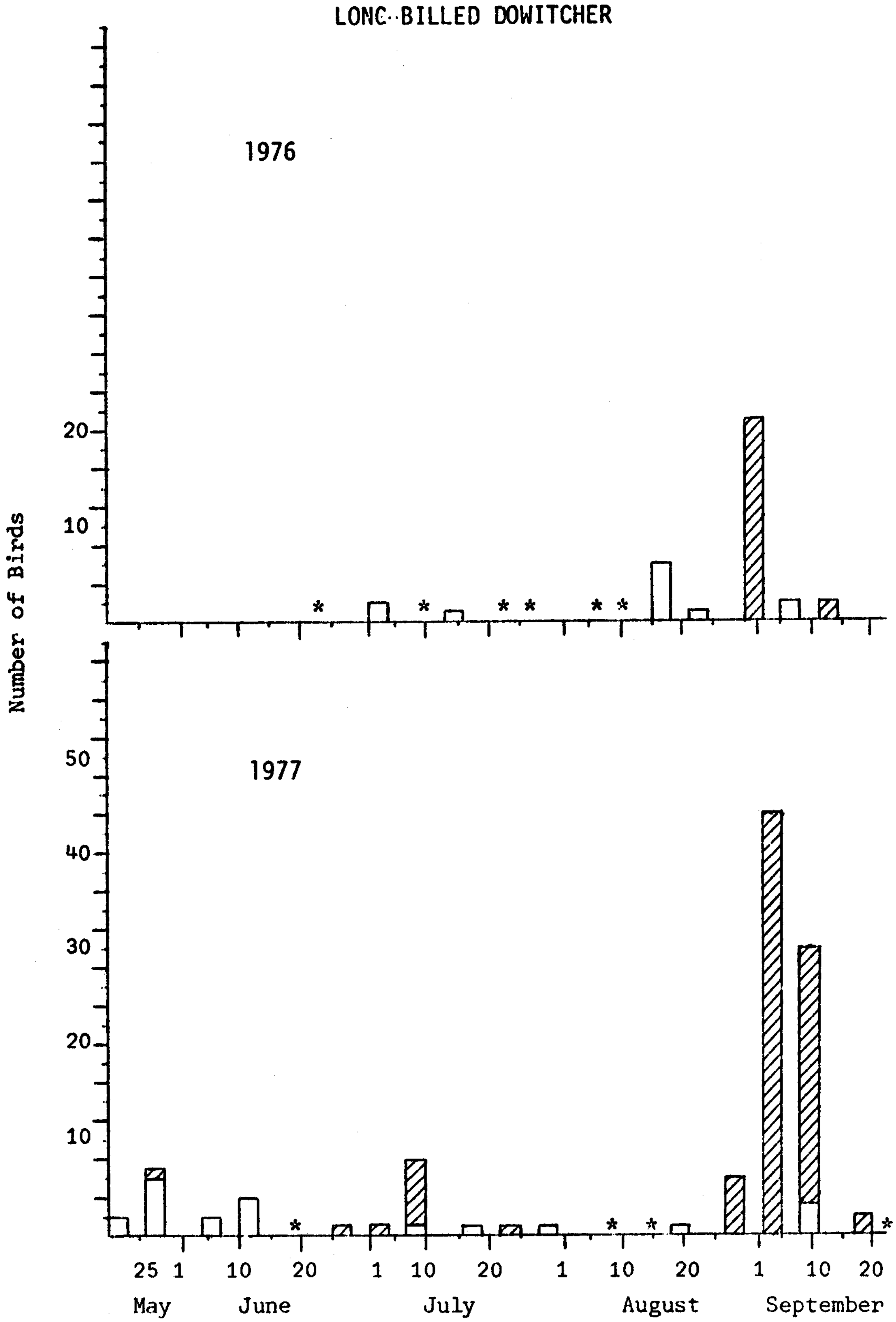

Figure 51. Summary of numbers of Long-billed Dowitchers on the census transects, 1976-1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

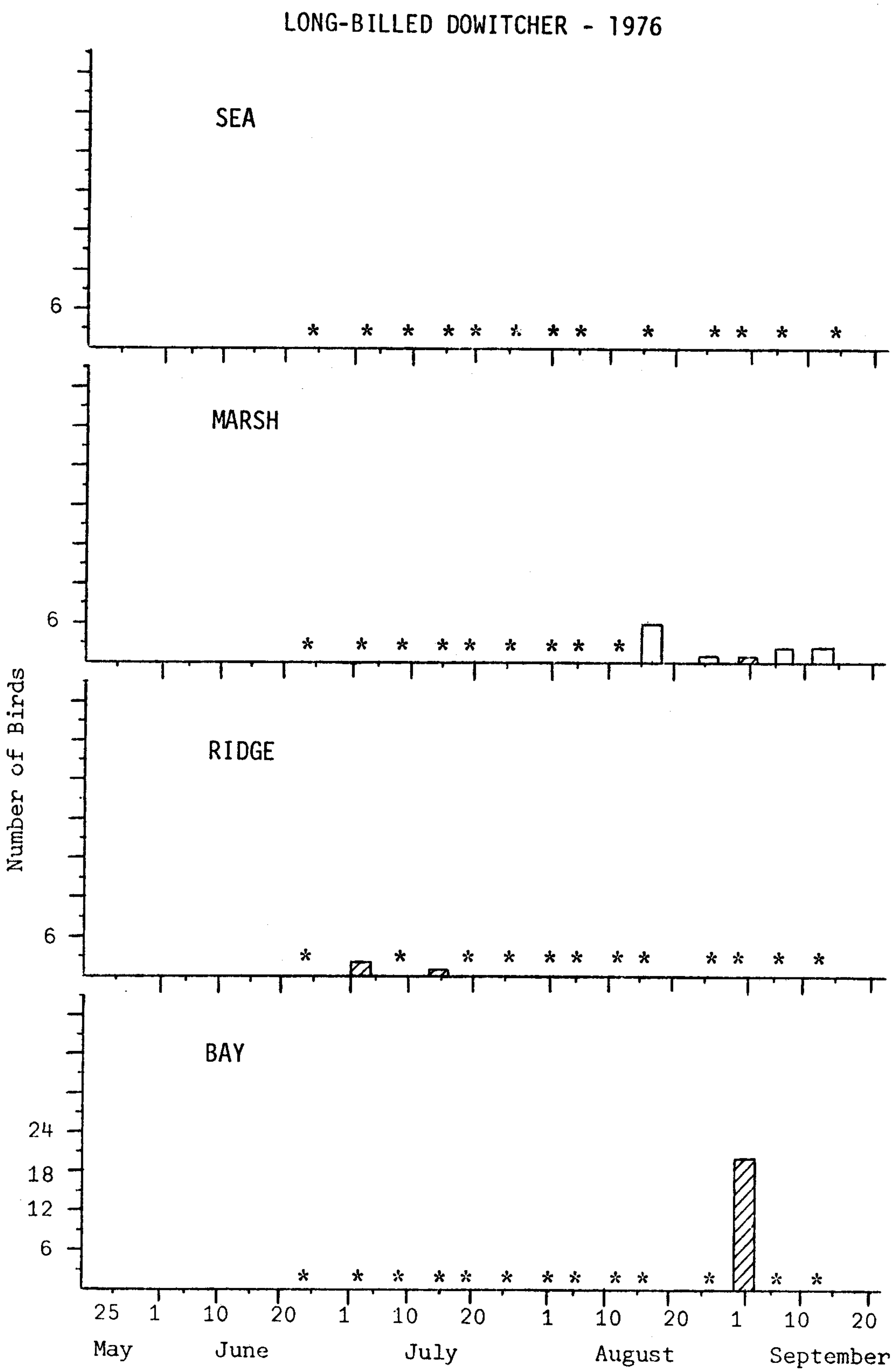

Figure 52. Numbers and distribution of Long-billed Dowitchers on the census transects, 1976, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

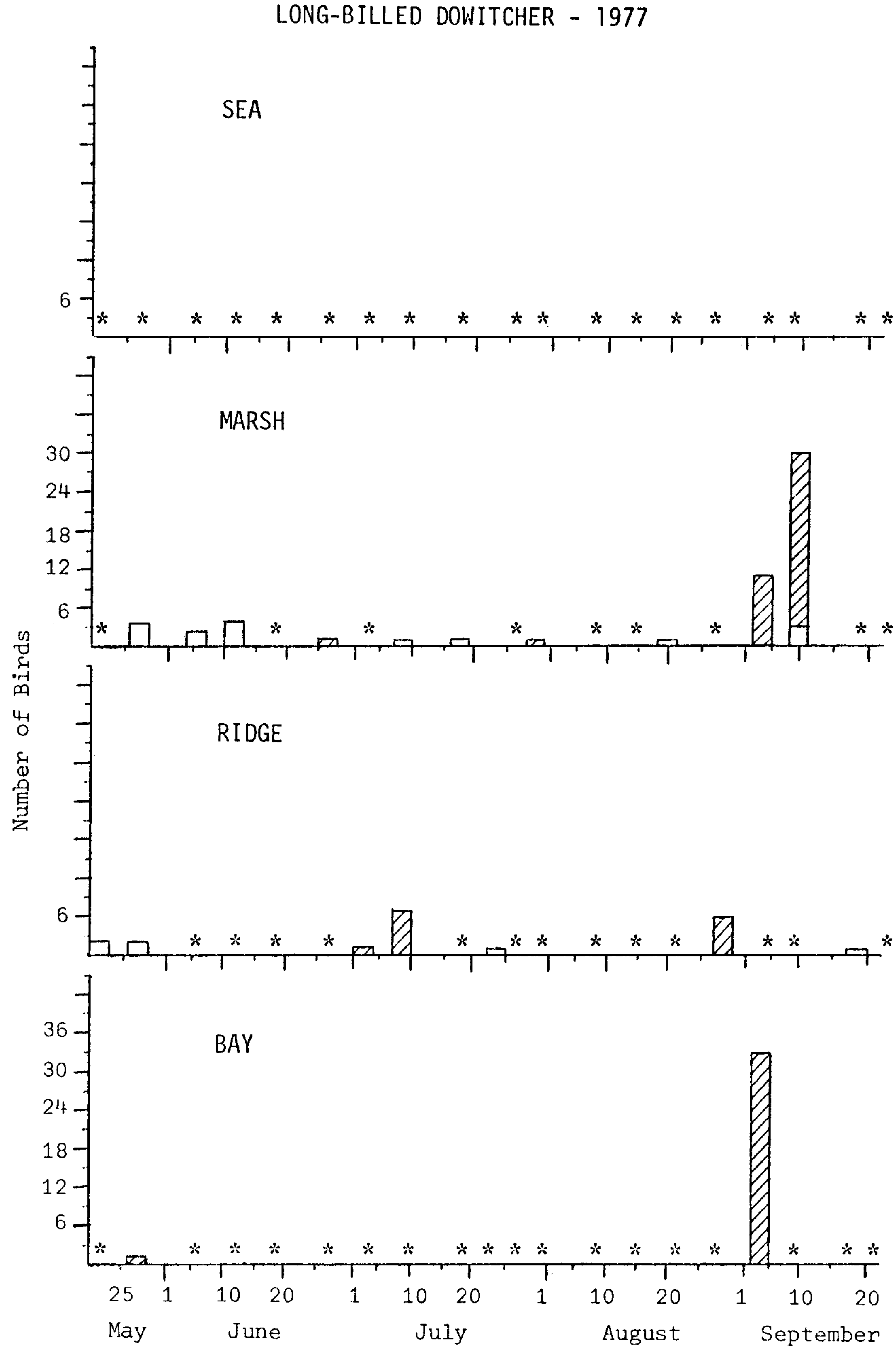

Figure 53. Numbers and distribution of Long-billed Dowitchers on the census transects, 1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

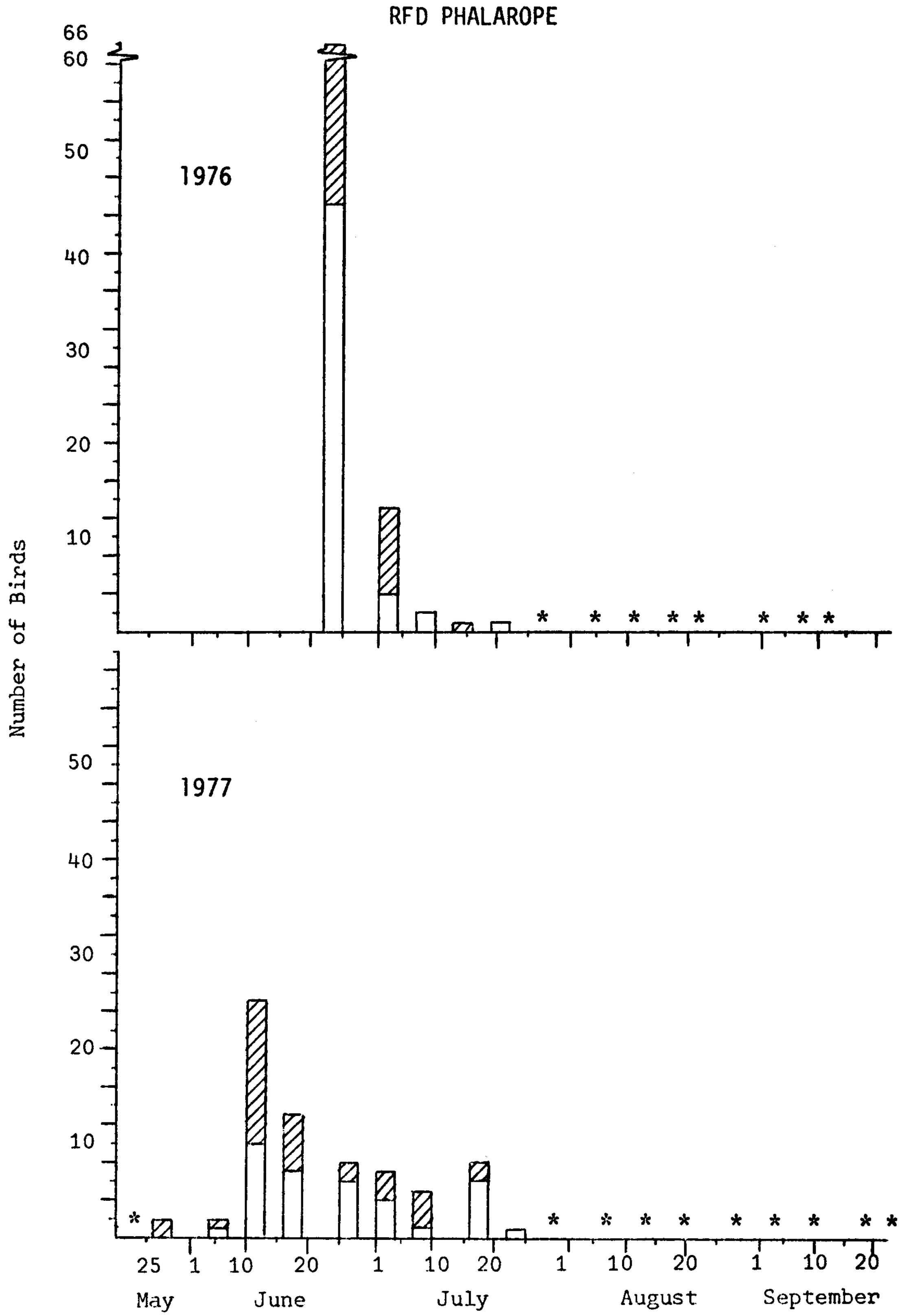

Figure 54. Summary of numbers of Red Phalaropes on the census transects, 1976-1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

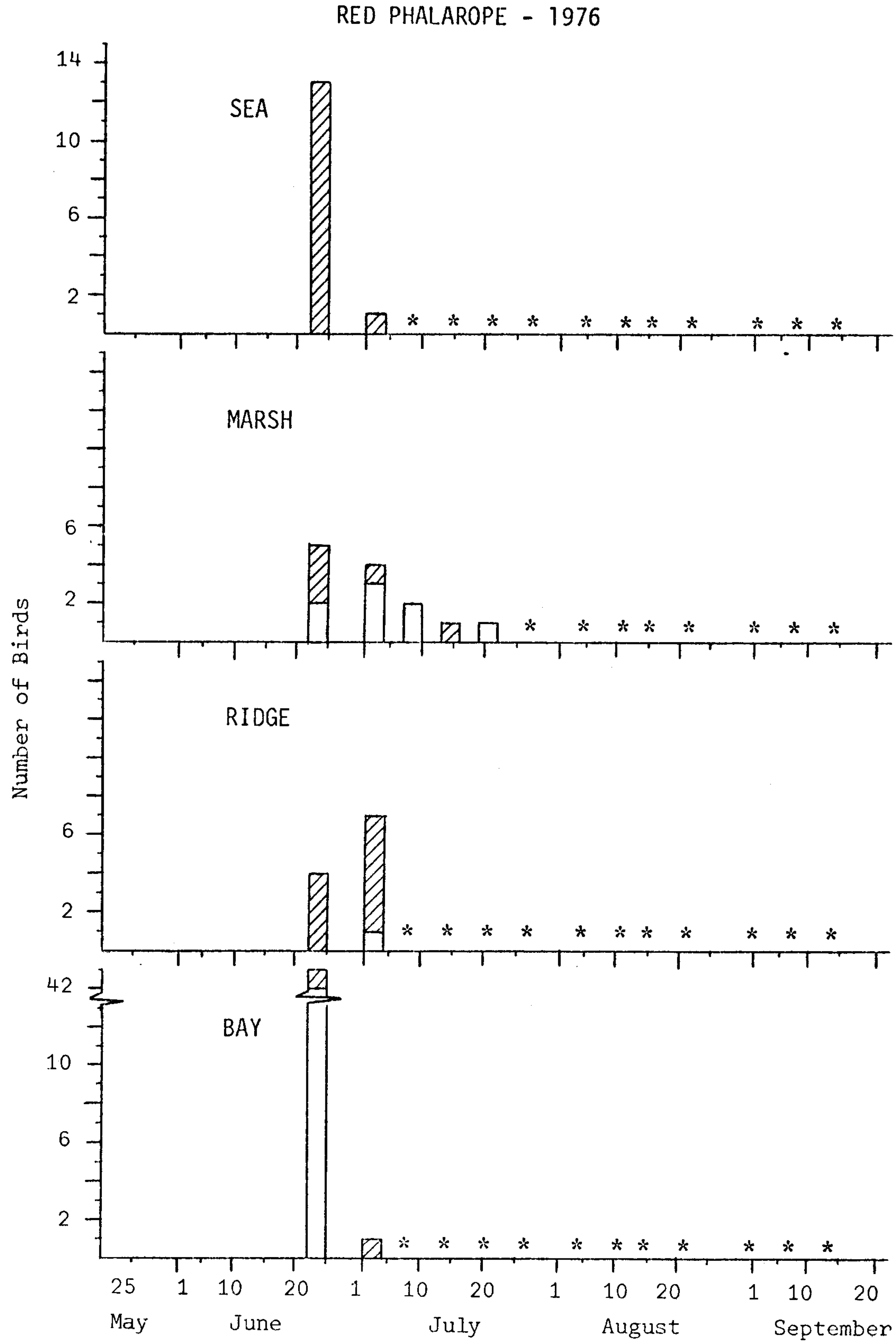

Figure 55. Numbers and distribution of Red Phalaropes on the census transects, 1976, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

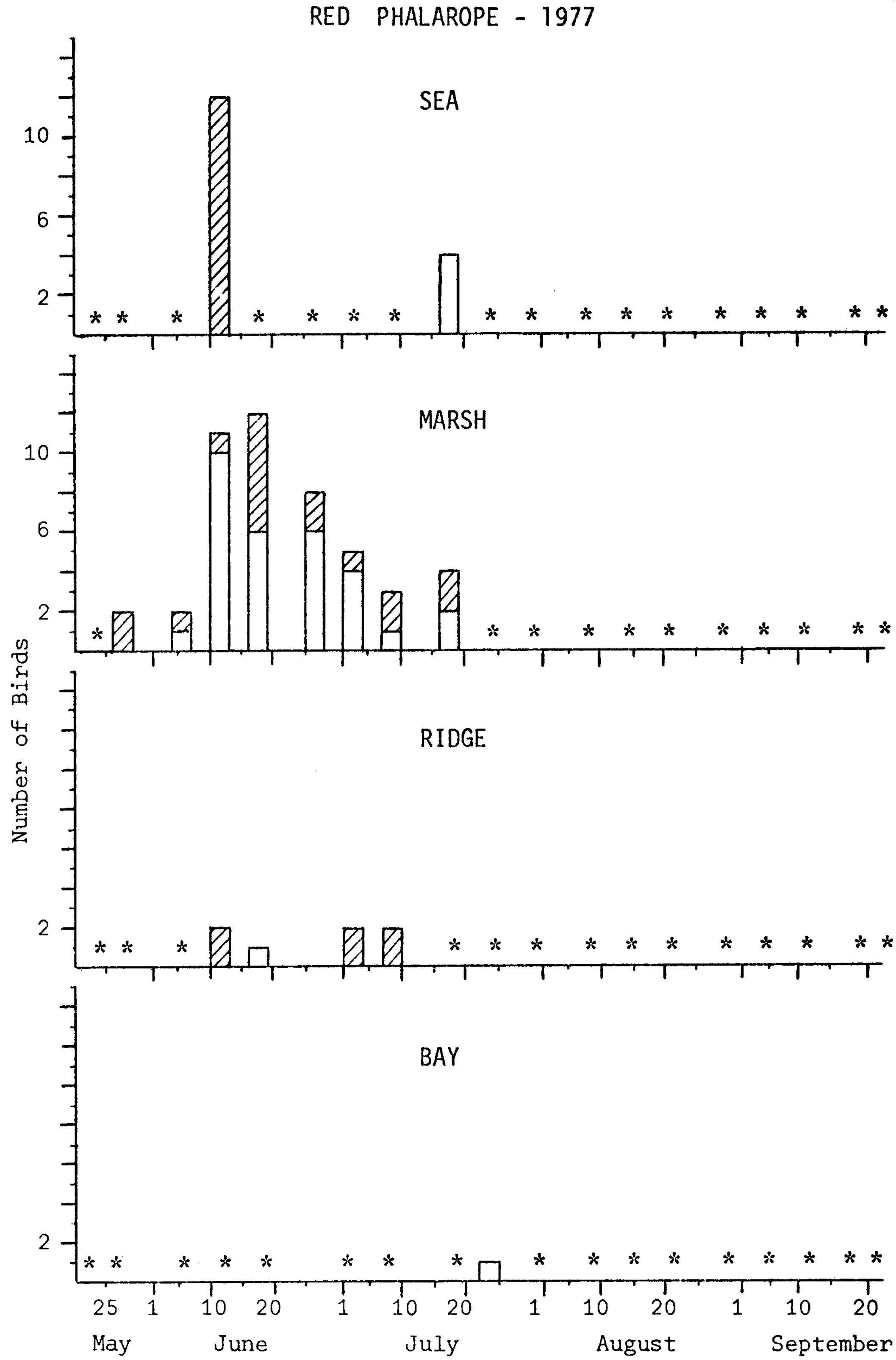

Figure 56. Numbers and distribution of Red Phalaropes on the census transects, 1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

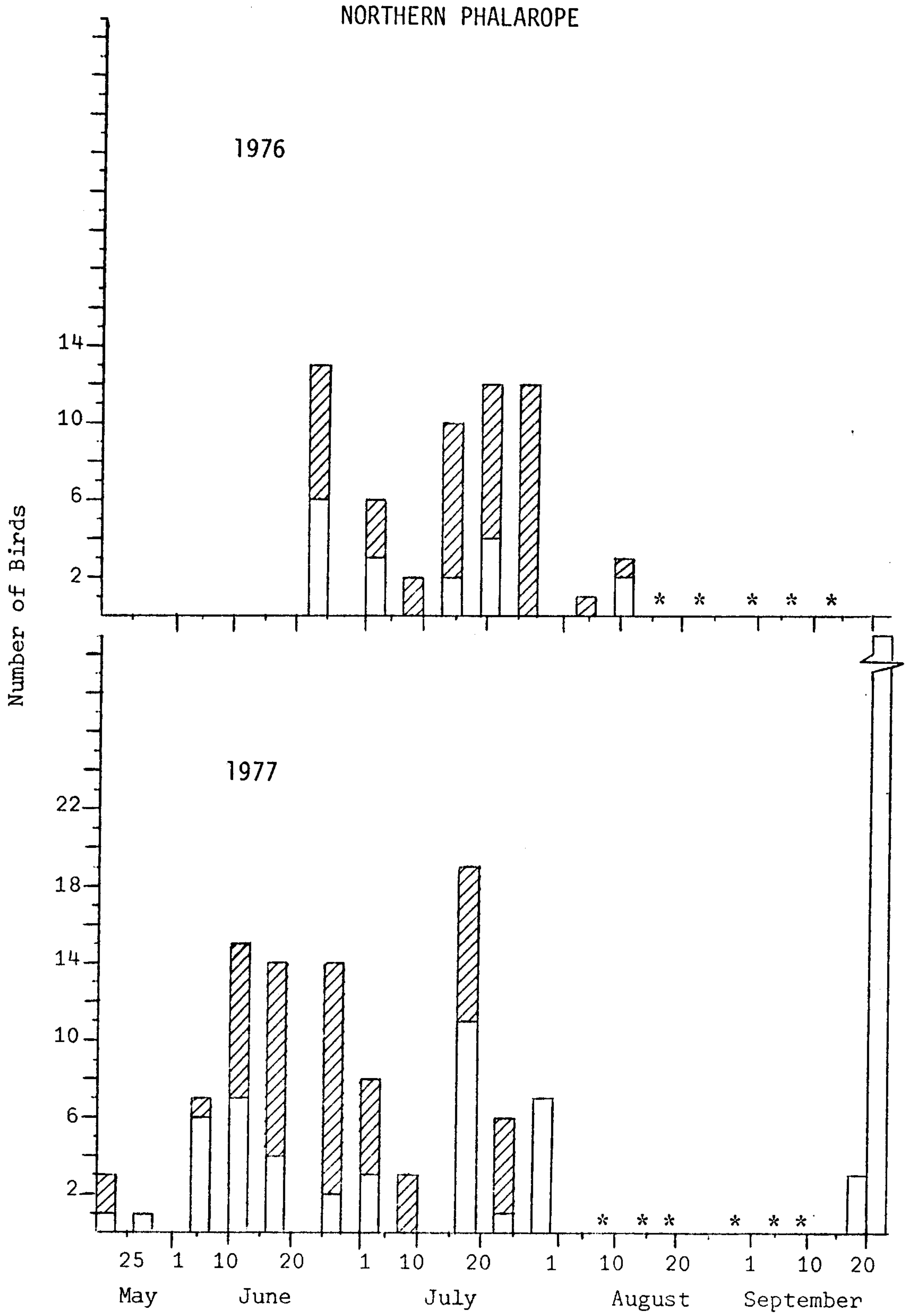

Figure 57. Summary of numbers of Northern Phalaropes on the census transects, 1976-1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

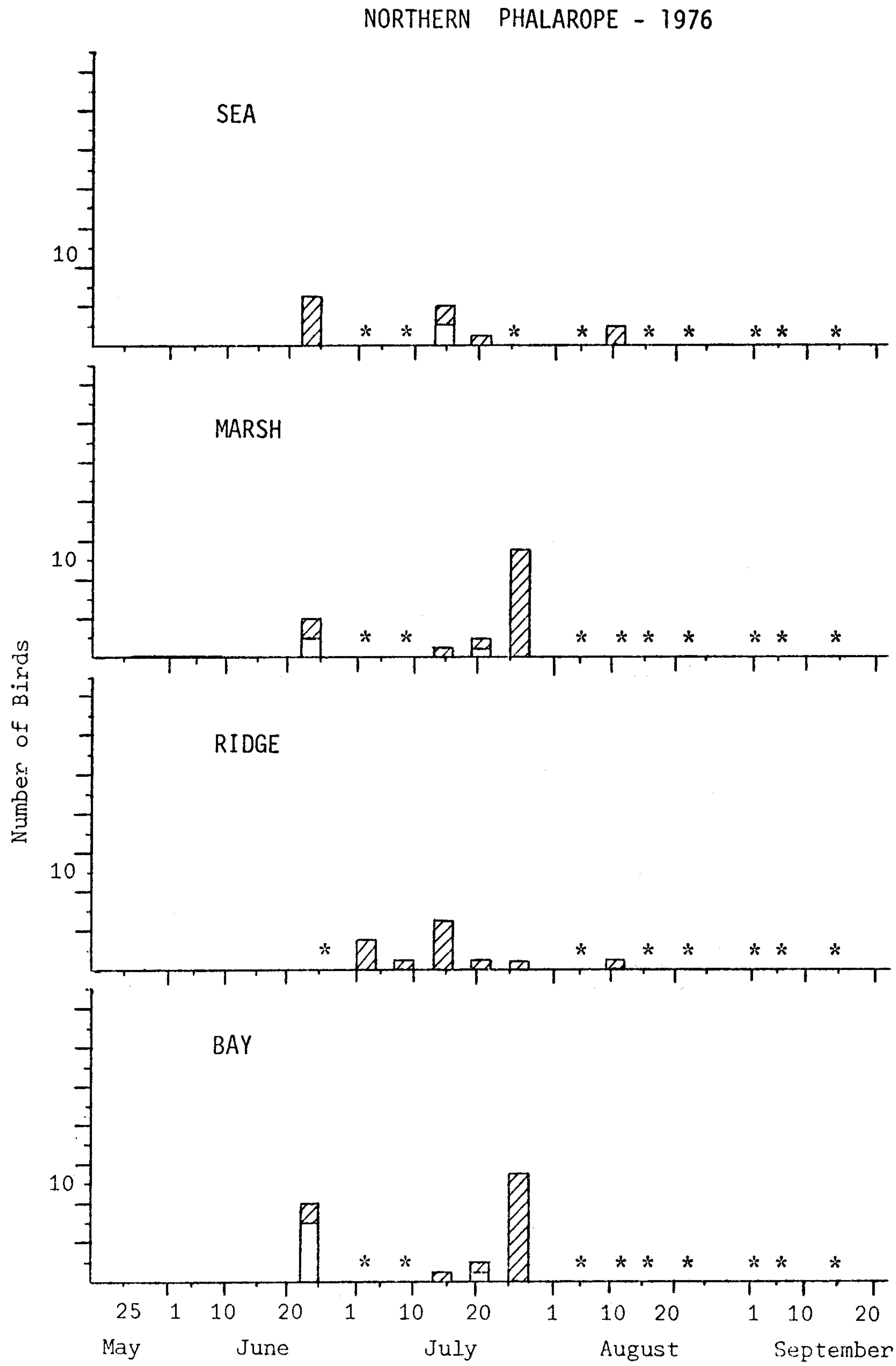

Figure 58. Numbers and distribution of Northern Phalaropes on the census transects, 1976, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

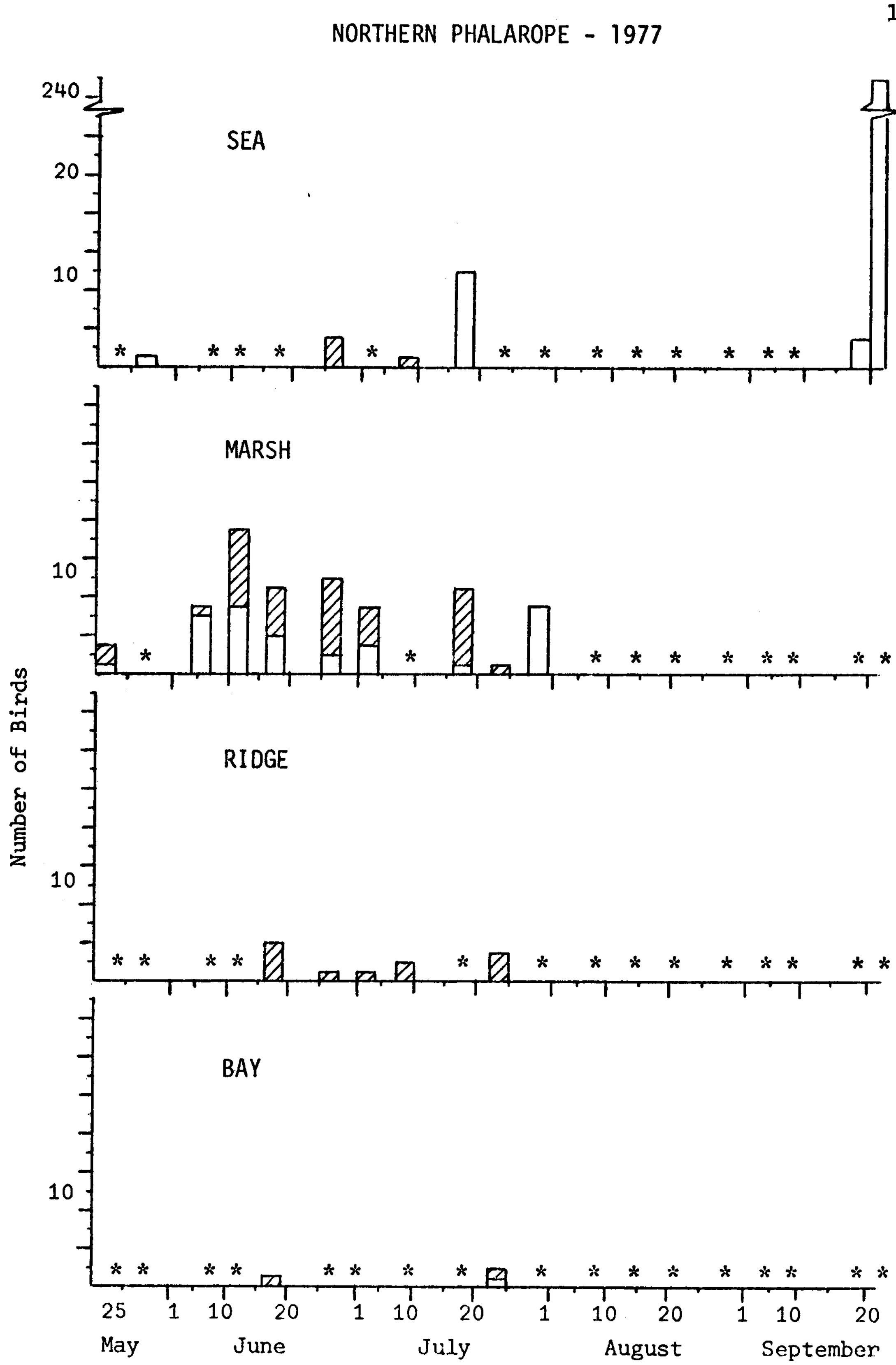

Figure 59. Numbers and distribution of Northern Phalaropes on the census transects, 1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

anticipated and suggests that they are present at this time out at sea off the Cape. Densities on transects on the Cape (0.3 birds/ha) were somewhat higher than those reported from Wales and Krusenstern (Connors 1978). Unfortunately, Connors' camps were not in operation during the late September influx of Northern Phalaropes.

Parasitic Jaegers. Parasitic Jaegers were present throughout the field season, although numbers were much reduced in late September (Figs. 60, 61 and 62). Jaegers were seen on all transects, but were most numerous on tundra transects. Here, they nested and hunted eggs, young birds, berries, insects, and robbed fish from brood-rearing loons.

Glaucous Gulls. Glaucous Gulls were present during the entire study period (Figs. 63, 64 and 65). These gulls used all habitats. They nested and robbed duck eggs in the marsh, roosted on and foraged berries and insects from ridges, and fed on marine organisms from both coasts. Greatest foraging use of the Chukchi coast occurred early in the season (prior to waterfowl nesting) and in late August and September (when groups of adults and newly-fledged young gathered on the beach).

Black-legged Kittiwakes. Kittiwakes were noted from late May through mid-September (Figs. 66, 67 and 68). They were observed almost exclusively on the Chukchi coast transect and nearly all birds were flying laterally along the coast. On only a few occasions did Kittiwakes feed in transect waters. As nearshore ice began to break-up in June 1977, kittiwakes were frequently observed feeding near foraging Ringed Seals. The seals seemed to be driving small fish or invertebrates to the surface, where the kittiwakes could plunge for them. Densities of kittiwakes (ca. 0.5 bird/ha) were somewhat higher than at Krusenstern (ca. 0.3 birds/ha), but much lower than at Wales (ca. 2.0 birds/ha) (Connors 1978).

Sabine's Gulls. In 1976, Sabine's Gulls were noted only on the bay transect, and then, only infrequently (Figs. 69, 70 and 71). In 1977, they fed not only on the bay transect, but also along the Chukchi coast. Before nesting commenced, these birds fed primarily at the edge of tundra ponds and among the disintegrating ice chunks along the Chukchi coast. With the onset of nesting, most feeding occurred on the Espenberg Bay mudflats.

Arctic Terns. Terns foraged primarily along both coasts from early June through early September (Figs. 72, 73 and 74). They nested in both marsh and ridge areas and, to some extent, fed on flying insects there. Terns also nested in the driftwood on the north beach. Terns remained in the Cape area for about 2 weeks after the young fledged.

Lapland Longspurs. Longspurs were seen on the Cape during the entire summer (Figs. 75, 76 and 77). Maximum longspur numbers occurred during August as young-of-the-year migrated through the area. Longspurs were common on all tundra habitats throughout the summer, but few were observed on the beaches until the August migration. Even then, few were seen along the Chukchi coast. However, longspurs were common along the bay coast, where they fed in the flotsam and *Elymus* (probably on adult shoreflies). Seasonal trends from Espenberg matched those from Krusenstern

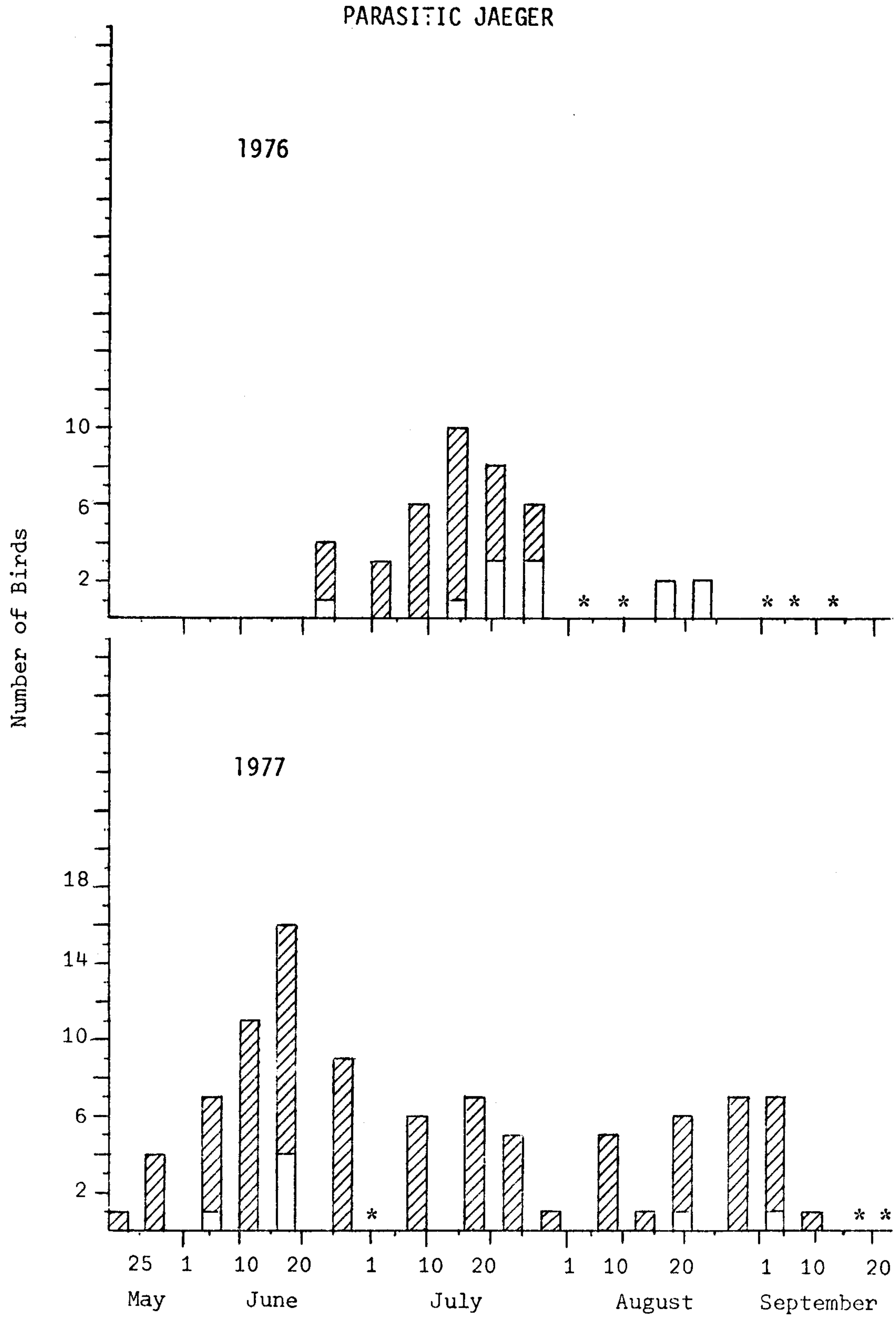

Figure 60. Summary of numbers of Parasitic Jaegers on the census transects, 1976-1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

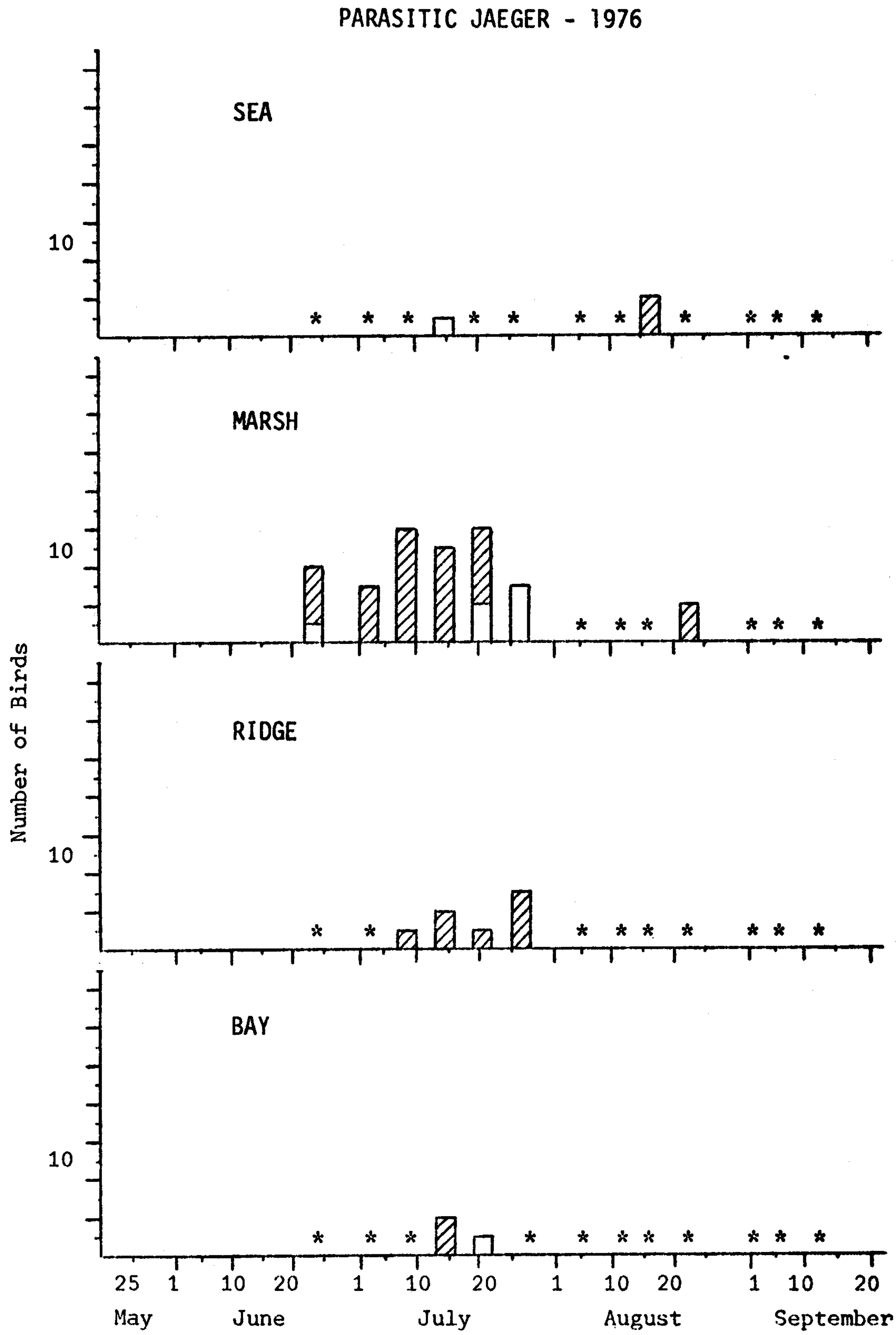

Figure 61. Numbers and distribution of Parasitic Jaegers on the census transects, 1976, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

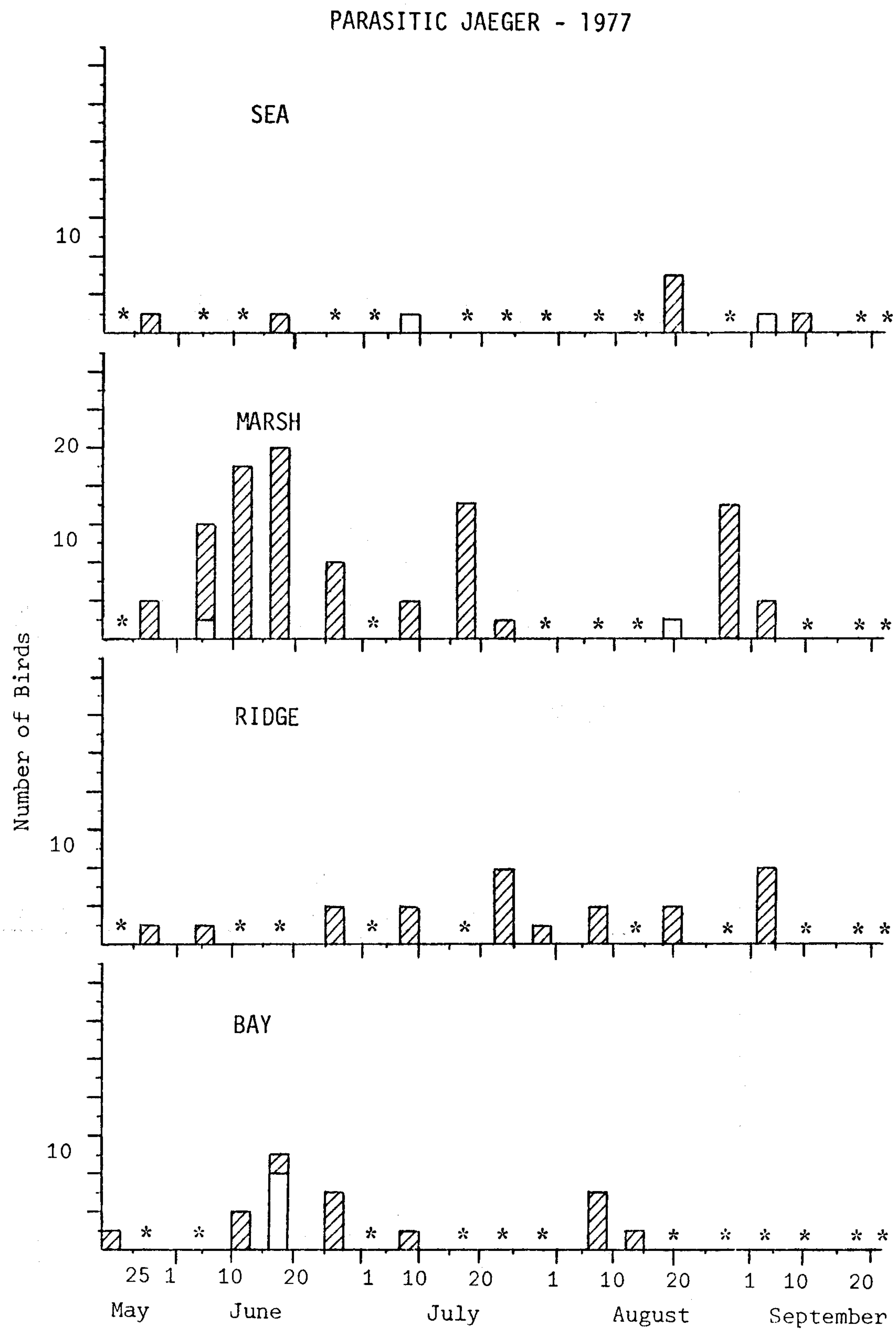

Figure 62. Numbers and distribution of Parasitic Jaegers on the census transects, 1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

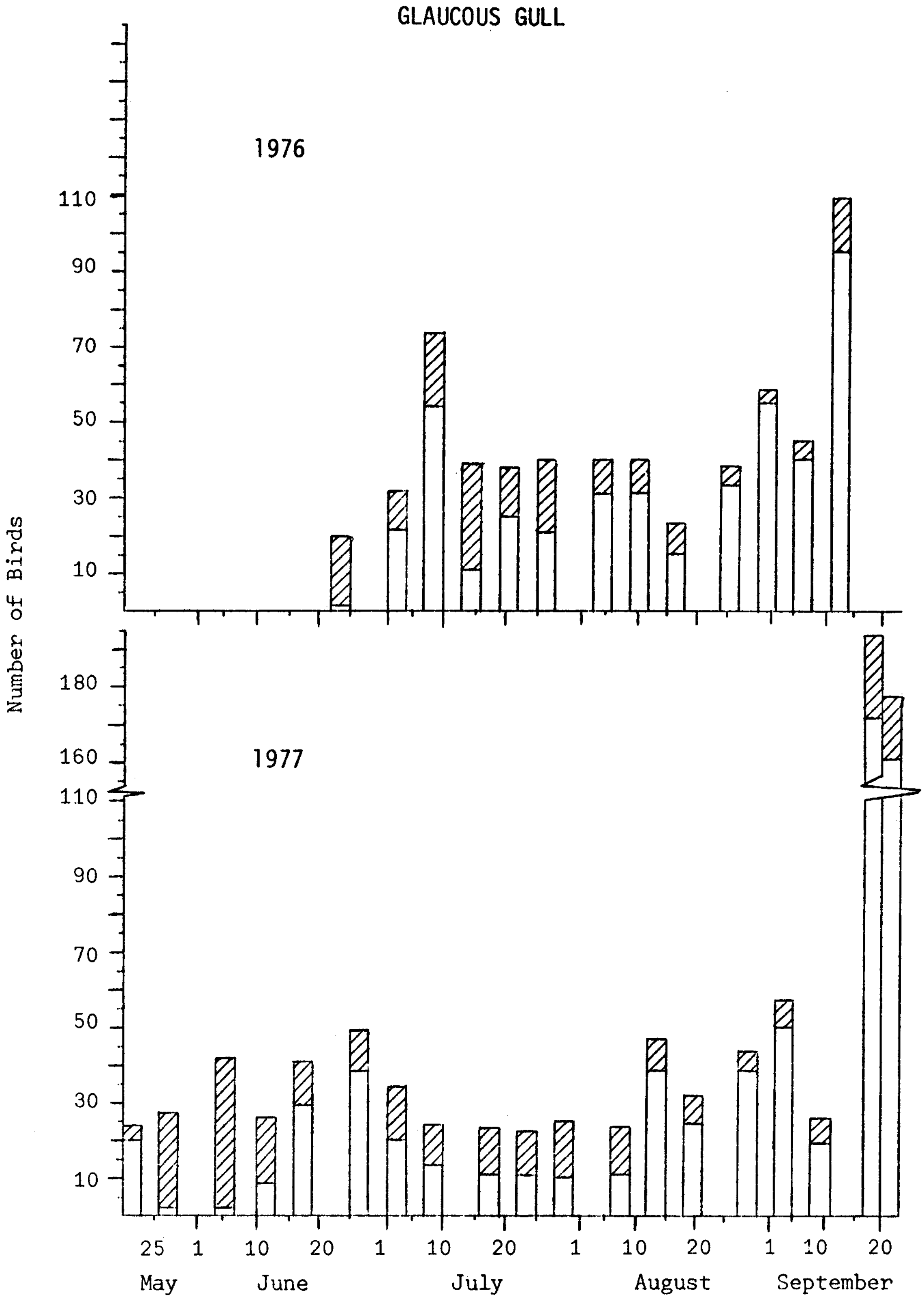

Figure 63. Summary of numbers of Glaucous Gulls on the census transects, 1976-1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

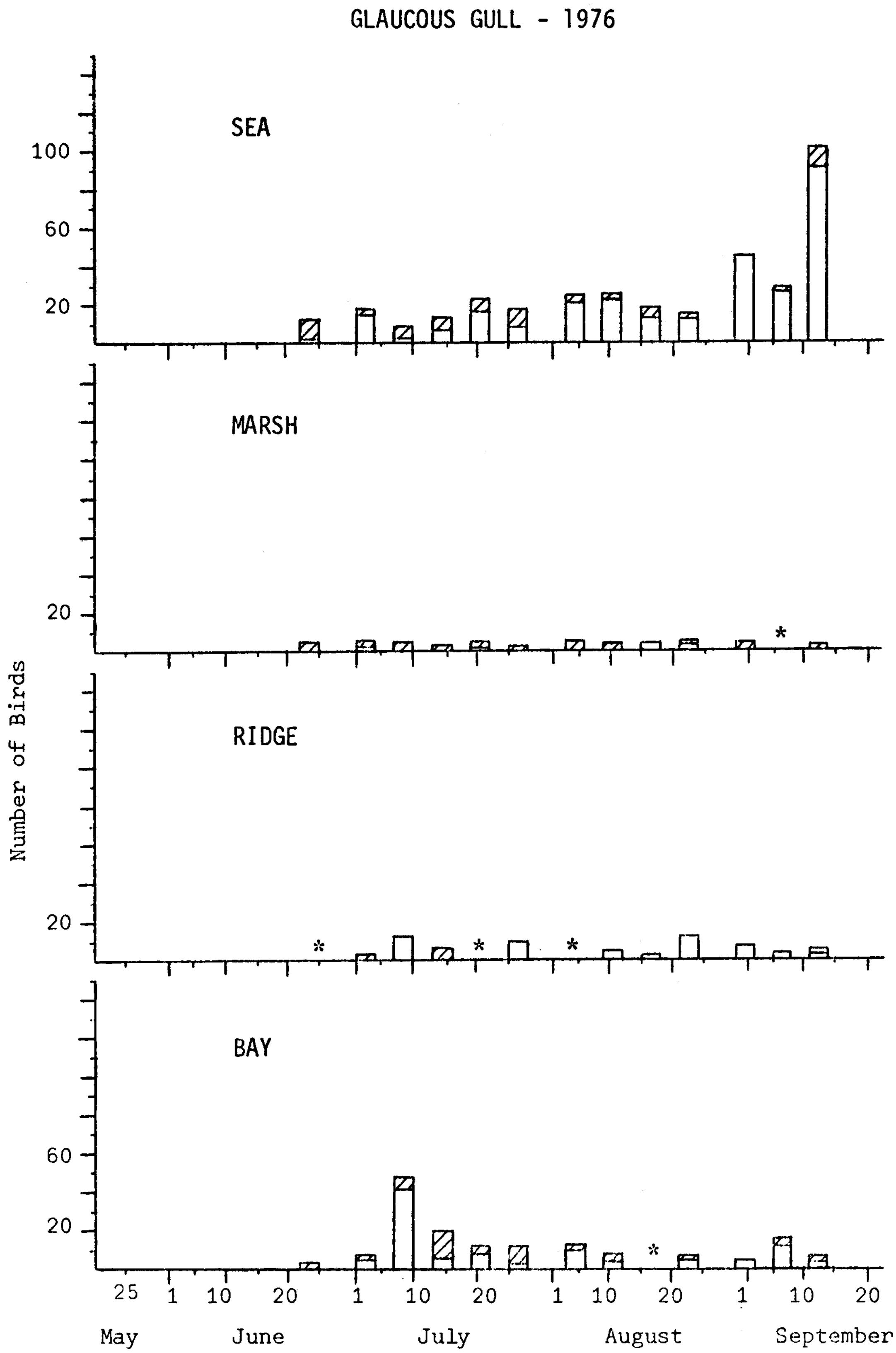

Figure 64. Numbers and distribution of Glaucous Gulls on the census transects, 1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

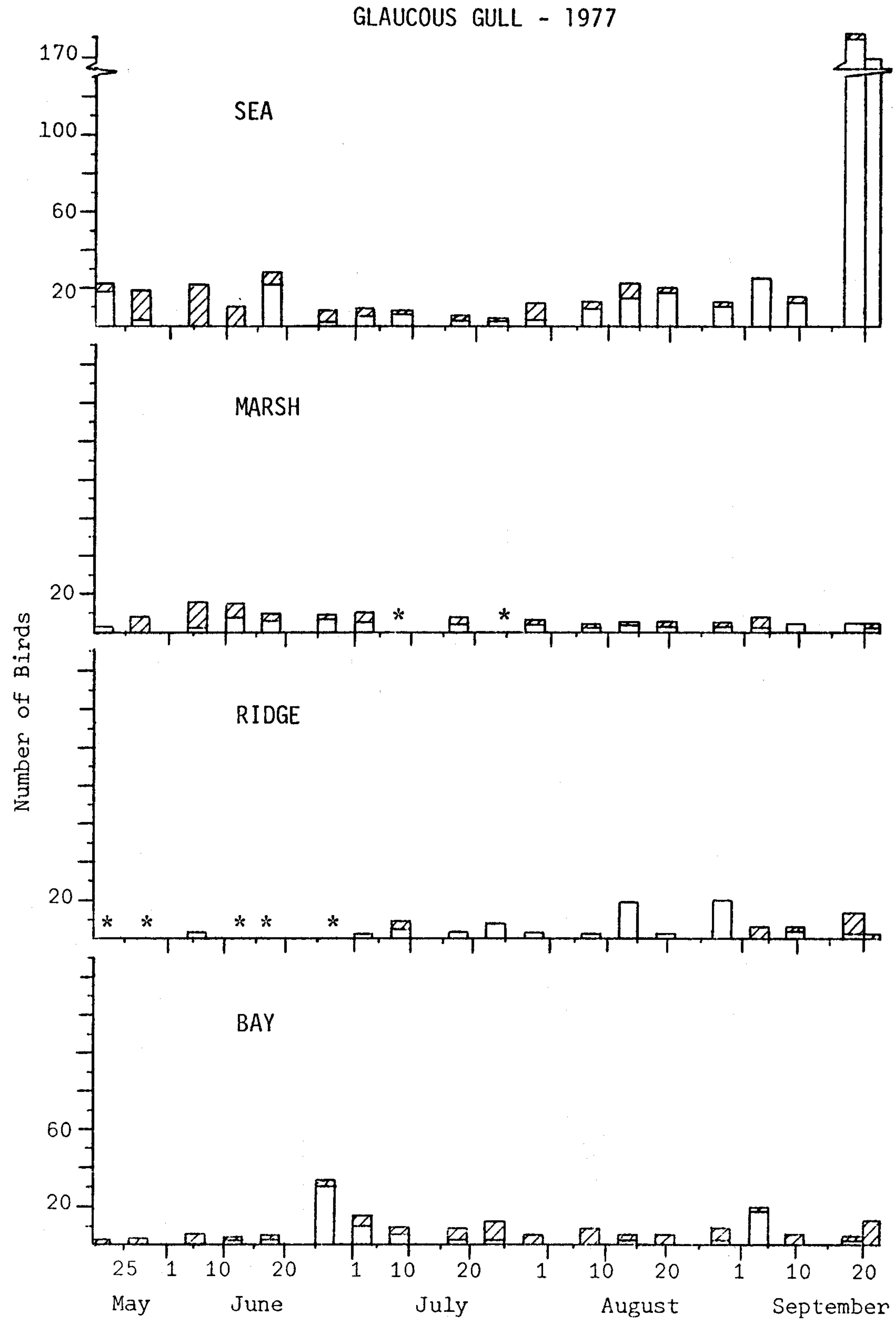

Figure 65. Numbers and distribution of Glaucous Gulls on the census transects, 1976, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

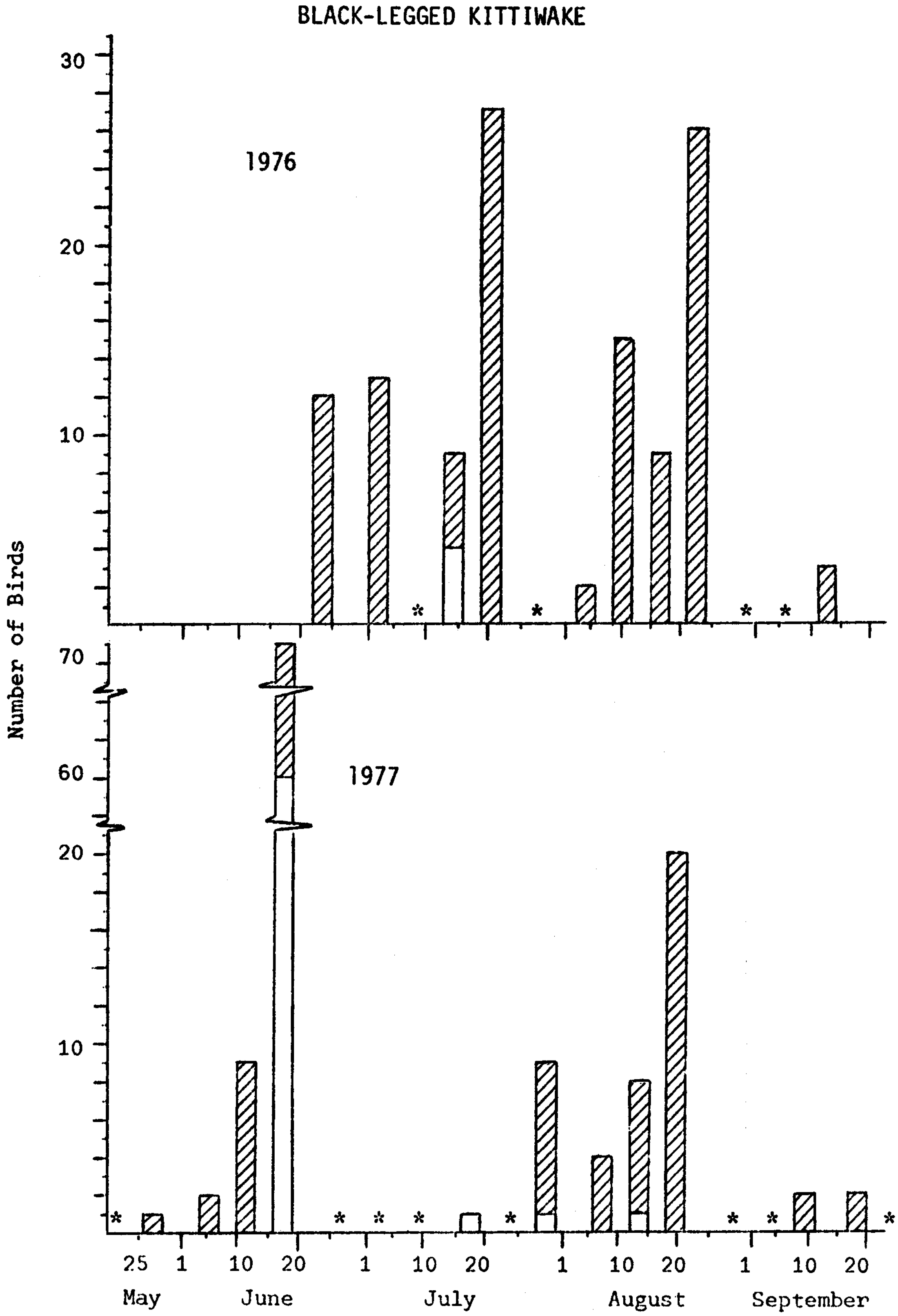

Figure 66. Summary of numbers of Black-legged Kittiwakes on the census transects, 1976-1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

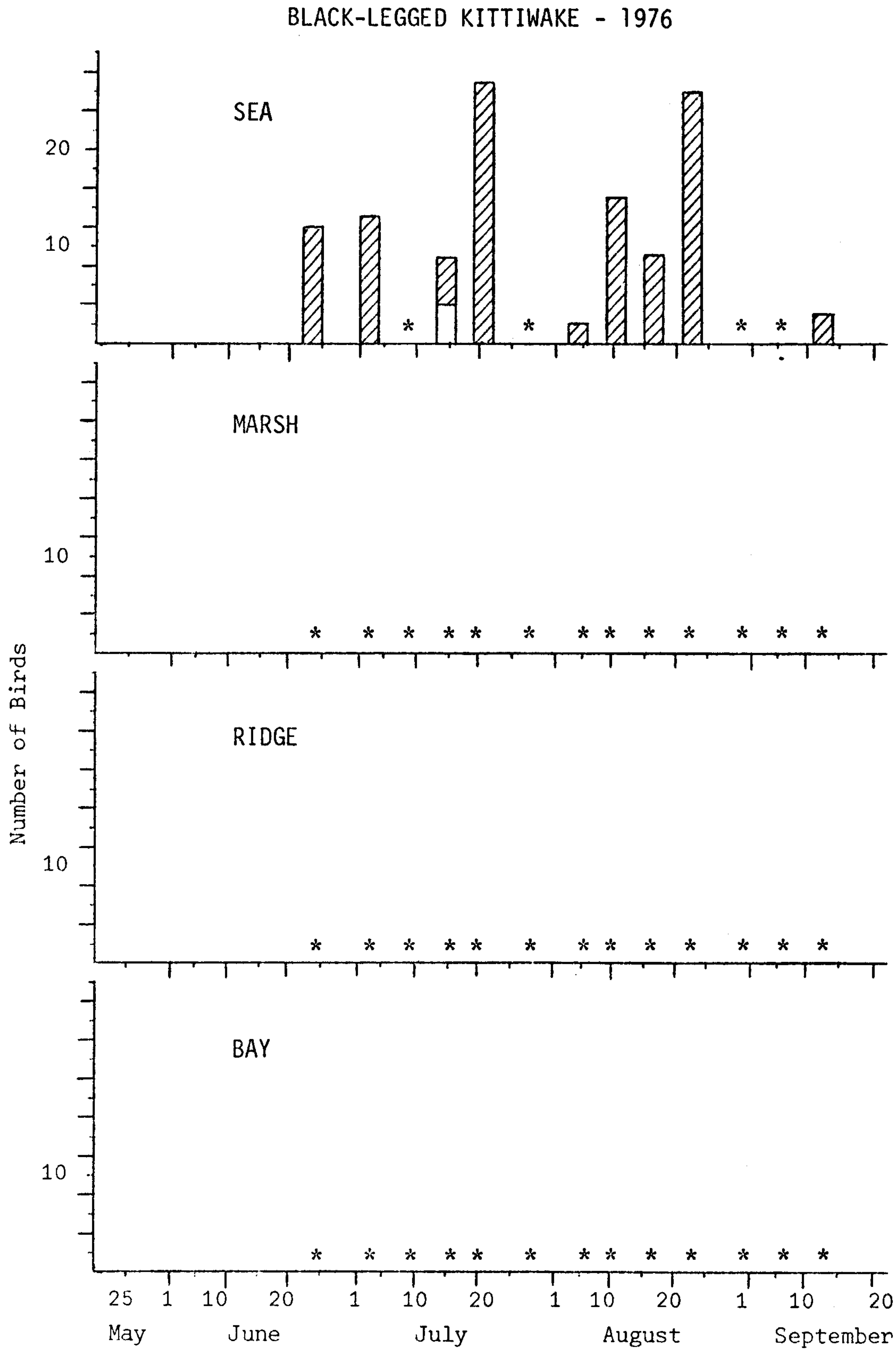

Figure 67. Numbers and distribution of Black-legged Kittiwakes on the census transects, 1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

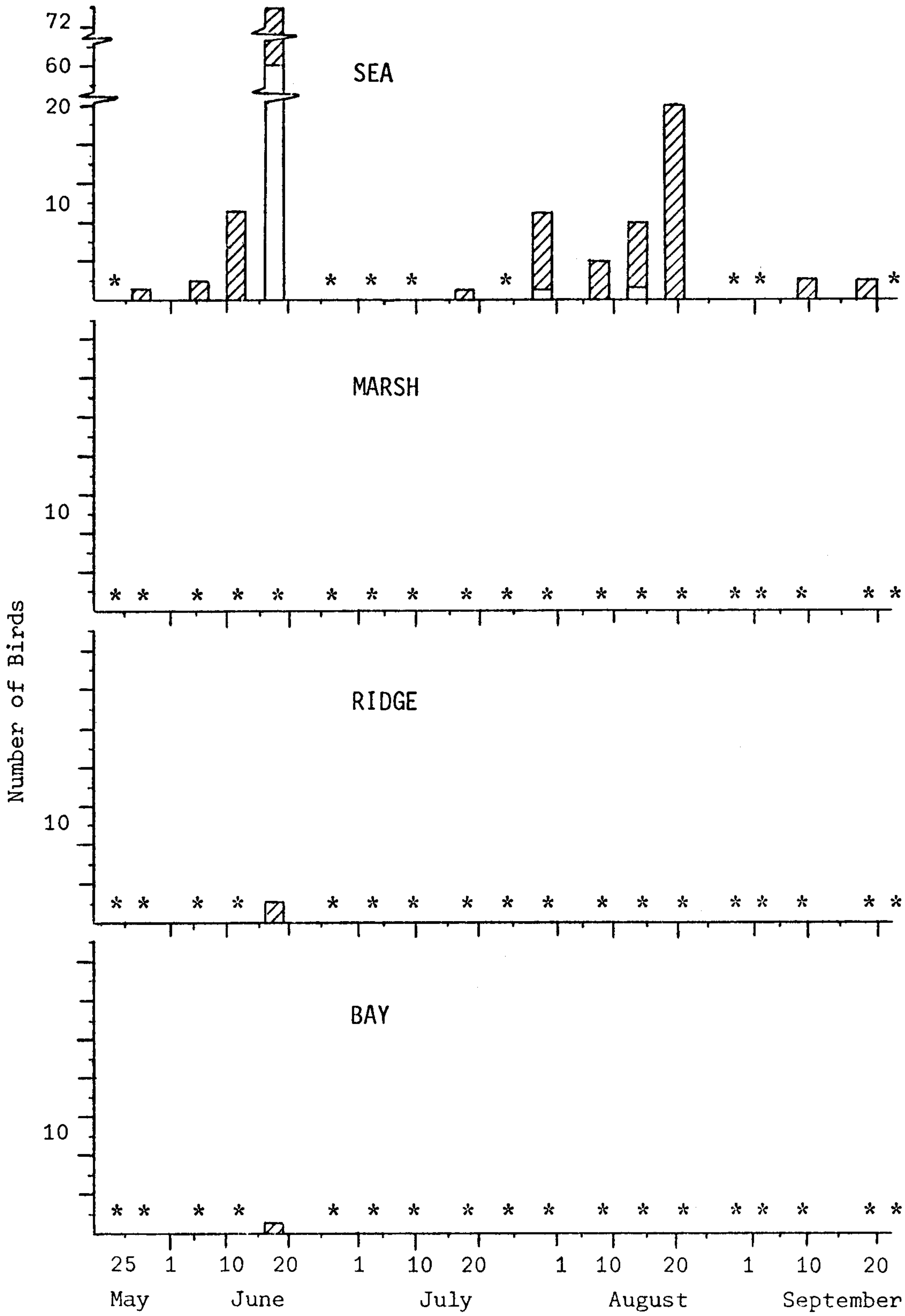

Figure 68. Numbers and distribution of Black-legged Kittiwakes on the census transects, 1976, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

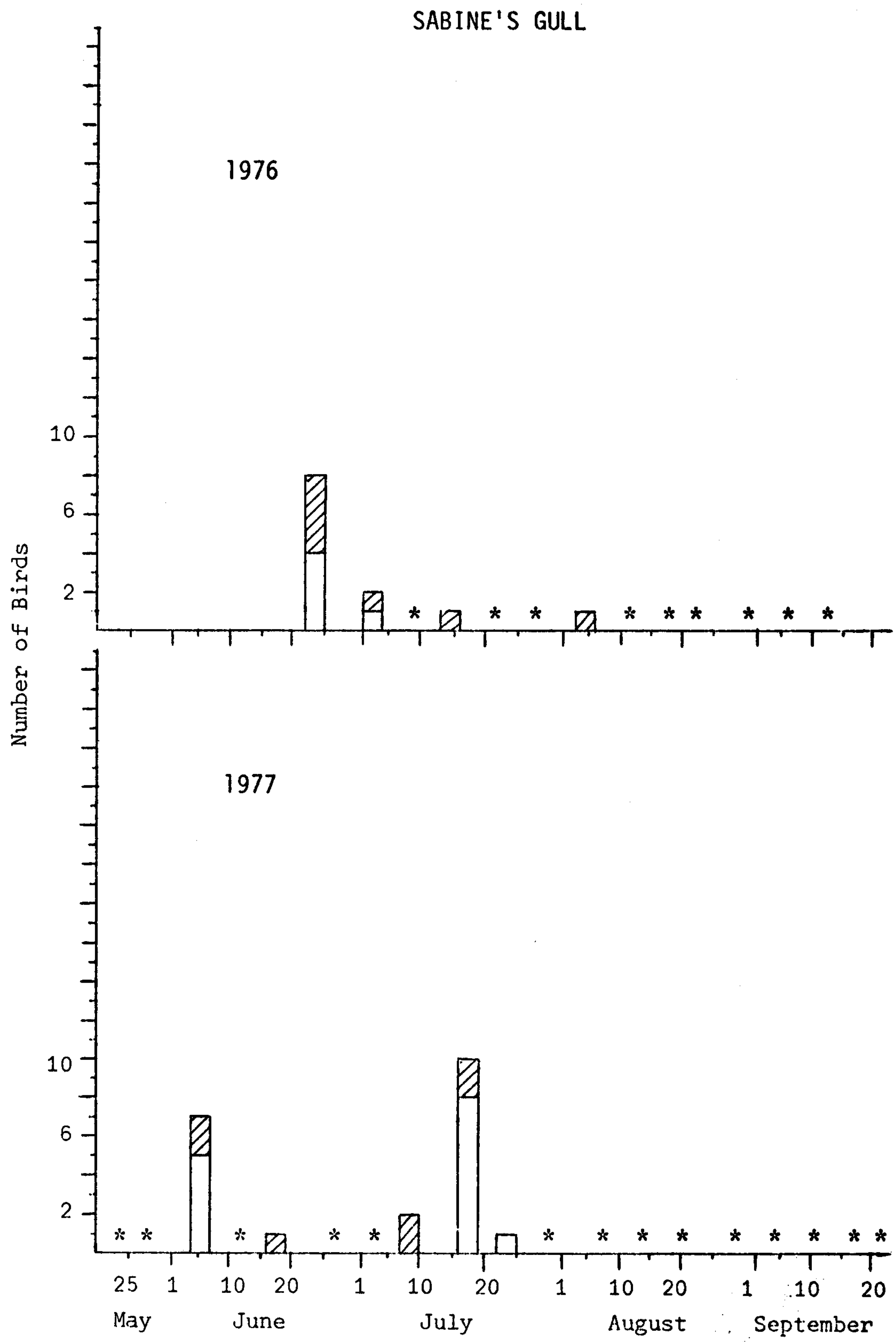

Figure 69. Summary of numbers of Sabine's Gulls on the census transects, 1976-1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

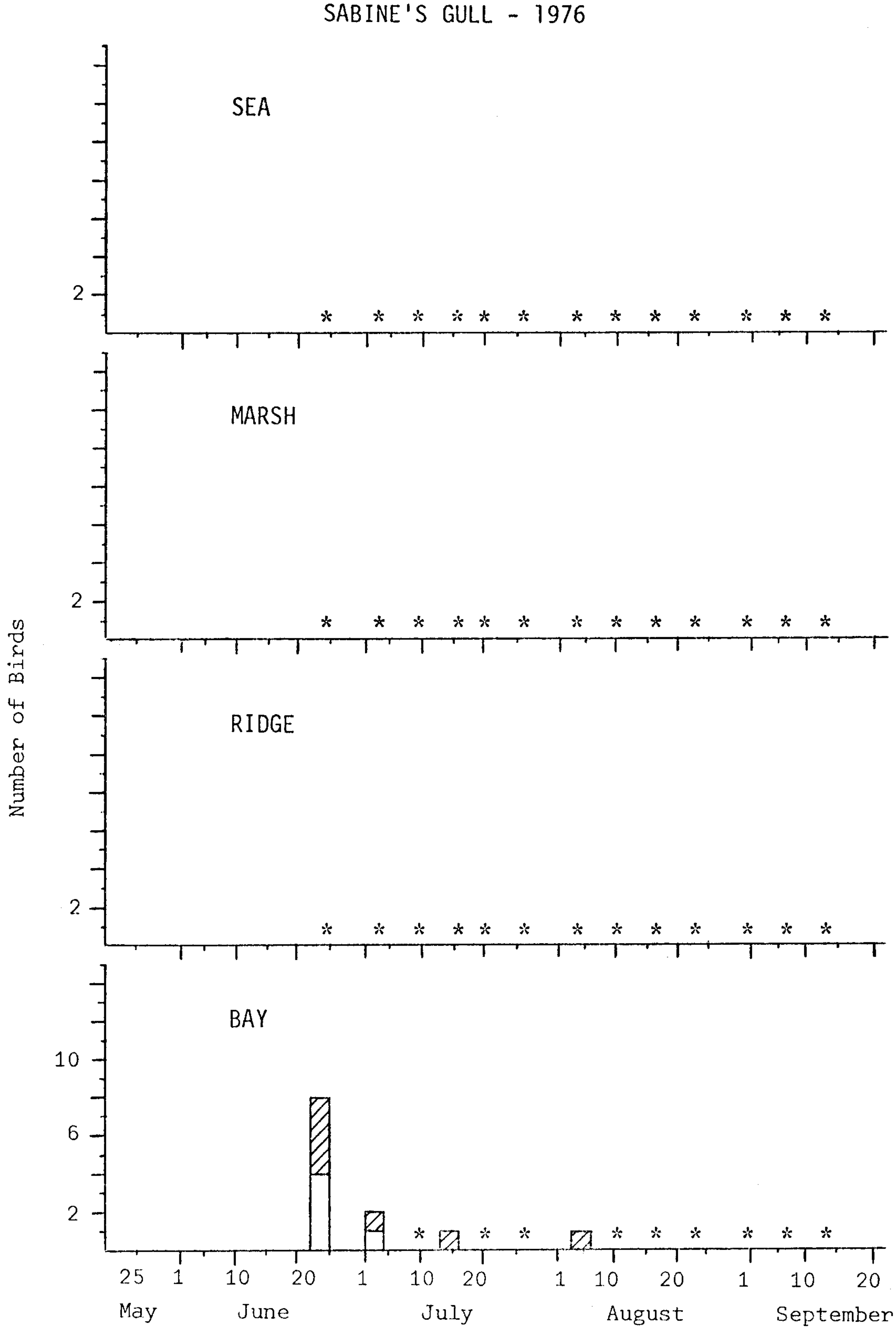

Figure 70. Numbers and distribution of Sabine's Gulls on the census transects, 1976, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

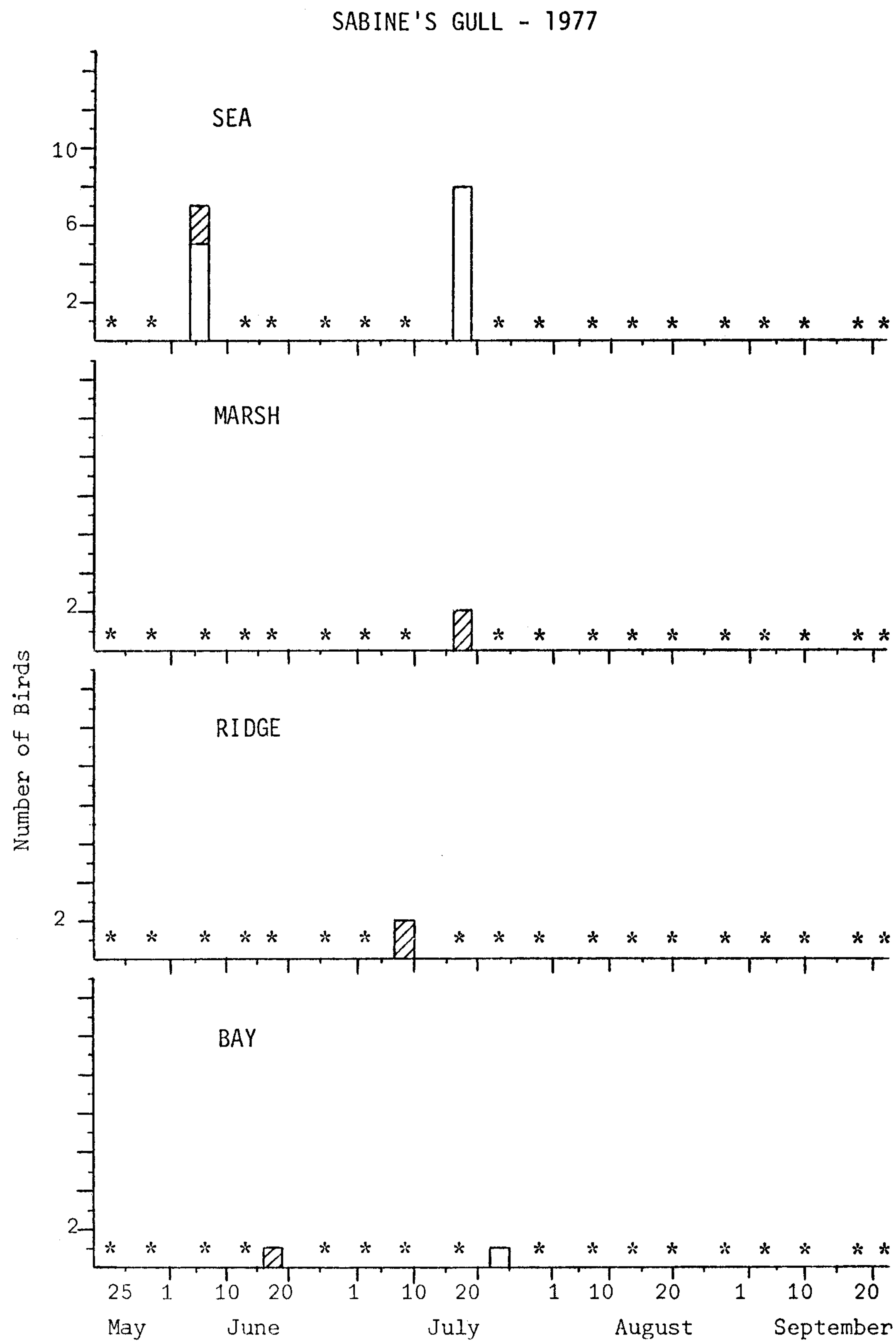

Figure 71. Numbers and distribution of Sabine's Gulls on the census transects, 1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

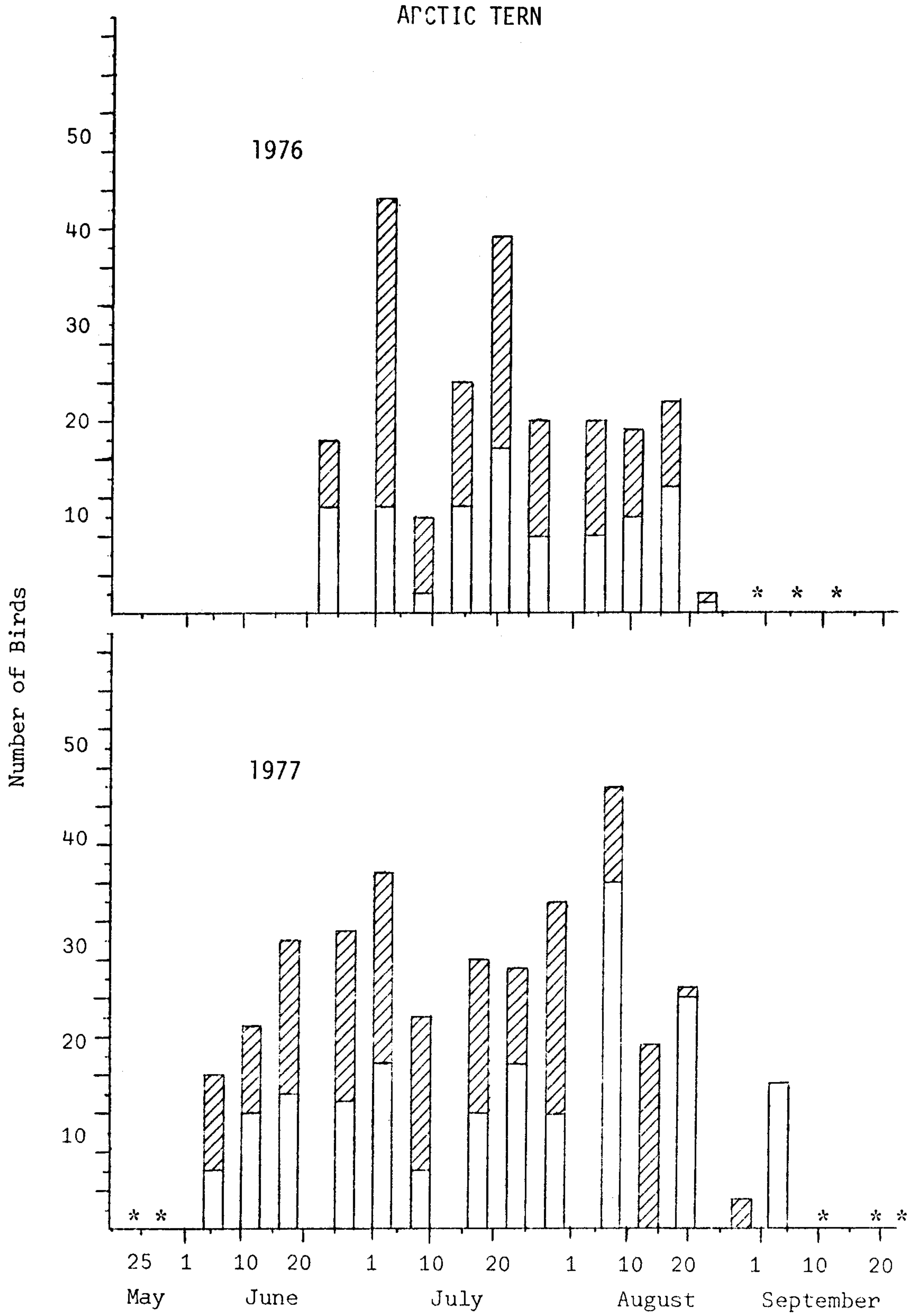

Figure 72. Summary of numbers of Arctic Terns on the census transects, 1976-1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

ARCTIC TERN - 1976

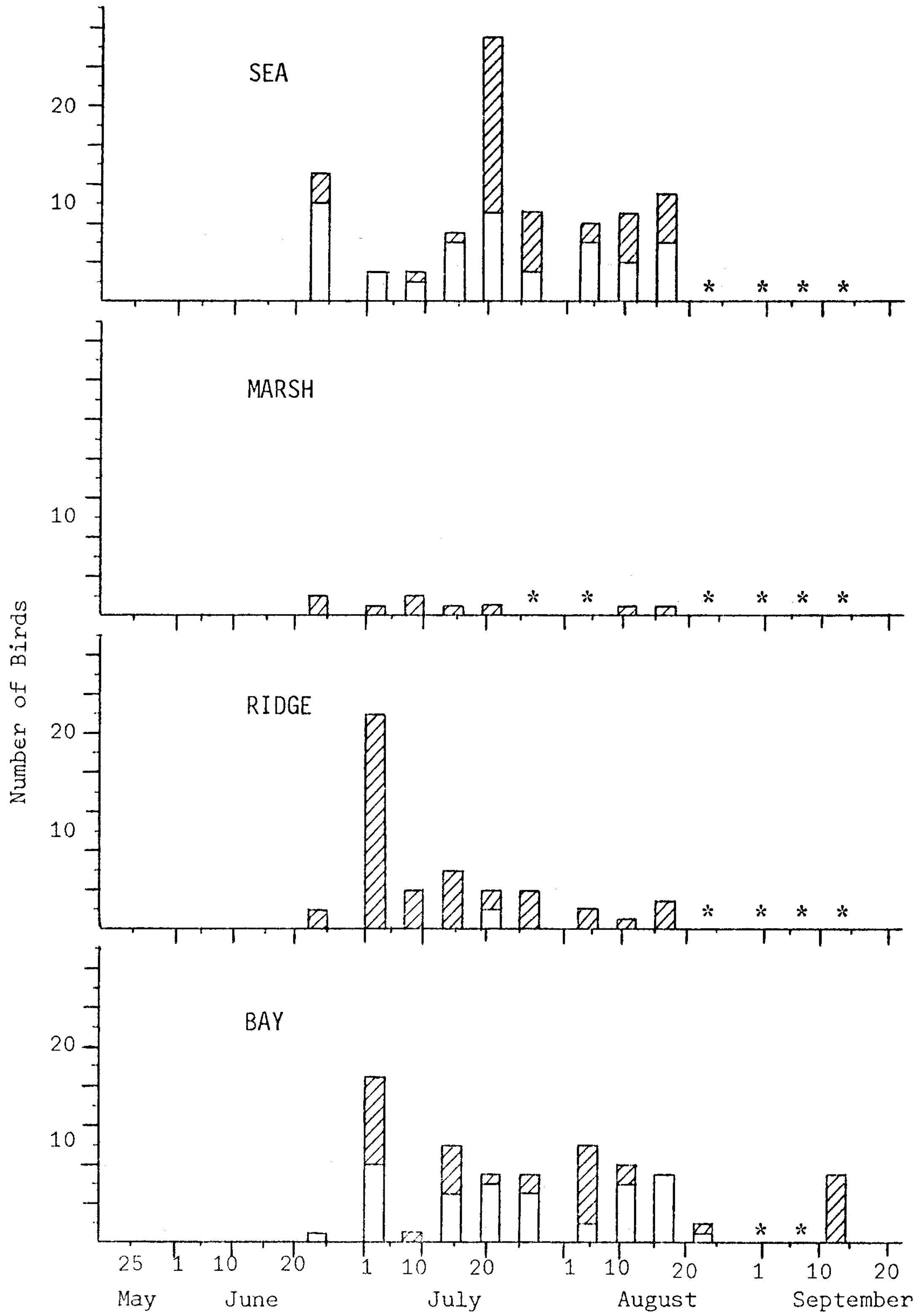

Figure 73. Numbers and distribution of Arctic Terns on the census transects, 1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

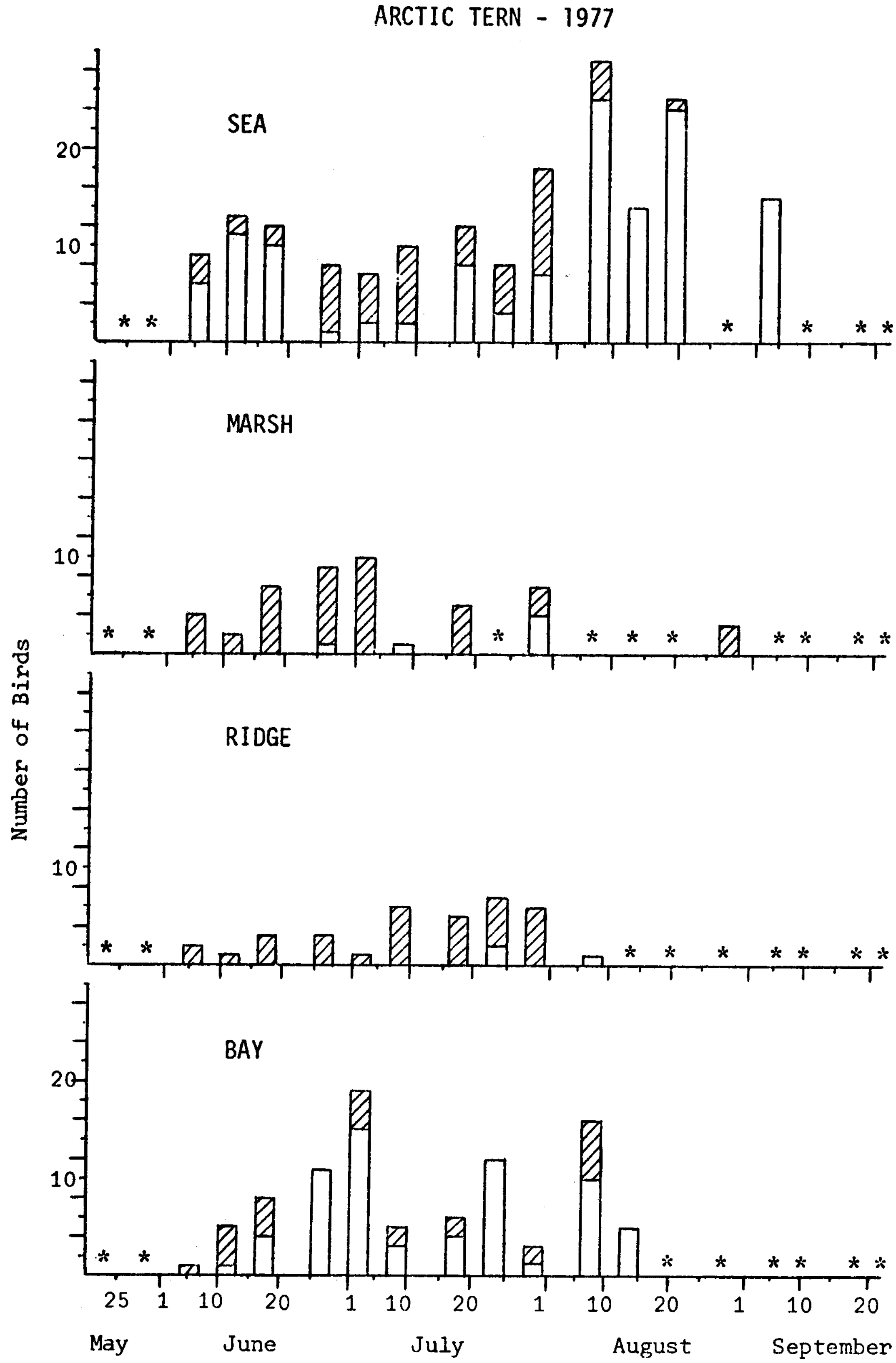

Figure 74. Numbers and distribution of Arctic Terns on the census transects, 1976, Cape Espenberg, Alaska, (unshaded = on ground or water, shaded = flying, * = not present).

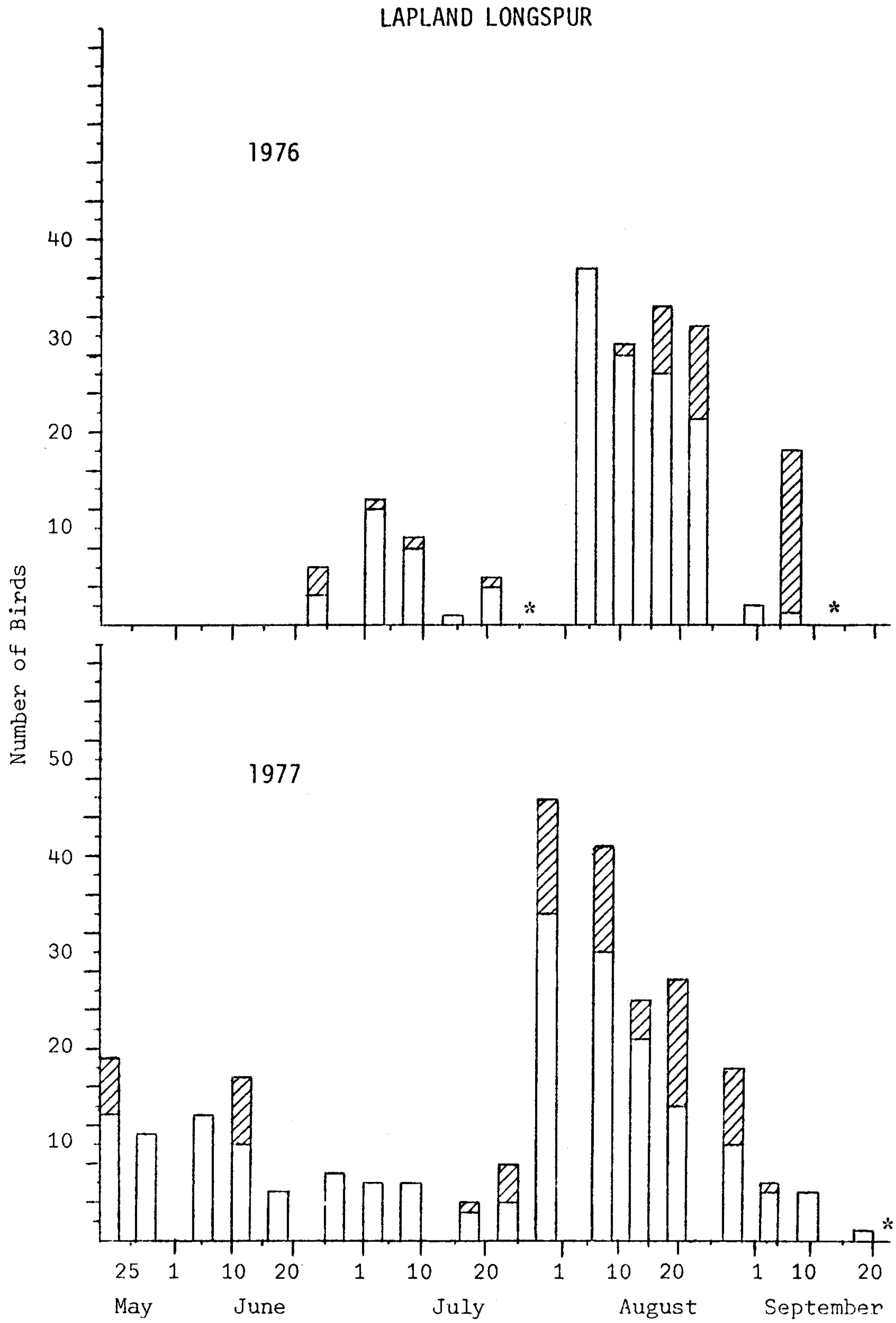

Figure 75. Summary of numbers of Lapland Longspurs on the census transects, 1976-1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

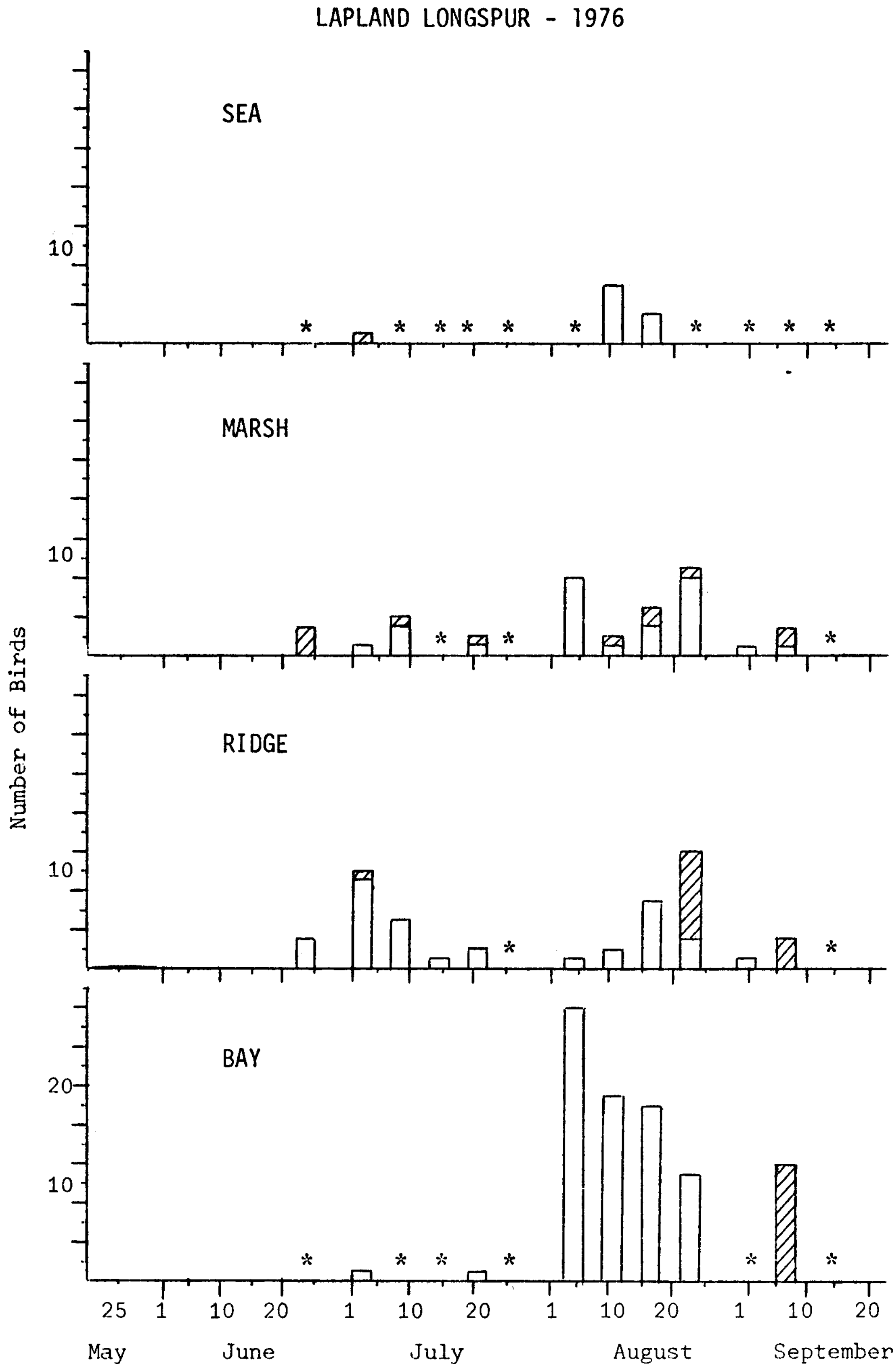

Figure 76. Numbers and distribution of Lapland Longspurs on the census transects, 1976, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

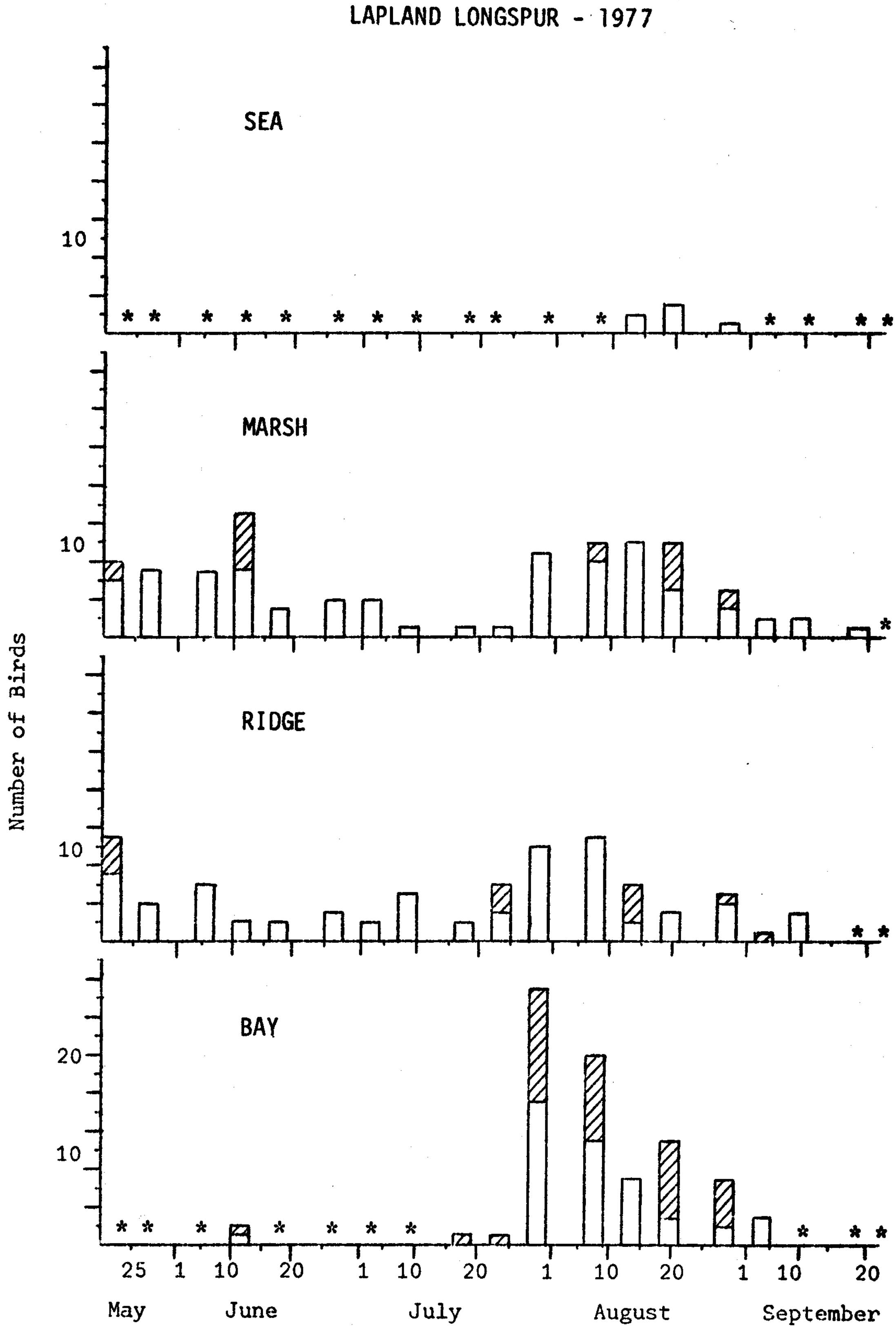

Figure 77. Numbers and distribution of Lapland Longspurs on the census transects, 1977, Cape Espenberg, Alaska (unshaded = on ground or water, shaded = flying, * = not present).

(Connors 1978) almost exactly.

Snow Buntings. A few Snow Buntings were observed in late May 1977 (Table 5). Thereafter, none were noted until 18 September. They were seen nearly every day from that point until the end of field observation, 24 September, when at least 250 were counted. Connors' field camps and that of Shields and Peyton had been struck by this date, so comparative sightings are lacking.

Mudflat Surveys

Thousands of birds foraged on the South Mudflats during August and September of 1976 and 1977 (Tables 8 and 9). Ducks, primarily Pintails, sporadically used this area during June and early July. In 1977, their numbers peaked at 5600 birds (1870 birds/km^2) in late July/early August. After mid-August, few ducks fed on the mudflats. Female eiders, both with and without broods, were found on these mudflats and in adjacent sloughs in June and July. Geese (10-150 birds per observation period) frequented the mudflats and nearby saltmarshes in late August and early September.

In 1977, shorebird numbers peaked twice on the mudflats, once in late July/early August (ca. 2000 birds; 667 birds/km^2) and then from late August through mid-September (ca. 3000-7000 birds; 1000-2340 birds/km^2). The first peak was brief and consisted primarily of Semipalmated and Western Sandpipers. The later peak was comprised of Dunlins. Smaller numbers (hundreds of each species, maximum) of Pectoral Sandpipers and Northern Phalaropes, as well as tens of Red Knots and Black Turnstones were observed feeding here in mid-July 1977.

Sabine's Gulls fed on the mudflats during their entire residency in the Espenberg area. Arctic Terns fed in pools on the mudflats and at the mudflat's edge during much of their stay in the area.

Beached Bird and Mammal Surveys

During each field season, after spring breakup, the outer (north) beach of Cape Espenberg was surveyed for carcasses of birds and mammals which washed ashore. Results of these surveys are presented in Table 10. Nearly twice as many surveys were conducted in 1976 as in 1977. In 1977 carcasses were not oiled and in 1976 only 1 Horned Puffin had evidence of oil (a moderate amount). More dead birds were found in 1976. Two storms in 1976 probably accounted for more beached birds, especially Fulmars and kittiwakes, compared with 1977.

More beached sea mammals were found in 1977 than in 1976. This may reflect better hunting conditions in the spring of 1977. Better hunting would suggest more animals shot, but not necessarily retrieved.

Aerial Surveys

After observing large fluxes of shorebirds through Espenberg Bay in 1976, we wondered just how many other mudflats are available to shorebirds and waterfowl in nearby southern Kotzebue Sound. To answer this question,

Table 8. Bird censuses in Espenberg Bay, Cape Espenberg, Alaska, 1976.

	August										Sep.
	2	3	5	6	7	9	12	15	22	30	9
Unid. ducks	1400	--	--	--	100	500	250	100	--	--	--
Pintail	--	1600	320	300	670	--	--	--	--	--	--
Eiders	--	--	--	--	20	--	--	--	--	--	--
Unid. Shorebirds	--	--	355	400	350	--	--	300	7000[a]	4000[b]	1500[c]
Cranes	--	--	--	--	2	--	--	--	--	--	--
Glaucous Gull	100	--	147	150	70	20	110	26	175	--	--
Sabine's Gull	--	--	59	--	--	--	--	--	--	--	--
Arctic Tern	--	--	--	--	20	--	35	17	15	--	--
Total	1500	1600	881	850	1232	520	395	443	7190	4000	1500

[a] Approximately 90% Dunlins, 10% probably Western Sandpipers.

[b] Most (90%) were probably Dunlins.

[c] All Dunlins.

Table 9. Bird censuses in Espenberg Bay, Cape Espenberg, Alaska, 1977.

	31 May		22 June		23 June		24 June		27 June		28 June		29 June		1 July		2 July		3 July		4 July	
	Mud	Bay	Mud	Bay	Mud	Bay	Mud	Bay	Mud	Bay	Mud	Bay	Mud	Bay	Mud	Bay	Mud	Bay	Mud	Bay	Mud	Bay
loons	-	*	-	*	-	*	-	*	-	*	-	*	-	15	-	-	-	-	-	12	-	-
unid. geese	-	*	-	*	-	*	-	*	-	*	-	*	-	-	-	-	-	-	-	-	-	-
Emperor Goose	-	*	-	*	-	*	-	*	-	*	-	*	-	-	-	-	-	-	-	-	-	-
Black Brant	-	*	-	*	-	*	-	*	-	*	-	*	-	-	-	-	-	-	-	-	-	-
unid. ducks	10	*	1000	*	460[a]	*	-	*	-	*	20[a]	*	-	70	10	-	15	-	-	-	-	-
Pintail	-	*	-	*	200	*	160	*	225	*	57	*	1	-	-	-	-	-	-	-	4	80
Oldsquaw	-	*	-	*	-	*	-	*	-	*	-	*	-	50	-	-	-	7	-	7	-	-
eiders	-	*	-	*	-	*	40	*	-	*	-	*	-	10	-	-	-	5	-	-	-	-
mergansers	-	*	-	*	-	*	-	*	-	*	-	*	-	-	-	-	-	-	-	-	-	-
Sandhill Crane	4	*	-	*	-	*	-	*	-	*	-	*	-	2	-	-	-	-	-	-	-	-
unid. shorebirds	10	*	10	*	-	*	-	*	10	*	4	*	5[b]	40	-	-	8	-	-	-	-	-
plovers	-	*	-	*	-	*	-	*	-	*	-	*	-	-	-	-	-	-	-	-	-	-
turnstones	-	*	-	*	-	*	-	*	-	*	-	*	-	-	-	-	-	-	-	-	-	-
Dunlin	-	*	-	*	-	*	-	*	-	*	-	*	-	-	-	-	-	-	-	-	-	-
phalaropes	-	*	-	*	15	*	-	*	-	*	-	*	-	-	-	-	-	-	-	-	-	-
jaegers	-	*	-	*	-	*	-	*	-	*	-	*	-	-	-	-	-	-	-	-	1	-
Glaucous Gull	5	*	25	*	12	*	45	*	18	*	12	*	3	100	20	100	1	100	28	24	3	27
Sabine's Gull	1	*	-	*	6	*	4	*	-	*	0	*	-	15	4	-	-	-	3	-	-	-
Arctic Tern	-	*	15	*	0	*	-	*	-	*	0	*	-	45	-	70	5	15	-	30	-	10
Total	30	*	1050	*	692	*	249	*	253	*	93	*	9	347	34	170	29	127	31	73	8	217

*No observations.

[a]More than 70% Pintail.

[b]Mixed Semipalmated and Western Sandpipers.

[c]Mixed Pintails and eiders.

[d]In saltgrass near mudflats.

[e]More than 70% Dunlin.

[f]More than 70% Canada Goose. In saltgrass.

Table 9. Continued.

	5 July		7 July		8 July		10 July		13 July		14 July		15 July		16 July		17 July		19 July		20 July	
	Mud	Bay	Mud	Bay	Mud	Bay	Mud	Bay	Mud	Bay	Mud	Bay	Mud	Bay	Mud	Bay	Mud	Bay	Mud	Bay	Mud	Bay
loons	-	1	-	18	-	8	-	1	-	4	-	6	-	21	-	7	-	10	-	15	-	22
unid. geese	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Emperor Goose	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Black Brant	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
unid. ducks	75[a]	5	-	-	290	-	475	12	65[c]	-	400	-	680	-	850	-	1400[c]	-	1330[c]	-	1480[c]	-
Pintail	-	-	20	-	30	-	-	-	-	-	-	-	-	-	10	-	-	-	-	-	-	-
Oldsquaw	-	-	-	8	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
eiders	-	-	300	6	18	-	-	-	13	-	-	-	-	-	20	-	-	1	-	-	-	5
mergansers	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sandhill Crane	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
unid. shorebirds	36	-	-	-	-	-	4	-	10	-	10	-	325[b]	-	375[b]	1[b]	40	4[b]	100	51	20	18
plovers	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
turnstones	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dunlin	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
phalaropes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
jaegers	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Glaucous Gull	20	15	64	74	29	54	6	23	16	35	8	25	10	1	4	1	25	3	18	1	14	6
Sabine's Gull	1	-	30	-	-	3	-	7	-	-	-	-	-	1	3	-	-	-	-	-	46	4
Arctic Tern	25	-	15	-	1	36	10	15	-	3	1	1	3	3	0	3	-	1	-	-	-	-
Total	157	21	431	107	369	106	495	58	104	42	419	32	1018	26	1262	12	1465	19	1448	69	1560	55

Table 9. Continued.

	23 July		24 July		26 July		29 July		31 July		4 August		6 August		7 August		10 August		13 August		16 August	
	Mud	Bay	Mud	Bay	Mud	Bay	Mud	Bay	Mud	Bay	Mud	Bay	Mud	Bay	Mud	Bay	Mud	Bay	Mud	Bay	Mud	Bay
loons	-	20	-	21	-	34	-	51	-	42	-	5	-	1	-	6	-	27	-	4	-	16
unid. geese	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Emperor Goose	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25[d]	-	-	-
Black Brant	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
unid. ducks	1350[a]	-	2100[a]	-	5600[a]	-	2200[a]	-	1150[a]	-	1530[a]	-	620[a]	-	420[a]	-	180[a]	-	135	-	-	-
Pintail	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	7	-	22	-	-	20	-
Oldsquaw	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
eiders	-	-	-	-	-	2	-	2	-	-	-	5	-	-	-	-	-	1	-	-	-	-
mergansers	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sandhill Crane	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	3	-	-	-
unid. shorebirds	-	28	100[b]	-	100	9	800	-	50	2	750	-	3700	2	2000	-	360	-	750	-	100	-
plovers	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
turnstones	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dunlin	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
phalaropes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
jaegers	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Glaucous Gull	68	-	25	2	33	2	33	-	41	1	21	-	36	1	91	2	66	4	49	1	62	-
Sabine's Gull	-	-	3	-	0	2	1	-	1	-	1	-	-	4	10	-	-	-	2	-	-	-
Arctic Tern	-	4	10	1	3	1	7	-	10	3	12	1	8	6	40	2	18	13	7	-	75	-
Total	1418	52	2238	24	5736	50	3041	55	1251	58	2314	13	4364	13	2561	20	624	67	871	5	257	16

Table 9. Continued.

	19 August		22 August		24 August		26 August		31 August		3 Sept.		7 Sept.		8 Sept.		9 Sept.		16 Sept.		17 Sept.	
	Mud	Bay	Mud	Bay	Mud	Bay	Mud	Bay	Mud	Bay	Mud	Bay	Mud	Bay	Mud	Bay	Mud	Bay	Mud	Bay	Mud	Bay
loons	-	1	-	18	-	-	-	31	-	4	-	-	-	1	-	-	-	-	3	2	-	-
unid. geese	-	-	-	-	-	-	4[d]	-	-	-	-	-	100	-	30	-	48	-	28[f]	-	-	-
Emperor Goose	-	-	7[d]	-	-	-	19[d]	-	-	23[d]	45[d]	-	45[d]	7	-	7	7	-	7	4	8	-
Black Brant	-	-	-	-	-	-	20[d]	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-
unid. ducks	8[a]	-	18[a]	-	-	-	-	-	-	-	-	-	35	6	-	5	32	-	45	20	-	-
Pintail	-	-	-	-	1	-	-	-	3	-	28	-	-	-	-	-	-	-	-	-	-	-
Oldsquaw	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
eiders	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
mergansers	-	-	-	-	-	-	-	-	-	-	-	4	-	29	-	-	-	-	-	-	5	-
Sandhill Crane	-	-	-	-	-	-	-	-	-	5	-	-	5	-	9	8	-	-	-	-	-	-
unid. shorebirds	920	4	390	-	2700[e]	-	1100[e]	-	870[e]	8[e]	1200[e]	-	-	-	-	-	-	-	-	-	-	-
plovers	-	-	-	-	-	-	-	-	-	-	5	-	-	-	33	-	-	-	-	-	100	-
turnstones	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Dunlin	-	12	-	-	-	-	-	4	-	45	-	15	1250	50	25	-	2200	17	450	-	1700	-
phalaropes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	40	-
jaegers	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Glaucous Gull	91	2	55	5	33	2	59	3	63	15	166	20	8	102	105	260	57	-	80	123	20	2
Sabine's Gull	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arctic Tern	12	-	-	-	-	1	2	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Total	1131	19	470	23	2734	4	1204	39	956	101	1444	40	1443	145	202	280	2344	17	613	149	1873	4

Table 9. Continued.

	18 Sept.		21 Sept.		22 Sept.	
	Mud	Bay	Mud	Bay	Mud	Bay
loons	-	2	-	-	-	-
unid. geese	8[f]	-	-	-	-	-
Emperor Goose	19[d]	-	-	-	-	-
Black Brant	-	-	-	-	-	-
unid. ducks	2	-	-	-	-	-
Pintail	-	-	-	-	-	-
Oldsquaw	-	6	-	-	-	-
eiders	-	-	-	-	-	-
mergansers	4	-	-	-	-	10
Sandhill Crane	-	-	-	-	-	-
unid. shorebirds	-	-	-	-	-	-
plovers	?	14	60	14	-	-
turnstones	-	-	-	-	-	-
Dunlin	3400	110	1000	20	700	70
phalaropes	20	-	-	8	-	-
jaegers	-	-	-	-	-	-
Glaucous Gull	13	1	11	55	100	30
Sabine's Gull	-	-	-	-	-	-
Arctic Tern	-	-	-	-	-	-
Total	3466	133	1071	97	830	110

Table 10 . Summary of bird and mammal carcasses found beached on Cape Espenberg, 1976 and 1977[1].

Species	Number 1976	Number 1977	Species	Number 1976	Number 1977
Red-throated Loon	0	2	Arctic Tern	3	1
Shearwater spp.	2	2	Kittiwake spp.	39	10
Fulmar	4	0	Murre spp.	20	20
Dabbler	1	2	Puffin spp.[2]	4[2]	1
Oldsquaw	6	1	Crested Auklet	1	0
Eider spp.	3	4	Unidentified Alcid	3	0
Black Scoter	1	0	Unidentified Seabird	5	0
White-winged Scoter	1	0	Common	2	0
Unidentified Waterfowl	0	5	Unidentified Bird	2	11
Shorebird	1	1	Largha Seal	0	2
Parasitic Jaeger	2	0	Bearded Seal	3	4
Long-tailed Jaeger	1	0	Unidentified Seal	0	4
Glaucous Gull	4	2	Walrus	1[3]	3
Mew Gull	0	1			

[1] Beach surveys were more frequent in 1976 (24, 118 km) compared with 1977 (10, 68 km).

[2] Only one Horned Puffin was found with a moderate amount of oil; no other carcasses were oiled.

[3] Carcass washed ashore during 1976; approximately 25 remained from previous years.

we flew six surveys in 1977 from Cape Espenberg eastward to Kiwalik Lagoon (near Candle, Alaska) (Figs. 4 and 5).

Except for the seabird nesting cliffs at Sullivan Bluffs and at Cape Deceit, the greatest bird concentrations (>30 birds/linear km) occurred in selected river deltas (sections E and P), one saltmarsh/island area (section C) and Espenberg Bay (section A) (Tables 11-18, Figs. 78-89). These four coastal sections contain the largest expanses of saltmarsh and mudflats along our survey route.

A few seasonal trends for 1977 are readily apparent in summary Table 19. Geese increased noticeably beginning 15 August and peaked 1 September, although their numbers remained high through 15 September. Geese probably move westward along the coast in late summer. Although numerous geese were counted on our mid-August survey, few were seen on the Cape until 22 August; they were not common there until 28 August.

Large numbers of ducks (mostly pintails) were present all summer. Peak numbers (ca. 4300 birds; 20.3 ducks/km of coast) occurred on 1 August, although many ducks were present through 15 September. In comparison, peak numbers of ducks were counted on Espenberg Bay mudflats in late July.

Crane numbers were highest during the September aerial surveys, at the same time they were most numerous in Espenberg Bay.

Maximum shorebird numbers (ca. 9900 birds; 44.3 shorebirds/km of coast) occurred on 1 September and they were still numerous on 15 September. In Espenberg Bay, shorebirds appeared in large numbers during August and September.

Larids were present in fairly consistent numbers (ca. 1800 birds; 8.1 larids/km of coast) from 15 July through 15 September.

We were able to repeat the June and mid-July surveys in 1978. We were particularly anxious to fly these surveys because droughts in the Canadian prairies had forced a record number of ducks to fly to Alaska in 1977 (King and Bartonek 1977).

We found concentrations of birds in the same areas as in 1977 (Tables 17 and 18). In contrast to 1977, ducks increased from June to July (Table 20). As anticipated, Pintail numbers were down considerably from 1977. Our estimates indicate that 2.3-3.2 times as many Pintails were present on the June survey in 1977 as compared with 1978 estimates for the same period. Our estimates agree well with the state-wide estimate of King and Bartonek (1977) of 2.3 times as many Pintails in 1977 as normally seen. Three times as many geese were seen in 1978 than in 1977. We cannot, at present, explain this increase. About 50% more larids were counted in mid-July 1978 than in mid-July 1977. Increases were noted in Glaucous Gulls, kittiwakes, and Arctic Terns. More immature Glaucous Gulls were noted on surveys and on the Cape in 1978 than in previous summers. This influx of young birds may be related to the phenologically early spring.

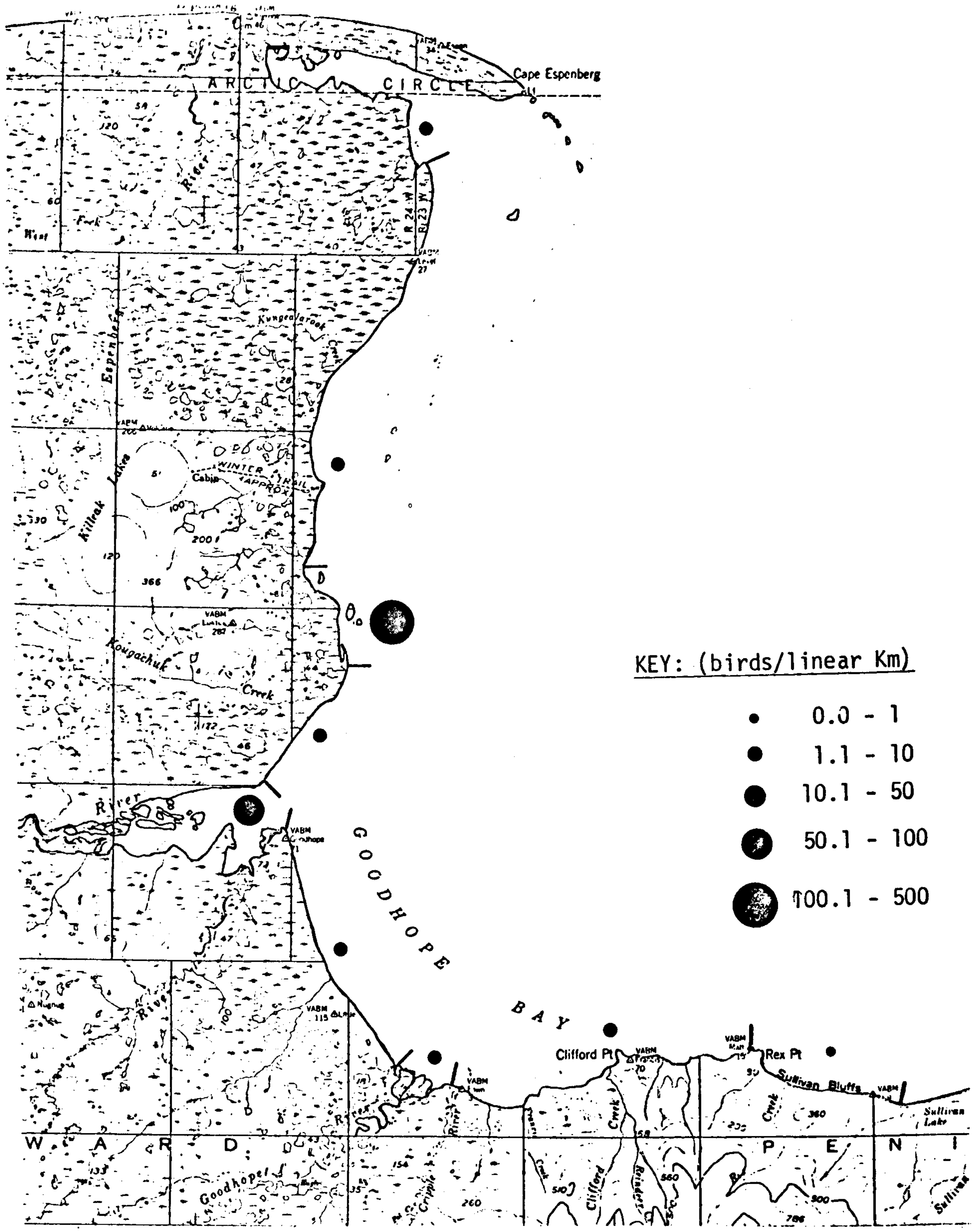

Figure 78. Bird numbers on western part of aerial survey, 3 June 1977, southern Kotzebue Sound, Alaska.

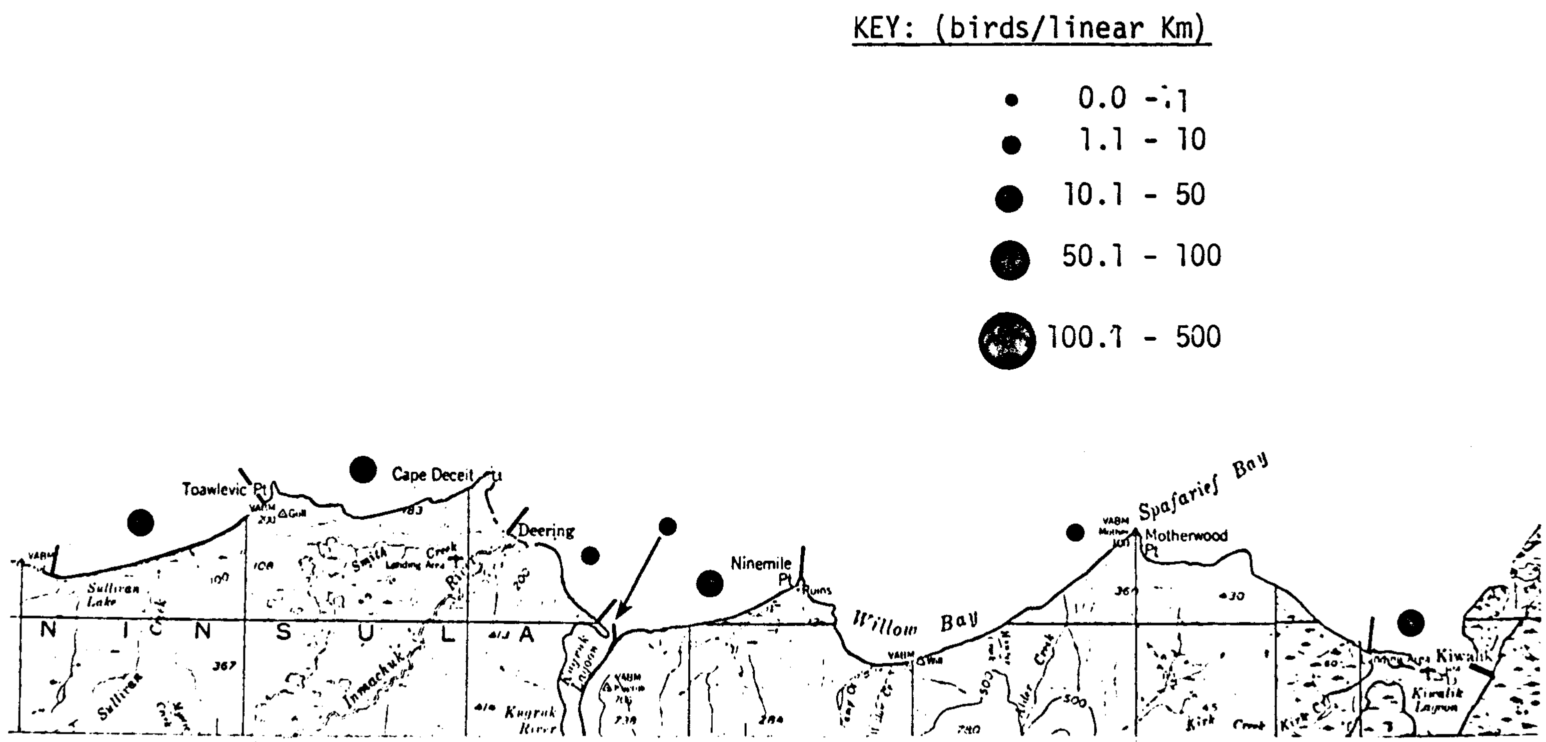

Figure 79. Bird numbers on eastern part of aerial survey, 3 June 1977, southern Kotzebue Sound, Alaska.

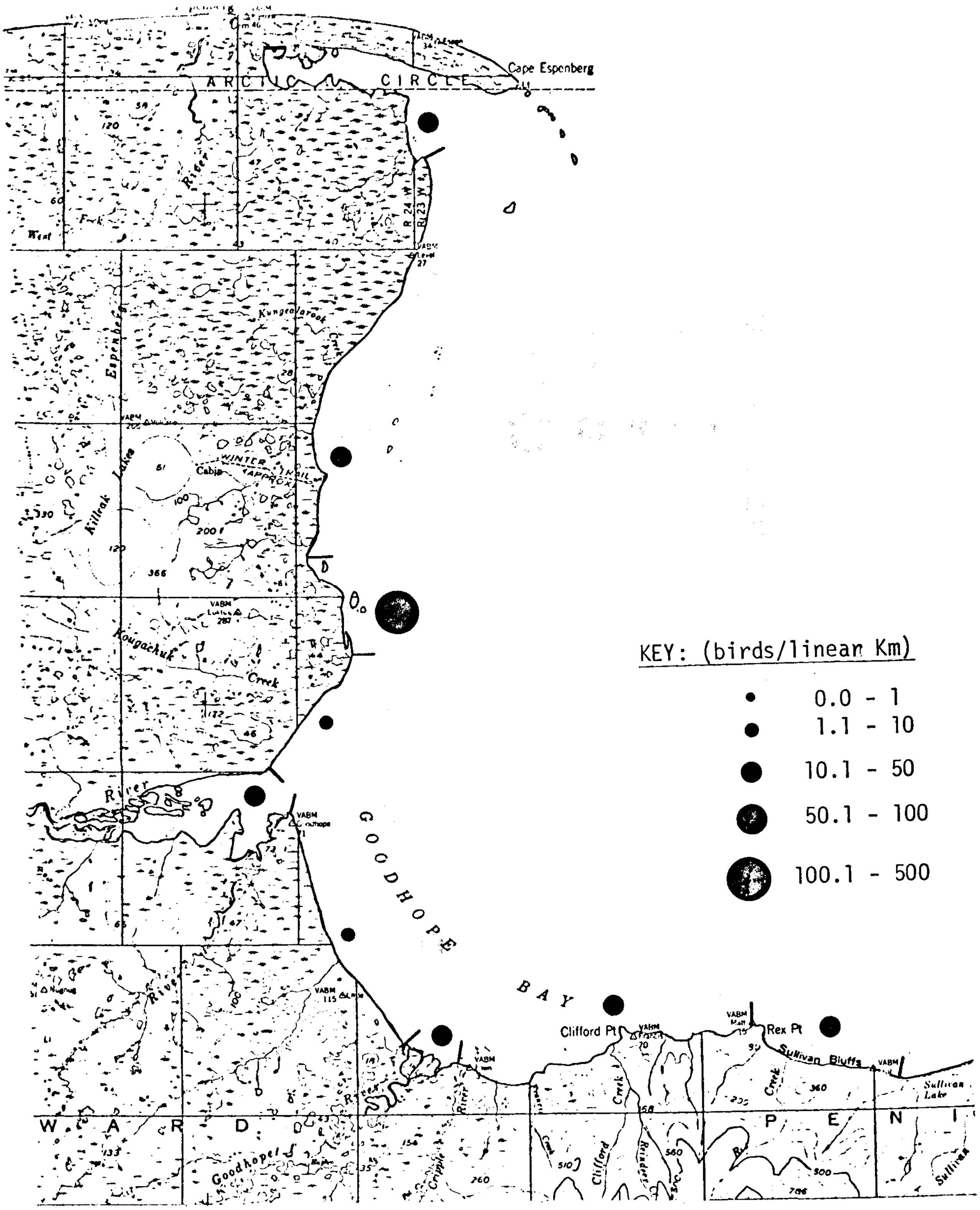

Figure 80. Bird numbers on western part of aerial survey, 15 July 1977, southern Kotzebue Sound, Alaska.

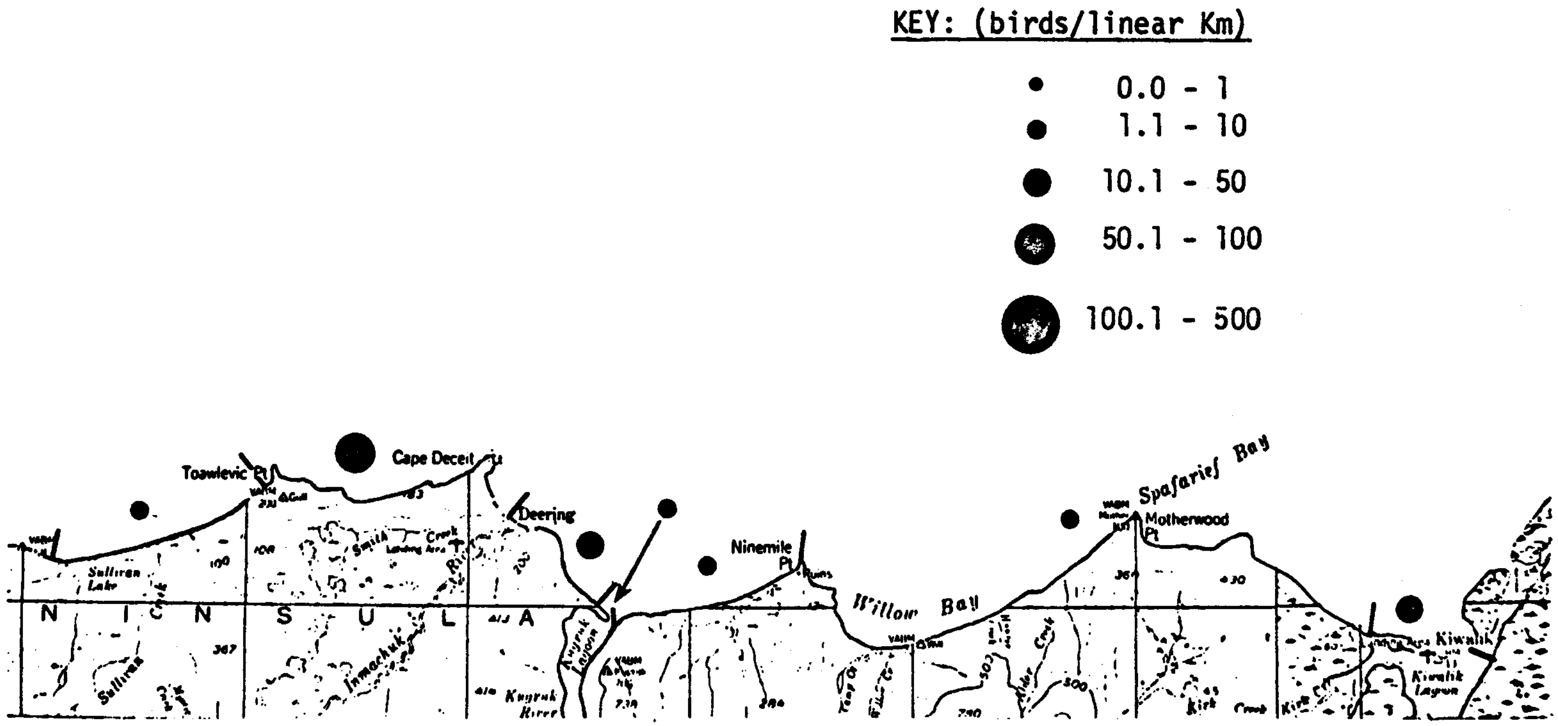

Figure 81. Bird numbers on eastern part of aerial survey, 15 July 1977, southern Kotzebue Sound, Alaska.

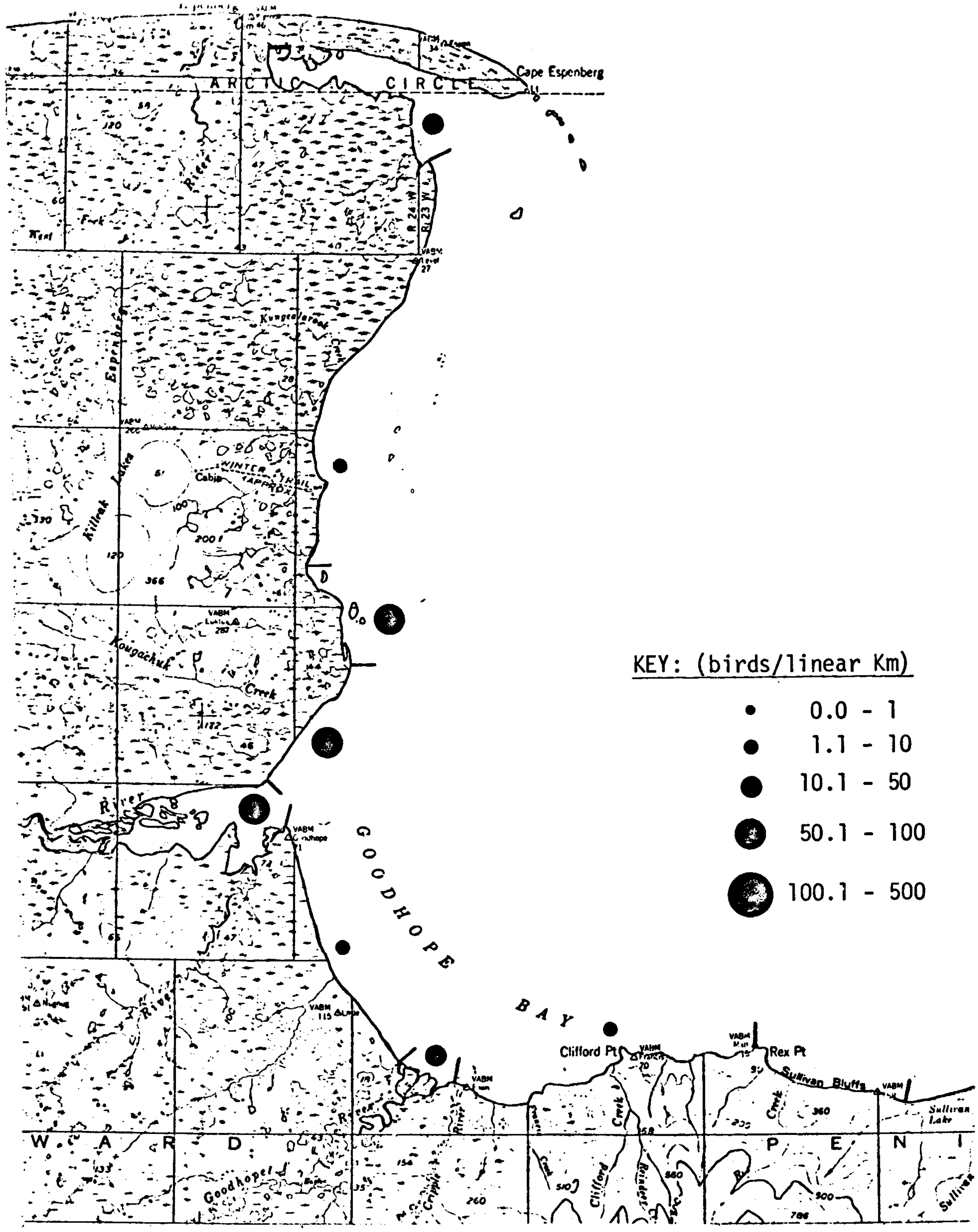

Figure 82. Bird numbers on western part of aerial survey, 1 August 1977, southern Kotzebue Sound, Alaska.

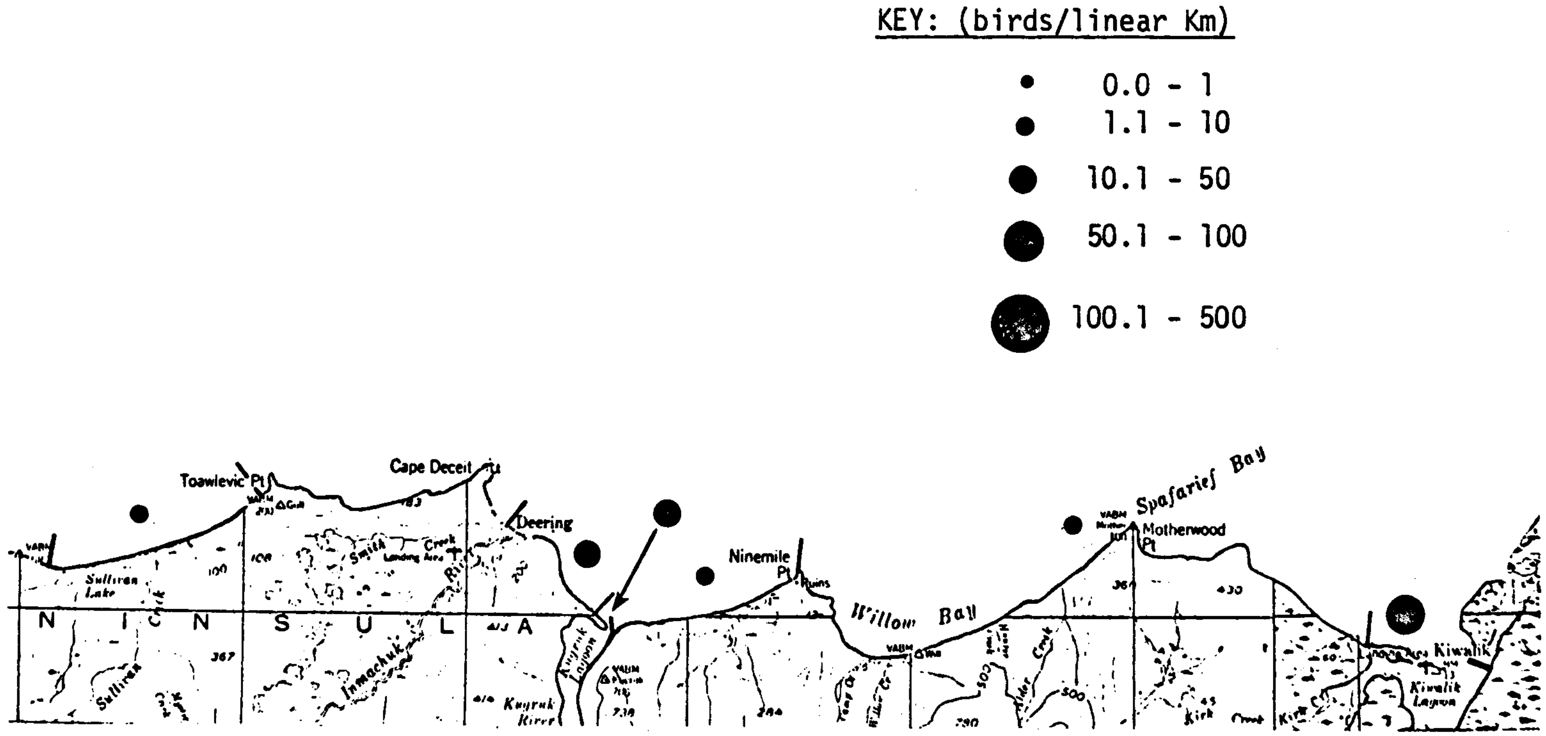

Figure 83. Bird numbers on eastern part of aerial survey,
1 August 1977, southern Kotzebue Sound, Alaska.

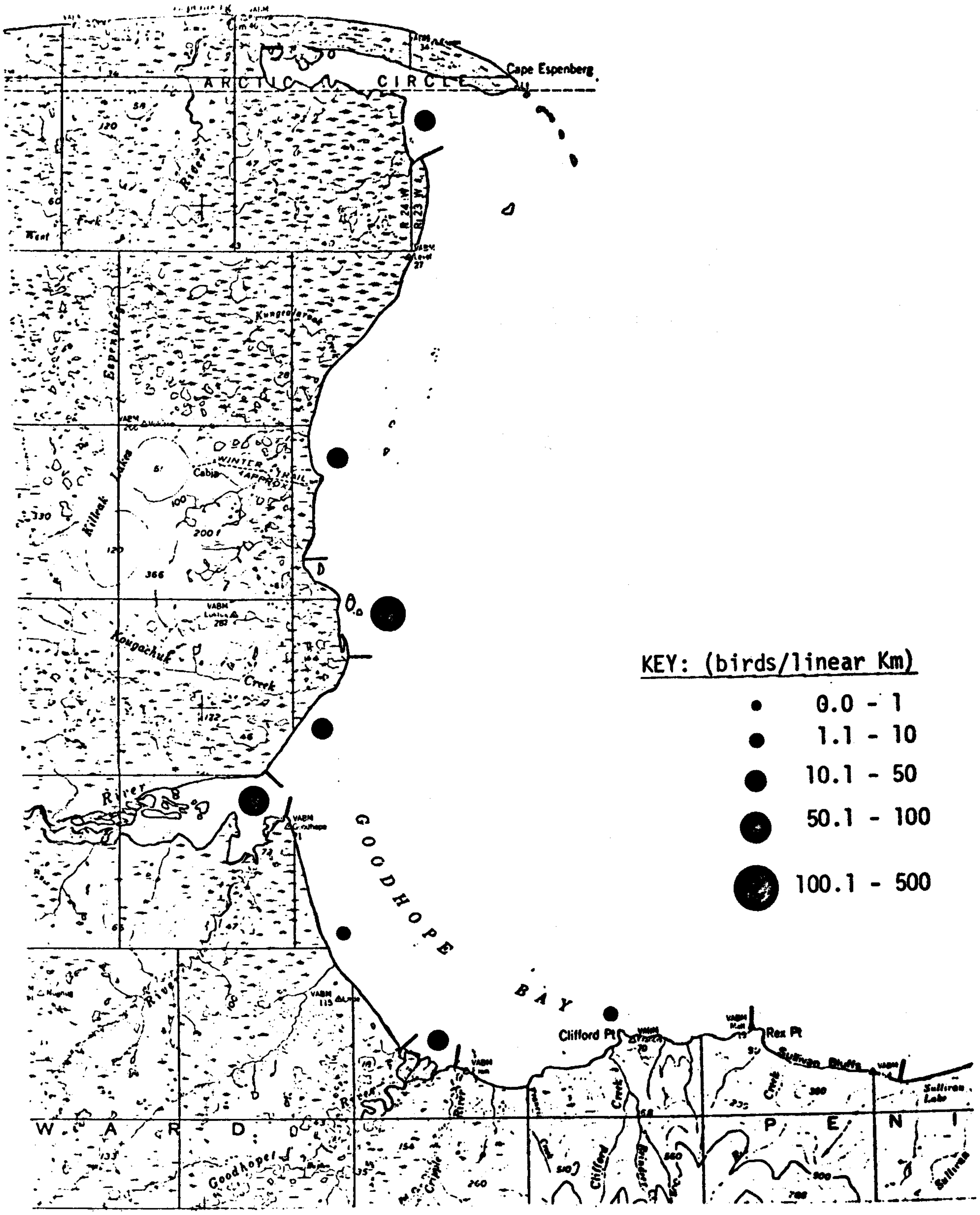

Figure 84. Bird numbers on western part of aerial survey, 15 August 1977, southern Kotzebue Sound, Alaska.

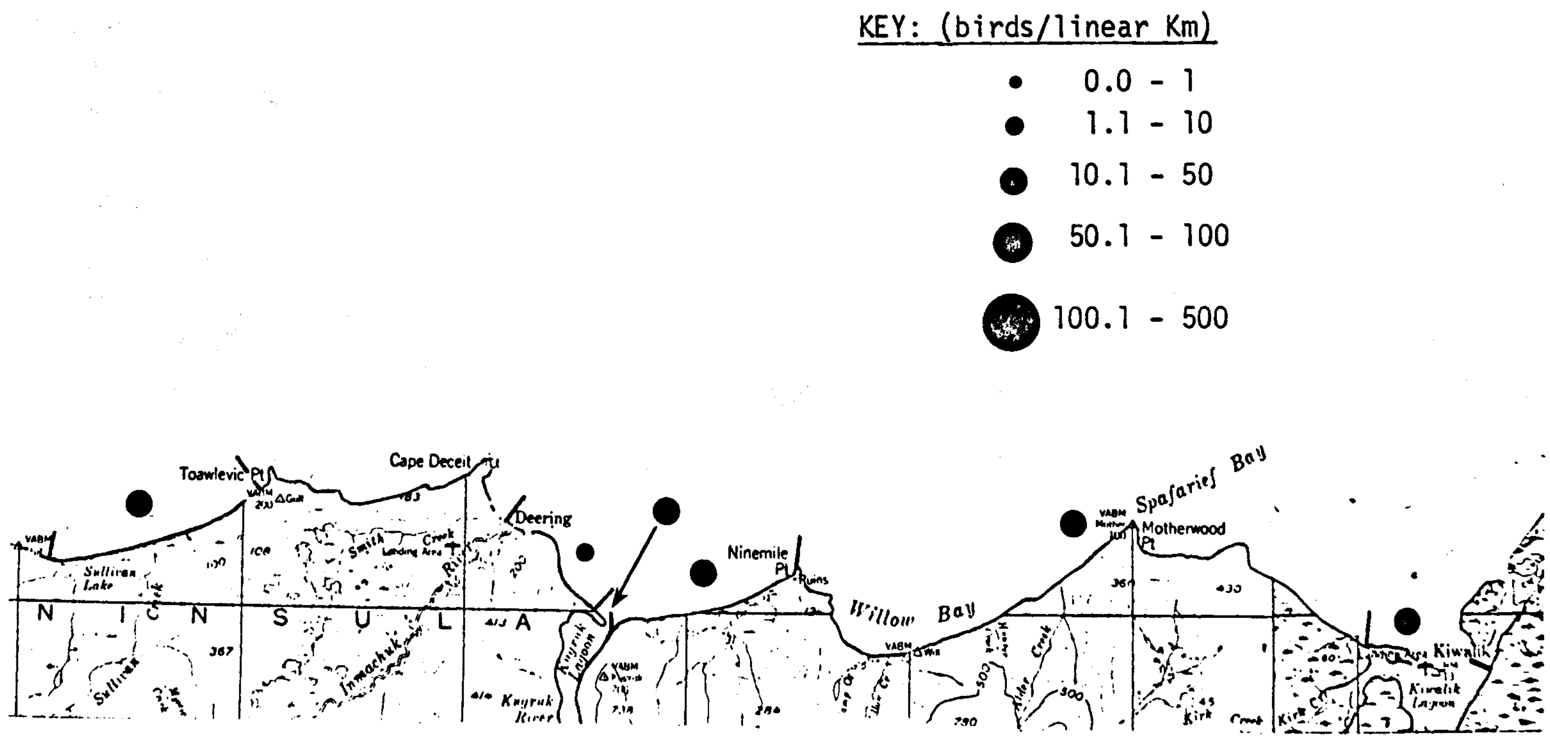

Figure 85. Bird numbers on eastern part of aerial survey, 15 August 1977, southern Kotzebue Sound, Alaska.

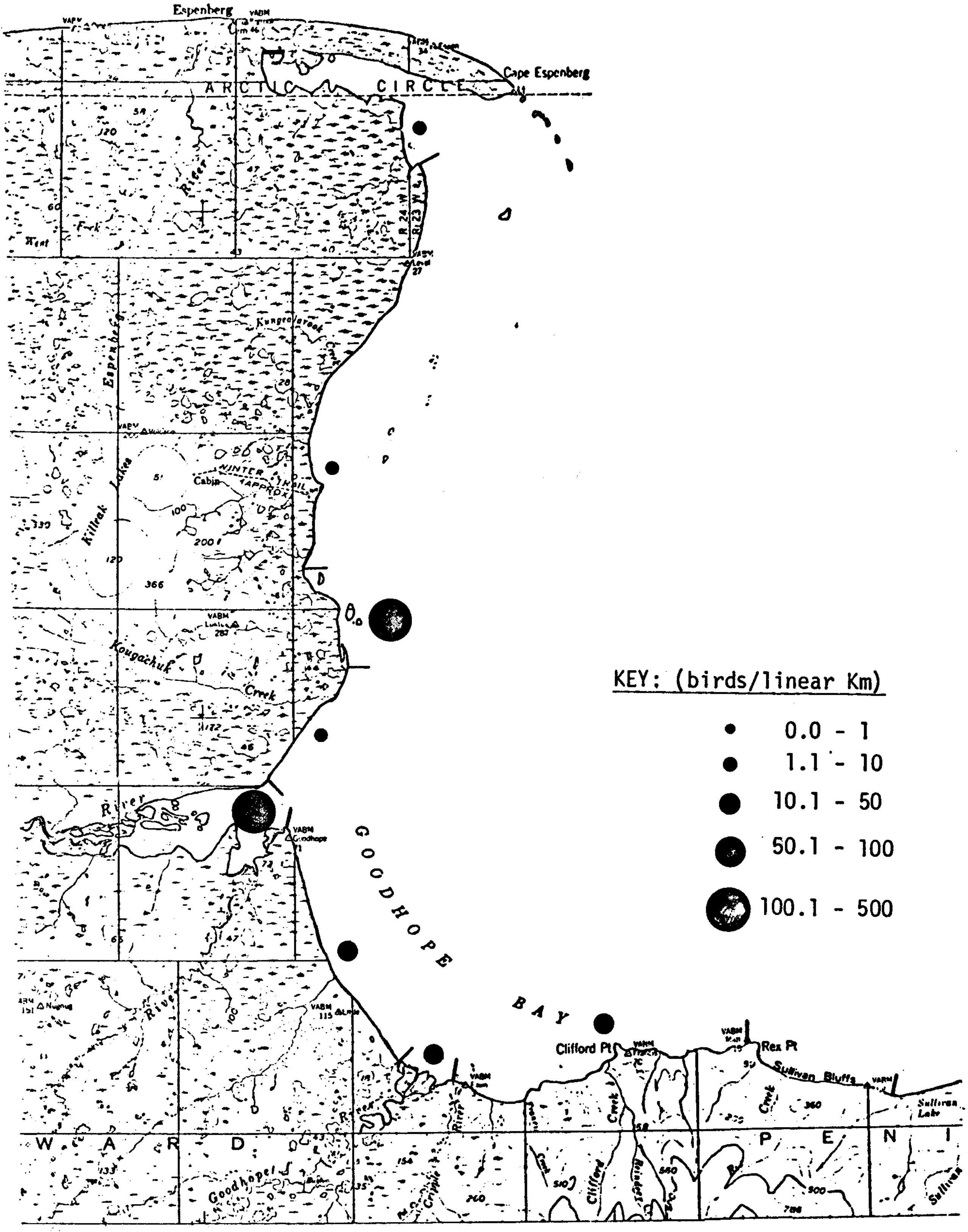

Figure 86. Bird numbers on western part of aerial survey, 1 September 1977, southern Kotzebue Sound, Alaska.

KEY: (birds/linear Km)

- 0.0 - 1
- 1.1 - 10
- 10.1 - 50
- 50.1 - 100
- 100.1 - 500

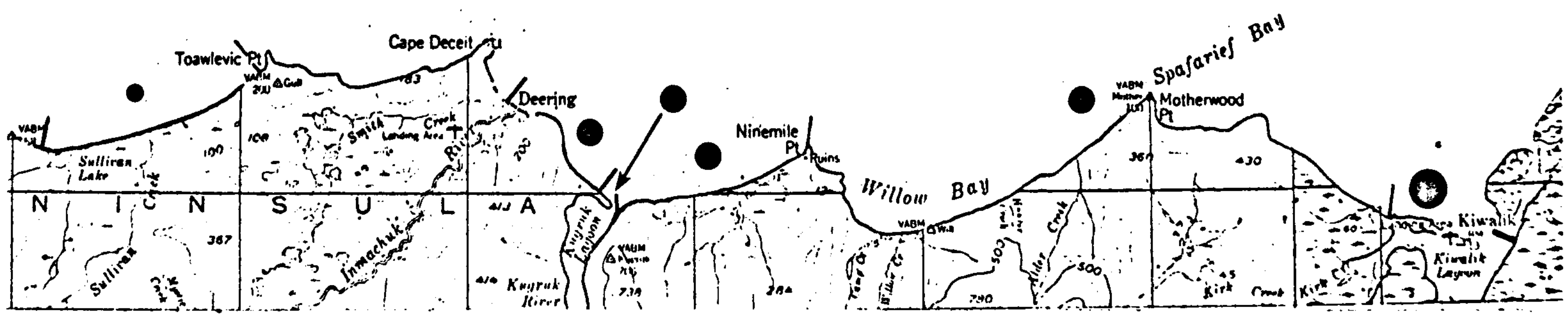

Figure 87. Bird numbers on eastern part of aerial survey, 1 September 1977, southern Kotzebue Sound, Alaska.

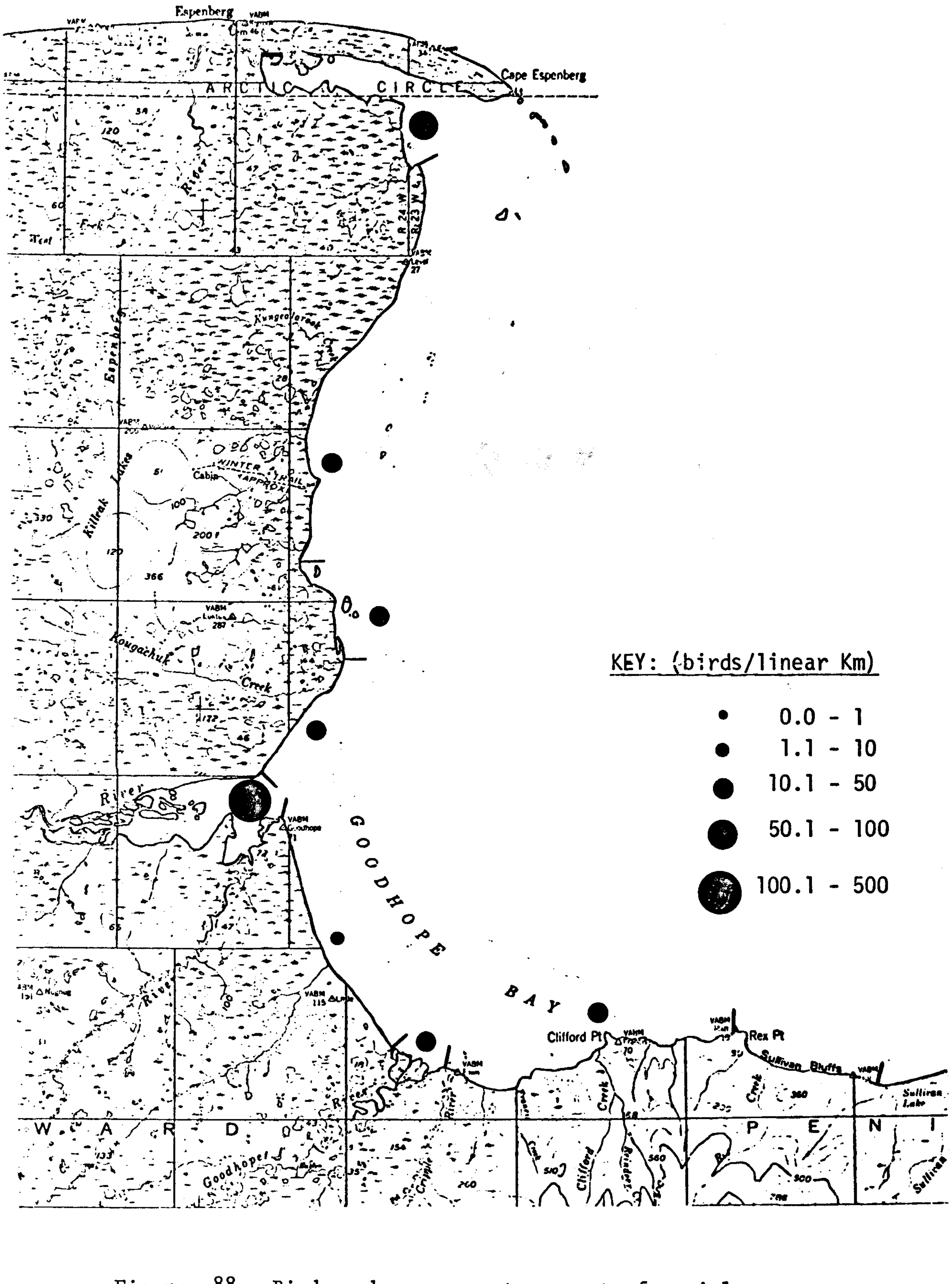

Figure 88. Bird numbers on western part of aerial survey, 15 September 1977, southern Kotzebue Sound, Alaska.

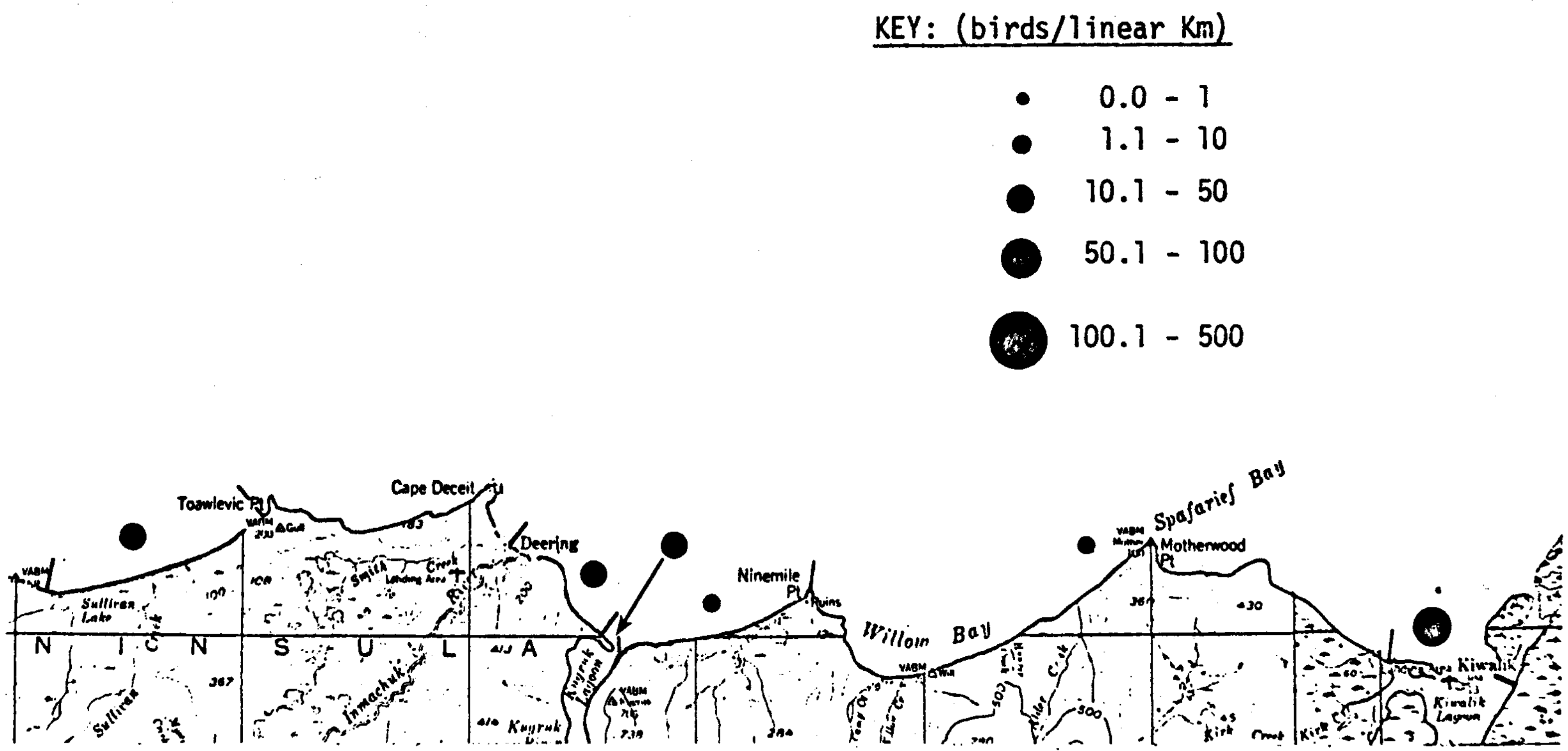

Figure 89. Bird numbers on eastern part of aerial survey, 15 September 1977, southern Kotzebue Sound, Alaska.

Table 11. Number of birds observed during aerial survey on June 3, 1977, southern Kotzebue Sound, Alaska.

Species	Number Observed in Each Area[1]																Total[2]
	A	B	C	D	E	F	G	H	I[2]	J	K[2]	L	M	N	O	P	
Unid. Loon	-	3	-	-	1	10	-	-	-	-	-	-	-	-	2	-	16
Yellow-billed Loon	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1
Arctic Loon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Red-throated Loon	-	1	-	-	-	-	-	-	-	-	-	-	3	-	-	-	4
Unid. Waterfowl	-	-	-	-	-	-	-	-	-	10	-	-	-	100	-	-	110
Whistling Swan	-	-	2	-	-	-	-	-	-	2	-	-	-	-	-	1	5
Unid. Goose	-	-	-	-	8	-	2	-	-	-	-	-	-	-	-	2	12
Canada Goose	-	-	2	24	-	7	25	-	-	-	-	-	-	-	5	-	63
Black Brant	-	-	10	-	-	-	-	-	-	-	-	-	-	-	-	-	10
Emperor Goose	-	2	-	-	2	-	-	-	-	-	-	-	-	-	-	-	4
Unid. Duck	6	11	38	10	325	36	1	-	-	2	-	6	8	-	-	107	550
Mallard	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	4	10
Pintail	6	16	243	-	637	1	-	-	1	-	-	-	54	10	10	261	1238
Unid. Teal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
American Widgeon	-	-	-	-	6	-	-	-	-	-	-	-	2	-	2	-	10
Northern Shoveler	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Canvasback	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1
Unid. Scaup	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Oldsquaw	6	-	235	6	135	-	-	-	-	250	-	-	2	-	-	-	634
Unid. Eider	12	7	-	-	183	6	-	30	-	-	-	-	30	-	8	137	413
Unid. Scoter	-	-	-	-	-	-	-	2	-	2	-	-	4	-	-	-	8
Red-breasted Merganser	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Unid. Hawk	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Marsh Hawk	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Golden Eagle	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unid. Ptarmigan	-	2	-	2	-	-	-	-	-	-	-	-	-	-	-	-	4
Sandhill Crane	-	2	-	-	1	3	-	1	-	-	-	-	-	-	-	-	7
Unid. Shorebird	-	3	210	-	89	-	-	-	-	-	-	-	-	-	-	10	312
Unid. Small Shorebird	-	-	-	-	74	-	-	-	-	-	-	-	12	-	-	-	86
Unid. Medium Shorebird	-	10	-	-	163	-	-	-	-	-	-	-	-	-	-	6	179
Unid. Large Shorebird	-	-	-	-	-	-	1	-	2	-	-	-	-	-	-	-	3
Unid. Turnstone	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	2
Whimbrel	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dunlin	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Red Phalarope	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Northern Phalarope	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Unid. Jaeger	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Parasitic Jaeger	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unid. Larid	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Glaucous Gull	-	3	2	1	114	-	4	3	2	-	10	-	19	9	59	36	250
Mew Gull	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1
Unid. Kittiwake	-	-	-	-	-	-	-	-	-	-	178	1	-	-	-	-	1
Sabine's Gull	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	6
Arctic Tern	-	6	-	-	11	3	2	1	1	1	-	-	-	2	-	10	36
Unid. Murre	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 11. Continued

Species	A	B	C	D	E	F	G	H	I[2]	J	K[2]	L	M	N	O	P	Total[2]
	Number Observed in Each Area[1]																
Common Raven	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lapland Longspur	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unid. Bird	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1
Total	30	68	743	21	1780	59	19	63	6	268	188	7	141	121	87	575	3982
No. Birds Per Linear Km.	2.3	2.6	121.8	2.2	52.7	4.0	2.0	3.3	0.6	26.5	12.1	1.5	9.9	14.9	2.8	25.8	18.0

[1]See Figs. 4 and 5 for location of areas.

[2]Areas I and K not included in total because they were not included in subsequent surveys.

Table 12. Number of birds observed during aerial survey on July 15, 1977, southern Kotzebue Sound, Alaska.

Species	Number Observed in Each Area[1]																
	A	B	C	D	E	F	G	H	I[2]	J	K[2]	L	M	N	O	P	Total[2]
Unid. Loon	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Yellow-billed Loon	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	2
Arctic Loon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2
Red-throated Loon	-	2	1	-	4	5	1	7	-	-	-	-	1	-	2	4	27
Unid. Waterfowl	20	13	-	-	6	-	2	150	-	-	-	-	-	15	15	43	264
Whistling Swan	-	6	-	5	2	-	-	-	-	1	-	-	-	-	-	-	14
Unid. Goose	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	2
Canada Goose	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Black Brant	-	15	-	-	25	-	-	-	-	-	-	-	-	-	-	-	40
Emperor Goose	17	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	19
Unid. Duck	25	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	27
Mallard	-	-	-	-	10	-	-	-	-	-	-	-	-	-	-	-	10
Pintail	45	1	367	16	714	50	15	244	5	-	-	-	33	-	-	270	1755
Unid. Teal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
American Widgeon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Northern Shoveler	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Canvasback	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unid. Scaup	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18
Oldsquaw	-	-	2	-	-	-	5	3	1	-	-	-	-	-	-	-	10
Unid. Eider	58	97	110	-	99	-	6	20	1	-	-	-	1	-	7	2	400
Unid. Scoter	-	-	-	-	-	-	2	1	-	-	-	-	-	-	-	-	3
Red-breasted Merganser	-	-	-	-	5	-	-	1	2	2	-	-	-	-	-	3	11
Unid. Hawk	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Marsh Hawk	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Golden Eagle	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unid. Ptarmigan	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sandhill Crane	1	7	-	-	5	7	-	3	-	-	-	-	-	-	-	2	25
Unid. Shorebird	50	-	15	-	60	-	-	-	-	10	-	-	-	-	-	6	141
Unid. Small Shorebird	-	35	-	-	32	-	-	-	-	-	-	-	7	-	-	-	74
Unid. Medium Shorebird	-	-	-	-	-	-	-	-	6	-	-	-	-	-	-	-	6
Unid. Large Shorebird	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	14	17
Unid. Turnstone	-	-	-	-	-	-	-	10	-	-	-	-	-	1	-	-	11
Whimbrel	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dunlin	-	-	-	-	130	-	-	-	-	-	-	-	-	-	-	6	136
Red Phalarope	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Northern Phalarope	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1
Unid. Jaeger	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Parasitic Jaeger	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unid. Larid	-	-	1	-	6	-	1	-	-	-	-	-	1	-	30	-	39
Glaucous Gull	19	42	253	32	244	31	36	17	9	31	28	74	20	16	104	51	970
Mew Gull	-	2	-	-	10	-	3	-	-	-	-	-	4	-	-	-	19
Unid. Kittiwake	-	4	-	-	1	-	-	-	175	-	273	1	1	14	24	-	45
Sabine's Gull	6	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	8
Arctic Tern	10	37	9	9	71	1	20	23	6	14	-	-	39	20	3	37	293
Unid. Murre	-	-	-	-	-	-	-	-	62	-	969	-	-	-	7	-	7

Table 12. Continued

	Number Observed in Each Area[1]																
Species	A	B	C	D	E	F	G	H	I[2]	J	K[2]	L	M	N	O	P	Total[2]
Common Raven	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	5
Lapland Longspur	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unid. Bird	-	-	-	-	10	-	-	-	-	-	-	-	-	-	-	-	10
Total	270	265	759	62	1437	99	96	480	268	60	1270	75	107	66	192	440	4408
No. Birds Per Linear Km.	21.9	10.1	124.4	6.6	42.5	6.7	10.2	25.4	28.5	5.9	81.9	16.0	7.5	8.1	6.2	19.8	19.9

[1]See Figs. 4 and 5 for location of areas.

[2]Areas I and K not included in total because they were not included in subsequent surveys.

Table 13. Number of birds observed during aerial survey on August 1, 1977, southern Kotzebue Sound, Alaska.

	Number Observed in Each Area[1]																
Species	A	B	C	D	E	F	G	H	I[2]	J	K[2]	L	M	N	O	P	Total
Unid. Loon	-	2	-	-	20	-	-	-	*	-	*	-	-	-	-	-	22
Yellow-billed Loon	-	2	-	-	-	-	-	-	*	-	*	-	-	-	-	-	2
Arctic Loon	-	-	-	-	-	-	-	-	*	-	*	-	-	-	3	1	4
Red-throated Loon	-	-	-	-	1	1	-	6	*	3	*	1	-	-	-	-	14
Unid. Waterfowl	-	4	3	15	465	-	5	-	*	-	*	2	-	20	5	26	545
Whistling Swan	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Unid. Goose	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Canada Goose	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Black Brant	-	-	-	18	15	20	-	-	*	-	*	-	-	-	-	-	53
Emperor Goose	60	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	60
Unid. Duck	-	-	-	50	-	-	-	-	*	-	*	-	-	-	1	-	51
Mallard	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Pintail	142	55	37	297	1002	-	11	-	*	13	*	-	85	-	1	2081	3724
Unid. Teal	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
American Widgeon	-	-	-	-	1	-	-	-	*	-	*	-	-	-	-	-	1
Northern Shoveler	-	-	--	-	1	-	-	-	*	-	*	-	-	-	-	-	1
Canvasback	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Unid. Scaup	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Oldsquaw	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Unid. Eider	-	65	-	244	140	-	-	21	*	-	*	8	-	-	6	-	484
Unid. Scoter	-	-	-	-	-	-	-	-	*	-	**	-	-	-	-	-	-
Red-breasted Merganser	-	-	-	-	1	-	3	-	*	-	*	-	-	-	6	-	10
Unid. Hawk	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Marsh Hawk	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Golden Eagle	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Unid. Ptarmigan	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	- -
Sandhill Crane	-	-	-	-	32	-	2	-	*	-	*	-	-	-	-	-	34
Unid. Shorebird	-	-	1	-	30	-	-	-	*	-	*	-	125	-	-	-	156
Unid. Small Shorebird	10	50	-	45	35	-	32	7	*	-	*	-	30	-	-	1	210
Unid. Medium Shorebird	-	4	-	-	2	-	5	4	*	-	*	-	-	-	-	1	16
Unid. Large Shorebird	-	-	-	-	1	-	-	-	*	-	*	-	-	-	-	-	1
Unid. Turnstone	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Whimbrel	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Dunlin	75	1	21	-	105	-	-	-	*	-	*	-	-	-	-	-	202
Red Phalarope	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Northern Phalarope	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Unid. Jaeger	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Parasitic Jaeger	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Unid. Larid	-	-	-	-	-	4	-	3	*	-	*	-	-	-	-	-	7
Glaucous Gull	30	39	427	75	121	13	97	62	*	22	*	15	12	17	186	74	1190
Mew Gull	-	-	-	4	5	1	-	-	*	-	*	25	1	-	-	-	36
Unid. Kittiwake	-	-	-	-	-	-	-	59	*	16	*	2	-	1	20	6	104
Sabine's Gull	8	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	8
Arctic Tern	23	27	4	7	41	81	15	17	*	-	*	-	-	1	1	23	240
Unid. Murre	-	-	-	-	-	-	-	-	*	-	*	-	-	-	1	-	1

Table 13. Continued

Species	A	B	C	D	E	F	G	H	I[2]	J	K[2]	L	M	N	O	P	Total
	Number Observed in Each Area[1]																
Common Raven	-	-	-	-	-	2	-	-	*	-	*	-	-	-	6	-	8
Lapland Longspur	-	-	-	-	-	-	4	-	*	-	*	-	-	-	-	-	4
Unid. Bird	-	-	-	-	-	-	-	1	*	-	*	-	-	-	-	-	1
Total	348	249	493	755	2018	122	174	180	*	54	*	53	253	39	236	2215	7189
No. Birds Per Linear Km.	27.2	9.5	80.8	80.3	59.7	8.2	18.5	9.5	*	5.4	*	11.3	17.8	4.8	7.6	99.3	32.4

[1] See Figs. 4 and 5 for location of areas.

*Area not surveyed.

Table 14. Number of birds observed during aerial survey on August 15, 1977, southern Kotzebue Sound, Alaska.

	Number Observed in Each Area[1]																
Species	A	B	C	D	E	F	G	H	I[2]	J	K[2]	L	M	N	O	P	Total
Unid. Loon	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Yellow-billed Loon	-	-	-	-	-	-	-	2	*	-	*	-	-	-	-	-	2
Arctic Loon	-	1	-	-	2	-	-	-	*	-	*	-	-	-	-	3	6
Red-throated Loon	1	2	3	1	1	3	3	1	*	-	*	2	-	-	6	1	24
Unid. Waterfowl	-	11	10	50	137	-	-	10	*	84	*	5	10	-	80	21	418
Whistling Swan	-	-	-	-	2	-	-	-	*	-	*	-	-	-	-	-	2
Unid. Goose	-	10	-	-	134	-	-	-	*	-	*	-	-	-	-	-	144
Canada Goose	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Black Brant	-	17	-	-	247	-	-	47	*	40	*	-	-	40	-	215	606
Emperor Goose	59	-	-	-	25	-	-	-	*	-	*	-	-	-	-	-	84
Unid. Duck	1	1	30	-	-	2	12	-	*	-	*	-	-	-	-	5	51
Mallard	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Pintail	37	56	14	-	771	15	51	10	*	30	*	-	117	80	-	524	1705
Unid. Teal	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
American Widgeon	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Northern Shoveler	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Canvasback	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Unid. Scaup	-	10	-	-	5	-	-	15	*	-	*	-	-	-	-	-	30
Oldsquaw	-	1	-	-	-	-	-	-	*	-	*	-	-	-	-	-	1
Unid. Eider	-	60	-	12	-	-	-	-	*	-	*	-	-	-	-	-	72
Unid. Scoter	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Red-breasted Merganser	-	-	-	-	58	-	-	-	*	-	*	-	5	-	-	6	69
Unid. Hawk	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Marsh Hawk	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Golden Eagle	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Unid. Ptarmigan	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Sandhill Crane	-	-	-	-	-	-	4	-	*	-	*	-	-	-	-	2	6
Unid. Shorebird	-	15	10	-	67	-	-	-	*	-	*	-	-	-	-	4	96
Unid. Small Shorebird	-	-	175	2	-	-	50	-	*	-	*	-	-	-	-	-	227
Unid. Medium Shorebird	-	-	-	-	5	-	25	-	*	-	*	-	-	-	-	-	30
Unid. Large Shorebird	-	-	10	-	-	-	-	-	*	-	*	-	-	-	-	-	10
Unid. Turnstone	-	11	-	-	-	-	-	1	*	-	*	-	-	-	-	-	12
Whimbrel	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Dunlin	407	-	-	-	6	-	50	10	*	-	*	-	-	-	-	-	473
Red Phalarope	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Northern Phalarope	-	-	50	-	-	-	-	-	*	-	*	-	-	-	-	-	50
Unid. Jaeger	-	1	-	-	1	-	-	-	*	1	*	-	-	-	-	-	3
Parasitic Jaeger	-	2	-	-	-	-	-	-	*	-	*	-	-	-	-	-	2
Unid. Larid	-	-	-	-	2	-	-	-	*	-	*	-	1	-	-	-	3
Glaucous Gull	7	93	352	13	289	7	22	130	*	37	*	-	54	112	202	92	1410
Mew Gull	-	-	-	-	1	-	-	-	*	10	*	-	1	-	-	-	12
Unid. Kittiwake	-	-	-	-	15	-	-	-	*	1	*	9	1	96	12	-	134
Sabine's Gull	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	1	1
Arctic Tern	6	24	7	26	66	3	10	18	*	-	*	-	2	-	8	12	182
Unid. Murre	-	-	-	-	-	-	-	-	*	-	*	-	-	-	14	-	14

Table 14. Continued

Species	A	B	C	D	E	F	G	H	I[2]	J	K[2]	L	M	N	O	P	Total
								Number Observed in Each Area[1]									
Common Raven	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Lapland Longspur	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Unid. Bird	-	-	-	-	30	-	-	-	*	-	*	-	-	-	-	-	30
Total	518	315	661	104	1864	30	227	244	*	203	*	16	191	328	322	886	5909
No. Birds Per Linear Km.	40.5	12.0	108.4	11.1	55.2	2.0	24.2	12.9	*	20.1	*	3.4	13.4	40.5	10.4	39.7	26.6

[1] See Figs. 4 and 5 for location of areas.

* Area not surveyed.

Table 15. Number of birds observed during aerial survey on September 1, 1977, southern Kotzebue Sound, Alaska.

Species	Number Observed in Each Area[1]																
	A	B	C	D	E	F	G	H	I[2]	J	K[2]	L	M	N	O	P	Total
Unid. Loon	-	1	1	-	-	-	-	-	*	-	*	-	-	1	-	-	3
Yellow-billed Loon	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Arctic Loon	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	2	2
Red-throated Loon	-	1	1	-	-	-	1	-	*	-	*	-	-	-	-	2	5
Unid. Waterfowl	-	-	-	-	-	-	-	10	*	-	*	-	-	-	-	-	10
Whistling Swan	-	-	-	-	12	-	1	-	*	-	*	-	-	-	-	-	13
Unid. Goose	-	-	-	20	160	-	-	1	*	2	*	-	20	-	2	77	282
Canada Goose	-	-	-	-	-	220	-	-	*	-	*	-	-	-	-	20	240
Black Brant	-	-	-	25	1898	15	128	50	*	10	*	-	25	-	-	155	2306
Emperor Goose	-	10	-	-	7	-	-	5	*	-	*	-	1	-	-	16	39
Unid. Duck	-	12	14	-	770	-	-	25	*	-	*	-	-	20	20	377	1238
Mallard	-	-	-	-	10	-	-	-	*	-	*	-	-	-	-	-	10
Pintail	-	1	4	-	2064	-	5	-	*	-	*	-	20	-	-	145	2239
Unid. Teal	-	7	-	-	-	-	-	-	*	-	*	-	-	-	-	-	7
American Widgeon	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Northern Shoveler	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Canvasback	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Unid. Scaup	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Oldsquaw	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Unid. Eider	-	10	-	-	-	-	-	-	*	-	*	-	-	-	4	10	24
Unid. Scoter	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Red-breasted Merganser	-	15	-	-	-	-	-	4	*	-	*	-	-	-	-	18	37
Unid. Hawk	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Marsh Hawk	-	-	-	-	-	-	-	-	*	-	*	-	1	-	-	-	1
Golden Eagle	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Unid. Ptarmigan	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Sandhill Crane	-	1	-	-	24	40	-	17	*	-	*	-	-	-	32	6	120
Unid. Shorebird	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	65	65
Unid. Small Shorebird	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Unid. Medium Shorebird	-	-	-	-	89	-	-	-	*	-	*	-	1	2	2	21	115
Unid. Large Shorebird	-	1	--	3	9	-	-	-	*	-	*	-	-	-	-	5	18
Unid. Turnstone	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Whimbrel	-	-	-	-	-	-	-	2	*	-	*	-	-	-	-	4	6
Dunlin	-	60	2540	-	6800	-	91	-	*	-	*	50	-	-	-	160	9701
Red Phalarope	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Northern Phalarope	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Unid. Jaeger	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Parasitic Jaeger	-	-	-	-	1	-	-	-	*	-	*	-	-	-	-	-	1
Unid. Larid	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Glaucous Gull	86	102	248	9	322	45	21	135	*	67	*	68	80	71	408	124	1786
Mew Gull	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Unid. Kittiwake	-	16	75	-	-	-	-	-	*	-	*	-	-	-	46	-	137
Sabine's Gull	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Arctic Tern	-	-	-	-	-	-	-	-	*	-	*	-	-	1	-	-	1
Unid. Murre	-	-	-	-	-	-	-	-	*	-	*	-	-	-	15	-	15

Table 15. Continued

Species	Number Observed in Each Area[1]																
	A	B	C	D	E	F	G	H	I[2]	J	K[2]	L	M	N	O	P	Total
Common Raven	-	-	-	-	-	1	-	-	*	-	*	-	-	-	-	-	1
Lapland Longspur	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Unid. Bird	-	3	-	-	-	-	-	-	*	-	*	-	-	-	-	-	3
Total	86	240	2883	57	12166	321	247	249	*	79	*	118	148	95	529	1207	18425
No. Birds Per Linear Km.	6.7	9.1	472.6	6.1	359.9	21.7	26.3	13.2	*	7.8	*	25.1	10.4	11.7	17.1	54.1	83.0

[1]See Figs. 4 and 5 for location of areas.

*Area not surveyed.

Table 16. Number of birds observed during aerial survey on September 15, 1977, southern Kotzebue Sound, Alaska.

Species	Number Observed in Each Area[1]																
	A	B	C	D	E	F	G	H	I[2]	J	K[2]	L	M	N	O	P	Total
Unid. Loon	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Yellow-billed Loon	-	-	-	-	3	-	1	-	*	-	*	-	-	-	-	-	-
Arctic Loon	-	-	-	-	1	-	-	-	*	-	*	-	-	-	-	-	-
Red-throated Loon	-	-	4	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Unid. Waterfowl	-	-	-	1	87	-	-	-	*	-	*	-	100	-	-	642	832
Whistling Swan	-	-	-	-	6	-	8	-	*	-	*	-	-	-	-	-	14
Unid. Goose	75	39	-	12	488	-	59	32	*	-	*	-	-	-	-	91	796
Canada Goose	-	-	-	-	280	-	-	12	*	15	*	-	-	-	-	55	362
Black Brant	-	53	-	-	148	-	-	-	*	-	*	-	-	-	-	-	201
Emperor Goose	10	-	-	-	52	-	-	-	*	15	*	-	-	-	-	29	106
Unid. Duck	7	38	15	-	1441	-	23	8	*	20	*	-	105	20	1	135	1813
Mallard	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Pintail	-	77	40	2	67	-	7	-	*	-	*	25	10	-	-	602	830
Unid. Teal	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
American Widgeon	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Northern Shoveler	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Canvasback	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Unid. Scaup	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Oldsquaw	-	62	14	-	-	-	-	-	*	-	*	-	-	-	-	-	76
Unid. Eider	-	1	-	-	-	-	-	2	*	-	*	-	-	-	-	-	3
Unid. Scoter	-	-	-	7	-	-	-	-	*	-	*	-	-	-	-	-	7
Red-breasted Merganser	250	2	-	-	47	-	-	-	*	-	*	-	-	-	-	223	522
Unid. Hawk	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Marsh Hawk	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Golden Eagle	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	1	1
Unid. Ptarmigan	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Sandhill Crane	-	-	-	-	-	-	-	-	*	-	*	-	4	-	-	84	88
Unid. Shorebird	-	1	-	-	17	13	10	-	*	-	*	-	-	-	-	2	43
Unid. Small Shorebird	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Unid. Medium Shorebird	-	3	-	-	8	4	-	-	*	-	*	-	-	-	-	-	15
Unid. Large Shorebird	-	-	-	-	27	-	-	-	*	-	*	-	-	-	-	-	27
Unid. Turnstone	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Whimbrel	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Dunlin	552	-	50	50	1218	-	81	-	*	-	*	-	-	-	-	81	2032
Red Phalarope	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Northern Phalarope	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Unid. Jaeger	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Parasitic Jaeger	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Unid. Larid	-	-	-	-	-	-	-	-	*	-	*	-	-	-	1	-	1
Glaucous Gull	3	109	69	71	439	60	80	149	*	30	*	84	109	43	245	171	1662
Mew Gull	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Unid. Kittiwake	-	70	-	-	-	-	-	-	*	22	*	25	-	-	-	-	117
Sabine's Gull	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Arctic Tern	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Unid. Murre	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-

Table 16. Continued

Species	A	B	C	D	E	F	G	H	I[2]	J	K[2]	L	M	N	O	P	Total
	Number Observed in Each Area[1]																
Common Raven	-	-	-	-	-	-	-	-	*	-	*	1	-	-	-	-	1
Lapland Longspur	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-
Unid. Bird	-	-	-	-	-	-	-	-	*	-	*	-	-	-	18	-	18
Total	897	455	192	143	4329	77	269	203	*	104	*	135	328	63	265	2116	9576
No. Birds Per Linear Km.	70.1	17.3	31.5	15.2	128.1	5.2	28.6	10.7	*	10.3	*	28.7	23.1	7.8	8.6	94.9	43.2

[1]See Figs. 4 and 5 for location of areas.

*Area not surveyed.

Table 17. **Number of birds observed during aerial survey on June 1, 1978, southern Kotzebue Sound, Alaska.**

Species	Number Observed in Each Area[1]																
	A	B	C	D	E	F	G	H	I[2]	J	K[2]	L	M	N	O	P	Total[2]
Unid. Loon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yellow-billed Loon	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1
Arctic Loon	-	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-	2
Red-throated Loon	-	-	-	2	1	-	2	-	-	1	-	-	3	1	-	-	10
Unid. Waterfowl	15	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	19
Whistling Swan	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	2	4
Unid. Goose	-	2	-	4	4	-	1	-	-	-	-	-	-	-	1	24	36
Canada Goose	-	-	-	-	-	-	10	-	-	-	-	-	5	-	-	21	36
Black Brant	1	-	7	-	155	-	6	-	-	-	-	-	-	-	-	20	189
Emperor Goose	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unid. Duck	-	4	20	2	40	-	15	-	-	-	-	-	41	-	-	26	148
Mallard	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pintail	-	2	73	-	194	4	1	1	-	-	-	-	41	-	-	75	391
Unid. Teal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
American Widgeon	-	-	-	-	-	-	-	-	-	-	-	-	12	-	-	3	15
Northern Shoveler	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Canvasback	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unid. Scaup	-	2	-	10	-	-	-	-	-	-	-	-	2	-	-	-	14
Oldsquaw	-	8	23	1	17	-	14	-	-	-	-	-	-	-	-	2	65
Unid. Eider	18	-	-	53	201	-	-	5	-	-	-	-	42	-	-	5	324
Unid. Scoter	-	4	-	-	10	-	5	-	-	-	-	-	16	-	-	1	36
Red-breasted Merganser	-	1	-	-	-	-	5	-	-	-	-	2	42	2	-	4	56
Unid. Hawk	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Marsh Hawk	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Golden Eagle	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Unid. Ptarmigan	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sandhill Crane	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	3
Unid. Shorebird	95	3	98	-	345	1	3	-	-	-	-	-	173	-	-	7	725
Unid. Small Shorebird	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unid. Medium Shorebird	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unid. Large Shorebird	-	-	-	-	10	-	-	-	-	-	-	-	-	-	-	-	10
Unid. Turnstone	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1
Whimbrel	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dunlin	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Red Phalarope	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Northern Phalarope	-	-	-	-	7	-	-	-	-	-	-	-	-	-	-	1	8
Unid. Jaeger	-	10	-	-	-	-	1	-	-	3	-	-	-	-	-	10	24
Parasitic Jaeger	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unid. Larid	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Glaucous Gull	4	14	11	7	40	4	7	13	8	1	4	39	5	9	70	96	320
Mew Gull	-	-	-	-	-	-	-	1	-	-	-	-	2	-	-	1	4
Unid. Kittiwake	-	-	-	1	-	-	-	-	80	1	250	-	-	-	-	-	2
Sabine's Gull	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	5
Arctic Tern	3	20	10	9	12	4	7	3	1	-	3	-	6	-	-	37	111
Unid. Murre	-	1	-	-	-	-	-	-	-	-	600	-	-	-	-	-	1

Table 17. Number of birds observed during aerial survey on June 1, 1978, wouthern Kotzebue Sound, Alaska. (Cont.)

	Number Observed in Each Area[1]																
Species	A	B	C	D	E	F	G	H	I[2]	J	K[2]	L	M	N	O	P	Total[2]
Common Raven	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1
Lapland Longspur	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unid. Bird	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	136	71	242	91	1044	15	78	27	89	6	857	41	392	12	72	335	2562
No. Birds Per Linear Km.	10.6	2.7	39.7	9.7	30.9	1.0	8.3	1.4	9.5	0.6	55.3	8.7	27.6	1.5	2.3	15.0	11.5

[1]See Figs. 4 and 5 for location of areas.

[2]Areas I and K not included in total because they were not included in subsequent surveys.

Table 18. Number of birds observed during aerial survey on July 9, 1978, southern Kotzebue Sound, Alaska.

	Number Observed in Each Area[1]																
Species	A	B	C	D	E	F	G	H	I[2]	J	K[2]	L	M	N	O	P	Total[2]
Unid. Loon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yellow-billed Loon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arctic Loon	-	-	-	-	-	-	2	2	-	-	-	-	-	-	-	1	5
Red-throated Loon	-	6	2	1	-	-	4	1	-	1	-	-	-	-	3	4	22
Unid. Waterfowl	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Whistling Swan	-	20	-	-	1	-	3	-	-	-	-	-	-	-	-	3	27
Unid. Goose	-	2	-	-	-	-	6	-	-	-	-	-	-	-	-	-	8
Canada Goose	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	2
Black Brant	1	48	7	8	95	-	-	-	-	-	-	-	-	-	-	-	159
Emperor Goose	1	-	-	-	21	-	-	-	-	-	-	-	-	-	-	-	22
Unid. Duck	14	14	21	150	53	12	16	6	-	-	-	-	-	-	5	44	335
Mallard	-	-	-	-	-	-	-	-	-	5	-	-	2	-	-	-	5
Pintail	21	-	12	-	560	-	5	-	-	-	-	-	-	-	-	28	628
Unid. Teal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
American Widgeon	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	2
Northern Shoveler	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Canvasback	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unid. Scaup	-	1	-	100	-	-	-	-	-	-	-	-	15	-	-	-	116
Oldsquaw	5	21	10	-	4	1	13	-	-	1	-	-	-	-	-	1	56
Unid. Eider	189	83	199	11	163	40	-	48	-	-	-	-	-	-	70	5	808
Unid. Scoter	-	-	-	-	-	-	4	2	-	3	-	-	-	-	1000	-	1009
Red-breasted Merganser	-	32	14	70	48	1	2	59	-	-	-	-	-	-	44	9	279
Unid. Hawk	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Marsh Hawk	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	2
Golden Eagle	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unid. Ptarmigan	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sandhill Crane	-	2	2	2	5	-	-	-	-	-	-	-	-	-	-	3	14
Unid. Shorebird	30	4	-	-	132	-	17	-	-	-	-	-	1	-	1	31	216
Unid. Small Shorebird	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unid. Medium Shorebird	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unid. Large Shorebird	-	-	-	-	21	-	2	-	-	-	-	-	1	-	-	52	76
Unid. Turnstone	2	7	-	-	7	-	-	1	-	-	-	-	-	-	-	2	19
Whimbrel	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dunlin	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Red Phalarope	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Northern Phalarope	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unid. Jaeger	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Parasitic Jaeger	-	1	-	-	3	-	-	-	-	-	-	-	1	-	-	-	5
Unid. Larid	-	-	-	18	92	5	-	16	5	39	175	-	1	3	4	7	185
Glaucous Gull	82	31	352	52	290	79	27	158	12	10	49	5	39	32	139	49	1345
Mew Gull	-	-	1	-	5	-	-	1	-	-	-	-	15	-	-	1	23
Unid. Kittiwake	-	-	-	105	-	2	-	16	62	29	489	16	18	17	31	2	236
Sabine's Gull	3	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	5
Arctic Tern	27	37	13	9	99	12	57	19	-	1	-	-	50	6	21	17	368
Unid. Murre	-	-	-	-	-	-	-	-	2550	-	4396	-	-	-	-	-	-

Table 18. Number of birds observed during aerial survey on July 9, 1978, southern Kotzebue Sound, Alaska. (Cont.)

	Number Observed in Each Area[1]																
Species	A	B	C	D	E	F	G	H	I[2]	J	K[2]	L	M	N	O	P	Total[2]
Common Raven	-	-	-	-	-	-	-	-	-	7	-	-	2	-	-	-	9
Lapland Longspur	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unid. Bird	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	375	309	633	526	1601	152	163	329	2629	96	5109	21	145	58	1318	260	5986
No. Birds Per Linear Km.	29.3	11.8	103.8	56.0	47.4	10.3	17.3	17.4	279.7	9.5	329.6	4.5	10.2	7.2	42.5	11.7	27.0

[1]See Figs. 4 and 5 for location of areas.

[2]Areas I and K not included in total because they were not included in subsequent surveys.

Table 19. Summary of aerial survey data, southern Kotzebue Sound, Alaska, 1977. Areas I and K (Figs. 4 and 5) are excluded from this table because they were not covered during every survey.

	Number Observed During Each Survey					
Species	June 3	July 15	August 1	August 15	September 1	September 15
Loons	21	33	42	32	10	9
Unid. Waterfowl	110	264	545	418	10	832
Swans	5	14	-	2	13	14
Geese	89	61	113	834	2867	1465
Ducks	2867	2234	4271	1928	3555	3251
Accipiters	2	-	-	-	1	1
Ptarmigan	4	-	-	-	-	-
Cranes	7	25	34	6	120	88
Shorebirds	581	381	585	898	9905	2117
Jaegers	-	-	-	5	1	-
Larids	295	1374	1585	1742	1924	1780
Alcids	-	7	1	14	15	-
Passerines	-	5	12	-	1	1
Unid. Birds	1	10	1	30	3	18
TOTAL	3982	4408	7189	5909	18425	9576
No. Birds Per Linear Km.	18.0	19.9	32.4	26.6	83.0	43.2

Table 20. Summary of aerial survey data, southern Kotzebue Sound, Alaska, 1978. Areas I and K (Figs. 4 and 5) are excluded from this table because they were not covered during every survey.

Species	Number Observed During Each Survey	
	June 1	July 9
Loons	13	27
Unid. Waterfowl	19	--
Swans	4	27
Geese	261	191
Ducks	1049	3238
Accipiters	1	2
Ptarmigan	--	--
Cranes	3	14
Shorebirds	744	311
Jaegers	24	5
Larids	442	2162
Alcids	1	--
Passerines	1	9
Unid. Birds	--	--
TOTAL	2562	5986
No. Birds Per Linear Km.	11.5	27.0

Avian Production

We were attracted to Cape Espenberg because it was thought to support large concentrations of breeding waterbirds (Kessel and Gibson 1974). We were not disappointed. Compared to nearby coastal areas (Table 21), the Cape supported very high densities of loons, Oldsquaws, Common Eiders, Sandhill Cranes, Northern Phalaropes, Parasitic Jaegers, and Glaucous Gulls. On our aerial surveys along southern Kotzebue Sound, we saw no areas with marsh habitat comparable to Cape Espenberg. We therefore conclude that the Cape has atypically high nesting densities for this area.

Our estimates of nesting density, nesting success, and clutch size are based primarily upon data collected from six nesting plots. Two shorebird plots (each 25 ha) were searched intensively for all nesting birds. Approximately 90% of the nests in these plots were located. Two waterfowl plots (each 1.0 km^2) were searched for loon, waterfowl, and gull nests, but other nests were recorded when found. About 80% of the nests of the large birds were found. Additional data came from the dune plot and the eider island. The numbers of nests of each species found in these plots are given in Tables 22 through 24. Nests outside the study plots were recorded when found and nest fate monitored whenever possible.

Production data recorded at nests included 1) number of eggs present, 2) condition of eggs, including state of incubation as determined by the flotation method (Westerskov 1950), or whether destroyed or deserted, and 3) number of egg shells with inner membranes separated (indicating a successfully hatched egg, Mickelson 1975). Some nests which were deserted were probably destroyed by predators before we rechecked them.

Production data are presented in Tables 25 through 31. The following results and discussions on production are organized by species or species group.

Loons

Yellow-billed, Arctic, and Red-throated loons nested on Cape Espenberg. In 1976 no Yellow-billed Loon nests were found, but three pairs occupied three different portions of the Cape and two nest scrapes were found. Two broods were seen in 1977 and two nests were found in 1978.

Nesting data for Arctic Loons from 1976 are extremely poor. These birds were present, nested, and at least several broods were seen. In 1977, we counted 12 broods (including 10 single-chick broods and 2 broods of 2 chicks) during a foot survey of the Cape in late July/early August. Assuming a 30% nesting success rate (Table 27), we suspect that at least 36 nests were initiated that year.

Red-throated Loons were very abundant on the Cape, compared with other study sites listed in Table 21. During the late July foot survey mentioned above, 62 Red-throated Loon families were counted (including 37 single-chick broods and 25 two-chick broods). Assuming a 30% nesting success rate, we suspect that at least 174 nests were initiated in 1977.

Table 21. Nesting densities of selected bird species at Cape Espenberg in 1976 and 1977 in comparison with adjacent areas.

Species	Estimated Nesting Density (Nests/km^2) at: Cape Espenberg (66°N)[1] 1976	Cape Espenberg (66°N)[1] 1977	Prudhoe Bay (70°N)[2]	Barrow (71°N)[3]	Shishmaref (66°N)[4]	Norton Bay (64°N)[5]	Yukon-Kusk. Delta (61°N)[6]
Arctic Loon	1	1.6	0.8	-	-	4	4.9
Red-throated Loon	6	8	0.4	-	-	2	0.3
Black Brant	0.1	0.2	-	-	-	-	2.8-1650
Emperor Goose	1	1	-	-	-	-	1.3-27
Pintail	0.1	2-28	-	-	10	0.1	-
Green-winged Teal	0.2	0.1	-	-	10	-	-
Oldsquaw	4-80	10-128	-	2	-	0.1	
Common Eider	50-130	60-120	-	-	-	0.1	-
Spectacled Eider	0.5	0.8	-	-	-	-	2.8-6.8
Willow Ptarmigan	1	1	-	-	10	-	-
Sandhill Crane	0.8	0.9	-	-	-	1-2	0.36-0.74
Dunlin	16-20	16	5	15;21	30	10-20	75
Semipalmated Sandpiper	8-60	8-88	37	12	30	61-85	-
Western Sandpiper	4-60	4-60	-	-	20	8-20	240-350
Long-billed Dowitcher	4	4-8	-	-	10	-	-
Red Phalarope	0-72	4-64	22-37	24-44	-	-	-
Northern Phalarope	32-104	24-100	4-6	-	39	30-35	-
Parasitic Jaeger	0.8	0.8	-	0.03-0.04	-	0.05-0.1	0.29
Glaucous Gull	11	14-16	-	-	-	1	5.9
Sabine's Gull	0-44	0-56	-	-	-	0.05	-
Arctic Tern	0-108	0-132	-	-	-	8-10	-
Redpoll sp.	0.1	-	-	-	30	0.6	-
Savannah Sparrow	0-4	0-4	-	-	-	25-30	-
Lapland Longspur	12-24	24-48	7-8	30	20	16-20	-

[1]This study, range of densities represents varying densities for different habitats.

[2]Norton et al 1975; Bergman and Derksen 1977.

[3]Holmes 1966, Maher 1974, Schamel and Tracy 1977, Myers (pers. comm.).

[4]Noble and Wright 1977.

[5]Shields and Peyton 1978.

[6]Holmes 1970, 1971, Dau 1974, Mickelson 1975 and unpublished data, Eisenhauer 1976, Strang 1976, C. Boise (pers. comm.)

Table 22 . Nests located in waterfowl nesting plots 1976-1977, Cape Espenberg, Alaska (Plot 1 ≅ 1.0 km^2, Plot 2 ≈ 1.0 km^2 in 1976 and 0.83 km^2 in 1977, Plot 3 ≈ 0.001 km^2).

	Number of Nests					
	Plot 1		Plot 2		Plot 3	
Species	1976	1977	1976	1977	1976	1977
Arctic Loon	0	0	1	2	1	0
Red-throated Loon	13	22	10	7	0	0
Loon sp.	0	1	0	0	0	0
Black Brant	1	3	0	0	0	0
Emperor Goose	3	1	1	4	0	0
Pintail	0	2	0	1	0	0
Greater Scaup	1	2	0	5	0	0
Oldsquaw	3	5	0	0	1	6
Common Eider	90	111	52	100	272	323
King Eider	0	2	0	0	0	0
Spectacled Eider	1	1	0	0	0	0
*Willow Ptarmigan	-	0	-	0	0	0
*Sandhill Crane	0	0	1	2	0	0
*Dunlin	2	6	4	3	0	0
*Semipalmated Sandpiper	6	4	1	2	0	0
*Western Sandpiper	-	13	-	2	0	0
*Long-billed Dowitcher	-	0	1	0	0	0
*Red Phalarope	5	3	1	4	0	0
*Northern Phalarope	1	1	4	5	0	0
Parasitic Jaeger	1	1	0	1	0	0
Glaucous Gull	35	27	41	62	2	3
Sabine's Gull	3	0	0	0	0	0
*Arctic Tern	2	5	4	6	17	20
*Savannah Sparrow	-	0	-	0	0	0
*Lapland Longspur	-	1	-	1	0	0
Total	167	211	121	207	293	352

* Very minimum figures, as waterfowl plots were not intensively searched for ptarmigan, crane, shorebird or passerine nests.

Table 23. Nests located in shorebird nesting plots (each 0.25 km^2), Cape Espenberg, Alaska, 1976 and 1977.

	Number of Nests			
	Marsh Plot		Mixed Habitat Plot	
Species	1976	1977	1976	1977
Arctic Loon	1	2	1	0
Red-throated Loon	5	6	1	2
Emperor Goose	1	0	0	0
Pintail	0	7	0	4
Greater Scaup	4	0	1	0
Oldsquaw	21	32	1	5
Common Eider	34	27	13	17
King Eider	1	2	0	0
Spectacled Eider	1	1	0	0
Willow Ptarmigan	0	1	1	0
Sandhill Crane	1	0	0	0
Black Turnstone	1	1	0	0
American Golden Plover	0	1	0	0
Pectoral Sandpiper	0	1	0	0
Dunlin	5	4	4	4
Semipalmated Sandpiper	15	22	2	2
Western Sandpiper	15	15	1	1
Long-billed Dowitcher	1	2	1	1
Red Phalarope	18	16	0	1
Northern Phalarope	26	25	8	6
Parasitic Jaeger	0	0	0	1
Glaucous Gull	0	0	1	1
Sabine's Gull	11	14	0	0
Arctic Tern	27	33	0	0
Savannah Sparrow	0	1	1	0
Lapland Longspur	6	12	3	6
Total	194	225	40	51

Table 24. Nests located in dune nesting plot (0.082 km^2), Cape Espenberg, Alaska, 1977.

Species	Number of Nests[a]
Pintail	1
Common Eider	1
Ruddy Turnstone	1
Semipalmated Sandpiper	6
Lapland Longspur	8
Total	17

[a] This plot was searched only on 7 and 8 June, so the figures do not give a nesting density for the entire summer.

Table 25. Mean clutch size for birds on Cape Espenberg, Alaska, 1976 and 1977.

	Mean Clutch Size			
	1976		1977	
Species	Initial (No.)	Hatched (No.)	Initial (No.)	Hatched (No.)
Arctic Loon	1.50 (2)	-	2.00 (3)	1.00 (1)
Red-throated Loon	2.00 (6)	2.00 (2)	1.70 (33)	1.56 (9)
Canada Goose	6.00 (1)	6.00 (1)	-	-
Black Brant	5.00 (1)	-	3.00 (3)	-
Emperor Goose	4.30 (10)	3.33 (6)	5.12 (8)	3.75 (4)
Pintail	-	-	5.33 (3)	-
Green-winged Teal	6.00 (1)	-	-	-
Greater Scaup	7.10 (7)	5.00 (2)	8.00 (5)	4.50 (2)
Oldsquaw	6.05 (20)	4.86 (7)	6.44 (9)	3.00 (1)
Common Eider	5.26 (381)	3.46 (298)	5.42 (494)	3.18 (297)
King Eider	1.00 (1)	-	-	-
Spectacled Eider	3.66 (3)	4.50 (2)	-	-
Willow Ptarmigan	10.67 (3)	9.75 (4)	-	-
Sandhill Crane	2.00 (2)	2.00 (2)	2.00 (8)	2.00 (4)
American Golden Plover	-	-	4.00 (1)	0 (0)
Black-bellied Plover	-	-	4.00 (1)	?
Ruddy Turnstone	3.50 (4)	3.00 (1)	4.00 (2)	4.00 (1)
Black Turnstone	3.00 (1)	-	4.00 (1)	-
Pectoral Sandpiper	-	-	3.33 (3)	3.00 (2)
Dunlin	4.00 (16)	4.00 (14)	3.90 (20)	3.90 (10)
Semipalmated Sandpiper	3.91 (22)	3.86 (14)	3.70 (32)	3.60 (15)
Western Sandpiper	3.17 (24)	3.00 (9)	3.70 (33)	3.95 (17)
Long-billed Dowitcher	3.67 (3)	3.67 (3)	3.67 (3)	4.00 (1)
Red Phalarope	3.41 (26)	3.26 (19)	3.88 (24)	3.60 (15)
Northern Phalarope	3.61 (43)	3.76 (25)	3.92 (37)	3.83 (23)
Parasitic Jaeger	1.77 (13)	1.33 (3)	2.00 (14)	2.00 (10)
Glaucous Gull	2.68 (100)	2.47 (48)	2.61 (62)	2.43 (14)
Sabine's Gull	2.00 (11)	2.00 (11)	2.72 (14)	1.89 (9)
Arctic Tern	1.94 (32)	1.94 (27)	1.89 (37)	1.68 (19)
Savannah Sparrow	4.00 (2)	3.50 (2)	-	7.00 (1)
Lapland Longspur	4.62 (8)	3.67 (12)	5.33 (24)	4.55 (9)

Table 26. Nest fate for birds on Cape Espenberg, Alaska, 1976.

Species	Total Nests[1]	Nest fate: % Success	Nest fate: % lost to Predators	Nest fate: % Abandoned
Arctic Loon	2	-	100	-
Red-throated Loon	6	17	83	-
Canada Goose	1	100	-	-
Black Brant	1	-	100	-
Emperor Goose	7	100	-	-
Pintail	-	-	-	-
Green-winged Teal	1	-	100	-
Greater Scaup	8	25	62	13
Oldsquaw	26	31	69	-
Common Eider	459	65	32	3
King Eider	1	-	-	100
Spectacled Eider	2	100	-	-
Willow Ptarmigan	3	100	-	-
Sandhill Crane	4	50	25	25
American Golden Plover	-	-	-	-
Black-bellied Plover	-	-	-	-
Ruddy Turnstone	1	100	-	-
Black Trunstone	1	-	100	-
Pectoral Sandpiper	-	-	-	-
Dunlin	14	100	-	-
Semipalmated Sdp	17	82	12	6
Western Sandpiper	17	53	23	23
Long-billed Dowitcher	3	100	-	-
Red Phalarope	26	73	15	12
Northern Phalarope	33	76	18	6
Parasitic Jaeger	4	100	-	-
Glaucous Gull	63	76	24	-
Sabine's Gull	11	91	9	-
Arctic Tern	32	84	9	6
Savannah Sparrow[2]	2	100	-	-
Lapland Longspur[2]	10	70	30	-

[1]Total nests for which the fate was known.

[2]Fate determined through departure of chicks from nest.

Table 27. Nest fate for birds on Cape Espenberg, Alaska, 1977.

Species	Total Nests[1]	Nest fate		
		% Success	% lost to Predators	% Abandoned
Arctic Loon	3	33	67	-
Red-throated Loon	32	28	72	-
Canada Goose	-	-	-	-
Black Brant	3	-	100	-
Emperor Goose	11	82	18	-
Pintail	19	-	100	-
Green-winged Teal	-	-	-	-
Greater Scaup	8	38	62	-
Oldsquaw	46	7	91	2
Common Eider	429	56	43	1
King Eider	4	25	75	-
Spectacled Eider	2	50	50	-
Willow Ptarmigan	-	-	-	-
Sandhill Crane	3	67	33	-
American Golden Plover	1	-	100	-
Black-bellied Plover	1	100	-	-
Ruddy Turnstone	1	100	-	-
Black Turnstone	1	-	100	-
Pectoral Sandpiper	2	100	-	-
Dunlin	12	83	17	-
Semipalmated Sdp	26	58	42	-
Western Sandpiper	24	71	21	8
Long-billed Dowitcher	1	100	-	-
Red Phalarope	20	75	20	5
Northern Phalarope	27	89	7	4
Parasitic Jaeger	16	88	12	-
Glaucous Gull	68	75	21	4
Sabine's Gull	14	64	36	-
Arctic Tern	27	70	26	4
Savannah Sparrow[2]	1	100	-	-
Lapland Longspur[2]	21	48	52	-

[1]Total nests for which the fate was known.

[2]Fate determined through departure of chicks from nest.

Table 28. Estimated nesting success for selected bird species at Cape Espenberg in 1976 and 1977 compared with adjacent areas.

Species	Estimated Nesting Success (%) at: Cape Espenberg (66° N)[1] '76	'77	Barrow (71° N)[2]	Prudhoe Bay (70° N)[3]	Cape Sabine (67° N)[4]	Norton Bay (64° N)[4]	Yukon-Kusk. delta (61° N)[6]
Arctic Loon	-	33	-	28-92	-	25-59	-
Red-throated Loon	17	28	-	33-78	-	0-25	33-75
Emperor Goose	100	82	-	-	-	-	66-100
King Eider	-	25	-	0-15	-	-	-
Spectacled Eider	100	50	-	-	-	-	50-90
Dunlin	100	83	77-94;72	50	-	50-100	-
Semipalmated Sdp.	82	58	73	52-84	-	88-94	-
Western Sdp.	53	71	-	-	-	50-75	72-92
Red Phalarope	73	75	47-73;50	31-83	-	-	-
Parasitic Jaeger	100	88	0	0-100	50-75	-	-
Glaucous Gull	76	75	-	-	-	50-100	73-88
Lapland Longspur	70	48	63	60	-	70	-

[1]This study; [2]Maher 1974, Norton et al. 1975, Schamel (unpubl.); [3]Norton et al. 1975, Bergman et al. 1977; [4]Maher 1974; [5]Shields and Peyton 1978; [6]Holmes 1972, Dau 1974, Mickelson 1975, Eisenhauer 1976, Petersen 1976.

Table 29. Fate of Common Eider Nests, Cape Espenberg, Alaska.

Location	Percent of Nests for Which Fate is Known						No. Nests Fate Known		No. Nests Fate Unknown		Total No. Nests	
	Hatched		Lost to Predators		Abandoned							
	1976	1977	1976	1977	1976	1977	1976	1977	1976	1977	1976	1977
Shorebird Marsh Plot	15	0	82	96	3	4	34	27	0	0	34	27
Shorebird Mixed Habitat Plot	8	12	92	88	0	0	13	17	0	0	13	17
Other	21	29	79	65	0	6	29	17	2	5	31	22
Waterfowl Plot 1	58	23	42	75	0	2	64	107	26	4	90	111
Waterfowl Plot 2	52	52	44	48	4	0	52	94	7	5	59	99
Eider Colony (Island)	84	95	12	5[b]	4	-	268	167[a]	5	6	273	173[a]

[a]Sample of nests on island.

[b]Includes abandoned nests.

Table 30. Clutch size of Common Eiders, Cape Espenberg, Alaska.

Location	Incubated Clutch Size		Hatched Clutch Size	
	1976	1977	1976	1977
Shorebird Marsh Plot	3.62 (29[a]/8[b])	4.20 (21[a]/5[b])	3.00 (15[a]/5[b])	0.00 (0[a]/0[b])
Shorebird Mixed Plot	5.00 (15/3)	6.00 (6/1)	5.00 (5/1)	2.00 (4/2)
Other	4.16 (25/6)	5.25 (42/8)	2.80 (14/5)	4.33 (13/3)
Waterfowl Plot 1	4.33 (377/87)	4.20 (361/86)	3.21 (122/38)	3.96 (103/26)
Waterfowl Plot 2	4.12 (177/43)	4.45 (347/78)	3.44 (93/27)	2.90 (145/50)
Eider Colony (Island)	5.90 (1382/234)	6.02 (1902/316)	3.53 (783/222)	3.14 (679/216)
TOTAL	5.26 (2005/381)	5.42 (2679/494)	3.46 (1032/298)	3.18 (944/297)

[a]Total eggs.

[b]Total nests.

Table 31. Productivity of Common Eiders reported by other studies.

Investigator	Location	Clutch Size	Percent Successful Nests
Cooch (1965)	Cape Dorset, NWT	3.44 (1598[a])	-
Choate (1966)	Penobscot Bay, Maine	3.81 (345) 3.79 (272)	39.0 (201[a]) 35.9 (161)
Guignion (1967)	St. Lawrence Estuary	4.33 (315)	13 - 51.7 (45-30)
Bourget (1970)	Penobscot Bay, Maine	-	44.9 (196)
Schamel (1974)	Beaufort coast, Alaska	5.6 (10) 4.9 (14)	33 (39)

[a] Number of nests.

Their high nesting densities might be explained by the 1) abundance of small, shallow, fishless ponds which are unsuitable for nesting by the larger loons, and 2) proximity to marine waters for feeding.

Geese

In 1976 one pair of Canada Geese successfully hatched eggs and reared a brood on the Cape; in 1977 one pair of Canada Geese may have nested on the Cape. There were at least three Black Brant nests in 1977 with a mean incubated clutch size of 3.0 eggs (Table 25); all of these were found in Waterfowl Plot 1. As in 1976, none of the brant nests hatched (Table 27). The disappearance of the eggs roughly coincided with egging by neighboring Natives and may have been a result of their activities. The one known Black Brant nest in 1976 was taken by predators (Table 26).

Ten Emperor Goose nests were located in 1976, and 11 nests were located in 1977 on the Cape. However, a complete search of the Cape for Emperor nests was not made, so these are minimum numbers. Mean incubated clutch size was slightly higher in 1977 (Table 25). Mean hatched clutch size somewhat greater in 1977 (Table 25) although nesting success dropped from 100% in 1976 to 82% in 1977 (Tables 26 and 27).

Ducks

Although breeding Green-winged Teals were observed in 1976 and Pintails were not, the opposite was true for 1977. Mean incubated clutch size for three Pintail nests was 5.33 eggs in 1977. However, none of 19 Pintail nests found hatched in 1977 (Table 27).

The mean incubated clutch size of seven Greater Scaup nests was slightly greater in 1977, 8.00 eggs per clutch compared to 7.10 eggs per clutch in 1976 (Table 25). Greater Scaup had slightly higher hatching success in 1977 (38%) than in 1976 (25%) (Tables 26 and 27).

Mean incubated Oldsquaw clutch size was virtually the same for both years of the study (Table 25). Success was markedly reduced in 1977 with only 7% of the nests hatching one or more young (Table 27). In 1976, 31% of Oldsquaw nests were successful (Table 26).

Common Eider nests were not as successful in 1977 as in 1976. Only 56% of the nests were successful that year (Table 27). In 1976 65% hatched at least one young (Table 26). Subsistence use of eider eggs occurred only in 1977 and probably accounts at least in part for the lower proportion of successful nests in 1977. Success in the unharvested Waterfowl Plot 2 was about the same for both 1976 and 1977 (Table 29). Compared with 1976 the eider colony located on an island near Waterfowl Plot 2 was more successful in 1977 with approximately 95 percent of the nests hatching one or more ducklings (Table 29).

In all the study areas except Waterfowl Plot 1, mean incubated Common Eider clutch size was higher in 1977 (Table 30). However, mean hatched clutch size was consistently lower in all plots but Waterfowl Plot 1 and "Other" (Table 30).

Incubated clutch size of the Common Eider on Cape Espenberg is similar to Schamel's (1974) calculations but considerably higher than that reported by Cooch (1965), Choate (1966), Guignion (1967), and Bourget (1970) (Table 31). Likewise, the proportion of successful nests is among the highest of those reported by Choate (1966), Guignion (1967), Bourget (1970), and Schamel (1974) (Table 31). However, the high mean Common Eider nest success on the Cape was generally due to the extremely high success of the island eider colony, and success was much lower on other parts of the Cape (Table 29).

Four King Eider nests and two Spectacled Eider nests were found on Cape Espenberg in 1977. Only one King Eider and two spectacled Eider nests were found in 1976. One of the 1977 Spectacled Eider nests was successful (Table 27). The other was lost to predators (Table 27). Similarly, only one of the four 1977 King Eider nests hatched (Table 27). The 1976 King Eider nest was abandoned and consequently did not hatch (Table 26).

Ptarmigan

An estimated 20 pairs of Willow Ptarmigan nested on Cape Espenberg in both 1976 and 1977 (0.9 nests/km^2). This estimate is based upon nesting plot data (Table 23) and numbers of territorial males in early June. Observations of nests and broods are too few to warrant worthwhile estimates on production.

Cranes

We estimated that 18 pairs of Sandhill Cranes nested on Cape Espenberg in 1977 (0.90 nests/km^2). This estimate is based primarily upon finding 8 nests in the western half of the Cape in less than 8 hours of general observations. Nesting density in 1976 was probably quite similar. From reports from other parts of Alaska (Table 21), the breeding density of cranes on the Cape is surpassed only by densities at Norton Bay (1-2 nests/km^2) (Shields and Peyton 1978). Cranes are extremely sensitive to disturbances, especially during the laying and early incubation period. At this time, they frequently flush when an observer approaches to within 300 m of the nest site. While the birds are away from the nests, avian predators may take the eggs. At least two nests were lost to predators directly as a result of our activities. However, production was generally good. Nine different young in eight broods were counted in July and August 1976.

Shorebirds

In general, shorebird nesting densities at Cape Espenberg were similar to or greater than other areas of coastal arctic Alaska and the Seward Peninsula (Table 21). However, densities were apparently lower than Holmes (1970, 1971) found for some species along the Kolomak River on the Yukon-Kuskokwim delta (Table 21). Large intra-year variations in nesting density on the Cape correspond primarily to habitat differences. Densities were greatest in the "fine-grained mosaic" (MacLean 1973) of shallow water and narrow ridges in the marsh shorebird plot (see Table 23) and least in the mixed habitat plot, where marsh was much less extensive and more homogeneous. Inter-year variations in density were negligible for the first two summers. In contrast, maximum nesting densities of Western Sandpipers increased 100% from 1977 to 1978, while Northern Phalarope nesting densities increased 75%.

An inter-year variation of 10-14 days in nesting chronology may be anticipated for shorebirds at Cape Espenberg, depending upon local weather conditions from mid-May through early June. Shorebird nesting occurred 2-6 days earlier in 1977 than during the phenologically late summer of 1976 (Figs. 90 and 91). Nesting was slightly earlier in 1978 than it had been in 1977. The summer of 1978 was one of the phenologically earliest on record for much of Alaska's west coast.

Comparative information on shorebird nesting success in coastal northern and western Alaska is scant (Table 28). Some species, such as the Dunlin, are apparently remarkably consistent in their productivity (clutch size and nesting success). Semipalmated and Western Sandpipers, however, show inconsistencies. In 1976, Western Sandpipers had low clutch size and nesting success (Tables 25 and 26). Predation and abandonment of nests were high. Semipalmated Sandpipers, however, had good productivity that year. In 1977, however, the situation was reversed. To further complicate matters, both species had good productivity in 1978. Additional, intensive research on these two species may clarify our observations. At present, however, we cannot explain this phenomenon. In contrast, Holmes (1972) recorded a consistently high clutch size ($\bar{x}$=3.84) and nesting success (72-92%) for Kolomak River Western Sandpipers over three summers.

For other shorebirds, clutch sizes generally increased from 1976 to 1977, while nesting success showed no major differences. The overall high nesting success noted in 1978 is discussed in the section of this report pertaining to PREDATION.

Renesting (production of a second clutch of eggs following loss of the first clutch) was noted for Semipalmated Sandpipers, Western Sandpipers, Red Phalaropes, and Northern Phalaropes. Renesting appears to be most prevalent when nest destruction occurs early in the nesting period. The ability of most shorebirds to renest buffers the affect of early-season predation on shorebird productivity. It also increases nesting density figures slightly and elongates the nesting season.

To study return rates of adult and young birds, we banded a large number of shorebirds on our study areas (Table 32). Color-marked adults of all species, except Red Phalaropes, showed a strong tendency to return to the same nesting area (Table 33). Return rates of adult Dunlins (Soikkeli 1970), Western Sandpipers (Holmes 1971), and Northern Phalaropes (Hilden and Vuolanto 1972) reported by other workers correspond closely with our data on Espenberg birds. Although the return rate of Red Phalaropes was quite low, it matched figures for this species determined at Barrow, Alaska (Schamel and Tracy 1977). Minimum return rates for young birds also correspond well with figures presented by others for Dunlins (Soikkeli 1970) and Western Sandpipers (Holmes 1971). We cannot satisfactorily explain the low return of Western Sandpipers in 1977, except that this species had poor nesting success in 1976.

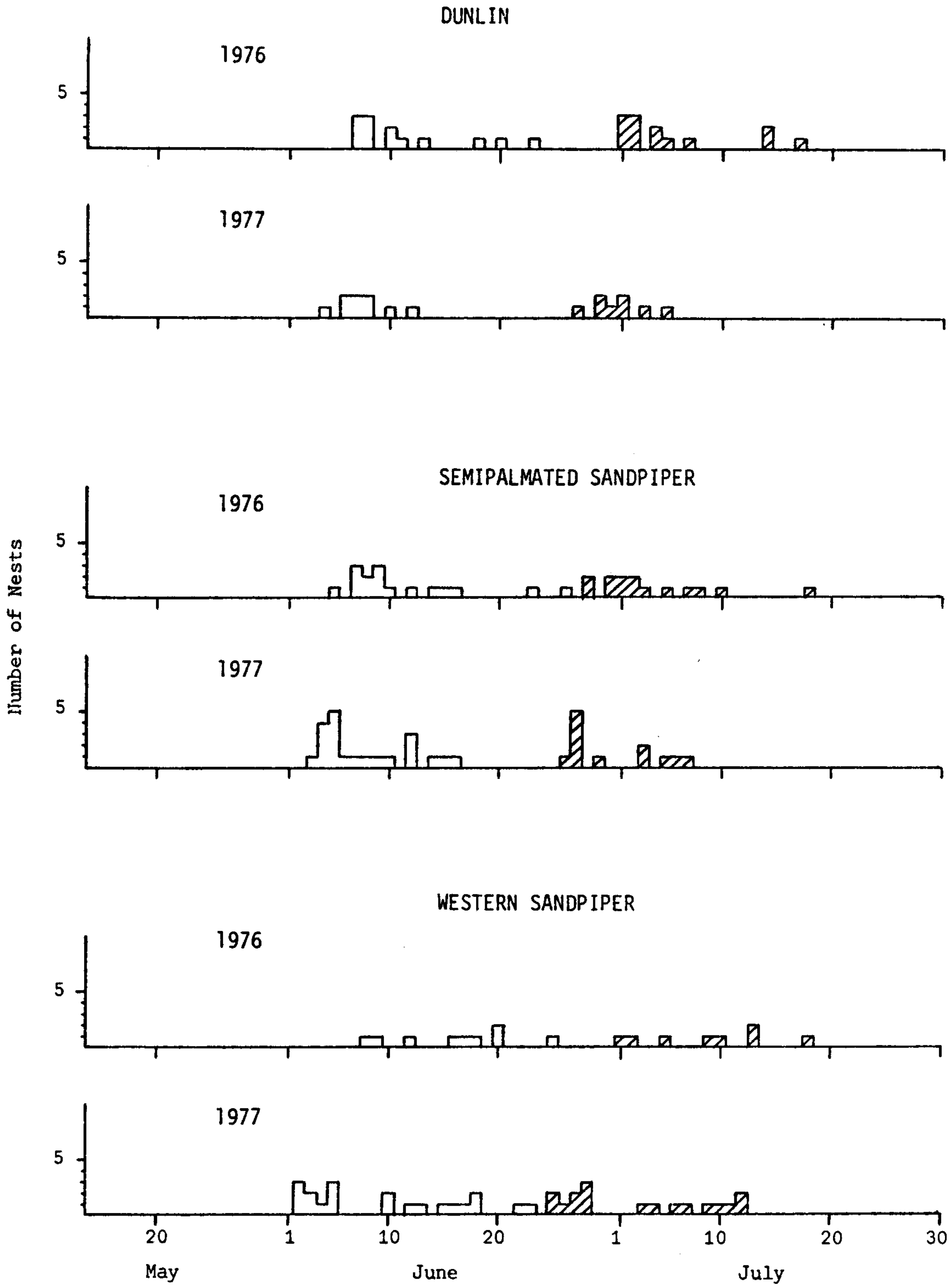

Figure 90. Nest initiation and hatching dates for Dunlins, Semipalmated Sandpipers, and Western Sandpipers, 1976-1977, Cape Espenberg, Alaska (unshaded = nest initiation, shaded = hatching).

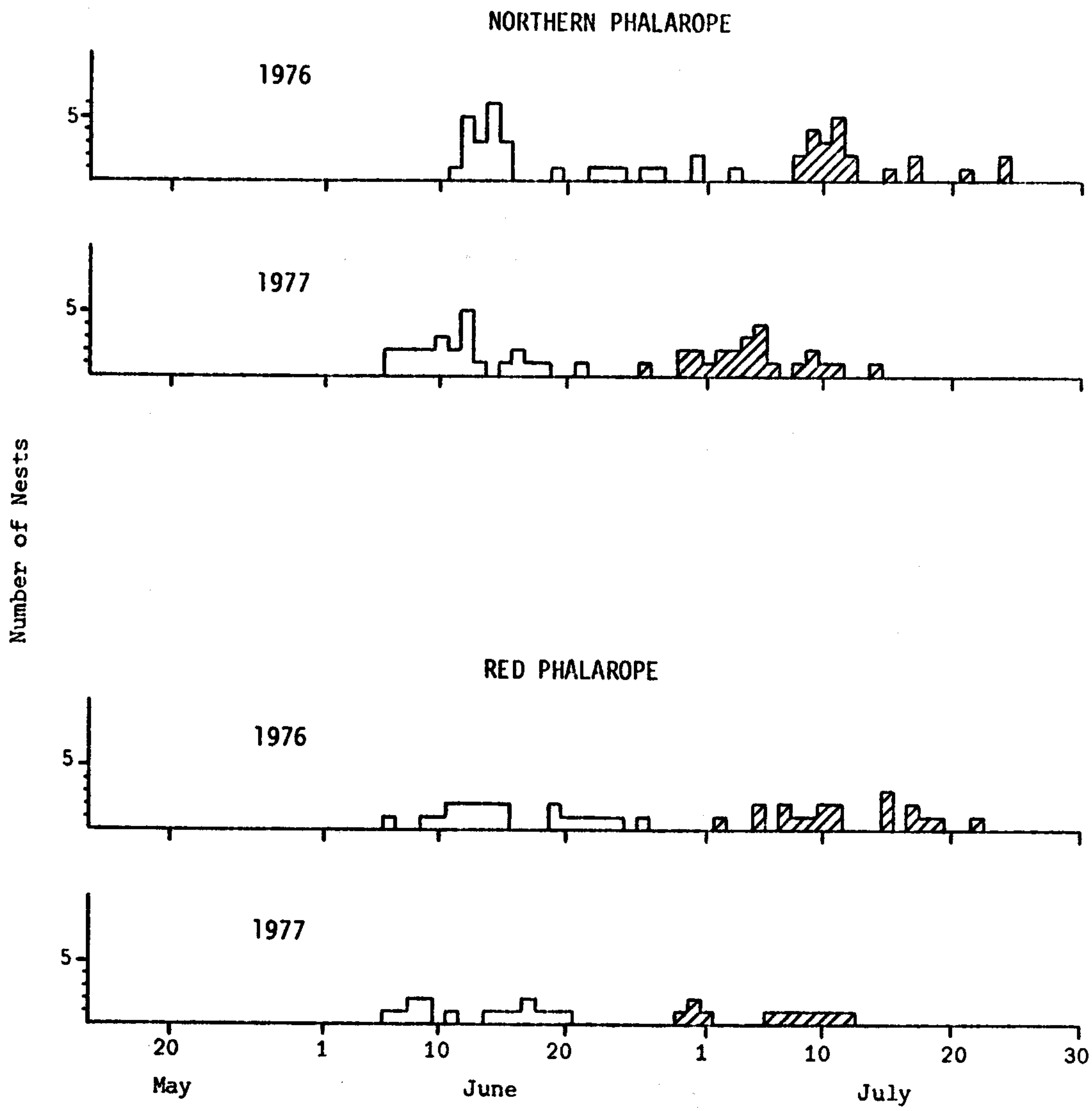

Figure 91. Nest initiation and hatching dates for Northern and Red Phalaropes, 1976-1977, Cape Espenberg, Alaska (unshaded = nest initiation, shaded = hatching).

Table 32. Numbers of birds banded at Cape Espenberg, Alaska, 1976 and 1977.

Species	Number Banded					
	1976			1977		
	Adults	Young	Total	Adults	Young	Total
Sandhill Crane	0	7	7	0	0	0
Ruddy Turnstone	6	2	8	1	0	1
Pectoral Sandpiper	0	0	0	0	2	2
Dunlin	28	64	92	15	32	47
Semipalmated Sandpiper	33	66	99	18	56	74
Western Sandpiper	26	50	76	39	61	100
Long-billed Dowitcher	0	7	7	0	1	1
Red Phalarope	29	53	82	20	34	54
Northern Phalarope	46	75	121	38	74	112
Parasitic Jaeger	24	1	25	0	8	8
Glaucous Gull	0	30	30	0	176	176
Sabine's Gull	0	13	13	0	19	19
Arctic Tern	5	45	50	0	36	36
Savannah Sparrow	0	0	0	0	4	4
Lapland Longspur	1	6	7	2	10	12
Total	198	418	616	133	513	646

Table 33. Banding and resighting records of adult and young color-marked shorebirds, Cape Espenberg, Alaska.

Species	1977 No. Return	1977 No. Possible[1]	1977 %	1978 No. Return	1978 No. Possible[1]	1978 %
Ruddy Turnstone, adults	3	6	50.0	1	4	25.0
young	-	2	-	-	-	-
Dunlin, adults	20	28	71.5	7	10	70.0
young	1	64	1.6	1	32	3.2
Semipalmated Sdp, adults	21	33	63.8	23	34	68.0
young	1	66	1.5	1	56	1.8
Western Sdp, adults	5	26	19.2	19	34	56.0
young	1	50	2.0	2	61	1.6
Red Phalarope, adults	4	29	14.0	2	20	10.0
young	-	53	-	-	34	-
Northern Phalarope, adults	16	43	37.2	26	46	57.0
young	3	75	4.0	2	74	2.7

[1]Number of banded birds on study area previous year.

Arctic Terns

Figure 92 presents the data on nesting phenology for Arctic Terns on the Cape. Nesting success of Arctic Terns during 1976 and 1977 (70-84%) (Tables 26 and 27) was considerably higher than figures reported for southern Finland (55-77%) (Lemmetyinen 1973) and for Spitsbergen (49-70%) (Bengtson 1971). Clutch sizes were comparable during both summers. No three-egg clutches were found in 1976; only one was found in 1977. In contrast, three-egg clutches were relatively common in 1978. In addition, only one nest was lost to predation in 1978 (see the section of this report dealing with predation). The slight increase in numbers of tern nests in the marsh plot from 1976 to 1977 probably represents renesting.

Weight gain in Arctic Tern chicks at Cape Espenberg (66.3° N) (Fig. 93) was comparable to that reported from the Finnish archipelago (60.6° N) (Lemmetyinen 1973). Arctic Tern chicks from Spitsbergen (78.9° N) gained weight at a slower rate (Lemmetyinen 1972).

Two additional growth parameters were measured: bill length and wing length (Figs. 94 and 95). Of the three measurements, wing length appears to have the least scatter of data points and may be the best single criterion for determining the age of tern chicks.

Six of 45 banded chicks (13.3%) were found dead on the study area. All had apparently died of starvation. Five of these chicks (83.3%) had been the second to hatch at a nest. The only first-hatched chick to succomb to starvation died 2 days following the death of its sibling. Five of the deaths occurred in the period 26 to 29 July, suggesting a temporary shortage of food. Age at death ranged from 5 to 11 days. Lemmetyinen (1972) found that second-hatched chicks died before their older sibling. Bengtson (1971) reported that most mortality in tern chicks occurred in their first week.

At least some tern chicks were eaten by foxes and Glaucous Gulls (see predation section). Both Lemmetyinen (1972) and Bengtson (1971) surmised that losses to predation were unimportant on Spitsbergen.

Tern chicks on the Cape were able to fly by 22-23 days. One chick was probably flying at age 19 days. According to Witherby et al. (1944), Arctic Terns fly at about 3 weeks of age.

Sabine's Gulls

Nesting success of Sabine's Gulls during the two summers of the contract period ranged from 64% to 91% (Tables 26 and 27). All nests were successful in 1978. Initial clutches in 1977 were considerably larger than those in 1976 (Table 25). Three-egg clutches were rare in 1976, but common thereafter. Nesting density was relatively constant in each year. The slight increase in nests in 1977 is probably due to renesting attempts.

Growth rate data are presented in Figures 96, 97 and 98. As found with tern chicks, wing length may be the best single criterion for age determination.

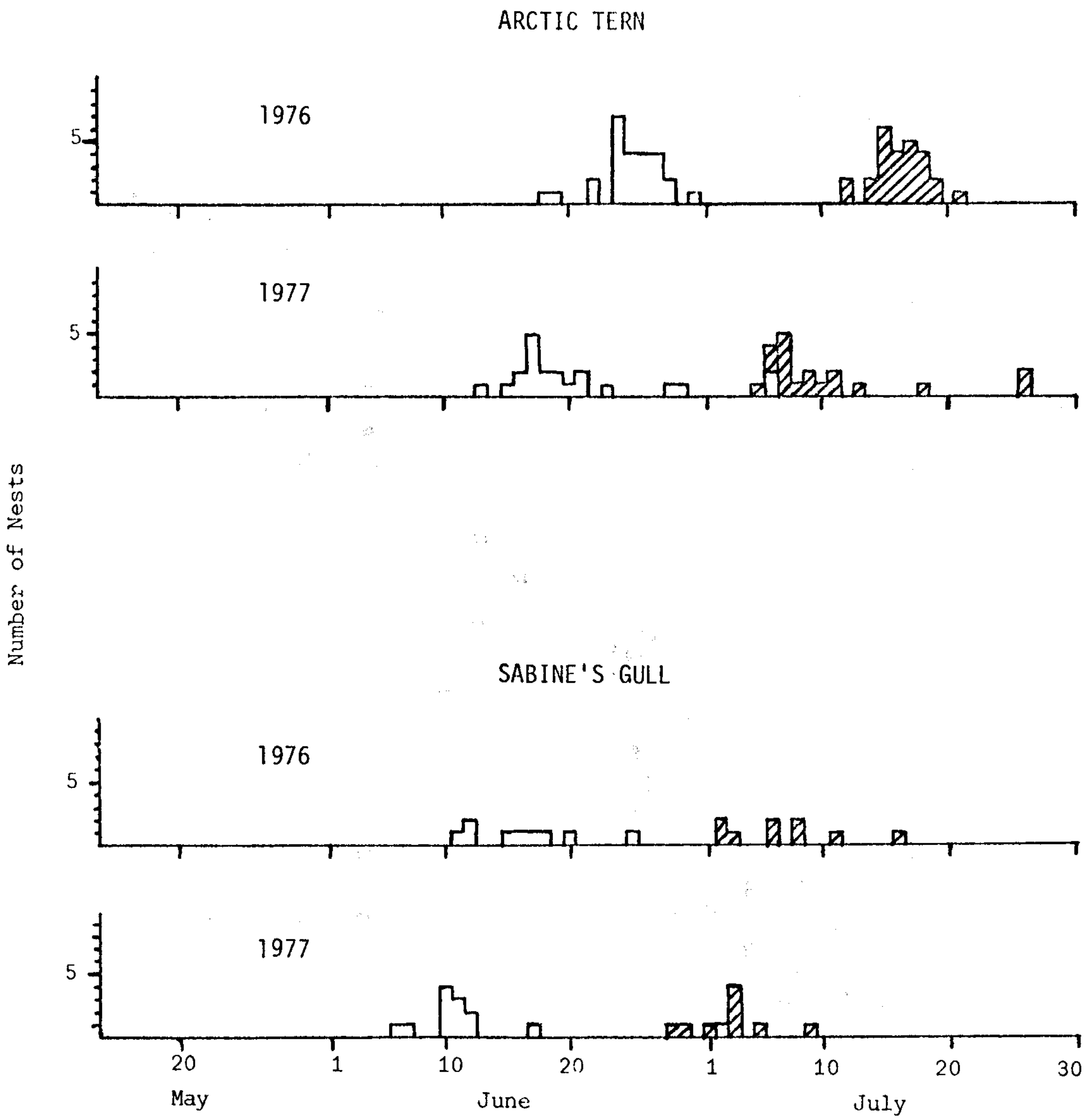

Figure 92. Nest initiation and hatching dates for Arctic Terns and Sabine's Gulls, 1976-1977, Cape Espenberg, Alaska (unshaded = nest initiation, shaded = hatching).

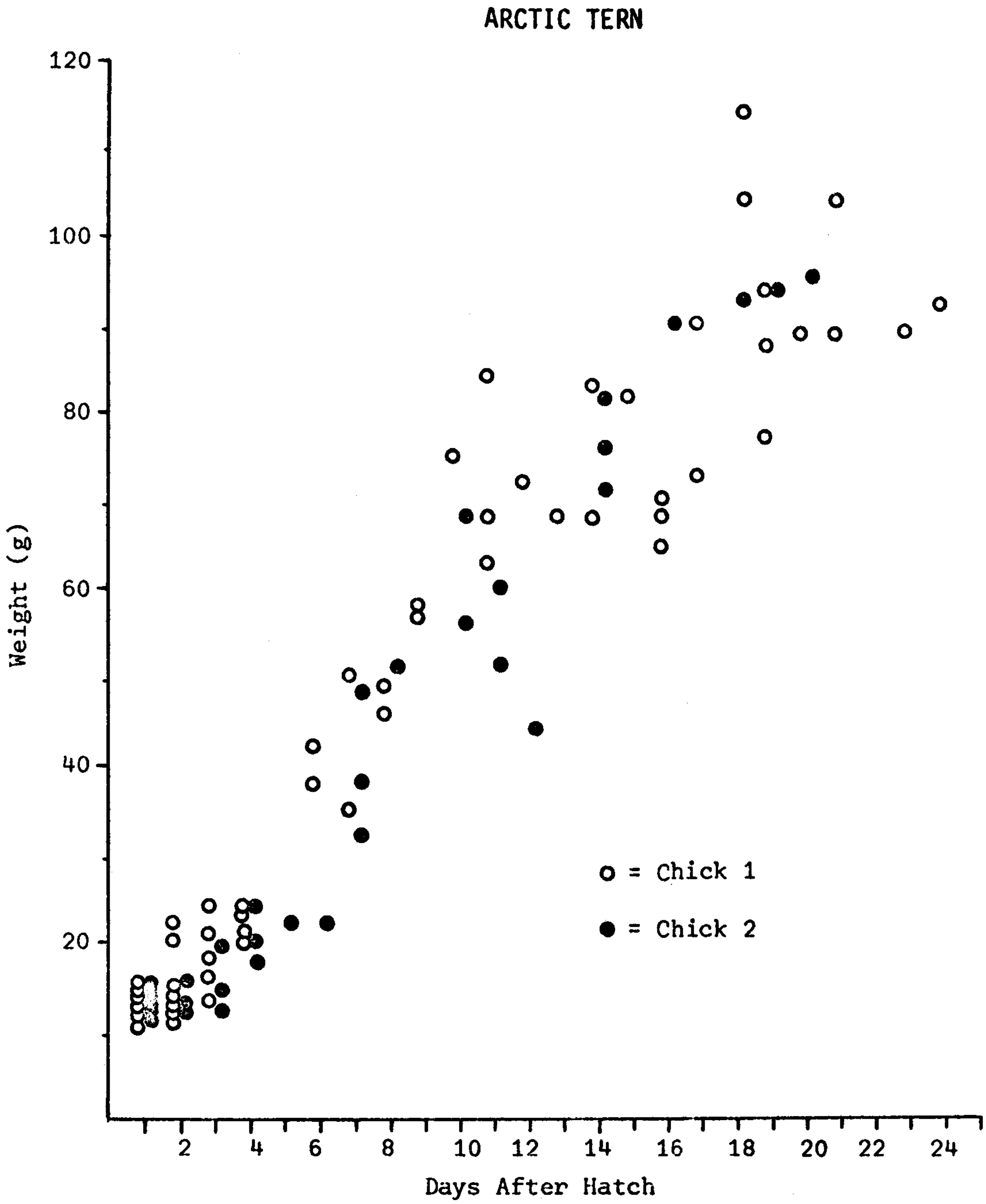

Figure 93. Weight change of Arctic Tern chicks, 1976, Cape Espenberg, Alaska.

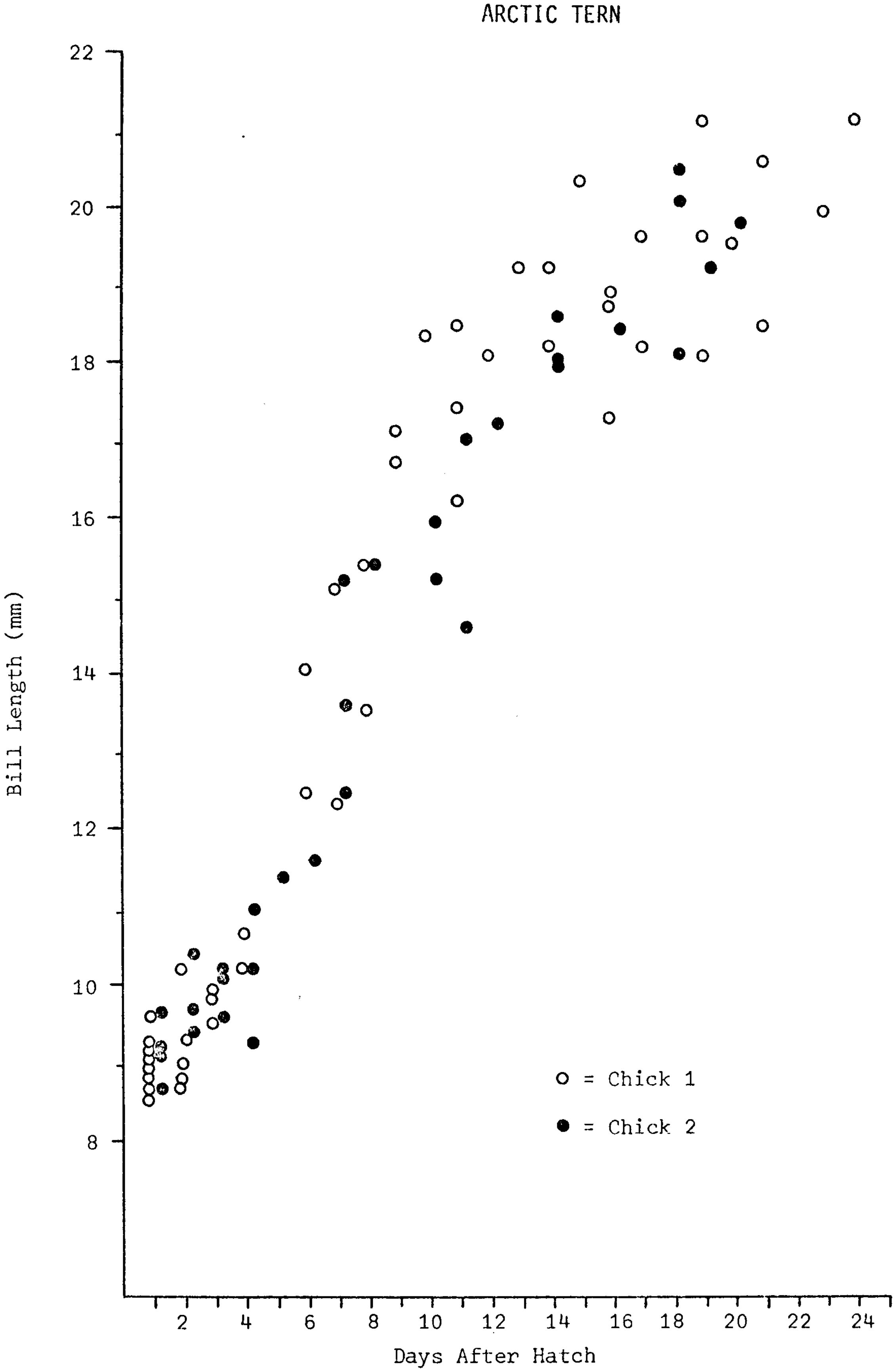

Figure 94. Bill growth of Arctic Tern chicks, 1976, Cape Espenberg, Alaska.

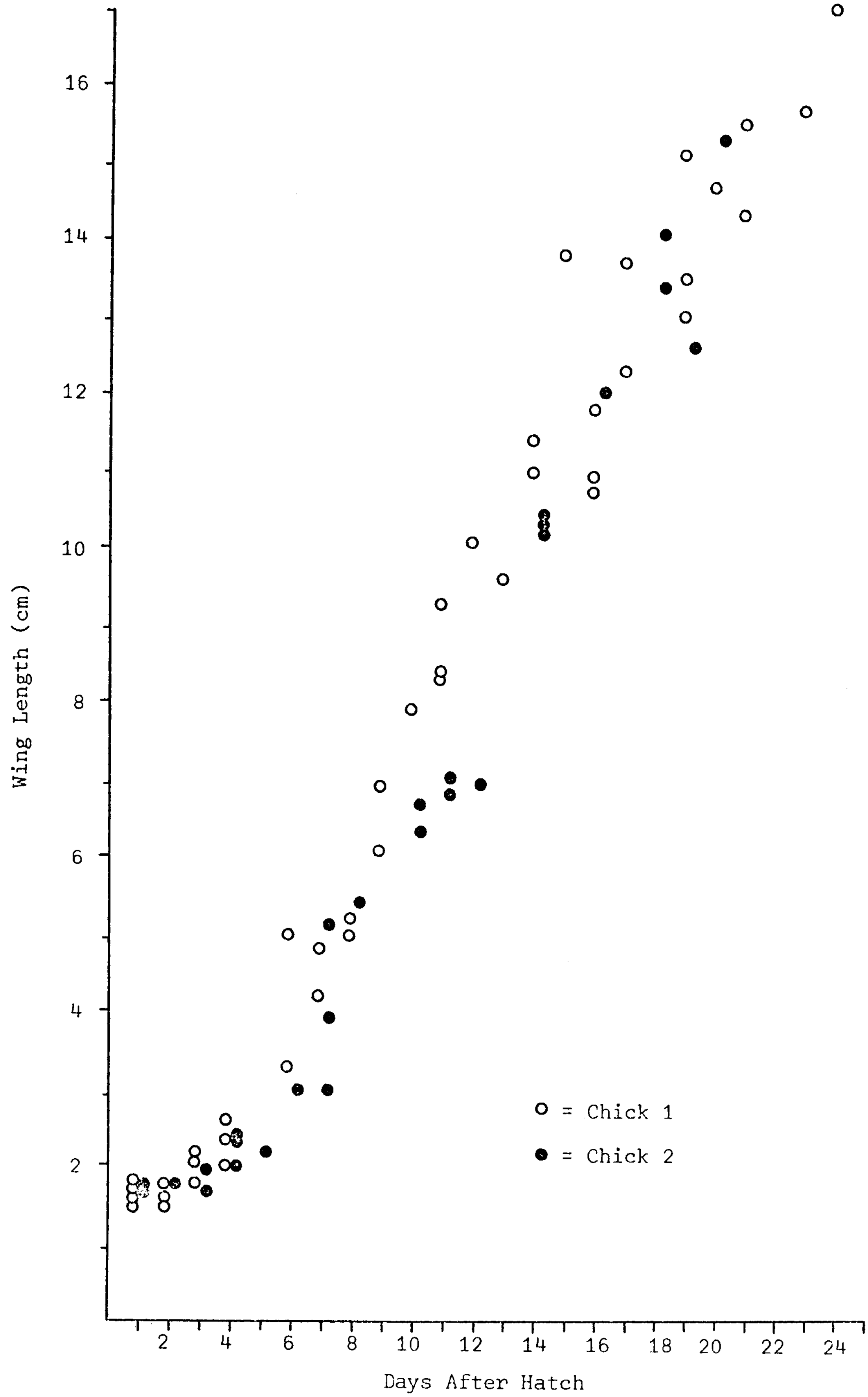

Figure 95. Wing growth of Arctic Tern chicks, 1976, Cape Espenberg, Alaska.

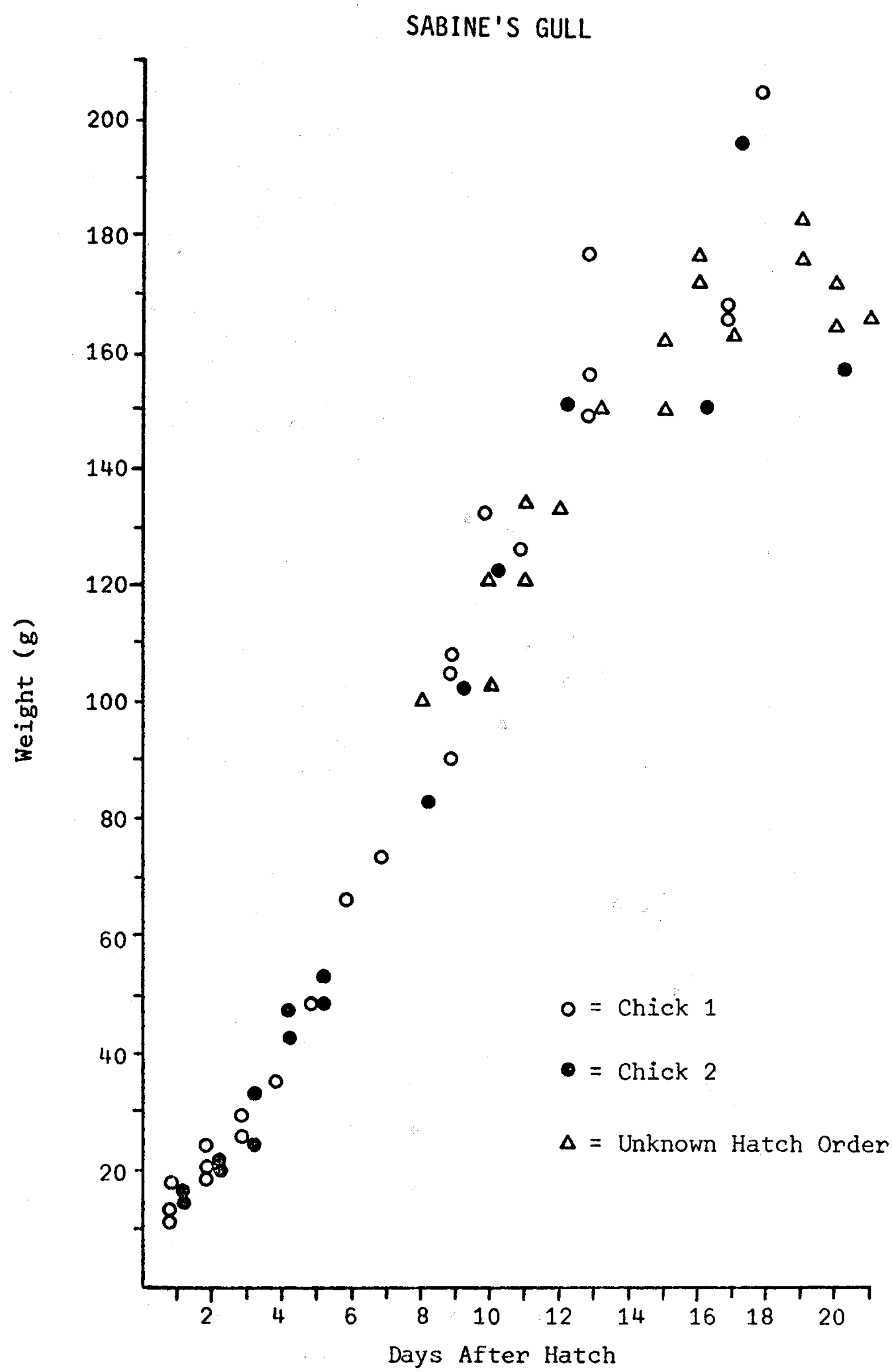

Figure 96. **Weight change of Sabine's Gull chicks, 1976, Cape Espenberg, Alaska.**

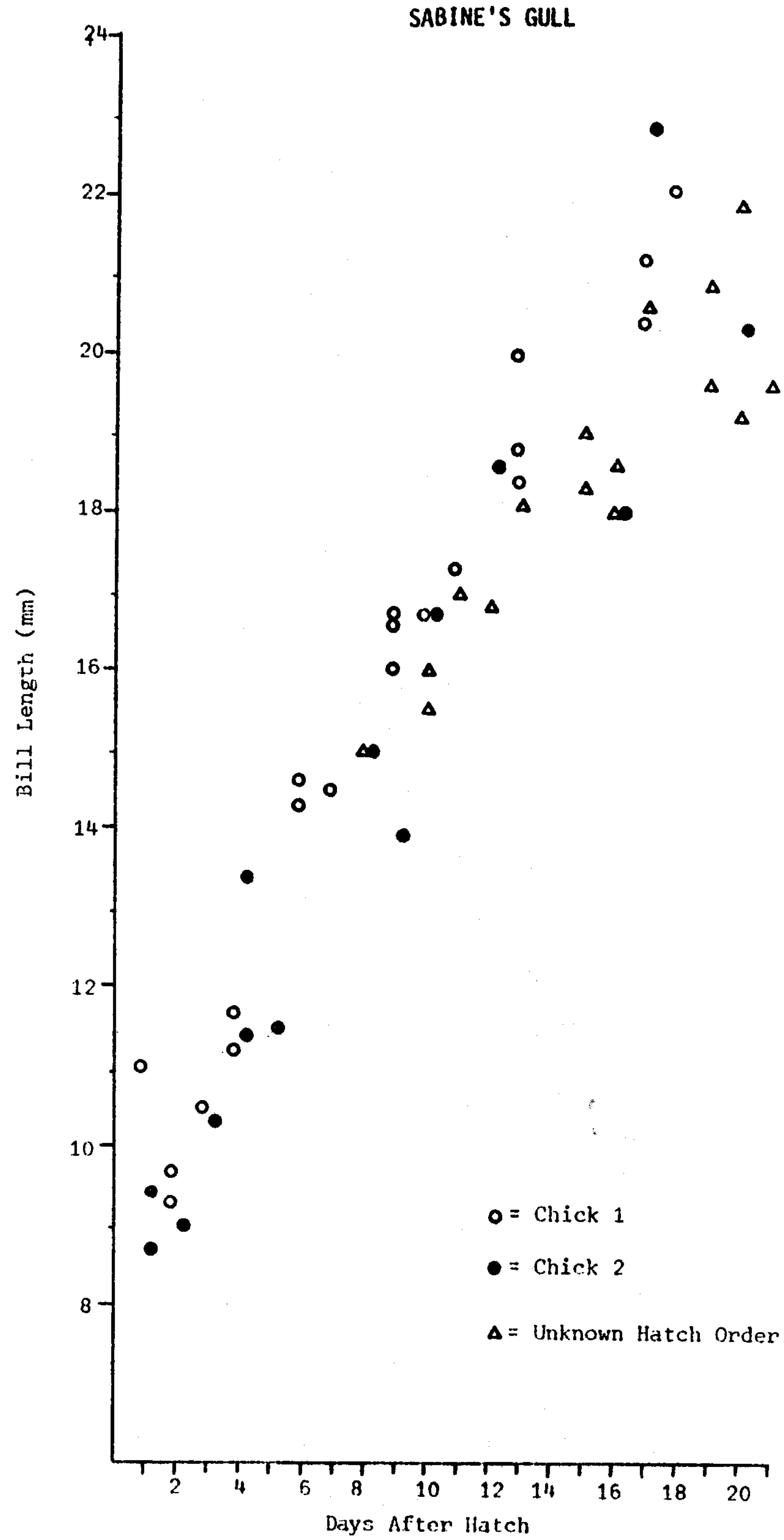

Figure 97. Bill growth of Sabine's Gull chicks, 1976, Cape Espenberg, Alaska.

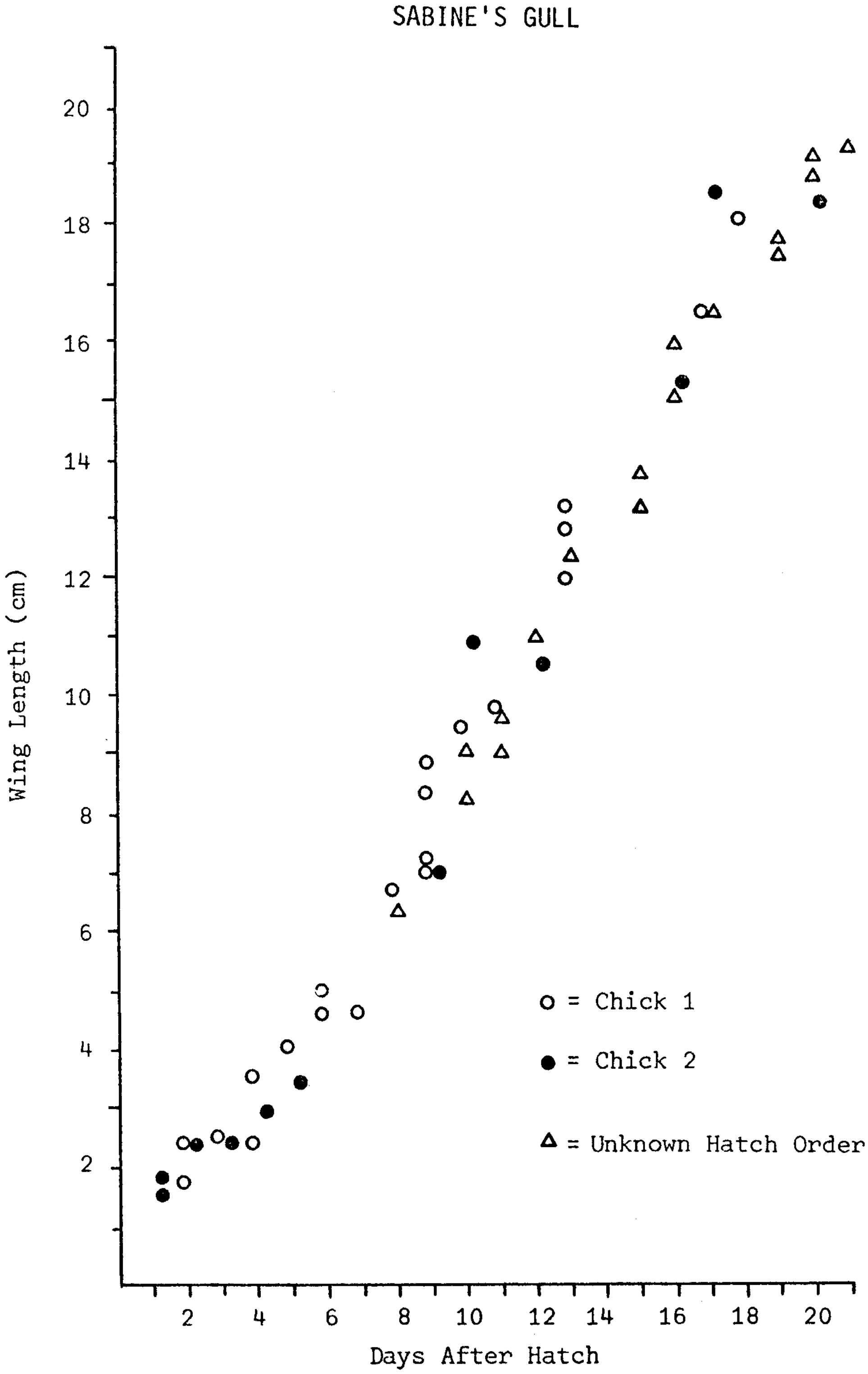

Figure 98. Wing growth of Sabine's Gull chicks, 1976, Cape Espenberg, Alaska.

In 1976, two dead chicks were found at nests. Each was the third chick to hatch of three-egg clutches. These were the only three-egg clutches in the study area. In 1977, two first-hatch chicks and one second-hatch chick were found dead in the study area. All dead chicks found in the study area apparently died of starvation.

Sabine's Gull chicks were able to fly at 20 days.

We have been unable to find comparative quantitative data on these birds in the literature. According to Witherby et al. (1944), details of the fledging period are unknown.

Passerines

Nesting success of Lapland Longspurs (48-70%) (Tables 26 and 27) on the Cape is similar to other areas (Table 28). Clutches in 1976 were considerably smaller than in 1977, but showed no more variation than was noted in a 7-year study at Barrow (Custer and Pitelka 1977). Nesting densities are also similar to other areas (Table 21). The increase in nests in 1977 is almost certainly due to renesting.

Overall Productivity

We have estimated the total number of chicks produced by each species on the Cape in 1976 and 1977 in Table 6. These figures were derived by combining our data on nesting densities (Tables 21-24), the amount of different nesting habitat types on the Capes (Table 34, derived from our habitat map for the Cape), clutch sizes (Table 25), and nesting success (Tables 26 and 27). About 14,000-16,000 chicks were probably produced on the Cape both summers. Because of the difficulty of obtaining accurate fledging data for most species, we could not estimate the number of fledglings.

Factors Affecting Production and Habitat Use

Phenology

Each summer at Cape Espenberg was phenologically different. Based on observations made by H. Melchior (pers. comm.), J. King (pers. comm.) over many years, and F. Goodhope, Jr. (pers. comm.) throughout his lifetime as a resident on the Chukchi coast, the spring of 1976 was later than usual. Comparison of nesting dates from 1976 and 1977 indicates about a one week delay in nest initiation in 1976. In contrast, the spring of 1978 was one of the earliest on record for Western Alaska. Some species nested several days to one week earlier in 1978 than they had in 1977.

Weather conditions, as reported by the National Weather Service station in Kotzebue, are given in Appendices 4 and 5. Generally, weather was only slightly better at Cape Espenberg than at Kotzebue. We experienced less cloud cover and less wind than Kotzebue. An analysis of weather data from Kotzebue in 1976 shows a departure from normal daily temperatures of -0.8° F during May and -4.1° F during June. These figures for 1977 were -0.3° F in May and +0.3° F in June. This indicates that 1977 was

Table 34. Major nesting habitat types on Cape Espenberg, Alaska.

Habitat Type	Area (KM^2)	Percent of Total Area of Cape
Sand beach	0.96	4.4
Mud beach[a]	0.25	1.1
Sand dunes, zero to sparse vegetation	0.80	3.6
Sand dunes, moderate to dense vegetation	1.92	8.7
Tundra ridge	3.15	14.3
Salt grass meadow	0.61	2.8
Short sedge-grass meadow	0.98	4.4
Tall sedge	0.25	1.1
Dry tussock	2.40	10.9
Wet tussock	3.43	15.5
Complex mosaic of dry and wet tussocks and broken ridges with low shrubs	0.82	3.7
Shallow water marsh, dense hummocks and broken ridges	2.68	12.1
Deep water marsh, sparse hummocks	0.49	2.2
Island	<0.01	<0.1
Slough	0.04	<0.1
Pond	3.30	14.9
Total	22.1	100

[a]Amount of beach area, of course, depends on the tide, figure given here represents a minimum present most of the time except during the highest tides.

nearly normal. However, in 1976 the cool weather during the usual nest initiation period postponed nesting attempts that year.

In both 1976 and 1977, we arrived on the study area after much of the spring migration activity had ended; we know little about tundra snow cover and avian habitat use in early spring. Upon arrival on 4 June 1976, snow was confined to the north slopes of the dunes. Conditions were nearly identical upon our arrival on 19 May 1977. Below normal temperatures from then through late May (Appendix 5) retarded snow melt, plant development, and nesting of at least a few bird species.

Sandhill Cranes were probably least affected by inter-year phenological differences. Based upon hatching dates and clutch size, cranes probably began nesting 20-23 May both years. Lapland Longspurs are the next species to commence laying. In the phenologically "normal" year of 1977, they began nesting 9 days earlier than in 1976. However, early laying dates (25 May) in 1978 matched 1977, suggesting that nesting phenology cannot be further advanced.

Loons, shorebirds, and larids have relatively fixed clutch sizes. Except for Western Sandpipers, clutch sizes varied little from one year to the next, as anticipated. These birds can vary their productivity only slightly by changes in the clutch size. However, they can affect productivity by replacing lost clutches. This has been shown for larids and shorebirds (see Graul 1973). We suspect the same phenomenon holds true for loons (see PREDATION section for our evidence). When the potential nesting period is extended (as in phenologically early summers), birds may increase the possibility of renesting. Loons, shorebirds, and larids nested earlier each successive summer, as we anticipated (see Figs. 90, 91 and 92).

Waterfowl do have the potential for increasing their clutch size. In years of early snow melt and mild weather geese and ducks can begin nesting early rather than burning up fat reserves (necessary for egg laying) while waiting for favorable nesting conditions. Thus, early breakup conditions permit earlier nesting, slightly larger average clutch sizes and potentially more fledged young (Mickelson 1975). At Cape Espenberg the overall average clutch laid for waterfowl (Table 25) in 1977, a near normal spring, was larger than in 1976, a late spring. This agrees with similar studies on waterfowl of the Yukon-Kuskokwim Delta (Mickelson 1975, Eisenhauer and Kirkpatrick 1977).

However, average clutch hatched in 1977 was lower than in 1976. Perhaps the factor of greatest importance in reducing production was predation (discussed below).

Predators and Predation

<u>Foxes</u>

Numbers and Denning

In 1976 a systematic search was made of the entire Cape in an attempt to locate all fox dens. Seven den sites were located, three in the dunes on the north side of the Cape and four in the dunes on the south side. The number of entrances to these dens was as follows: 5, 7, 12, 18, 26, 36, and 43. Foxes tend to add new entrances each year a den is used (Allison 1971). Dens with over 25 entrances have been considered old (Skrobov 1959, cited in Macpherson 1969). At least three of the dens on Espenberg apparently have been used many times in the past. Four of the dens were used in 1976. Apparently, two Red Fox (Vulpes vulpes) families each used two dens during the course of the summer. During the end of July and in August, we observed the active dens to determine the number of pups present. One family included two pups and one family included four pups. Our best estimate of the number of Red Foxes using the Cape during the summer of 1976 is four adults and six pups. It is possible that one or more non-breeding individuals were also present. No Arctic Foxes (Alopex lagopus) were observed in 1976, but two relatively fresh skulls, with some white winter fur and muscle still attached, were found. Arctic Foxes were probably present on the Cape during the previous winter.

In 1977, none of the dens on the Cape were active. However, adult foxes were observed very frequently. At least two different adult Red Foxes and two, probably three, adult Arctic Foxes remained on the Cape all summer. We estimate a population of five to six adult foxes on the Cape in 1977.

In 1978, one adult Red Fox and one adult Arctic Fox were each observed once during late May-early June. No pups were raised on the Cape, but there was evidence that the Arctic Fox used one of the dens frequently as a resting area. However, there was little evidence that foxes visited the Shorebird Marsh Plot in 1978. The fox population during most of the summer may have been limited to one adult Arctic Fox.

The varying fox activity on the Cape is probably related to factors other than the avian community. Most birds and eggs are not available to foxes during the period of mating, pregnancy, and early pup rearing. Thus winter food sources, such as microtines or marine mammals, may be especially important. During our study, foxes denned on the Cape only in 1976, the only year that a detectable microtine population occurred there. If microtines were low over a wide area in 1977 and if they are important to the reproductive success of the foxes, the 1977 fox population on the Cape may have consisted of a large number of non-breeding adults, several of which could have been attracted by the high density of nesting birds. In 1978 the overall density of adult foxes in a wide area may have been down because of reproductive failure in 1977; no pups occurred on the Cape again in 1978, so the fox density was very low that year. Although the fox densities and activities on the Cape for 1976-1978 are known, this explanation for the variations is quite speculative. However, if such a relationship exists between microtine populations (or other variable food sources) and fox reproductive success, it would have a significant affect on annual variations in avian reproductive successes (see discussion below). Additional work on this problem could prove interesting and useful.

Food Habits

Red Fox scats were collected at active dens during 1976. The dens were not discovered until midway through the summer, so the scats could not be closely dated. All scats at three den sites were collected about August 1 and all scats at all dens were collected about September 10. Thus, it was possible to date many of the scats as being deposited before or after August 1. No scats were collected in 1977 because there were no active dens and no good collection areas were found.

The results of the Red Fox scat analyses are presented in Figure 99 and Tables 35-37. Adult and young birds occurred in 52% of all the scats analyzed, while eggshell fragments occurred in 23% of the scats (Table 37). Birds and eggs were the most frequently occurring food items in the pellets collected before August 1; after this date birds and eggs still occurred in 59% of the scats but mammals occurred more frequently. The relatively high frequency of eggs eaten in late summer (Table 36) is undoubtedly the result of caching activities. Three of our bird bands were found in the fox scats; these were from one adult male Northern Phalarope, one Dunlin chick, and one Western Sandpiper chick. In addition, the carcasses of several female Common Eiders and Oldsquaws were found at the dens.

Mammals, especially microtines and ground squirrels were an important part of the foxes' diet throughout the summer (Figure 99). Berries occurred in 35% of the scats in late summer (Table 36). Insects also occurred in 33% of the late summer scats; since many of these scats were probably from pups, the insects probably represent the prey the pups captured while playing, exploring, and hunting near the den.

The results show that the Red Foxes preyed heavily on birds and eggs but that other items, especially small mammals, also composed a large part of their diets.

The reader is cautioned that scat analyses give an indication of diet but that the percentages observed are not absolute indicators of the importance of each item in the diet, as the occurrence of food items in scats is related to digestibility and other factors. Eggs may be underrepresented in the scats because the egg yolk is often licked out and very few shell fragments are ingested.

During the Predator Watches (Table 57) on the Shorebird Marsh Plot, the hunting techniques of foxes were observed. Generally, foxes trotted on a meandering course through the plot and investigated areas where waterfowl flushed. Although much of the observation area was marshy, foxes were able to travel through and to all areas of the plot. Foxes were observed walking through water and mud up to their bellies. One Red Fox was observed to jump 3.4 m over a marshy area to get to a hummock from which a Common Eider had flushed from a nest. Of 41 waterfowl eggs observed taken by foxes during the Predator Watches, only 1 was eaten immediately; all the rest were cached a few meters to over 100 m from the nest. Foxes were observed to eat most shorebird and tern eggs immediately, although even some small eggs were cached.

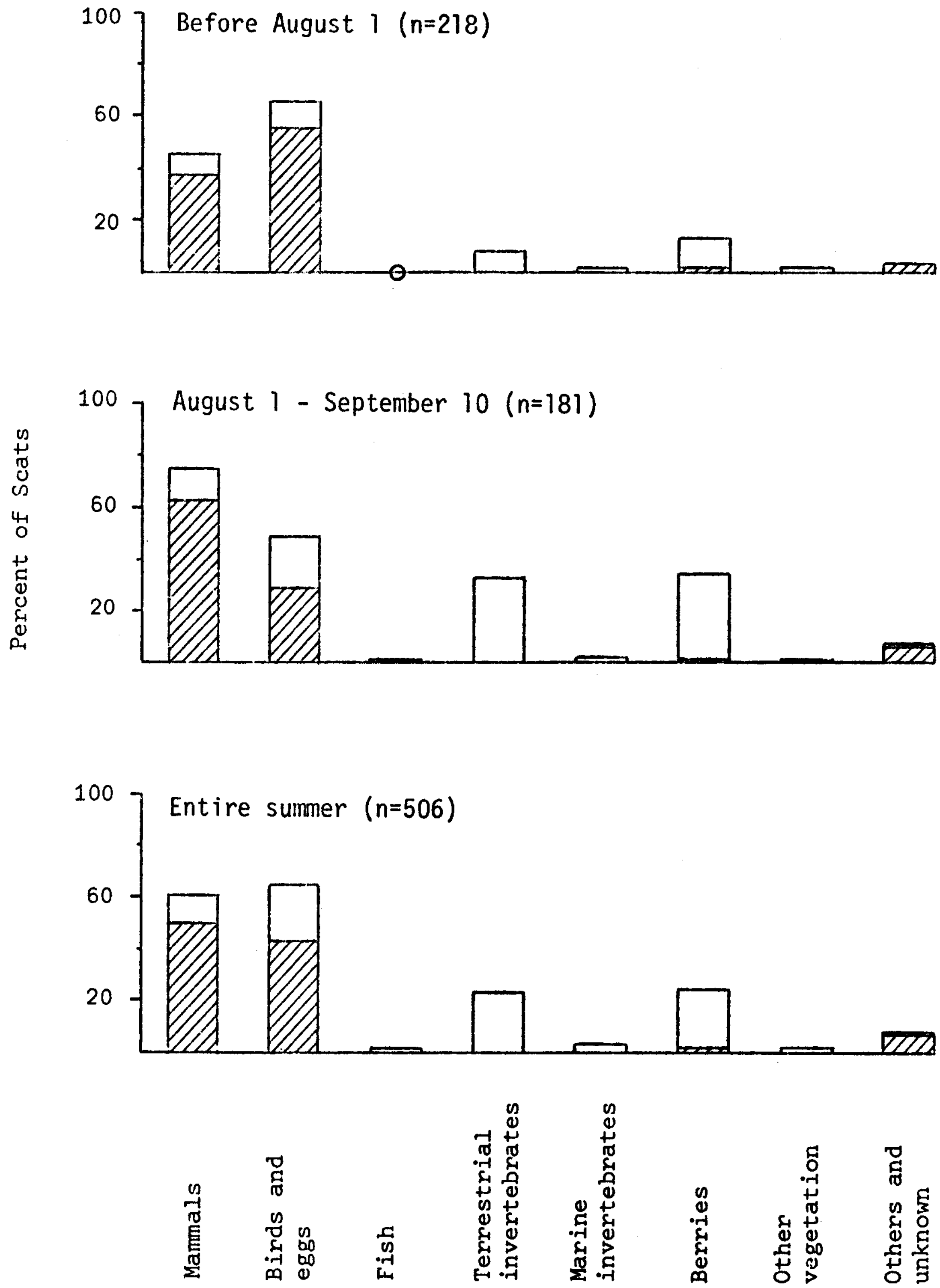

Figure 99. Percent of Red Fox scats containing various food items, 1976, Cape Espenberg, Alaska (shaded = 50% or more of volume of scat consists of given food item, unshaded = less than 50% of volume of scat consists of given food item).

Table 35. Analysis of Red Fox scats chiefly from May-August 1, 1976, no. of scats = 218, Cape Espenberg, Alaska.

Food Item	Percent of Volume of Pellet Consisting of Item 0-10 No. of Pellets	(% of Pellets)	11-49 No. of Pellets	(% of Pellets)	50-89 No. of Pellets	(% of Pellets)	90-100 No. of Pellets	(% of Pellets)	Total No. and (%) of Pellets	
MAMMALS										
Spermophilus undulatus (Arctic Ground Squirrel)	1	(<1)	4	(2)	7	(3)	22	(10)	34	(16)
Cricedidae (mice, lemmings)	-	-	7	(3)	10	(5)	27	(12)	44	(20)
Unidentified small mammals	1	(<1)	3	(1)	6	(3)	11	(5)	21	(10)
Pinnipedia (seals, walruses)	-	-	2	(1)	-	-	-	-	2	(1)
Rangifer tarandus (reindeer)	-	-	-	-	-	-	-	-	-	-
Other unidentified mammals	-	-	1	(<1)	-	-	1	(<1)	2	(1)
Total	2	(1)	16	(7)	20	(9)	63	(29)	101	(46)
BIRDS AND BIRD EGGS										
Waterfowl eggs	9	(4)	12	(6)	3	(1)	7	(3)	21	(10)
Adult and young birds[1]	5	(2)	11	(5)	32	(15)	78	(36)	126	(58)
Total	8	(4)	16	(7)	28	(13)	92	(42)	144	(66)
FISH[1]										
Total	-	-	-	-	-	-	-	-	-	-
TERRESTRIAL INVERTEBRATES										
Insecta	13	(6)	4	(2)	-	-	-	-	17	(8)
MARINE INVERTEBRATES										
Mollusca (clams, snails)	2	(1)	-	-	-	-	-	-	2	(1)
Brachyura (crabs)	-	-	-	-	-	-	-	-	-	-
Asteroidea (starfish)	-	-	-	-	-	-	-	-	-	-
Total	2	(1)	-	-	-	-	-	-	2	(1)
BERRIES										
Rubus chamaemorus (cloudberry)	1	(<1)	-	-	-	-	-	-	1	(<1)
Empetrum nigrum (crowberry)	15	(7)	8	(4)	2	(1)	1	(<1)	26	(12)
Arctostaphylos sp. (bearberry)	2	(1)	1	(<1)	-	-	-	-	3	(1)
Vaccinium spp. (blueberry, cranberry)	-	-	-	-	-	-	-	-	-	-
Total	16	(7)	9	(4)	1	(<1)	2	(1)	28	(13)
OTHER VEGETATION										
Total	-	-	1	(<1)	1	(<1)	-	-	2	(1)
UNIDENTIFIED ITEMS										
Total	-	-	1	(<1)	2	(1)	3	(1)	6	(3)

[1] For details about species see text.

Table 36. Analysis of Red Fox scats from August 1-September 10, 1976, no. of scats = 181, Cape Espenberg, Alaska.

Food Item	Percent of Volume of Pellet Consisting of Item: 0-10 No. of Pellets	0-10 (% of Pellets)	11-49 No. of Pellets	11-49 (% of Pellets)	50-89 No. of Pellets	50-89 (% of Pellets)	90-100 No. of Pellets	90-100 (% of Pellets)	Total No. and (%) of Pellets	
MAMMALS										
Spermophilus undulatus (Arctic Ground Squirrel)	-	-	8	(4)	12	(7)	12	(7)	32	(18)
Cricedidae (mice, lemmings)	2	(1)	4	(2)	14	(7)	13		33	(18)
Unidentified small mammals	3	(2)	12	(7)	37	(20)	22	(12)	74	(41)
Pinnipedia (seals, walruses)	1	(<1)	2	(1)	-	-	1	(<1)	4	(2)
Rangifer tarandus (reindeer)	-	-	1	(<1)	-	-	-	-	1	(<1)
Other Unidentified Mammals	-	-	-	-	-	-	2	(1)	2	(1)
Total	6	(3)	16	(9)	57	(31)	57	(31)	136	(75)
BIRDS AND BIRD EGGS										
Waterfowl eggs	31	(17)	16	(9)	8	(4)	1	(<1)	56	(31)
Adult and young birds[1]	5	(3)	26	(14)	20	(11)	20	(11)	71	(39)
Total	19	(10)	36	(20)	29	(16)	23	(13)	107	(59)
FISH[1]										
Total	1	(<1)	-	-	-	-	-	-	1	(<1)
TERRESTRIAL INVERTEBRATES										
Insecta (except Ephydridae)	45	(25)	14	(8)	-	-	-	-	59	(33)
MARINE INVERTEBRATES										
Mollusca (clams, snails)	2	(1)	-	-	-	-	-	-	2	(1)
Brachyura (crabs)	1	(<1)	-	-	-	-	-	-	1	(<1)
Asteroidea (starfish)	-	-	1	(<1)	-	-	-	-	1	(<1)
Total	3	(2)	1	(<1)	-	-	-	-	4	(2)
BERRIES										
Rubus chamaemorus (cloudberry)	9	(5)	1	(<1)	1	(<1)	-	-	11	(6)
Empetrum nigrum (crowberry)	32	(18)	14	(8)	1	(<1)	1	(<1)	48	(27)
Arctostaphylos sp. (bearberry)	5	(3)	-	-	-	-	-	-	5	(3)
Vaccinium spp. (blueberry, cranberry)	6	(3)	2	(1)	-	-	-	-	8	(4)
Total	39	(22)	21	(12)	2	(1)	1	(<1)	63	(35)
OTHER VEGETATION										
Total	1	(<1)	-	-	-	-	-	-	1	(<1)
UNIDENTIFIED ITEMS										
Total	-	-	2	(1)	7	(4)	3	(2)	12	(7)

[1]For details about species see text.

Table 37. Analysis of Red Fox scats from the entire summer of 1976, no. of scats = 506 (includes scats included in previous two tables, plus others for which a date was not available), Cape Espenberg, Alaska.

Food Item	Percent of Volume of Pellet Consisting of Item								Total No. and (%) of Pellets	
	0-10		11-49		50-89		90-100			
	No. of Pellets	(% of Pellets)	No. of Pellets	(% of Pellets)	No. of Pellets	(% of Pellets)	No. of Pellets	(% of Pellets)		
MAMMALS										
Spermophilus undulatus (Arctic Ground Squirrel)	2	(<1)	23	(5)	27	(5)	41	(8)	93	(18)
Cricedidae (mice, lemmings)	3	(1)	21	(4)	46	(9)	50	(10)	120	(24)
Unidentified Small Mammals	7	(1)	20	(4)	46	(9)	34	(7)	107	(21)
Pinnipedia (seals, walruses)	3	(1)	4	(1)	-	-	1	(<1)	7	(1)
Rangifer tarandus (reindeer)	1	(<1)	1	(<1)	-	-	-	-	2	(<1)
Other Unidentified Mammals			1	(<1)			3	(1)	4	(1)
Total	12	(2)	42	(8)	103	(20)	148	(29)	305	(60)
BIRDS AND BIRD EGGS										
Waterfowl eggs	66	(13)	32	(6)	12	(2)	8	(2)	118	(23)
Adult and young birds[1]	20	(4)	56	(11)	68	(13)	117	(23)	261	(52)
Total	40	(8)	74	(15)	74	(15)	136	(27)	324	(64)
FISH[1]										
Total	2	(<1)	-	-	-	-	-	-	2	(<1)
TERRESTRIAL INVERTEBRATES										
Insecta (except Ephydridae)	91	(18)	24	(5)	-	-	-	-	115	(23)
MARINE INVERTEBRATES										
Mollusca (clams, snails)	10	(2)	-	-	-	-	-	-	10	(2)
Brachyura (crabs)	1	(<1)	-	-	-	-	-	-	1	(<1)
Asteroidea (starfish)	3	(1)	1	(<1)	-	-	-	-	4	(1)
Total	14	(3)	1	(<1)	-	-	-	-	15	(3)
BERRIES										
Rubus chamaemorus (cloudberry)	10	(2)	2	(<1)	1	(<1)	-	-	13	(3)
Empetrum nigrum (crowberry)	66	(13)	27	(5)	4	(1)	4	(1)	101	(20)
Arctostaphylos sp. (bearberry)	12	(2)	1	(<1)	-	-	-	-	13	(3)
Vaccinium spp. (blueberry, cranberry)	6	(1)	2	(<1)	-	-	-	-	8	(1)
Total	76	(15)	36	(7)	3	(1)	6	(1)	121	(24)
OTHER VEGETATION										
Total	4	(1)	1	(<1)	2	(<1)	-	-	7	(1)
UNIDENTIFIED ITEMS										
Total	1	(<1)	4	(1)	21	(4)	7	(1)	33	(7)

[1]For details about species see text.

The foxes always took one egg at a time and cached it, then returned to the nest for another egg. Sometimes a fox was distracted, occasionally by finding a new nest, and not all the eggs were taken from a nest. Occasionally foxes returned to nests after an absence of an hour or longer. The intensive caching of eggs undoubtedly allowed eggs to continue to serve as an important food source after all the nests had hatched or been destroyed. One Arctic Fox, which could be identified by its shedding pattern, was observed on at least two occasions concentrating on finding cached eggs in the plot, even though nests were still present. Many of these eggs were probably cached by other individuals, as this fox was not observed taking eggs from any waterfowl nests in the plot. The fox searching for caches acted differently than those searching for nests. It generally walked, rather than trotted, and it kept its nose to the ground continuously. It consumed a few of the cached eggs it found but most of them were recached nearby. The foxes were not observed capturing any adult birds in the plot.

Glaucous Gulls

Breeding Biology

In both 1977 and 1978 Glaucous Gull nests were located in the waterfowl and shorebird nesting plots, along the gull pellet collecting route, and in a few other nearby colonies. The number of nests visited was 107 in 1976 and 169 in 1977. The number of other Glaucous Gull nests on the entire Cape was estimated by surveying the entire area from viewpoints on the dunes, using a spotting scope and counting incubating Glaucous Gulls. The resulting estimate of the number of nests on the Cape was 250 nests in 1976 and 300-350 nests in 1977. These figures give a density of 11 nests/km^2 in 1976 and 14-16 nests/km^2 in 1977. The data from the nesting plots (Tables 22 and 23) and from the gull pellet collecting route indicate some increase in the numbers of nests from 1976 to 1977. However, at least half of the difference in the estimates of total nests for the two years probably results from more complete data, especially on nests lost early in the season, in 1977. Thus the estimate for 1976 is probably a little low. Any actual increase in nesting density in 1977 is probably attributable to the earlier breakup and beginning of the nesting season. The nesting densities of Glaucous Gulls on the Cape are at least two times greater than densities reported from other areas of Alaska (Table 21). The high densities on the Cape probably occur because of the presence of good nesting habitat in conjunction with the potential of plentiful food in most years, from both marine and terrestrial sources (Tables 38-52).

Complete data on the breeding phenology of Glaucous Gulls on the Cape were obtained only in 1977 (Figure 100). However, the bits of information available for 1976 and 1978 strongly indicate that the gulls' breeding phenology is very flexible and responds to spring weather conditions. On the west coast of Alaska, 1976 was a late spring while 1978 was an extremely early one. In response to these varying conditions, the peak of gull egg laying varied by as much as two weeks between the years. Available data indicate the peak of laying occurred on the following dates: 1) 12-13 June 1976, 2)6-7 June 1977, and 3) 28-20 May 1978. Most of the hatching in 1977 occurred during the first two weeks of July;

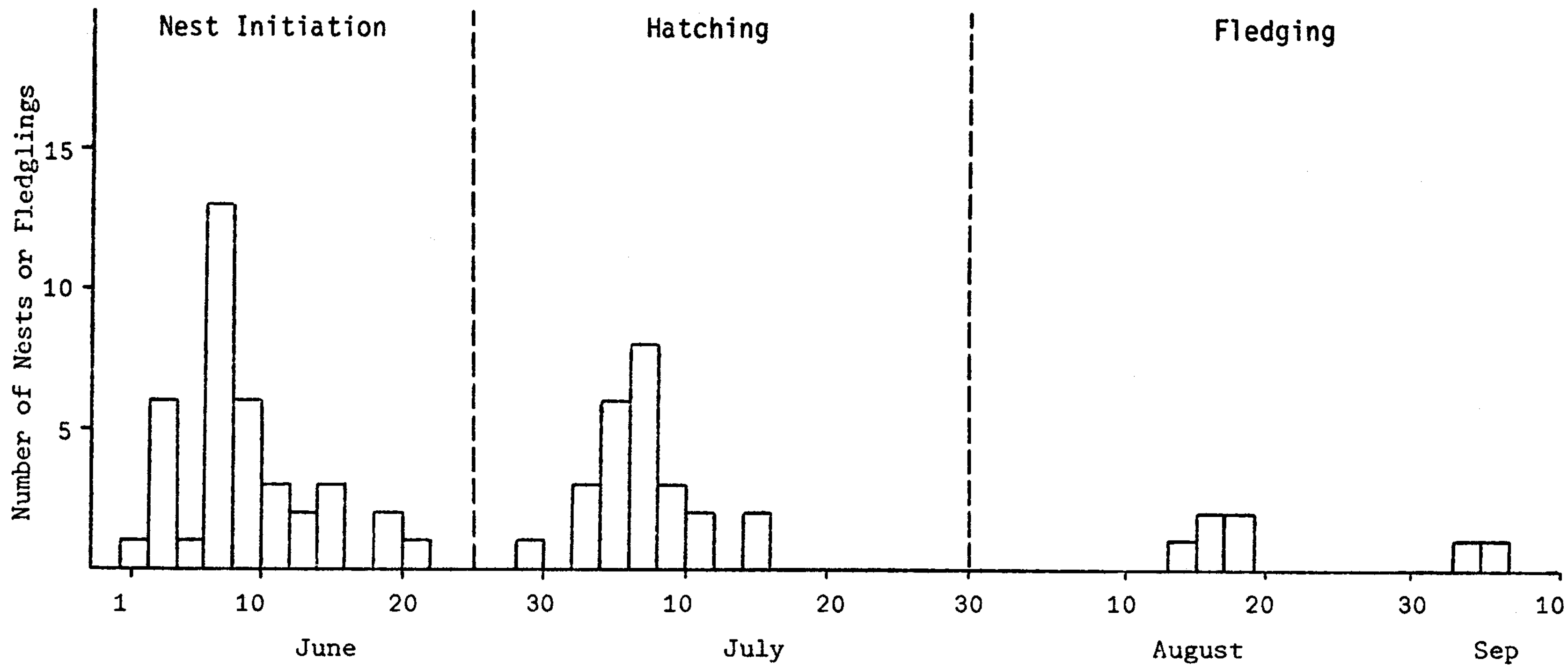

Figure 100. Nest initiation, hatching, and fledging dates for Glaucous Gulls, 1977, Cape Espenberg, Alaska.

the first fledged young was observed on August 10, and fledging continued into early September.

The mean clutch size was about the same in both 1976 and 1977 (Table 25) and was similar to the mean clutch size of 2.70 reported by Strang (1976) for the Yukon-Kuskokwim Delta. Strang's (1976) study provides the only major work on breeding Glaucous Gulls in Alaska.

Hatching success was about 75% in both 1976 and 1977 (Tables 26 and 27). Strang (1976) reported Glaucous Gull hatching success rates of 75-88% for 1972-1974. It appears that this species commonly exhibits relatively high hatching success. Success for breeding pairs was probably also influenced by renesting. In 1977, second clutches were found in each of three territories 8-14 days after the first clutches were lost during early incubation. Two of the second clutches were in the same nest bowls as the first clutches; the other second clutch was in a new bowl less than 1 m from the original nest. Although it is possible that new pairs claimed these territories and laid the second clutches after the original pairs failed, it is probable that these were renesting attempts by the original pairs. If so, 38 nests were initiated by 35 pairs.

The mean number of eggs hatched per nest was smaller than the mean clutch size (Table 25). In 1977 we noted that the third egg in a three egg clutch was often abandoned after the first two eggs hatched; this also occurred occasionally to the second egg of two egg clutches. However, 1977 may have been a year of food shortage (see below) and this factor may affect egg abandonment. Partial predation also occurred at 2 of 38 nests that were monitored closely in 1977. Thus, the hatching rate of 97 eggs monitored closely in 1977 was about 53%.

Glaucous Gull nests were lost to a variety of factors. They appeared most vulnerable during or shortly after the laying period, possibly because the adults were less attentive at this time. Of the 38 monitored nests in 1977, 6 were destroyed during this short period, at least 2 of which appeared to be destroyed by avian predators. During the much longer period beginning 2-3 days after laying and continuing to hatching, 5 nests were destroyed: 2 by foxes, 1 by reindeer, and 2 by unidentified predators.

In 1977, fledging success was very low at the intensively monitored colonies. Eleven young fledged from 38 nests, an average of 0.29 young/nest. Figures 101-103 show details of chick growth. Eight young fledged at the age of 40-45 days, while three young fledged at the ages of 50-63 days. The variations in age at fledging were probably due to differing nutritional regimes. The survival of young from hatching to fledging was only 22% (11 fledglings/51 chicks hatched). Sixty-seven percent (34/51) of the chicks apparently died between the ages of 0-10 days; of these, 18 were found intact but dead near their nests, 13 disappeared without the carcasses being found, and the web tags from 3 were found in Glaucous Gull pellets. The chicks that disappeared did not move to nearby areas because most of the chicks on the entire Cape were eventually captured; tagged chicks were found only near their places of hatching. Most of these young chicks probably died of starvation

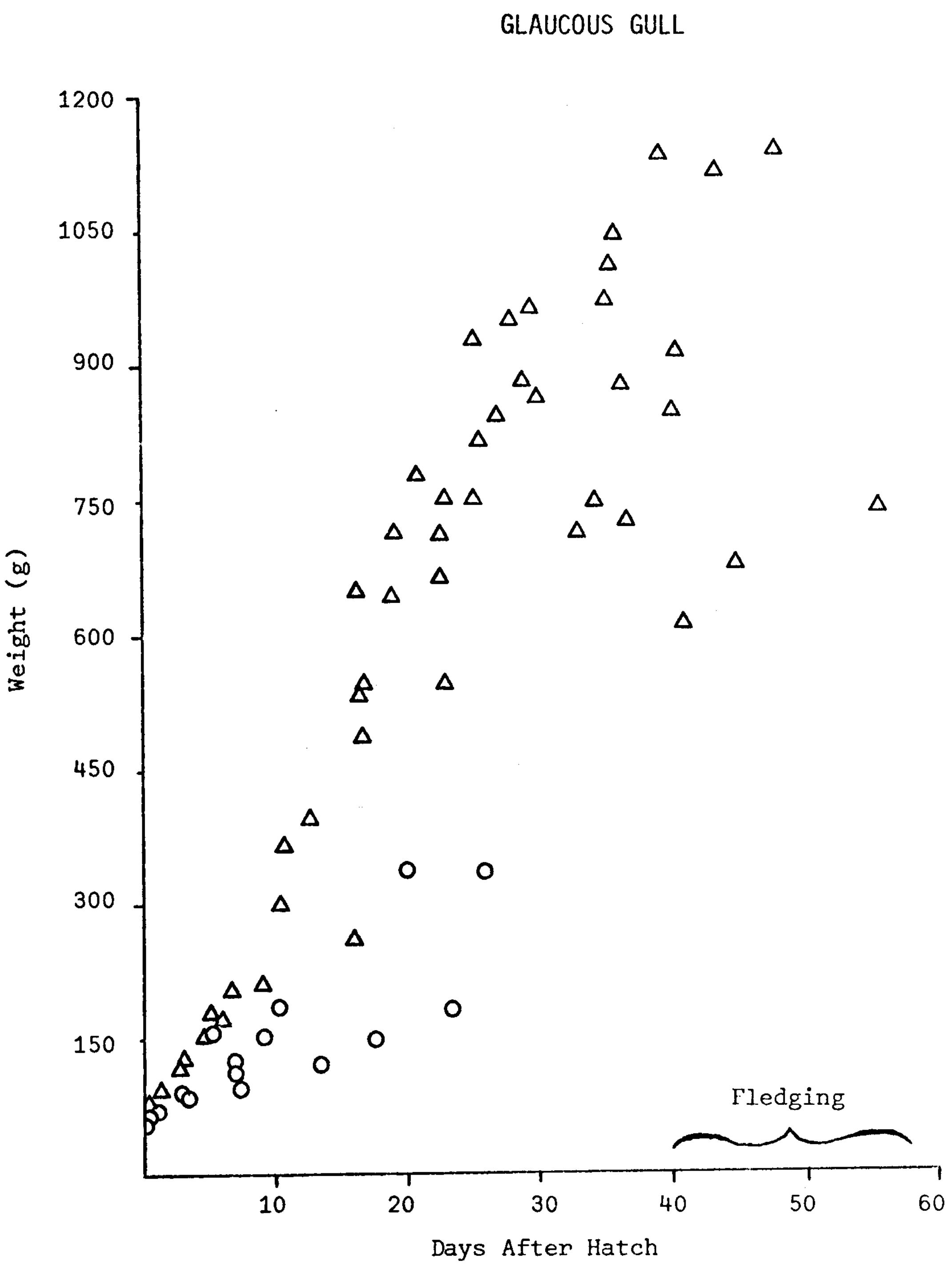

Figure 101. Weight change of Glaucous Gull chicks, 1977, Cape Espenberg, Alaska. (o = chicks that eventually died of apparent starvation, Δ = chicks that did not die of apparent starvation).

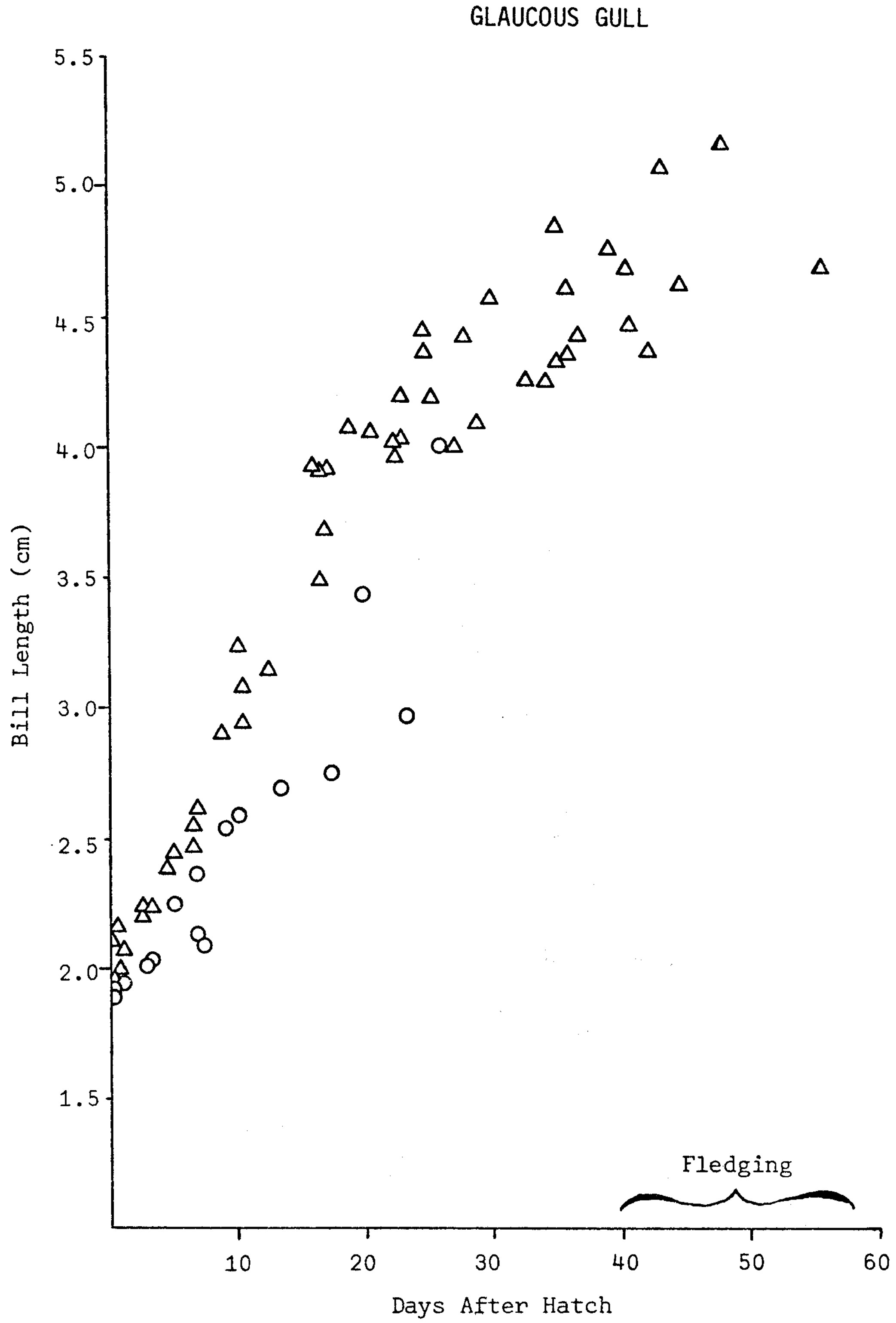

Figure 102. Bill growth of Glaucous Gull chicks, 1977, Cape Espenberg, Alaska. (o = chicks that eventually died of apparent starvation, Δ = chicks that did not die of apparent starvation).

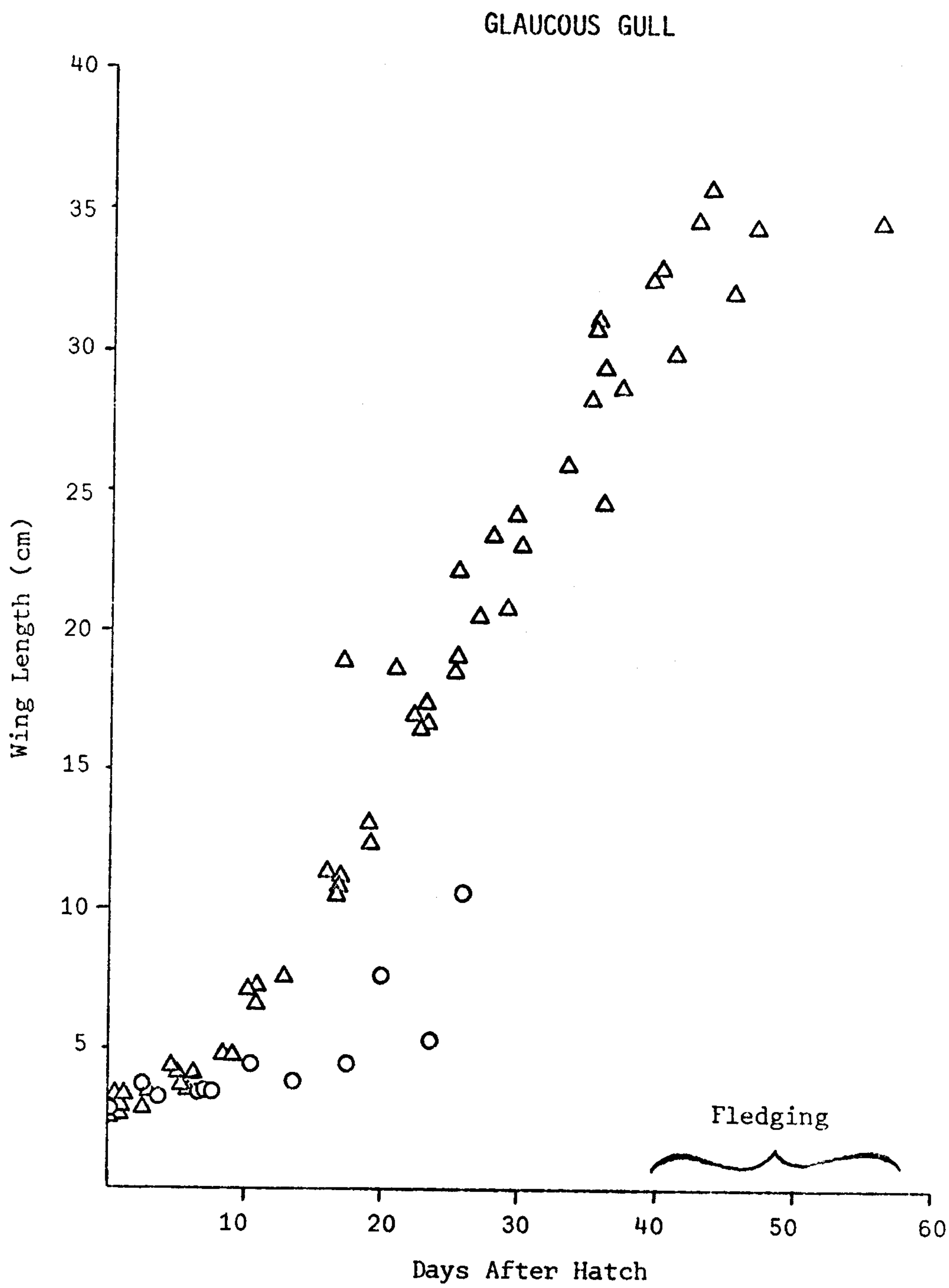

Figure 103. Wing growth of Glaucous Gull chicks, 1977, Cape Espenberg, Alaska. (o = chicks that eventually died of apparent starvation, Δ = chicks that did not die of apparent starvation).

and/or exposure. The gull pellet collection data (Tables 38-52) suggest poor food availability in 1977. Gull pellets were collected at the same colonies in 1976 and 1977. All pellets in the collection area were collected every two weeks. The area was not exactly the same during the two summers because some variation occurred in nest sites; however, at least 90% of the area was the same ground both summers. During July, when the chicks were quite young, 2,936 pellets were collected in 1976 while only 583 pellets were collected in 1977. The main cause of this variation was a very large decline in 1977 (Tables 48 and 49) of the number of pellets containing as the main food item the marine isopod Saduria entomon and Ephydridae (shorefly) pupae. Also, in 1976 there were numerous pellets and miscellaneous food items in the area that were completely or totally undigested, suggesting that the adults were bringing in more food than the young could utilize. In 1977 every bit of food seemed to be fully utilized by the young. These data suggest that these marine food sources are important for chick survival and growth. The marine invertebrate sampling data (Table 66) also indicate that Saduria was much less common in the waters near Espenberg in 1977 than in 1976. The other cause of death noted for three young chicks was predation by adult Glaucous Gulls. At least one such predation incident was caused because of human disturbance.

Of the 17 chicks that survived past 10 days of age, 6 more died before fledging; 3 young were found dead but intact within their territories, 1 chick was trampled by reindeer, and 2 chicks disappeared. At least one of these chicks may have died of starvation; at 24 days of age it weighed 185 g, while its 23-day-old sibling weighed 665 g.

One chick was found dead in the pond in which it was reared after it had fledged. It had a deep stab wound in the breast. A small Arctic Loon chick and its parents occupied this same pond. It is possible that the loons killed the gull. The loon chick was observed diving and surfacing near gull chicks that swam near it and jabbing at the gull chicks with its bill.

In 1977, all the ponds on the Cape east of the large slough in Section 28 (Figure 3) were surveyed for Glaucous Gull chicks; 254 chicks were counted outside the intensively studied colonies; 160 of these were captured, weighed, measured, and banded. Only two of these chicks were judged to be less than 10 days old, so most of them had already lived through the period of highest mortality. From the size and estimated ages of these chicks and from the mortality rates observed at the intensively studied colonies, it was estimated that 20% of these chicks may have died before fledging. Thus about 203 of these chicks probably fledged. Adding the 11 fledglings from the intensive study colony, we arrive at an estimate of 214 Glaucous Gull chicks fledged on the Cape in 1977. Combined with the estimate of the number of nests, these figures give a mean fledging rate of 0.66 fledglings/nest. This is considerably higher than the fledging rate observed in the intensively studied colony. Some of the difference may have been caused by human disturbance at the intensively studied colonies. However, we do not believe this was a major factor. We attempted to minimize our disturbance and watched closely for evidence of our effects; only 1 chick was known to have died of predation as a direct result of our disturbance. Also, several other colonies were monitored by only one or two visits during nesting and one visit near the time of fledging. These colonies appeared to exhibit widely varying fledging success rates. Colony location, activities, age and experience of adults, and other factors may cause variations in reproductive success from colony to colony.

Opportunistic observations made in 1978 also indicate that reproductive success may vary greatly from year to year. A survey of three ponds in 1978 revealed 55 Glaucous Gull chicks where there had been only 17 during the same stage of growth in 1977. Only one of the chicks in the 1978 count appeared to still be under 10 days of age. Cursory observations at other colonies in 1978 indicated that large numbers of chicks were present all over the Cape, compared with 1977. Also, most chicks were associating in groups of two or three. In 1977, we observed that siblings generally associated closely as long as disturbance was mild and all the chicks were not forced into one large milling group. The 1978 observations suggest that many pairs of adults were successfully raising two or even three young. In 1977 few groups of two and almost no groups of three siblings were observed after the initial high mortality of very young chicks. The 1978 observations indicated that in this extremely early year Glaucous Gull production may have been as much as two or three times greater than in 1977.

Strang (1976) reports mean fledging rates for Glaucous Gulls on the Yukon-Kuskokwim delta of 0.96 fledglings/nest (n=23) to 2.13 fledglings/nest (n=16) for 1972-1974, and an overall rate of 1.30 fledglings/nest (n=177). These rates are considerably higher than those found at Espenberg in 1977, when there appeared to be a food shortage.

Food Habits

An intensive study was made on Glaucous Gull food habits in 1976 and 1977, as described in the methods. Figures 104-105 and Tables 38-52 present the results of the pellet analysis. During early June in 1976 microtines, especially Microtus oeconomus, were by far the most frequently occurring food item in the pellets, followed in frequency by birds and eggs, and crowberries (Empetrum nigrum). In 1977, microtines were very scarce on the Cape and the early June diet of the gulls was shifted to other food sources, especially starfish, which were probably obtained by scavenging the thousands of dead starfish that had been washed up on the north beach of the Cape by winter storms. The gulls also took a higher percentage of fish, crowberries, and other vegetation during this period in 1977 than in 1976.

By July in 1976, marine invertebrates occurred in over 90% of the gull pellets. The marine isopod Saduria entomon was by far the most prevalent prey species, occurring in 93% of the pellets during the first half of July (Table 40) and providing over 90% of the volume of most of these pellets. During the second half of July (Table 41), Saduria still occurred in 60% of the pellets but gulls were also taking large numbers of marine Ephydridae (shorefly) pupae, which occurred in 39% of the pellets.

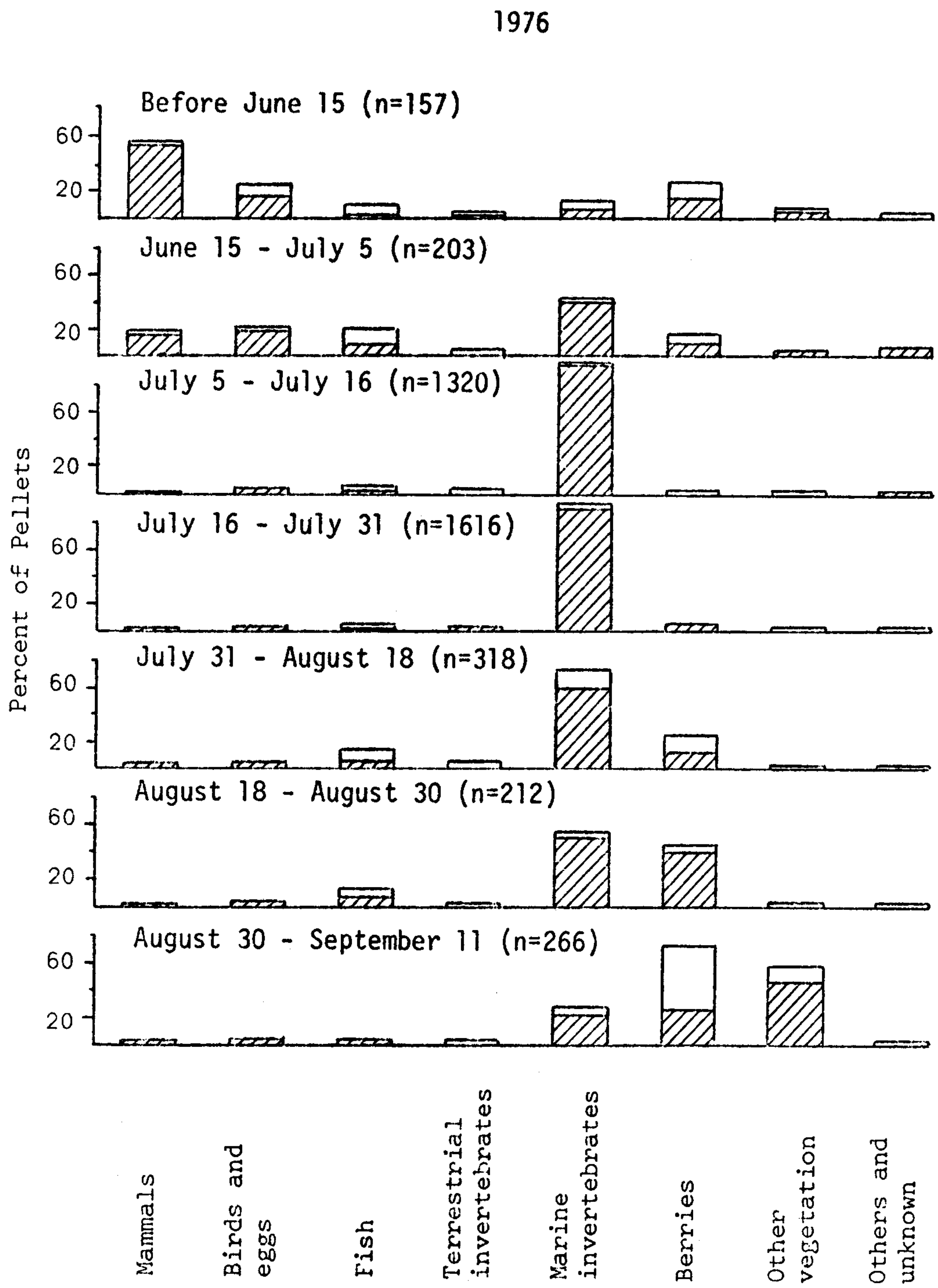

Figure 104. Percent of Glaucous Gull pellets containing various food items, 1976, Cape Espenberg, Alaska (shaded = 50% or more of volume of pellet consists of given food item, unshaded = less than 50% of volume of pellet consists of given food item).

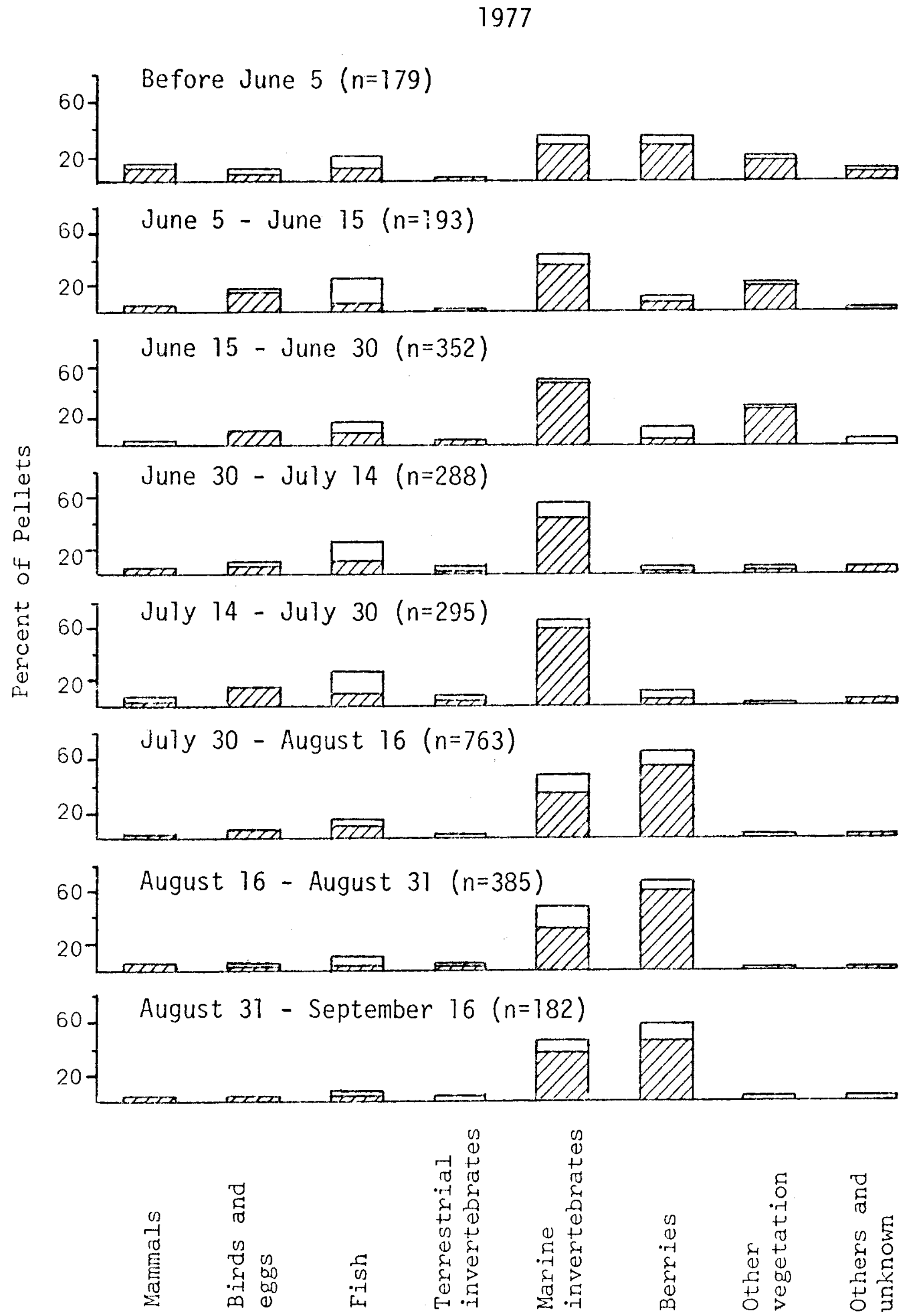

Figure 105. Percent of Glaucous Gull pellets containing various food items, 1977, Cape Espenberg, Alaska (shaded = 50% or more of volume of pellet consists of given food item, unshaded = less than 50% of volume of pellet consists of given food item).

Table 38. Analysis of Glaucous Gull pellets for the period before June 15, 1976, no. of pellets = 157, Cape Espenberg, Alaska.

Food Item	Percent of Volume of Pellet Consisting of Item: 0-10 No. of Pellets	0-10 (% of Pellets)	11-49 No. of Pellets	11-49 (% of Pellets)	50-89 No. of Pellets	50-89 (% of Pellets)	90-100 No. of Pellets	90-100 (% of Pellets)	Total No. and (%) of Pellets	
MAMMALS										
Soricidae (shrews)	-	-	-	-	-	-	2	(1)	2	(1)
Spermophilus undulatus (Arctic Ground Squirrel)	-	-	-	-	-	-	-	-	-	-
Cricedidae (mice, lemmings)[1]	1	(1)	1	(1)	10	(6)	70	(45)	82	(52)
Pinnipedia (seals, walruses)	-	-	-	-	-	-	-	-	-	-
Rangifer tarandus (reindeer)	-	-	-	-	-	-	-	-	-	-
Unidentified mammals	1	(1)	-	-	1	(1)	2	(1)	4	(3)
Total	1	(1)	1	(1)	11	(7)	74	(47)	87	(55)
BIRDS AND BIRD EGGS										
Somateria mollissima eggs (Common Eider)	3	(2)	2	(1)	1	(1)	9	(6)	15	(10)
Eggs of other species[1]	-	-	-	-	-	-	1	(1)	1	(1)
Unidentified eggs	1	(1)	-	-	-	-	-	-	1	(1)
Adult and young birds[1]	5	(3)	3	(2)	2	(1)	10	(6)	20	(13)
Total	9	(6)	5	(3)	3	(2)	20	(13)	37	(24)
FISH[1]										
Total	10	(6)	3	(2)	2	(1)	1	(1)	16	(10)
TERRESTRIAL INVERTEBRATES										
Insecta (except Ephydridae)	1	(1)	4	(3)	2	(1)	1	(1)	8	(5)
MARINE INVERTEBRATES										
Mollusca (clams, snails)	3	(2)	1	(1)	-	-	3	(2)	7	(4)
Ephydridae pupae (shoreflies)	1	(1)	-	-	-	-	-	-	1	(1)
Saduria entomon (isopods)	2	(1)	1	(1)	-	-	5	(3)	8	(5)
Brachyura (crabs)	-	-	-	-	-	-	2	(1)	2	(1)
Other Crustacea (except *Saduria* and Brachyura)	-	-	-	-	-	-	-	-	-	-
Asteroidea (starfish)	4	(3)	3	(2)	2	(1)	1	(1)	10	(6)
Echinoidea (sea urchins)	-	-	-	-	-	-	-	-	-	-
Total	5	(3)	5	(3)	1	(1)	12	(8)	23	(15)
BERRIES										
Rubus chamaemorus (cloudberry)	3	(2)	-	-	-	-	-	-	3	(2)
Empetrum nigrum (crowberry)	8	(5)	7	(4)	9	(6)	14	(9)	38	(24)
Arctostaphylos sp. (bearberry)	-	-	-	-	-	-	-	-	-	-
Vaccinium spp. (blueberry, cranberry)	-	-	-	-	-	-	-	-	-	-
Total	11	(7)	7	(4)	9	(6)	14	(9)	41	(26)
OTHER VEGETATION[1]										
Total	-	-	4	(3)	3	(2)	4	(3)	11	(7)
REFUSE FROM HUMANS										
Total	-	-	-	-	-	-	-	-	-	-
UNIDENTIFIED ITEMS										
Total	1	(1)	3	(2)	-	-	-	-	4	(3)

[1]For details about species see text.

Table 39. Analysis of Glaucous Gull pellets for the period June 15-July 5, 1976, no. of pellets = 203, Cape Espenberg, Alaska.

Food Item	Percent of Volume of Pellet Consisting of Item: 0-10 No. of Pellets	0-10 (% of Pellets)	11-49 No. of Pellets	11-49 (% of Pellets)	50-89 No. of Pellets	50-89 (% of Pellets)	90-100 No. of Pellets	90-100 (% of Pellets)	Total No. and (%) of Pellets	
MAMMALS										
Soricidae (shrews)	-	-	-	-	-	-	3	(1)	3	(1)
Spermophilus undulatus (Arctic Ground Squirrel)	-	-	-	-	-	-	-	-	-	-
Cricedidae (mice, lemmings)	1	(<1)	4	(2)	2	(1)	27	(13)	34	(17)
Pinnipedia (seals, walruses)	-	-	-	-	-	-	-	-	-	-
Rangifer tarandus (reindeer)	-	-	1	(<1)	-	-	-	-	1	(<1)
Unidentified mammals	-	-	-	-	1	(<1)	-	-	1	(<1)
Total	-	-	5	(2)	3	(1)	30	(15)	38	(19)
BIRDS AND BIRD EGGS										
Somateria mollissima eggs (Common Eider)	-	-	-	-	2	(1)	21	(10)	23	(11)
Eggs of other species[1]	-	-	-	-	-	-	3	(1)	3	(1)
Unidentified eggs	-	-	1	(<1)	-	-	-	-	1	(<1)
Adult and young birds[1]	-	-	2	(1)	3	(1)	10	(5)	15	(7)
Total	-	-	3	(1)	5	(2)	34	(17)	42	(21)
FISH[1]										
Total	18	(9)	3	(1)	2	(1)	17	(8)	40	(20)
TERRESTRIAL INVERTEBRATES										
Insecta (except Ephydridae)	6	(3)	-	-	-	-	1	(<1)	7	(3)
MARINE INVERTEBRATES										
Mollusca (clams, snails)	3	(1)	4	(2)	1	(<1)	1	(<1)	9	(4)
Ephydridae pupae (shoreflies)	1	(<1)	-	-	1	(<1)	2	(1)	4	(2)
Saduria entomon (isopods)	2	(1)	2	(1)	4	(2)	26	(13)	34	(17)
Brachyura (crabs)	-	-	-	-	-	-	1	(<1)	1	(<1)
Other Crustacea (except Saduria and Brachyura)	-	-	-	-	-	-	-	-	-	-
Asteroidea (starfish)	4	(2)	3	(1)	3	(1)	36	(18)	46	(23)
Echinoidea (sea urchins)	-	-	-	-	-	-	-	-	-	-
Total	4	(2)	3	(1)	5	(2)	70	(35)	82	(41)
BERRIES										
Rubus chamaemorus (cloudberry)	1	(<1)	-	-	-	-	-	-	1	(<1)
Empetrum nigrum (crowberry)	7	(3)	5	(2)	5	(2)	15	(7)	32	(16)
Arctostaphylos sp. (bearberry)	-	-	-	-	-	-	-	-	-	-
Vaccinium spp. (blueberry, cranberry)	-	-	-	-	-	-	-	-	-	-
Total	8	(4)	5	(2)	5	(2)	15	(7)	33	(16)
OTHER VEGETATION[1]										
Total	1	(<1)	1	(<1)	1	(<1)	3	(1)	6	(3)
REFUSE FROM HUMANS										
Total	-	-	-	-	-	-	1	(<1)	1	(<1)
UNIDENTIFIED ITEMS										
Total	2	(1)	-	-	1	(<1)	9	(4)	12	(6)

[1]For details about species see text.

Table 40. Analysis of Glaucous Gull pellets for the period July 5-July 16, 1976, no. of pellets = 1320, Cape Espenberg, Alaska.

Food Item	Percent of Volume of Pellet Consisting of Item: 0-10 No. of Pellets	0-10 (% of Pellets)	11-49 No. of Pellets	11-49 (% of Pellets)	50-89 No. of Pellets	50-89 (% of Pellets)	90-100 No. of Pellets	90-100 (% of Pellets)	Total No. and (%) of Pellets	
MAMMALS										
Soricidae (shrews)	-	-	-	-	-	-	-	-	-	-
Spermophilus undulatus (Arctic Ground Squirrel)	-	-	-	-	-	-	-	-	-	-
Cricedidae (mice, lemmings)	-	-	1	(<1)	-	-	8	(1)	9	(1)
Pinnipedia (seals, walruses)	1	(<1)	2	(<1)	3	(<1)	-	-	6	(<1)
Rangifer tarandus (reindeer)	-	-	-	-	-	-	-	-	-	-
Unidentified mammals	1	(<1)	1	(<1)	-	-	-	-	2	(<1)
Total	2	(<1)	4	(<1)	3	(<1)	8	(1)	17	(1)
BIRDS AND BIRD EGGS										
Somateria mollissima eggs (Common Eider)	2	(<1)	-	-	3	(<1)	12	(1)	17	(1)
Eggs of other species[1]	-	-	-	-	1	(<1)	2	(<1)	3	(<1)
Unidentified eggs	2	(<1)	1	(<1)	-	-	-	-	3	(<1)
Adult and young birds[1]	4	(<1)	-	-	8	(1)	11	(1)	23	(2)
Total	8	(1)	1	(<1)	12	(1)	25	(2)	46	(3)
FISH[1]										
Total	29	(2)	14	(1)	8	(1)	27	(2)	67	(5)
TERRESTRIAL INVERTEBRATES										
Insecta (except Ephydridae)	37	(3)	7	(1)	1	(<1)	-	-	45	(3)
MARINE INVERTEBRATES										
Mollusca (clams, snails)	1	(<1)	-	-	1	(<1)	3	(<1)	5	(<1)
Ephydridae pupae (shoreflies)	-	-	-	-	-	-	5	(<1)	5	(<1)
Saduria entomon (isopods)	5	(<1)	15	(1)	27	(2)	1184	(90)	1231	(93)
Brachyura (crabs)	-	-	-	-	-	-	1	(<1)	1	(<1)
Other Crustacea (except Saduria and Brachyura)	-	-	1	(<1)	-	-	-	-	1	(<1)
Asteroidea (starfish)	13	(1)	-	-	3	(<1)	20	(2)	36	(3)
Echinoidea (sea urchins)	-	-	-	-	-	-	1	(<1)	1	(<1)
Total	10	(1)	15	(1)	28	(2)	1217	(92)	1270	(96)
BERRIES										
Rubus chamaemorus (cloudberry)	-	-	1	(<1)	-	-	-	-	1	(<1)
Empetrum nigrum (crowberry)	8	(1)	5	(<1)	4	(<1)	2	(<1)	19	(1)
Arctostaphylos sp. (bearberry)	-	-	-	-	-	-	-	-	-	-
Vaccinium spp. (blueberry, cranberry)	-	-	-	-	-	-	-	-	-	-
Total	8	(1)	6	(<1)	4	(<1)	2	(<1)	20	(2)
OTHER VEGETATION[1]										
Total	-	-	3	(<1)	3	(<1)	4	(<1)	10	(1)
REFUSE FROM HUMANS										
Total	-	-	-	-	-	-	-	-	-	-
UNIDENTIFIED ITEMS										
Total	-	-	-	-	5	(<1)	11	(1)	16	(1)

[1]For details about species see text.

Table 41. Analysis of Glaucous Gull pellets for the period July 16-July 31, 1976, no. of pellets = 1616, Cape Espenberg, Alaska.

Food Item	Percent of Volume of Pellet Consisting of Item								Total No. and (%) of Pellets	
	0-10		11-49		50-89		90-100			
	No. of Pellets	(% of Pellets)	No. of Pellets	(% of Pellets)	No. of Pellets	(% of Pellets)	No. of Pellets	(% of Pellets)		
MAMMALS										
Soricidae (shrews)	-	-	-	-	-	-	-	-	-	-
Spermophilus undulatus (Arctic Ground Squirrel)	-	-	-	-	-	-	-	-	-	-
Cricedidae (mice, lemmings)	-	-	3	(<1)	3	(<1)	4	(<1)	10	(1)
Pinnipedia (seals, walruses)	-	-	1	(<1)	1	(<1)	-	-	2	(<1)
Rangifer tarandus (reindeer)	-	-	-	-	-	-	1	(<1)	1	(<1)
Unidentified mammals	-	-	1	(<1)	2	(<1)	-	-	3	(<1)
Total	-	-	5	(<1)	6	(<1)	5	(<1)	16	(1)
BIRDS AND BIRD EGGS										
Somateria mollissima eggs (common Eider)	3	(<1)	-	-	1	(<1)	5	(<1)	9	(1)
Eggs of other species[1]	1	(<1)	-	-	-	-	-	-	1	(<1)
Unidentified eggs	1	(<1)	-	-	1	(<1)	-	-	2	(<1)
Adult and young birds[1]	1	(<1)	3	(<1)	9	(1)	21	(1)	34	(2)
Total	6	(<1)	3	(<1)	11	(1)	26	(2)	46	(3)
FISH[1]										
Total	35	(2)	18	(1)	14	(1)	21	(1)	88	(5)
TERRESTRIAL INVERTEBRATES										
Insecta (except Ephydridae)	7	(<1)	3	(<1)	1	(<1)	1	(<1)	12	(1)
MARINE INVERTEBRATES										
Mollusca (clams, snails)	67	(4)	2	(<1)	1	(<1)	-	-	70	(4)
Ephydridae pupae (shoreflies)	1	(<1)	18	(1)	49	(3)	564	(35)	632	(39)
Saduria entomon (isopods)	63	(4)	40	(2)	44	(3)	818	(51)	965	(60)
Brachyura (crabs)	-	-	-	-	-	-	3	(<1)	3	(<1)
Other Crustacea (except Saduria and Brachyura)	-	-	1	(<1)	-	-	-	-	1	(<1)
Asteroidea (starfish)	3	(<1)	-	-	3	(<1)	14	(1)	20	(1)
Echinoidea (sea urchins)	-	-	-	-	-	-	-	-	-	-
Total	7	(<1)	20	(1)	40	(2)	1448	(90)	1515	(94)
BERRIES										
Rubus chamaemorus (cloudberry)	17	(1)	-	-	-	-	-	-	17	(1)
Empetrum nigrum (crowberry)	27	(2)	3	(<1)	3	(<1)	4	(<1)	37	(2)
Arctostaphylos sp. (bearberry)	-	-	-	-	-	-	-	-	-	-
Vaccinium spp. (blueberry, cranberry)	-	-	-	-	-	-	-	-	-	-
Total	42	(3)	3	(<1)	3	(<1)	4	(<1)	52	(3)
OTHER VEGETATION[1]										
Total	9	(1)	-	-	1	(<1)	1	(<1)	11	(1)
REFUSE FROM HUMANS										
Total	1	(<1)	1	(<1)	-	-	-	-	2	(<1)
UNIDENTIFIED ITEMS										
Total	5	(<1)	-	-	-	-	1	(<1)	6	(<1)

[1] For details about species see text.

Table 42. Analysis of Glaucous Gull pellets for the period July 31-August 18, 1976, no. of pellets = 318, Cape Espenberg, Alaska.

Food Item	Percent of Volume of Pellet Consisting of Item: 0-10 No. of Pellets	0-10 (% of Pellets)	11-49 No. of Pellets	11-49 (% of Pellets)	50-89 No. of Pellets	50-89 (% of Pellets)	90-100 No. of Pellets	90-100 (% of Pellets)	Total No. and (%) of Pellets	
MAMMALS										
Soricidae (shrews)	-	-	-	-	-	-	1	(<1)	1	(<1)
Spermophilus undulatus (Arctic Ground Squirrel)	-	-	-	-	-	-	-	-	-	-
Cricedidae (mice, lemmings)	1	(<1)	-	-	1	(<1)	1	(<1)	3	(1)
Pinnipedia (seals, walruses)	-	-	-	-	-	-	-	-	-	-
Rangifer tarandus (reindeer)	-	-	-	-	-	-	1	(<1)	1	(<1)
Unidentified mammals	-	-	-	-	-	-	1	(<1)	1	(<1)
Total	1	(<1)	-	-	1	(<1)	4	(1)	6	(2)
BIRDS AND BIRD EGGS										
Somateria mollissima eggs (Common Eider)	-	-	-	-	-	-	-	-	-	-
Eggs of other species[1]	-	-	-	-	-	-	-	-	-	-
Unidentified eggs	-	-	-	-	1	(<1)	-	-	1	(<1)
Adult and young birds[1]	-	-	-	-	2	(1)	9	(3)	11	(3)
Total	-	-	-	-	3	(1)	9	(3)	12	(4)
FISH[1]										
Total	13	(4)	14	(4)	4	(1)	15	(5)	46	(14)
TERRESTRIAL INVERTEBRATES										
Insecta (except Ephydridae)	10	(3)	2	(1)	-	-	2	(1)	14	(4)
MARINE INVERTEBRATES										
Mollusca (clams, snails)	7	(2)	1	(<1)	-	-	-	-	8	(3)
Ephydridae pupae (shoreflies)	6	(2)	1	(<1)	1	(<1)	9	(3)	17	(5)
Saduria entomon (isopods)	11	(3)	13	(4)	13	(4)	186	(58)	223	(70)
Brachyura (crabs)	1	(<1)	-	-	-	-	-	-	1	(<1)
Other Crustacea (except *Saduria* and Brachyura)	1	(<1)	-	-	1	(<1)	-	-	2	(1)
Asteroidea (starfish)	9	(3)	2	(1)	4	(1)	15	(5)	30	(9)
Echinoidea (sea urchins)	-	-	-	-	-	-	-	-	-	-
Total	14	(4)	12	(4)	17	(5)	187	(59)	230	(72)
BERRIES										
Rubus chamaemorus (cloudberry)	7	(2)	-	-	1	(<1)	-	-	8	(3)
Empetrum nigrum (crowberry)	8	(3)	6	(2)	13	(4)	20	(6)	47	(15)
Arctostaphylos sp. (bearberry)	-	-	-	-	-	-	-	-	-	-
Vaccinium spp. (blueberry, cranberry)	9	(3)	6	(2)	5	(2)	8	(3)	28	(9)
Total	18	(6)	7	(2)	13	(4)	33	(10)	71	(22)
OTHER VEGETATION[1]										
Total	2	(1)	2	(1)	1	(<1)	1	(<1)	6	(2)
REFUSE FROM HUMANS										
Total	-	-	-	-	-	-	-	-	-	-
UNIDENTIFIED ITEMS										
Total	1	(<1)	3	(1)	-	-	-	-	4	(1)

[1]For details about species see text.

Table 43. Analysis of Glaucous Gull pellets for the period August 18-August 30, 1976, no. of pellets = 212, Cape Espenberg, Alaska.

Food Item	Percent of Volume of Pellet Consisting of Item								Total No. and (%) of Pellets	
	0-10		11-49		50-89		90-100			
	No. of Pellets	(% of Pellets)	No. of Pellets	(% of Pellets)	No. of Pellets	(% of Pellets)	No. of Pellets	(% of Pellets)		
MAMMALS										
Soricidae (shrews)	-	-	-	-	-	-	-	-	-	-
Spermophilus undulatus (Arctic Ground Squirrel)	-	-	-	-	-	-	-	-	-	-
Cricedidae (mice, lemmings)	-	-	-	-	2	(1)	1	(4)	3	(1)
Pinnipedia (seals, walruses)	-	-	-	-	-	-	-	-	-	-
Rangifer tarandus (reindeer)	-	-	-	-	-	-	-	-	-	-
Unidentified mammals	-	-	-	-	-	-	-	-	-	-
Total	-	-	-	-	2	(1)	1	(<1)	3	(1)
BIRDS AND BIRD EGGS										
Somateria mollissima eggs (Common Eider)	-	-	1	(<1)	-	-	-	-	1	(<1)
Eggs of other species[1]	-	-	-	-	-	-	-	-	-	-
Unidentified eggs	-	-	-	-	-	-	-	-	-	-
Adult and young birds[1]	-	-	-	-	3	(1)	3	(1)	6	(3)
Total	-	-	1	(<1)	3	(1)	3	(1)	7	(3)
FISH[1]										
Total	11	(5)	3	(1)	2	(1)	11	(5)	27	(13)
TERRESTRIAL INVERTEBRATES										
Insecta (except Ephydridae)	2	(1)	-	-	-	-	-	-	2	(1)
MARINE INVERTEBRATES										
Mollusca (clams, snails)	1	(<1)	-	-	-	-	-	-	1	(<1)
Ephydridae pupae (shoreflies)	-	-	-	-	1	(<1)	7	(3)	8	(4)
Saduria entomon (isopods)	7	(3)	2	(1)	4	(2)	90	(42)	103	(49)
Brachyura (crabs)	-	-	-	-	-	-	3	(1)	3	(1)
Other Crustacea (except *Saduria* and Brachyura)	1	(<1)	-	-	-	-	-	-	1	(<1)
Asteroidea (starfish)	1	(<1)	1	(<1)	1	(<1)	3	(1)	6	(3)
Echinoidea (sea urchins)	-	-	-	-	-	-	-	-	-	-
Total	7	(3)	2	(1)	5	(2)	104	(49)	118	(56)
BERRIES										
Rubus chamaemorus (cloudberry)	13	(6)	7	(3)	2	(1)	1	(<1)	23	(11)
Empetrum nigrum (crowberry)	12	(6)	8	(4)	30	(14)	23	(11)	73	(34)
Arctostaphylos sp. (bearberry)	1	(<1)	-	-	-	-	-	-	1	(<1)
Vaccinium spp. (blueberry, cranberry)	15	(7)	23	(11)	7	(3)	18	(8)	63	(30)
Total	7	(3)	4	(2)	7	(3)	75	(35)	93	(44)
OTHER VEGETATION[1]										
Total	-	-	1	(<1)	1	(<1)	-	-	2	(1)
REFUSE FROM HUMANS										
Total	-	-	-	-	-	-	1	(<1)	1	(<1)
UNIDENTIFIED ITEMS										
Total	1	(<1)	-	-	-	-	1	(<1)	2	(1)

[1]For details about species see text.

Table 44. Analysis of Glaucous Gull pellets for the period August 30-September 11, 1976, no. of pellets = 266, Cape Espenberg, Alaska.

Food Item	Percent of Volume of Pellet Consisting of Item: 0-10 No. of Pellets	0-10 (% of Pellets)	11-49 No. of Pellets	11-49 (% of Pellets)	50-89 No. of Pellets	50-89 (% of Pellets)	90-100 No. of Pellets	90-100 (% of Pellets)	Total No. and (%) of Pellets	
MAMMALS										
Soricidae (shrews)	-	-	-	-	-	-	-	-	-	-
Spermophilus undulatus (Arctic Ground Squirrel)	-	-	-	-	-	-	1	(<1)	1	(<1)
Cricedidae (mice, lemmings)	-	-	-	-	-	-	-	-	-	-
Pinnipedia (seals, walruses)	-	-	-	-	-	-	-	-	-	-
Rangifer tarandus (reindeer)	-	-	-	-	-	-	-	-	-	-
Unidentified mammals	-	-	-	-	1	(<1)	-	-	1	(<1)
Total	-	-	-	-	1	(<1)	1	(<1)	2	(1)
BIRDS AND BIRD EGGS										
Somateria mollissima eggs (Common Eider)	-	-	-	-	-	-	1	(<1)	1	(<1)
Eggs of other species[1]	-	-	-	-	-	-	1	(<1)	1	(<1)
Unidentified eggs	-	-	-	-	-	-	-	-	-	-
Adult and young birds[1]	-	-	2	(1)	1	(<1)	2	(1)	5	(2)
Total	-	-	2	(1)	1	(<1)	4	(2)	7	(3)
FISH[1]										
Total	3	(1)	-	-	1	(<1)	5	(2)	9	(3)
TERRESTRIAL INVERTEBRATES										
Insecta (except Ephydridae)	3	(1)	1	(<1)	-	-	-	-	4	(2)
MARINE INVERTEBRATES										
Mollusca (clams, snails)	2	(1)	-	-	-	-	-	-	2	(1)
Ephydridae pupae (shoreflies)	3	(1)	-	-	-	-	5	(2)	8	(3)
Saduria entomon (isopods)	6	(2)	3	(1)	6	(2)	37	(14)	52	(20)
Brachyura (crabs)	-	-	-	-	-	-	-	-	-	-
Other Crustacea (except Saduria and Brachyura)	-	-	2	(1)	-	-	-	-	2	(1)
Asteroidea (starfish)	2	(1)	-	-	3	(1)	14	(5)	19	(7)
Echinoidea (sea urchins)	-	-	-	-	-	-	-	-	-	-
Total	4	(2)	5	(2)	6	(2)	58	(22)	73	(27)
BERRIES										
Rubus chamaemorus (cloudberry)	16	(6)	8	(3)	1	(<1)	2	(1)	27	(10)
Empetrum nigrum (crowberry)	26	(10)	84	(10)	49	(18)	12	(5)	171	(64)
Arctostaphylos sp. (bearberry)	-	-	-	-	-	-	-	-	-	-
Vaccinium spp. (blueberry, cranberry)	7	(3)	5	(2)	3	(1)	5	(2)	20	(8)
Total	30	(11)	92	(36)	41	(15)	30	(11)	193	(73)
OTHER VEGETATION[1]										
Total	3	(1)	10	(4)	110	(41)	31	(12)	154	(58)
REFUSE FROM HUMANS										
Total	1	(<1)	-	-	-	-	-	-	1	(<1)
UNIDENTIFIED ITEMS										
Total	-	-	-	-	1	(<1)	-	-	1	(<1)

[1]For details about species see text.

Table 45. Analysis of Glaucous Gull pellets for period before June 5, 1977, no. of pellets = 179, Cape Espenberg, Alaska.

Food Item	Percent of Volume of Pellet Consisting of Item: 0-10 No. of Pellets	0-10 (% of Pellets)	11-49 No. of Pellets	11-49 (% of Pellets)	50-89 No of Pellets	50-89 (% of Pellets)	90-100 No. of Pellets	90-100 (% of Pellets)	Total No. and (%) of Pellets	
MAMMALS										
Soricidae (shrews)	-	-	-	-	-	-	-	-	-	-
Spermophilus undulatus (Arctic Ground Squirrel)	-	-	-	-	1	(1)	-	-	1	(1)
Cricedidae (mice, lemmings)	1	(1)	4	(2)	2	(1)	6	(3)	13	(7)
Pinnipedia (seals, walruses)	-	-	-	-	1		-	-	1	(1)
Rangifer tarandus (reindeer)	-	-	-	-	-	-	-	-	-	-
Unidentified mammals	-	-	1	(1)	4	(2)	5	(3)	10	(6)
Total	1	(1)	4	(2)	7	(4)	12	(7)	24	(13)
BIRDS AND BIRD EGGS										
Somateria mollissima eggs (Common Eider)	1	(1)	-	-	1	(1)	1	(1)	3	(2)
Eggs of other species[1]	1	(1)	-	-	-	-	2	(1)	3	(2)
Unidentified eggs	4	(2)	-	-	-	-	-	-	4	(2)
Adult and young birds[1]	-	-	-	-	-	-	5	(3)	5	(3)
Total	6	(3)	-	-	1	(1)	8	(4)	15	(8)
FISH[1]										
Total	8	(4)	8	(4)	3	(2)	15	(8)	34	(19)
TERRESTRIAL INVERTEBRATES										
Insecta (except Ephydridae)	-	-	-	-	-	-	1	(1)	1	(1)
MARINE INVERTEBRATES										
Mollusca (clams, snails)	4	(2)	1	(1)	-	-	-	-	5	(3)
Ephydridae pupae (shoreflies)	-	-	-	-	1	(1)	-	-	1	(1)
Saduria entomon (isopods)	1	(1)	3	(2)	1	(1)	10	(6)	15	(8)
Brachyura (crabs)	1	(1)	-	-	2	(1)	3	(2)	6	(3)
Other Crustacea (except Saduria and Brachyura)	-	-	-	-	-	-	-	-	-	-
Asteroidea (starfish)	1	(1)	3	(2)	5	(3)	28	(16)	37	(21)
Echinoidea (sea urchins)	-	-	-	-	-	-	-	-	-	-
Total	5	(3)	6	(3)	5	(3)	44	(25)	60	(34)
BERRIES										
Rubus chamaemorus (cloudberry)	-	-	-	-	-	-	-	-	-	-
Empetrum nigrum (crowberry)	7	(4)	9	(5)	18	(10)	29	(16)	63	(35)
Arctostaphylos sp. (bearberry)	-	-	1	(1)	-	-	-	-	1	(1)
Vaccinium spp. (blueberry, cranberry)	2	(1)	1	(1)	-	-	-	-	3	(2)
Total	7	(4)	9	(5)	16	(9)	31	(17)	63	(35)
OTHER VEGETATION[1]										
Total	-	-	2	(1)	10	(6)	22	(12)	34	(19)
REFUSE FROM HUMANS										
Total	-	-	-	-	-	-	-	-	-	-
UNIDENTIFIED ITEMS										
Total	2	(1)	2	(1)	5	(3)	7	(4)	16	(9)

[1] For details about species see text.

Table 46. Analysis of Glaucous Gull pellets for the period June 5-June 15, 1977, no. of pellets = 193, Cape Espenberg, Alaska.

Food Item	Percent of Volume of Pellet Consisting of Item								Total No. and (%) of Pellets	
	0-10		11-49		50-89		90-100			
	No. of Pellets	(% of Pellets)	No. of Pellets	(% of Pellets)	No. of Pellets	(% of Pellets)	No. of Pellets	(% of Pellets)		
MAMMALS										
Soricidae (shrews)	-	-	-	-	-	-	-	-	-	-
Spermophilus undulatus (Arctic Ground Squirrel)	-	-	-	-	-	-	2	(1)	2	(1)
Cricedidae (mice, lemmings)	1	(1)	-	-	-	-	1	(1)	2	(1)
Pinnipedia (seals, walruses)	-	-	-	-	-	-	1	(1)	1	(1)
Rangifer tarandus (reindeer)	-	-	-	-	-	-	-	-	-	-
Unidentified mammals	-	-	-	-	2	(1)	2	(1)	4	(2)
Total	1	(1)	-	-	2	(1)	6	(3)	9	(5)
BIRDS AND BIRD EGGS										
Somateria mollissima eggs (Common Eider)	-	-	2	(1)	5	(3)	14	(7)	21	(11)
Eggs of other species[1]	-	-	1	(1)	-	-	3	(2)	4	(2)
Unidentified eggs	-	-	1	(1)	2	(1)	1	(1)	4	(2)
Adult and young birds[1]	-	-	2	(1)	1	(1)	1	(1)	4	(2)
Total	-	-	4	(2)	9	(5)	19	(10)	32	(17)
FISH[1]										
Total	14	(7)	14	(7)	5	(3)	11	(6)	44	(23)
TERRESTRIAL INVERTEBRATES										
Insecta (except Ephydridae)	-	-	1	(1)	-	-	-	-	1	(1)
MARINE INVERTEBRATES										
Mollusca (clams, snails)	6	(3)	2	(1)	-	-	1	(1)	9	(5)
Ephydridae pupae (shoreflies)	1	(1)	-	-	-	-	-	-	1	(1)
Saduria entomon (isopods)	1	(1)	3	(2)	3	(2)	12	(6)	19	(10)
Brachyura (crabs)	3	(2)	-	-	4	(2)	6	(3)	13	(7)
Other Crustacea (except *Saduria* and Brachyura)	-	-	-	-	-	-	2	(1)	2	(1)
Asteroidea (starfish)	2	(1)	7	(4)	4	(2)	56	(29)	69	(36)
Echinoidea (sea urchins)	-	-	-	-	-	-	-	-	-	-
Total	4	(2)	8	(4)	7	(4)	82	(42)	101	(52)
BERRIES										
Rubus chamaemorus (cloudberry)	-	-	-	-	-	-	-	-	-	-
Empetrum nigrum (crowberry)	4	(2)	5	(3)	3	(2)	12	(6)	24	(12)
Arctostaphylos sp. (bearberry)	1	(1)	-	-	-	-	-	-	1	(1)
Vaccinium spp. (blueberry, cranberry)	-	-	-	-	-	-	-	-	-	-
Total	4	(2)	5	(3)	3	(2)	12	(6)	24	(12)
OTHER VEGETATION[1]										
Total	1	(1)	-	-	6	(3)	33	(17)	40	(21)
REFUSE FROM HUMANS										
Total	-	-	-	-	-	-	-	-	-	-
UNIDENTIFIED ITEMS										
Total	-	-	-	-	-	-	2	(1)	2	(1)

[1] For details about species see text.

Table 47. Analysis of Glaucous Gull pellets for the period June 15-June 30, 1977, no. of pellets = 352, Cape Espenberg, Alaska.

Food Item	Percent of Volume of Pellet Consisting of Item: 0-10 No. of Pellets	0-10 (% of Pellets)	11-49 No. of Pellets	11-49 (% of Pellets)	50-89 No. of Pellets	50-89 (% of Pellets)	90-100 No. of Pellets	90-100 (% of Pellets)	Total No. and (%) of Pellets	
MAMMALS										
Soricidae (shrews)	-	-	-	-	-	-	-	-	-	-
Spermophilus undulatus (Arctic Ground Squirrel)	-	-	-	-	-	-	-	-	-	-
Cricedidae (mice, lemmings)	-	-	-	-	-	-	1	(<1)	1	(<1)
Pinnipedia (seals, walruses)	-	-	-	-	-	-	-	-	-	-
Rangifer tarandus (reindeer)	-	-	-	-	-	-	-	-	-	-
Unidentified mammals	-	-	-	-	-	-	1	(<1)	1	(<1)
Total	-	-	-	-	-	-	2	(1)	2	(1)
BIRDS AND BIRD EGGS										
Somateria mollissima eggs (Common Eider)	-	-	-	-	1	(<1)	19	(5)	20	(6)
Eggs of other species[1]	-	-	-	-	-	-	1	(<1)	1	(<1)
Unidentified eggs	1	(<1)	-	-	2	(1)	4	(1)	7	(2)
Adult and young birds[1]	-	-	-	-	-	-	1	(<1)	1	(<1)
Total	1	(<1)	-	-	3	(1)	25	(7)	29	(8)
FISH[1]										
Total	18	(5)	15	(4)	6	(2)	16	(5)	55	(16)
TERRESTRIAL INVERTEBRATES										
Insecta (except Ephydridae)	-	-	2	(1)	1	(<1)	2	(1)	5	(1)
MARINE INVERTEBRATES										
Mollusca (clams, snails)	2	(1)	1	(<1)	2	(1)	-	-	5	(1)
Ephydridae pupae (shoreflies)	-	-	-	-	-	-	4	(1)	4	(1)
Saduria entomon (isopods)	5	(1)	7	(2)	18	(5)	117	(33)	147	(42)
Brachyura (crabs)	1	(<1)	2	(1)	1	(<1)	5	(1)	9	(3)
Other Crustacea (except *Saduria* and Brachyura)	2	(1)	3	(1)	-	-	7	(2)	12	(3)
Asteroidea (starfish)	-	-	1	(<1)	5	(1)	34	(10)	40	(11)
Echinoidea (sea urchins)	-	-	-	-	-	-	-	-	-	-
Total	-	-	6	(2)	19	(5)	175	(50)	200	(57)
BERRIES										
Rubus chamaemorus (cloudberry)	-	-	-	-	-	-	-	-	-	-
Empetrum nigrum (crowberry)	19	(5)	14	(4)	6	(2)	5	(1)	44	(12)
Arctostaphylos sp. (bearberry)	-	-	-	-	-	-	-	-	-	-
Vaccinium spp. (blueberry, cranberry)	-	-	-	-	-	-	-	-	-	-
Total	19	(5)	14	(4)	6	(2)	5	(1)	44	(12)
OTHER VEGETATION[1]										
Total	1	(<1)	3	(1)	16	(5)	76	(22)	96	(27)
REFUSE FROM HUMANS										
Total	-	-	-	-	-	-	-	-	-	-
UNIDENTIFIED ITEMS										
Total	-	-	3	(1)	-	-	5	(1)	7	(2)

[1]For details about species see text.

Table 48. Analysis of Glaucous Gull pellets for the period June 30-July 14, 1977, no. of pellets = 288, Cape Espenberg, Alaska.

Food Item	Percent of Volume of Pellet Consisting of Item: 0-10 No. of Pellets	0-10 (% of Pellets)	11-49 No. of Pellets	11-49 (% of Pellets)	50-89 No. of Pellets	50-89 (% of Pellets)	90-100 No. of Pellets	90-100 (% of Pellets)	Total No. and (%) of Pellets	
MAMMALS										
Soricidae (shrews)	-	-	-	-	-	-	-	-	-	-
Spermophilus undulatus (Arctic Ground Squirrel)	-	-	-	-	-	-	1	(<1)	1	(<1)
Cricedidae (mice, lemmings)	-	-	-	-	-	-	-	-	-	-
Pinnipedia (seals, walruses)	-	-	2	(1)	1	(<1)	2	(1)	5	(2)
Rangifer tarandus (reindeer)	-	-	-	-	-	-	1	(<1)	1	(<1)
Unidentified mammals	-	-	-	-	1	(<1)	1	(<1)	2	(1)
Total	-	-	2	(1)	2	(1)	5	(2)	9	(3)
BIRDS AND BIRD EGGS										
Somateria mollissima eggs (Common Eider)	-	-	-	-	1	(<1)	14	(5)	15	(5)
Eggs of other species[1]	-	-	-	-	-	-	4	(1)	4	(1)
Unidentified eggs	1	(<1)	-	-	-	-	1	(<1)	2	(1)
Adult and young birds[1]	1	(<1)	-	-	-	-	7	(2)	8	(3)
Total	2	(1)	-	-	1	(<1)	26	(9)	29	(10)
FISH[1]										
Total	17	(6)	21	(7)	12	(4)	23	(8)	73	(25)
TERRESTRIAL INVERTEBRATES										
Insecta (except Ephydridae)	4	(1)	5	(2)	2	(1)	6	(2)	17	(6)
MARINE INVERTEBRATES										
Mollusca (clams, snails)	2	(1)	2	(1)	1	(<1)	-	-	5	(2)
Ephydridae pupae (shoreflies)	-	-	2	(1)	-	-	3	(1)	5	(2)
Saduria entomon (isopods)	10	(3)	13	(5)	21	(7)	120	(42)	164	(57)
Brachyura (crabs)	3	(1)	3	(1)	6	(2)	7	(2)	19	(7)
Other Crustacea (except *Saduria* and Brachyura)	-	-	2	(1)	4	(1)	5	(2)	11	(4)
Asteroidea (starfish)	1	(<1)	2	(1)	2	(1)	9	(3)	14	(5)
Echinoidea (sea urchins)	-	-	-	-	-	-	-	-	-	-
Total	6	(2)	11	(4)	16	(6)	160	(56)	193	(67)
BERRIES										
Rubus chamaemorus (cloudberry)	-	-	-	-	-	-	-	-	-	-
Empetrum nigrum (crowberry)	2	(1)	2	(1)	1	(<1)	6	(2)	11	(4)
Arctostaphylos sp. (bearberry)	-	-	-	-	-	-	-	-	-	-
Vaccinium spp. (blueberry, cranberry)	-	-	-	-	-	-	-	-	-	-
Total	2	(1)	2	(1)	1	(<1)	6	(2)	11	(4)
OTHER VEGETATION[1]										
Total	1	(<1)	3	(1)	5	(2)	6	(2)	15	(5)
REFUSE FROM HUMANS										
Total	-	-	-	-	-	-	-	-	-	-
UNIDENTIFIED ITEMS										
Total	-	-	-	-	1	(<1)	12	(4)	13	(5)

[1]For details about species see text.

Table 49. Analysis of Glaucous Gull pellets for the period July 14-July 30, 1977, no. of pellets = 295, Cape Espenberg, Alaska.

Food Item	Percent of Volume of Pellet Consisting of Item								Total No. and (%) of Pellets	
	0-10		11-49		50-89		90-100			
	No. of Pellets	(% of Pellets)	No. of Pellets	(% of Pellets)	No. of Pellets	(% of Pellets)	No. of Pellets	(% of Pellets)		
MAMMALS										
Soricidae (shrews)	-	-	-	-	-	-	1	(<1)	1	(<1)
Spermophilus undulatus (Arctic Ground Squirrel)	-	-	-	-	-	-	-	-	-	-
Cricedidae (mice, lemmings)	-	-	-	-	-	-	2	(1)	2	(1)
Pinnipedia (seals, walruses)	5	(2)	3	(1)	1	(<1)	1	(<1)	10	(3)
Rangifer tarandus (reindeer)	-		1	(<1)	-	-	-	-	1	(<1)
Unidentified mammals	2	(1)	-	-	-	-	3	(1)	5	(2)
Total	7	(2)	4	(1)	1	(<1)	7	(2)	19	(6)
BIRDS AND BIRD EGGS										
Somateria mollissima eggs (Common Eider)	-	-	-	-	1	(<1)	2	(1)	3	(1)
Eggs of other species[1]	-	-	-	-	-	-	1	(<1)	1	(<1)
Unidentified eggs	-	-	-	-	1	(<1)	1	(<1)	2	(1)
Adult and young birds[1]	1	(<1)	2	(1)	6	(2)	29	(10)	38	(13)
Total	1	(<1)	2	(1)	8	(3)	33	(11)	44	(15)
FISH[1]										
Total	26	(9)	18	(6)	4	(1)	27	(9)	75	(25)
TERRESTRIAL INVERTEBRATES										
Insecta (except Ephydridae)	7	(2)	4	(1)	2	(1)	12	(4)	25	(8)
MARINE INVERTEBRATES										
Mollusca (clams, snails)	8	(3)	-	-	-	-	5	(2)	13	(4)
Ephydridae pupae (shoreflies)	6	(2)	2	(1)	13	(4)	24	(8)	45	(15)
Saduria entomon (isopods)	6	(2)	5	(2)	20	(7)	60	(20)	91	(31)
Brachyura (crabs)	2	(1)	4	(1)	4	(1)	36	(12)	46	(16)
Other Crustacea (except *Saduria* and Brachyura)	2	(1)	2	(1)	3	(1)	6	(2)	13	(4)
Asteroidea (starfish)	2	(1)	1	(<1)	2	(1)	4	(1)	9	(3)
Echinoidea (sea urchins)	-	-	-	-	-	-	-	-	-	-
Total	9	(3)	7	(2)	32	(11)	143	(48)	191	(65)
BERRIES										
Rubus chamaemorus (cloudberry)	1	(<1)	-	-	-	-	-	-	1	(<1)
Empetrum nigrum (crowberry)	11	(4)	7	(2)	2	(1)	2	(1)	22	(7)
Arctostaphylos sp. (bearberry)	-	-	-	-	-	-	-	-	-	-
Vaccinium spp. (blueberry, cranberry)	-	-	1	(<1)	6	(2)	6	(2)	13	(4)
Total	11	(4)	5	(2)	8	(3)	9	(3)	33	(11)
OTHER VEGETATION[1]										
Total	-	-	-	-	-	-	1	(<1)	1	(<1)
REFUSE FROM HUMANS										
Total	-	-	-	-	-	-	-	-	-	-
UNIDENTIFIED ITEMS										
Total	-	-	2	(1)	1	(<1)	10	(3)	13	(4)

[1]For details about species see text.

Table 50. Analysis of Glaucous Gull pellets for the period July 30-August 16, 1977, no. of pellets = 763, Cape Espenberg, Alaska.

Food Item	Percent of Volume of Pellet Consisting of Item								Total No. and (%) of Pellets	
	0-10		11-49		50-89		90-100			
	No. of Pellets	(% of Pellets)	No. of Pellets	(% of Pellets)	No. of Pellets	(% of Pellets)	No. of Pellets	(% of Pellets)		
MAMMALS										
Soricidae (shrews)	-	-	-	-	-	-	-	-	-	-
Spermophilus undulatus (Arctic Ground Squirrel)	-	-	-	-	-	-	-	-	-	-
Cricedidae (mice, lemmings)	-	-	-	-	-	-	1	(<1)	1	(<1)
Pinnipedia (seals, walruses)	-	-	-	-	1	(<1)	3	(<1)	4	(1)
Rangifer tarandus (reindeer)	-	-	-	-	-	-	3	(<1)	3	(<1)
Unidentified mammals	-	-	-	-	2	(<1)	-	-	2	(<1)
Total	-	-	-	-	3	(<1)	7	(1)	10	(1)
BIRDS AND BIRD EGGS										
Somateria mollissima eggs (Common Eider)	-	-	-	-	-	-	2	(<1)	2	(<1)
Eggs of other species[1]	-	-	-	-	-	-	-	-	-	-
Unidentified eggs[1]	8	(1)	1	(<1)	1	(<1)	3	(<1)	13	(2)
Adult and young birds[1]	-	-	2	(<1)	6	(1)	22	(3)	30	(4)
Total	8	(1)	3	(<1)	7	(1)	27	(4)	45	(6)
FISH[1]										
Total	43	(6)	34	(4)	16	(2)	33	(4)	116	(15)
TERRESTRIAL INVERTEBRATES										
Insecta (except Ephydridae)	8	(1)	3	(<1)	2	(<1)	-	-	13	(2)
MARINE INVERTEBRATES										
Mollusca (clams, snails)	17	(2)	1	(<1)	1	(<1)	-	-	19	(2)
Ephydridae pupae (shoreflies)	8	(1)	2	(<1)	2	(<1)	3	(<1)	15	(2)
Saduria entomon (isopods)	44	(6)	20	(3)	27	(4)	178	(23)	269	(35)
Brachyura (crabs)	-	-	1	(<1)	-	-	2	(<1)	3	(<1)
Other Crustacea (except Saduria and Brachyura)	2	(<1)	4	(1)	2	(<1)	-	-	8	(1)
Asteroidea (starfish)	15	(2)	6	(1)	9	(1)	42	(6)	72	(9)
Echinoidea (sea urchins)	-	-	-	-	-	-	-	-	-	-
Total	68	(9)	19	(2)	32	(4)	236	(31)	355	(47)
BERRIES										
Rubus chamaemorus (cloudberry)	30	(4)	28	(4)	19	(2)	10	(1)	87	(11)
Empetrum nigrum (crowberry)	40	(5)	42	(6)	13	(2)	24	(3)	119	(16)
Arctostaphylos sp. (bearberry)	-	-	-	-	-	-	-	-	-	-
Vaccinium spp. (blueberry, cranberry)	43	(6)	51	(7)	82	(11)	248	(33)	424	(56)
Total	38	(5)	34	(4)	38	(5)	381	(50)	491	(64)
OTHER VEGETATION[1]										
Total	4	(1)	3	(<1)	1	(<1)	3	(<1)	11	(1)
REFUSE FROM HUMANS										
Total	-	-	-	-	-	-	-	-	-	-
UNIDENTIFIED ITEMS										
Total	-	-	-	-	1	(<1)	2	(<1)	3	(<1)

[1] For details about species see text.

Table 51. Analysis of Glaucous Gull pellets for the period August 16-August 31, 1977, no. of pellets = 385, Cape Espenberg, Alaska.

Food Item	Percent of Volume of Pellet Consisting of Item: 0-10 No. of Pellets	0-10 (% of Pellets)	11-49 No. of Pellets	11-49 (% of Pellets)	50-89 No. of Pellets	50-89 (% of Pellets)	90-100 No. of Pellets	90-100 (% of Pellets)	Total No. and (%) of Pellets	
MAMMALS										
Soricidae (shrews)	-	-	-	-	-	-	-	-	-	-
Spermophilus undulatus (Arctic Ground Squirrel)	-	-	-	-	-	-	-	-	-	-
Cricedidae (mice, lemmings)	-	-	-	-	-	-	-	-	-	-
Pinnipedia (seals, walruses)	-	-	-	-	-	-	3	(1)	3	(1)
Rangifer tarandus (reindeer)	-	-	-	-	-	-	-	-	-	-
Unidentified mammals	-	-	-	-	-	-	-	-	-	-
Total	-	-	-	-	-	-	3	(1)	3	(1)
BIRDS AND BIRD EGGS										
Somateria mollissima eggs (Common Eider)	-	-	-	-	-	-	-	-	-	-
Eggs of other species[1]	-	-	-	-	-	-	-	-	-	-
Unidentified eggs	7	(2)	1	(<1)	1	(<1)	9	(2)	18	(5)
Adult and young birds[1]	-	-	-	-	1	(<1)	1	(<1)	2	(1)
Total	7	(2)	1	(<1)	2	(1)	10	(3)	20	(5)
FISH[1]										
Total	16	(4)	12	(3)	3	(1)	9	(2)	40	(10)
TERRESTRIAL INVERTEBRATES										
Insecta (except Ephydridae)	9	(2)	4	(1)	2	(1)	3	(1)	18	(5)
MARINE INVERTEBRATES										
Mollusca (clams, snails)	20	(5)	3	(1)	1	(<1)	-	-	24	(6)
Ephydridae pupae (shoreflies)	-	-	-	-	-	-	-	-	-	-
Saduria entomon (isopods)	26	(7)	15	(4)	11	(3)	69	(18)	121	(3)
Brachyura (crabs)	-	-	-	-	-	-	-	-	-	-
Other Crustacea (except Saduria and Brachyura)	1	(<1)	3	(1)	1	(<1)	1	(<1)	6	(2)
Asteroidea (starfish)	-	-	-	-	-	-	-	-	-	-
Echinoidea (sea urchins)	-	-	1	(<1)	7	(2)	42	(11)	50	(13)
Total	24	(6)	28	(7)	13	(3)	117	(30)	182	(47)
BERRIES										
Rubus chamaemorus (cloudberry)	15	(4)	21	(5)	13	(3)	-	-	49	(13)
Empetrum nigrum (crowberry)	24	(6)	7	(2)	45	(12)	8	(2)	84	(22)
Arctostaphylos sp. (bearberry)	-	-	-	-	-	-	-	-	-	-
Vaccinium spp. (blueberry, cranberry)	23	(6)	27	(7)	63	(16)	123	(32)	236	(61)
Total	15	(4)	9	(2)	42	(11)	187	(49)	253	(66)
OTHER VEGETATION[1]										
Total	1	(<1)	1	(<1)	-	-	2	(1)	4	(1)
REFUSE FROM HUMANS										
Total	-	-	-	-	-	-	-	-	-	-
UNIDENTIFIED ITEMS										
Total	-	-	1	(<1)	-	-	2	(1)	3	(1)

[1]For details about species see text.

Table 52. Analysis of Glaucous Gull pellets for the period August 31-September 16, 1977, no. of pellets = 182, Cape Espenberg, Alaska.

Food Item	Percent of Volume of Pellet Consisting of Item: 0-10 No. of Pellets	0-10 (% of Pellets)	11-49 No. of Pellets	11-49 (% of Pellets)	50-89 No. of Pellets	50-89 (% of Pellets)	90-100 No. of Pellets	90-100 (% of Pellets)	Total No. and (%) of Pellets	
MAMMALS										
Soricidae (shrews)	-	-	-	-	-	-	-	-	-	-
Spermophilus undulatus (Arctic Ground Squirrel)	-	-	-	-	-	-	-	-	-	-
Cricedidae (mice, lemmings)	-	-	-	-	-	-	1	(1)	1	(1)
Pinnipedia (seals, walruses)	-	-	-	-	-	-	-	-	-	-
Rangifer tarandus (reindeer)	1	(1)	-	-	-	-	-	-	1	(1)
Unidentified mammals	-	-	1	(1)	-	-	-	-	1	(1)
Total	1	(1)	1	(1)	-	-	1	(1)	3	(2)
BIRDS AND BIRD EGGS										
Somateria mollissima eggs (Common Eider)	-	-	-	-	-	-	-	-	-	-
Eggs of other species[1]	-	-	-	-	-	-	-	-	-	-
Unidentified eggs	-	-	-	-	-	-	-	-	-	-
Adult and young birds[1]	-	-	-	-	1	(1)	2	(1)	3	(2)
Total	-	-	-	-	1	(1)	2	(1)	3	(2)
FISH[1]										
Total	1	(1)	1	(1)	-	-	11	(6)	13	(7)
TERRESTRIAL INVERTEBRATES										
Insecta (except Ephydridae)	-	-	3	(2)	2	(1)	1	(1)	6	(3)
MARINE INVERTEBRATES										
Mollusca (clams, snails)	3	(2)	-	-	-	-	1	(1)	4	(2)
Ephydridae pupae (shoreflies)	1	(1)	-	-	-	-	3	(2)	4	(2)
Saduria entomon (isopods)	4	(2)	2	(1)	4	(2)	20	(11)	30	(16)
Brachyura (crabs)	-	-	-	-	-	-	1	(1)	1	(1)
Other Crustacea (except *Saduria* and Brachyura)	2	(1)	5	(3)	3	(2)	5	(3)	15	(8)
Asteroidea (starfish)	3	(2)	3	(2)	7	(4)	27	(15)	40	(22)
Echinoidea (sea urchins)	-	-	-	-	-	-	-	-	-	-
Total	8	(4)	6	(3)	6	(3)	63	(35)	83	(46)
BERRIES										
Rubus chamaemorus (cloudberry)	3	(2)	3	(2)	-	-	1	(1)	7	(4)
Empetrum nigrum (crowberry)	9	(5)	9	(5)	14	(8)	29	(16)	61	(34)
Arctostaphylos sp. (bearberry)	-	-	-	-	-	-	-	-	-	-
Vaccinium spp. (blueberry, cranberry)	10	(5)	6	(3)	20	(11)	37	(20)	73	(40)
Total	9	(5)	3	(2)	11	(6)	85	(47)	108	(59)
OTHER VEGETATION[1]										
Total	1	(1)	-	-	-	-	-	-	1	(1)
REFUSE FROM HUMANS										
Total	-	-	-	-	-	-	-	-	-	-
UNIDENTIFIED ITEMS										
Total	2	(1)	-	-	-	-	1	(1)	3	(2)

[1]For details about species see text.

The situation in July of 1977 contrasted greatly with 1976. Although the collection area was almost identical, the number of pellets collected in July in 1977 was only about 20% the number collected in 1976, indicating a large drop in the number of prey taken. Also, in 1977 all the food in the pellets appeared fully utilized while in 1976 many prey items were not fully utilized. In the first half of July 1977 (Table 48), Saduria was still the most common prey, occurring in 57% of the pellets, but the absolute numbers of Saduria taken was greatly reduced compared to 1976. The diet of the gulls during this period in 1977 was more varied than in 1976, with fish especially taking on more importance. The number of Ephydridae pupae taken also dropped in 1977; they occurred in only 15% of the pellets during the second half of July (Table 49). However, the number of crabs utilized during this period (occurred in 16% of pellets) showed a major increase over this period in 1976 (occurred in <1% of pellets).

During August 1976 (Tables 42 and 43), Saduria continued to be the most prevalent food item, but berries increased dramatically in importance and fish increased noticeably. In August 1977 (Tables 50 and 51), berries were the most important food item, although Saduria isopods were still taken during the first half of August.

During the first half of September 1976 (Table 44), berries and other vegetation were the principal food items, although Saduria still occurred in 20% of the pellets. During this same period in 1977 (Table 52), berries occurred in 59% of the pellets, starfish in 22% of the pellets and Saduria in 16% of the pellets.

Adult and young birds and eggs seem to comprise only a small part of the diet of the Glaucous Gulls on the Cape (Figures 104 and 105). During all collection periods they occurred in less than 25% of the pellets and during 9 of the 15 collection periods (covering 1976 and 1977) they occurred in less than 10% of the pellets. However, because of the large number of Glaucous Gulls on the Cape, this predation could still be significant to some segments of the avian community. This factor is discussed in more detail in the section on impact of predation.

The majority of eggs eaten by the gulls were Common Eider eggs, although they undoubtedly took all types of eggs opportunistically. Several of our bird bands were found in gull pellets; they included bands from one Red Phalarope chick, two Northern Phalarope chicks, three Arctic Tern chicks, and five Glaucous Gull chicks. Also, on two occasions Glaucous Gull chicks were observed regurgitating Red-throated Loon chicks. Waterfowl young were also eaten. Some of the avian food items eaten by the gulls were undoubtedly scavenged. Gulls scavenged bird carcasses along the Cape beaches. They also scavenged eggs abandoned in waterfowl nests after most of the eggs had hatched and the adult had led the chicks away from the nest.

Several other investigators have collected information on Glaucous Gull food habits in Alaska. Olson (1951) collected 127 stomachs in the Hooper Bay-Kashunuk River area and found birds to be the most important food item. Strang (1976) collected pellets and stomachs on the Yukon-

Kuskokwim Delta during 1972-1974. He found fish to be the most important food overall at coastal areas, but mammals were important during early summer and birds and eggs were important when they were most readily available. At inland locations, Strang found that birds were much more important in the gulls' diets than along the coast. Eisenhauer and Kirkpatrick (1977) also collected Glaucous Gull stomachs on the Yukon-Kuskokwim Delta at Kokechik Bay during 1972-1973. They found fish, birds, and small mammals to be important components of the diet, in that order. None of these investigators found marine invertebrates to be very important, in contrast to our results from Espenberg. However, workers at some non-Alaskan Arctic locations found marine invertebrates to be important in Glaucous Gull diets (Ingolfsson 1967, cited in Strang 1976). Strang (1976) provides a good discussion on Glaucous Gull food habits on a world-wide basis. The major food sources for Glaucous Gulls appear to be fish, birds and marine invertebrates, their relative importance depending on availability.

Parasitic Jaegers

Breeding Biology

The nesting density (0.8 nests/km^2) of Parasitic Jaegers on the Cape is very high compared to densities (0.03-0.29 nests/km^2) reported from other areas of Alaska (Table 21). The actual number of breeding pairs located each year was 14 in 1976, 16 in 1977, and 17 in 1978. However, time did not allow a completely thorough search for jaeger nests any year and we estimate that the actual number of nests present each year was 18-20. The high density of breeding Parasitic Jaegers may result from 1) the overall high density of breeding birds on the Cape, which provides a dependable food source of eggs, chicks and adult birds, and 2) the close proximity of the ocean which provides an additional food source of fish and invertebrates (Maher 1974).

Relatively complete nesting success data were obtained only in 1977. During that year, hatching success for 16 nests was 88%, while young were fledged from 56% of the nests. Only one young was fledged from each of eight nests. Two young were fledged at one nest. Thus the year's production of jaegers on the Cape was at least 10, but probably 11-12 if undiscovered nests are estimated. Although data for 1978 are incomplete, they indicate that jaegers had a high hatching success in that year also. Maher (1974) had limited data on nesting success for Parasitic Jaegers, but estimated that their success was usually quite high in Alaska, ranging from 50-75%.

Most Parasitic Jaegers nesting on the Cape were light phase birds. The dark phase made up 13-17% of the breeding birds each of the years 1976-1978.

Nesting jaegers on the Cape showed high site tenacity. In 1976 we banded 24 nesting adults. In 1977 we observed 14 adult banded jaegers, while in 1978 we observed 18 banded birds. The 1978 returns suggest that we failed to locate some nests and banded birds in 1977. The 1977 observations indicate a minimum return rate of adult birds of 58% from

1976 to 1977. However, the 1977 observations show a return rate of 75% two years after banding, indicating an actual return rate of about 88% one year after banding. This high return rate suggests that the adults are long-lived. In 1977 two of the banded jaegers were recaptured to check the band numbers. Both were nesting in the same territories in which they had been captured and banded in 1976. The nesting territories used on the Cape were highly predictable from one year to the next, indicating that adults return in successive years. At least nine territories were known to be used all three years. Maher (1974) suspected that pairs returned repeatedly to the same territories although he banded very few birds and observed a return for only one.

Food Habits

A few Parasitic Jaeger pellets were collected opportunistically when they were found near jaeger nests. The analysis of these pellets (Table 53) gives only a qualitative idea of their diet. The pellets show that bird eggs, young, and adults were an important part of the jaegers' diet but that many other types of food were also used, especially insects and berries. Parasitic Jaegers were observed taking eggs and young of loons, waterfowl, shorebirds, and gulls.

Maher (1974) conducted an intensive study on jaeger food habits in Alaska. He found that birds, especially passerines, and eggs were usually a very important part of their diets but that small mammals, fish, and insects were used in significant quantities when available.

Other Avian Predators

Several other species of predatory birds occasionally occurred on the Cape in low numbers. These included Long-tailed Jaegers, Pomarine Jaegers, hawks (especially Marsh Hawks), Short-eared Owls, and Snowy Owls. A few Snowy Owls were present on the Cape from late July through early September 1976. Nineteen Snowy Owl pellets were collected at this time. Eleven of the pellets contained microtine remains, five contained Arctic Ground Squirrel remains, and four contained bird remains. None of these predators probably had much impact on avian production while we were on the Cape, chiefly because they were uncommon.

Reindeer

In 1976 only one reindeer was observed on the Cape. In 1977 and 1978, at least 1200 reindeer used the Cape each year. Every summer reindeer are rounded-up and herded to the corrals at the village of Espenberg, at the base of the Cape. Here, antlers are harvested and animals are tagged before release. These operations occurred in early July in 1976-1978. Except for 1976, when airplane traffic frightened the reindeer away, these animals moved onto the Cape soon after release from the corrals in early July. The first large bands of reindeer were observed near our base camp on 9 July in 1977 and on 7 July in 1978. In 1977 large numbers of reindeer stayed on the Cape for about three weeks, and 20-30 reindeer (most of them having leg injuries) were still on the Cape when we left in late September.

Table 53. Analysis of Parasitic Jaeger pellets, results only qualitative because pellets not systematically collected, no. of pellets = 43, 1976-1977, Cape Espenberg, Alaska.

Food Item	Percent of Volume of Pellet Consisting of Item: 0-10 No. of Pellets	0-10 (% of Pellets)	11-49 No. of Pellets	11-49 (% of Pellets)	50-89 No. of Pellets	50-89 (% of Pellets)	90-100 No. of Pellets	90-100 (% of Pellets)	Total No. and (%) of Pellets	
MAMMALS										
Cricedidae (mice, lemmings)	1	(2)	-	-	-	-	1	(2)	2	(5)
BIRDS AND BIRD EGGS										
Eggs	-	-	4	(9)	7	(16)	7	(16)	18	(42)
Adult and young birds	1	(2)	1	(2)	6	(14)	7	(16)	15	(35)
Total	1	(2)	2	(5)	14	(33)	14	(33)	31	(72)
FISH										
Total	1	(2)	1	(2)	-	-	-	-	2	(5)
TERRESTRIAL INVERTEBRATES										
Insecta	8	(19)	11	(26)	1	(2)	2	(5)	22	(51)
MARINE INVERTEBRATES										
Mollusca (clams, snails)	1	(2)	-	-	-	-	-	-	1	(2)
Asteroidea (starfish)	-	-	-	-	-	-	1	(2)	1	(2)
Total	1	(2)	-	-	-	-	1	(2)	2	(5)
BERRIES										
Empetrum nigrum (crowberry)	8	(19)	5	(12)	1	(2)	7	(16)	21	(49)
OTHER VEGETATION										
Total	-	-	-	-	1	(2)	1	(2)	2	(5)

The reindeer were often observed moving in compact bands of 100-300 animals. Single groups as large as 1200 animals were observed. These bands leave wide paths of trampled ground behind them. However, both years that reindeer were present, they arrived after the majority of nests had hatched. They also often moved along the dry ridges rather than in the marsh, where nest and chick densities were greatest. But they did graze and travel in the marsh, too. On 8 July 1978 at least 200-300 reindeer grazed through part of the Shorebird Marsh Plot. In doing so they completely or partially destroyed the eggs or newly-hatched young at seven nests (2 Oldsquaw nests, 3 Common Eider nests, 1 Arctic Tern nest, 1 Northern Phalarope nest); this represented 35% of the waterfowl and 9% of the shorebird and tern nests still active in the area. At other times we observed other nests and chicks destroyed by reindeer, including an Oldsquaw nest, a Common Eider duckling, a Red Phalarope nest, a Northern Phalarope chick, an Arctic Tern nest an Arctic Tern chick, a Glaucous Gull nest, and a Glaucous Gull chick. Some of the eggs may have been eaten by the reindeer, as well as trampled. John Wright (pers. comm.) observed a tame reindeer eating Glaucous Gull eggs with apparent relish (not hamburger!).

If reindeer ventured out on the Cape in June, they could trample a high percentage of nests and significantly reduce avian production. However, when they do not arrive on the Cape until after the first week in July, trampling of nests is minimized. The percentage of trampled chicks is not known.

Small Mammals as a Food Source for Predators

In 1976 and 1977, small mammals were systematically trapped in five different habitat types. Table 54 presents the results of this trapping effort. In 1976 a detectable population of *Microtus oeconomus* (tundra vole) occurred on the Cape, but densities were low in most habitats. The most extensive and most populated microtine colonies occurred in areas of dense *Elymus arenarius* and *Lathyrus maritimus* vegetation in the north dunes. In 1977 no microtines were captured or observed by the investigators. None were observed in 1978, either.

In 1973, Melchior (1974) captured one *Microtus oeconomus* and one *Sorex arcticus* in ca. 410 trap-days of effort on Cape Espenberg. His trapping techniques were not directly comparable to ours, and he did not trap in the habitat where we found the largest colonies.

Arctic Ground Squirrels (*Spermophilus undulatus*) were observed very frequently from 1976 through 1978, especially in the north dunes. We roughly estimated a population of 1,000-1,500 squirrels on the Cape.

The use of small mammals by predators is discussed under the food habits of each predator species.

Impact of Predators on Avian Production

The immediate impact of predators, as they affect hatching success, varied between types of birds, types of nest locations, and years (Tables 26, 27 and 29).

Table 54. Number of Microtus oeconomus (Tundra Vole) captured in live-traps on small mammal trap lines, Cape Espenberg, Alaska, 1976-1977.

Trap Line No.	No. of Trap-Days Each Year	Trapping Date Period 1976	Trapping Date Period 1977	Location On Cape	Habitat	No. of Individuals Captured 1976	No. of Individuals Captured 1977	No. of Captures 1976	No. of Captures 1977
1	80	July 23- July 31	July 20- July 24	Shorebird Marsh Plot	Dry Tussocks	0	0	0	0
2	80	" "	" "	" "	Marsh	0	0	0	0
3	80	" "	" "	" "	Marsh	2	0	5	0
4	80	August 4- August 16	August 20- August 24	Shorebird Mixed Habitat Plot	Elymus-Dunes	7	0	14	0
5	80	" "	" "	" "	Dwarf shrub-Dunes	2	0	2	0
6	80	" "	" "	" "	Sedge-Pond edge	2	0	2	0

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Data collected in the Shorebird Marsh Plot for 1976-1978 help distinguish between fox and avian-caused predation (Tables 55 and 56). In 1976, Red Foxes were present on the Cape and were occasionally observed in the plot. In 1977, both Red Foxes and Arctic Foxes were present on the Cape and were very active (especially Arctic Foxes) in the plot (Table 57). In 1978, fox activity on the Cape was very much reduced, and foxes were not observed in the plot. An attempt was made to identify the predators of waterfowl nests in the plot by the systematic predation observations and by tracks and other signs at destroyed nests. Nests where eggs were punctured, contents eaten, and shells and down left scattered about the nest site were considered destroyed by avian predators. Nests where the eggs simply disappeared, with no shells remaining and with the down still intact within the nest bowl, were considered destroyed by foxes. We have found, during actual observations of predator activities, these indicators to be relatively accurate, as did Strang (1976). However, some inaccurate interpretations can occur under the following conditions: 1) if a fox consumes some eggs at the nest and leaves the shells (during the predator watches we observed foxes take 41 waterfowl eggs from 18 nests; only 1 egg was eaten at a nest), 2) if a fox takes some eggs from a nest and then leaves, leaving exposed eggs that an avian predator then eats at the nest (partial predation by foxes was observed during the Predator Watches, but subsequent avian predation was not, although it undoubtedly occurs at times), and 3) if an avian predator removes the eggs from the nest site (this would be most likely if only one egg was present and the avian predator was disturbed while consuming it). Our observations indicate that these sources of error were minimal in the Shorebird Marsh Plot and this method has some usefulness. When considering the results of this work, it must be remembered that Arctic Tern and Sabine's Gull colonies were present in the Shorebird Marsh Plot. The results are discussed below under species groups.

In both 1976 and 1977 predators apparently destroyed 70% or more of the loon nests. In 1977, when foxes were common in the Shorebird Marsh Plot, 88% (n=8) of the loon nests were destroyed. In 1978, when very little or no fox activity occurred in the plot, only 20% (n=5) of the nests were destroyed, indicating that foxes were the major predator of loon eggs. However, despite high predation rates, Red-throated Loon production on the Cape in 1977 was relatively high. We observed (in the nesting plots) that when nests were destroyed on small ponds, each of which harbored one pair of loons, second clutches of eggs often appeared on the same ponds. On one pond even a third clutch was laid after two consecutive nests had been destroyed. These observations indicate that either the loons were renesting, which we suspect, or that there was a large segment of the loon population continuously searching for suitable ponds on which to nest and that these birds quickly replaced birds that had lost nests. Loon production in 1976 was very low, however, which may have resulted from heavy fox predation combined with a phenologically late year, which precluded many successive nesting attempts. Avian predation on loon eggs seemed to be very light as long as the loons were not disturbed, causing them to leave their eggs exposed. We saw one Red-throated Loon chase a Glaucous Gull away from its exposed eggs by landing, running across the pond, and jabbing at the hovering gull. Avian predation did occur on loon chicks. In 1977, loon chicks were regurgi-

Table 55. Predation on duck and goose nests in the Shorebird Marsh Plot, 1976-1978, Cape Espenberg, Alaska.

Species	Year	% Hatched	% Abandoned	% Predation			Total No. Nests
				Probable[a] Avian	Probable[a] Fox	Probable[a] Reindeer	
Pintail	1976	-	-	-	-	-	-
	1977	0	0	14	86	0	7
	1978	75 + 25[b]	0	0	0	0	4
Oldsquaw	1976	29	0	24	48	0	21
	1977	0	0	9	87	3	32
	1978	43 + 21[b]	7	14	7	7	28
Common Eider	1976	15	3	47	35	0	34
	1977	0	7	30	63	0	27
	1978	57 + 4[b]	9	26	4	0	23
Other ducks and geese	1976	28	14	0	57	0	7
	1977	0	0	0	100	0	3
	1978	0 + 100[b]	0	0	0	0	1
Total ducks and geese	1976	21	3	34	42	0	62
	1977	0	3	17	78	1	69
	1978	50 + 16[b]	7	18	5	4	56

[a]Method of determining predator discussed in text.

[b]Percent of nests still with eggs when investigators left field on July 16, 1978; most of these nests were near hatching and it is assumed that they hatched.

Table 56. Predation on loon, shorebird, gull and tern nests in the Shorebird Marsh Plot, 1976-1978, Cape Espenberg, Alaska.

Species	Year	% of Nests with Known Fate: Hatched	Abandoned	Destroyed By Reindeer	Predation	Total No. Known Fate Nests	No. Unknown Fate Nests	Total No. Nests in Plot
Arctic and Red-throated Loons	1976	17	0	0	83	6	0	6
	1977	12	0	0	88	8	0	8
	1978	60 + 20[a]	0	0	20	5	0	5
Dunlin	1976	100	0	0	0	5	0	5
	1977	66	0	0	33	3	1	4
	1978	100	0	0	0	2	0	2
Semipalmated Sandpiper	1976	75	8	0	17	12	3	15
	1977	53	0	0	47	16	6	22
	1978	87	0	0	13	15	2	17
Western Sandpiper	1976	33	22	0	44	9	6	15
	1977	64	9	0	27	11	4	15
	1978	81	0	0	19	27	5	32
Red Phalarope	1976	75	12	0	12	16	2	18
	1977	66	7	0	27	15	1	16
	1978	93	0	7	0	15	0	15
Northern Phalarope	1976	75	8	0	17	24	2	26
	1977	65	9	0	26	23	2	25
	1978	71 + 10[a]	2		17	41	3	44
Other Shorebirds	1976	0	0	0	100	1	1	2
	1977	33	0	0	66	3	2	5
	1978	100	0	0	0	2	0	2
Total Shorebirds	1976	70	10	0	19	67	14	81
	1977	62	6	0	32	71	16	87
	1978	80 + 4	1	1	14	102	10	112
Sabine's Gull	1976	90	0	0	10	10	1	11
	1977	64	0	0	36	14	0	14
	1978	100	0	0	0	10	0	10
Arctic Tern	1976	85	4	0	11	27	0	27
	1977	71	0	0	29	24	9	33
	1978	90 + 5[a]	0	5	0	20	0	20

[a]Percent of nests still with eggs when investigators left field on July 16, 1978; most of these nests were near hatching and it is assumed that they hatched.

Table 57. Summary of Predator Watches on Shorebird Marsh Plot, 1977, Cape Espenberg, Alaska.

Date	Time Observations Begin	Length Observation Period (Min.)	Predator Species	No. Times Enter Plot During Period	No. Individuals	% of Period that Species in Plot	Minimum No. of Nests Visited, Eggs and Chicks Taken
June 21	2100	157	Arctic Fox	1	1	19	3 Common Eider nests - 5 eggs
			Red Fox	0	0	0	0
			Parasitic Jaeger	9	-	6	0
			Glaucous Gull	6	-	4	0
June 22	1845	273	Arctic Fox	0	0	0	0
			Red Fox	0	0	0	0
			Parasitic Jaeger	2	-	1	0
			Glaucous Gull	4	-	35	1 probably Red Phalarope nest - 4 eggs
June 23	1855	171	Arctic Fox	1	1	13	1 Common Eider nest - 1 egg, 1 Shorebird or Tern nest 1 + egg.
			Red Fox	0	0	0	0
			Parasitic Jaeger	18	-	11	1 unidentified nest - 1 + egg
			Glaucous Gull	5	-	3	0
June 24	1830	180	Arctic Fox	0	0	0	0
			Red Fox	0	0	0	0
			Parasitic Jaeger	13	-	11	1 Unidentified nest - 1 + eggs
			Glaucous Gull	2	-	2	0
June 27	1900	240	Arctic Fox	0	0	0	0
			Red Fox	0	0	0	0
			Parasitic Jaeger	0	0	0	0
			Glaucous Gull	1	1	<1	0
June 28	1820	240	Arctic Fox	0	0	0	0
			Red Fox	0	0	0	0
			Parasitic Jaeger	8	-	3	0
			Glaucous Gull	2	-	4	0
June 29	1800	240	Arctic Fox	1	1	9	1 Unidentified waterfowl nest - 3 eggs
			Red Fox	0	0	0	0
			Parasitic Jaeger	6	-	14	1 Common Eider nest - 3 eggs
			Glaucous Gull	1	-	<1	0
July 1	1930	60	Arctic Fox	0	0	0	0
			Red Fox	0	0	0	0
			Parasitic Jaeger	1	1	2	0
			Glaucous Gull	0	0	0	0
July 2	1820	255	Arctic Fox	1	1	7	0
			Red Fox	0	0	0	0
			Parasitic Jaeger	0	0	0	0
			Glaucous Gull	0	0	0	0

Table 57. Summary of Predator Watches on Shorebird Marsh Plot, 1977, Cape Espenberg, Alaska. (Cont.)

Date	Time Observations Begin	Length Observation Period (Min.)	Predator Species	No. Times Enter Plot During Period	No. Individuals	% of Period that Species in Plot	Minimum No. of Nests Visited, Eggs and Chicks Taken
July 3	1800	240	Arctic Fox	1	1	21	1 Probably Sabine's Gull nest - 1 + eggs
			Red Fox	0	0	0	0
			Parasitic Jaeger	0	0	0	0
			Glaucous Gull	0	0	0	0
July 4	1810	240	Arctic Fox	4	2	50	3 Oldsquaw nests - 13 eggs, 4 Common Eider nests - 5 eggs, 1 unidentified waterfowl nest - 3 eggs 1 Arctic Loon nest - 2 eggs, 1 probably Shorebird nest - 4? eggs, 4 cached eggs dug up and recached.
			Red Fox	0	0	0	0
			Parasitic Jaeger	0	0	0	0
			Glaucous Gull	2	-	1	0
July 5	1815	240	Arctic Fox	2	2	37	1 Oldsquaw nest - 2 eggs, 2 Common Eider nests - 3 eggs, 2 possible Shorebird nests - 8? eggs
			Red Fox	0	0	0	0
			Parasitic Jaeger	0	0	0	0
			Glaucous Gull	0	0	0	0
July 7	1830	265	Arctic Fox	2	2	25	2 Oldsquaw nests - 6 eggs, 2 Arctic Tern nests - 3 eggs, 1 Arctic Tern chick
			Red Fox	1	1	4	1 Oldsquaw nest - 3 eggs
			Parasitic Jaeger	6	-	4	1 unidentified chick
			Glaucous Gull	1	1	<1	0
July 8	1925	240	Arctic Fox	0	0	0	0
			Red Fox	0	0	0	0
			Parasitic Jaeger	8	-	3	0
			Glaucous Gull	1	1	<1	0
July 10	1930	240	Arctic Fox	1	1	5	0
			Red Fox	1	1	2	0
			Parasitic Jaeger	0	0	0	0
			Glaucous Gull	1	1	<1	0
July 11	1830	240	Arctic Fox	1	1	1	0
			Red Fox	0	0	0	0
			Parasitic Jaeger	1	-	<1	0
			Glaucous Gull	6	-	2	0
July 13	1815	255	Arctic Fox	1	1	7	0
			Red Fox	0	0	0	0
			Parasitic Jaeger	0	0	0	0
			Glaucous Gull	0	0	0	0

Table 57. Summary of Predator Watches on Shorebird Marsh Plot, 1977, Cape Espenberg, Alaska. (Cont.)

Date	Time Observations Begin	Length Observation Period (Min.)	Predator Species	No. Times Enter Plot During Period	No. Individuals	% of Period that Species in Plot	Minimum No. of Nests Visited, Eggs and Chicks Taken
July 14	1815	240	Arctic Fox	0	0	0	0
			Red Fox	0	0	0	0
			Parasitic Jaeger	1	0	<1	0
			Glaucous Gull	0	0	0	0
July 16	1843	240	Arctic Fox	0	0	0	0
			Red Fox	0	0	0	0
			Parasitic Jaeger	2	-	1	0
			Glaucous Gull	5	-	2	0
July 17	1830	240	Arctic Fox	0	0	0	0
			Red Fox	0	0	0	0
			Parasitic Jaeger	8	-	3	0
			Glaucous Gull	2	-	1	0
Total	Between 1800-2100	4496 (74.9 hrs.)	Arctic Fox	16	-	10	6 Oldsquaw nests - 21 eggs, 10 Common Eider nests - 14 eggs, 2 unidentified waterfowl nests - 6 eggs, 1 Arctic Loon nest - 2 eggs, 3 probably shorebird nests - 12? eggs, 1 Shorebird or Tern nest - 1 + egg 1 probably Sabine's Gull nest - 1 + egg 2 Arctic Tern nests - 3 eggs, 1 Arctic Tern chick.
			Red Fox	2	-	<1	1 Oldsquaw nest - 3 eggs
			Parasitic Jaeger	83	-	3	1 Common Eider nest - 3 eggs, 2 unidentified nests - 2 + eggs, 1 unidentified chick.
			Glaucous Gull	39	-	3	1 probably Red Phalarope nest - 4 eggs.

tated on two occasions when we were banding Glaucous Gull chicks and loon chicks were found in at least two Glaucous Gull pellets. However, several times loon chicks were observed evading Parasitic Jaegers and Glaucous Gulls by diving; the adult loons also often tried to protect the chicks. Factors such as food availability probably affect loon chick survival more than avian predators.

In contrast to loons, Emperor Geese suffered very little egg predation (Tables 26 and 27). Some predation probably occurred during the laying period; a few goose egg shells were found near Glaucous Gull colonies and in gull pellets. After incubation began little predation occurred. John Wright (pers. comm.) observed a Canada Goose successfully defend its nest from an Arctic Fox at Prudhoe Bay and Strang (1976) saw a White-fronted Goose chase a Red Fox from its nest on the Yukon-Kuskokwim Delta. Eisenhower and Kirkpatrick (1977) reported a predation rate of only 10.6% on 332 Emperor Goose nests during 1971-1973 on the Yukon-Kuskokwim Delta; a few nests were known to have been destroyed by Glaucous Gulls, Parasitic Jaegers, and foxes. Soon after hatching, goose broods left Cape Espenberg proper and the affect of predation on the young is not known.

Ducks, along with loons, suffered the highest egg predation rates on the Cape (Tables 26, 27 and 29). Common Eiders were subjected to nest predation rates ranging from 5% of 96% in different years and locations on the Cape. The highest predation rates occurred in the shorebird nesting plots in 1976 and 1977. Predation rates may have been higher in the shorebird nesting plots than in the waterfowl nesting plots because of several factors: 1) the shorebird plots were both near the north or south edges of the Cape and both dune ridges and major inner dry ridges ran through, into, and along the sides of these plots; these ridges provided easy travel routes and access to the plots for foxes; the waterfowl plots included large areas of marsh in the center of the Cape where more travel through marsh was involved for access, 2) the waterfowl plots included Glaucous Gull colonies and associated special habitat types where waterfowl hatching success was greater, 3) to minimize disturbance the waterfowl plots were not searched during the laying period, thus most nests that were destroyed during laying are not included in the waterfowl plot data, and predation rates are probably underestimated in these plots, and 4) more human disturbance occurred in the shorebird plots, although areas around waterfowl nests were avoided after they were discovered and very little predation was observed while we were in the plots. Foxes were the predators of over 60% of the Common Eider nests in the Shorebird Marsh Plot in 1977 (Table 55). In 1978, when foxes were not active in the plot predation on the Common Eider nests dropped from 93% to 30%. The 30% loss probably represents the level of avian predation on eider nests in this plot; this study plot contained colonies of predator-harassing species (Arctic Terns, Sabine's Gulls). Much of the avian predation occurred during the laying period.

In the waterfowl nesting plots (1976-1977), about 40-50% of the Common Eider nests were lost to predators, at least during the post-laying period (Table 29). These plots experienced different rates of predation in 1977, probably due chiefly to egging by Natives. Eiders appeared to nest more densely and suffer less predation around Glaucous Gull colonies. This association may have resulted from independent selection of a favored habitat type. Glaucous Gulls tended to nest where they were surrounded by ponds and/or extensive very wet marsh. This habitat may have inhibited easy travel and searching by foxes, although during the Predator Watches foxes were frequently observed moving freely through marshy areas and wading in water and mud up to their bellies. It is also possible that the gulls afford some protection to nearby waterfowl nests by harassing both avian and mammalian predators. Schamel (1977) found that eiders had significantly higher nesting success when they nested within Glaucous Gull territories rather than outside them. The gull-waterfowl association has been noted by many investigators (Bourget 1973, Dwernychuk and Boag 1972, Schamel 1977, Strang 1976) but the explanation of its significance awaits more intensive and controlled investigations.

That foxes have a significant impact on the individual reproductive fitness of Common Eiders on the Cape may be reflected in the fact that eiders nest in extremely dense aggregations (ca. 0.3 nests/m^2) on the only sizeable (1,000 m^2) island on the Cape. In 1976 and 1977, predation on eider nests on this island was only 5-12% (Table 29) and some of that was probably caused by human disturbance.

Both Glaucous Gulls and Parasitic Jaegers were observed capturing young eiders, but the magnitude of this predation is not known. When young were on water with adults, they were usually able to avoid avian predation.

Other ducks on the Cape are probably affected by predators in a similar manner to eiders (Table 55). In 1977, Oldsquaws lost about 87% of their nests to foxes in the Shorebird Marsh Plot (Table 55). In 1978, with foxes nearly absent, total predation (except reindeer) on Oldsquaw nests in the plot was 20%. Avian predation on Oldsquaw nests may be somewhat lower than on eider nests (Table 55); this could be because Oldsquaw nests are better camouflaged and because the females are not easily flushed from their nests by disturbances.

In 1976 and 1977, overall predation rates on shorebirds were generally below 25% (Tables 26 and 27). In 1977, in the Shorebird Marsh Plot, where fox predation was very heavy on waterfowl nests, shorebirds lost about 32% of their nests to predation (Table 56). In the same plot in 1978, with foxes virtually absent, the shorebirds lost about 14% of their nests to predation. The 14% probably closely represents the level of avian predation, indicating a fox predation rate of about 18% in 1977. The presence of Arctic Terns and Sabine's Gulls in this plot probably reduced avian predation. All over the Cape, shorebird nests were very likely buffered from predation by the high density of waterfowl nests. During Predator Watches, both foxes and avian predators appeared to concentrate on a search image for waterfowl nests, usually ignoring flushing shorebirds. As long as waterfowl eggs are readily available, it would be energetically most efficient for predators to concentrate on these much larger eggs. Most predation on shorebird nests occurred very early, when the density of waterfowl nests was still very low. Renesting by shorebirds probably compensated for some of this predation. All major predator species were observed taking shorebird young, but we do not know the magnitude of this predation. In 1976, bands from four chicks were found in predator pellets and scats; these included bands of two Northern Phalarope chicks (75 banded) in Glaucous Gull pellets and bands of one Western Sandpiper chick (50 banded) and one Dunlin chick (64 banded) in fox scats. The likelihood of finding any given pellet or scat that contained a band is very low.

Predation rates on larids were generally low, ranging from 9-36%. In 1977, with foxes common in the Shorebird Marsh Plot, the predation rate on nests of Arctic Terns was 29% and on Sabine's Gulls, 36%. In 1978, with foxes absent, neither species suffered any predation in the plot, indicating that foxes are the major predator on the nests of these species. Like shorebirds, predation on the eggs of these species is probably buffered by the high density of waterfowl nests. During Predator Watches, Arctic Terns, and to a lesser extent Sabine's Gulls, mobbed and harassed jaegers and Glaucous Gulls flying over the plot. They generally caused flying predators to leave the vicinity quickly. However, once jaegers or Glaucous Gulls landed in the plot, the harassers seemed less effective and were unable to drive them away. Arctic Terns also mobbed foxes, but were usually ignored; foxes only occasionally exhibited visible annoyance at the terns. Both foxes and Glaucous Gulls were known to have taken a number of tern chicks from the plot in 1976 and 1977, and their impact was probably significant. However, fairly large numbers of tern chicks died of other causes also, probably starvation or exposure. These latter factors were probably the most important causes of mortality in Glaucous Gull and jaeger chicks, also.

When common, foxes are the most important predators on bird eggs, especially waterfowl eggs, on the Cape. They can exert a very severe impact on hatching success in certain areas during some years, destroying over 80% of the waterfowl nests (Table 55). However, predation pressure from foxes varies greatly from year to year (Table 55). During three years on the Cape, fox predation ranged from very low to moderate to very high. A very important, but at present unknown, factor is the percentage of all years that foxes are common. Strang (1976) reported that on the Yukon-Kuskokwim Delta foxes were common in only one of six years of study.

From 1976-1978 Glaucous Gull and Parasitic Jaeger densities remained relatively stable and they probably exert a relatively constant predation pressure on the avian community. Since much of the avian predation occurs during laying or early incubation, renesting probably compensates for a large amount of it. These predators probably also take a significant percentage of chicks, although information is scant.

Use of Birds by Natives

In 1976, Natives did not collect eggs on Cape Espenberg. In 1977, natives did collect some eggs for subsistence use. To the best of our knowledge, only the marsh area of Waterfowl Plot 1 was egged. This area had moderate nesting densities of waterfowl and Glaucous Gulls and was close to the Native settlement of Espenberg. Natives were seen collecting eggs only once--during the afternoon of June 17. Later inspection on June 21, when the area was first systematically searched for nests, suggested that Common Eider, Glaucous Gull, and Black Brant eggs were taken. At this time, eggs were either newly laid or incubated only 4 or 5 days. Usually all the eggs in a nest were removed. Probably a number of eider nests were lost from the effects of disturbance, in addition to egging. When an eider is flushed from the nest, often she does not cover the clutch with down. In this state, gulls and jaegers seem to have little difficulty finding the nests and destroying one or more eggs. Probably some waterfowl nests were lost to avian predators because of disturbance when the Natives were collecting eggs. The percentage of successful Common Eider nests in Waterfowl Plots 1 and 2 were quite close in 1976--58% and 52%, respectively. In 1977, the proportion of successful Common Eiders in Plot 1 was 23%, less than half that of Plot 2 in 1977 (Table 29). Subsistence use was at least a partial cause of the low 1977 nesting success in Waterfowl Plot 1

In 1976, break-up was late. By 10 July, the ice was moving offshore. Ten days later the ice was gone. Ice movement came much earlier in 1977. By June 19, ice was moving offshore. By June 25, all ice between the north shore of Cape Espenberg and about a half mile from shore was gone.

Boat travel from Shishmaref would have been first possible, assuming that ice conditions were the same or better between the village and Cape Espenberg, sometime between 19 and 25 June. This is somewhat after the start of laying for Common Eiders and especially Glaucous Gulls. However, a number of eiders were still laying on June 24. It would be possible for Natives of Shishmaref to reach Espenberg when waterfowl and gulls are either laying or in early incubation.

Perhaps historically Espenberg has primarily been used only by Natives living on the Cape. The extent of the harvest is difficult to determine as the presence of researchers in 1976 and 1977 may have discouraged Natives from taking birds and eggs.

Because of the number of old house pits on the Cape, it is possible that considerably more subsistence use of nesting birds and their eggs occurred in the past than in 1976 and 1977. Native dogs, if free-ranging, may also have affected avian breeding distributions and abundance on Cape Espenberg in the past. However, during 1976-1977 Native subsistence use on the Cape had little impact on overall avian production.

Availability and Importance of Invertebrates as Food

Terrestrial Invertebrates

Pooled results of the sticky board insect traps are given in Tables 58 and 59. Emergence of adult Tipulids (craneflies) was about 10 days earlier in 1977 than it had been in 1976. Emergence corresponded closely with hatching dates of young sandpipers and Sabine's Gulls. In 1976, hatching dates of Arctic Terns corresponded well with the emergence of adult caddisflies (Trichoptera). We observed terns capturing and feeding adult caddisflies to the young frequently that year. In 1977, however, tern chicks hatched 2 weeks prior to the emergence of caddisflies; these insects were infrequently offered to young terns that year.

Intertidal Invertebrates

Intertidal invertebrate samples were collected from seven stations:

Table 58. Invertebrates collected from 0.25m^2 sticky boards, Cape Espenberg, Alaska, 1977.

Collection period ending	Taxon							
	Tipulidae (♂/♀)	Culicidae (♂/♀)	large midge	small midge	Diptera: Oestridae	other Diptera	all spiders	ichneumonids and braconids
21 June	17/4	9/0	33	157	-	34	6	-
24	20/3	5/0	11	57	-	21	8	-
27	22/2	2/1	16	93	-	17	9	1
30	8/0	4/2	18	171	-	16	6	10
3 July	6/0	0/1	6	155	-	24	7	6
6	1/0	1/1	17	193	-	21	10	8
9	6/1	-	11	347	-	27	9	11
12	0/1	0/1	11	545	-	42	6	8
15	1/0	-	33	595	-	27	4	18
*19	-	-	13	272	-	5	4	7
22	-	0/1	4	487	-	23	10	13
25	-	-	7	428	-	19	8	15
28	-	-	5	371	-	21	1	14
31	-	-	7	389	-	13	6	26
3 August	-	0/1	6	231	-	23	2	34
*7	3/0	-	8	295	-	26	1	51
10	2/0	1/0	43	174	-	28	2	53
13	10/0	-	34	205	-	37	1	34
16	12/0	-	38	151	-	37	1	39
19	20/0	-	14	160	-	59	7	37
22	3/0	0/1	31	163	-	42	7	43
25	6/0	-	17	92	-	15	1	15
28	2/0	-	16	53	-	21	4	5

*Boards exposed for 4 days

Table 59. Invertebrates collected from 0.25m^2 sticky boards,

Cape Espenberg, Alaska, 1976.

Collection period ending	Taxon							
	Tipulidae (♂/♀)	Culicidae (♂/♀)	large midge	small midge	Diptera: Oestridae	other Diptera	all spiders	ichneumonids and braconids
26 June	11/2	46/5	8	570	-	281	2	-
29	9/1	20/5	4	122	-	34	7	1
2 July	5/0	4/0	1	3	-	7	2	1
5	9/1	6/5	0	38	-	83	5	1
8	22/2	11/12	1	13	-	38	5	3
11	19/0	10/13	1	191	-	51	12	23
14	9/0	4/1	3	104	-	22	4	16
17	6/0	2/6	2	429	-	53	8	43
20	-	6/5	6	128	-	60	3	18
25	-	14/1	-	460	-	23	6	14
28	-	1/1	6	299	-	25	-	12
31	-	0/1	7	451	-	41	3	31
3 August	-	-	6	510	-	46	6	15
6	-	0/2	5	345	-	59	3	38
9	-	-	32	251	-	25	3	14
12	-	-	7	199	-	11	4	23
15	-	-	47	200	-	57	3	17
18	-	-	9	235	-	91	-	15
21	-	-	180	251	-	37	2	23
24	-	-	51	258	-	72	2	15
27	2/0	-	33	262	1	35	2	19
30	2/0	-	7	140	-	17	2	25
2 September	2/1	-	8	81	-	23	1	10
5	1/0	-	13	19	-	1	-	-
8	-	-	92	33	-	14	2	9

Table 59. Continued.

Collection period ending	Collembola	Homoptera	Hemiptera	Trichoptera	Coleoptera larvae	Plecoptera	Lepidoptera	TOTAL
	Taxon							
26 June	-	-	-	-	-	-	-	925
29	-	-	-	-	-	-	-	203
2 July	-	-	-	-	-	-	-	23
5	-	-	-	-	-	-	-	148
8	-	2	-	-	-	-	-	109
11	-	-	-	1	-	-	-	321
14	32	-	-	1	-	1	-	197
17	11	-	1	-	-	-	1	562
20	6	-	-	5	1	-	-	238
25	9	-	-	7	-	-	-	534
28	9	-	-	6	-	-	-	359
31	2	4	-	13	-	-	-	553
3 August	13	-	-	11	-	-	-	607
6	12	-	-	9	-	-	-	473
9	4	-	-	3	2	-	-	334
12	9	1	-	12	1	-	-	267
15	9	1	-	12	-	-	-	346
18	5	1	1	2	-	-	-	360
21	4	-	1	1	-	-	-	499
24	4	-	1	1	-	-	-	404
27	5	1	1	2	-	-	-	363
30	6	-	-	-	-	-	1	200
2 September	4	-	-	-	1	-	-	126
5	4	-	-	1	-	-	-	39
8	1	-	-	1	-	-	-	152

three along the sea coast, three along the Espenberg Bay coast, and one from the South Mudflats in Espenberg Bay. A total of 19 living species were identified from these samples. Six species were found along the sea coast (Table 60). Only one of these, the amphipod Anisogammarus, was common. Espenberg Bay harbored 17 species. An additional 11 types of insects were found dead in samples taken from the sea coast.

The distribution of organisms along the sea coast was relatively uniform (see Tables 61-65). In Espenberg Bay, however, the greatest biomass and diversity of organisms occurred at the base of the Cape (station 4) and on the South Mudflats (station 7). Biomass and diversity both decreased progressively towards the tip of the Cape (stations 5 and 6). Biomass at each station in Espenberg Bay showed trends, also. Both sides of the water's edge supported the greatest biomass. Biomass decreased landward and was least at the high tide line.

Several differences were evident between 1976 and 1977. Comparing only the August sampling period of both years, we can note a decrease in amphipods, chironomids, and isopods (Table 66). During this same period pelecypods and ephydrid flies increased. Samples from July and September suggest that these trends are probably real for amphipods, isopods, and pelecypods.

Size-class distributions of the clam Macoma, the isopod Saduria entomon, and Anisogammarus were examined for all sampling periods. Macoma showed no major change from August 1976 to July 1977 (Fig. 106). However, there was a definite shift towards larger clams from July to August 1977. Little change was noted from August to September 1977. The mid-summer shift cannot be explained by growth. The August and September size-class distributions almost certainly indicate that a different population of clams was sampled. This may be due to sampling error or real differences in the Espenberg Bay clam population. August sampling occurred within 2 m of July sampling. Therefore, we suspect the differences are real.

Young isopods (Saduria entomon), newly-emerged from the female's brood pouch, measure 3-4 mm in length. They are deposited in Espenberg Bay mud in June and July, after the break-up of ice in the bay. There was a definite shift to larger isopods during successive collection periods both summers (Figs. 107 and 108). If we can assume that samples were taken from the same population, then these young isopods probably grow 3-4 mm per month.

Only immature amphipods (Anisogammarus) were collected along the sea coast. A shift towards larger individuals was noted during the three collection periods in 1977 (Fig. 109). If the same population was sampled throughout the summer, then a growth rate of 3-4 mm per month is suggested. Note that the size distribution of Anisogammarus for August of both years is approximately the same.

Invertebrates as Foods

Invertebrates were important primary foods for many bird species and alternate foods for foxes. Casual observations on the tundra

Table 60. Invertebrates identified from intertidal samples, Cape Espenberg, Alaska, 1976 and 1977.

Taxon	Year	Location: Sea	Bay	Mudflats
Mollusca, Pelecypoda, Macoma balthica	76, 77		x	x
Annelida, Oligochaeta	76, 77		x	x
Polychaeta, Eteone longa	76			x
Scolecolepides arctius	76, 77		x	x
Spio mimus	77	x		
Pygospio elegans	76, 77		x	x
Chone duneri	76			x
Arthropoda, Mysidacea, Neomysis sp.	76, 77		x	
Isopoda, Saduria entomon	76, 77		x	x
Amphipoda, Pontoporeia affinis	76		x	
Calliopus laeviusculus	76	x		
Onisimus littoralis	76, 77	x	x	x
Gammarus setosa	76, 77		x	
Anisogammarus cf. A. schmidti	76, 77	x	x	
unidentified amphipod	76, 77	x	x	x
Decapoda, Crangon dalli	76		x	x
Insecta, Hemiptera	77	x		
Homoptera, Aphidoidea	76, 77	x		
Chermidae	76, 77	x		
Cicadellidae	77	x		
Coleoptera	77	x		
Trichoptera	77	x		
Lepidoptera	76	x		
Diptera, Mycetophilidae	76, 77	x		
Dolichopodidae	77		x	
Chironomidae	76, 77	x	x	x
Ephydridae	76, 77	x	x	x
Ephydra	77		x	x
Hymenoptera, Braconidae	76, 77	x		
Ichneumonidae	76	x		

Table 61. Intertidal invertebrate samples, Cape Espenberg, Alaska, 12-19 August, 1976 (5 samples per station total).

Station	Taxon	Total #	%	Total Wt. (g)	%
1A	*Anisogammarus*	43	97.7	0.661	99.9
	Aphidoidea	1	2.3	0.001	-
	Total	44		0.662	
1B	*Anisogammarus*	3	100.0	0.054	100.0
1C	Chermidae	1	100.0	0.001	100.0
1D	Mycetophilidae	1	50.0	0.002	66.7
	diptera	1	50.0	0.001	33.3
	Total	2		0.003	
2A	*Anisogammarus*	23	96.0	0.311	99.4
	diptera	1	4.0	0.002	0.6
	Total	24		0.313	
2B	*Anisogammarus*	9	100.0	0.150	100.0
2C	Chermidae	1	16.6	0.001	16.6
	lepidoptera	2	33.3	0.002	33.3
	Mycetophilidae	1	16.6	0.001	16.6
	diptera	1	16.6	0.001	16.6
	hymenoptera	1	16.6	0.001	16.6
	Total	6		0.006	
2D	Chermidae	1	25.0	0.001	20.0
	Aphidoidea	1	25.0	0.001	20.0
	Mycetophilidae	2	50.0	0.003	60.0
	Total	4		0.005	

Table 61 . Intertidal invertebrate samples, Cape Espenberg, Alaska, 12-19 August, 1976 (5 samples per station total). Cont.

Station	Taxon	Total #	%	Total Wt. (g)	%
3A	*Anisogammarus*	36	97.5	0.583	99.9
	diptera	1	2.5	0.001	0.1
	Total	37		0.584	
3B	*Calliopus laeviusculus*	1	4.3	0.001	0.1
	Anisogammarus	20	87.0	0.479	99.7
	Mycetophilidae	1	4.3	0.001	0.1
	Aphidoidea	1	4.3	0.001	0.1
	Total	23		0.482	
3C	Chermidae	2	40.0	0.002	22.2
	Aphidoidea	1	20.0	0.001	11.1
	diptera	2	40.0	0.006	66.7
	Total	5		0.009	
3D	Chermidae	3	25.0	0.002	6.9
	Chironomidae	1	8.3	0.001	3.6
	diptera pupae	3	25.0	0.003	10.3
	adult	1	8.3	0.011	38.0
	Braconidae	1	8.3	0.005	17.2
	Ichneumonidae	1	8.3	0.004	13.8
	hymenoptera	2	16.6	0.003	10.3
	Total	12		0.029	
4A	Oligochaete	58	10.0	0.035	1.6
	Scolecolepides arctius	3	0.5	0.007	0.3
	Pygospio elegans	155	26.7	0.296	13.4
	Saduria entomon	34	5.9	0.300	13.6
	Gammarus setosa	1	0.2	0.017	0.8
	chironomid larvae	326	56.2	1.546	70.1
	ephydrid pupae	2	0.4	0.004	0.2
	Total	580		2.205	

Table 61. Intertidal invertebrate samples, Cape Espenberg, Alaska, 12-19 August, 1976 (5 samples per station total). Cont.

Station	Taxon	Total #	%	Total Wt. (g)	%
4B	Oligochaete	539	70.5	0.299	25.2
	Pygospio elegans	32	4.2	0.066	5.6
	Saduria entomon	6	0.8	0.048	4.0
	chironomid larvae	178	23.3	0.753	63.5
	ephydrid larvae	2	0.3	0.004	3.3
	pupae	7	0.9	0.016	1.3
	Total	764		1.186	
4C	Oligochaete	679	87.0	0.297	56.2
	Pygospio elegans	9	1.2	0.007	1.3
	Saduria entomon	4	0.5	0.022	4.2
	chironomid larvae	30	3.8	0.120	22.7
	ephydrid larvae	12	1.5	0.019	3.6
	pupae	46	5.9	0.063	11.9
	Total	780		0.528	
5A	*Macoma* sp.	12	6.4	0.020	8.3
	Oligochaete	23	12.2	0.015	6.2
	Scolecolepides arctius	1	9.5	0.002	0.8
	Pygospio elegans	136	72.3	0.108	44.8
	Saduria entomon	7	3.7	0.049	20.3
	Onisimus littoralis	3	1.6	0.010	4.1
	Gammarus setosa	1	0.5	0.006	2.5
	mysid	1	0.5	0.001	0.4
	Crangon sp.	3	1.6	0.026	11.8
	chironomid larvae	1	0.5	0.004	1.6
	Total	188		0.241	
5B	*Macoma* sp.	1	1.1	0.003	1.4
	Oligochaete	11	11.7	0.005	2.4
	Pygospio elegans	62	66.0	0.066	31.4
	Saduria entomon	13	13.8	0.115	54.8
	Onisimus littoralis	3	3.2	0.010	4.8
	Anisogammarus	1	1.1	0.002	1.0
	chironomid larvae	1	1.1	0.005	2.4
	unid. cumacean	1	1.1	0.003	1.4
	ephydrid pupae	1	1.1	0.001	0.5
	Total	94		0.210	

Table 61. Intertidal invertebrate samples, Cape Espenberg, Alaska 12-19 August, 1976 (5 samples per station total). Cont.

Station	Taxon	Total #	%	Total Wt. (g)	%
5C	Macoma	2	2.1	0.004	1.2
	Oligochaete	41	42.3	0.018	5.4
	Pygospio elegans	13	13.4	0.011	3.3
	Saduria entomon	40	41.2	0.290	86.8
	Pontoporeia affinis	1	1.0	0.011	3.3
	Total	97		0.334	
5D	Oligochaete	285	99.0	0.175	97.0
	ephydrid pupae	2	1.0	0.004	3.0
	adult	1	-	0.001	-
	Total	288		0.180	
6A	Oligochaete	7	15.2	0.004	2.6
	Pygospio elegans	22	47.8	0.018	11.8
	Saduria entomon	11	23.9	0.088	57.5
	Gammarus setosa	1	2.2	0.004	2.6
	mysid	4	8.7	0.033	21.6
	Crangon sp.	1	2.2	0.006	3.9
	Total	46		0.153	
6B	Oligochaete	10	37.0	0.004	4.0
	Pygospio elegans	7	25.9	0.005	5.0
	Saduria entomon	8	29.6	0.085	85.0
	Onisimus sp.	1	3.7	0.002	2.0
	Gammarus setosa	1	3.7	0.004	4.0
	Total	27		0.100	
6C	Oligochaete	1	5.6	0.001	1.0
	Saduria entomon	16	88.9	0.093	94.9
	Onisimus littoralis	1	5.6	0.004	4.1
	Total	18		0.098	
6D	Oligochaete	111	99.1	0.101	98.0
	ephydrid pupae	1	0.9	0.002	2.0
	Total	112		0.103	

See Fig. 2 for station locations.

Table 62. Intertidal invertebrate samples, Cape Espenberg, Alaska, 9 September, 1976 (5 samples per station total).

Station	Taxon	Total #	%	Total Wt.(g)	%
7A	*Macoma*	5	0.8	0.004	0.3
	Oligochaete	25	3.8	0.015	1.1
	Eteone longa	1	0.2	0.003	0.2
	Scolecolepides arctius	159	24.4	0.462	34.8
	Pygospio elegans	413	63.3	0.378	28.5
	Chone duneri	1	0.2	0.002	0.2
	Saduria entomon	16	2.4	0.252	19.0
	Crangon sp.	4	0.6	0.040	3.0
	chironomid larvae	27	4.1	0.171	12.9
	ephydrid pupae	1	0.2	0.001	0.1
	Total	652		1.328	
7B	*Macoma*	22	9.1	0.014	4.9
	Oligochaete	143	59.3	0.087	30.6
	Scolecolepides arctius	9	3.7	0.048	16.9
	Pygospio elegans	35	14.5	0.043	15.1
	Saduria entomon	1	0.4	0.015	5.3
	Onisimus sp.	1	0.4	0.002	0.7
	chironomid larvae	9	3.7	0.036	12.7
	ephydrid larvae	1	0.4	0.002	0.7
	pupae	20	8.3	0.037	13.0
	Total	241		0.284	

See Fig. 2 for station locations.

Table 63 . Intertidal invertebrate samples, Cape Espenberg, Alaska, 9-19 July 1977 (5 samples per station total).

Station	Taxon	Total #	%	Total Wt. (g)	%
2A	Spio mimus	11	64.7	0.004	9.3
	Anisogammarus schmidti	6	35.3	0.039	90.7
	Total	17		0.043	
2B	Onisimus	1	20.0	0.012	33.3
	Anisogammarus schmidti	4	80.0	0.024	66.7
	Total	5		0.036	
4A	Oligochaete	40	37.0	0.028	13.7
	Gammarus	1	0.9	0.004	2.0
	ephydridae pupae	1	0.9	0.002	1.0
	chironomidae larvae	59	54.6	0.155	76.0
	pupae	3	2.8	0.013	6.4
	midges, adult	4	3.7	0.002	1.0
	Total	108		0.204	
4B	Oligochaete	106	77.4	0.068	44.4
	Pygospio elegans	2	1.4	0.002	1.3
	ephydridae larvae	1	0.7	0.001	0.7
	pupae	1	0.7	0.001	0.7
	chironomidae larvae	27	19.7	0.081	52.9
	Total	137		0.153	
5A	Macoma	8	7.6	0.014	14.6
	Pygospio elegans	92	87.6	0.070	72.9
	Saduria entomon	4	3.8	0.009	9.4
	Onisimus	1	1.0	0.003	3.1
	Total	105		0.096	

Table 63. Intertidal invertebrate samples, Cape Espenberg, Alaska, 9-19 July 1977 (5 samples per station total). Cont.

Station	Taxon	Total #	%	Total Wt. (g)	%
5B	Macoma	12	28.6	0.016	34.0
	Oligochaete	2	4.8	0.001	2.1
	Pygospio elegans	27	64.3	0.020	42.5
	Anisogammarus	1	2.4	0.010	21.3
	Total	42		0.047	
7A	Macoma	6	2.7	0.004	3.1
	Oligochaete	7	3.2	0.004	3.1
	Scolecolepides arctius	6	2.7	0.003	2.3
	Pygospio elegans	195	89.0	0.099	77.3
	Saduria entomon	3	1.4	0.004	3.1
	chironomid larvae	2	0.9	0.014	10.9
	Total	219		0.128	
7B	Macoma	10	8.1	0.008	7.0
	Oligochaete	79	63.7	0.058	50.4
	Pygospio elegans	30	24.2	0.026	22.6
	Saduria entomon	1	0.8	0.002	1.7
	ephydridae pupae	1	0.8	0.002	1.7
	chironomidae larvae	3	2.4	0.019	16.5
	Total	124		0.115	

See Fig. 2 for station locations.

Table 64 . Intertidal invertebrate samples, Cape Espenberg, Alaska, 15-27 August 1977 (5 samples per station total).

Station	Taxon	Total #	%	Total Wt. (g)	%
1A	no organisms				
1B	no organisms				
1C	chermidae	2	100.0	0.003	100.0
1D	chermidae	2	50.0	0.004	14.8
	mycetophilidae	1	25.0	0.002	7.4
	ephydridae	1	25.0	0.021	77.8
	Total	4		0.027	
2A	*Anisogammarus schmidti*	20	100.0	0.553	100.0
2B	*Anisogammarus schmidti*	7	100.0	0.160	100.0
2C	trichoptera	1	2.0	0.025	27.5
	cicadellidae	1	2.0	0.005	5.5
	chermidae	48	94.0	0.059	64.8
	braconid	1	2.0	0.002	2.2
	Total	51		0.091	
2D	chermidae	4	66.7	0.006	60.0
	mycetophilidae	1	1.7	0.002	20.0
	braconidae	1	1.7	0.002	20.0
	Total	6		0.010	
3A	*Anisogammarus schmidti*	6	100.0	0.220	100.0
3B	*Anisogammarus schmidti*	2	100.0	0.048	100.0

Table 64. Intertidal invertebrate samples, Cape Espenberg, Alaska, 15-27 August 1977 (5 samples per station total). Cont.

Station	Taxon	Total #	%	Total Wt. (g)	%
3C	chermidae	11	52.4	0.015	42.9
	coleoptera	1	4.8	0.007	20.0
	unid. diptera	5	23.8	0.006	17.1
	braconidae	4	19.0	0.007	20.0
	Total	21		0.035	
3D	hemiptera	1	4.2	0.010	24.4
	cicadellidae	2	8.4	0.003	7.3
	chermidae	14	58.3	0.016	39.0
	aphidae	1	4.2	0.001	2.4
	mycetophilidae	1	4.2	0.002	4.8
	ephydridae	2	8.4	0.003	7.3
	unid. diptera	3	12.5	0.006	14.6
	Total	24		0.041	
4A	Oligochaete	1059	95.0	0.580	82.7
	ephydridae larvae	1	0.1	0.001	0.2
	pupae	47	4.2	0.094	13.4
	chironomidae larvae	8	0.7	0.026	3.7
	Total	1115		0.701	
4B	Oligochaete	933	88.3	0.679	72.1
	ephydridae larvae	1	0.1	0.002	0.2
	pupae	121	11.4	0.230	24.2
	Ephydra pupae	2	0.2	0.031	3.3
	Total	1057		0.942	
4C	Oligochaete	36	6.8	0.026	3.4
	ephydridae larvae	38	7.2	0.049	6.3
	pupae	456	86.0	0.698	90.3
	Total	530		0.773	

Table 64. Intertidal invertebrate samples, Cape Espenberg, Alaska 15-27 August 1977 (5 samples per station total). Cont.

Station	Taxon	Total #	%	Total Wt. (g)	%
5A	Macoma	29	20.3	0.545	84.0
	Pygospio elegans	113	79.0	0.102	15.7
	unid. amphipod	1	0.7	0.002	0.3
	Total	143		0.649	
5B	Macoma	7	4.6	0.104	47.3
	Oligochaete	4	2.6	0.002	0.9
	Pygospio elegans	138	90.2	0.101	45.9
	Saduria entomon	1	0.6	0.007	3.2
	Onisimus	1	0.6	0.003	1.4
	ephydrid pupae	2	1.3	0.003	1.4
	Total	153		0.220	
5C	Macoma	1	5.9	0.010	47.6
	Oligochaete	3	17.6	0.002	9.5
	Pygospio elegans	13	76.5	0.009	42.9
	Total	17		0.021	
5D	Oligochaete	4	80.0	0.002	50.0
	ephydridae pupae	1	20.0	0.002	50.0
	Total	5		0.004	
6A	Macoma	2	18.2	0.012	25.5
	Pygospio elegans	6	54.5	0.005	10.6
	mysid	3	27.3	0.030	63.8
	Total	11		0.047	
6B	Macoma	2	33.3	0.020	87.0
	Oligochaete	1	16.7	--	-
	Pygospio elegans	3	50.0	0.003	13.0
	Total	6		0.023	

Table 64. Intertidal invertebrate samples, Cape Espenberg, Alaska, 15-27 August 1977 (5 samples per station total). Cont.

Station	Taxon	Total #	%	Total Wt. (g)	%
6C	Oligochaete	8	100.0	0.004	100.0
6D	Oligochaete	261	99.6	0.150	88.2
	dolichopodidae larvae	1	0.4	0.020	11.8
	Total	262		0.170	
7A	Oligochaete	408	89.3	0.223	67.6
	ephydridae pupae	48	10.5	0.096	29.1
	Ephydra pupae	1	0.2	0.011	3.3
	Total	457		0.330	
7B	Oligochaete	499	82.2	0.312	58.0
	ephydridae pupae	106	17.5	0.212	39.4
	Ephydra pupae	2	0.3	0.014	2.6
	Total	607		0.538	

See Fig. 2 for station locations.

Table 65. Intertidal invertebrate samples, Cape Espenberg, Alaska, 16-20 September 1977 (5 samples per station total).

Station	Taxon	Total #	%	Total Wt. (g)	%
2A	Spio mimus	9	90.0	0.008	15.7
	Anisogammarus schmidti	1	10.0	0.043	84.3
	Total	10		0.051	
2B	Spio mimus	24	96.0	0.020	14.6
	Anisogammarus schmidti	1	4.0	0.117	95.4
	Total	25		0.137	
4A	Scolecolepides arctius	11	4.2	0.108	6.6
	Pygospio elegans	19	7.3	0.013	0.8
	chironomidae larvae	230	88.5	1.512	92.6
	Total	260		1.633	
4B	Macoma	2	1.0	0.042	3.6
	Oligochaete	1	0.5	-	-
	Scolecolepides arctius	3	1.5	0.014	1.2
	Pygospio elegans	41	20.0	0.034	2.9
	chironomidae larvae	158	77.0	1.076	92.3
	Total	205		1.166	
5A	Macoma	35	10.6	0.476	74.8
	Oligochaete	18	5.4	0.013	2.0
	Pygospio elegans	274	82.8	0.127	20.0
	Saduria entomon	1	0.3	0.014	2.2
	Onisimus	3	0.9	0.006	0.9
	Total	331		0.636	
5B	Macoma	35	17.4	0.808	90.2
	Oligochaete	19	9.4	0.011	1.2
	Pygospio elegans	147	73.1	0.077	8.6
	Total	201		0.896	

Table 65. Intertidal invertebrate samples, Cape Espenberg, Alaska, 16-20 September 1977 (5 samples per station total). Cont.

Station	Taxon	Total #	%	Total Wt. (g)	%
7A	Macoma	36	11.1	1.327	43.7
	Oligochaete	1	0.3	-	-
	Scolecolepides arctius	261	80.5	1.440	47.4
	Pygospio elegans	17	5.2	0.014	0.4
	Saduria entomon	4	1.2	0.243	8.0
	Onisimus	2	0.6	0.009	0.3
	unid. amphipod	1	0.3	0.002	0.1
	chironomidae larvae	2	0.6	0.001	-
	Total	324		3.036	
7B	Macoma	27	6.5	0.689	26.0
	Scolecolepides arctius	348	84.1	1.807	68.1
	Pygospio elegans	134	32.6	0.085	3.2
	Saduria entomon	1	0.2	0.060	2.3
	Onisimus	1	0.2	0.002	0.1
	chironomid larvae	3	0.7	0.009	0.3
	Total	414		2.652	

See Fig. 2 for station locations.

Table 66. A comparison of abundance of potential avian prey items collected from intertidal samples, August 1976, 1977, Cape Espenberg, Alaska.

Organism	Year	Sea Tot. No.	Sea Tot. Wgt. (g)	Bay Tot. No.	Bay Tot. Wgt. (g)
Macoma	76	--	---	15	0.027
	77	--	---	41	0.691
Polychaetes	76	--	---	441	0.586
	77	--	---	273	0.220
Mysids	76	--	---	5	0.034
	77	--	---	3	0.030
Saduria entomon	76	--	---	139	1.090
	77	--	---	1	0.007
Amphipods	76	135	2.239	11	0.060
	77	35	0.981	2	0.005
Crangon	76	--	---	4	0.032
	77	--	---	--	---
Chironomid larvae	76	--	---	536	2.428
	77	--	---	8	0.026
Ephydrid larvae, pupae and adults	76	--	---	74	0.114
	77	3	0.024	667	1.079

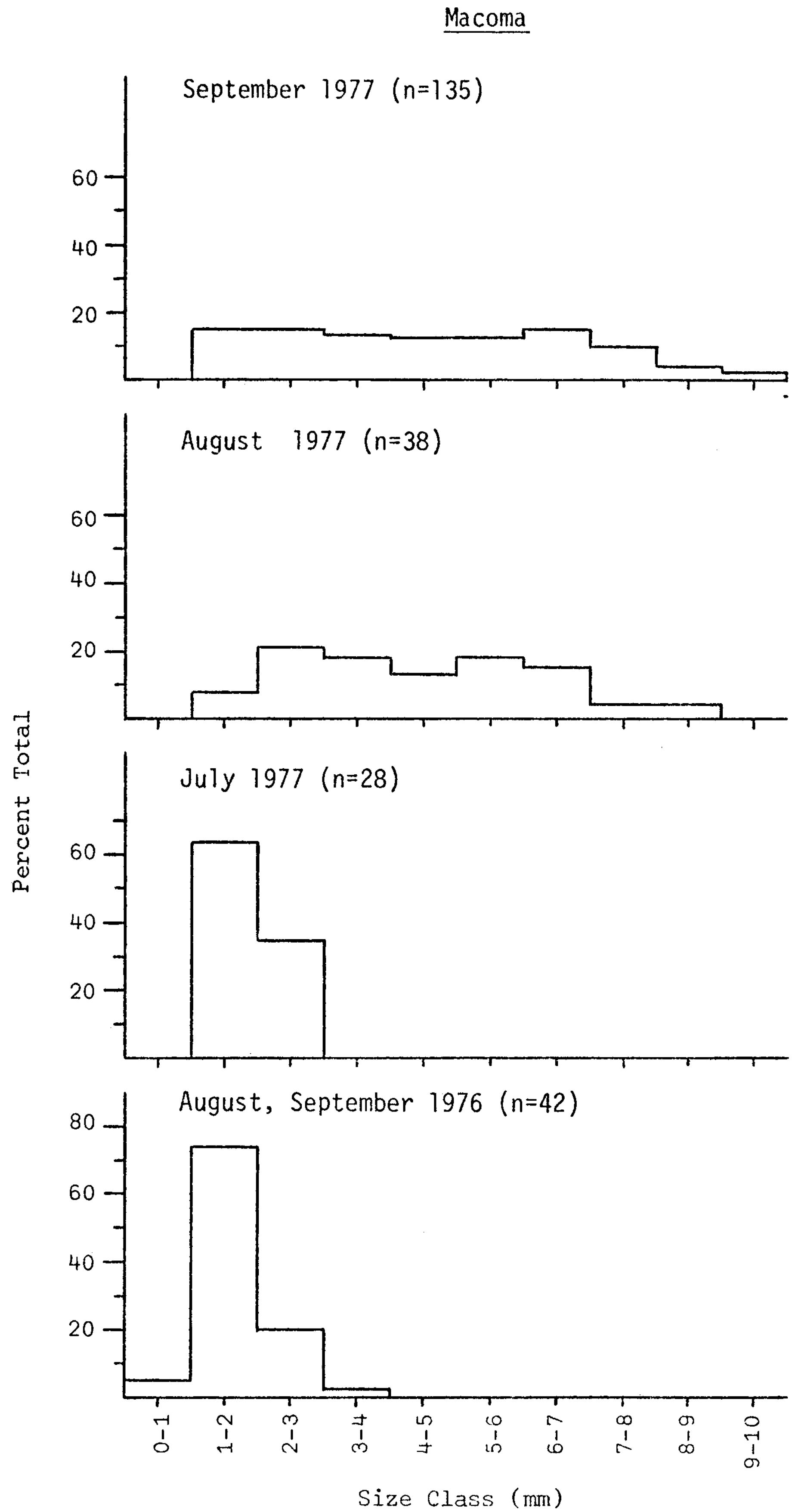

Figure 106. Size class distribution of the clam Macoma, August-September 1976 and July-September 1977, Cape Espenberg, Alaska.

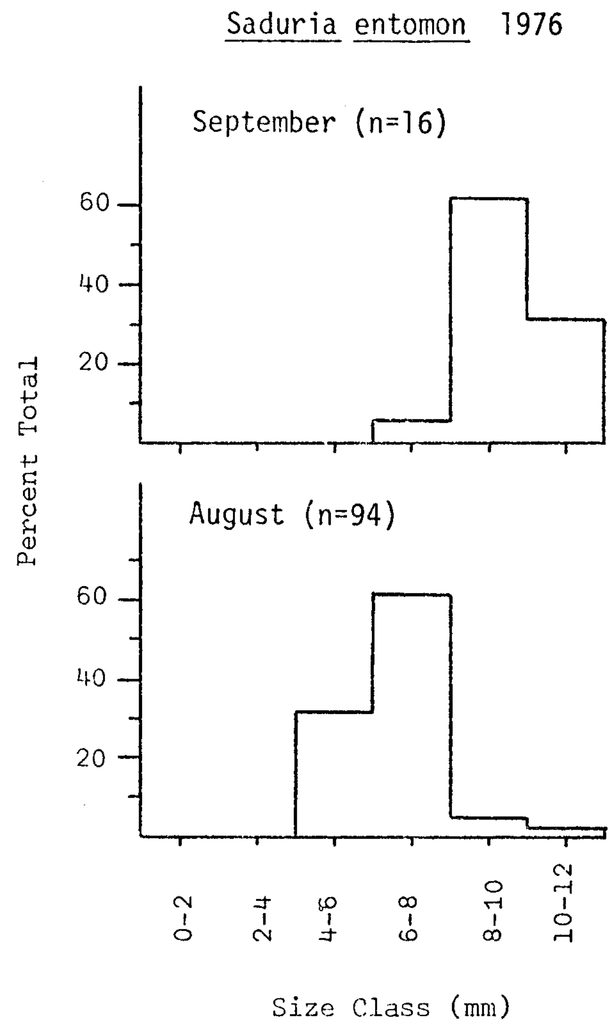

Figure 107. Size class distribution of the isopod *Saduria entomon*, August-September 1976, Cape Espenberg, Alaska.

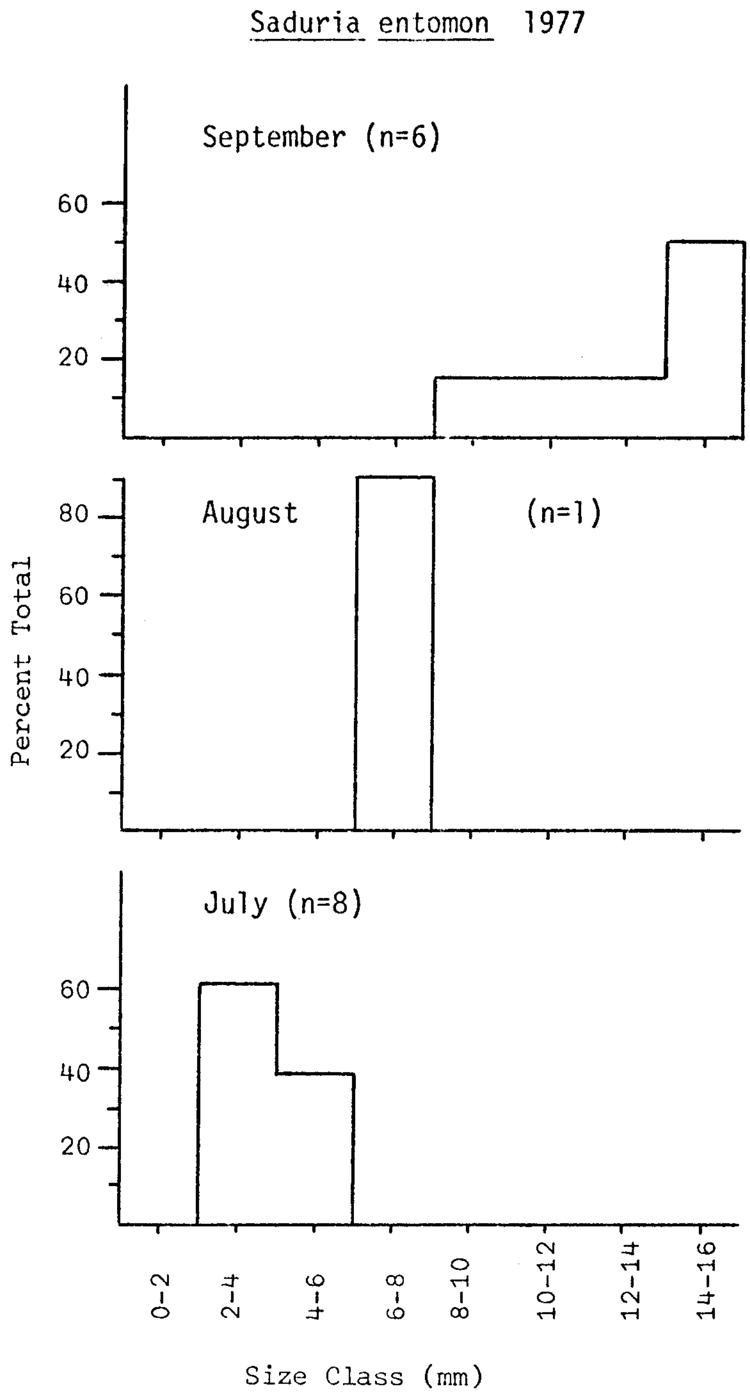

Figure 108. Size class distribution of the isopod Saduria entomon, July-September 1977, Cape Espenberg, Alaska.

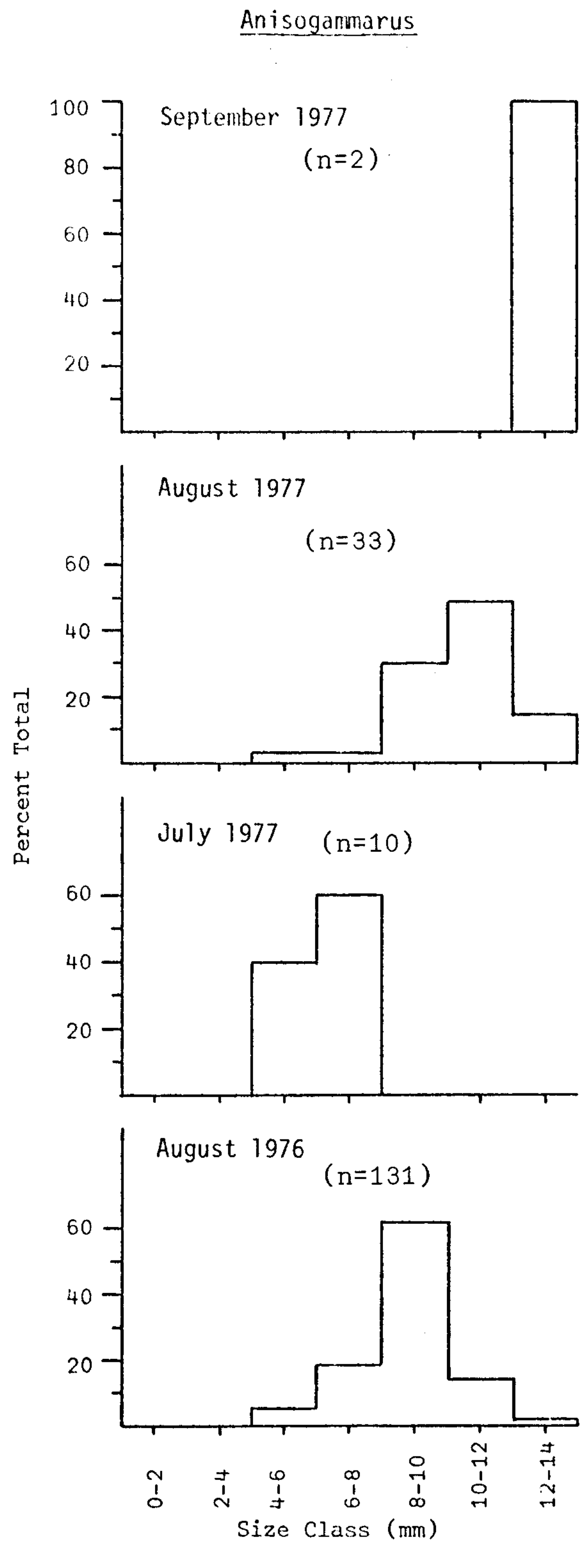

Figure 109. Size class distribution of the amphipod *Anisogammarus*, August 1976 and July-September 1977, Cape Espenberg, Alaska.

indicate that adult and/or larval terrestrial and aquatic insects were extensively taken by most birds. On numerous occasions, Arctic Terns and Parasitic Jaegers were observed capturing flying insects in mid-air. Sabine's Gull regurgitation pellets contained at least some adult insect parts and the young gulls were seen capturing emerging adult insects at pond margins.

Many fall migrant shorebirds fed primarily on the mudflats. Fall migrant Dunlins were collected from Espenberg Bay mudflats in both summers. The stomach contents of these birds (Table 67) reflects the different array of invertebrates available in the mud. As previously discussed, isopods were numerous in 1976, while pelecypods were few and small. Most Dunlin stomachs contained isopods; none contained pelecypods. In 1977, however, the situation was reversed, both in the mud samples and the bird stomachs. Connors (1978) noted neither item in Dunlins collected from Barrow, Krusenstern, and Wales. Western Sandpipers, collected in 1976, had stomach contents quite similar to Dunlins collected in the same area (Table 67). Sanderlings were collected along the sea coast. They had eaten amphipods from the water's edge and insects from the drift debris. Connors (1978) reported amphipods and insects in Sanderlings collected at Wales.

Casual observations were made on Arctic Terns and Sabine's Gulls in nearshore waters. Terns and gulls fed on large concentrations of mysids in Espenberg Bay in June and July 1977. Terns captured *Crangon* shrimps on both coasts and at least occasionally fed shrimp to their young. Shorefly (Ephydrid) larvae, pupae, and adults appeared to be a main food item for Sabine's Gulls. These items were procured from the South Mudflats throughout the summer. Young Sabine's Gulls were apparently fed primarily regurgitated shoreflies (larvae, pupae, and some adults).

Shoreflies are an important food source for Glaucous Gulls (see Table 41) and shorebirds (Table 67). These insects can be quite abundant. Mud samples taken from the center of the South Mudflats indicated a density of 3.5 shoreflies per cm^2 (primarily larvae and pupae, but some adults). Shoreflies were an important food item in shorebirds collected on the Copper River delta of south-central Alaska (Senner 1977).

Invertebrates taken by Glaucous Gulls and foxes are discussed under the section of this report dealing with predation.

Assessment of the Probable Impacts on Birds of Oil and Gas Development

Oil Pollution

Based on currents (J. Cannon, pers. comm.), prevailing winds (National Weather Service records) and driftwood deposits, oil spilled in the Chukchi Sea in the area north of Bering Strait to Kotzebue Sound will likely be deposited on Cape Espenberg beaches. Of the 10 classes of shoreline susceptible to oil pollution (M. O. Hayes 1977), Cape Espenberg contains the two most vulnerable, protected estuarine *tidal flats* and *salt marshes*.

Table 67. Results of shorebird stomach analysis, Cape Espenberg, Alaska, 1976, 1977.

			Percent of Bird Stomachs Containing:								
			Mollusca	Annelida		Arthropoda					
Bird Species	Year Coll.	No.	pelecypod	oligochaete	polychaete	mysid	amphipod	isopod	chironomid	ephydrid	Other insects
Dunlin	76	9	---	11	11	33	22	67	33	78	22
	77	8	50	--	12	12	25	12	38	38	--
Western Sdp	76	3	--	33	--	--	--	67	--	100	33
Sanderling	76	1	--	--	--	--	--	--	--	100	100
	77	2	--	--	--	--	100	--	--	100	100

Chemical and biogenic processes must degrade the oil if it is to be removed with human effort (M. O. Hayes 1977).

The direct effect of oil on birds is a reduction in the insulative value of feathers. This often results in hypothermia and consequent death (Erickson 1963, Bourne 1968). Oiled birds attempt to preen their plumage to remove such deposits. In the process, oil is ingested and this may cause death (Hartung and Hunt 1966, Hartung 1967).

At Cape Espenberg, species most susceptible to spilled oil include those which derive most of their food in marine waters, especially by diving (loons, seaducks, and alcids) and by surface-seizing (phalaropes and larids). Table 68 presents our estimates of the degree and timing of susceptibility to direct effects of oil pollution for common species of birds at Cape Espenberg. Our estimates of vulnerability are based on the relative amount of time that birds in the Espenberg area fed or rested in a given habitat.

Of the Cape Espenberg avifauna, loons, seaducks, larids, and alcids spend nearly all of their feeding time at sea. Phalaropes feed at sea prior to nesting. Females return to sea after egg-laying, males after brood rearing, and young after fledging. These are also the arctic species most often found dead as a result of oil pollution in the marine environment (Vermeer and Anweiler 1975:475).

Concentrations of these species occur in leads during spring. Oil contamination in these leads may result in catastrophic die-offs. Other feeding aggregations were noted at Cape Espenberg after ice disintegrated or was blown offshore. Both years concentrations of several 100s of Glaucous Gulls were observed at the tip of Cape Espenberg and in Espenberg Bay during periods from late July to late September.

Gulls, alcids, seaducks, loons, and phalaropes also tend to land on and feed in calmer water after flying to new feeding and resting sites. Since oil calms choppy waters, these are the very locations where birds would likely land and hence become contaminated (Curry-Lindahl 1960).

Molting sea ducks and flightless young are especially susceptible to oil spills because their only locomotion is by swimming or walking. At present we do not know where most adult male Oldsquaws and eiders from Cape Espenberg molt during July, nor where adult female eiders molt in August and September. We do know that eider broods are present on Espenberg Bay and on coastal waters. Creches of about 100 young eiders were occasionally noted along the Chukchi coast in late August and September. Creches of about 20-50 young were regularly observed in the Bay during late July and August. These birds rested on the beaches and fed in the water. An oil spill in these areas would result in death of downy young, and possibly of adults. Likewise, downy young of brant and Emperor Geese would be susceptible if led by their parents into contaminated waters or onto oiled mudflats.

Thousands of staging Pintails and 10,000s (minimally) of shorebirds would be subject to oil spilled on the mudflats of Espenberg Bay from July through September. Pintails, plovers, curlews, godwits, dowitchers,

Table 68. Estimated degree and time[1] of susceptibility of birds in the area of Cape Espenberg to oiling of plumage and ingestion of oil based on percent of time birds spend on the water and their feeding behavior (rarely seen birds not included).

	Location of Oil				
Species	Unlikely to Be Susceptible[2]	Nearshore Coastal Waters and Intertidal Flats	Bay Waters and Intertidal Flats	Beaches to Driftwood Zone	Sedge-Saltgrass Meadows
Yellow-billed Loon		Low: June-Sept.	High: June-Sept.	-	-
Arctic Loon		High: June-Sept.	High: June-Sept.	-	-
Red-throated Loon		High: June-Sept.	High: June-Sept.	-	-
Whistling Swan		-	Mod: Aug.-Sept.	-	-
Canada Goose		-	Low: July-Sept.	-	Mod: June-Sept.
Black Brant		-	Mod: July-Sept.	-	Low: June-Sept.
Emperor Goose		-	Mod: June-Sept.	-	Mod: June-Sept.
Snow Goose	X				
Mallard	X				
Pintail		-	High: June-Aug.	-	Low: May-Aug.
Green-winged Teal	X				
American Wigeon	X				
Northern Shoveler	X				
Canvasback	X				
Greater Scaup	X				
Oldsquaw		High: May-Sept.	High: May-Sept.	-	-
Common Eider		High: May-Sept.	High: May-Sept.	-	-
King Eider		High: May-Sept.	High: May-Sept.	-	-
Spectacled Eider		High: June-Suly	High: June-Sept.	-	-
Surf Scoter		High: June-July	-	-	-
Red-breasted Merganser		Mod: June-Sept.	High: Sept.	-	-
Goshawk	X				
Marsh Hawk	X				
Willow Ptarmigan		-	-	Low: May-Sept.	-
Sandhill Crane			Low: June-Sept.	Low: May-Sept.	Low: May-Sept.
American Golden Plover		-	Low: June-Sept.	-	Low: June-Sept.
Black-bellied Plover		-	Low: June-Aug.	-	Low: June-Aug.
Ruddy Turnstone		Mod: May-Aug.	Low: May-Aug.	Mod: May-Aug.	-
Black Turnstone		Mod: Aug.	Low: Aug.	Mod: Aug.	Mod: June-Aug.
Common Snipe	X				
Whimbrel		Low: July-Aug.	Low: July-Aug.	-	-
Bristle-thighed Curlew		Low: July-Aug.	Low: July-Aug.	-	-
Red Knot		Low: July-Aug.	Mod: July-Aug.	-	-
Sharp-tailed Sandpiper		-	Low: Aug.-Sept.	-	-
Pectoral Sandpiper		Low: July-Aug.	Low: July-Aug.		Low: July-Aug.
Baird's Sandpiper		Low: June-Aug.	Low: June-Aug.	Low: June-Aug.	Low: Aug.

Table 68 . Estimated degree and time[1] of susceptibility of birds in the area of Cape Espenberg to oiling of plumage and ingestion of oil based on percent of time birds spend on the water and their feeding behavior (rarely seen birds not included). (Cont.)

Location of Oil

Species	Unlikely to Be Susceptible[2]	Nearshore Coastal Waters and Intertidal Flats	Bay Waters and Intertidal Flats	Beaches to Driftwood Zone	Sedge-Saltgrass Meadows
Dunlin		Low: May-Sept.	High: May-Sept.	Low: May-Sept.	Low: July-Sept.
Semipalmated Sandpiper		Low: May-Aug.	Mod: May-Aug.	Low: May-Aug.	Low: July-Aug.
Western Sandpiper		Low: June-Aug.	Mod: June-Aug.	Low: June-Aug.	Low: July-Aug.
Sanderling		Mod: July-Sept.	Low: July-Sept.	Low: July-Sept.	-
Long-billed Dowitcher		-	Mod: July-Sept.	-	Low: July-Sept.
Bar-tailed Godwit		Low: July-Aug.	Low: July-Aug.	-	-
Hudsonian Godwit	X				
Red Phalarope		High: June-Aug.	High: June-Aug.	-	Mod: June-Aug.
Northern Phalarope		High: June-Sept.	High: June-Sept.	-	Mod: June-Aug.
Pomarine Jaeger		Low: June-July	-	-	-
Parasitic Jaeger		Low: June-Sept.	Low: June-Sept.	Low: June-Sept.	Low: June-Sept.
Long-tailed Jaeger		Low: June-July	-	-	-
Glaucous Gull		High: May-Sept.	High: May-Sept.	Mod: May-Sept.	Low: May-Sept.
Black-legged Kittiwake		High: June-Sept.	Mod: June-Sept.	Low: June-Sept.	-
Sabine's Gull		Mod: June-Aug.	High: June-Aug.	-	-
Arctic Tern		High: June-Aug.	High: June-Aug.	Mod: June-Aug.	-
Common Murre		High: June-Aug.	-	-	-
Thick-billed Murre		High: June-Aug.	-	-	-
Horned Puffin		High: July	-	-	-
Tufted Puffin		High: July-Aug.	-	-	-
Snowy Owl	X				
Short-eared Owl	X				
Say's Phoebe	X				
Tree Swallow	X				
Bank Swallow	X				
Common Raven	X				
Wheatear	X				
Arctic Warbler	X				
Yellow Wagtail	X				
Redpoll sp.		-	-	Low: June-Aug.	-
Savannah Sparrow	X				
White-crowned Sparrow	X				
Lapland Longspur		Low: June-Sept.	Low: June-Sept.	Low: May-Sept.	Low: June-Sept.
Snow Bunting		-	-	Low: Sept.	-

[1]Only for months of May through September, based on 1976 and 1977 observations.

[2]Based on data for 1976 and 1977; birds could use oiled waters in the future.

Dunlins, small sandpipers, and phalaropes would be susceptible since these species often wade into the water and at least their belly plumage is wetted.

Seaducks and alcids in offshore waters near Cape Espenberg would be very susceptible to oil pollution in fall when birds are staging and are concentrated. C. Harrison (1977 pers. comm.) reported 60,000 to 70,000 murres off Cape Espenberg in October 1977, and 10,000+ Oldsquaws in Kotzebue Sound (some just north of Cape Espenberg) during the fall.

Pollution incidents in several sections of southern Kotzebue Sound could cause major bird mortality, particularly in late summer (see Aerial Surveys section). These coastal sections include: Espenberg Bay, Cape Deceit, Sullivan Bluffs, Nugnugaluktuk/Pish River Delta, Kiwalik Lagoon, and coastal section C" (Figs. 4 and 5). Since birds appear to move laterally along the coast during fall migration (see Aerial Surveys section), a pollution incident at a single locality could affect a very large number of birds as they pass that locale.

Oil spills also affect bird populations by killing or contaminating their food source (Evans and Rice 1974). Only very small amounts of crude oil produce lethal or sub-lethal effects on avian food organisms (Hawkes 1977). Prey items, such as crustacean larvae and molluscs, containing sub-lethal concentrations of petroleum may be less able to find food, avoid predators, or to reproduce (Shaw 1977:78). Some, like the clam, Macoma balthica (which was eaten by Dunlins at Espenberg), react to oil pollution by coming to the surface where they would be susceptible to avian predation. Zooplankton and other invertebrates retain and/or concentrate hydrocarbons when exposed to low levels of oil pollution (Lee 1975, Neff and Anderson 1975, Stainken 1975). Also, effects of oil pollution on intertidal organisms may persist through successive seasons (Carter 1976). Oil contamination of these foods at Espenberg would affect most shorebirds and Glaucous Gulls and some alcids and seaducks. Contamination of intertidal invertebrates would be a serious loss to staging shorebirds and dabbling ducks during July through September. Glaucous Gulls at Espenberg were found to depend heavily on marine invertebrates as a major food source and a reduction in this source would probably greatly reduce chick survival and overall gull production (see Glaucous Gull section). Since fishes are often mobile enough to avoid oil spills (Rice 1973), piscivorous birds such as loons and mrres probably would have a food source available. However, these species and terns, small gulls, and other alcids also feed on crustaceans, which could be very susceptible to oil pollution (especially larval stages).

Beached carcasses of oiled birds and mammals might be unsuitable for such scavengers as gulls, ravens and foxes. Other contaminated foods include vegetation near the high tide and storm tide lines. The sedge-saltgrass meadows would be affected by oil contamination. These would be unusable by grazing geese and brant, and by resting shorebirds.

The net result of contamination of these foods and feeding areas would be movement of birds to other feeding areas which likely would be of lower quality and/or already occupied by other staging birds which are also competitors for a limited food supply. And since many of the breeding birds at the Cape use marine food sources even during the nesting and chick rearing periods, contamination of these foods would reduce production.

Oil may cause indirect effects which lower survival of birds (Evans and Rice 1974). For instance, oil taken into the eyes or ingested could affect feeding behavior. Likewise, oil may obscure food items of plunge divers like terns and kittiwakes, and of surface-seizers like phalaropes and gulls. This, in turn, could force them away from contaminated areas, which may result in competition with other birds.

It should be pointed out that although Cape Espenberg does not harbor a cliff-nesting "seabird" (or Alcid) colony, the avian community on the Cape is still highly dependent upon marine habitats. Of the 34 nesting species on the Cape, 13 species used marine food sources during part or all of the nesting and brood-rearing period; 16 other nesting species used marine food sources at least occasionally during this period. Marine habitats (including beaches and salt marshes) were also used for nesting sites, resting sites, and brood-rearing sites by some breeding birds on the Cape. It is sometimes incorrectly assumed that avian productivity would be greatly affected by perturbations in the marine environment only at "seabird colonies". Our studies at Espenberg clearly show that the productivity of birds nesting in coastal habitats other than cliffs may also be greatly influenced by oil pollution and other changes in marine habitats. In addition to the breeding birds, thousands of migrants also use marine habitats on or near the Cape. Excluding the rarely observed species, of 70 bird species using the Cape we judged 21 species to be highly susceptible to the direct effects of oil pollution during some part of the summer, 11 species to be moderately susceptible, 16 species to have only a low susceptibility, and 16 species not to be susceptible (Table 68).

In summary, oil spills can produce a variety of direct and indirect effects which reduce the survival of birds. All possible caution should be used to minimize the probability of a large oil spill. Chronic low level oil pollution especially should be minimized. It is potentially more dangerous to the ecosystem than catastrophic spills since food organisms may concentrate hydrocarbons and remain contaminated for several years (Evans and Rice 1974).

In view of the danger from oil spills, the most rigid safety standards for petroleum exploration, production, and transportation must be developed and enforced by the U.S. Coast Guard. In addition, the most modern and efficient clean-up equipment must be stationed nearby exploration and production centers. This clean-up equipment must be readily deployed for containment or dispersal of spilled oil.

In regard to petroleum exploration, a blowout in an exploratory well could lead to massive losses of fish, birds, and mammals. Carter (1976) suggested that an auxilliary drilling platform be stationed nearby to quickly drill a relief well. A nearby auxilliary drilling platform would vastly reduce the time and problems (such as winter ice) associated with shipping such a platform north to attempt drilling a relief well.

Exploratory and producing platforms must be able to withstand both wind and wave action in addition to wind and current-driven ice sheets. Pipelines should be buried deep enough to avoid being caught up in ships' anchors or gouged by keels of ice chunks moved by currents or wind.

Tanker safety precautions as suggested and modified from J. B. Hayes (1977) include: double bottoms on all tankers, segregated ballast, inert gas systems, back-up radar with collision avoidance systems, and improved emergency steering capabilities. With the advent of tanker traffic in the Chukchi and Bering Seas, the following may need to be established or improved: vessel traffic lanes, aids to navigation, better communications, anchorages, and facilities for damaged tankers. In particularly hazardous areas, a pilot trained for the locale, one-way traffic, radar, and tug assistance may be required (as at Valdez Arm [J. B. Hayes 1977] for Prudhoe Bay crude oil shipment out of Alaska).

J. B. Hayes (1977) reported that human error was responsible for 80 to 85% of tanker accidents. He stressed the need for properly trained pilots and such navigational aids as LORAN C radio for positioning, VHF-FM radio for communication, and shore radar for monitoring tanker positions.

Oil spill clean-up equipment for harbor spills includes: booms, skimmers, and boats with lights for night operation. For lagoons and bays with shallow water, boats with shallow draft or helicopters may be best suited for oil clean-up. For open ocean spills booms, skimmers, sorbents, and dispersants should be readily available. Self-inflating booms which can be helicopter lifted would be very advantageous for containment of spills in remote areas. All of this equipment must be frequently inspected and tested. Personnel must be trained and drilled to quickly and efficiently combat a spill. J. B. Hayes (1977) reported that the U.S. Coast Guard and the Environmental Protection Agency planned to upgrade their spill response to within 6 hours of a spill of 100,000 tons. Perhaps this should be modified to within 6 hours of a spill of 1,000 barrels!

Material Sites

Sand and gravel extraction will be necessary for a variety of oil development-related activities. Likely material sites are those areas where an abundance of sand and gravel is easily obtained with a minimum disturbance to flora and fauna. Mining of sand dunes, with resultant removal of vegetation, would promote instability of the dunes and result in loss of habitat. In addition, protection of marshes from storm tides and winds would be lost if dunes were removed. More likely sites include the outer beaches of capes and points where sand and/or gravel is continuously deposited by ocean currents. Point Hope, Cape Krusenstern, and Cape Espenberg are such sites (J. Cannon, pers. comm.).

However, sand extraction along the outer beach of Cape Espenberg may have harmful effects. The outer beach is a loafing and feeding area for several bird species (discussed under Habitat Use). Sand extraction during July through September would result in turbid waters which would obscure food items for divers like loons, seaducks and alcids, for plunge divers like kittiwakes and terns, and for surface-seizing feeders such as phalaropes and gulls. Furthermore, turbid waters and sand extraction during summer may lower the carrying capacity for the marine species eaten by birds.

Also, sand is important for the maintenance of Cape Espenberg and associated sand bar islands to the south (J. Cannon, pers. comm.). These sand bars are loafing sites for Glaucous Gulls, Black-legged Kittiwakes, Common Eiders, and Oldsquaws during June through September. In September and October they are used by Bearded and Largha Spotted Seals (F. Goodhope Jr., pers. comm.).

Therefore, extraction of sand when the coast is ice-free would disrupt feeding and loafing birds and loafing seals. However, it may be possible to extract sand during winter when biological effects would be reduced by heavy ice cover along the coast and in Kotzebue Sound, although any extraction would be unadvisable if it threatened the integrity of the Cape.

Shore-based Operations

Because of the unique character of Cape Espenberg and its dense population of nesting birds, we suggest that no shore-based support operations for oil development be permitted here. Such an operation would almost certainly reduce avian productivity on the Cape significantly. Any activity that causes loons, waterfowl, cranes, or larids to flush from their nests can easily increase predation by avian predators, since the eggs are left exposed and are easily located. Also, some species, especially Sandhill Cranes are very easily disturbed by human activities, even at a distance of many hundreds of meters.

Garbage associated with on-shore operations could indirectly affect avian productivity on the Cape. Both foxes and gulls are likely to use refuse dumps as a food source and these dumps may cause an increase in the numbers of foxes and gulls in the area. Increasing or stabilizing fox numbers at a relatively high level would greatly increase predation pressure on the birds nesting on the Cape.

Noise

Oil and gas developments have associated construction and transportation needs which produce noise. Airplanes and helicopters ferrying supplies and personnel to and from drilling and production platforms; earthmoving equipment, compressors, and tugs in coastal waters all produce noise which can affect the distribution of birds, and, possibly, their production and survival.

High noise levels near Cape Espenberg during spring may affect distribution of birds using leads in the sea ice. Noise from aircraft contributed to abandonment of nests and lowered fledging success of Lapland Longspurs, based on studies along the Firth River, Yukon Territory (Gollop et al. 1974). Aircraft also have been found to frighten non-breeding waterfowl from small lakes in arctic Canada; however, brood-rearing females were unwilling to relocate or abandon their broods (Schweinsburg et al. 1974).

Post-breeding waterfowl very considerably in their reaction to aircraft. Snow Geese are perhaps the most sensitive. Salter and Davis (1974) reported that flocks of these birds flushed due to fixed-wing aircraft overflights at altitudes up to 10,000 ft. (ca. 3,000 m). Other species of geese react by flushing, milling about in the air, or departing for their staging or wintering areas (P. Mickelson, pers. observ.). In contrast, helicopter overflights were found to have little affect on molting Oldsquaws (Ward and Sharp 1974). On low overflights, birds dived. However, this was only a momentary disturbance and birds soon returned to pre-disturbance activities. Moreover, frequently-disturbed areas were not abandoned by these birds (Ward and Sharp 1974). Studies such as these are necessary to determine species-specific reactions to aircraft and seasonal changes in sensitivity. This information, when coupled with knowledge of avian distribution and density, can be used to provide realistic recommendations for minimizing harassment of birds. Other studies are necessary to set standards for noise levels from construction activities.

Based upon our observations and data from studies like those reported above, we can make a few predictions. Frequent low aircraft traffic would likely reduce productivity drastically for cranes. Productivity would probably be noticeably lowered for loons and eiders (primarily from egg loss to predators during laying). Productivity of other birds would probably be little affected. Post-breeding concentrations of birds would be adversely affected only if they were frightened from feeding areas for a significant period of time. This could happen if overflights were quite frequent in the area. The critical frequency is not known.

Baseline Monitoring Program

Studies in other Arctic areas have shown large annual variations in the numbers, distribution, and productivity of many bird species (Pitelka 1959, Barry 1960, Childs 1969, Bergman 1974, Maher 1974, Pitelka et al. 1974, Norton et al. 1975). Factors influencing this variation include: weather (for waterfowl and some shorebirds), cyclic prey species (for jaegers), variations in predator densities, and features not yet determined (for species such as Buff-breasted Sandpipers). The nature and magnitude of normal annual fluctuations need to be understood before the effects of oil and gas development can be assessed meaningfully. For this reason, we have established census transects, nesting plots, aerial surveys, and carcass surveys to monitor the avian community at Cape Espenberg and in nearby areas. Intertidal invertebrate transects were also established. Although it would be best to continue our present intensity of study, monetary and time constraints will probably limit future efforts (after the 1977 field season) to monitoring census transects, aerial surveys, and/or a few indicator species.

Table 58. Continued

Collection period ending	Taxon: Collembola	Homoptera	Hemiptera	Trichoptera	Coleoptera larvae	Plecoptera	Lepidoptera	TOTAL
21 June	20	-	-	-	-	-	-	280
24	9	-	-	1	-	-	-	135
27	2	-	-	-	1	-	-	166
30	15	-	-	-	-	-	-	250
3 July	10	-	-	-	-	-	3	218
6	9	-	-	-	1	-	-	262
9	5	1	-	-	2	-	-	420
12	6	2	-	-	1	-	-	623
15	2	2	-	3	-	-	1	686
*19	4	2	-	1	2	-	1	311
22	6	6	-	2	-	-	1	553
25	4	2	-	5	3	-	1	492
28	1	5	-	2	-	-	1	421
31	3	7	-	4	-	-	-	455
3 August	3	2	1	1	-	-	2	306
*7	3	2	-	2	1	-	-	400
10	3	9	-	-	-	-	1	316
13	2	3	1	2	-	-	-	329
16	2	6	-	-	-	-	-	286
19	5	8	1	-	-	-	-	311
22	2	7	2	-	-	-	1	302
25	-	2	-	-	-	-	-	148
28	4	5	-	-	1	-	-	118

* Boards exposed for 4 days.

Although numerical differences were noted between years, seasonal and distributional trends from foot and aerial surveys showed remarkable consistency between years for the short period of this study. This consistency may be extremely important; drastic changes there may indicate significant changes in habitat use.

Criteria for choosing indicator species might include breeding birds that have: 1) a high position in the food chain, 2) a high degree of site tenacity, 3) a dispersed nesting distribution, 4) at least moderate abundance, and 5) little annual variation in density. Such birds would be most readily affected by the biological magnification of contaminants in the food chain. Strongly site tenacious birds are more likely to show the effects of disturbance to a small area than are free-ranging birds. If the birds normally show only a small amount of annual variation in breeding numbers, then the effects of disturbance should be readily noticeable.

Of the larger waterbirds, Red-throated Loons may best fit these criteria (Bundy 1976:249). They feed almost entirely at sea, where they are one of the top-level consumers. These birds nest solitarily on small ponds throughout the Cape.

Of the shorebird species at Cape Espenberg, Dunlins should be considered. Dunlins show a high degree of site tenacity and low annual variations in breeding densities (this study and Holmes 1970). They feed primarily in the marsh during the breeding season. Dunlins move to coastal mudflats in late July and August where they feed mainly on fly pupae, isopods and clams. Oil contamination of these intertidal areas would likely affect these birds and result in a much lessened return rate of breeding adults the following year.

By following populations of indicator species, impacts on most habitats could be evaluated. Furthermore, beaches could be surveyed for carcasses of birds and mammals. Only one carcass, a Horned Puffin, was found to be oiled during the period of our study. Future surveys could be conducted to monitor losses due to oil pollution.

VIII. CONCLUSIONS

Cape Espenberg is exceedingly rich in nesting waterbirds and its nearshore waters provide important foraging areas for thousands of resident and migrant birds. During our flights along 221 km of coastal southern Kotzebue Sound, we saw no marsh areas comparable in area or quality (for nesting) to that of Cape Espenberg. The Cape supports greater nesting densities of loons, waterfowl, shorebirds, and larids than other coastal areas along the Seward Peninsula (Noble and Wright 1977, Connors 1978, Shields and Peyton 1978), the Chukchi coast (Williamson et al. 1966, Connors 1978), and the Beaufort coast (Norton et al. 1975, Bergman et al. 1977).

Although small in total area (22.1 km^2), the Cape produced an estimated 14,000-16,000 chicks each summer, 1976-1977. The high production can be attributed largely to an ideal nesting habitat of mosaic wet marsh, interspersed with hummocks, broken ridges, small ponds and lakes. This type of habitat excluded Alcids and tree-nesting songbirds from the Cape, but supported very high densities of waterbirds. Banding studies indicate that a large percentage of nesting birds return to breed here, year after year.

Avian production was influenced by several factors, the most important of which was predation. Foxes (both Red and Arctic) were the most important predators. In years when foxes were common (1976-1977), production was significantly lower than in the year when foxes were not common (1978). Glaucous Gulls and Parasitic Jaegers also preyed upon eggs, young, and adult birds. However, they destroyed a much smaller percentage of nests than foxes. Small mammal populations were not large enough to effectively buffer predation pressure on nesting birds.

Other factors influenced production to a lesser extent. Phenology was quite different each year. This had only a small effect on clutch sizes, even in the ducks and geese. The greatest effect of phenological differences was probably related to adjustments to the nesting period. In early years, birds have a greater opportunity to replace clutches lost to predation. Subsistence activities by local Natives claimed a few eggs. Subsistence activities are currently conducted by only a few people and the net effect is very small. Reindeer trampled some nests and young. Because they did not arrive on the Cape until the end of the hatching period, total egg losses were small. However, large numbers of reindeer on the Cape during June could destroy a very high percentage of nests. Our studies on chick growth indicated that at least some young Glaucous Gulls and Arctic Terns starved to death. Thus, food supply may be limited during some summers.

Although littoral habitats were used by birds all summer, greatest use came in late summer. Beginning in July, thousands of ducks congregated on Espenberg Bay mudflats to feed. These birds were gradually replaced, beginning in late July, by thousands of sandpipers. Several thousand Dunlins were still present on these mudflats when the 1977 field season ended in late September. Concentrations of late summer migrants were not limited to mudflats. Golden Plovers, Pectoral Sandpipers, and Sandhill Cranes were abundant in the marsh. Dunlins rested in the marsh between feeding bouts in littoral areas. Juvenile Lapland Longspurs were very abundant along the Espenberg Bay high tide mark.

Food habitats studies of Glaucous Gulls and migrant shorebirds, plus incidental observations on other species, indicate that nearly all bird species on Cape Espenberg relied upon littoral foods at some time. Glaucous Gulls and some migrant shorebirds fed largely upon marine organisms. Changes in their diets, either seasonally or between years, reflect changes in food availability. In 1977, for instance, isopods were far less common than they had been in 1976. Both Glaucous Gulls and shorebirds consumed far fewer isopods in 1977. Glaucous Gulls substituted more fish in their diet in 1977, while shorebirds took advantage of an apparent increase in the local clam population.

Differences in available intertidal invertebrates were documented by invertebrate sampling during both summers.

Although Cape Espenberg does not harbor a cliff-nesting "seabird" colony, the avian community is still highly dependent upon marine habitats. Of 34 nesting species on the Cape, 13 used marine food sources during part or all of the nesting and brood-rearing period. An additional 16 species used marine foods at least occasionally during this period.

We have identified six areas of southern Kotzebue Sound that support large concentrations of birds in coastal waters: Cape Deceit, Sullivan Bluffs, Nugnugaluktuk/Pish River Delta, Kiwalik Lagoon, coastal section "C", and Espenberg Bay.

Oil contamination of nearshore waters poses a threat to bird populations throughout the summer. Oil in leads in the ice may affect spring migrants which often concentrate there. Numerous birds rely upon marine food sources throughout the summer and would be subjected to oil contamination while foraging at sea or along the coast. Birds may also be indirectly affected by oil contamination through loss of food resources.

The beach of Cape Espenberg is a likely site of sand extraction for petroleum development and related activities. Such activity during summer may produce sufficient turbidity to lower the feeding efficiency of birds near the site and downcurrent. Associated noise may lower the productivity of some nesting birds. Of prime concern, however, is the possibility that sand extraction may endanger the integrity of the Cape through erosion of the dunes. This might jeopardize the marsh habitat and its extremely high concentration of nesting waterbirds.

Because of the unique character of the Cape and the susceptibility of its dense population of nesting birds to disturbance, we suggest that no on-shore development be permitted on the Cape proper and that aerial disturbances be minimized.

Our work on the Cape has provided a large amount of baseline data on the avian community on Cape Espenberg. We have also marked out a number of permanent plots and transects. Hopefully, these data will be useful in revealing future changes in the avian community.

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Appendix 1. Birds banded on Cape Espenberg, Alaska and later observed in areas away from the Cape.

Three of our banded shorebirds were sighted away from the Cape. On 23 July 1976, a color-banded adult Dunlin was seen in a flock on a small island in Kotzebue Sound, 6 km south of the Cape. An adult Western Sandpiper that we captured and banded at a nest in 1976 was observed near Vancouver, B.C. on 1 and 2 August 1977. We also observed this bird at Cape Espenberg in June 1977, although it was not found associated with a nest. Finally, a Semipalmated Sandpiper, banded as a local chick in 1977, was shot in Cuba on 19 September 1977. It probably left the Cape in late July.

Appendix 2. Observations of marine mammals and terrestrial mammals not mentioned in the text, Cape Espenberg, Alaska, 1976-1977.

Moose (*Alces alces*)

Four moose were observed on the Cape in 1976 and 1977. These sightings included: 1) two small bulls together on 16 July 1976, 2) one large cow on 18 July 1977, and 3) one yearling or two-year old bull on 22 July 1977.

Grizzly Bear (*Ursus arctos*)

A grizzly bear or its fresh tracks was observed on 20, 21, 24 and 27 August and 12 and 29 September in 1977. All these observations were likely of the same individual, a large chocolate-brown bear. The bear walked the beaches searching for carcasses and two or more times crossed through the marsh from one side of the Cape to the other. No bears were observed in 1976.

Seals

Seals were not observed to haul out on the Cape proper. The only exception to this was a spotted seal (*Phoca vitulina largha*) pup observed alive on the beach on 10 August 1977. Seals were most visible in the area when the ice pack was breaking up off the Cape. At this time as many as hundreds of seals, chiefly spotted seals and ringed seals (*Phoca hispida*), were hauled out on the ice off the north beach of the Cape. On 13 June 1977 we counted a minimum of 98 seals on the ice in an area of about 0.7 km^2 and within 0.7 km of the beach. After the ice had left the area a few seals could be observed swimming in the Chukchi off the Cape throughout the summer. Fred Goodhope, Jr. (pers. comm.) indicated that seals hauled out on the sand bars and in the shallow water off the tip of the Cape in the fall. On 10 September 1977 we observed about 50 bearded seals (*Erignathus barbatus*) hauled out in shallow water about 400 m off the tip of the Cape.

Appendix 3. Dates of collection for vascular plants in the Cape Espenberg area, 1976 and 1977.

Family, Genus, Species	1976	1977
Gramineae		
Elymus arenarius	July 30	July 18
Arctophila fulva	August 16	--
Festuca rubra	present, not collected	August 3
Colpodium Vahlianum	August 18	--
Poa alpigena	August 16	--
P. glauca	July 30	--
P. arctica	August 16	July 18
P. eminens	present, not collected	August 3
Calamagrostis purpurascens	present, not collected	July 18
Hierchloe alpina	present, not collected	July 18
Cyperaceae		
Eriophorum Scheuchzeri	present, not collected	July 18
E. angustifolium	present, not collected	July 24
E. russeolum	present, not collected	June 24
Trichophorum caespitosum	present, not collected	July 18
Carex saxatilis	July 30	--
C. sitchensis	August 16	--
C. rostrata	present, not collected	July 18
C. aquatilis	August 16	July 18
C. rariflora	August 19	July 18
C. Gmelini	July 30	--
C. chordorrhiza	August 18	--
Juncaceae		
Juncus arcticus	July 30	August 3
Luzula confusa	July 30	--
Liliaceae		
Tofieldia pusilla	present, not collected	July 7
Iridaceae		
Iris setosa	August 2	July 22

Appendix 3 . Dates of collection for vascular plants in the Cape Espenberg area, 1976 and 1977. (Cont.)

Family, Genus, Species	1976	1977
Polygonaceae		
Polygonum bistorta	August 2	July 18
P. viviparum	present, not collected	July 28
Rumex arcticus	present, not collected	July 18
Caryophyllaceae		
Cerastium Beeringianum	present, not collected	June 14 flowering
Honckenya peploides	July 30	June 23 flowering
Minuartia rubella	present, not collected	--
Stellaria crassifolia	present, not collected	September 10
S. humifusa	present, not collected	July 17
S. monantha	present, not collected	July 28
Melandrium affine	present, not collected	July 18
Ranunculaceae		
Caltha palustris	present, not collected	June 17
Ranunculus Escholtzii	present, not collected	June 16
R. Pallasii	present, not collected	June 19
R. pedatifidus	present, not collected	June 18
Papaveraceae		
Papaver lapponicum	August 8	--
Cruciferae		
Cardamine pratensis	present, not collected	July 1
Cochlearia officinalis	July 30	June 19
Draba hirta	present, not collected	June 16
Crassulaceae		
Sedum rosea	present, not collected	June 21
Saxifragaceae		
Chrysosplenium tetrandrum	present, not collected	July 28
Parnassia palustris	August 2	July 23

Appendix 3 . Dates of collection for vascular plants in the Cape Espenberg area, 1976 and 1977. (Cont.)

Family, Genus, Species	1976	1977
Saxifraga exilis	August 12	July 9
S. foliolosa	present, not collected	August 6
S. hieracifolia	present, not collected	July 10
S. hirculus	July 30	July 12
Rosacea		
Potentilla Egedii	present, not collected	August 11
P. Hookeriana	July 30	--
P. palustris	July 30	July 25
P. villosa	present, not collected	June 12
Rubus chamaemorus	August 2	June 14
Leguminosae		
Astragalus alpinus	present, not collected	July 10
Lathyrus maritimus	July 30	June 24
Oxytropis Maydelliana	present, not collected	July 17
O. nigrescens	present, not collected	June 12
Onagraceae		
Epilobium angustifolium	August 21	September 4 with seeds
Haloragaceae		
Hippuris vulgaris	August 9	September 4
Umbelliferae		
Angelica lucida	present, not collected	July 18
Bupleurum triradiatum	August 9	July 10
Ligusticum scoticum	August 2	--
Cornaceae		
Cornus suecica	August 2	--
Pyrolaceae		
Pyrola grandiflora	present, not collected	July 12

Appendix 3. Dates of collection for vascular plants in the Cape Espenberg area, 1976 and 1977. (Cont.)

Family, Genus, Species	1976	1977
Empetraceae		
Empetrum nigrum	present, not collected	September 4 with berries
Ericaceae		
Andromeda polifolia	July 30	June 14
Arctostaphylos alpina	August 19	June 13
A. rubra	August 16	--
Cassiope tetragona	August 12	June 12
Ledum palustre	July 30	June 19
Loiseleuria procumbens	August 16	June 12
Vaccinium uliginosum	August 16	June 14
V. vitis-idaea	July 30	July 16
Primulaceae		
Androsace chamaejasme	July 30	June 19
Primula borealis	present, not collected	June 23
Plumbaginaceae		
Armeria maritima	present, not collected	July 7
Gentianaceae		
Lomatogonium rotatum	present, not collected	July 28
Polemoniaceae		
Polemonium acutiflorum	August 25	July 10
Boraginaceae		
Myosotis alpestris	July 30	June 26
Scrophulariaceae		
Castilleja elegans	August 9	July 11
Pedicularis capitata	present, not collected	July 1
P. labradorica	July 30	July 7
P. lanata	present, not collected	June 12

Appendix 3 . Dates of collection for vascular plants in the Cape Espenberg area, 1976 and 1977. (Cont.)

Family, Genus, Species	1976	1977
P. parviflora	July 30	July 9
P. sudetica	present, not collected	June 29
Lentibulariaceae		
Pinguicula villosa	present, not collected	July 5
Valerianaceae		
Valeriana capitata	July 30	--
Campanulaceae		
Campanula uniflora	present, not collected	July 5
Compositae		
Artemesia Tilesii	July 30	September 4
Aster sibiricus	August 9	July 5
Chrysanthemum arcticum	July 30	July 10
Petasites frigidus	present, not collected	June 7
Saussurea nuda	July 30	July 18
Senecio congestus	present, not collected	August 2
S. pseudo-Arnica	July 30	--
Taraxacum ceratophorum	present, not collected	--
T. kamtschaticum	present, not collected	June 26
Tripleurospermum phaeocephalum	August 29	July 7

Appendix 4. Daily weather data collected at Kotzebue during May through September, 1976, based on National Weather Service observations.

Date	Temperature °F. Max.	Min.	Ave.	Departure from Ave.	Weather Type	Precipitation (in.)	Wind Speed (MPH) Ave.	Max.	Direction (Degrees)	Sky Cover (Tenths)
May										
1	46	33	40	18		0	9.8	20	90	2
2	46	28	37	14		0	6.2	12	70	3
3	49	35	42	18		0	11.4	17	100	8
4	46	28	37	13		0	6.9	9	240	3
5	41	26	34	9	Heavy Fog	0	6.0	9	250	3
6	37	24	31	5		0	15.0	25	290	4
7	30	24	27	1	Fog	Trace	15.0	21	290	9
8	27	23	25	-2	Fog, Glaze	Trace	8.8	14	310	10
9	28	21	25	-2	Glaze	Trace	8.9	14	270	8
10	42	20	31	3		0	5.6	10	90	4
11	32	23	28	0		0	7.6	12	70	7
12	31	21	26	-3		Trace	7.3	12	230	8
13	28	20	24	-6		0	10.5	15	250	8
14	28	13	21	-9		Trace	10.8	21	280	8
15	40	16	28	-3		Trace	13.7	23	130	10
16	45	35	40	9		Trace	13.1	21	120	10
17	46	35	41	9		.01	7.6	12	100	9
18	46	31	39	7		0	8.1	15	300	8
19	38	24	31	-2		0	16.3	22	280	5
20	35	20	28	-5		0	19.1	25	290	0
21	31	17	24	-10		0	10.4	15	260	0
22	33	21	27	-7	Heavy Fog	0	11.5	23	290	5
23	30	23	27	-8	Fog	Trace	20.7	30	290	10
24	29	24	27	-8	Fog, Snow	Trace	31.6	39	290	9
25	29	23	26	-9	Fog, Glaze	.10	24.3	28	270	10
26	27	21	24	-12	Fog, Glaze	.01	11.9	20	270	10
27	27	19	23	-13		0	21.6	35	300	4
28	33	18	26	-11		Trace	24.3	35	300	7
29	31	26	29	-8		Trace	13.7	20	280	10
30	33	28	31	-6	Fog, Glaze	Trace	16.4	29	290	10
31	46	30	38	0		Trace	14.0	21	140	10

Appendix 4. Continued.

Date	Temperature °F Max.	Min.	Ave.	Departure from Ave.	Weather Type	Precipitation (in.)	Wind Speed (MPH) Ave.	Max.	Direction (Degrees)	Sky Cover (Tenths)
June										
1	56	37	47	9		.04	12.7	20	120	10
2	48	36	42	4	Heavy Fog	.09	6.9	14	190	10
3	40	30	35	-4	Fog	Trace	8.5	12	290	8
4	54	30	42	3		0	8.3	14	90	7
5	58	34	46	6	Fog	0.4	14.1	20	140	10
6	39	33	36	-4		Trace	5.6	13	200	7
7	43	30	37	-3		0	7.2	15	290	5
8	40	30	35	-6	Fog	0	8.5	21	300	5
9	34	30	32	-9	Fog	0	24.9	30	290	6
10	38	31	35	-6		0	19.4	24	300	1
11	40	34	37	-5		0	12.5	17	290	3
12	47	33	40	-2		0	7.3	14	300	4
13	50	33	42	0		0	8.8	15	300	3
14	42	34	38	-5		0	11.7	21	270	2
15	42	33	38	-5	Fog	0	11.9	17	280	5
16	41	33	37	-7		Trace	9.4	12	260	5
17	40	34	37	-7		Trace	10.4	16	260	10
18	39	33	36	-8	Fog	Trace	11.2	15	250	10
19	46	33	40	-5		Trace	4.9	12	10	10
20	50	35	43	-2	Fog	.01	8.6	13	180	10
21	39	34	37	-9	Fog	.20	5.5	12	200	10
22	47	37	42	-4		.06	7.3	16	120	10
23	53	41	47	1		0	16.4	22	120	8
24	47	33	40	-7	Heavy Fog	.11	13.4	21	280	8
25	65	32	49	2	Heavy Fog	Trace	10.9	16	190	7
26	59	39	49	1		0	9.2	14	200	5
27	41	33	37	-11	Fog	0	14.1	20	280	8
28	40	33	37	-11		0	16.7	25	280	7
29	42	34	38	-11		.10	15.8	26	290	9
30	40	33	37	-12	Fog	.03	20.4	28	290	9

Appendix 4. Continued.

Date	Temperature °F Max.	Min.	Ave.	Departure from Ave.	Weather Type	Precipitation (in.)	Wind Speed (MPH) Ave.	Max.	Direction (Degrees)	Sky Cover (Tenths)
July										
1	37	32	35	-15	Fog	Trace	21.0	24	280	9
2	45	30	38	-12	Fog	.02	13.8	18	120	9
3	44	36	40	-10		.73	20.3	35	150	10
4	39	34	37	-14	Fog	.07	18.7	25	280	9
5	47	34	41	-10		0	7.2	12	300	10
6	54	42	48	-3		Trace	10.6	17	300	10
7	44	35	40	-12	Fog	0	15.0	18	290	7
8	48	36	42	-10	Heavy Fog	0	8.8	14	280	5
9	55	44	50	-2		0	9.4	14	300	3
10	60	48	54	-2		0	8.1	15	300	0
11	61	50	56	3		0	8.3	12	360	1
12	69	55	62	9		0	9.9	16	300	1
13	59	39	49	-4	Heavy Fog	0	22.4	30	290	9
14	40	39	45	-8	Fog	0	9.9	17	280	6
15	67	48	58	5		0	7.8	14	210	0
16	58	50	54	0		0	10.4	15	300	2
17	61	47	54	0	Fog	0	13.5	20	190	7
18	56	45	51	-3	Fog	.12	12.1	23	180	8
19	67	46	57	3		0	10.4	16	160	6
20	66	51	59	5		.05	12.8	18	70	10
21	68	53	61	7		0	10.2	17	300	6
22	63	51	57	3	Fog	0	15.8	25	290	4
23	67	47	57	3	Fog	0	9.2	18	290	2
24	70	57	64	10		0	12.8	23	310	5
25	62	53	58	4		0	17.5	26	300	7
26	57	50	54	0		0	20.6	28	300	7
27	55	39	47	-7	Heavy Fog	0	15.8	25	290	8
28	63	52	57	3		.10	16.5	24	160	10
29	56	48	52	-2		.07	18.1	26	160	10
30	58	48	53	-1		0	17.1	21	170	8
31	63	47	55	1		0	11.8	18	120	5

Appendix 4. Continued.

Date	Temperature °F Max.	Min.	Ave.	Departure from Ave.	Weather Type	Precipitation (in.)	Wind Speed (MPH) Ave.	Max.	Direction (Degrees)	Sky Cover (Tenths)
August										
1	60	50	55	1	Fog	0	6.6	13	230	2
2	65	50	58	5		0	11.5	18	290	6
3	54	50	52	-1		0	6.5	15	200	10
4	59	51	55	2		0	7.3	13	300	10
5	64	55	60	7		0	9.1	16	290	5
6	66	54	50	7		0	13.1	20	350	1
7	63	51	57	4		0	10.1	15	350	8
8	61	46	54	2		0	8.6	12	240	2
9	61	52	57	5		0	8.5	16	310	4
10	56	51	54	2		.03	8.6	16	310	10
11	62	52	57	5		0	9.8	17	300	5
12	64	53	59	7		.02	9.1	16	280	8
13	58	53	56	5		.09	8.5	18	260	10
14	61	53	57	6		.27	11.7	16	130	10
15	56	46	51	0	Fog	.07	18.0	25	180	10
16	58	47	53	2		0	14.7	21	170	7
17	59	47	53	2		0	8.5	12	210	4
18	60	43	52	2		0	9.6	25	300	1
19	56	47	52	2		0	12.8	24	300	3
20	56	50	53	3		0	13.2	16	270	3
21	56	50	53	3		0	11.5	18	290	7
22	64	48	56	6	Fog	Trace	8.1	13	150	7
23	65	50	58	9		0	10.2	21	260	8
24	62	49	56	7		0	10.4	18	160	9
25	65	52	59	10		Trace	12.8	23	160	4
26	62	52	57	8		0	9.6	20	310	3
27	60	50	55	7		0	9.4	14	280	2
28	57	52	55	7	Heavy Fog	0	14.5	21	280	4
29	58	53	56	8		0	11.8	15	290	1
30	58	48	53	5		0	5.5	9	270	2
31	66	46	56	9		0	8.5	14	100	3

Appendix 4. Continued.

Date	Temperature °F Max.	Min.	Ave.		Weather Type		Wind Speed (MPH) Ave.	Max.	Direction (Degrees)	Sky Cover (Tenths)
Sept.										
1	59	48	54	7		0	9.9	20	300	0
2	53	39	46	-1		0	23.7	31	310	7
3	43	33	38	-8		.01	21.1	28	300	2
4	41	34	38	-8	Fog	.23	12.9	20	280	10
5	41	34	38	-8		.46	12.1	18	350	10
6	44	37	41	-5		0	8.9	14	300	3
7	49	37	43	-2		0	8.3	17	350	9
8	46	37	42	-3		0	23.0	32	310	8
9	43	37	40	-4		Trace	15.5	30	300	9
10	48	39	44	0	Fog	.10	16.4	23	100	9
11	49	42	46	2	Fog	.05	17.0	22	110	9
12	56	40	48	5		Trace	16.3	21	90	8
13	57	43	50	7		0	15.8	23	90	6
14	54	43	49	7		Trace	9.2	15	80	10
15	49	42	46	4		Trace	5.2	8	310	9
16	51	41	46	5		Trace	3.9	7	300	10
17	50	42	46	5		Trace	5.9	12	40	8
18	56	41	49	9		0	10.4	21	90	5
19	54	39	47	7	Fog	0	7.9	16	280	4
20	49	39	44	5	Heavy Fog	.23	7.5	14	90	10
21	51	38	45	6		.16	11.9	22	230	6
22	51	38	45	7		Trace	16.2	21	360	8
23	49	40	45	7		.08	11.8	17	100	10
24	52	42	47	10		0	8.1	12	70	4
25	52	41	47	10		0	11.9	17	90	9
26	54	39	47	11		0	10.2	16	90	4
27	50	42	46	11	Heavy Fog	.01	9.1	14	100	7
28	53	39	46	11		0	13.7	20	360	8
29	43	37	40	6		.01	13.1	21	90	9
30	47	35	41	8		0	16.4	22	100	5

Appendix 5. Daily weather data collected at Kotzebue during May through September, 1977, based on National Weather Service observations.

Date	Temperature °F. Max.	Min.	Ave.	Departure from Ave.	Weather Type	Precipitation (in.)	Wind Speed (MPH) Ave.	Max.	Direction (Degrees)	Sky Cover (Tenths)
May										
1	30	5	18	-4		0	11.8	18	350	3
2	19	3	11	-12		0	12.8	18	280	1
3	20	3	12	-12		0	7.6	12	240	4
4	26	11	19	-5		Trace	15.0	23	90	8
5	37	22	30	5		Trace	19.8	25	100	10
6	38	26	32	6		0	12.1	15	100	8
7	38	24	31	5		0	8.9	12	120	4
8	39	25	32	5		0	11.8	17	140	6
9	37	27	32	5		0	16.7	23	90	6
10	40	32	36	8		0	19.1	23	120	10
11	49	34	42	14		0	13.1	17	110	7
12	47	28	38	9		0	5.3	10	300	7
13	39	27	33	3		0	7.1	13	230	9
14	32	23	28	-2		.14	14.2	26	270	10
15	36	23	30	-1	Fog	Trace	16.7	25	120	10
16	37	29	33	2	Fog, Blowing Snow	.08	22.9	30	110	9
17	40	30	35	3	Fog	.02	10.5	17	60	10
18	50	34	42	10		.02	13.1	17	70	9
19	53	37	45	12		0	16.4	26	70	4
20	40	29	35	2	Fog	.02	13.8	23	90	10
21	37	26	32	-2	Fog	.03	13.8	23	70	9
22	34	26	30	-4	Fog	0	12.1	18	290	1
23	31	22	27	-8		0	18.7	25	290	4
24	29	20	25	-10		0	21.1	24	270	7
25	30	21	26	-9		0	19.4	24	280	7
26	33	24	29	-7	Fog	Trace	12.9	21	270	8
27	37	31	34	-2		Trace	11.9	17	290	9
28	44	27	36	-1		0	6.9	16	290	5
29	38	28	33	-4		0	12.8	23	300	0
30	35	26	31	-6	Fog	0	16.5	21	270	7
31	43	26	35	-3	Fog	0	9.2	15	280	2

Appendix 5. Continued.

Date	Temperature °F. Max.	Min.	Ave.	Departure from Ave.	Weather Type	Precipitation (in.)	Wind Speed (MPH) Ave.	Max.	Direction (Degrees)	Sky Cover (Tenths)
June										
1	38	31	35	-3		0	14.5	20	280	7
2	39	27	33	-5	Heavy Fog	0	11.5	16	290	7
3	54	27	41	2	Heavy Fog	Trace	11.8	23	120	7
4	50	35	43	4		0	11.1	14	200	6
5	46	35	41	1		Trace	9.9	16	110	7
6	50	36	43	3		Trace	11.9	15	270	8
7	48	38	43	3	Heavy Fog	Trace	7.6	14	60	8
8	63	40	52	11		Trace	14.5	28	160	9
9	58	45	52	11		Trace	11.2	16	120	6
10	48	38	43	2		0	8.6	21	300	8
11	49	34	42	0		0	10.6	21	300	5
12	60	38	49	7		Trace	8.2	10	290	5
13	44	39	42	0		Trace	10.2	14	290	9
14	48	41	45	2		Trace	15.2	25	290	5
15	44	37	41	-2		0	16.5	23	290	6
16	51	37	44	0	Fog	0	10.1	14	300	7
17	54	40	47	3		0	8.5	15	210	4
18	52	45	49	5		0	17.3	30	300	4
19	60	45	53	8		0	13.1	20	290	2
20	51	38	45	0	Fog	.02	11.8	15	280	8
21	48	39	44	-2	Fog	Trace	14.7	20	280	7
22	45	35	40	-6	Heavy Fog	0	15.0	20	250	7
23	40	33	37	-9	Heavy Fog	0	20.3	32	290	9
24	40	33	37	-10	Fog	0	24.4	32	290	6
25	49	34	42	-5		0	17.1	24	290	0
26	54	42	48	0		0	18.1	25	290	1
27	55	45	50	2		0	17.3	28	290	3
28	55	45	50	2		0	20.9	29	290	1
29	55	42	49	0		0	20.7	28	290	0
30	48	38	43	-6	Heavy Fog	0	28.6	40	290	5

Appendix 5. Continued.

Date	Temperature °F. Max.	Min.	Ave.	Departure from Ave.	Weather Type	Precipitation (in.)	Wind Speed (MPH) Ave.	Max.	Direction (Degrees)	Sky Cover (Tenths)
July										
1	41	35	38	12	Heavy Fog	0	28.9	36	280	10
2	56	34	45	-5	Heavy Fog	0	10.5	16	280	5
3	60	40	50	0		0	15.0	29	280	6
4	53	44	49	-2		0	12.4	18	70	6
5	56	43	50	-1		Trace	11.1	20	120	6
6	62	41	52	1		Trace	13.4	17	140	8
7	76	52	84	12		0	15.1	23	90	9
8	70	53	62	10		.01	11.5	23	340	5
9	71	56	64	12		0	9.4	15	10	5
10	67	56	62	10		0	12.5	18	140	5
11	74	80	67	14		0	10.6	16	300	2
12	84	64	74	21		0	15.0	25	130	1
13	67	51	59	6	Smoke, Haze	0	9.1	12	280	3
14	73	49	61	8		Trace	9.6	20	150	6
15	69	57	63	10	Heavy Fog	Trace	7.2	14	310	5
16	66	51	59	5	Fog	0	14.7	23	270	7
17	51	45	48	-6	Heavy Fog	0	17.8	26	290	10
18	46	41	44	-10	Heavy Fog	0	23.4	31	280	10
19	56	42	49	-5	Heavy Fog	0	9.2	21	280	5
20	63	48	56	2		0	12.2	23	280	4
21	71	55	63	9	Smoke, Haze	0	9.4	16	90	3
22	70	60	65	11	Smoke, Haze	0	8.5	12	90	6
23	69	58	64	10	Smoke, Haze	0	10.2	15	130	5
24	75	55	65	11	Smoke, Haze	0	11.8	18	140	5
25	73	58	66	12	Smoke, Haze	0	15.0	21	110	7
26	77	57	67	13	Smoke, Haze	Trace	15.7	23	90	6
27	69	61	65	11	Smoke, Haze	Trace	13.7	21	130	10
28	64	57	61	7	Smoke, Haze	Trace	18.7	26	150	9
29	69	56	63	9	Smoke, Haze	0	10.6	16	310	9
30	72	58	65	11	Smoke, Haze	0	10.5	16	340	6
31	73	84	69	15	Smoke, Haze	0	10.6	20	360	7

Appendix 5. Continued.

Date	Temperature °F. Max.	Min.	Ave.	Departure from Ave.	Weather Type	Precipitation (in.)	Wind Speed (MPH) Ave.	Max.	Direction (Degrees)	Sky Cover (Tenths)
August										
1	64	59	62	8	Smoke, Haze	0	11.9	17	280	7
2	66	57	62	9	Fog, Thunderstorm, Smoke, Haze	Trace	10.5	18	100	8
3	74	57	66	13	Smoke, Haze	0	14.8	20	100	7
4	66	59	63	10	Smoke, Haze	.01	13.5	17	180	10
5	65	55	60	7	Fog, Smoke, Haze	.01	11.1	16	170	10
6	62	54	58	5	Fog, Smoke, Haze	0	11.8	16	290	6
7	69	53	61	8	Smoke, Haze	0	13.2	20	70	8
8	72	57	65	13	Smoke, Haze	.01	15.1	20	90	8
9	67	54	61	9	Smoke, Haze	Trace	11.1	15	20	7
10	63	58	61	9	Fog, Smoke, Haze	.04	9.5	17	290	9
11	61	55	58	6	Fog, Smoke, Haze	.09	11.8	18	270	10
12	70	55	63	11	Fog, Smoke, Haze	Trace	15.2	23	80	9
13	66	54	60	9	Fog, Smoke, Haze	.22	11.1	18	90	7
14	67	54	61	10	Fog	.25	13.4	20	170	8
15	64	53	59	8		Trace	19.8	25	160	8
16	62	55	59	8		.01	19.7	28	160	10
17	67	54	61	10		Trace	16.4	22	90	9
18	66	58	62	12	Fog	Trace	19.8	31	160	9
19	66	54	60	10	Fog	Trace	16.3	23	160	8
20	72	52	62	12		0	9.2	15	100	6
21	70	59	65	15		0	11.1	16	300	1
22	70	59	65	15		0	8.9	16	10	0
23	66	54	60	11		0	12.7	22	290	1
24	63	53	58	9		0	17.5	26	300	2
25	60	51	56	7		0	22.7	28	320	1
26	54	43	49	0		0	17.5	23	300	2
27	53	41	47	-1		Trace	9.2	14	280	8
28	55	48	52	4		.02	9.1	17	240	10
29	53	49	51	3	Fog	.05	10.9	23	240	10
30	55	50	53	5	Fog	Trace	6.6	12	190	10
31	58	47	53	6		0		15	240	8

Appendix 5. Continued.

Date	Temperature °F. Max.	Min.	Ave.	Departure from Ave.	Weather Type	Precipitation (in.)	Wind Speed (MPH) Ave.	Max.	Direction (Degrees)	Sky Cover (Tenths)
September										
1	60	45	53	6		0	5.5	13	220	3
2	57	46	52	5	Fog	0	9.5	15	310	6
3	55	48	52	6		Trace	12.5	22	300	9
4	50	44	47	1	Fog	Trace	11.1	21	290	9
5	51	46	49	3	Fog, Smoke, Haze	.64	23.3	29	100	10
6	53	49	51	5	Fog, Thunderstorm	1.44	20.4	28	90	10
7	56	43	50	5		Trace	12.9	17	360	7
8	53	40	47	2		0	9.4	15	10	0
9	58	41	50	6		0	8.5	13	90	3
10	58	47	53	9		.09	14.4	28	10	9
11	53	44	49	5		.03	14.0	24	280	10
12	50	45	48	5	Fog	.08	18.3	23	150	10
13	55	47	51	8		.12	25.5	37	150	9
14	49	42	46	4	Fog	.09	15.4	26	280	10
15	50	37	44	2		0	11.9	22	310	8
16	48	43	46	3		.01	13.2	23	290	10
17	45	42	44	3		.06	21.1	29	100	8
18	49	41	45	5		0	10.1	16	80	6
19	46	35	41	1		.15	16.7	23	70	10
20	41	30	36	-3	Fog	.05	15.0	22	360	8
21	40	28	34	-5		0	13.7	24	360	0
22	40	25	33	-5		0	10.9	26	120	7
23	43	34	39	1	Ice Pellets	.26	28.3	37	110	10
24	45	40	43	6		.09	25.0	33	220	9
25	44	40	42	5	Fog	.05	27.2	33	250	10
26	43	37	40	4		.10	15.1	23	80	10
27	38	36	37	2	Fog	.47	22.3	35	320	8
28	36	31	34	-1		0	34.7	41	320	5
29	37	29	33	-1		.13	19.8	31	230	7
30	41	37	39	6		.45	24.2	31	240	10

FINAL REPORT

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AVIAN COMMUNITY ECOLOGY OF THE AKULIK-INGLUTALIK RIVER DELTA, NORTON BAY, ALASKA

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Boulder, Colorado

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I. Synopsis of objectives, results, and recommendations regarding OCS-related oil and gas exploration and development at the Akulik-Inglutalik River Delta

The Norton Sound area of western coastal Alaska has high potential for future petroleum related exploration and development activities. Large tracts of both the continental shelf and associated nearshore waters and delta systems have not been well characterized with regard to the botanical and zoological life forms they support. Detailed analyses of the flora and fauna of these regions can provide realistic determinations of the relative value of these areas to man and the organisms which use them on a year around basis. It can be assumed that many areas have been subjected to relatively little environmental perturbation in the recent past and that the organisms which they sustain can be used as indicators of environmental fluctuations resulting from oil and gas related activities at the local level.

We chose to study the avian ecology of the Akulik-Inglutalik River Delta since essentially nothing was known of this region except the fact that it supported relatively large populations of waterfowl and shorebirds during both migrations and the breeding season. Our primary objectives were: to characterize the area as to species diveristy, breeding densities, productivity, and to determine the extent to which migrants used the area in spring and fall. We used standard methods to determine these parameters during two summers of intense field observations which were directed from a research-tent camp on the delta.

Avian species diversity in the area is relatively high but the majority of species are either spring or fall migrants most of which frequent the area in small numbers. Breeding species diversity is relatively low but nesting densities of some species in optimum habitats are moderate to high. The delta is used extensively by a number of waterfowl species and cranes in the spring and by a variety of waterfowl, shorebirds, and particularly cranes in the fall.

We recommend limited use of the delta particularly during spring and summer when potential nesters are affected greatly by human related activity. Further we indicate the importance of exposed near-shore mudflat and delta pond edges as feeding and staging areas primarily during spring and fall migrations. Finally, we recommend caution regarding the use of all-terrain-vehicles especially in the spring when peak periods of native hunting on the delta may coincide with melt-off and the exposure of virgin tundra area.

II. INTRODUCTION

Justification

Norton Bay is a northeastern extension of Norton Sound. It is bounded on the north and west by the Seward Peninsula, on the east by the Alaskan mainland, and on the south by the Ungalik River Delta and the Shaktoolik Peninsula. The Akulik, Inglutalik, Koyuk, Kwik, Kwiniuk and Ungalik Rivers empty into this bay. Of these, the Akulik, Inglutalik and Koyuk form a large low-lying delta at the head of the bay. This delta with its associated tidal flats and slough system attracts large numbers of waterfowl and shorebirds during both migratory and breeding seasons. Avifaunal studies of the area are essentially non-existent and since this area has high potential for oil and gas exploration and development studies designed to determine its relative importance as breeding habitat for resident birds as well as a feeding and resting area for migrants are important. This baseline study will serve as a focal point for future comparative studies directed at monitoring environmental stability. In this regard, bird populations act as indicators, responding to the total environment, which if changed, will cause a slow but perceptible change in the density of certain species. This, then, can indicate the presence or absence of a crisis situation. Having made these baseline determinations we will provide recommendations to lessen potential deleterious effects of this area by future oil and gas development and the concomitant human habitation.

Objectives

1) To determine species and numbers of breeding, non-breeding, and migratory birds on the delta,

2) to determine dates of arrival and departure for breeding, non-breeding and migratory birds,

3) to determine mean dates of hatching and fledging for species breeding on the delta,

4) to determine the relative productivity of breeding birds on the delta by the determination of total hatching and fledging success,

5) to determine general habitat preference of breeding birds,

6) to determine abundance and distribution of mammals on the delta,

7) to determine the extent of the interaction of birds and mammals,

8) to describe the general flora of the delta,

9) to determine the general climatological conditions of the region,

10) to establish baseline analyses of the importance of the delta as breeding habitat for resident birds as well as a feeding and resting area for migrants, and

11) to provide recommendations to lessen the potential impact of future oil and gas development in the area.

III. CURRENT STATE OF KNOWLEDGE

Knowledge of the avifauna of the Akulik-Inglutalik River Delta is confined to a brief visit along the south bank of the Koyuk River by Brina Kessel during the summer of 1975 and to our two-year study during the summers of 1976 and 1977. During her visit Dr. Kessel observed 46 species of birds including sizable concentrations of Arctic Loons, Whistling Swans, Canada Geese, White-fronted Geese, Pintails, American Wigeons, Greater Scaups, Semipalmated Sandpipers, Northern Phalaropes, Galucous and Mew Gulls and Arctic Terns.

Although unable to observe birds at the mouths of the Akulik and Inglutalik Rivers due to transportation problems, Dr. Kessell learned from local inhabitants that these areas support relatively large populations of the above mentioned birds. She also reported that these observations were substantiated by helicopter and fixed-wing pilots working for the Bureau of Land Management in this area.

We were unable to observe spring and fall migrations on the delta during our study in 1976. However, we arrived in the area in early May of 1977 and recorded the entire spring migration. Additionally, we remained in the area until late September and recorded near complete observations of the fall migration. We recorded a total of one hundred and three species of birds on the delta. Of these, thirty nine were observed as nesters or potential nesters. These values indicate that the Akulik-Inglutalik River Delta has a comparable avifauna with other areas of western coastal Alaska, but see detailed accounts of the migratory and breeding sections.

IV. STUDY AREA

The eastern shore of Norton Bay is delineated on the north and south by the Koyuk and Ungalik Rivers respectively (Fig. 1). The intervening coastline (ca. 30 miles) is characterized by a transition from alluvial mud flat to wet tundra meadow to upland dry tundra meadow and finally to the dense spruce forest of the foothills of the interior. This region exhibits extensive slough systems and numerous brakish ponds and tidal pools. Low-lying areas adjacent to the coastline are subjected to severe tidal fluctuations particularly during periods of mid to late summer when high tides coincide with high winds and rain from the southwest.

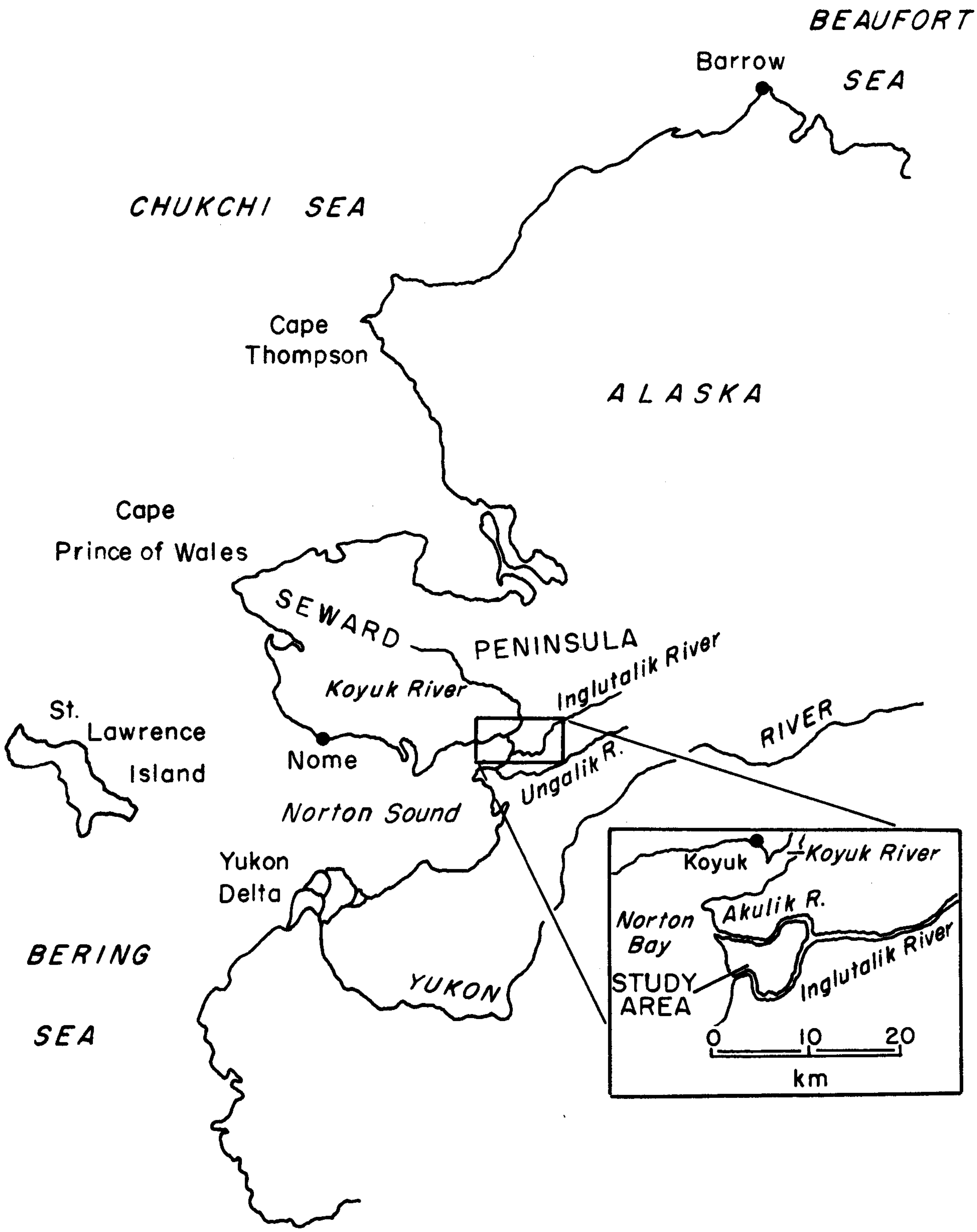

Figure 1. Location of study area.

Our study area was located on the tidal flat-tundra meadow ecotype between the mouths of the Akulik and Inglutalik Rivers (sections 31, 32, and 33, T5N, R11W of the Keteel River Meridian) about ten air miles southeast of the native village of Koyuk. This area was chosen in preference to other potential areas of the region since it is essentially representative of the delta tidal flat and is subjected to relatively little human interference.

The vegetation of the east coast of Norton Bay has been characterized as moist and wet tundra meadow by Viereck and Little (1972). We have utilized a format which characterizes seven vegetation types which constitute a continuum from the highest elevations on the delta (ca. 20 m) to the submergent vegetation in ponds and along tidal mud flats. These categories are also used to indicate avifaunal-vegetation associations for the delta and are included in table 3.

Elevated areas (above 10 m). This vegetation type is restricted to a single, .5 km^2 region on the north bank of the Inglutalik River (Fig. 2). This raised mound constitutes the only significant relief on the delta. It is dominated by Ledum palustre, Betula nana, and Eriophorum vaginatum. Widespread but less dense, or less conspicuous due to their small size, were Arctostaphylos alpina, Vaccinium vitis-idea, and Rubus chamaemorus.

The "tree and shrub" transition to lower areas was dominated by Alnus crispa, Betula nana, Salix arctica, and S. glauca and to a lesser extent by Spiraea beauverdiana. Less dominant were Calamagrostis canadensis, Empetrum nigrum, Ledum palustre.

Tundra ridges were characterized as wind blown areas of sparse vegetation which were not subject to tidal wave exposure. These areas were dominated by Empetrum nigrum and Salix ovalifolia. Less dense were Lathryus maritimus, Rubus chamaemorus and Carex rariflora.

Dry tundra meadow was dominated by Salix ovalifolia, Sausaurea nuda, and Carex rariflora. Less dominant were Elymus arenarius, Chrysanthemum arcticum, Carex ramenskii, Empetrum nigrum, and Triglochin palustris.

Wet tundra meadow, although intransition from dry meadow to pond edge and therefore difficult to quantify was dominated by Carex lyngbyaei, Carex ramenskii, and Chrysanthemum arcticum. Less dominant were Stellaria humifusa, Salix ovalifolia, and Potentilla egedii.

Brackish pond edges and edges of tidal pools were dominated primarily by Triglochin palustris, Puccinellia phryganodes, Carex lyngbyaei and Atriplex gmelini.

Emergent pond vegetation was dominated by Hippuris vulgaris, Potamogeton filiformis and Myriophyllum spicatum. During dry summers such as that of 1977 all of these can become incorporated into the pond edge ecotype due to extreme desiccation of most shallow ponds.

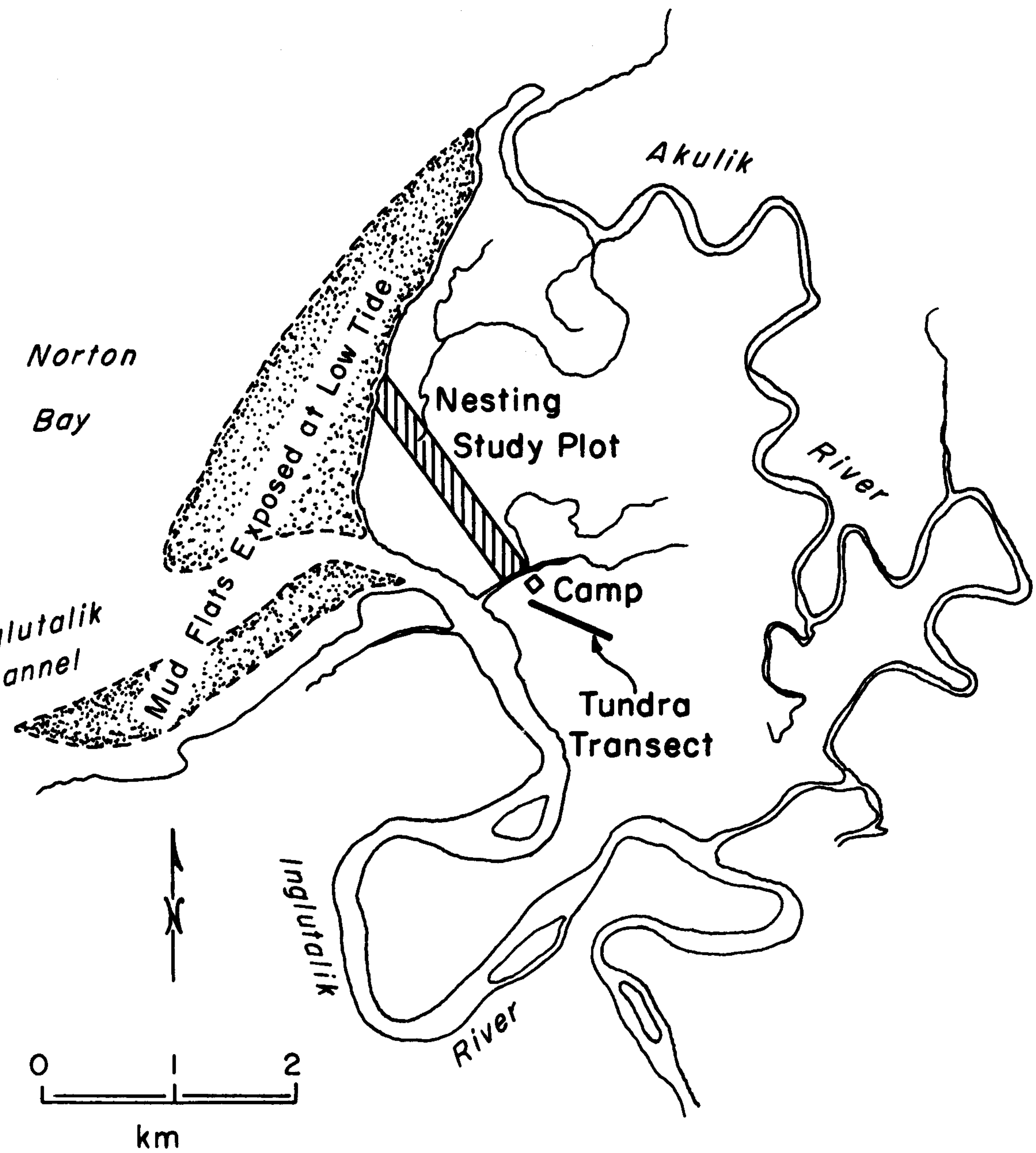

Figure 2. Detail of study area.

V. GENERAL METHODOLOGY

This study was conducted during the summers of 1976-1977. Research objectives for both years were identical. Our activities were greatly expanded in 1977, however, based on incomplete data of 1976. In 1976, a team of four biologists, including two senior scientists and two field assistants entered the area on June 4. Late breakup of pack ice on both the Koyuk River and Norton Bay prevented us from reaching the study area until June 10. Consequently, we have no spring migration data for 1976. We left the area by boat on August 24.

We entered the area via helicopter on May 7, 1977 and made continuous observations on the delta until September 21. Observations recorded during 1976 have been included in quarterly reports and an annual report and they are used here only as comparative data. Observations of 1977 are much more extensive and complete and the majority of this final report is based on them.

In keeping with the primary objectives of this study we surveyed the breeding biology and migrations of the birds on the delta. These surveys were carried out in such a way as to maximize our observation efforts in relation to the activities of the birds (i.e. spring migration, breeding period, fall migration). The following methods were used:

1) Delta Surveys:

From May 10 to September 20 surveys of all birds on the delta were made with spotting scopes. Observations were made from an elevated area (ca. 20 m) near the research camp. From this vantage point the entire delta, including the mouths of both the Akulik and Inglutalik Rivers, could be observed. To maximize our efforts, twice daily (morning and evening) surveys were conducted during the periods of intense migratory activity (spring migration May 10-June 15 and fall migration August 1-September 20). Surveys of the area were conducted daily regardless of weather conditions.

2) Tundra Transect:

To correct for sample bias that may have been inherent in the delta surveys we conducted a 1 km transect across the tundra at midday. During this transect an observer walked the same path daily at a constant rate (60 paces/min.) and recorded all birds seen with the naked eye and 35 X binoculars. The observer stopped only to record data (cassette recorder) and the entire walk lasted about one hour. No other field activities were conducted in the area of the tundra transect and therefore, it served as an accurate estimate of species diversity, density, and phenology of the birds in a typical delta area.

3) Nesting Study Plot:

In order to obtain a more accurate estimate of species diversity and nesting densities on the delta we expanded our nesting plot to twice its 1976 size. During 1977 a 2X.3 km study plot was constructed in homogeneous lowland tundra (Fig. 2). The entire area was divided into 50 X 50 m sections and monitored for the following parameters: nest initiations, nest failures, laying dates, clutch sizes, hatching dates, predation, and relative productivity. The majority of the nesting plot was constructed prior to the spring arrival of most breeders and therefore nest failures due to our presence were minimal.

4) Upland Tundra Study Plot:

A second breeding plot was monitored for resident birds as well as migrants. This area (.5 km^2) consisted of an elevated region calculated to be about 20 meters high and comprised the only significant relief on the delta. This region attracted large numbers of migrating birds, particularly in the fall; densities of resident and migratory birds of this area were monitored with mist nets and drop nets.

5) Exposed Mud Flat Study Plot:

At low tide an extensive area (2 km^2) of tidal mud flat was exposed at the mouth of the Inglutalik River. This area was monitored daily throughout the summer but was surveyed extensively during August and September when the area attracted large numbers of migrants. Estimates of numbers of birds in this area were made using spotting scopes and field glasses. In addition, birds were captured in mist nets and banded at intervals during the migration.

6) River and Slough System:

The Akulik-Inglutalik River system with its accompanying sloughs was monitored by boat at irregular intervals. Travel by boat allowed us to monitor avifauna using the river systems. In addition, it allowed us access to remote areas of the delta which otherwise were inaccessible on foot. Species and number of birds observed during river and slough travel contributed greatly to our overall description of chronology of migration through the area.

VI. AVIFAUNA - GENERAL

One hundred and three speices of birds were observed on the delta during the summer of 1977 (Table 1). Of these, eighteen were observed as common nesters, fourteen as uncommon nesters, and seven as potential nesters. Six species were observed as common migrants but did not nest on the delta. Twenty five species not observed in 1976 were seen in 1977.

Table 1. Birds observed at the Akulik-Inglutalik River Delta (summers 1976, 1977)

Species	Occurrence	Nesting Status
Yellow-billed Loon (Gavia adamsii)	rare	0
Arctic Loon (Gavia arctica)	common	CN
Red-throated Loon (Gavia stellata)	common	CN
*Horned Grebe (Podiceps auritus)	rare	0
Whistling Swan (Olor columbianus)	common	CN
Canada Goose (Branta canadensis)	common	0
Black Brant (Branta nigricans)	common	0
*White-fronted Goose (Anser albifrons)	uncommon	0
*Snow Goose (Chen caerulescens)	common	0
Mallard (Anas platyrhynchos)	uncommon	UN
Gadwall (Anas strepera)	rare	0
Pintail (Anas acuta)	very common	CN
Green-winged Teal (Anas crecca)	uncommon	PN
American Wigeon (Anas americana)	uncommon	PN
Northern Shoveler (Anas clypeata)	uncommon	PN
*Canvasback (Aythya valisineria)	uncommon	UN
Greater Scaup (Aythya marila)	uncommon	UN
Common Goldeneye (Bucephala clangula)	rare	0
Oldsquaw (Clangula hyemalis)	common	CN
Common Eider (Somateria mollissima)	uncommon	UN
White-winged Scoter (Melanitta deglandi)	rare	0
Surf Scoter (Melanitta perspicillata)	uncommon	UN
Black Scoter (Melanitta nigra)	rare	UN
*Common Merganser (Mergus merganser)	rare	0
Red-breasted Merganser (Mergus serrator)	uncommon	UN
Sharp-shinned Hawk (Accipiter striatus)	rare	0
Golden Eagle (Aquila chrysaetos)	rare	0
Marsh Hawk (Circus cyaneus)	uncommon	UN
Gyrfalcon (Falco rusticolus)	rare	0
*Peregrine Falcon (Falco peregrinus)	rare	0
Merlin (Falco columbarius)	rare	0
Willow Ptarmigan (Lagopus lagopus)	uncommon	PN
Sandhill Crane (Grus canadensis)	common	CN
Semipalmated Plover (Charadrius semipalmatus)	uncommon	0
American Golden Plover (Pluvialis dominica)	uncommon	0

Table 1 (Cont.)

Species	Occurrence	Nesting Status
*Black-bellied Plover (Pluvialis squatarola)	rare	0
Black Turnstone (Arenaria melanocephala)	rare	0
Common Snipe (Capella gallinago)	uncommon	0
Whimbrel (Numenius phaeopus)	uncommon	0
*Spotted Sandpiper (Actitis macularia)	uncommon	0
Lesser Yellowlegs (Tringa flavipes)	rare	0
*Red Knot (Calidris canutus)	uncommon	0
*Sharp-tailed Sandpiper (Calidris acuminata)	uncommon	0
*Pectoral Sandpiper (Calidris melanotos)	uncommon	0
*Baird's Sandpiper (Calidris bairdii)	uncommon	0
*Least Sandpiper (Calidris minutilla)	uncommon	PN
Dunlin (Calidris alpina)	common	CN
Semipalmated Sandpiper (Calidris pusilla)	very common	CN
Western Sandpiper (Calidris mauri)	common	CN
*Sanderling (Calidris alba)	uncommon	0
Long-billed Dowitcher (Limnodromus scolopaceus)	common	0
Bar-tailed Godwit (Limosa lapponica)	common	0
Hudsonian Godwit (Limosa haemastica)	common	0
Red Phalarope (Phalaropus fulicarius)	rare	0
Northern Phalarope (Lobipes labatus)	very common	CN
Pomarine Jaeger (Stercorarius pomarinus)	uncommon	0
Parasitic Jaeger (Stercorarius parasiticus)	very common	CN
Long-tailed Jaeger (Stercorarius longicaudus)	uncommon	0
Glaucous Gull (Larus hyperboreus)	very common	CN
Glaucous-winged Gull (Larus glaucescens)	rare	0
Herring Gull (Larus argentatus)	uncommon	0
Mew Gull (Larus canus)	common	UN
Bonaparte's Gull (Larus philadelphia)	uncommon	0
Black-legged Kittiwake (Rissa tridactyla)	uncommon	0
Sabine's Gull (Xema sabini)	uncommon	UN
Arctic Tern (Sterna paradisaea)	very common	CN
Snowy Owl (Nyctea scandiaca)	rare	PN
Short-earned Owl (Asio flammeus)	uncommon	PN
Belted Kingfisher (Megaceryle alcyon)	rare	UN
*Common Flicker (Colaptes auratus)	rare	0

Table 1 (Cont.)

Species	Occurrence	Nesting Status
*Downy Woodpecker (Dendrocopos pubescens)	rare	0
*Alder Flycatcher (Empidonax alnorum)	rare	0
Tree Swallow (Iridoprocne bicolor)	uncommon	0
Bank Swallow (Riparia riparia)	common	CN
*Cliff Swallow (Petrochelidon pyrrhonota)	rare	0
Gray Jay (Perisoreus canadensis)	uncommon	0
Common Raven (Corvus corax)	common	UN
*Black-capped Chickadee (Parus atricapillus)	uncommon	0
*Boreal Chickadee (Parus hudsonicus)	uncommon	0
Robin (Turdus migratorius)	uncommon	0
Varied Thrush (Ixoreus naevius)	uncommon	0
Gray-cheeked Thrush (Catharus minimus)	uncommon	0
Wheatear (Oenanthe oenanthe)	rare	0
*Arctic Warbler (Phylloscopus borealis)	rare	0
Ruby-crowned Kinglet (Regulus calendula)	rare	0
Yellow Wagtail (Motacilla flava)	common	CN
Waterpipit (Anthus spinoletta)	rare	0
Northern Shrike (Lanius excubitor)	uncommon	0
Orange-crowned Warbler (Vermivora celata)	uncommon	0
Yellow Warbler (Dendroica petechia)	uncommon	0
Northern Waterthrush (Seiurus noveboracensis)	uncommon	0
Wilson's Warbler (Wilsonia pusilla)	uncommon	0
Rusty Blackbird (Euphagus carolinus)	uncommon	0
Redpoll (sp.) (Carduelis)	very common	CN
White-winged Crossbill (Loxia leucoptera)	uncommon	0
Savannah Sparrow (Passerculus sandwichensis)	very common	CN
Dark-eyed Junco (Junco hyemalis)	uncommon	0
Tree Sparrow (Spizella arborea)	uncommon	UN
White-crowned Sparrow (Zonotrichia leucophrys)	uncommon	UN
*Golden-crowned Sparrow (Zonotrichia atricapilla)	rare	0
Fox Sparrow (Paserella iliaca)	uncommon	0
*Lincoln's Sparrow (Melospiza lincolnii)	rare	0
Lapland Longspur (Calcarius lapponicus)	very common	CN

CN = common nester, UN = uncommon nester, PN = probable nester, 0 = non-nester

* indicates species observed in 1977 but not in 1976.

Of these, only the Canvasback was observed as a breeder in 1977; the remainder were observed as migrants. Our extended research activities both in early spring and late fall of 1977, no doubt, allowed us to monitor more thoroughly both migrations. For example, the heavy migration of Snow Geese and Sandhill Cranes in mid and late May of 1977 was not recorded in 1976 due to the fact that we did not commence research activities until June 12 of that year. Similarly, fall migrations of Spotted, Sharp-tailed, Pectoral, Baird's and Least Sandpipers, Red Knots and Sanderlings were missed in 1976.

Compared to other areas of the western Alaska coast the Akulik-Inglutalik River Delta has a comparable breeding avifauna but somewhat more diverse migrant avifauna. Elevated areas on the delta composed of alder, willow, and dwarf birch ecotypes attract large numbers of birds, particularly passerines, as migrants in the fall. Some passerines also breed in these areas. If we exclude these areas from typical coastal breeding habitats the Akulik-Inglutalik River Delta is rather deplete of breeders with only thirty two breeding species (Table 2).

VII. SPRING MIGRATION (1977) ARRIVAL

Methods

We arrived on the Akulik-Inglutalik River Delta on May 8 via helicopter. Our research camp was established on May 10 and we commenced detailed surveys of the spring migration on that date. Less detailed observations during the period (May 8-10) of camp construction allowed us to estimate relative numbers of birds present on the delta. Additionally, aerial surveys via helicopter on May 8 and 9 allowed us to assess the relative amount of exposed terrain and open water on the delta as well as ice conditions on both Norton Bay and the Akulik-Inglutalik River system. No comparative data are available for spring migration in 1976 since we did not arrive on the study site until June 12 of that year.

Results

Nearshore waters of Norton Bay, the Akulik-Inglutalik River system and all ponds on the delta were totally ice-bound when we arrived on the study area. Only tundra ridges and elevated upland areas (willow-alder-dwarf birch) were partially snow free. We estimate that about 30% of the delta terrain was exposed at this time. The ice-pack on nearshore waters of Norton Bay and the Akulik-Inglutalik River system receded on June 3 and all waters were open after that date. Break up occurred on June 9, 1976.

Eleven species of birds were present on the delta when we arrived (Table 4). Only Sandhill Cranes and Redpolls (sp.) occurred in significant numbers and later observations of banded birds as well as daily

Table 2. Breeding and non-breeding species diversity of various regions of coastal Alaska.*

	LOCATION						
SPECIES	Barrow (71°N)	Cape Sabine (69°N)	Cape Thompson (68°N)	Cape Espenberg (66°N)	Shishmaref Inlet (66°N)	Akulik-Inglutalik River Delta, Norton Bay (64°N)	Clarence Rhode National Wildlife Range (61°N)
Breeding	35	55	65	30	39	39	75
Non-breeding	116	35	55	37	39	64	20
Total	151	90	120	67	78	103	95

*modified from Mickelson et al., 1976.

Table 3. Avifaunal-habitat associations at the Akulik-Inglutalik River Delta.

	Habitat Type						
Species	Nearshore Waters	Brackish Ponds	Mudflat	Agulik-Inglutalik River System	Wet Tundra	Dry Tundra	Upland Alder-Willow-Birch
Yellow-billed Loon r	B	--	--	--	--	--	--
Arctic Loon	BFMS	FR	--	FMS	N	--	--
Red-throated Loon	BFMS	FR	--	FMS	N	--	--
Horned Grebe r	--	--	--	FMS	--	--	--
Whistling Swan	--	BRFMS	FMS	FMS	NBRFMS	--	--
Canada Goose	--	--	MS	BRFMS	NBRFMS	--	--
Black Brant	--	--	MS	MS	--	--	--
White-front Goose	--	MS	MS	MS	--	--	--
Snow Goose	--	MS	MS	--	--	--	--
Mallard	--	MS	MS	BRMS	--	--	--
Gadwall	--	--	--	--	MS	--	--
Pintail	--	BRFMS	MS	BRFMS	NBRFMS	NBRFMS	--
Green-winged Teal	--	--	--	MS	MS	--	--

Table 3 (Cont.)

Species	Nearshore Waters	Brackish Ponds	Mudflat	Aguliк-Inglutalik River System	Wet Tundra	Dry Tundra	Upland Alder-Willow-Birch
	Habitat Type						
American Wigeon	--	MS	--	MS	MS	--	--
Northern Shoveler	--	MS	--	MS	MS	--	--
Canvasback	--	BRFMS	--	BRFMS	NBRFMS	--	--
Greater Scaup	--	BRFMS	--	BRMS	NBRFMS	--	--
Common Goldeneye	--	MS	--	MS	MS	--	--
Oldsquaw	MS	BRFMS	--	BRFMS	NBRFMS	--	--
Common Eider	MS	--	--	BRFMS	NBRFMS	--	--
White-winged Scoter	MS	--	--	MS	--	--	--
Surf Scoter	MS	--	--	MS	--	--	--
Black Scoter	MS	--	--	MS	--	--	--
Common Merganser	--	--	--	MS	--	--	--
Red-breasted Merganser	--	--	--	BRFMS	NBRFMS	--	--
Sharp-shinned Hawk (r)	--	--	--	--	--	--	--

Table 3 (Cont.)

	Habitat Type						
Species	Nearshore Waters	Brackish Ponds	Mudflat	Agulik-Inglutalik River System	Wet Tundra	Dry Tundra	Upland Alder-Willow-Birch
Golden Eagle r	--	--	--	--	--	--	--
Marsh Hawk	--	--	B	--	NB	NB	B
Gyrfalcon r	--	--	--	--	--	--	--
Peregrine Falcon r	--	--	--	--	--	--	--
Merlin	--	--	--	--	NB	NB	B
Willow Ptarmigan	--	--	--	--	--	MS	MS
Sandhill Crane	--	BFS	MS	--	NBRFMS	NBRFMS	--
Semipalmated Plover	--	--	MS	--	MS	MS	--
American Golden Plover	--	--	MS	--	MS	--	--
Black-bellied Plover	--	--	MS	--	--	--	--
Black Turnstone	--	--	MS	--	MS	--	--
Common Snipe	--	--	--	--	MS	--	--

Table 3 (Cont.)

Species	Habitat Type: Nearshore Waters	Brackish Ponds	Mudflat	Agulik-Inglutalik River System	Wet Tundra	Dry Tundra	Upland Alder-Willow-Birch
Whimbrel	--	--	MS	--	MS	MS	--
Spotted Sandpiper	--	--	MS	--	MS	MS	--
Lesser Yellowlegs	--	MS	MS	--	MS	--	--
Red Knot	--	--	MS	--	--	--	--
Sharp-tailed Sandpiper	--	--	MS	--	MS	--	--
Pectoral Sandpiper	--	--	MS	--	MS	--	--
Baird's Sandpiper	--	--	MS	--	MS	--	--
Least Sandpiper	--	--	MS	--	MS	--	--
Dunlin	--	--	MS	--	NBRFMS	NBRFMS	--
Semipalmated Sandpiper	--	--	MS	--	NBRFMS	NBRFMS	--
Western Sandpiper	--	--	MS	--	NBRFMS	NBRFMS	NBRFMS
Sanderling	--	--	MS	--	--	--	--

Table 3 (Cont.)

	Habitat Type						
Species	Nearshore Waters	Brackish Ponds	Mudflat	Agulik-Inglutalik River System	Wet Tundra	Dry Tundra	Upland Alder-Willow-Birch
Long-billed Dowitcher	--	--	MS	--	MS	MS	--
Bar-tailed Gidwit	--	--	MS	--	MS	--	--
Hudsonian Godwit	--	--	MS	--	MS	--	--
Red Phalarope	--	MS	--	--	MS	--	--
Northern Phalarope	--	BRFMS	--	MS	NBRFMS	NBRFMS	--
Pomarine Jaeger	--	--	MS	MS	MS	MS	MS
Parasitic Jaeger	--	--	MS	MS	MS	NBRFMS	MS
Long-tailed Jaeger	--	--	MS	MS	MS	MS	MS
Glaucous Gull	BRFMS	NBRFMS	BRFMS	BRFMS	BRFMS	BRFMS	BRFMS
Glaucous-winged Gull	BRFMS	NBRFMS	BRFMS	BRFMS	BRFMS	BRFMS	BRFMS
Mew Gull	BRFMS	NBRFMS	BRFMS	BRFMS	BRFMS	BRFMS	BRFMS
Bonapart's Gull	MS	MS	MS	MS	MS	MS	--

Table 3 (Cont.)

Species	Nearshore Waters	Brackish Ponds	Mudflat	Agulik-Inglutalik River System	Wet Tundra	Dry Tundra	Upland Alder-Willow-Birch
Sabine's Gull	BRFMS	NBRFMS	BRFMS	BRFMS	BRFMS	BRFMS	--
Arctic Tern	BRFMS	NBRFMS	BRFMS	BRFMS	BRFMS	--	--
Snowy Owl r	--	--	--	--	--	--	--
Short-eared Owl	--	--	--	--	--	BRFMS	BRFMS
Belted Kingfisher	--	--	--	--	--	--	NBRF
Common Flicker	--	--	--	--	--	--	NBRF
Downy Woodpecker	--	--	--	--	--	--	NBRF
Alder Flycatcher	--	--	--	--	--	--	MS
Tree Swallow	--	--	--	--	--	--	NBRF A
Bank Swallow	--	--	BRF	NBRF	BRF	BRF	BRF
Cliff Swallow r							
Gray Jay	--	--	--	--	--	--	F
Common Raven	--	F	F	--	F	F	F

Table 3 (Cont.)

	Habitat Type						
Species	Nearshore Waters	Brackish Ponds	Mudflat	Agulik-Inglutalik River System	Wet Tundra	Dry Tundra	Upland Alder-Willow-Birch
Black-capped Chickadee	--	--	--	--	--	--	MS
Boreal Chickadee	--	--	--	--	--	--	MS
Robin	--	--	--	--	--	--	MS
Varied Thrush	--	--	--	--	--	--	MS
Gray-cheeked Thrush	--	--	--	--	--	--	MS
Wheatear	--	--	--	--	--	--	MS
Arctic Warbler	--	--	--	--	--	--	MS
Ruby-crowned Kinglet	--	--	--	--	--	--	MS
Yellow Wagtail	--	F	F	--	F	F	NBRFMS
Waterpipit r							
Northern Shrike	--	--	--	--	--	--	F
Orange-crowned Warbler	--	--	--	--	--	--	MS

Table 3 (Cont.)

Species	Habitat Type: Nearshore Waters	Brackish Ponds	Mudflat	Agulik-Inglutalik River System	Wet Tundra	Dry Tundra	Upland Alder-Willow-Birch
Ywllow Warbler	--	--	--	--	--	--	MS
Northern Waterthrush	--	--	--	--	--	--	MS
Wilson's Warbler	--	--	--	--	--	--	MS
Rusty Blackbird	--	--	--	--	--	--	MS
Redpoll (sp.)	--	--	--	--	FMS	FMS	NBRFMS
White-winged Crossbill r							
Savannah Sparrow	--	--	FMS	--	NBRFMS	NBRFMS	NBRFMS
Dark-eyed Junco	--	--	--	--	--	--	MS
Tree Sparrow	--	--	--	--	--	--	NBRFMS
White-crowned Sparrow	--	--	--	--	--	--	NBRFMS
Golden-crowned Sparrow	--	--	--	--	--	--	MS

Table 3 (Cont.)

	Habitat Type						
Species	Nearshore Waters	Brackish Ponds	Mudflat	Agulik-Inglutalik River System	Wet Tundra	Dry Tundra	Upland Alder-Willow-Birch
Fox Sparrow	--	--	--	--	--	--	MS
Lincoln's Sparrow	--	--	--	--	--	--	MS
Lapland Longspur	--	FMS	--	--	NBRFMS	NBRFMS	NBRFMS

N = nesting habitat

B = feeding habitat during breeding

R = brood rearing habitat, resting

F = brood rearing, habitat, feeding

M = migration resting site

S = migration feeding site

(A) = artificial nest cavity provided

(r) = indicates rare species

turnover rates indicated that all of these were migrants. Lesser numbers of Snow Geese and Pintails were observed and of the remaining seven species all were observed in concentrations of ten birds or less.

VIII. SPRING MIGRATION

Methods

Assessment of the importance of coastal tundra habitat for use by birds must not only be based on analysis of breeding periods but also during utilization during migration in spring and fall. Large numbers of birds depend heavily on the coastal tundra ecotype of western Alaska for staging and feeding during long distant migrations. Waterfowl and shorebirds constitute the most significant coastal migrants along the Akulik-Inglutalik River Delta and for this reason we conducted extensive surveys of spring and fall migrations.

Morning and evening surveys were conducted for the entire delta area from May 12 to June 15 according to the methods outlined above. We concentrated, however, on areas of exposed mudflat at low tide (utilized primarily by shorebirds) and brackish ponds and tundra meadow (utilized by waterfowl and cranes).

Results

We observed no significant migration of shorebirds along the coastal regions of the study area. Shorebirds which bred on the delta entered the area in mid May (Table 4) and their numbers gradually reached breeding densities. It is likely that spring migrations of shorebirds occurred primarily over the open waters of Norton Sound from the Yukon Delta on the south to the Seward Peninsula on the north.

The most significant spring migratory activity was exhibited by Snow Geese, Black Brant, and Sandhill Cranes (Table 4). Densities of Snow Geese were low (50 birds) when we entered the area but movement of birds into the area occurred on May 11 (600 birds/day). Movement through the area continued for the next two weeks. The observed drop in densities from May 13 to 16 coincided with heavy snowfall during which surveys were inaccurate. The last Snow Geese were seen on the delta on May 27; none was seen as a fall migrant. We estimate that about 5,000 Snow Geese utilized the delta for staging and feeding during northern migration from May 10 to May 26 (Figure 3).

Densities of Black Brant were low on May 20 but continued to increase to a peak of 1,800 birds per day on May 25. We estimate that about 3,000 Black Brant utilized the delta during spring migration. The last Brants were seen on May 2 and none was seen as a fall migrant (Figure 4).

Table 4. Summary of spring migration for the Akulik-Inglutalik River Delta (1977).

Species	Date of First Observation and Number Present	Date of Peak Migration and Migration Per Day
Arctic Loon	5/11 (1)	BL
Red-throated Loon	5/11 (1)	BL
*Whistling Swan	*5/8 (<10)	6/11 **300/day
*Canada Goose	*5/10 (<10)	NSM
Black Brant	5/20 (200)	5/25 **1,800/day
White-fronted Goose	6/19 (26)	NSM
*Snow Goose	*5/8 (50)	5/11-21 **600/day
*Pintail	*5/8 (50)	5/12 200/day
Oldsquaw	5/19 (2)	BL
*Sandhill Crane	*5/8 (500)	5/19 **2,800/day
Dunlin	5/12 (<10)	BL
Semipalmated Sandpiper	5/12 (<10)	BL
Western Sandpiper	5/19 (<10)	BL
*Northern Phalarope	*5/8 (<10)	BL
Parasitic Jaeger	5/14 (2)	BL
*Glaucous Gull	*5/8 (<10)	BL
*Mew Gull	*5/8 (<10)	BL
Arctic Tern	5/13 (1)	BL
Yellow Wagtail	5/25 (1)	BL

Table 4 (Cont.)

Species	Date of First Observation and Number Present	Date of Peak Migration and Migration Per Day
*Redpoll (sp.)	*5/8 (100)	5/15 200/day
*Savannah Sparrow	*5/8 (<10)	BL
*Lapland Longspur	*5/8 (<10)	BL

* species was present on the study site upon our arrival May 8, 1977

BL = no migration was observable, counts gradually reached counts for breeding birds

NSM = no significant migration was observed

** = significant spring migrants

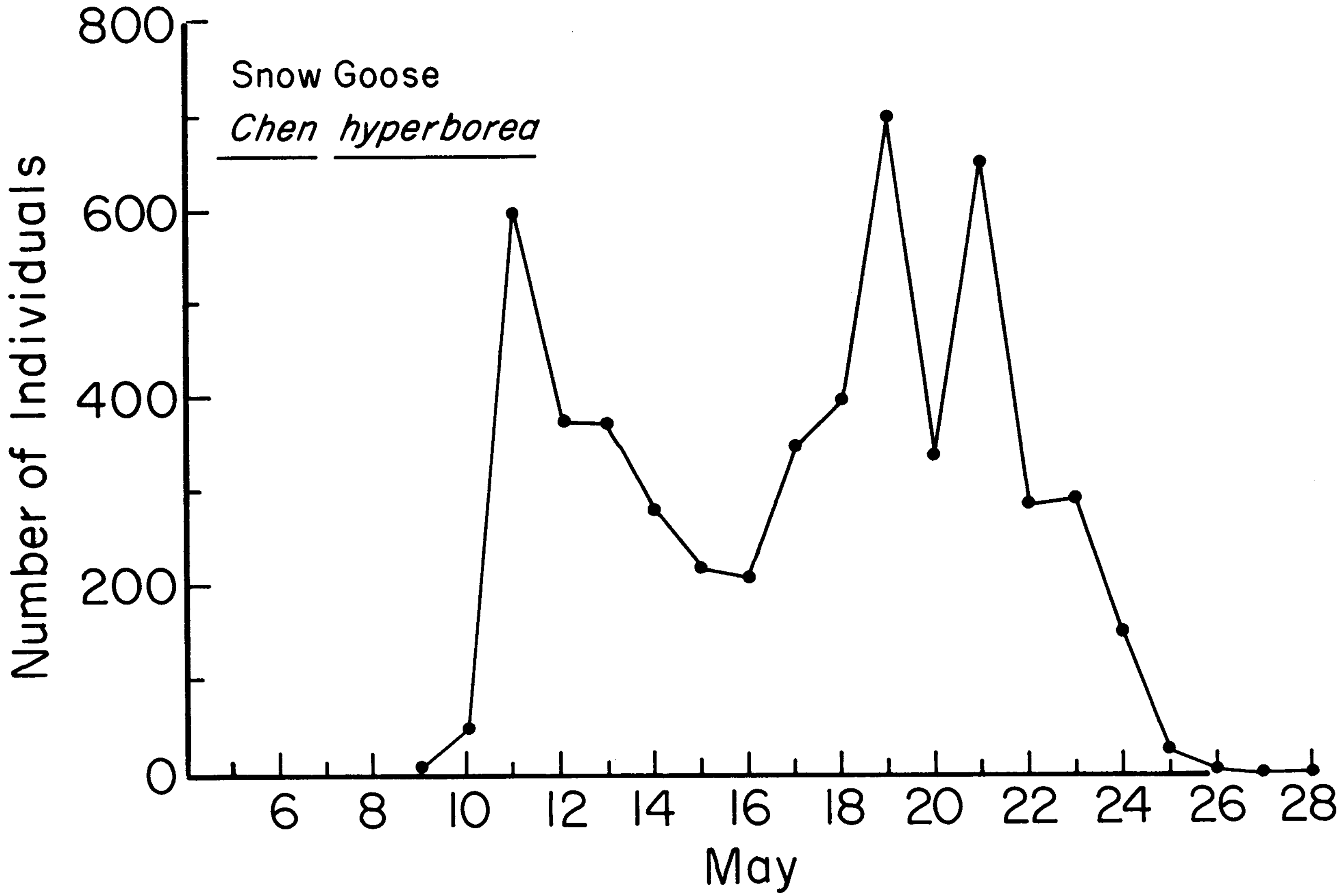

Figure 3. Densities of Snow Geese on Akulik-Inglutalik River Delta - spring 1977.

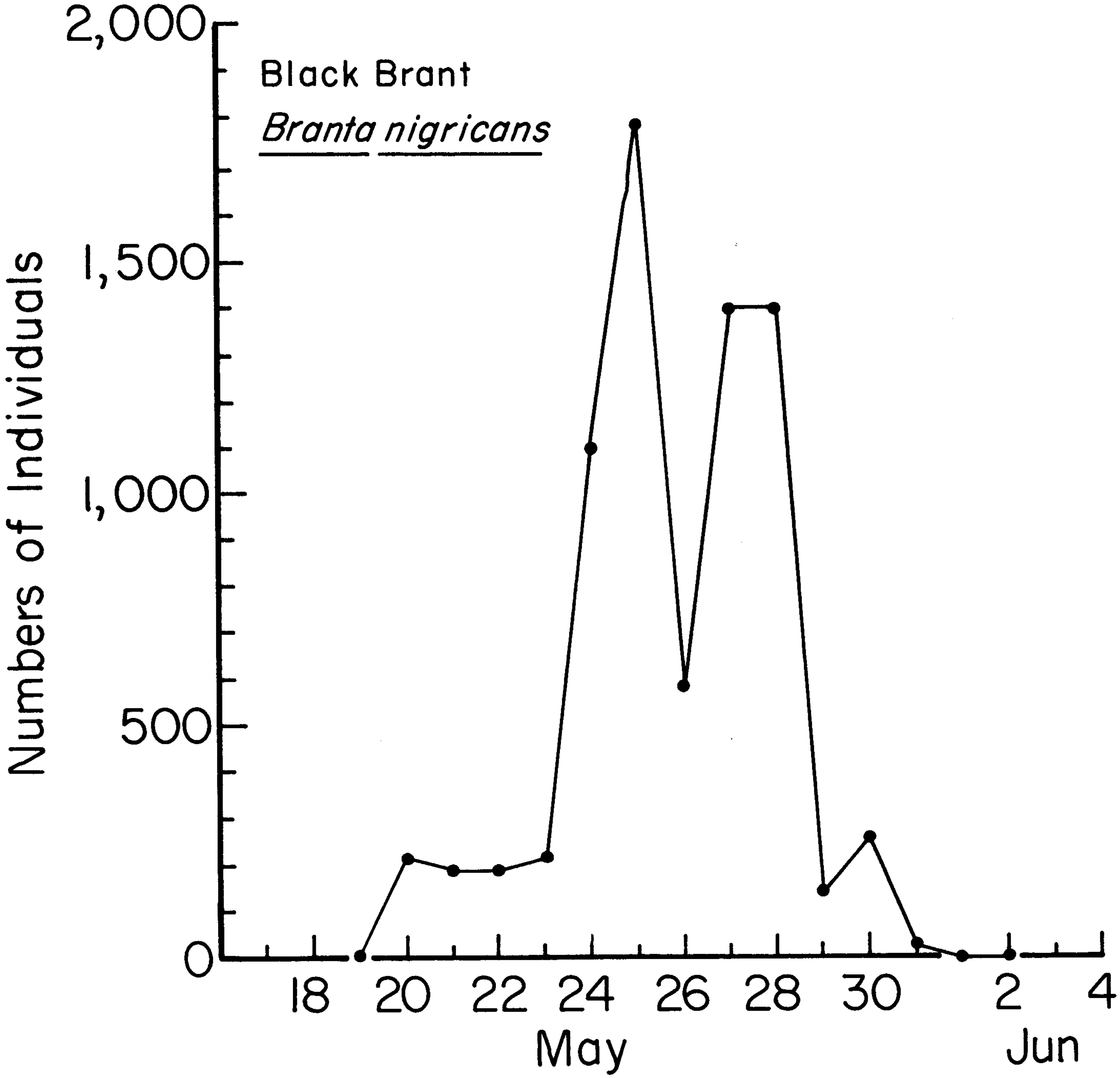

Figure 4. Densities of Black Brant on Akulik-Inglutalik River Delta, spring 1977.

Not more than 50 Sandhill Cranes were observed on the delta during the initial stages of our camp construction (May 8-10). However, birds began moving into the area on May 10 in large numbers. The migration of Sandhill Cranes was characterized by large numbers of birds moving into the area from midday to evening. Subsequent morning counts of birds were reduced indicating that birds were using the delta for a single evening and night and then continuing the northern migration. Morning observations were characterized by large flocks of birds taking flight from the delta and moving north. The peak of the spring migration occurred from May 19 when nearly 3,000 cranes were observed on the delta. Gradually, our daily counts decreased to those of breeding densities for the delta (50 birds). Sandhill Cranes migration through the area took place from May 8 to May 31 and we estimate that about 6,000 cranes used the delta during spring migration.

Significant fluctuations in densities of Whistling Swans occurred during early and mid June. Breeding pairs were known to be in the process of incubating full clutches of eggs at this time and therefore we suspect that these fluctuations can be accounted for by movements of relatively large groups on non-breeding birds through the delta area. On June 11, 300 Whistling Swans used the exposed mud-flat at the mouth of the Inglutalik River (Figure 6).

IX. AVIAN PRODUCTIVITY

Methods

We monitored various parameters of the breeding biology of the birds which nested on the delta study area. The majority of our observations on breeding birds were made on a breeding study plot which included most of the potential breeding habitat types on the delta (Fig. 2). By increasing the area of this plot in 1977 to twice its former size we were better able to assess realistic breeding parameters for the birds of this region. Additionally, since the entire 1976 study plot was included in that of 1977, comparisons of breeding parameters for both years could be made. The entire area was divided into 50 X 50 meter sections. These were numbered and topographic and floral characteristics of each were described (see section on nest site preferences).

Nests were located by surveying the area on foot. On occasion a 50 m rope was dragged through each section and nests were discovered as the incubating birds flushed from their nests. Nests were marked with colored plastic flagging and the following parameters were recorded: location within the section, species and number of eggs.

The area was monitored daily and ultimately we recorded the following parameters for each nest: clutch size, number of young banded and number of young which left the nest. Fledgling success is very difficult

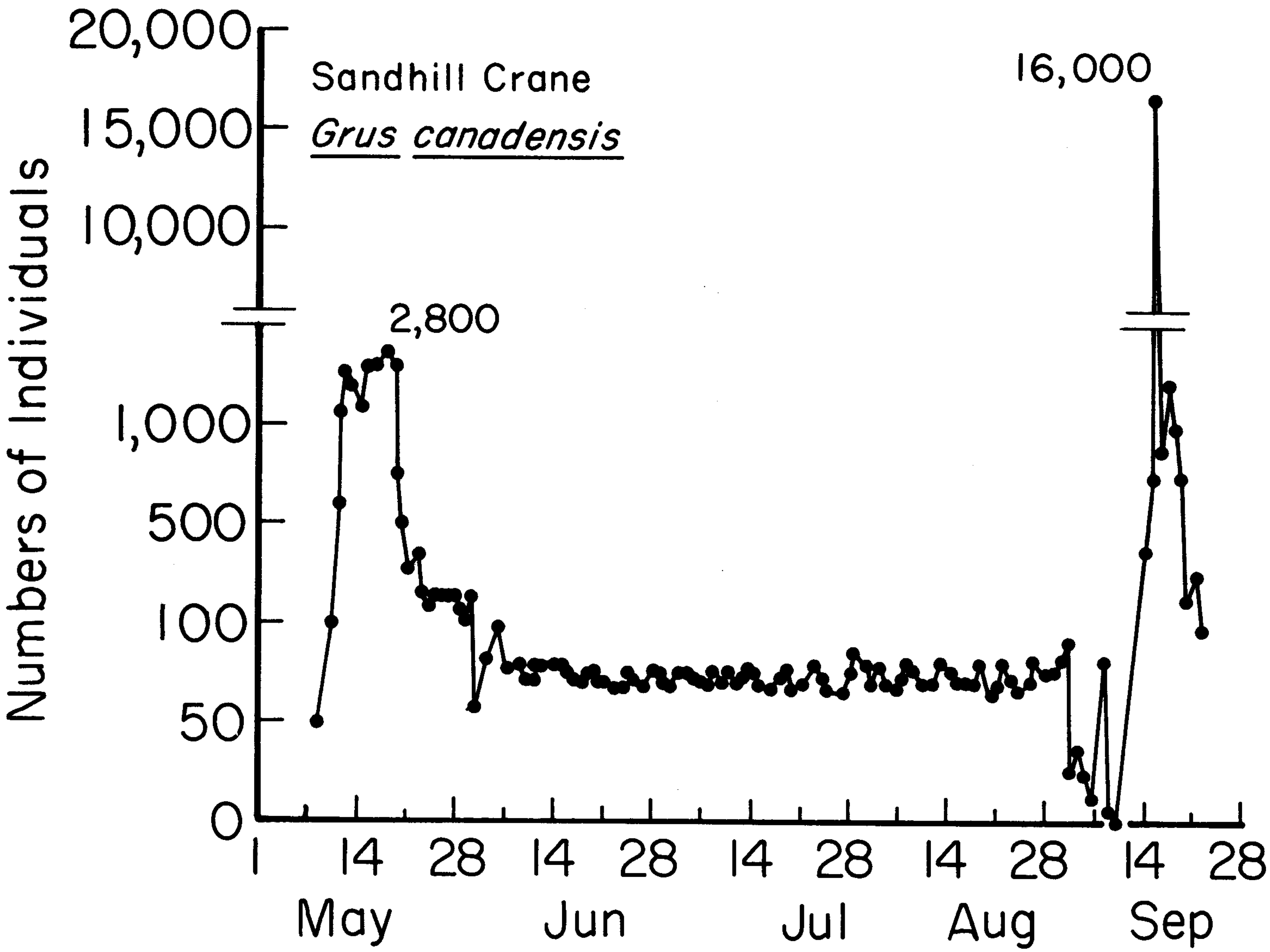

Figure 5. Densities of Sandhill Cranes on Akulik-Inglutalik River Delta, summer 1977.

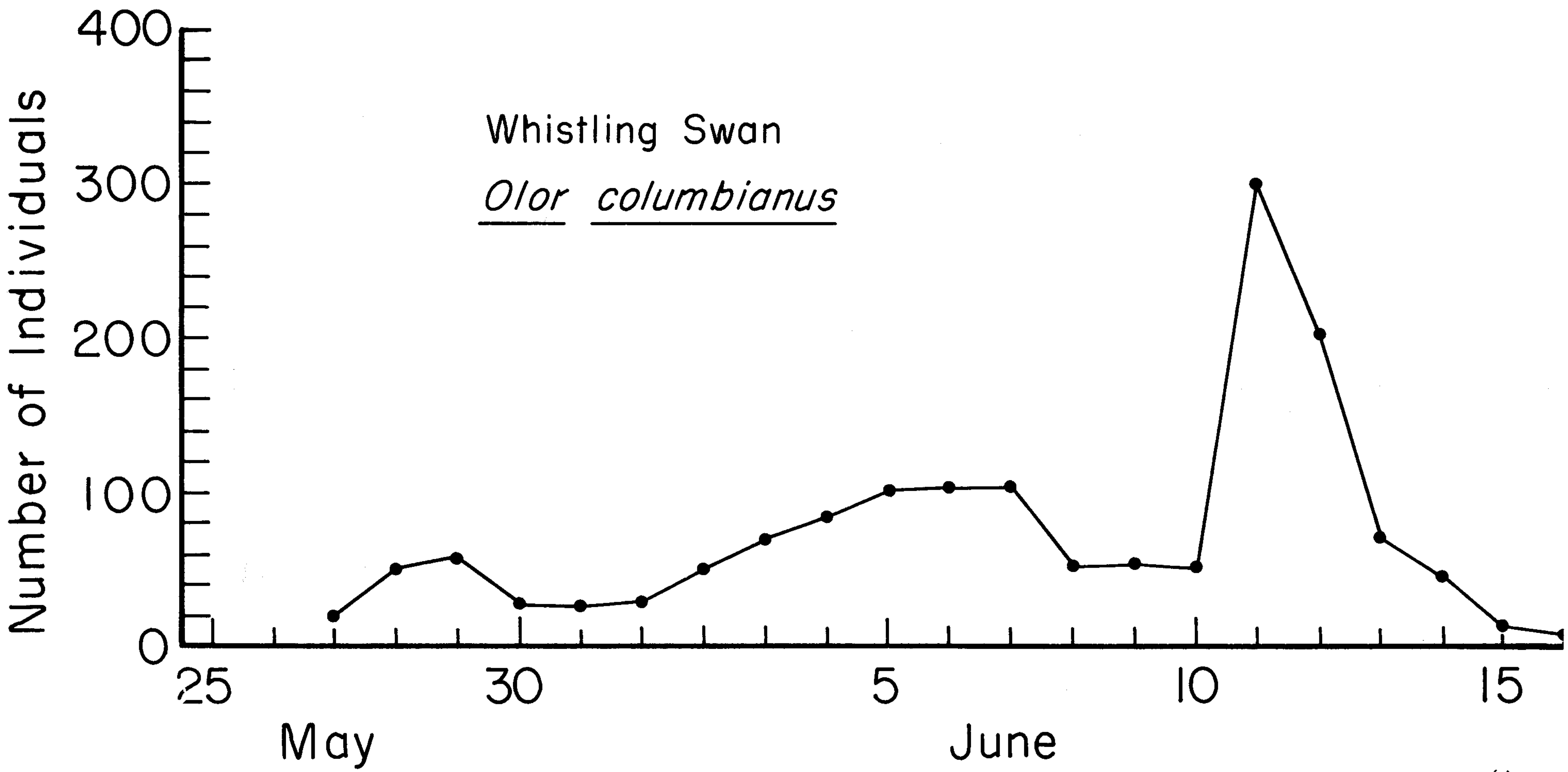

Figure 6. Densities of Whistling Swans on Akulik-Inglutalik River Delta, spring 1977.

to monitor and for this reason a young bird was considered successful if it left the nest on its own. No other specific determinations of fledging success were made. We feel assurred that we monitored breeding parameters of nearly all nests on the study area.

Results

A. Nesting Densities

Table 5 lists nesting densitites of the most abundant breeders on the delta for both years of this study. It is obvious that most breeding species on the delta nest in very low numbers. Of the 22 tundra breeding species, 11 nest in densities of from one to four nests/18 km^2. Breeding densities of these birds fluctuated little from 1976 to 1977. Although we monitored a small portion of the delta in an intense way, general observations of the remainder of the region indicate that these determinations are relatively accurate.

Far more accurate determinations were made of birds which nested at higher densities. In nearly all cases, densities in 1977 are slightly below those of 1976. Many factors influence these levels and many are difficult if not impossible to assess. However, we feel that since we monitored a larger area in 1977 determinations for that year are probably more representative for the delta.

B. Species Group Accounts and Comparative Data

Table 6 lists our most accurate estimates of nesting densities expressed as nests/km^2 for tundra breeding birds on the Akulik-Inglutalik River Delta. Where range values are reported they represent the best estimates for the two year study period. Also included are comparative data on nesting densities for other areas of coastal Alaska. In many cases comparative data represent personal communications with research workers situated in generally similar areas. Local habitat diversity, however, can be extensive and therefore species comparisons over the broad spectrum of western coastal Alaska ecotypes might not be totally legitimate. Nonetheless, these data represent our best general estimates of breeding species diversity on which determinations of area productivity might be based. In this light, they are probably the most significant data sets of these studies. They represent outright, the potential breeding productivity for a given area; and on this basis contribute to ultimate determinations of the relative importance of an area as breeding habitat for resident avifauna. Additionally, they represent baseline productivity estimates against which future comparisons might be made. Significant fluctuations from original baseline determinations may indicate a response on the part of the birds to local habitat disturbance. Appropriate measures might then be taken to lessen or eliminate such disturbance.

Table 5. Nesting Densities of Tundra Breeding Birds, Akulik-Inglutalik River Delta, Norton Bay, Alaska.

Common Name	Scientific Name	Nesting Densities 1976 (km^2)	1977
Arctic Loon	*Gavia arctica*	4	4
Red-throated Loon	*Gavia stellata*	2	3
Whistling Swan	*Olor columbianus*	.06	.17
Mallard	*Anas platyrhynchos*	.06	.17
Pintail	*Anas acuta*	.11	.22
Oldsquaw	*Clangula hyemalis*	.06	.22
Canvasback	*Aythya valisineria*	--	.17
Greater Scaup	*Aythya marila*	--	.17
Common Eider	*Somateria mollissima*	.11	.11
Red-breasted Merganser	*Mergus serrator*	.11	.11
Marsh Hawk	*Circus cyaneus*	.06	.06
Sandhill Crane	*Grus canadensis*	2	1
Semipalmated Sandpiper	*Calidris pusilla*	85	61
Western Sandpiper	*Calidris mauri*	20	8

Table 5 (Cont.)

Common Name	Scientific Name	Nesting Densities 1976 (km^2)	1977
Dunlin	*Calidris alpina*	20	10
Northern Phalarope	*Lobipes lobatus*	35	30
Parasitic Jaeger	*Stercorarius parasiticus*	.06	.11
Glaucous Gull	*Larus hyperboreus*	1	1
Sabine's Gull	*Xema sabini*	.06	.06
Arctic Tern	*Sterna paradisaea*	10	8
Savannah Sparrow	*Passerculus sandwichensis*	30	25
Lapland Longspur	*Calcarius lapponicus*	20	16

Table 6. Nesting densities of tundra breeding birds of the Akulik-Inglutalik River Delta compared with those of adjacent areas.

	Nests/km^2					
Species	Akulik-Inglutalik River Delta	Cape Espenberg[1]	Prudhoe Bay[2]	Barrow[3]	Shishmaref[4]	Yukon-Kuskokwim Delta[5]
Arctic Loon	4	0.2	-	-	-	4.9
Red-throated Loon	2-3	5	-	-	-	.3
Black Brant	-	0.1	-	-	-	2.8-1650
Emperor Goose	-	0.5	-	-	-	1.3-27.0
Pintail	.11-.2	0.1	-	-	10	-
Green-winged Teal	-	0.2	-	-	10	-
Oldsquaw	.05-.2	6	-	2	-	-
Canvasback	.16	-	-	-	-	-
Greater Scaup	.16	-	-	-	-	-
Common Eider	.11	45	-	-	-	-
Spectacled Eider	-	0.1	-	-	-	2.8-6.8
Willow Ptarmigan	-	0.5	-	-	10	-
Sandhill Crane	1-2	0.5	-	-	-	0.36-0.74
Dunlin	10-20	16-20	5	15-21	30	75

Table 6 (Cont.)

			Nests/km^2			
Species	Akulik-Inglutalik River Delta	Cape Espenberg[1]	Prudhoe Bay[2]	Barrow[3]	Shishmaref[4]	Yukon-Kuskokwim Delta[5]
Semipalmated Sandpiper	61-85	4-60	37	12	30	-
Western Sandpiper	8-20	4-60	-	-	20	240-350
Long-billed Dowitcher	-	4	-	-	10	-
Red Phalarope	-	0-72	22-37	44.9-24	-	-
Northern Phalarope	30-35	32-104	4-6	-	39	-
Parasitic Jaeger	.05-.11	.07	-	.03-.04	-	.29
Glaucous Gull	1	12	-	-	-	5.0
Sabine's Gull	.05	0-44	-	-	-	-
Arctic Tern	8-10	0-108	-	-	-	-
Redpoll (sp.)	.55	.1	-	-	30	-
Savannah Sparrow	25-30	0-4	-	-	-	-
Lapland Longspur	16-20	12-24	7-8	30	20	-

[1]Mickelson 1977, [2]Norton et al. 1975, [3]Maher et al. 1974, [4]Nobel and Wright 1977, [5]Mickelson 1977.

<u>Loons</u>

A single Yellow-billed Loon was seen on the nearshore waters of Norton Bay on June 10, 1976. No others were seen during the study and we found no evidence that this species nested on the delta.

Arctic Loons nested in relative abundance during both years of the study. Their abundance might be attributable to significant numbers of large, deep ponds in the area. Arctic Loon densities are approximately 20 times higher than those at Cape Espenberg. This, again, might be based on a relative lack of appropriate ponds at Espenberg. Densities are comparable to those at the Yukon-Kuskokwim Delta (Clarence Rhode National Wildlife Range).

Densities of Red-throated Loon nests were approximately half those of Arctic Loons on our study area. We found red-throats restricted to very small, shallow ponds and their densities may be a simple reflection of the number of such ponds which become available during territorial formation. Densities of red-throats were about half those of Espenberg and significantly higher than those on the Yukon-Kuskokwim Delta.

In summary, then, the Akulik-Inglutalik River Delta represents relatively important local habitat for both Arctic and Red-throated Loons. Nesting densities for the entire delta are estimated in the productivity section. Here total productivity for the area is comparatively low due to habitat restriction. Hence, while not representing large breeding populations both species are important at the local level.

<u>Waterfowl</u>

One of the most significant observations of this study is the absence of even moderate nesting densities of waterfowl on the delta. Nesting densities of all waterfowl in this area are well below .5 nests/ km^2. On the Yukon-Kuskokwim Delta breeding densities of Black Brant (1650/km^2), Emperor Goose (27 nests/km^2), and Spectacled Eider (6.8 nests/km^2) are high. Similarly, at Cape Espenberg breeding levels of Emperor Goose (0.5 nests/km^2) and Common Eiders (45 nests/km^2) are moderate to high. None of these species breeds on the Akulik-Inglutalik River Delta. The area is used heavily during spring migration by both Snow Geese (600/birds/day) and Black Brant (1,800 birds/day). It is used to a lesser extent by Whistling Swans and Pintails.

In summary the area is not important as breeding habitat for waterfowl. It is, however, important as a feeding and staging area particularly in the spring. In fall, the area is used moderately by migrating Canada and White-fronted Geese and Pintails (see fall migration section).

Glaucous Gulls

Nesting distribution of Glaucous Gulls varied from nests in isolation to those in relatively large colonies. In 1976 a single Glaucous Gull nest on the study plot produced three chicks which we banded. No active nests occurred in the plot in 1977.

Three relatively large colonies were active on the delta during both years. One colony to the northeast of the study area produced five chicks in 1976 and ten in 1977 all of which were banded. A second colony north of the study area produced no young in 1977 (see section on factors affecting production). A third colony north of the study area produced four chicks in 1977. Breeding levels of Glaucous Gulls on the delta (1 nest/km^2) are well below those at either the Yukon-Kuskokwim Delta (5.0 nests/km^2) or at Cape Espenberg (12 nests/km^2). While all of these values may be influenced by sample error (influenced by the fact that gulls are usually colonial nesters and densities are affected by sample area), densities at the Akulik-Inglutalik River Delta are low and this species is not an important component of the breeding avifauna of the region.

Arctic Terns

Nesting densities of Arctic Terns were moderate (8-10 nests/km^2) on the delta. Densitites are far below the locally high levels reported by Mickelson at Cape Espenberg. Distribution of tern nests appear relatively uniform over both the study area and the delta in general. We suspect that our estimate of from 144 to 180 nests on the delta is accurate.

Cranes

Nesting densities of Sandhill Cranes on the delta were high (1-2 nests/km^2). Densities on the delta are nearly four times greater than those on the Yukon-Kuskokwim Delta or at Cape Espenberg. We suspect that our estimates taken from the study area are subject to sample bias. First, the densities are low and therefore are subject to considerable sample error. Secondly, during our delta surveys throughout the breeding season densities of adult cranes were consistently in the range of from 50 to 70 adult birds. It is well known that some sub-adult cranes do not breed as first or later year adults and that therefore many birds residing in breeding areas do not attempt nesting (Walkinshaw, 1965; Boise, 1977). Based on observations of adults and young during both years of the study we estimate a breeding density of slightly less than one pair/km^2 over the 18 km^2 delta area.

Cranes utilize the delta heavily during both spring and fall migrations with densities approaching 2,800 birds/day and 16,000 birds/day respectively. No doubt the delta is of prime importance as a staging and feeding area during migration. Also, although the delta area is restricted locally (18 km^2), in prime habitat, cranes are breeding in relatively high numbers and the area is therefore important for breeding.

Shorebirds

Nesting densities of the three shorebirds on the delta are low and comparable to those at Cape Espenberg. Densities of Semipalmated Sandpipers were 6 to 7 times as high as those of Western Sandpipers on the delta. Semipalmated Sandpipers are abundant breeders at Barrow and to the east. Western Sandpipers are rare there. Conversely, Western Sandpipers are the dominant breeding shorebird on the Yukon-Kuskokwim Delta (240-350/nests/km^2). Our area appears to be a transitional part of the range of overlap of the two species. We agree with Pitelka et al. (1974) who suggest that Semipalmated Sandpipers may prefer moist tundra as opposed to the Western Sandpiper which may prefer drier areas. Two observations on our area support this contention. First, Semipalmated Sandpipers nested in areas where Carex (sp.) was the dominant vegetation type. Alternatively, Western Sandpipers chose areas where willow (Salix (sp.)) constituted 63.6% of the vegetation. Second, Western Sandpipers were the only shorebirds which breed in the upland tussock (Eriophorum) vegetation type. We suspect that our area can be classified as generally "wet" since it is subject to considerable precipitation accompanying storms from the south. Hence, the area is generally preferred by Semipalmated Sandpipers.

Passerines

Savannah Sparrows and Lapland Longspurs constitute the tundra breeding passerine avifauna of the delta. Yellow Wagtails, Redpolls (sp.), Tree Sparrows and White-crowned Sparrows breed in moderate concentrations in local upland habitat but they do not constitute a significant proportion of the breeding passerine avifauna.

Savannah Sparrows are far more dense on the delta than at Cape Espenberg. Nesting densities of the Lapland Longspur are comparable to those of other regions of western coastal Alaska.

C. Individual Production - Clutch Size

We monitored more than twice as many nests in 1977 as in 1976 (Table 7). This increase was largely due to the fact that we expanded the area of the breeding study plot in 1977. Determinations of average clutch sizes in 1977 are probably more reliable due to increased sample size and lack of human disturbance during laying and incubation periods of that year. In general, clutch sizes of 1977 are slightly larger than those of 1976. Three of the four most abundant breeders on the delta had increased clutch sizes in 1977. Only Northern Phalaropes decreased clutch sizes. It is difficult to generalize on factors influencing these data but it is obvious that 1977 was far warmer and dryer than 1976 (see climatological data). Due to our late arrival in 1976 we were

Table 7. Clutch sizes of the most common breeders on the Akulik-Inglutalik River Delta, Norton Bay, Alaska (data taken from nesting study plot only).

Species	Number of Nests		Average Clutch Size	
	1976	1977	1976	1977
Arctic Loon	4	2	2.0	2.0
Red-throated Loon	2	2	2.0	2.0
Sandhill Crane	4	2	2.0	2.0
Semipalmated Sandpiper	17	37	3.35	3.73
Western Sandpiper	4	3	3.75	4.00
Dunlin	4	3	3.75	4.00
Northern Phalarope	7	18	3.85	3.72
Arctic Tern	4	6	2.00	1.75
Parasitic Jaeger	1	1	1.00	1.00
Savannah Sparrow	6	9	4.70	5.00
Lapland Longspur	4	10	4.25	5.25

forced to conduct construction activities on the study area during periods of nest site establishment, egg laying, and incubation. We do not rule out the possibility that some clutches in that year were prematurely completed or deserted due to our presence. Several shorebird nests were deserted in 1976; none was deserted in 1977.

Clutch sizes of the most abundant tundra breeders on the Akulik-Inglutalik River Delta are shown in Table 8. These are compared with data from similar locations along coastal Alaska. With the exception of data taken on the Kolomak River by Holmes (1971) and at Barrow by a number of observers over a number of years the sample sizes are relatively small and comparisons are therefore subject to sample error. In species with sample sizes large enough for comparative purposes trends in increasing clutch size from south to north are apparent, for example in the Semipalmated Sandpiper and the Lapland Longspur. The trend is reversed, however, for Western Sandpipers, Northern Phalaropes and Savannah Sparrows.

D. Hatching Dates

Table 9 lists hatching dates for tundra breeding birds on the delta for both years. In the majority of cases early and mean dates of hatching occurred sooner in 1977 than those in 1976. This is no doubt reflected in the fact that increases in late May and early June daily temperatures (see section on climatological results) of 1977 contributed to an earlier break up of pack ice on the bay and river system and an earlier melt off of snow covering the tundra. Break up and melt off took place on June 3 of 1977 six days in advance of 1976. Extremely late hatches in both years (e.g. July 19 for Dunlin and July 6 and 20 for Arctic Terns) may represent replacement clutches for those lost to predation.

E. Species Productivity

Hatching Success

Productivity determinations must ultimately be based on the number of young that adults may rear successfully per year. In most cases such determinations are difficult to make since it is often times impossible to follow the fate of young. Precocial young disperse from the nest soon after hatching and in the absence of recaptures of banded birds as evidence of breeding success and data on fledging success if they are available. We have chosen to analyze our data on productivity in two ways. First, we present potential productivity determinations based on 1) our best estimates of nesting densities taken from the nesting study plot; 2) mean clutch size frequencies; 3) the product of these values (eggs/species/km^2) times the estimated 18 km^2 delta area (Table 10). These values are crude estimates of productivity in that they do not consider hatching success, predation, and the extent of homogeneity in

Table 8. Clutch sizes for the most abundant breeders on the Akulik-Inglutalik River Delta compared with those of similar coastal regions.

Species	Location				
	Barrow	Cape Espenberg	Shishmaref Inlet	Akulik-Inglutalik River	Kolomak River, Yukon Delta
Dunlin	4.00	4.00 (16)	-	3.75 (3) 4.00 (4)	4.00
Semipalmated Sandpiper	4.00	3.91 (22)	3.60 (9)	3.35 (17) 3.75 (37)	-
Western Sandpiper	-	3.25 (24)	3.70 (7)	3.75 (4) 4.00 (3)	3.84
Northern Phalarope	-	3.61 (43)	-	3.85 (7) 3.72 (18)	-
Savannah Sparrow	-	4.00 (2)	-	4.70 (6) 5.00 (9)	-
Lapland Longspur	5.31	4.62 (8)	-	4.24 (4) 5.25 (10)	-

Table 9. Hatching dates for the most abundant breeders on the Akulik-Inglutalik River Delta, Norton Bay, Alaska.

Species	1976 Mean	1976 Range	1977 Mean	1977 Range
Arctic Loon	July 10	June 30-July 16	-	-
Red-throated Loon	July 3	June 30-July 5	-	-
Sandhill Crane	June 13	June 11-June 14	June 6	June 4-June 8
Semipalmated Sandpiper	June 28	June 17-July 12	June 28	June 17-July 10
Western Sandpiper	July 1	July 1-July 2	July 1	June 26-July 7
Dunlin	July 15	July 12-July 19	June 23	June 20-June 26
Northern Phalarope	July 2	July 1-July 2	July 2	June 22-July 13
Glaucous Gull	June 13	June 11-June 17	June 10	June 8-June 14
Arctic Tern	June 18	June 17-July 20	July 6	-
Savannah Sparrow	June 21	June 18-June 28	June 29	June 17-July 15
Lapland Longspur	June 22	June 13-June 25	June 16	Juen 13-June 20

Table 10. Potential productivity expressed as the number of eggs laid per species extrapolated for the Akulik-Inglutalik River Delta, Norton Bay, Alaska.

Species	Potential Productivity (km^2)	Potential Productivity (Delta)
Arctic Loon	8	144
Red-throated Loon	5	90
Pintail	.9	16
Oldsquaw	.8	14
Canvasback	1	18
Greater Scaup	1	18
Common Eider	.4	8
Sandhill Crane	3	54
Dunlin	60	1080
Semipalmated Sandpiper	270	4860
Western Sandpiper	56	1008
Northern Phalarope	120	2165
Parasitic Jaeger	.5	9
Glaucous Gull	3	54
Sabine's Gull	.5	9
Arctic Tern	15.8	283
Savannah	138	2475
Lapland Longspur	95	1717

breeding habitat. However, they remove sample bias attributable to predation brought on by our presence during post-laying periods.

Secondly, we present data on estimated productivity based on our knowledge of hatching success, extents of predation, and comparative floral and topographic analyses for the delta (see section on habitat comparisons). All of these estimates are influenced by many factors not the least of which was our presence in the area.

In determining hatching success we relied on a number of egg and nest characteristics which we feel improved the accuracy of our determinations. For example, Semipalmated Sandpiper chicks, which are precocial, leave the nest soon after hatching. If the hatch was not observed in progress it was difficult to determine if an empty nest was the result of predation or a normal hatch. We observed laying dates for first eggs of clutches but in many cases the clutch was complete or nearly so when we first found the nest. For many nests we had accurate dates for completion of the clutch. If these nests were empty any time before the normal incubation period for the species they were scored as lost to predation.

Predation of nests by red or arctic foxes usually results in destruction of the nest cavity. Predation by Parasitic Jaegers, Glaucous Gulls, and foxes can on occasion be determined by the presence of egg shell fragments at or near the original nest location. On occasion, however, we observed predation by red foxes during which eggs or chicks were carried off and buried.

Although we recovered a large number of young which we originally banded as chicks, we made no additional effort to determine fledging success. If the hatch was normal, if the chicks left the nest on their own and if we found no evidence of predation the clutch was scored as successful. Table 11 lists hatching success for the most common tundra breeding birds on the delta for both years of the study. In addition, it lists comparative data on hatching success for birds at Cape Espenberg reported by Mickelson (1977).

X. FACTORS AFFECTING PRODUCTIVITY

A. Severe Storm Conditions

Throughout the two summers of this study we monitored climatological conditions and tide levels on the delta. Aside from the daily fluctuations in temperature and precipitation nearshore coastal regions of the delta are subjected to extreme tidal variations particularly when periods of high tide coincide with high winds and heavy rain from the southwest. A severe storm in November of 1974 coincided with high tides and the majority of low-lying tundra was temporarily flooded. On July 3,

Table 11. Percent hatching success of the most common tundra breeding birds of the Akulik-Inglutalik River Delta and at Cape Espenberg. Values in parentheses represent numbers of nests monitored.

Species	Akulik-Inglutalik River		Cape Espenberg	
	1976	1977	1976	1977
Arctic Loon	25 (4)	59 (2)	9 (2)	25 (4)
Red-throated Loon	25 (2)	0 (2)	17 (6)	28 (32)
Sandhill Crane	50 (4)	50 (2)	50 (4)	67 (3)
Semipalmated Sandpiper	88 (17)	94 (37)	82 (17)	58 (26)
Western Sandpiper	50 (4)	75 (3)	53 (17)	71 (24)
Dunlin	50 (4)	100 (3)	100 (14)	83 (12)
Northern Phalarope	95 (7)	92 (18)	76 (33)	86 (28)
Glaucous Gull	100 (4)	50 (8)	76 (63)	70 (37)
Arctic Tern	63 (4)	0 (6)	84 (32)	70 (27)
Parasitic Jaeger	-	0 (1)	100 (4)	88 (16)
Savannah Sparrow	79 (6)	67 (9)	100 (2)	100 (1)
Lapland Longspur	75 (4)	67 (10)	70 (10)	48 (21)

1976 and September 5, 1977 similar conditions prevailed on the delta. To our knowledge the July 3 storm did not result in loss of young birds. Wave action was restricted to the western portion of the delta and few if any nests were placed there.

Of potentially greater importance is the relative loss of nesting habitat due to severe wave action and increase in soil salinity during periods of tidal fluctuation. Koyuk natives indicate that prior to the severe storms of November of 1974, vegetation along nearshore areas of the delta was much more dense; waterfowl were far more abundant, as well.

B. Native Hunting Pressure

The breeding status of waterfowl and cranes was affected by the presence of native hunters on the delta. The Koyuk, Akulik, and Inglutalik Rivers are frozen during middle and late May and it is possible to cross them on foot or by snow machine. An average of one hunter/day visited the delta during the last two weeks of May, 1977. During this time many potential avian breeders are arriving on the delta and show machine noise and harassment by hunters may have prohibited nesting. Additionally, large numbers of Cranes, Snow Geese, and Black Brant pass through the area during these times and their period of residence may have been curtailed by hunting activity. Although we did not interview native hunters, it appeared as if the numbers of waterfowl and cranes actually taken were small. With breakup of the pack ice hunting visits ceased. It is difficult to assess the affects of hunting pressure by natives but spring migratory residence on the delta by cranes and waterfowl was certainly decreased.

"Egging" of nests, the traditional native custom of removal of freshly laid eggs from nests for subsistence purposes,was documented in 1977. To our knowledge, only eggs of a single Glaucous Gull colony (est. 10 eggs) were taken by natives in 1977. Potentially, the large clutches of waterfowl, and large eggs of cranes and swans may be taken by natives. We have no evidence that removal of eggs of these birds occurred. Sandhill crane chicks can be captured by running them down during the flightless post hatching period. A single juvenile crane was captured and eaten by natives in August of 1976. Fall hunting by natives on the delta was minimal.

C. Small Mammal Predation on Birds

On separate occasions we observed single adult least and short-tailed weasels, Mustila rixosa, and M. erminea, respectively near the research camp. We did not observe predation on birds by least weasels; however, a short-tailed weasel killed five redpolls which were captured in a mist-net during banding operations. We assume that avian predation by weasels was minimal and that weasels may have preyed heavily on the small population of Red-backed tundra voles, Clethrionomys rutilus, (approx. 30 individuals) which resided on the upland area near the research camp.

We monitored the entire delta area for the presence of red fox, Vulpes fulva, and arctic fox, Alopex lagopus, and their dens, Three active red fox dens were observed on the delta during both summers of the study. No arctic foxes were seen in 1976. A single individual was observed daily during late May of 1977. We found no arctic fox dens on the delta but suspect one was located there.

We have direct evidence that red foxes preyed consistently on eggs of Arctic and Red-throated Loons, Sandhill Cranes, Pintails, Oldsquaws, Canvasbacks, Mallards, and Greater Scaups. In addition, we observed adult red foxes preying on eggs and young of Arctic Terns, Savannah Sparrows and Lapland Longspurs. It is known that foxes may locate nests previously associated with human activity and for this reason we avoided direct contact with nests and eggs. Several broods of Lapland Longspurs and Savannah Sparrow chicks were lost to red foxes after they had been banded by us.

D. Large Mammals

Grizzly bears, Ursus horribilis, were observed on the delta on four occasions in 1977. Visits to the low lying areas of the delta were more frequent during periods of avian incubation. We observed predation of a single Whistling Swan nest by a single adult grizzly bear. The nest was not located on the breeding study plot but by monitoring the behavior of the incubating female we determined that the four eggs of the clutch were about a week old at the time of predation. We did not observe predation on other birds by grizzlies but since they can actively hunt large areas in short time intervals they potentially may have significant effects on the productivity of cranes, swans, and other waterfowl.

On several occasions we observed individual or small groups of barren ground caribou on the delta. Usually their travel was restricted to the coastal mudflat or along river banks. We therefore feel that they had no effect on avian production through nest destruction. A herd of reindeer, Rangifer tarandus, estimated at about 665 animals, is tended by Mr. Archie Henry of Koyuk in an area near Corral Creek on the south bank of the Koyuk River five miles east of Koyuk. We have no evidence that this herd was allowed to graze on the Akulik-Inglutalik River Delta during 1976 or 1977. Local reindeer herding, therefore, had no effect on avian production.

E. Avian Predators

A pair of Parasitic Jaegers nested on the breeding study plot during 1977. Their presence plus the fact that our activities on the study area disturbed incubating Arctic and Red-throated Loons, Sandhill Cranes and Arctic Terns lead to reduction in productivity of these species. Although we attempted to avoid disturbance of sitting adults, this was very often impossible, the birds flushing from nests far in advance of our approach. With the exception of Arctic Terns, most disturbed birds would not return to the exposed nests from which they were flushed until all human activity in the area had ceased. Consequently, eggs were exposed to predation by jaegers for considerable time periods. The realtively low hatching success of Arctic Loons and lack of success of Red-throated Loons and Arctic Terns was directly associated with the interaction of our presence and hunting jaegers on the delta. Casual observations of predation attempts by jaegers on tern eggs indicate that if the eggs are not exposed by the sitting adult predation usually will fail. We believe that the majority of tern pairs which nested on the study area in 1977 were young birds, both of which engaged in chasing bouts with jaegers and hence left exposed eggs.

Flying juvenile Semipalmated Sandpipers and Northern Phalaropes were taken on the wing by pairs of hunting jaegers. Indeed, adult Arctic Terns were harassed by small flocks of hunting jaegers and although predation did not result adult terns were nearly captured during attempts to chase off jaegers.

The delta area was consistently hunted by Short-eared Owls, Marsh Hawk, and Merlin. Densities of these avian predators was not higher than 2-3 adults/species on the delta. We did not observe predation on birds by these species but there is no doubt that they took flightless shorebird chicks (Semipalmated Sandpipers) and flightless Northern Phalarope chicks. Adult and juvenile Grey Jays hunted the upland area near the research camp during periods when eggs and chicks were in nests. On occasion we captured jays, banded them and released them some distance from the research camp. Consequently, predation on passerine eggs and young might have been prohibited. Northern Shrikes which probably bred in spruce forests near the head waters of the Inglutalik River or near Koyuk hunted the area near the research camp in late summer of both years. Shrikes destroyed a single redpoll nest and ate four chicks in August of 1976 but we observed no predation by Shrikes in 1977.

We observed no predation on birds by either Glaucous Gulls or Common Ravens. These species scavenged the delta area throughout both summers and supposedly fed on dead material along the coastal regions and river systems. We observed predation by Glaucous Gulls on both Arctic and Starry Flounder, Liopsetta glacialis, and Platichythys stellatus, respectively.

XI. ESTIMATED DELTA PRODUCTIVITY

In an effort to estimate total productivity for all breeding birds on the delta we modified our potential density levels in relation to a number of variables. Included were: hatching and fledging success, where possible, and determinations of the extent of the delta which was restricted as breeding habitat (i.e. open water of ponds, sloughs and rivers or areas inappropriate as breeding habitat for any given species).

Determinations of real productivity based partially on hatching and fledging success are biased since on our part actual breeding densities and the subsequent hatching and fledging success were influenced greatly by our presence. Hatching and fledging success of Arctic Terns and Loons, for example, were probably much higher in undisturbed areas. For these categories we simply record the most appropriate determination of success based on our observations of all parameters for any given species.

The extent of the delta which was restricted as breeding habitat was analyzed in two ways. First, we determined via aerial photographs that the total area circumvented by the Akulik-Inglutalik Rivers and Norton Bay on the west was 20.67 km^2. Of this 4.74 sq. km existed as open water. Hence, 15.93 km^2 of the delta existed as low-lying tundra and potential breeding habitat. Additionally, we attempted to determine habitat preferences for the most abundant breeding birds by 1) mapping the entire breeding study area as to vegetation type (per species) and extent of cover and 2) by constructing m^2 analysis grids around each active nest. All plants within these grids we identified to species and the percent cover afforded by each was determined. A total of 104 nests were analyzed in this way; table 12 summarizes habitat preferences for the most abundant nesters on the delta.

The distribution of plants on the study area was mapped free-hand by walking through each section and scoring each plant species and its extent of cover. In this way we compared the extensively analyzed study plot with other areas of the delta by 1) sight analysis and 2) comparisons of aerial photographs (infrared, color, and black and white). Our conclusions are that with the exception of nearshore areas of Norton Bay (approx. 2 km^2), the pronounced upland area near the research camp (Fig. 2) (approx. .09 km^2), and slough banks, the remainder of the delta is remarkably homogenous. Hence, an area of about 13.84 sq. km on the delta exists as similar breeding habitat to that of our extensively studied nesting plot.

All values on hatching and fledging success and extent of breeding habitat are incorporated into table 13 which summarizes estimated species productivity for the entire delta area.

Table 12. Plant species preferences used by the most abundant bird nesters on the Akulik-Inglutalik River Delta, Norton Bay, Alaska, during the summer of 1977.

Bird Species	Number of Nests Analyzed	Percent Cover	Dominant Plant Species	
1. Semipalmated Sandpiper	34	100-60 mean = 90%	<u>Carex</u> sp.	28.3%
			<u>Salix</u> sp.	28.3%
			<u>Chrysanthemum arcticum</u>	11.2%
			<u>Saussurea nuda</u>	11.0
2. Northern Phalarope	13	100-75% mean = 90%	<u>Carex</u> sp.	48.7%
			<u>Salix</u> sp.	19.5%
			<u>Chrysanthemum arcticum</u>	14.4%
			<u>Stellaria</u>	4.6%
3. Lapland Longspur	12	100-55% mean = 95%	<u>Carex</u> sp.	32.3%
			<u>Elymse</u>	18.6%
			<u>Salix</u>	11.6%
			<u>Empetrum</u>	11.4%
4. Savannah Sparrow	7	100-60% mean = 90%	<u>Carex</u> sp.	27.9%
			<u>Elymus</u>	18.6%
			<u>Salix</u>	16.3%
5. Western Sandpiper	2	85-80% mean = 83%	<u>Salix</u>	63.6%
6. Dunlin	2	100-95% mean = 98%	<u>Carex</u>	56.4%
			<u>Chrysanthemum arcticum</u>	20.5%

Table 13. Estimated yearly productivity of breeding birds of the Akulik-Inglutalik River Delta expressed as post-fledging young of each species.

Species	Estimated Delta Productivity
Arctic Loon	55.36
Red-throated Loon	34.60
Pintail	3.10
Oldsquaw	2.77
Canvasback	3.46
Greater Scaup	3.46
Common Eider	2.77
Sandhill Crane	20.76
Dunlin	581.28
Semipalmated Sandpiper	2615.76
Western Sandpiper	542.53
Northern Phalarope	1328.64
Parasitic Jaeger	1.73
Glaucous Gull	29.06
Sabine's Gull	3.46
Arctic Tern	54.67
Savannah Sparrow	1145.95
Lapland Longspur	788.88

XII. BIRD BANDING

A. Methodology and General Results

Throughout the two summers of this study we banded young and adult birds in an effort to gain further insight into their residence status on the delta. A variety of capture methods was employed including: nest snap-traps, mist-nets, drop nets (Johns, 1963), and Bol Chatri traps. Nestlings were banded in the nest while shorebird chicks were banded when they hatched or immediately after leaving the nest. Waterfowl, loon, and gull chicks were captured in ponds or on foot.

We intended to band a number of adult breeding shorebirds in 1976 in order to determine nest site tenacity in 1977. Unfortunately, we were unable to band large numbers of these birds since many were incubating eggs when we arrived in early June of 1976 and we feared wholesale desertion of nests by captured adults. We therefore possess only marginal information on nest site tenacity for shorebirds.

We banded 5,560 individual adults and young of 44 species during the two year study. In 1976 we banded 2,042 birds of 31 species (Shields and Peyton, 1977); in 1977 we banded 3,518 of 38 species (Table 14). All data for both years have been registered with the U.S. Fish and Wildlife Service.

B. Recovery of Banded Birds

Recoveries of birds previously banded on the study area can provide information on migration routes, territorial tenacity, and age structure of populations as well as the length of time birds may utilize an area. During our banding activities in 1976 we marked a total of 2,042 birds of 31 species. We recovered a total of 50 of these on the study site in 1977. These data are largely fragmentary and in no way are they intended as species comparisons. Frequencies of recoveries are based on a number of variables most of which cannot be controlled. Returns of known aged birds, however, are meaningful in themselves. Table 15 lists birds recovered in 1977.

In addition to birds recovered from the previous year, several recoveries during the same year were significant. A Semipalmated Sandpiper, collected at Hartney Bay, Cordova, Alaska by Mr. Stan Senner on August 9, 1976 was banded as a migrant on the study area on July 30th. This indicates that birds which probably breed to the north of our study area migrate through our region and that it may take a maximum of ten days to reach the Prince William Sound area.

A Western Sandpiper, banded as a juvenile in 1976 returned to an area 30 meters from the location of banding and raised a brood of four young successfully.

Table 14. Bird banding summary for the summer of 1977 at the Akulik-Inglutalik River.

Species	Young	Adults	Total
Pintail	3	0	3
Spotted Sandpiper	1	0	1
Sharp-tailed Sandpiper	21	0	21
Pectoral Sandpiper	6	0	6
Least Sandpiper	14	7	21
Dunlin	23	0	23
Semipalmated Sandpiper	485	1	486
Western Sandpiper	160	0	160
Northern Phalarope	84	3	87
Glaucous Gull	10	0	10
Arctic Tern	1	0	1
Alder Flycatcher	-	-	4
Tree Swallow	9	5	14
Bank Swallow	1	2	3
Gray Jay	3	0	3
Black-capped Chickadee	2	0	2
Boreal Chickadee	-	-	2
American Robin	1	1	2
Varied Thrush	1	0	1
Gray-cheeked Thrush	11	1	12
Arctic Warbler	7	1	8
Ruby-crowned Kinglet	6	1	7
Yellow Wagtail	25	18	43
Northern Shrike	6	0	6
Orange-crowned Warbler	3	1	4
Yellow Warbler	8	9	17
Blackpoll Warbler	1	0	1
Northern Waterthrush	3	1	4
Wilson's Warbler	6	3	9
Hoary Redpoll	-	-	33
Common Redpoll	-	-	68
Redpoll (sp.)	-	-	1,008
Savannah Sparrow	1,021	130	1,151
Dark-eyed Junco	4	1	5
Tree Sparrow	106	15	121
White-crowned Sparrow	98	38	136
Golden-crowned Sparrow	1	7	8
Fox Sparrow	8	1	9
Lincoln's Sparrow	0	1	1
Lapland Longspur	264	42	306
TOTAL	3,518	289	3,807

Table 15. Summary of birds banded in 1976 which returned to the Akulik-Inglutalik River Delta in 1977.

	Number of Return Birds			
Species	Banded as Adult	Banded as Young	Total	Total Species Banded 1976
Western Sandpiper	-	1♀	1	82
Semipalmated Sandpiper	-	1♀	1	116
Redpoll (sp.)	2♀♀	1♀	3	356
Tree Sparrow	2♂,♀	1♂	3	13
Fox Sparrow	1♂	-	1	13
White-crowned Sparrow	2♂	-	2	42
Savannah Sparrow	4♂♂, 3♀♀	14♂♂, 1♀, 14?	36	1,134
Lapland Longspur	1♂	2♂♂	3	108

C. Post-breeding Residence on the Delta

Fluctuations in densities of post-breeding populations on the delta are fairly indicative of migratory movements. In addition, adult/young ratios of captured birds can be used to indicate migratory status of a population, adults generally leaving the breeding area before maturing young. Our data on known-aged recaptured birds, however, is direct evidence of the duration of post-breeding delta residence. Table 16 summarizes a portion of selected data on recaptures of known-aged birds.

Each of these data represent recoveries of birds remaining on the delta for the longest duration after the date of initial banding. We do not know if these individuals are atypical for their speices; neither do we know if they or other birds remained on the delta for longer periods. It is clear, however, that some juvenile shorebirds remain on the delta after they are able to fly (e.g. Western Sandpiper, 29 days and Dunlin 35 days). Additionally, some adult passerines may maintain residence on the delta long after chicks have fledged.

XIII. UTILIZATING OF EXPOSED NEARSHORE MUDFLAT

Extensive areas (3 km^2) of coastal mudflat became exposed at the mouth of the Inglutalik River at low tide. We monitored this area daily in an effort to determine utilization by both avian residents and migrants. Observations of the area from August 1 to August 22 of 1976 indicated marginal use by local breeders but a significant increase in use by migrants in late August. We were unable to monitor this use by migrants since we left the area on August 22.

During 1977 we monitored the area daily in great detail from August 1 to the time of our departure on September 14. Table 17 lists early movement into the area by migrants, peak dates of utilization and dates of apparent completion of migration. We have no data beyond September 18 of 1977 but we suspect no significant migratory movements through the area after that date (Drury, 1977).

It is obvious that concentrations of Canada Geese, Pintails, Whimbrel, Dunlin, Western Sandpiper, Galucous Gulls and Arctic Terns use the area extensively in late August and early September. Migratory movements through the area suggest peak use in the evening hours when birds congregated in feeding and staging flocks. Our observations are means of morning and evening daily counts. Obviously, thousands of Dunlins and Western Sandpipers use the mudflat during the third week of August. This entire area then is of prime importance as a feeding and staging site for birds migrating through the area both in spring and fall. Environmental perturbations in this area from early May through mid September will certainly affect the extent of utilization by birds.

Table 16. Summary of duration of post-breeding residence of selected tundra breeding birds (1977).

Species	Banding Date and Status	Recovery Date	Minimum Duration of Delta Residence
Western Sandpiper	June 27 one day old	July 25 flying juvenile	29 days
Semipalmated Sandpiper	June 30 one day old	July 20 flying juvenile	20 days
Dunlin	June 30 one day old	August 4 flying juvenile	35 days
Northern Phalarope	July 3 one day old	July 31 flying juvenile	28 days
Savannah Sparrow	June 23 four days old	August 2 flying juvenile	40 days
	May 13 adult	June 11, August 20 post breeding adult	98 days
Lapland Longspur	June 20 four days old	August 5 flying juvenile	46 days

Table 17. Fall utilization of nearshore mudflat, Akulik-Inglutalik River Delta, 1977.

	Utilization		
Species	Early	Peak	Late
Whistling Swan	-	8/31 (32)	-
Canada Goose	8/15 (15)	9/4 (200)*	9/11 (42)
White-fronted Goose	-	8/21 (5)	-
Pintail	8/13 (70)	8/17 (113)*	9/11 (6)
Sandhill Crane	9/11 (10)	9/15 (1000)*	9/18 (150)
Black Turnstone	8/26 (2)	8/30 (3)	8/30 (3)
Whimbrel	8/17 (5)	9/7 (120)*	9/11 (16)
Red Knot	8/13 (20)	8/13 (20)	8/15 (13)
Sharp-tailed Sandpiper	8/29 (1)	9/1 (36)	9/4 (4)
Pectoral Sandpiper	8/22 (10)	8/24 (37)	8/31 (3)
Baird's Sandpiper	8/10 (8)	8/13 (10)	8/15 (5)
Dunlin	8/13 (120)	8/27 (1500)*	9/14 (4)
Western Sandpiper	8/13 (100)	8/27 (360)*	9/9 (13)
Sandlering	8/15 (3)	8/26 (33)	9/9 (1)
Long-billed Dowitcher	9/8 (3)	9/11 (32)	9/11 (32)
Bar-tailed Godwit	8/25 (3)	9/8 (56)	9/9 (6)
Hudsonian Godwit	8/13 (4)	8/16 (7)	8/16 (7)
Northern Phalarope	8/15 (13)	8/20 (26)	8/22 (1)
Glaucous Gull	8/10 (11)	8/31 (250)*	9/11 (161)
Mew Gull	8/15 (18)	8/28 (18)	9/4 (1)
Arctic Tern	8/10 (4)	8/19 (53)*	9/3 (1)

* periods and intensities of peak usage.

XIV. DESCRIPTION OF INVERTEBRATE FAUNA OF POND EDGE AND MUDFLAT

In the fall we observed concentrations of shorebirds feeding on exposed areas of pond edge on the breeding study plot and near the tundra transect and on the extensive mudflat at the mouth of the Inglutalik River. In an effort to determine the importance of these areas as feeding habitat for shorebirds we monitored the densities of feeding birds in these areas daily (Table 17). Additionally, we attempted to describe portions of the invertebrates which were available in these areas as food for birds.

In general, extensively exposed pond edges were used by American Golden Plovers, Long-billed Dowitchers, Bar-tailed and Hudsonian Godwits and Least and Western Sandpipers. The exposed mudflat at the mouth of the Inglutalik River was used more extensively by Dunlin and Western Sandpipers.

In order to describe the invertebrate fauna of these regions we sampled areas where birds had recently fed. We collected samples of the surface substratum with standard core samplers (4x16x12 cm) in areas of intense feeding activity. We were unable to perform serial sampling during the entire fall migration due to time limitations as well as the fact that our research activities were directed elsewhere. Consequently our invertebrate analyses are a simple description of species diversity and wet weight of each sample. Samples were sorted in the field and preserved in 70% EtOH. Later they were identified as completely as possible. Table 18 summarizes the available invertebrates in these respective areas.

XV. FALL MIGRATION

In order to determine the intensity of fall migration both in terms of numbers of species and individuals we conducted: morning and evening delta surveys, the tundra transect, surveys of exposed mudflat, and, when necessary, continuous observations of migrations in progress (e.g. during the period September 14-15 when 16,000 Sandhill Cranes passed through the delta). Table 19 summarizes the fall migration in terms of days of peak intensity and cessation.

Species Accounts

Loons

During the second week of September flocks of from five to 100 Arctic Loons congregated near the mouth of the Inglutalik River. We suspect that these birds were post-breeding adults and young of local origin. We observed no major migration of Arctic Loons into the area. The last remaining Red-throated Loons left the area on September 6 and we observed no significant migration.

Table 18. Summary of invertebrates sampled from pond edge and nearshore mudflat, 1977.

Class / Order / Family / Species		Crustacea / Isopoda / Idioteidae / *Saduria*	*entomon*	Mysidacea / Mysidae / *Neomysis*	sp.	Amphipoda / Haustoriidae / *Pontoporeia*	*affinis*	Gammaridae / *Crangonyx*	sp.	*Gammarus*	sp.	Insecta / Diptera / Chironomidae / larvae	
Location	Date												
ITM 23	8/21					4	.034						
ITM 25	8/21	(12)*	.139										
ITM 26	8/21					2	.007						
ITM 27	8/21	(17)	.151			3	.163	3	.163	18	.959		
ITM 48	8/21	(11)	.047	(43)	.191			1	.009	9	.096		
ITM	8/23	(1)	TSTW	(5)	.008			4	.181	2	.006		
ITM	8/23	(36)	.511										
ITM	8/23	(4)	.008	(1)	TSTW			1	.005	1	TSTW		
ITM	8/23			(10)	.101	1	.004			6	.071		
ITM	8/23	(6)	.031	(6)	.014	1	.003						
ITM	8/25	(4)	.015										
ITM	8/25			(5)	.007			5	.160	11	.731		
ITM	8/25	(13)	.050			3	.251						
ITM	8/25							3	.241	3	.071		
PS	7/18											11	.052
PS	7/18											4	.002
PS	7/18											26	.008
PS	7/18											1	TSTW
PS	7/18											36	.027
PS	7/18											70	.141
PS	7/22											16	.031
PS	7/22											41	.091
PS	7/22											13	.050
PS	7/22											7	.021

PS = Pond shore
TSTW = Too small to weigh
ITM = Intertidal mudflat
* = numbers in () indicate sample size followed by wet weight in grams

Table 19. Summary of fall migration, Akulik-Inglutalik River Delta, 1977.

Species	Date of Last Observation and Number Present	Date of Peak Migration and Migrants/day
Arctic Loon	9/18 (4)	9/12 (100)
Red-throated Loon	9/6 (3)	NSM
Whistling Swan	9/18 (58)	9/18 (58)
Canada Goose	9/18 (32)	8/26 (200)
White-fronted Goose	9/4 (46)	9/1 (100)
Mallard	9/16 (10)	NSM
Pintail	9/18 (100)	9/13 (600)
Greater Scaup	9/18 (150)	9/14 (375)
Oldsquaw	9/18 (3)	NSM
American Widgeon	9/18 (170)	9/18 (170)
Sandhill Crane	9/18 (100)	9/14-15 (16,000)
American Golden Plover	9/15 (10)	9/1 (375)
Whimbrel	9/11 (10)	9/8 (100)
Dunlin	9/18 (100)	8/27 (1,500)
Semipalmated Sandpiper	8/18 (25)	8/3 (300)
Western Sandpiper	9/12 (100)	8/30 (450)
Northern Phalarope	8/22 (10)	7/7 (400)
Sharp-tailed Sandpiper	9/18 (10)	9/1 (90)
Pectoral Sandpiper	8/30 (2)	8/26 (95)
Long-billed Dowitcher	9/14 (150)	9/11 (370)
Bar-tailed Godwit	9/12 (35)	9/8 (60)
Hudsonian Godwit	8/27 (15)	8/17 (70)

Table 19. (Cont.)

Species	Date of Last Observation and Number Present	Date of Peak Migration and Migrants/day
Parasitic Jaeger	9/8 (2)	NSM
Glaucous Gull	9/18 (200)	NSM
Mew Gull	9/18 (1)	NSM
Arctic Tern	9/3 (1)	NSM
Yellow Wagtail	8/17 (2)	NSM
Redpoll (sp.)	9/18 (100)	NSM
Savannah Sparrow	9/12 (10)	8/8 (450)
Lapland Longspur	9/10 (10)	8/15 (800)

NSM = no significant migration

Waterfowl

On September 18 a flock of 58 Whistling Swans passed through the delta area. Sporadic movements of Canada Geese through the area occurred during late August and early September (Fig. 7). Flocks of up to 600 Pintails/day migrated during mid-September. Significnat movements of both Greater Scaup and American Widgeon occurred in mid-September. Finally, we observed no significant migrations of either Mallards or Oldsquaw.

Cranes

Possibly the most spectacular and intense migration in the fall was that of Sandhill Cranes. We recorded low densities of cranes on the delta throughout the second week of September, however, on September 13 flocks of from 20 to 60 birds began moving into the area for feeding and staging. These birds typically arrived from the northwest during afternoon hours and congregated in large gregarious flocks both on the tundra and exposed mudflat. Peak daily densities occurred during our evening counts. Cranes left the area in large numbers during the early morning hours. On September 16th we observed the movement of 16,000 cranes through the delta. When we left the area on September 18 these densities had decreased to less than 100 birds.

Shorebirds

A significant movement of Dunlin occurred from August 25 to August 30. During this time our evening counts reached 1,500 birds. Obviously many more Dunlin migrated through the area during this time; a reasonable estimate is from 10,000-20,000 birds (Fig. 8).

The differential migration of Semipalmated and Western Sandpipers through the area was of interest. Breeding densities of Semipalmated Sandpipers exceeded those of the Western by a factor of about four. Nonetheless, Western Sandpipers migrated through our area in much higher densities (Fig. 9). We monitored the migration of these two species with a great deal of concern in the fall. Our data are taken from visual observations but they were further substantiated by determining the species ratio of hand held migrants which had been caught in mist-nets along feeding areas. During late July and throughout early August we recorded accurate ratios of captures. Apparently, a wave of locally breeding Semipalmated Sandpipers migrated through our area in late July. This movement was moderate (approx. 300/count) and we observed no major later migration. During this time the densities of Western Sandpipers increased markedly. Apparently, these birds bred in areas northwest of our study site, possibly along the western coast of the Seward Peninsula.

A significant local migration of Northern Phalaropes occurred in late June-early July. These birds were mostly post breeding females of

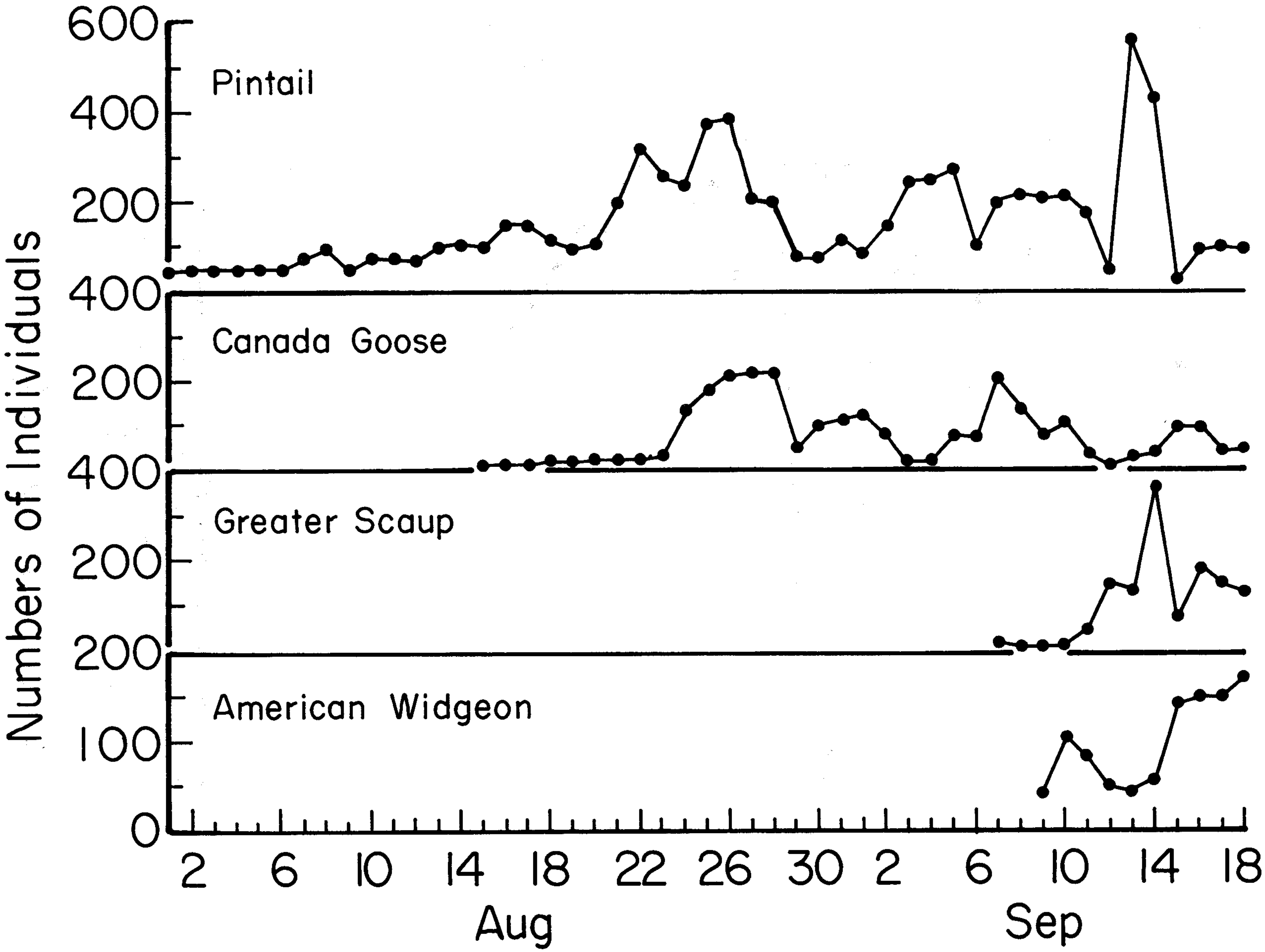

Figure 7. Fall migration densities of Pintail, Canada Goose, Greater Scaup, and American Widgeon on Akulik-Inglutalik River Delta, 1977.

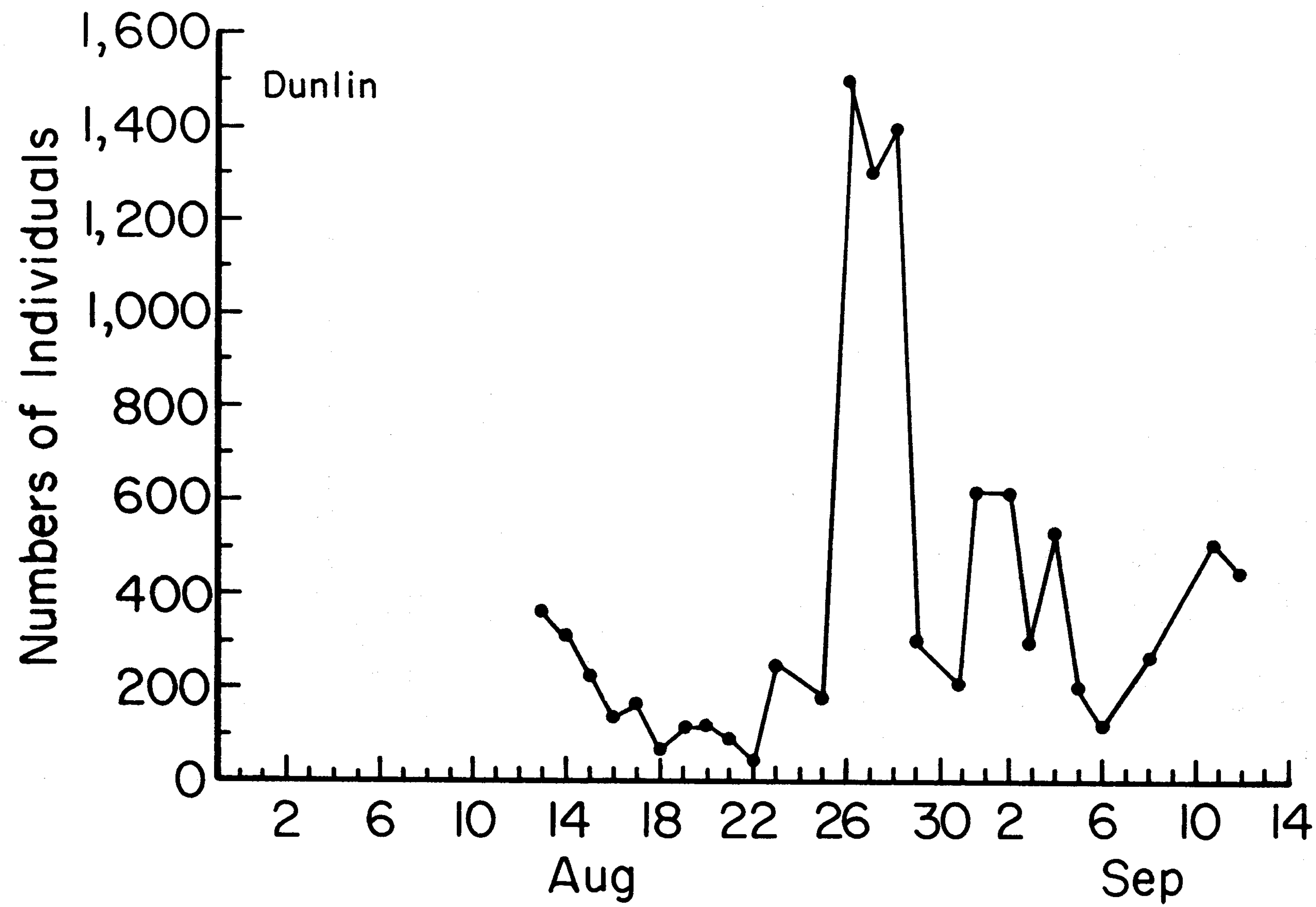

Figure 8. Fall migration densities of Dunlin at the Akulik-Inglutalik River Delta, 1977.

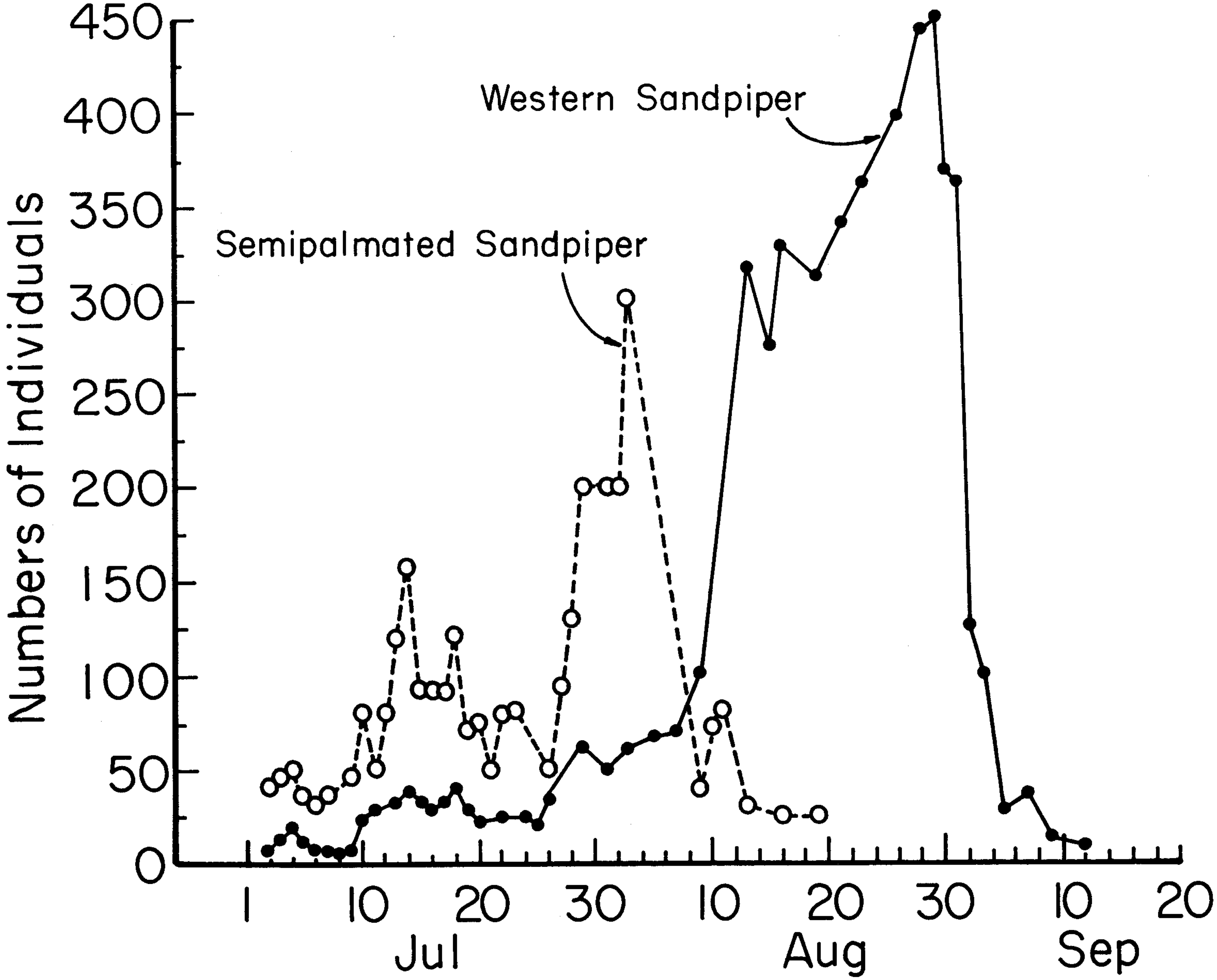

Figure 9. Fall migration densities of Semiplamated and Western Sandpipers on the Akulik-Inglutalik River Delta, 1977.

local origin; we observed no significant fall migration. Moderately high densities of migrating Golden Plover, Whimbrel, Sharp-tailed, and Pectoral Sandpipers passed through the delta in late August-early September (Fig. 11). A significant movement of long-billed Dowitcher occurred (September 6-14). However, movements of Bar-tailed and Hudsonian Godwits were sporadic (Fig. 12).

Passerines

We extensively monitored the passerine migration through the delta primarily by scoring frequencies of birds captured in a network of mist-nets established on the upland study plot near the research camp. We feel reasonably assurred that our estimates of migratory densities are accurate since we netted during equal morning and evening periods daily. Also, ratios of recaptures to newly trapped birds depict the status of the captured population over time. Much of our fall migration data for passerines concerns species which occurred in very low densities or which breed on the delta but never in large numbers. We summarize the data for the two most abundant delta breeding passerines, the Savannah Sparrow and Lapland Longspur.

Large numbers of juvenile Savannah Sparrows began moving into the area in early August. This movement peaked on or about August 8. We estimate that at this time nearly 500 Savannah Sparrows passed through the area of the research camp daily (Figure 13). Estimates of rate of movement through the delta are very difficult to determine.

Migration of Lapland Longspurs was similar to that of Savannah Sparrows except that it peaked later (August 15, 800 birds/day) and ended abruptly on Aguust 18 (Figure 14).

Table 20 lists the chronology of summer residence events for the most abundant breeding birds on the delta.

XVI. Conclusions and recommendation to lessen potential impact of oil and gas related development on the delta

General Avifauna

Avian species diversity of the Akulik-Inglutalik River Delta is comparable to that of other areas exhibiting similar habitats along western coastal Alaska. The majority of species, however, are observed as migrants in spring and fall and many of these occur in relatively small numbers. Only eighteen species are considered as common breeders on the delta; this is no doubt due to habitat restriction. Additionally, these common delta breeders exist in relatively moderate densities when compared with breeding levels for the same species in optimum habitats elsewhere.

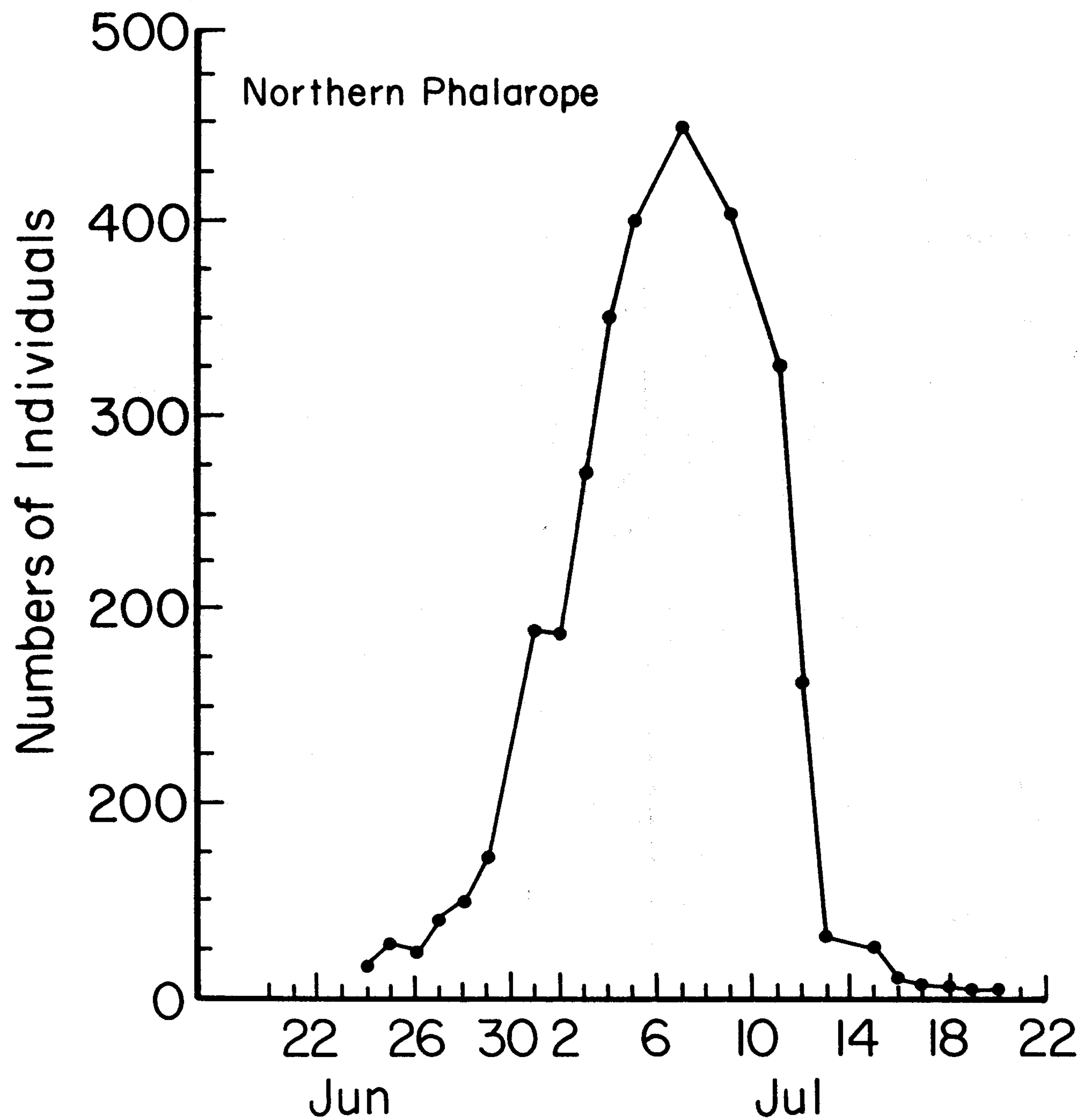

Figure 10. Fall migration densities of Northern Phalaropes at the Akulik-Inglutalik River Delta, 1977.

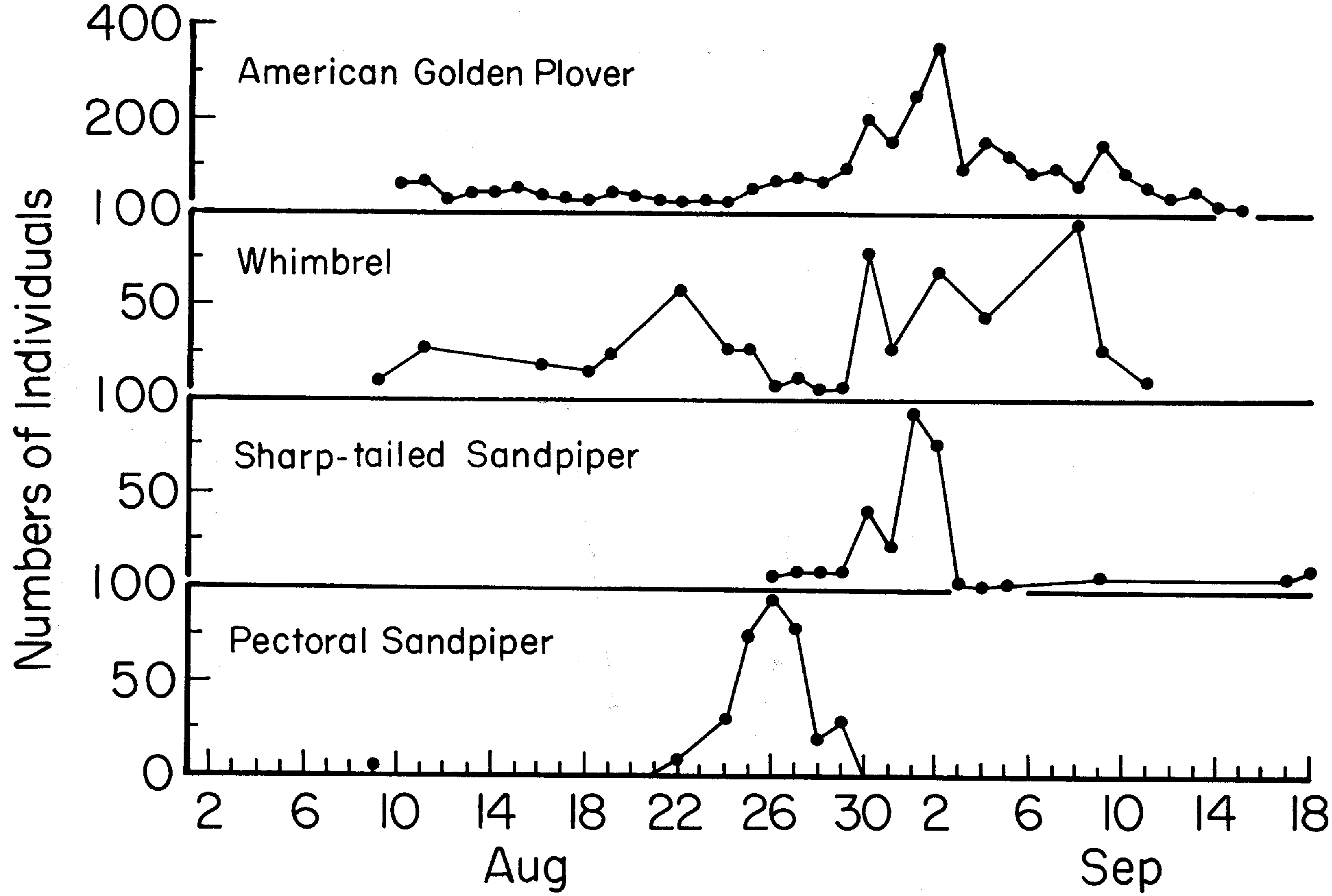

Figure 11. Fall migration densities of American Golden Plover, Whimbrel, Sharp-tailed Sandpiper, and Pectoral Sandpiper on Akulik-Inglutalik River Delta, 1977.

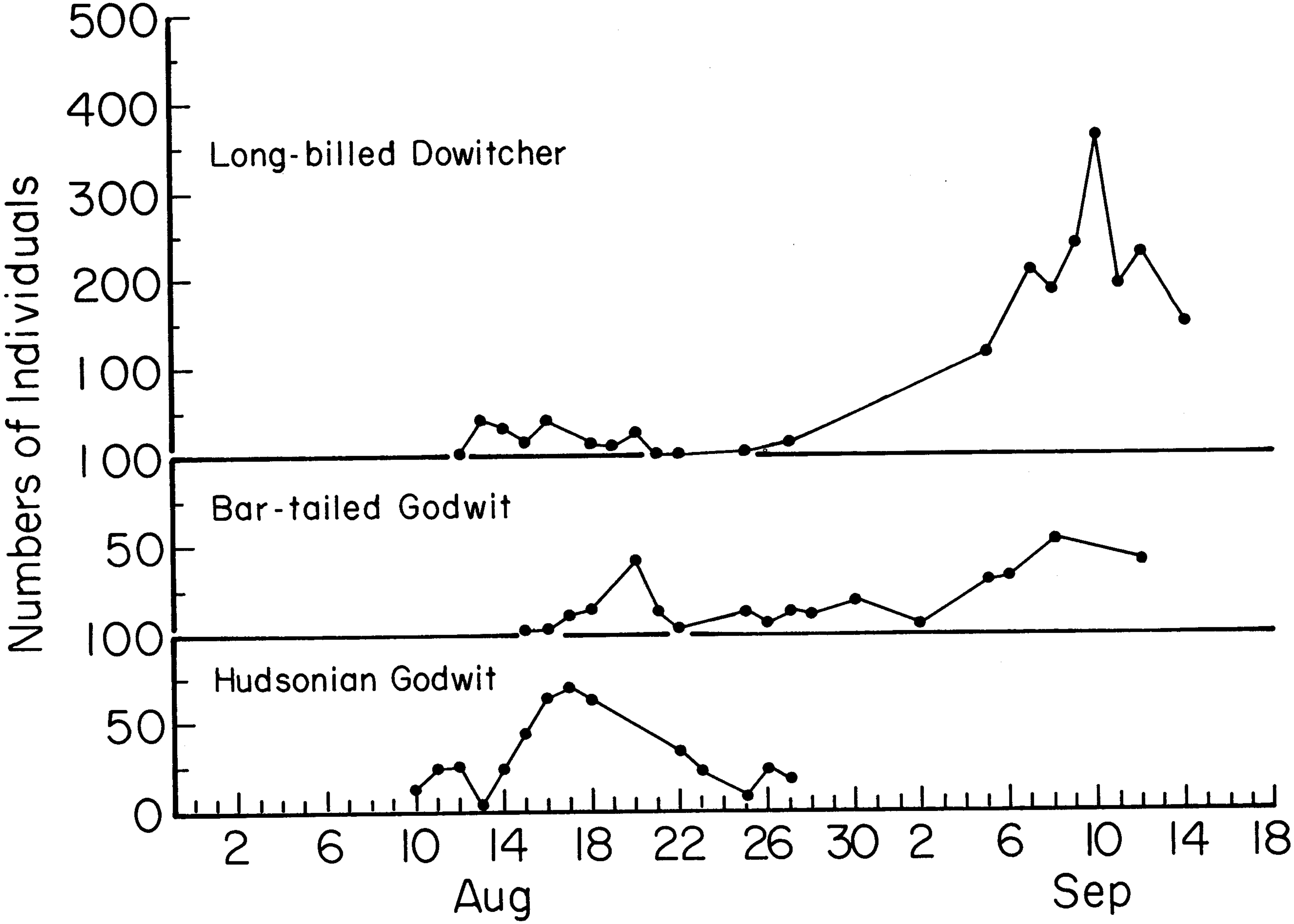

Figure 12. Migration densities of Long-billed Dowitchers, Bar-tailed and Hudsonian Godwits on the Akulik-Inglutalik River Delta, 1977.

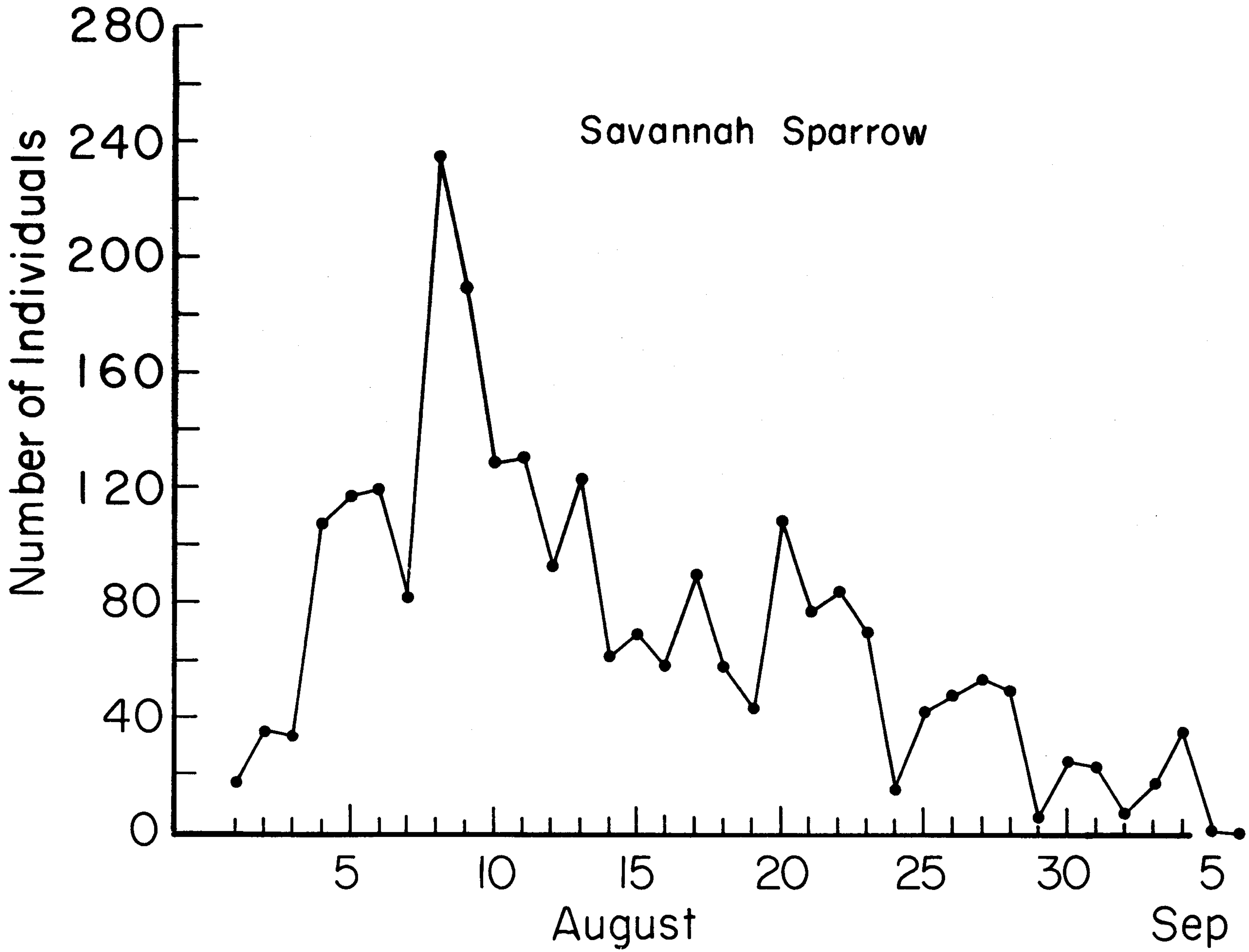

Figure 13. Fall migration densities of Savannah Sparrows on the Akulik-Inglutalik River Delta, 1977.

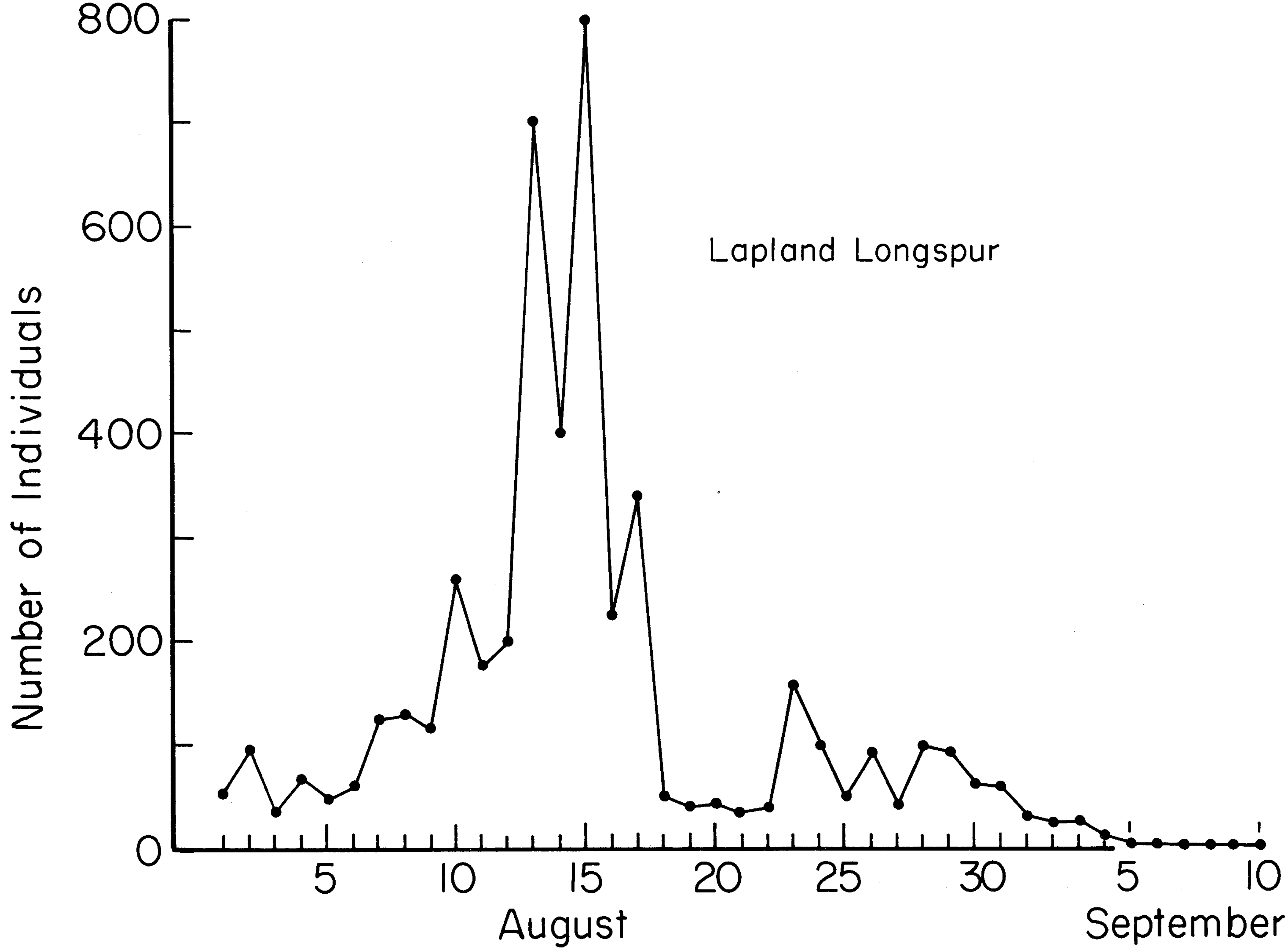

Figure 14. Fall migration densities of Lapland Longspurs on the Akulik-Inglutalik River Delta, 1977.

Table 20. Chronology of significant activities of the major breeding birds on the Akulik-Inglutalik River Delta (1977).

Arctic Loon:	
May 11	First arrival on study site (single bird - no open ice-free ponds)
June 12	First complete egg clutches observed
July 8	First observed hatch (4 nests/km^2)
September 12	Peak of local migration
September 18	Last date of observation (4 loons on delta)
Sandhill Crane:	
May 9	First observed on study area
May 18	First complete egg clutches observed
June 15	First hatch (1 nest km^2)
September 16	Peak of fall migration (16,000 birds/day)
September 18	Last date of observation (150 birds on delta)
Dunlin:	
May 12	First observed on study area
June 1	First complete clutch observed
June 30	First hatch (1 of 3 nests) - (10-20 nests/km^2)
July 1	Last hatch
August 4	Birds hatched on June 30 remain on study area (35 days)
August 13	Peak of local migration (400 birds/day)
August 26	Peak of fall migration (1,500 birds/day)
September 13	Last birds seen on study area
Semipalmated Sandpiper:	
May 12	First arrival on study site
June 2	First complete egg clutches
June 17	First hatch
June 27	Peak of hatch (8 of 38 nests) - (61-86 nests/km^2)
July 9	Last hatch

Table 20 (Cont.)

July 20	Some young hatched on study area remain (hatch June 30 recaptured July 20)
August 3	Peak of fall migration (300 birds/day)
August 18	Last migrants identified on study area
Western Sandpiper:	
May 19	First arrival on study site
June 6	First completed clutch of eggs
June 27	First hatch - (8-20 nests/km^2)
July 7	Last hatch
July 25	Young hatched on June 27 remain on study area
August 30	Peak of fall migration (450 birds/day)
September 12	Last identifiable bird seen on study area
Northern Phalarope:	
May 12	First observed on study site
June 3	First complete clutch observed
June 24	First hatch
June 27	Peak of hatch (4 of 17 nests) - (30-35 nests/km^2)
July 7	Peak of local migration-primarily females - 400 birds/day
July 13	Last hatch
July 31	Young hatched on July 3 remain on study area (28 days)
August 22	Last birds seen on study area
Savannah Sparrow:	
May 9	First observed on study site
June 3	First complete egg clutch observed
June 17	First hatch
June 24	Peak of hatch (25-30 nests/km^2)
June 28	First flying fledgling captured
July 18	Last hatch
August 2	Birds hatched on June 23 remain on study area (40 days)

August 8	Peak of fall migration (450 birds/day)
August 20	Some second-year breeders remain on study area (98 or more days of residence)
September 1	Last date of recapture
September 12	Last birds seen on study area
<u>Lapland Longspur</u>:	
May 9	First observed on study site
June 2	First complete egg clutch observed
June 18	First hatch
June 21	Peak of hatch - (16-20 nests/km^2)
July 3	Last Hatch
July 28	Some second-year breeders remain on study area
August 5	Birds hatched on June 20 remain on study area (46 days)
August 15	Peak of fall migration (800 birds/day)
August 20	Last date of recapture
September 10	Last birds seen on study area

The area supports high breeding densities (61-85 nests/km^2) of only the Semipalmated Sandpiper. Analyses of habitat types and hatching and fledging success suggest that over 2,500 young of this species fledge successfully on the delta each fall. These birds may rely heavily on invertebrates (isopods, Saduria entomon, and dipteran, chironomid larvae) which emerge on exposed nearshore mud flat and pond edge respectively from early July through September. Any environmental perturbation brought on by oil or gas related exploration in Norton Bay will most certainly affect the productivity of the invertebrate fauna of these areas and hence the birds which rely upon them.

In local optimum habitat Arctic and Red-throated Loons, Sandhill Cranes and Arctic Terns breed in relatively high densities. Since each can be affected greatly by slight environmental perturbation they can be considered as indicator species responding to local instability. For example, productivity of each of these species was greatly reduced by our activity on the nesting study plot. Each left exposed clutches of eggs in response to our presence and hence rendered them vulnerable to predation. Our association with these breeders was minimal and oil and gas associated exploration activities on a wholesale scale either on the delta or in nearshore waters of Norton Bay will certainly reduce breeding levels markedly.

Our observations indicate that loons and Arctic Terns rely, at least in part, on the Ninespined Stickelback, Pungitius pungitius, which occurs both in nearshore waters and in brackish ponds of the delta. Oil pollution resulting from either initial exploration or later processing will affect productivity of these food sources. Pollution resulting from exploratory or processing activity on Norton Bay may additionally be expected to be washed ashore even to interior tundra regions if periods of hgih tide coincide with high winds and precipitation from the southwest. Hence the majority of the breeding populations of these species may be adversely affected.

Spring Migration

Interviews with local natives and our knowledge of the area indicate that only four speices: the Gyrfalcon, Willow Ptarmigan, Raven and Redpolls (sp.) might use the delta year around. None of these species is specifically dependent on the delta during winter to the degree that are summer residents. When we established research facilities on the delta in early May of 1977 only eleven species were present; none occurred in high densities. Spring speices diveristy and densities, however, quickly rose with the completion of migration through the area and territorial establishment on the delta.

Snow Geese, Black Brant, Pintail and particularly Sandhill Cranes use the delta for feeding and staging during spring migration. These birds congregated on both the exposed mudflat along the western coast of the delta and alomg exposed pond edges on the study site. Such areas are apparently indispensable for these birds since they provide both resting and feeding areas during long distance migrations. We estimate that from May 10 to May 30 nearly 20,000 individuals of these species utilized the delta area and associated mudflat. Removal of these essential areas due to environmental perturbations associated with petroleum exploration activities during this time may prohibit migrants from reaching optimum breeding habitats and force them to reduce annual productivity as a consequence of breeding in areas less than optimum.

Local natives have traditionally frequented areas of the delta during summer both for subsistance and leisure activities. Delta visits by natives can be classified into: early summer hunting, mid-summer fish camp activities and fall hunting and berry picking. Disturbance of delta av ifauna is most acute during spring when birds are establishing territories and initiating breeding activities. Hunting on the delta might most appropriately be restricted to periods of fall migration when larger numbers of non-breeding birds are available. It is difficult to determine the degree to which delta productivity might increase in the absence of spring hunting pressure and harassment by natives.

Already, it is common practice to hunt in spring via snow machine or all-terrain-vehicle. Most areas of the delta are susceptible to destruction as a consequence of such travel since, in general, exposed areas are blown free of snow. Periods of peak travel associated with hunting coincide with periods of spring melt off when virgin tundra is greatly affected by tracking and the subsequent erosion. The degree to which optimum delta habitat might be withdrawn as a consequence of onshore oil and gas related activities should be determined in advance with great precision.

Fall Migration

Fall utilization of the exposed nearshore mudflat at the mouth of the Inglutalik River was extensive. This area was used as a feeding and staging area to various degrees by fifteen speices of shorebirds. Daily counts for the majority of these species were in excess of 100; only those for the Dunlin exceeded 1,000. Many of these shorebird species are seldom found in large concentrations and their relatively low migratory frequencies on the delta need not indicate that they are unimportant. We were unable to conduct feeding analyses for all these species but presumably they feed on isopods, Saduria entomon, which were prevalent in our samples taken directly from feeding areas on the mudflat. No doubt, these birds rely heavily on these and other invertebrates along coastal mudflat in the fall. Withdrawal of these areas due to petroleum related pollution would most certainly reduce shorebird numbers accordingly.

Similar migratory densities were observed for Canada Geese, White-fronted Geese, Pintails, Greater Scaups and American Widgeons. All rely on the delta for feeding and staging in the fall. The most intense use of the delta by migrants in fall occurred from September 10 through September 21 when literally thousands of Sandhill Cranes used the delta. Daily densities peaked at 16,000 birds on September 14-15. Potential effects of petroleum related pollution on these birds is obvious.

XVII. SUMMARY

Prior to this study little was known of the migrant and breeding avifauna of the Akulik-Inglutalik River Delta, Norton Bay, Alaska. Since this area has high potential for oil and gas exploration it was logical to conduct baseline studies of the avian community ecology of the area. These studies might provide a realistic assessment of the importance of the delta to migrant and breeding populations. Additionally, they might provide baseline data to which future avian productivity comparisons might be made. Declines in bird densities act as indicators of impending major impacts and appropriate measures might be taken to reverse such trends.

Major parameters of the migratory and breeding populations of the delta were described by a team of four biologists using standard methods during each of two field seasons. We obtained extensive breeding data for the area during both years but detailed analyses of spring and fall migrations were restricted to the second year of the study. General descriptions of the delta flora and climatological conditions were also made. Additionally, we attempted to determine realistic estimates of avian species productivity for the delta while considering levels of breeding density, hatching success, fledging success, and descriptions of observed or inferred predations on the birds.

The delta supports a comparable species diversity with other areas of western coastal Alaska. Breeding species diversity, however, is low. Similarly, nesting densitiies are low, the majority of species nesting in densities of less than 3 nests/km^2. Breeding species characterized as abundant on the delta nest in relatively low densities when compared with levels for the same species breeding in optimum habitats elsewhere. The area supports moderate breeding densities of Arctic and Red-throated Loons, Sandhill Cranes and Arctic Terns in appropriate habitat. All of these species are affected greatly by human activity on the delta which if increased during pre-nesting and nesting periods will certainly reduce breeding densities to even lower levels. Human activity associated with oil and gas development in the area could no doubt have a major impact on the breeding levels of these species. Breeding densities of waterfowl are surprisingly low in the area. This is no doubt due to a lack of appropriate breeding habitat but it may also be due, at least in part, to native hunting pressure in the spring. Extirpation of appropriate breeding habitat for waterfowl may also be caused by severe tidal action along the coast of Norton Bay. This action is most severe during periods when high coastal tides coincide with extreme winds and rain from the southwest.

Snow Geese, Black Brant, Whistling Swans, and particularly Sandhill Cranes use the area (for feeding and staging) during spring migration. Perturbations of the area brought on by oil and gas development during mid-May to mid-June, the peak of spring utilization by these species, would certainly reduce the numbers of birds using the delta at these times. Utilization of the delta in fall is characterized by increased species diversity. Extremely large numbers of Sandhill Cranes (16,000/day) use the delta during mid-September. Relatively large numbers of migrating shorebirds use the delta for feeding and staging throughout August and September. Recommendations to lessen potential impact of oil and gas related activities in the area during peak periods of avian susceptibility on the delta are elaborated.

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APPENDIX

Table 1. Vascular plants collected at the Akulik-Inglutalik River Delta (1976-77).

Species	Common Name	Collection Date
Lycopodiaceae		
Lycopodium annotinum L.	stiff club moss	August 22
Equisetaceae		
Equisetum arvense L.	field horsetail	July 26
Polypodiaceae		
Dryopteris dilitata (Hoffm) Gray	shield fern	July 27
Potamogetonaceae		
Potamogeton filiformis Pers.	pondweed	July 7-August 3
Juncoginaceae		
Triglochin palustris L.	arrow grass	July 24-August 17
Graminaceae		
Hierochloe odorata (L.) Wahlenb	vanilla grass	July 26
Arctagrostis latifolia (R.Br) Griseb.	polar grass	July 27-August 17
Calamagrostis canadensis (Michx.) Beauv.	bluejoint	July 26-August 22
C. deschampsoides Trin.	reed bent grass	July 7-August 19
Poa eminens Presl.	grass	August 11-August 23
P. alpigena (E. Fries) Lindm.	grass	July 27-August 24
Arctophila fulva (Trin. Anderss.	pendent grass	July 24
Puccinellia phryganodes (Trin.) Scribn. & Merr.	alkali grass	August 23
P. langeana (Berl.) Sørens	alkali grass	July 17
P. borealis Swallen	alkali grass	July 26
Festuca rubra L.	fescue grass	July 27-August 17
Elymus arenarius L.	lyme grass	July 1-August 23
Cyperaceae		
Eriophorum angustifolium Honck.	cotton grass	August 22
E. russeolum E. Fries	cotton grass	July 24
E. vaginatum L.	hare's-tail grass	August 23
Carex glareosa Wahlenb.	sedge	August 4-August 11
C. mackenziei Krecz.	sedge	August 3-5 (1976)
C. bigelowii Torr	sedge	August 4

C. lugens Holm.	sedge	August 25
C. aquatilis Wahlenb.	sedge	August 23-24
C. ramenskii Kom	sedge	July 17-August 19
C. lyngbyaei Hornem	sedge	August 3-August 22
C. rariflora (Wahlenb.) J.E. Sm.	sedge	July 7-August 23
Juncaceae		
Luzula multiflora (Retz.) Lej.	wood rush	August 26
Liliaceae		
Allium schoenoprasum L.	wild chives	August 22
Iridaceae		
Iris setosa Pall.	wild flag	July 1-August 13
Orchidaceae		
Corallorrhiza trifida Châtelaïn	early coralroot	June 17
Salicaceae		
Salix arctica Pall	arctic willow	August 22
S. ovalifolia Trautv.	willow	June 25-August 19
S. glauca L.	willow	August 27
S. pulchra Cham.	willow	August 3 (1976)
Petulaceae		
Betula nana L.	dwarf birch	August 11-23
Alnus crispa (Ait.) Pursh	mountain alder	July 27
Polygonaceae		
Rumex arcticus Trautv.	dock	July 24-August 24
Polygonum viviparum L.		July 27-August 23
P. alaskanum (Small) Wight		July 27-August 23
Chenopodiaceae		
Atriplex gmelini C. A. Mey	orach	July 26-August 23
Portulacaceae		
Montia fontana L.	water blinks	July 24-August 13
Caryophyllaceae		
Stellaria humifusa Rotth.	chickweed	June 24-August 17
S. crassifolia Ehrh.	chickweed	July 27
S. edwardsii R. Br.	chickweed	June 25
Cerastium berringianum Cham. & Schlecht.	mouse-ear chickweed	July 26
Moehringia lateriflora (L.) Fenzl.	grove sandwort	July 27
Wilhelmsia physodes (Fisch.) McNeill		July 26

Ranunculaceae		
Caltha natans Pall		July 24
Aconitum delphinifolium DC	monkshood	July 27
Anemone richardsonii Hook		
Ranunculus gmelini DC	crowfoot	July 24
R. hyperboreus Rottb.	crowfoot	July 24
R. lapponicus L.	crowfoot	July 24
R. cymbalaria pursh.	crowfoot	July 17
Brassicaceae		
Cochlearia officinalis L.	scurvey grass	June 23
Barbarea orthoceras Ledeb.	winter cress	August 22
Rorippa islandica (Oeder) Borb.	yellow cress	July 24
R. hispida (Desv.) Britt.	yellow cress	August 22
Cardamine pratensis L.	cuckoo flower	
Descurainia sophiodes (Fisch.) O. F. Schulz	tansy mustard	August 11
Crassulaceae		
Sedum rosea (L.) Scop.	roseroot	June 20
Saxifragaceae		
Parnassia palustris L.	northern grass-of parnassus	July 27
Rosaceae		
Spiraea beauverdiana Schneid	Alaska spireae	August 27
Rubus chamaemorus L.	cloudberry	June 24-August 27
R. arcticus L.		
Potentilla palustris (L.) Scop.	marsh fivefinger	July 24
P. egedii Wormsk.	silverweed	June 24-August 27
Febaceae		
Hedysarum alpinum L.		August 24
H. hedysaroides (L.) Schinz & Thell		August 24
Lathyrus maritimus L.		June 21-August 17
L. palustris L.	vetchling	July 26-August 24
Onagraceae		
Epilobium angustifolium L.	fireweed	July 27
Haloragaceae		
Myriophyllum spicatum L.	water milfoil	August 3
Hippuris vulgaris L.	mare's tail	July 24-August 23
H. tetraphylla L.f.	mare's tail	August 4

Apiaceae		
Cicuta mackensieana Raup.	water hemlock	July 24
Ligusticum scoticum L.	beach lovage	July 26-August 22
Angelica ludica		July 1-August 13
Cornaceae		
Cornus suecica L.	wedish dwarf cornel	June 21-August 27
Empetraceae		
Empetrum nigrum L.	crowberry	July 27-August 27
Ericaceae		
Ledum palustre L.	Labrador tea	August 23-27
Andromeda polifolia L.	bog rosemary	August 23
Arctostaphylos alpina (L.) Spreng.	bearberry	August 23-27
Vaccinium vitis-idaea L.	lingonberry	August 23-27
V. uliginosum L.	alpine blueberry	August 23-27
Oxycoccus microcarpus Turcz.	cranberry	August 25
Primulaceae		
Primula sibirica Jacq.	primrose	June 20-25
Androsace chamaejasme Host.		June 12
Trientalis europaea L.	starflower	June 25-August 17
Gentianaceae		
Lomatogonium rotatum (L.) E. Fries	star gentian	August 11
Polemoniaceae		
Polemonium acutiflorum Willd.	Jacob's ladder	June 25
Boraginaceae		
Mertensia paniculata (Ait.) G. Don	bluebell	
Scrophulariaceae		
Castilleja caudata (Pennell) Rebr.	Indian paintbrush	June 20-August 15
Pedicularis verticillata L.	lousewort	June 30
P. sudetica Willd.	lousewort	August 15-24 June 24-25
P. lanata Cham. & Schlecht.	woolly lousewort	August 23
Rubiaceae		
Galium brandegei Gray	bedstraw	July 24
Valerianaceae		
Valeriana capitata Pall.	valerian	July 27

Asteraceae		
Tripleurospermum phaeocephalium (Rupr.) Pobed.	wild camomile	June 26-27
Chrysanthemum arcticum L.	arctic daisy	June 24-August 19
Artemesia tilesii Ledeb.	wormwood	July 6-August 28
Petasites frigidus (L.) Fries.	sweet coltsfoot	August 13-24
Senicio congestus (R.Rr.) DC	marsh fleabane	July 6-24
Saussurea nuda Ledeb.		June 30-August 17

Appendix Table II. Summary of climatological data for the Akulik-Inglutalik River Delta, Summer 1977.

Date 1977	Temperature °c Maximum	Minimum	Average	Departure from 1976 Average	Relative Humidity	Weather Type	Precipitation m.m.	Wind Speed km/hr. Steady	Gusts	Wind Direction Degrees	Barometric Pressure (M.B.)
May											
10	6.7	-0.6	3.0			cloudy	T			00	
11	12.2	-1.1	5.5			scattered clouds	T			00	1021.6
12	13.9	-2.2	6.0			scattered clouds	T			00	1025.4
13	6.7	-1.1	2.8		91	cloudy	T	14.5		200	1024.7
14	6.7	-2.2	2.2			cloudy	snow 25.4	25.7	32.2	200	1032.8
15	1.1	-2.2	-0.6			cloudy	snow 25.4	12.9	19.3	200	1030.1
16	2.8	-2.8	0.0			heavy overcast	snow 38.1	12.9	16.1	200	1030.4
17	7.8	-1.7	3.0			heavy overcast	T			00	1012.5
18	16.7	+0.6	8.6		59	high thin clouds	T	8.0		50	1004.4
19	12.2	+1.7	6.9			heavy overcast	T	29.0	35.4	200	1019.9
20	10.0	+4.4	7.2		47	clear		11.3		360	1029.4
21	9.4	-1.7	3.8		57	clear		12.9	19.3	360	1024.7
22	12.2	-1.1	5.5		66	clear		22.6	29.0	360	1021.0
23	12.2	+0.0	6.1		67	clear		29.0	35.4	360	1016.9
24	10.0	-2.2	3.9		64	partly cloudy		22.6	29.0	360	1016.0
25	11.7	-2.2	4.7		83	clear	T	6.4	8.0	180	1019.9
26	6.1	-0.6	2.7		62	clear		3.2	6.4	180	1017.9
27	3.3	-3.3	0.0		81	clear		16.1	22.6	180	1019.6
28	2.8	-2.8	0.0		73	clear		8.0	12.9	180	1033.8
29	13.3	-5.0	4.1		56	clear		25.7	32.2	360	1030.4
30	10.6	+1.1	5.8		76	clear	T	8.0		180	1030.1
31	5.6	+0.0	2.8		83	high thin clouds	T	16.1	19.3	180	1031.8
June											
1	5.6	+0.0	2.8		92	partly cloudy		12.9	16.1	180	1030.8
2	6.1	+1.1	3.6		85	partly cloudy		12.9	19.3	180	1030.4
3	7.8	+0.0	3.9		67	fog		6.4	8.1	180	1024.7
4	5.6	+1.1	3.3			heavy fog		6.4	9.7	180	1022.0
5	8.9	-0.6	4.1		69	cloudy	28			00	1026.4
6	16.7	+2.8	9.7		47	heavy clouds	T			00	1024.4
7	17.8	+3.3	10.5		75	heavy clouds	T	4.8		18	1024.0
8	15.6	+7.2	11.4			heavy clouds	T	8.1		180	1023.7
9	21.1	+5.6	13.3			clear				00	1030.4
10	18.9	+5.6	12.2		94	cloudy	21	8.1	9.7	180	1031.5
11	16.1	+6.7	11.4		88	high clouds	8	9.7	12.9	180	1029.8
12	18.9	+7.2	13.0		69	cloudy	T			00	1028.8
13	15.0	+7.2	11.1		67	high clouds	3	11.3	12.9	180	1033.8
14	20.6	+5.0	12.8		50	clear		14.5	22.6	180	1030.4
15	23.3	+6.7	15.0		56	clear		11.3	12.9	50	1024.6
16	24.4	+10.0	17.2		78	scattered clouds	6	22.6		180	1019.9
17	21.7	+8.9	15.3		78	scattered clouds		4.8	6.4	180	1021.0
18	17.8	+8.3	13.0		89	scattered clouds	T	9.7		180	1020.6
19	20.6	+11.1	15.8	+4.2	94	partly cloudy	9			00	1017.6
20	19.4	+10.6	15.0	+3.6	88	partly cloudy		12.9	19.3	180	1016.9
21	13.3	+10.0	11.6	+4.1	94	partly cloudy		9.7	16.1	180	1017.6
22	12.2	+7.2	9.7	+4.7	82	partly cloudy		12.9	16.1	180	1022.0

Appendix Table II (Cont.)

Date 1977	Temperature °c Maximum	Minimum	Average	Departure from 1976 Average	Relative Humidity	Weather Type	Precipitation m.m.	Wind Speed km/hr. Steady	Gusts	Wind Direction Degrees	Barometric Pressure (M.B.)
June											
23	18.3	+4.4	11.3	+6.1	72	clear		6.4		180	1022.7
24	18.3	+5.6	11.9	+3.0	73	clear		12.9		180	1023.0
25	22.2	+5.0	13.6	+4.7	39	clear		16.1	19.3	180	1026.4
26	24.4	+6.1	15.2	+2.7	30	scattered clouds		16.1	22.6	360	1028.1
27	21.1	+7.2	14.1	+3.8	42	clear		16.1	19.3	360	1026.0
28	20.0	+5.6	12.8	+2.0	35	scattered clouds		19.3	22.6	360	1030.4
29	22.2	+4.4	13.3	+2.2	47	clear		6.4	8.0	360	1033.8
30	23.3	+6.7	15.0	+3.9	51	partly cloudy		19.3		360	1033.8
July											
1	17.8	+5.0	11.4	+5.0	65	thin clouds		19.3	25.7	180	995.6
2	18.3	+7.2	12.7	+8.0	93	heavy clouds		16.1	19.3	180	1028.1
3	13.9	+6.7	10.3		94	heavy clouds		19.3	24.1	180	1021.6
4	15.6	+8.3	11.9	+6.4	66	heavy clouds		9.7	12.9	360	1019.3
5	13.3	+5.6	9.4		65	heavy clouds	T	16.1	19.3	180	1024.4
6	20.0	+7.8	13.9	+3.1	59	high thin clouds	T			00	1033.8
7	23.3	+7.2	15.2	+1.3	73	scattered clouds	T			00	1033.8
8	26.1	+5.6	15.8	+4.7	83	heavy clouds		16.1	19.3	360	1028.8
9	23.9	+10.0	16.9		89	heavy clouds				00	1029.1
10	22.8	+8.9	15.8	-1.9	88	thin clouds				00	1032.2
11	31.7	+7.8	19.7	+1.1	36	clear		8.1		90	1027.1
12	29.4	+11.1	20.2	+0.2	84	partly cloudy	T	12.9		180	1025.4
13	26.7	+11.1	18.9	-1.1	80	scattered clouds		16.1	19.3	180	1023.7
14	21.1	+12.8	16.9	+5.0	70	scattered clouds		19.3	25.7	180	1022.0
15	18.9	+11.1	15.9	+3.1	84	scattered clouds		6.4	9.7	180	1024.7
16	17.8	+10.0	13.9	+1.2	82	cloudy		19.3	22.6	180	1026.0
17	16.7	+11.1	13.9		83	cloudy		19.3	25.7	180	994.2
18	16.1	+6.7	11.4	-1.9	84	cloudy		16.1		180	1030.4
16	17.2	+5.6	11.4	-2.5	82	cloudy		12.9		180	1029.8
20	18.9	+8.9	13.9	-2.1	79	cloudy		12.9		180	1029.8
21	24.4	+7.2	15.8		46	cloudy				00	1024.0
22	26.1	+9.4	17.7	-0.1	73	cloudy	T			00	1025.4
23	22.2	+10.0	16.1	-1.6	60	cloudy		9.7	12.9	180	1029.4
24	26.1	+9.4	17.7	+2.2	61	cloudy	T			00	1028.8
25	25.0	+10.6	17.8	+2.0	61	cloudy				00	1024.4
26	24.4	+10.0	17.2		62	cloudy	T	6.4	9.7	180	1019.6
27	21.1	+13.3	17.2	+3.6	66	cloudy	36	16.1	22.6	180	1023.7
28	20.0	+14.4	17.2	+2.5	74	cloudy	T			00	1026.4
29	26.1	+12.2	19.1	+5.2	53	cloudy				00	1026.0
30	28.9	+18.3	23.6	+11.4	50	cloudy; heavy smoke		3.2	8.1	180	1027.4
31	25.6	+16.1	20.8	+5.8	90	cloudy; heavy smoke		12.9	19.3	180	1027.4
Aug.											
1	18.3	+15.6	16.9	+5.0	89	haze and smoke		11.3	14.5	180	1032.1
2	22.2	+9.4	15.8	+3.3	67	scattered clouds; hazy		8.1	11.3	180	1033.8
3	27.2	+8.9	18.0		75	heavy clouds	9			00	1028.4

Appendix Table II (Cont.)

Date 1977	Temperature °c Maximum	Minimum	Average	Departure from 1976 Average	Relative Humidity	Weather Type	Precipitation m.m.	Wind Speed km/hr. Steady	Gusts	Wind Direction Degrees	Barometric Pressure (M.B.)
Aug.											
4	23.9	+12.8	18.3	+5.6	66	scattered clouds		12.9		180	1031.1
5	23.9	+11.1	17.5	+0.3	78	scattered clouds		1.6	3.2	180	1026.4
6	21.1	+4.4	12.7	-6.5	51	scattered clouds		3.2	4.8	180	1024.7
7	21.1	+7.2	14.1		57	scattered clouds; smoke		16.1	20.8	360	1019.6
8	24.4	+12.2	18.3	+2.2	67	scattered clouds; hazy	18			00	1022.0
9	23.3	+12.8	18.0	+2.5	79	cloudy	T			00	1025.4
10	22.2	+12.2	17.2	+3.3	72	scattered thunderheaas;smoke		16.1	25.7	360	1022.7
11	25.6	+13.3	19.4	+4.4	52	scattered clouds		19.3	25.7	180	1032.1
12	17.8	+10.6	14.2	+0.3	74	heavy clouds	15	6.4	14.5	140	1028.8
13	22.2	+10.6	16.4		74	cloudy	43			00	1026.4
14	21.1	+13.3	17.2		84	mostly cloudy	43	3.2		180	1023.7
15	18.3	+11.7	15.0		62	heavy clouds	10	19.3	25.7	180	1027.4
16	17.8	+11.7	14.7		73	heavy clouds	13	8.0		180	1032.5
17	20.0	+11.1	15.5	+3.3	84	heavy clouds	T	1.5		180	1023.7
18	16.1	+15.6	15.8	+4.2	84	heavy clouds	36	19.3	25.7	140	1029.4
19	19.4	+13.3	16.3	+5.5	84	cloudy	T	1.5		180	1035.5
20	26.1	+9.4	17.7	+8.3	76	scattered clouds	20			00	1032.1
21	27.8	+10.6	19.2	+6.4	61	clear		9.7	11.3	50	1026.0
22	28.3	+12.8	20.5		80	clear		8.0	9.7	50	1021.0
23	26.7	+11.7	19.2	+8.8	50	clear		8.0	11.3	50	1023.7
24	22.2	+6.1	14.1		61	clear		9.7	12.9	360	1020.3
25	16.7	+6.1	11.4		66	clear		11.3	16.1	360	1021.6
26	16.1	+1.1	8.6		41	clear		16.1	19.3	360	1021.0
27	16.1	-2.2	6.9		66	clear		6.4	8.0	220	1022.0
28	14.4	+6.1	10.2		77	heavy clouds	20	19.3	22.6	220	1021.0
29	14.4	+9.4	11.9		88	heavy clouds	T	9.7	11.3	220	1032.1
30	15.6	+10.0	12.8		78	few scattered clouds	T	11.3	14.5	220	1033.2
31	18.9	+3.3	11.1		81	partly cloudy		3.2	4.8	360	1033.8
Sep.											
1	18.3	+3.9	11.1		88	few scattered clouds;smoke				00	1033.2
2	17.2	+3.3	10.2			high thin clouds; smoke		3.2		180	1030.4
3	16.1	+4.4	10.2		82	cloudy	T	8.0	9.7	220	1032.1
4	14.1	+3.3	8.7		76	high thin clouds; scattered clouds				00	1028.1
5	12.2	+6.1	9.1		94	heavy clouds	67	16.1	24.1	180	1014.9
6	13.9	+9.4	11.6		87	heavy clouds	115	1.5		140	1002.3
7	15.0	+8.9	11.9		88	mostly cloudy	81	3.2		360	1017.6
8	17.8	+5.0	11.4		63	partly cloudy	3	1.5		360	1026.0
9	16.1	+5.0	10.5		94	mostly cloudy	22	6.4	8.0	180	1023.0
10	11.7	+5.6	8.6		87	heavy clouds	49	3.2		360	1009.8
11	11.7	+6.7	9.2		87	mostly cloudy	58	4.8	8.0	360	1019.6
12	11.1	+5.0	8.0		94	heavy clouds	5	22.6	38.6	180	1033.2
13	11.1	+9.4	10.2		87	cloudy	66	64.4	80.5	180	1018.3
14	11.1	+8.9	10.0		87	heavy clouds	65	22.6	32.2	220	1028.1
15	9.4	+5.6	7.5		93	few scattered clouds	82	6.4	11.3	360	1019.9
16	9.4	+2.2	5.8		79	heavy clouds		16.1	22.6	180	1027.4
17	10.0	+5.6	7.8		86	heavy clouds	5	3.2	8.0	220	1010.5
18	10.0	+1.1	5.5		79	partly cloudy	8	0.0	4.8	360	1014.9

Appendix Table II (Cont.)

Date 1976	Temperature °C Maximum	Minimum	Average	Departure from 1976 Average	Relative Humidity	Weather Type	Precipitation m.m.	Wind Speed km/hr. Steady	Gusts	Wind Direction Degrees	Barometric Pressure (M.B.)
June											
19	16.1	+7.2	11.6			heavy clouds	rain			220	
20	16.7	+6.1	11.4			partly cloudy				180	
21	8.9	+6.1	7.5			mostly cloudy				220	
22	5.0	+5.0	5.0			heavy clouds	intermittent light rain			220	
23						heavy clouds					
24	6.1	+4.4	5.2			heavy clouds					
25	12.2	+5.6	8.9			partly cloudy				00	
26	15.0	+10.0	12.5			scattered clouds					
27	15.0	+5.6	10.3			high thin clouds				220	
28	15.6	+6.1	10.8			clear				220	
29	17.2	+5.0	11.1			partly cloudy				320	
30	16.1	+6.1	11.1			high scattered clouds				90	
July											
1	12.2	+0.6	6.4			clear				50	
2	11.7	-2.2	4.7			few scattered clouds				00	
3						heavy clouds	hard rain		48.28	220	
4	7.8	+3.3	5.5			partly cloudy				220	
5						partly cloudy					
6	17.2	+4.4	10.8			partly cloudy				320	
7	21.1	+6.7	13.9			heavy clouds	intermittent rain			00	
8	15.6	+6.7	11.1			partly cloudy				220	
9	15.6					clear				220	
10	23.3	+12.2	17.7			clear				00	
11	25.0	+12.2	18.6			clear				00	
12	27.8	+12.2	20.0			clear				40	
13	27.8	+12.2	20.0			high thin clouds				90	
14	20.0	+3.9	11.9			high thin clouds					
15	20.0	+3.9	11.9			high thin clouds				220	
16	17.2	+8.3	12.7			high thin clouds				220	
17						heavy clouds	rain				
18	16.7	+10.0	13.3			partly cloudy				00	
19	16.7	+11.1	13.9			mostly cloudy					
20	22.1	+10.0	16.0			heavy clouds	light rain			180	
21											
22	25.6	+10.0	17.8		43					220	
23	27.2	+8.3	17.7		38	heavy clouds	light rain	16.1		220	
24	21.1	+10.0	15.5		74	partly cloudy		20.8		220	
25	21.1	+10.6	15.8		62	heavy clouds	2.5	12.9		220	
26						heavy clouds	light rain				
27	23.3	+3.9	13.6		44	partly cloudy	T			00	
28	16.7	+12.8	14.7		66	heavy clouds	45.3	16.1	45.1	220	
29	16.7	+11.1	13.9		62	heavy clouds	7.6	22.6	32.2	180	
30	14.4	+10.0	12.2		79	heavy clouds	25.4	29.0	45.1	220	
31	18.9	+11.1	15.0		87	clear				00	

Appendix Table II (Cont.)

Date 1976	Temperature °C Maximum	Minimum	Average	Departure from 1976 Average	Relative Humidity	Weather Type	Precipitation m.m.	Wind Speed km/hr. Steady	Gusts	Wind Direction Degrees	Barometric Pressure (M.B.)
Aug.											
1	17.2	+6.7	11.9		79	scattered clouds		6.4	12.9	220	
2	16.1	+8.9	12.5		88	cloudy		12.9	22.6	220	
3					70	cloudy		19.3	37.0	220	
4	21.1	+4.4	12.7		94	scattered clouds				00	
5	23.3	+11.1	17.2		51	partly cloudy		16.1	30.6	360	
6	26.7	+11.7	19.2			heavy clouds	light rain	29.0	38.6	180	
7						heavy clouds	48			00	
8	21.1	+11.1	16.1		83	heavy clouds	light rain			00	
9	22.2	+8.9	15.5		94	mostly cloudy					
10	18.9	+8.9	13.9		83	scattered cloudy	rain showers			220	
11	21.1	+8.9	15.0		84	partly cloudy	0.9			00	
12	20.1	+7.8	13.9		89	partly cloudy				00	
13						heavy clouds	intermittent rain			180	
14						heavy clouds	intermittent rain			180	
15						heavy clouds	intermittent rain			180	
16						heavy clouds	intermittent rain			180	
17	18.3	+6.1	12.2			partly cloudy	rain showers			00	
18	18.9	+4.4	11.6		76	mostly cloudy		25.7	32.2	50	
19	17.8	+3.9	10.8			partly cloudy				50	
20	17.2	+1.7	9.4		83	clear		8.0		270	
21	15.6	+10.0	12.8		88	heavy clouds				220	
22						heavy clouds				00	
23	13.6	+7.2	10.4		90	cloudy	intermittent light rain			00	

Table 18. Summary of invertebrates sampled from pond edge and nearshore mudflat, 1977.

Class		Crustacea										Insecta	
Order		Isopoda		Mysidacea		Amphipoda						Diptera	
Family		Idioteidae		Mysidae		Haustoriidae		Gammaridae				Chironomidae	
Species		Saduria entomon		Neomysis sp.		Pontoporeia affinis		Crangonyx sp.		Gammarus sp.		larvae	
Location	Date												
ITM 23	8/21					4	.034						
ITM 25	8/21	(12)*	.139										
ITM 26	8/21					2	.007						
ITM 27	8/21	(17)	.151			3	.163	3	.163	18	.959		
ITM 48	8/21	(11)	.047	(43)	.191			1	.009	9	.096		
ITM	8/23	(1)	TSTW	(5)	.008			4	.181	2	.006		
ITM	8/23	(36)	.511										
ITM	8/23	(4)	.008	(1)	TSTW			1	.005	1	TSTW		
ITM	8/23			(10)	.101	1	.004			6	.071		
ITM	8/23	(6)	.031	(6)	.014	1	.003						
ITM	8/25	(4)	.015										
ITM	8/25			(5)	.007			5	.160	11	.731		
ITM	8/25	(13)	.050			3	.251						
ITM	8/25							3	.241	3	.071		
PS	7/18											11	.052
PS	7/18											4	.002
PS	7/18											26	.008
PS	7/18											1	TSTW
PS	7/18											36	.027
PS	7/18											70	.141
PS	7/22											16	.031
PS	7/22											41	.091
PS	7/22											13	.050
PS	7/22											7	.021

PS = Pond shore
TSTW = Too small to weigh
ITM = Intertidal mudflat
* = numbers in () indicate sample size followed by wet weight in grams

Appendix Table II (Cont.)

Date 1976	Temperature °C Maximum	Minimum	Average	Departure from 1976 Average	Relative Humidity	Weather Type	Precipitation m.m.	Wind Speed km/hr. Steady	Gusts	Wind Direction Degrees	Barometric Pressure (M.B.)
June											
19	16.1	+7.2	11.6			heavy clouds	rain			220	
20	16.7	+6.1	11.4			partly cloudy				180	
21	8.9	+6.1	7.5			mostly cloudy				220	
22	5.0	+5.0	5.0			heavy clouds	intermittent light rain			220	
23						heavy clouds					
24	6.1	+4.4	5.2			heavy clouds					
25	12.2	+5.6	8.9			partly cloudy				00	
26	15.0	+10.0	12.5			scattered clouds					
27	15.0	+5.6	10.3			high thin clouds				220	
28	15.6	+6.1	10.8			clear				220	
29	17.2	+5.0	11.1			partly cloudy				320	
30	16.1	+6.1	11.1			high scattered clouds				90	
July											
1	12.2	+0.6	6.4			clear				50	
2	11.7	-2.2	4.7			few scattered clouds				00	
3						heavy clouds	hard rain		48.28	220	
4	7.8	+3.3	5.5			partly cloudy				220	
5						partly cloudy					
6	17.2	+4.4	10.8			partly cloudy				320	
7	21.1	+6.7	13.9			heavy clouds	intermittent rain			00	
8	15.6	+6.7	11.1			partly cloudy				220	
9	15.6					clear				220	
10	23.3	+12.2	17.7			clear				00	
11	25.0	+12.2	18.6			clear				00	
12	27.8	+12.2	20.0			clear				40	
13	27.8	+12.2	20.0			high thin clouds				90	
14	20.0	+3.9	11.9			high thin clouds					
15	20.0	+3.9	11.9			high thin clouds				220	
16	17.2	+8.3	12.7			high thin clouds				220	
17						heavy clouds	rain				
18	16.7	+10.0	13.3			partly cloudy				00	
19	16.7	+11.1	13.9			mostly cloudy					
20	22.1	+10.0	16.0			heavy clouds	light rain			180	
21											
22	25.6	+10.0	17.8		43					220	
23	27.2	+8.3	17.7		38	heavy clouds	light rain	16.1		220	
24	21.1	+10.0	15.5		74	partly cloudy		20.8		220	
25	21.1	+10.6	15.8		62	heavy clouds	2.5	12.9		220	
26						heavy clouds	light rain				
27	23.3	+3.9	13.6		44	partly cloudy	T			00	
28	16.7	+12.8	14.7		66	heavy clouds	45.3	16.1	45.1	220	
29	16.7	+11.1	13.9		62	heavy clouds	7.6	22.6	32.2	180	
30	14.4	+10.0	12.2		79	heavy clouds	25.4	29.0	45.1	220	
31	18.9	+11.1	15.0		87	clear				00	

Appendix Table II (Cont.)

Date 1976	Temperature °C Maximum	Minimum	Average	Departure from 1976 Average	Relative Humidity	Weather Type	Precipitation m.m.	Wind Speed km/hr. Steady	Gusts	Wind Direction Degrees	Barometric Pressure (M.B.)
Aug.											
1	17.2	+6.7	11.9		79	scattered clouds		6.4	12.9	220	
2	16.1	+8.9	12.5		88	cloudy		12.9	22.6	220	
3					70	cloudy		19.3	37.0	220	
4	21.1	+4.4	12.7		94	scattered clouds				00	
5	23.3	+11.1	17.2		51	partly cloudy		16.1	30.6	360	
6	26.7	+11.7	19.2			heavy clouds	light rain	29.0	38.6	180	
7						heavy clouds	48			00	
8	21.1	+11.1	16.1		83	heavy clouds	light rain			00	
9	22.2	+8.9	15.5		94	mostly cloudy					
10	18.9	+8.9	13.9		83	scattered cloudy	rain showers			220	
11	21.1	+8.9	15.0		84	partly cloudy	0.9			00	
12	20.1	+7.8	13.9		89	partly cloudy				00	
13						heavy clouds	intermittent rain			180	
14						heavy clouds	intermittent rain			180	
15						heavy clouds	intermittent rain			180	
16						heavy clouds	intermittent rain			180	
17	18.3	+6.1	12.2			partly cloudy	rain showers			00	
18	18.9	+4.4	11.6		76	mostly cloudy		25.7	32.2	50	
19	17.8	+3.9	10.8			partly cloudy				50	
20	17.2	+1.7	9.4		83	clear		8.0		270	
21	15.6	+10.0	12.8		88	heavy clouds				220	
22						heavy clouds				00	
23	13.6	+7.2	10.4		90	cloudy	intermittent light rain			00	

Appendix Table II. Summary of climatological data for the Akulik-Inglutalik River Delta, Summer 1977.

Date 1977	Temperature °C Maximum	Minimum	Average	Departure from 1976 Average	Relative Humidity	Weather Type	Precipitation m.m.	Wind Speed km/hr. Steady	Gusts	Wind Direction Degrees	Barometric Pressure (M.B.)
May											
10	6.7	-0.6	3.0			cloudy	T			00	
11	12.2	-1.1	5.5			scattered clouds	T			00	1021.6
12	13.9	-2.2	6.0			scattered clouds	T			00	1025.4
13	6.7	-1.1	2.8		91	cloudy	T	14.5		200	1024.7
14	6.7	-2.2	2.2			cloudy	snow 25.4	25.7	32.2	200	1032.8
15	1.1	-2.2	-0.6			cloudy	snow 25.4	12.9	19.3	200	1030.1
16	2.8	-2.8	0.0			heavy overcast	snow 38.1	12.9	16.1	200	1030.4
17	7.8	-1.7	3.0			heavy overcast	T			00	1012.5
18	16.7	+0.6	8.6		59	high thin clouds	T	8.0		50	1004.4
19	12.2	+1.7	6.9			heavy overcast	T	29.0	35.4	200	1019.9
20	10.0	+4.4	7.2		47	clear		11.3		360	1029.4
21	9.4	-1.7	3.8		57	clear		12.9	19.3	360	1024.7
22	12.2	-1.1	5.5		66	clear		22.6	29.0	360	1021.0
23	12.2	+0.0	6.1		67	clear		29.0	35.4	360	1016.9
24	10.0	-2.2	3.9		64	partly cloudy		22.6	29.0	360	1016.0
25	11.7	-2.2	4.7		83	clear	T	6.4	8.0	180	1019.9
26	6.1	-0.6	2.7		62	clear		3.2	6.4	180	1017.9
27	3.3	-3.3	0.0		81	clear		16.1	22.6	180	1019.6
28	2.8	-2.8	0.0		73	clear		8.0	12.9	180	1033.8
29	13.3	-5.0	4.1		56	clear		25.7	32.2	360	1030.4
30	10.6	+1.1	5.8		76	clear	T	8.0		180	1030.1
31	5.6	+0.0	2.8		83	high thin clouds	T	16.1	19.3	180	1031.8
June											
1	5.6	+0.0	2.8		92	partly cloudy		12.9	16.1	180	1030.8
2	6.1	+1.1	3.6		85	partly cloudy		12.9	19.3	180	1030.4
3	7.8	+0.0	3.9		67	fog		6.4	8.1	180	1024.7
4	5.6	+1.1	3.3			heavy fog		6.4	9.7	180	1022.0
5	8.9	-0.6	4.1		69	cloudy	28			00	1026.4
6	16.7	+2.8	9.7		47	heavy clouds	T			00	1024.4
7	17.8	+3.3	10.5		75	heavy clouds	T	4.8		18	1024.0
8	15.6	+7.2	11.4			heavy clouds	T	8.1		180	1023.7
9	21.1	+5.6	13.3			clear				00	1030.4
10	18.9	+5.6	12.2		94	cloudy	21	8.1	9.7	180	1031.5
11	16.1	+6.7	11.4		88	high clouds	8	9.7	12.9	180	1029.8
12	18.9	+7.2	13.0		69	cloudy	T			00	1028.8
13	15.0	+7.2	11.1		67	high clouds	3	11.3	12.9	180	1033.8
14	20.6	+5.0	12.8		50	clear		14.5	22.6	180	1030.4
15	23.3	+6.7	15.0		56	clear		11.3	12.9	50	1024.6
16	24.4	+10.0	17.2		78	scattered clouds	6	22.6		180	1019.9
17	21.7	+8.9	15.3		78	scattered clouds		4.8	6.4	180	1021.0
18	17.8	+8.3	13.0		89	scattered clouds	T	9.7		180	1020.6
19	20.6	+11.1	15.8	+4.2	94	partly cloudy	9			00	1017.6
20	19.4	+10.6	15.0	+3.6	88	partly cloudy		12.9	19.3	180	1016.9
21	13.3	+10.0	11.6	+4.1	94	partly cloudy		9.7	16.1	180	1017.6
22	12.2	+7.2	9.7	+4.7	82	partly cloudy		12.9	16.1	180	1022.0

Appendix Table II (Cont.)

Date 1977	Temperature °c Maximum	Minimum	Average	Departure from 1976 Average	Relative Humidity	Weather Type	Precipitation m.m.	Wind Speed km/hr. Steady	Gusts	Wind Direction Degrees	Barometric Pressure (M.B.)
June											
23	18.3	+4.4	11.3	+6.1	72	clear		6.4		180	1022.7
24	18.3	+5.6	11.9	+3.0	73	clear		12.9		180	1023.0
25	22.2	+5.0	13.6	+4.7	39	clear		16.1	19.3	180	1026.4
26	24.4	+6.1	15.2	+2.7	30	scattered clouds		16.1	22.6	360	1028.1
27	21.1	+7.2	14.1	+3.8	42	clear		16.1	19.3	360	1026.0
28	20.0	+5.6	12.8	+2.0	35	scattered clouds		19.3	22.6	360	1030.4
29	22.2	+4.4	13.3	+2.2	47	clear		6.4	8.0	360	1033.8
30	23.3	+6.7	15.0	+3.9	51	partly cloudy		19.3		360	1033.8
July											
1	17.8	+5.0	11.4	+5.0	65	thin clouds		19.3	25.7	180	995.6
2	18.3	+7.2	12.7	+8.0	93	heavy clouds		16.1	19.3	180	1028.1
3	13.9	+6.7	10.3		94	heavy clouds		19.3	24.1	180	1021.6
4	15.6	+8.3	11.9	+6.4	66	heavy clouds		9.7	12.9	360	1019.3
5	13.3	+5.6	9.4		65	heavy clouds	T	16.1	19.3	180	1024.4
6	20.0	+7.8	13.9	+3.1	59	high thin clouds	T			00	1033.8
7	23.3	+7.2	15.2	+1.3	73	scattered clouds	T			00	1033.8
8	26.1	+5.6	15.8	+4.7	83	heavy clouds		16.1	19.3	360	1028.8
9	23.9	+10.0	16.9		89	heavy clouds				00	1029.1
10	22.8	+8.9	15.8	-1.9	88	thin clouds				00	1032.2
11	31.7	+7.8	19.7	+1.1	36	clear		8.1		90	1027.1
12	29.4	+11.1	20.2	+0.2	84	partly cloudy	T	12.9		180	1025.4
13	26.7	+11.1	18.9	-1.1	80	scattered clouds		16.1	19.3	180	1023.7
14	21.1	+12.8	16.9	+5.0	70	scattered clouds		19.3	25.7	180	1022.0
15	18.9	+11.1	15.9	+3.1	84	scattered clouds		6.4	9.7	180	1024.7
16	17.8	+10.0	13.9	+1.2	82	cloudy		19.3	22.6	180	1026.0
17	16.7	+11.1	13.9		83	cloudy		19.3	25.7	180	994.2
18	16.1	+6.7	11.4	-1.9	84	cloudy		16,1		180	1030.4
16	17.2	+5.6	11.4	-2.5	82	cloudy		12.9		180	1029.8
20	18.9	+8.9	13.9	-2.1	79	cloudy		12.9		180	1029.8
21	24.4	+7.2	15.8		46	cloudy				00	1024.0
22	26.1	+9.4	17.7	-0.1	73	cloudy	T			00	1025.4
23	22.2	+10.0	16.1	-1.6	60	cloudy		9,7	12.9	180	1029.4
24	26.1	+9.4	17.7	+2.2	61	cloudy	T			00	1028.8
25	25.0	+10.6	17.8	+2.0	61	cloudy				00	1024.4
26	24.4	+10.0	17.2		62	cloudy	T	6.4	9.7	180	1019.6
27	21.1	+13.3	17.2	+3.6	66	cloudy	36	16.1	22,6	180	1023.7
28	20.0	+14.4	17.2	+2,5	74	cloudy	T			00	1026.4
29	26.1	+12.2	19.1	+5.2	53	cloudy				00	1026.0
30	28.9	+18.3	23.6	+11.4	50	cloudy; heavy smoke		3.2	8,1	180	1027.4
31	25.6	+16.1	20.8	+5,8	90	cloudy; heavy smoke		12,9	19,3	180	1027.4
Aug.											
1	18.3	+15.6	16.9	+5.0	89	haze and smoke		11.3	14.5	180	1032.1
2	22.2	+9.4	15.8	+3.3	67	scattered clouds; hazy		8,1	11.3	180	1033.8
3	27.2	+8.9	18.0		75	heavy clouds	9			00	1028.4

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Appendix Table II (Cont.)

Date 1977	Temperature °C Maximum	Minimum	Average	Departure from 1976 Average	Relative Humidity	Weather Type	Precipitation m.m.	Wind Speed km/hr. Steady	Gusts	Wind Direction Degrees	Barometric Pressure (M.B.)
Aug.											
4	23.9	+12.8	18.3	+5.6	66	scattered clouds		12.9		180	1031.1
5	23.9	+11.1	17.5	+0.3	78	scattered clouds		1.6	3.2	180	1026.4
6	21.1	+4.4	12.7	-6.5	51	scattered clouds		3.2	4.8	180	1024.7
7	21.1	+7.2	14.1		57	scattered clouds; smoke		16.1	20.8	360	1019.6
8	24.4	+12.2	18.3	+2.2	67	scattered clouds; hazy	18			00	1022.0
9	23.3	+12.8	18.0	+2.5	79	cloudy	T			00	1025.4
10	22.2	+12.2	17.2	+3.3	72	scattered thunderheads;smoke		16.1	25.7	360	1022.7
11	25.6	+13.3	19.4	+4.4	52	scattered clouds		19.3	25.7	180	1032.1
12	17.8	+10.6	14.2	+0.3	74	heavy clouds	15	6.4	14.5	140	1028.8
13	22.2	+10.6	16.4		74	cloudy	43			00	1026.4
14	21.1	+13.3	17.2		84	mostly cloudy	43	3.2		180	1023.7
15	18.3	+11.7	15.0		62	heavy clouds	10	19.3	25.7	180	1027.4
16	17.8	+11.7	14.7		73	heavy clouds	13	8.0		180	1032.5
17	20.0	+11.1	15.5	+3.3	84	heavy clouds	T	1.5		180	1023.7
18	16.1	+15.6	15.8	+4.2	84	heavy clouds	36	19.3	25.7	140	1029.4
19	19.4	+13.3	16.3	+5.5	84	cloudy	T	1.5		180	1035.5
20	26.1	+9.4	17.7	+8.3	76	scattered clouds	20			00	1032.1
21	27.8	+10.6	19.2	+6.4	61	clear		9.7	11.3	50	1026.0
22	28.3	+12.8	20.5		80	clear		8.0	9.7	50	1021.0
23	26.7	+11.7	19.2	+8.8	50	clear		8.0	11.3	50	1023.7
24	22.2	+6.1	14.1		61	clear		9.7	12.9	360	1020.3
25	16.7	+6.1	11.4		66	clear		11.3	16.1	360	1021.6
26	16.1	+1.1	8.6		41	clear		16.1	19.3	360	1021.0
27	16.1	-2.2	6.9		66	clear		6.4	8.0	220	1022.0
28	14.4	+6.1	10.2		77	heavy clouds	20	19.3	22.6	220	1021.0
29	14.4	+9.4	11.9		88	heavy clouds	T	9.7	11.3	220	1032.1
30	15.6	+10.0	12.8		78	few scattered clouds	T	11.3	14.5	220	1033.2
31	18.9	+3.3	11.1		81	partly cloudy		3.2	4.8	360	1033.8
Sep.											
1	18.3	+3.9	11.1		88	few scattered clouds;smoke				00	1033.2
2	17.2	+3.3	10.2			high thin clouds; smoke		3.2		180	1030.4
3	16.1	+4.4	10.2		82	cloudy	T	8.0	9.7	220	1032.1
4	14.1	+3.3	8.7		76	high thin clouds; scattered clouds				00	1028.1
5	12.2	+6.1	9.1		94	heavy clouds	67	16.1	24.1	180	1014.9
6	13.9	+9.4	11.6		87	heavy clouds	115	1.5		140	1002.3
7	15.0	+8.9	11.9		88	mostly cloudy	81	3.2		360	1017.6
8	17.8	+5.0	11.4		63	partly cloudy	3	1.5		360	1026.0
9	16.1	+5.0	10.5		94	mostly cloudy	22	6.4	8.0	180	1023.0
10	11.7	+5.6	8.6		87	heavy clouds	49	3.2		360	1009.8
11	11.7	+6.7	9.2		87	mostly cloudy	58	4.8	8.0	360	1019.6
12	11.1	+5.0	8.0		94	heavy clouds	5	22.6	38.6	180	1033.2
13	11.1	+9.4	10.2		87	cloudy	66	64.4	80.5	180	1018.3
14	11.1	+8.9	10.0		87	heavy clouds	65	22.6	32.2	220	1028.1
15	9.4	+5.6	7.5		93	few scattered clouds	82	6.4	11.3	360	1019.9
16	9.4	+2.2	5.8		79	heavy clouds		16.1	22.6	180	1027.4
17	10.0	+5.6	7.8		86	heavy clouds	5	3.2	8.0	220	1010.5
18	10.0	+1.1	5.5		79	partly cloudy	8	0.0	4.8	360	1014.9