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Outer Continental Shelf Environmental Assessment Program

Final Reports of Principal Investigators

Volume 35 December 1985

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ENVIRONMENTAL ASSESSMENT PROGRAM

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Anchorage, Alaska

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Outer Continental Shelf Environmental Assessment Program

Final Reports of Principal Investigators

VOLUME 35 DECEMBER 1985

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SHOREBIRD LITTORAL ZONE ECOLOGY OF THE SOUTHERN CHUKCHI COAST OF ALASKA

by

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Final Report
Outer Continental Shelf Environmental Assessment Program
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I. SUMMARY

Our studies of shorebird ecology at several coastal sites along the southern Chukchi and Kotzebue Sound coasts in 1977 and 1978 identify several contrasts as well as a number of similarities with shorebird littoral zone use along the Beaufort and northern Chukchi coasts (see Connors et al 1981 for results of Beaufort coast studies). In general, the same seasonal habitat shift is evident in both regions. Shorebirds nest on the tundra during June and July, with post-breeding adults and newly fledged juveniles shifting to littoral zone habitats during late July and August, where they forage before migrating southward to wintering areas. At the southern Chukchi study sites, however, the degree of this shift is not so marked as at Beaufort sites, and the expression of this habitat shift varies considerably at different local sites along the southern Chukchi coast. This difference arises from a greater availability and therefore heavier use of littoral habitats during the early migration and nesting period at southern Chukchi sites; the much lower levels of shorebird activity along southern Chukchi ocean beaches compared with the heavy concentrations of zooplankton-foraging shorebirds at many Beaufort sites; and the extensive areas of saltmarsh and mudflat which draw littoral zone foraging shorebirds away from some other sites after nesting activity is finished.

Differences in phenology among regions and among local sites account for some of the differences in relative habitat use, with some littoral habitats available much earlier at southern Chukchi sites than along the Beaufort coast. Differences in tundra phenology did not, however, affect dates of nesting activities as strongly as might be expected. Instead we believe bird nesting dates are set partly by requirements such as conditions at other sites during migration or hormonal schedules, and therefore do not fluctuate as severely as for example, melt-off dates from year to year at each site. During spring melt-off we observed a surprising phenomenon of shorebirds foraging on ice-lifted sediments above the ice over shallow lagoons near Kotzebue Sound. At this time (late May) shorebirds are still migrating or just beginning to nest. We recorded extremely high densities of birds on the lagoon ice, approximately ten to fifteen times the densities on nearby salt marsh transects and fifty times the densities on adjacent tundra transects. Shorebirds of several species were foraging principally on chironomid fly larvae, the same prey which they take in late summer from lagoon mudflats. We present a hypothesis for the occurrence of these food-rich sediments above the ice. The phenomenon may be quite variable from year to year, depending on a sequence of primarily meteorological events. Shorebirds probably take advantage of this rich resource opportunistically. Oil spilled during the previous open water period or released in the ice during winter might therefore attract large numbers of spring shorebirds because its appearance would mimic this natural phenomenon. We do not know how birds of various species would respond to such an encounter, or as discussed in this report, whether such encounters would be lethal.

Shorebird littoral zone prey identified at southern Chukchi sites are very similar to foods which shorebirds take at Beaufort and northern Chukchi sites, but the importance of different habitats and different prey systems to the shorebird community varies between these regions. Along the Beaufort coast, largest concentrations of littoral zone foraging shorebirds are associated with a coastal zooplankton trophic system. Large numbers of Red and Northern Phalaropes together with Dunlins, Sanderlings, Ruddy Turnstones and occasionally other species, as well as some gulls and terns, forage in late summer along sand and gravel beach shorelines, especially near spits and barrier islands of the Beaufort and northern Chukchi coasts. The zooplankton community is quite variable, but densities are frequently high, providing an excellent food source for large numbers of shorebirds. Important prey items include amphipods, euphausiids, copepods, mysids, and decapod zoea as well as other species. At Cape Krusenstern, Wales and other Chukchi sites, we did not encounter comparable concentrations of shorebirds, although the smaller numbers of phalaropes foraging in these areas were taking similar prey species. The alternative trophic system is based principally on chironomid fly larvae as well as on other insect larvae, oligochaetes, beetles, spiders, amphipods and seeds. These occur in good densities in saltmarshes, on mudflats, around saline pools and sloughs. These habitats are generally small and scattered along the Beaufort coast, where they are important to many species of shorebirds. At southern Chukchi sites, however, such habitats are much more extensive and support much larger numbers and a greater proportion of shorebirds. Most common species include Dunlins, Western and Semipalmated Sandpipers, Pectoral Sandpipers, Long-billed Dowitchers, and Golden Plovers.

These regional differences in importance of trophic systems and habitat areas may be important in determining the extent of effects on shorebirds produced by oil development disturbances. Oil slicks along Beaufort gravel beaches in late summer would have much greater immediate affects than along southern Chukchi beaches. However, a large spill in one of the extensive saltmarsh areas of the southern Chukchi could affect much greater numbers of several species than a similar spill along the Beaufort coast. Effects of spills in these two habitats will also differ in degree and duration. Spills on gravel beaches may have an immediate devastating effect because of the swimming habits of both Phalarope species, but the zooplankton prey base associated with the water column will likely recover in subsequent seasons after the oil precipitates or is removed. In saltmarsh and mudflat areas, in contrast, the immediate direct effects on shorebird plumages will be less severe because of the non-swimming habits of most of the species which forage there, but secondary effects on the prey base may last for many seasons.

The main shorebird concentration areas of importance along the southern Chukchi coast are those areas with extensive saltmarsh and mudflat habitat. Prime among these are the lagoon and island system of the Noatak Delta-Sisualik area and the lagoon barrier strip along the north shore of Seward Peninsula east and west of Shishmaref. Densities and total numbers of shorebirds in both these areas during August and early September are extremely high compared with most arctic sites.

Seasonal habitat use patterns of most species are similar in southern Chukchi areas to those measured along the Beaufort coast. Among the most important differences however, Golden Plovers along the southern Chukchi spend much more time in littoral habitats than do these birds farther north. The same is true of Pectoral Sandpipers, another species relatively restricted to tundra habitats at Barrow. These changes increase the sensitivity of both species to coastal oil development effects in the southern Chukchi compared to their relatively low sensitivity at Beaufort sites. Phalaropes of both species retain their high sensitivity in both regions but the seasonality of their exposure and the habitats in which they are exposed differ between regions. Compared with Beaufort sites, phalaropes are much less common along August shorelines in the southern Chukchi but more common in southern littoral habitats in early summer.

II. INTRODUCTION

In a companion report to this one (Shorebird Littoral Zone Ecology of the Alaskan Beaufort Coast, Connors et al (1981),we reported on the distribution, densities, seasonality, habitat use patterns, trophic relationships, and behavior of shorebirds along the Beaufort coast and northern Chukchi coast of Alaska. That report, based on field studies from 1975 to 1980, provides detailed information about the dependence of shorebirds of many species on resources in arctic littoral areas. The present report is based on studies in only 2 field seasons, 1977 and 1978, and is meant to extend the earlier observations to the southern Chukchi coast and Kotzebue Sound area, between Cape Thompson and Bering strait (Figure 1). It also addresses those aspects of shorebird littoral zone ecology which contrast between the southern Chukchi and the Beaufort coasts. However, since much of the ecology of the shorebirds studied is similar in both regions and because many details have been reported in previous annual reports (Connors and Risebrough 1978; 1979) we will not repeat all this basic descriptive material, choosing instead to concentrate on those aspects of southern Chukchi shorebird ecology which differ from more northern areas and particularly those which alter the susceptibility of shorebird species to oil development effects.

The list of 28 shorebird species occurring regularly along the southern Chukchi coast (Table 1) differs only slightly from a comparable list of Beaufort coast shorebirds (Connors et al 1981), but the relative abundance or breeding status of many of these species differs markedly between the two regions. All are migrants, many to and from areas as remote as the southern hemisphere, and collectively they comprise a major segment of the avifauna of the Chukchi coast. Their migratory habits make them an international resource dependent for part of each year on conditions along the Alaskan arctic coast.

Most arctic shorebirds nest during the summer months in tundra habitats where they are relatively free from immediate impacts of offshore oil development. However, it is well established (Connors et al 1979; 1981) that many arctic shorebird species depend during part of each year on resources and conditions in littoral habitats along beaches, on mudflat, and in saltmarshes. As we have reported previously and will expand in this report, this dependence on littoral habitats varies among species by season, age, and sex and by geographic location across the arctic.

Table 1. Shorebird species occurring regularly along the Southern Chukchi coast of Alaska.

Regular Breeders

Semipalmated Plover, *Charadrius semipalmatus*
American Golden Plover, *Pluvialis dominica*
Black-bellied Plover, *Pluvialis squatarola*
Ruddy Turnstone, *Arenaria interpres*
Black Turnstone, *Arenaria melanocephala*
Common Snipe, *Capella gallinago*
Whimbrel, *Numenius phaeopus*
Red Knot, *Calidris canutus*
Pectoral Sandpiper, *Calidris melanotos*
Baird's Sandpiper, *Calidris bairdii*
Dunlin, *Calidris alpina*
Rock Sandpiper, *Calidris ptilocnemis*
Semipalmated Sandpiper, *Calidris pusilla*
Western Sandpiper, *Calidris mauri*
Long-billed Dowitcher, *Limnodromus scolopaceus*
Bar-tailed Godwit, *Limosa lapponica*
Red Phalarope, *Phalaropus fulicarius*
Northern Phalarope, *Phalaropus lobatus*

Additional Migrants

Killdeer, *Charadrius vociferus*
Sharp-tailed Sandpiper, *Calidris acuminata*
Least Sandpiper, *Calidris minutilla*
Rufous-necked Sandpiper, *Calidris ruficollis*
Curlew Sandpiper, *Calidris ferruginea*
Stilt Sandpiper, *Micropalama himantopus*
Buff-breasted Sandpiper, *Tryngites subruficollis*
Sanderling, *Calidris alba*
Wandering Tattler, *Heteroscelus incanus*
Hudsonian Godwit, *Limosa haemastica*

III. METHODS

Study areas. Following the definition in Connors et al (1981), we consider the arctic littoral zone to extend from the lowest tide level up to the limits of the area which may be flooded by storms at least once every few years. This zone can be recognized by brackish water in flood pools, by the presence of salt-tolerant vegetation, and by the distribution of storm drift material. It includes the habitats most susceptible to coastal oil pollution.

We established permanent marked transects at two main study sites: Cape Krusenstern (67° o8'N, 163° 43'W), censused in 1977 and 1978; and Cape Prince of Wales (65° 38'N, 168° 08'W), censused only during 1977 (Figure 1). At each study site we established transects in a wide variety of littoral and near-littoral habitats (Tables 2 and 3; Figures 2 and 3). Observations at the principal study sites were supplemented in both years with brief visits to census transects and assess shorebird densities and habitat use at sites in the Noatak Delta lagoon system near Sisualik (Figure 1) and at several sites along the lagoon barrier strip of the north shore of Seward peninsula, east and west of Shishmaref (Figure 6).

Transect censusing. Permanent transects at study sites were marked with stakes at 50 meter intervals. In relatively uniform habitats such as mudflat, saltmarsh or tundra, transects were straight and 100 meters in width, with stakes running along the center line of a double row of 50 by 50 meter square plots. Transect distances varied from 300 meters to 1000 meters. Shoreline transects along lagoon edges or ocean beaches consisted of single rows of 50 meter by 50 meter square plots following the shoreline. These transects varied from 500 meters to 1000 meters in length.

We censused at least once every 5 days throughout the entire field season at each of the principal study sites, recording all birds within each censused plot. Study seasons at Cape Krusenstern included 5 June 1977 through 7 September 1977 and 26 May 1978 through 6 September 1978; at Wales transects were censused from 5 June 1977 through 12 September 1977.

This method of permanent transects, regularly censused, provides data which are easily analyzed to reflect seasonal changes in population density; it is especially well suited to habitats with marked seasonal changes in bird use, such as arctic littoral areas. To determine the more stable breeding densities on tundra at the main study sites we established rectangular gridded study areas and censused these every 5 days, recording locations of all birds as well as display territories and nest locations. Grid sizes were 29.8 ha at Cape Krusenstern and 25 ha at Wales. These breeding bird surveys allow us to compare local shorebird communities at these sites with other arctic coastal areas.

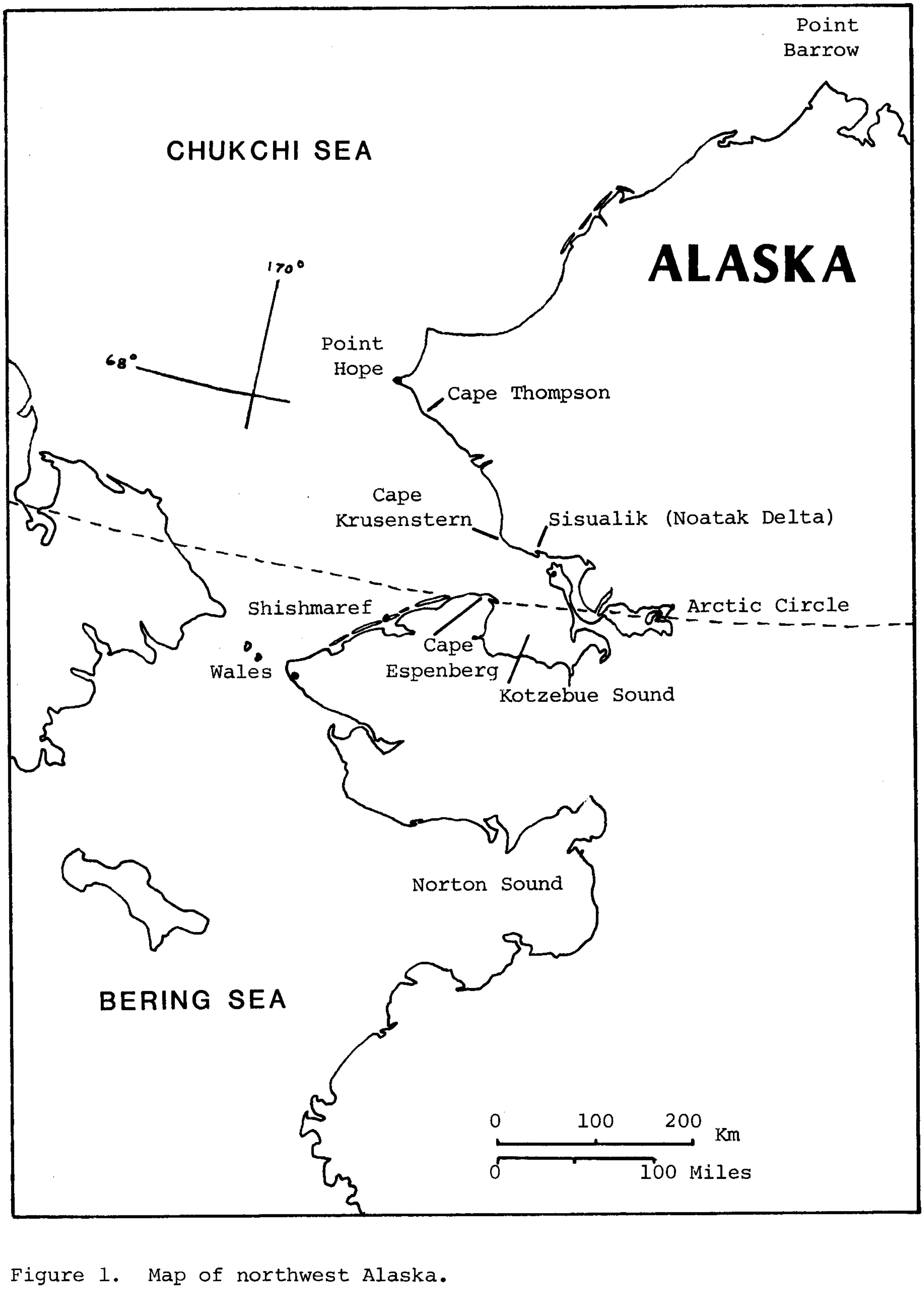

Figure 1. Map of northwest Alaska.

Table 2. Locality codes for transects and sampling stations. Wales, Alaska. (See Figure 3).

Code	Transect or station name	Tundra or littoral	Transect length (m)	Transect width (m)
WB1	Sea Beach 1	L	1000	50
WB2	Sea Beach 2	L	1000	50
WB3	Sea Beach 3	L	1000	50
WB4	Sea Beach 4	L	1000	50
WB5	Sea Beach 5	L	1000	50
WB6	Sea Beach 6	L	1000	50
WBB	Breeding Bird Plot	T	1000	100
WBD	Beach Ditch	L	500	50
WBT	N. Beach Tundra	T	1000	100
WEL	S.E. Lagoon 2	L	1000	50
WHL	Hill Transect	T	1000	100
WML	W. Lagoon 3	L	1000	50
WNL	W. Lagoon 4	L	1000	50
WNM	N. Red Mud	L	300	50
WRW	Runway	T	1000	100
WSL	S.E. Lagoon 1	L	1000	50
WSM	S. Red Mud	L	300	50
WSS	S. Beach Tundra	T	1000	100
WSW	Swan	T	1000	100
WVS	Village Stream	L	300	50
WWL	West Lagoon 1	L	1000	50
Not included in map-transects located 2 km northeast of B6 transect				
WBS	Sin-l-rock Sea	L	1000	50
WRL	Sin-l-rock Lagoon	L	1000	50
WRM	Sin-l-rock Mud	L	300	50

Total areas: Tundra: 60 hectares
Littoral: 73.5 hectares

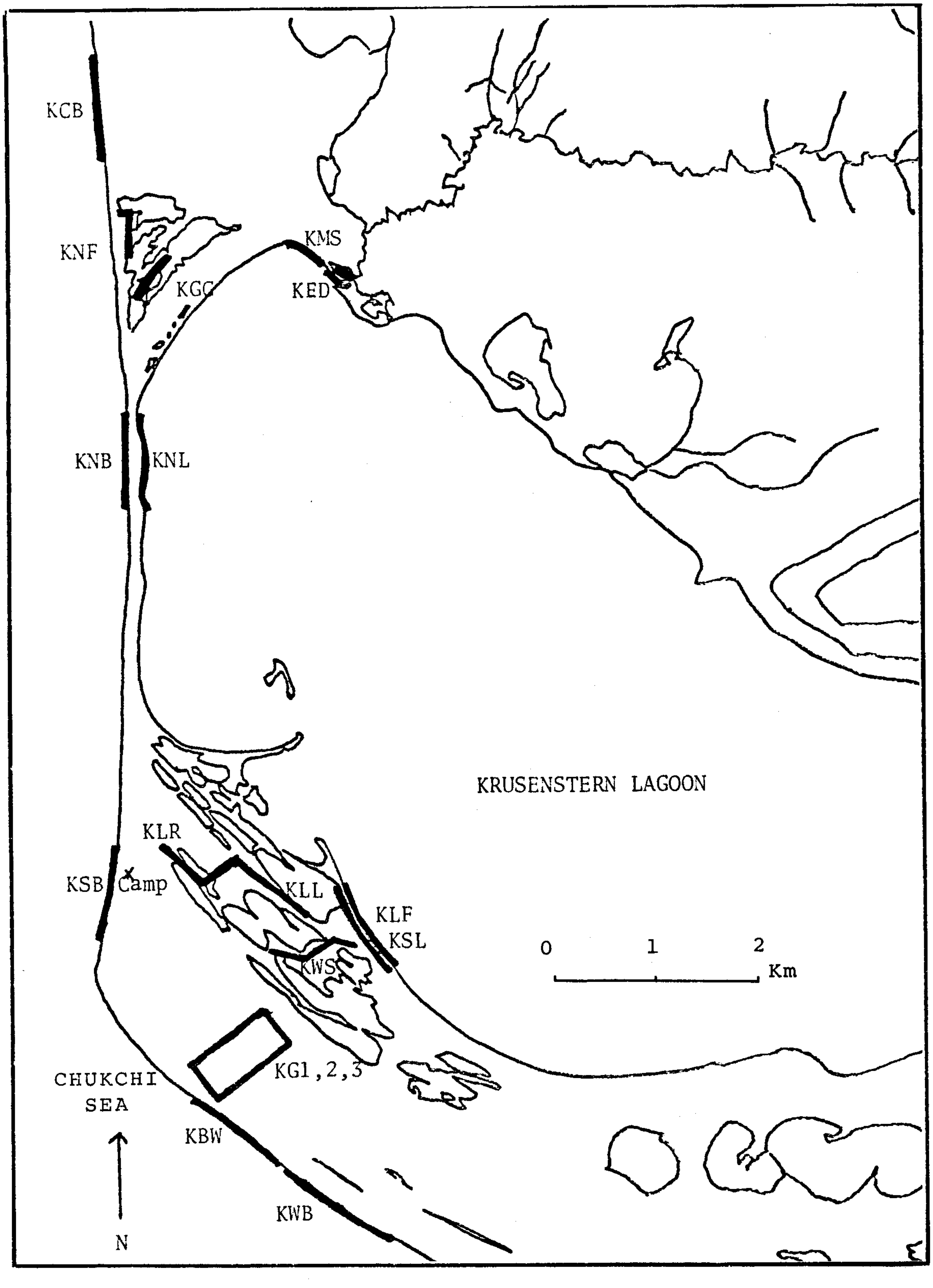

Figure 2. Locations of transects and sampling stations, Cape Krusenstern, Alaska.

Table 3. Locality codes for transects and sampling stations, Cape Krusenstern, Alaska. (See Figure 2).

Code	Transect or station name	Tundra or littoral	Transect length (m)	Transect width (m)
KBW	Baby Walrus	L	1000	50
KCB	Cliff Beach	L	1000	50
KED	Evelukpalik Delta	L	500	100
KG1	Grid one	T	850	100
KG2	Grid two	T	850	100
KG3	Grid three	T	850	100
KGC	Gull Colony	L	500	100
KLF	Lagoon Flood	L	1000	50
KLL	Lagoon Lake	L	1000	50
KLR	Lake Ridge	T	1000	100
KMS	Moon Snail	L	500	50
KNB	North Beach	L	1000	50
KNF	North Flats	L	500	100
KNL	North Lagoon	L	1000	50
KSB	Shell Beach	L	1000	50
KSL	South Lagoon	L	1000	50
KWB	Whimbrel Beach	L	1000	50
KWS	Whistling Swan	T	1000	100
	Not included in map: Transects located 4 km north of CB transect.			
KB1	Shelter Cabin Beach (SCB)	L	1000	50
KS1	Shelter Cabin Slough (SCS)	L	500	50

Total areas: Tundra: 45.4 hectares
Littoral: 70.0 hectares

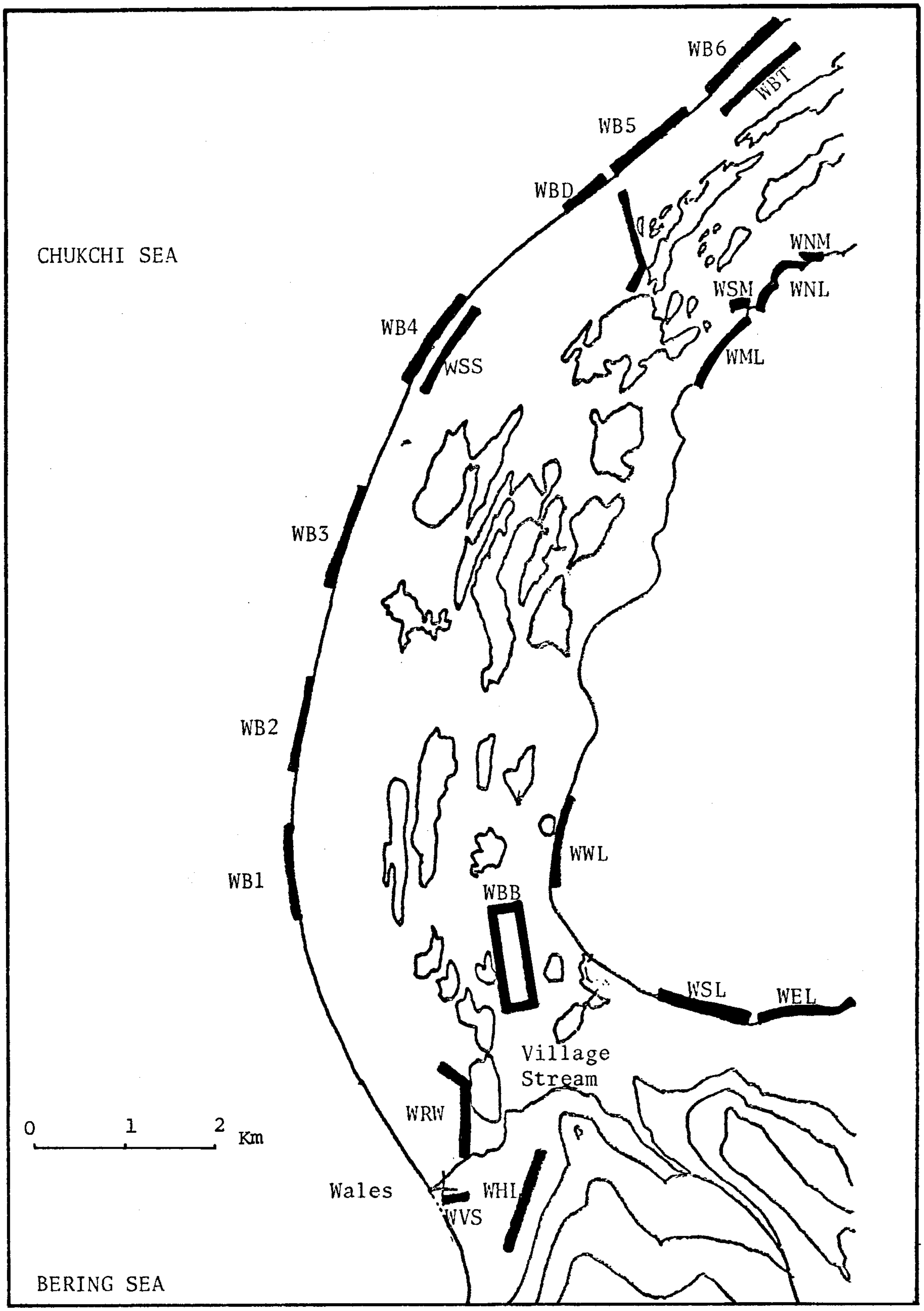

Figure 3. Locations of transects and sampling stations, Wales, Alaska.

Trophic studies. At Wales, Cape Krusenstern, Sisualik and Shishmaref we collected shorebirds of several common species for diet analysis and fat condition. Collection methods (by shotgun followed by immediate injection of formalin fixative solution in the field) were described in Connors and Risebrough (1976).

We collected plankton net samples at Wales and Cape Krusenstern in July, August and early September 1977. The surface net, towed parallel to shore in very shallow water to sample the phalarope foraging zone, was described in Connors and Risebrough (1977). Sampling procedures and sample analysis were identical at these sites and at Barrow, permitting comparison of plankton resources at the three sites (Connors and Risebrough 1978).

IV. RESULTS AND DISCUSSION

Seasonality of Habitat Use: An Overview

The transect census data can be analyzed to provide a phenology of shorebird habitat use at each site, as presented in Connors et al (1979; 1981). Our data from Barrow have shown a pronounced and consistent shift in habitat use from tundra to littoral habitats occurring in late summer for most shorebird species. In June and early July, almost all shorebird activities are centered on the tundra where shorebirds nest. As the season progresses, adults of one or both sexes, followed by fledged young, forage increasingly along shorelines as these habitats melt and become available. The degree of this shift is shown in Figure 4 for Barrow. These data are a composite of the patterns displayed by a large number of shorebird species differing in the timing, sequence, and degree of interhabitat movements. At Barrow, the late summer habitat used most heavily consists of shoreline areas along gravel beaches, where high densities of marine zooplankton provide a food source for phalaropes and several other shorebird species, as well as for gulls and terns. Areas of saltmarsh, mudflats and edges of lagoons and sloughs also attract high densities of many shorebird species. This general pattern of seasonal shift in habitat use also characterizes several other sites along the Beaufort and northern Chukchi coasts (Connors et al 1981).

In contrast, Figure 5 presents the equivalent results for all shorebirds combined from our transect census data for Wales and Cape Krusenstern. Densities at Wales showed an apparent habitat shift toward the littoral zone in late summer but peak densities were less than those recorded at Barrow. However, phalaropes, which accounted for the bulk of August littoral shorebirds at Barrow, were uncommon at Wales, where Western Sandpipers and Dunlins accounted for most of the late summer littoral zone activity. Cape Krusenstern, however, contrasts markedly with patterns at Barrow and Wales, showing instead moderately heavy use of littoral habitats throughout June and July, decreasing in August, while tundra densities remain low and constant. At Cape Krusenstern, outer coast shores with zooplankton as a food source were very little used by shorebirds in late summer. Saltmarsh and mudflat areas with shallow saline pools, open in late May at this phenologically early site, were heavily used by migrant shorebirds of several species, as well as by species nesting on the nearby tundra. Northern Phalaropes, Western Sandpipers, Semipalmated Sandpipers, Pectoral Sandpipers and Long-billed Dowitchers were common in these habitats in June and July. Species remaining in the arctic during August and September, most notably Dunlin, apparently move to areas of more extensive mudflat and saltmarsh such as the Noatak Delta, Cape Espenberg, and the Shishmaref barrier

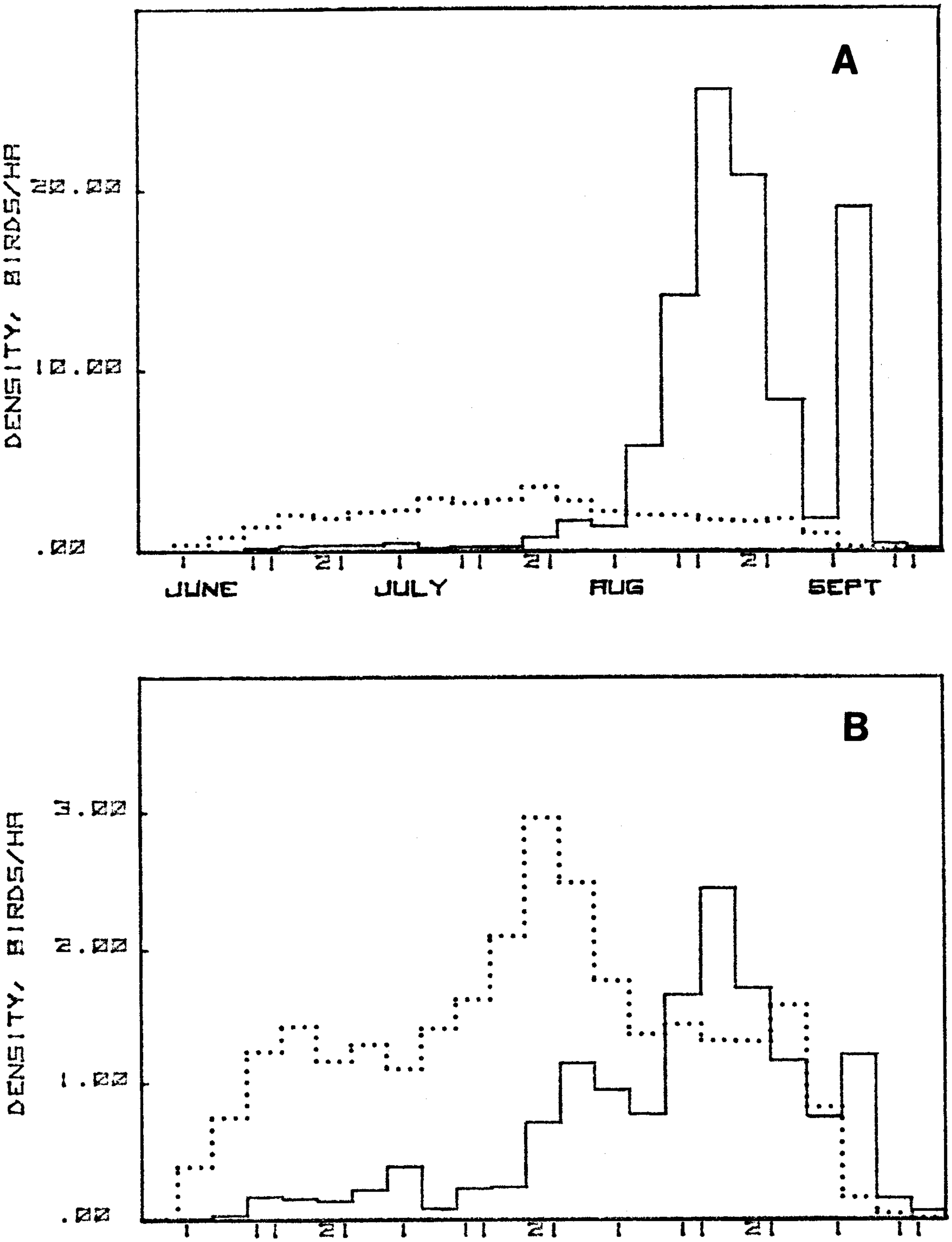

Figure 4. Transect densities, Barrow, 1976. A. Total shorebirds. Littoral (solid) vs. tundra (dotted). B. Total shorebirds excluding Red Phalarope. Littoral (solid) vs. tundra (dotted).

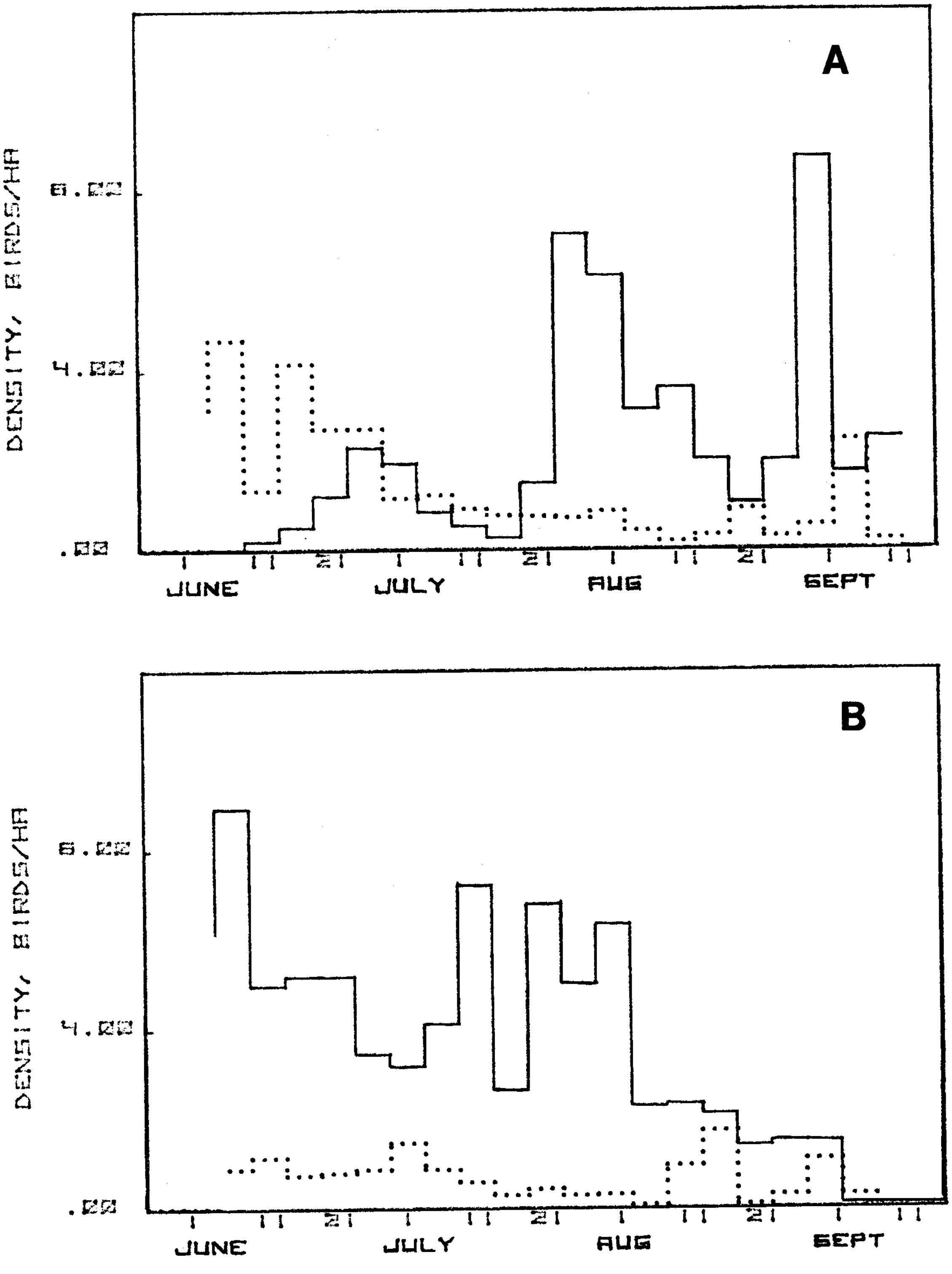

Figure 5. Transect densities, 1977. A. Wales, total shorebirds. Littoral (solid) vs. tundra (dotted). B. Cape Krusenstern, total shorebirds. Littoral (solid) vs. tundra (dotted).

strip on Seward Peninsula (see below). Thus the general pattern of heavier use of littoral habitats in late summer seems to be widespread in the arctic but its expression at any particular site depends upon the mixture of habitats available at that site. The discontinuous distribution of prime littoral zone foraging areas along the coast results in concentration areas where environmental disturbances would exert heavy influences on the populations of migrant shorebirds.

Geographic Variation in Habitat Use

The general differences among areas described above result from several factors, including differences in shorebird species distributions, seasonal phenologies, food resource differences and differences in littoral habitat availability on a local and regional scale. The most important incidence of this latter factor is the difference in relative availability of mudflat and saltmarshes compared with gravel shores of spits and barrier islands. In the southern Chukchi, south of Cape Thompson, the former habitats are common but gravel spits are infrequent. At Barrow and elsewhere along the Beaufort coast gravel spits and barrier islands are common coastal features, but areas of saltmarsh and mudflats are limited in extent. Gravel spits along the Beaufort coast frequently support very high densities of phalaropes in late summer, foraging on marine zooplankton. The attraction to phalaropes and other shorebirds may be the high densities of zooplankton available or features of the local geography which provide protected foraging conditions in a variety of wind conditions (Connors et al 1981). As a result the charcteristic gravel shoreline species (Red and Northern Phalaropes, Sanderlings, Ruddy Turnstones, Arctic Terns and Sabine's Gulls) are common at Barrow and many other sites along the Beaufort coast but occur in much lower densities at the study sites along the southern Chukchi. In contrast the northern shore of the Seward peninsula east and west of Shishmaref, and the Noatak Delta near Sisualik, as well as a few areas on southern Kotzebue Sound, provide much more extensive areas of mudflat and saltmarsh than occur along the Beaufort coast. In late summer these support large numbers of many species of shorebirds, primarily Western, Semipalmated and Pectoral Sandpipers, Dunlins, Long-billed Dowitchers and Golden Plovers. Thus a regional difference in the occurrence of important shorebird habitats corresponds with differences in relative abundance of species which forage in these habitats. On a local scale, habitat distribution sets limits on the numbers of birds of different species at a site. Differences in shorebird occurrence are also affected by interactions with the phenology of habitat availability and changes in prey availability within habitats.

Differences in Phenology

Among the contrasts between the Southern Chukchi shorebird environment and that of the Beaufort coast, the apparent differences in phenology affect shorebird use of littoral habitats to some extent. Relative phenologies of Wales, Cape Krusenstern, and Barrow were discussed in Connors and Risebrough (1978). Except for the western tip of Seward Peninsula near Wales, the areas of southern Chukchi and Kotzebue Sound coasts experience earlier dates of tundra melt-off, shoreline ice-breakup, plant growth and insect hatching than do similar habitats in areas farther north along the Chukchi and Beaufort coasts. Fall freeze-up occurs somewhat later in the southern coastal areas. The full season of shorebird occurrence in southern Chukchi littoral areas is therefore somewhat longer than on the Beaufort coast.

The different phenology of littoral habitat availability produces some additional contrasts in shorebird use between the areas. In late May and early June near Barrow, most littoral habitats are frozen and unavailable. At Cape Krusenstern and Kotzebue Sound however, many species forage on edges of mudflats and saltmarshes as well as on ice-lifted sediments (see below) that are available while shorebirds are still migrating and beginning to establish territories. The same thing can be true of ocean shorelines, although early summer conditions at Cape Krusenstern are apparently quite variable. In 1977 shore-fast ice at Cape Krusenstern in late May and early June precluded foraging by shorebirds in that habitat. During 1978, in contrast, the shoreline was free of ice, and we recorded the highest densities of Red Phalaropes seen at that site along outer coast shorelines at any time during our 2 year study. At Beaufort sites the shoreline waters were never available for foraging by Phalaropes in early summer and high densities of Phalaropes were only seen in late summer and early fall. As a result of these differences in phenology, oil introduced into littoral habitats during late fall or winter might affect shorebirds beginning in spring along the southern Chukchi coast but not until later in the summer along the northern Chukchi and Beaufort coasts.

Differences in phenology between Cape Krusenstern and Beaufort study sites were even greater in 1978 than in 1977 (Connors and Risebrough 1979). Areas near Kotzebue experienced one of the earliest springs within memory (W.R. Uhl, pers. comm.) while North Slope areas faced an extremely late melt-off. Differences between Cape Krusenstern and Prudhoe Bay melting dates and flowering dates averaged three to four weeks, and other sites along the Beaufort coast were even later than Prudhoe Bay. However, dates of bird nesting events differed by much less, averaging only 5 to 10 days earlier (and less for some species) at Cape Krusenstern. This delay was similar to that observed in 1977 in spite of a much greater difference in melt-off dates in 1978. Birds apparently did not respond simply to differences in melt-off dates between sites. Instead, we believe bird nesting dates are set partly by other requirements (conditions at other sites during migration, hormonal schedules, etc.) and are adjusted by local breeding ground conditions. In 1978 Beaufort coast birds were delayed in nest initiation but apparently began quickly when conditions improved. At Cape Krusenstern the early spring allowed some individuals to nest very early but many delayed nesting until nearer the normal dates in spite of the habitat conditions. This resulted in a less synchronous nesting season for some species. Of 20 Western Sandpiper nests discovered in our study area, the earliest clutch completion was 24 May, the latest 24 June, an unusually large spread of dates among arctic shorebirds.

These differences in phenology between years apparently had little affect on the nesting densities at coastal sites (Table 4). Nesting densities at Barrow and Cape Krusenstern were very similar on study plots in 1977 and 1978 in spite of differences in phenology between years. At an inland arctic coastal plain site at Atkasook on the Meade River, densities were higher in both years and differed primarily because of

Table 4. Comparison of breeding densities at arctic tundra sites, 1977 and 1978.

	Number of species nesting		Total pairs per hectare	
	1977	1978	1977	1978
Barrow Plot 1	10	10	1.10	1.09
Barrow Plot 2	11	12	1.10	1.29
Meade River	18	16	2.27	1.88
Cape Krusenstern	14	13	1.33	1.55

References: Myers et al 1978a,b,c; 1979a,b,c.

Connors and Connors 1978.

Connors et al 1979.

differences in densites of 2 common species - Semipalmated Sandpipers and Lapland Longspurs (Myers and Pitelka 1980)

Shorebird Species Distributions

The nesting and migrational distributions of each shorebird species determine to a great extent the potential mix of shorebirds occurring within any habitat at different sites across the Alaskan arctic. Table 1 lists species which occur regularly along the southern Chukchi coast. Since these are all long distance migrants there are few differences between this list and a similar one constructed for the Beaufort coast (Connors et al 1981) but the relative abundance of many of the species in these tables varies across that extensive range. The principal contrasts between areas are the much lower abundances in the southern Chukchi area of Ruddy Turnstone and Baird's Sandpiper and the absence as nesting birds of White-rumped Sandpiper, Stilt Sandpiper and Buff-breasted Sandpiper. Conversely, Rock Sandpiper and Black Turnstone nest on Seward Peninsula but not along the Beaufort Coast, and Common Snipe, Western Sandpiper, Bar-tailed Godwit and Sharp-tailed Sandpiper are all much more common along southern Chukchi coasts than in areas farther north and east. However, many species such as American Golden Plover, Pectoral Sandpiper, Dunlin, Semipalmated Sandpiper, Long-billed Dowitcher, and Red and Northern Phalarope are common throughout both regions.

Shorebird Use of Ice-lifted Sediments

We have observed a surprising phenomenon of shorebirds using littoral habitats during spring migration in the southern Chukchi. During melt-off in late May and early June, ice covering the shallow lagoons and sloughs of the western Noatak Delta and Sisualik area frequently supports a surface layer of mud. We believe these are ice-lifted benthic sediments and describe a possible mechanism of formation below. Beyond its geophysical interest, this phenomenon is apparently of biological importance because of its strong attraction to foraging birds of many species. On 24 and 25 May 1978, we recorded very high densities of 10 species of shorebirds in two different areas of ice-lifted sediments on a lagoon behind the Sisualik spit (Tables 5 and 6). Densities were 10 to 15 times those on nearby saltmarsh transects and 50 times the densities on adjacent tundra transects. The sediments did not occur on all areas of lagoon ice but were widespread in the Sisualik area. During at least this brief period of spring migration therefore, most of the shorebirds present apparently foraged on this surprising substrate in preference to nearby tundra or other littoral areas. The phenomenon raises several questions: What process is responsible for the formation of the sediment layer above lagoon ice? What food resource is available in

Table 5. Shorebird densities in 3 habitats, Sisualik, 24-25 May 1978.

	Total transect area (ha)	Shorebird species	Total shorebirds	Total other birds	Density of shorebirds (#/ha)
Tundra	17.5	4	30	20	1.7
Saltmarsh	15.3	8	104	4	6.8
Ice-lifted sediments	5.6	10	501	0	90.3

Table 6. Densities of common species in 3 habitats, Sisualik, 24-25 May 1978 (birds per ha).

	Semipalmated Sandpiper	Western Sandpiper	Red Knot	Bar-tailed Godwit
Tundra	1.1	0	0	0
Saltmarsh	2.1	.1	0	0
Ice-lifed sediments	15.0	31.5	12.4	13.2

sediments to attract such high densities of foraging birds? To what degree do migrating shorebirds depend on this resource? How consistent is the sediment layer as a shorebird resource from year to year? To what extent might this phenomenon expose shorebirds to the effects of oil pollution?

Mechanism of formation: an hypothesis. Mechanisms for the puzzling occurrence of sediments in nearshore sea ice along the arctic coast have attracted the interest of geophysicists in recent years (see review by Larson 1980). Proposed explanations for the occurrence of layers of sediment on the under surface of sea ice include floating of bottom-frozen sediments and incorporation of sediments suspended in the water column or scraped from the bottoms of lagoons into forming slush ice or frazil ice. The occurrence we describe in this report, however, is very different in character from those discussed by Larson. We have observed it only in protected areas of the lagoon and delta system; it consists of much greater concentrations and amounts of sediment; it is underlain by hard ice rather than incorporated as the bottom layer of soft ice; and it contains plant material characteristic of bottom sediments.

We also feel certain that the sediments observed on lagoon ice are not carried there directly by spring river runoff over the ice, a possibility which could be suggested by the close proximity of the Sisualik lagoon system to the mouth of the Noatak. Several factors lead us to reject this possibility:

(1) The phenomenon was observed principally in the shallow areas at the west end of the lagoon system, behind the Sisualik Spit rather than farther east in the Noatak Delta system where the river flow is greater.

(2) The thickness of mud deposits is variable over distances of tens of centimeters; the surface looks lumpy. Sediment deposition by over-ice currents would probably be relatively uniform on this fine scale and show current patterns on a scale of meters.

(3) Shorebirds collected while foraging on sediments over the ice were taking almost exclusively chironomid larvae, which are also the common prey taken from lagoon mudflats in the same areas during summer (Tables 7 and 11).

(4) During May, as melt-off began, water covered the ice in the same lagoon areas. At this time Pintails (Anas acuta) foraged over the ice by taking plant tubers from the mud. These same tubers are a favorite waterfowl food common in the lagoon in late summer (W.R. Uhl, pers. comm.).

These last observations in particular indicate strongly that the deposits found on the lagoon ice surface in spring consisted of the benthic sediments from the same lagoon rather than sediments carried down the river by flood waters.

Table 7. Diets of shorebirds foraging on ice-lifted sediments, Sisualik, 25 May 1978.

Species	Number of stomachs	Contents (in order of decreasing average % volume)
Bar-tailed Godwit	1	plant matter
Red Knot	1	plant matter adult diptera seeds
Long-billed Dowitcher	4	chironomid larvae plant matter seeds
Dunlin	2	chironomid larvae seeds
Semipalmated Sandpiper	4	chironomid larvae seeds
Western Sandpiper	4	chironomid larvae seeds

Another method of incorporating sediments into ice was described by Ugolini (1975). From observations of small ponds and patches of sediments deposited on islands in the Noatak Delta he suggested that sediments covered by shallow water were frozen during the winter and lifted by flotation when flood waters over-ran delta islands. These sediments were then ice-rafted to new locations and deposited as flood waters receded. Our observations, and particularly those of W.R. Uhl (pers. comm.), suggest a slightly different mechanism for the more extensive areas of sediments we observed in the lagoon system. Uhl states that the sediments freeze during storm conditions in autumn when benthic sediments in the lagoon normally covered by water are exposed during a negative storm surge. As atmospheric conditions subsequently change, water returns to the lagoon system, floating the frozen benthic sediments to the surface where they are incorporated into the ice forming over the lagoon. The ice sheet continues to thicken below the lifted sediment.

In early spring as the Noatak River breaks up, water flows over the ice throughout the lagoon system, both from the river and from local runoff. The lagoon ice begins to melt from the top down. At this time a cross-section through the lagoon would show undisturbed benthic sediments at the base of the lagoon, covered by water, then hard ice, next lifted sediments and finally a covering of water on which dabbling ducks can feed. As the melt proceeds, surface water drains from lagoon ice into Kotzebue Sound and holes melt through the lagoon ice. Lagoon ice begins to break up and is freed in patches to float to the surface of the water. At this time (late May), large areas of melted mud are exposed on the surface of the lagoons above the ice where they are available for foraging shorebirds. Eventually the ice sheet supporting these sediments melts and the sediments return to the lagoon in the approximate locations from which they were lifted the previous fall. Different areas of the lagoon system melt at different times, so migrant shorebirds concentrate in different areas in subsequent days or weeks.

Significance of the phenomenon. The foods taken by shorebirds from the ice-lifted sediments (principally chironomid larvae and plant matter) are substantially the same as the main prey taken by these species foraging on the lagoon mudflats during late summer (Tables 7 and 11). In spring however, the lagoon mudflats are not accessible to foraging birds; the ice-lifted sediments provide a uniquely rich foraging resource for many species. The extremely high densities of shorebirds foraging on ice-lifted sediments on our study plot (90 birds per hectare) suggest that large numbers of total shorebirds might use these areas in seasons when sediment areas are extensive at this and other lagoon systems. For example the same phenomenon may occur in the extensive lagoon system on the north shore of Seward Peninsula, but this is not yet known. It may also occur in certain areas along the Beaufort coast but except for our observation of a similar phenomenon of shorebirds foraging on sediments or algal mats above the ice of North Salt Lagoon at Barrow in 1976, we know of no reports of this. Southern Chukchi mudflats are more heavily used than the similar but less extensive Beaufort areas by shorebirds in late summer and the same may be true in spring.

The occurrence of this phenomenon may be quite variable from year to year since it depends on a sequence of primarily meteorological events, which certainly varies. We do not, however, know how sensitive the mechanism is to variation in these events. Assuming that the extent and precise location of ice-lifted sediments, as well as the timing of availability, varies from year to year, shorebirds which use this resource for spring foraging must be flexible and opportunistic, characteristics which apply to migrant shorebirds in many other areas. In the event of oil spilled during the previous open water period or released in the ice during winter, the resultant patches of dark surface ice occurring in lagoon areas in spring would probably attract large numbers of shorebirds to investigate. Without experimental evidence of shorebird reactions to an encounter with oil deposited on ice, we can only guess at the outcome. We predict that many species would be attracted to the oil, probably even to the extent of landing and probing its surface, but that most shorebirds would quickly abandon these efforts after finding no food. The only experimental study relevant to the question was done with Red Phalaropes foraging on water covered with a thin film of oil (Connors et al 1981). Even in the presence of available food these shorebirds quickly learned to avoid contact with the oil surface. In that case, however, even brief contact was potentially very damaging to the birds' survival. However, in the case of shorebirds walking on, rather than swimming in the oil, the brief learning contact is unlikely to be lethal. If, however birds wade at body depth in water covered by an oil film, plumage effects may be severe.

Shorebird Concentration Areas.

Our studies at Cape Krusenstern and at Wales describe the seasonal changes in densities of each of the shorebird species at these 3 southern Chukchi sites. For a general comparison of sites, Table 8 presents total shorebird

Table 8. Total shorebird densities in littoral habitat at study sites. Birds/hectare.

	30 July to 8 August	14 August to 23 August	29 August to 7 September
Oliktok	6.3	9.1	3.4
Barrow	5.5	21.5	1.4
Peard Bay	5.4	3.7	1.0
Icy Cape	21.7	8.4	.9
Cape Krusenstern	4.3	1.7	.8
Wales	4.6	1.5	5.2

densities recorded on all our littoral habitat transects at 6 study sites for 3 different late summer periods in 1977. Except for the latest period at Wales, shorebird densities at the 2 southern Chukchi sites were somewhat lower than densities at northern Chukchi and Beaufort sites during the same periods. Each of these southern Chukchi sites has areas of littoral habitat which are heavily used by some species during periods of the summer, as do many other locations along that coast. However, the regions supporting the largest numbers of shorebirds foraging in southern Chukchi littoral habitats are the regions with the most extensive saltmarsh and mudflat areas. From our aerial and occasional ground surveys we judge the two most important of these to be the Noatak Delta - Sisualik area and the lagoon barrier strip along the north shore of Seward Peninsula, east and west of Shishmaref (Figures 1 and 6). Less extensive but also heavily used areas include mudflat areas near Cape Espenberg (see Schamel et al 1979) and in southern Kotzebue Sound.

During July, August and early September the saltmarshes and mudflats of these 2 major areas support large flocks of Western and Semipalmated Sandpipers, Dunlins, Pectoral Sandpipers, Long-billed Dowitchers and Golden Plovers, and both Phalarope species forage on ponds within the saltmarsh. Individual flocks number in the hundreds and occasionally thousands. Lesser numbers of several other shorebird species are present also. Densities of total shorebirds on a series of saltmarsh transects near Sisualik were high compared to

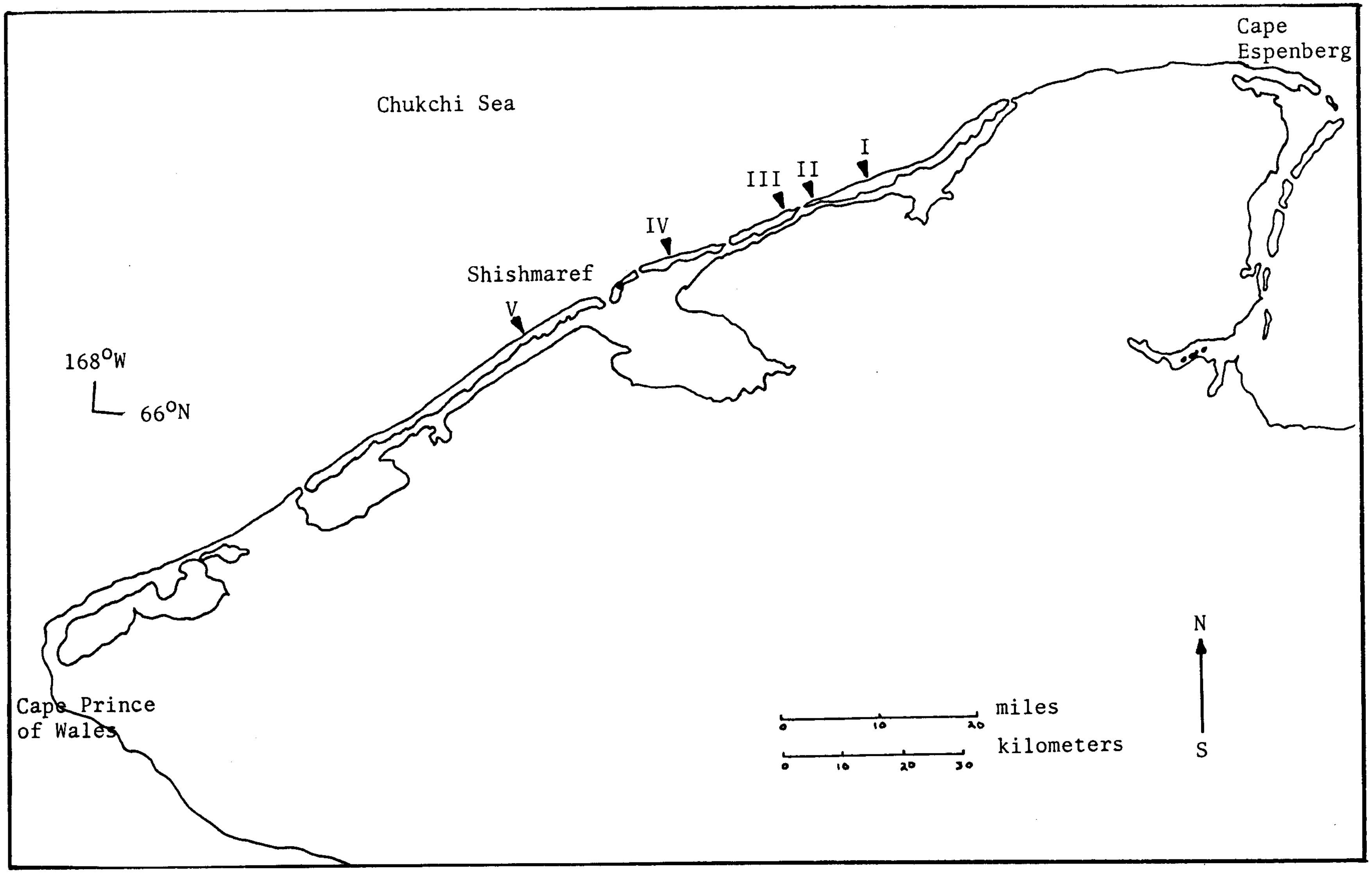

Figure 6. Locations of census sites, Shishmaref coast, Alaska.

tundra densities throughout the nesting season but peaked in August at approximately 15 birds per hectare (Figure 7B). Shorebird densities on transects crossing the Shishmaref barrier strip in August were similar (Figure 7A).

The Shishmaref lagoon barrier strip comprises the largest area of productive saltmarsh and mudflat habitats used by shorebirds north of Bering Strait in Alaska. The barrier strip is approximately 160 km in length, averaging 1.12 km in width (see Figure 6). Typically the ocean beach is backed by irregular dunes grading to sandy tundra and then to saltmarsh, pools, and occasional mudflats. The saltmarsh consists of Carex and Puccinellia flats with interspersed brackish pools. Few species nest in these habitats, and densities during June probably remain quite low, but waves of post-breeding adults and juveniles forage here in late July, August and September. Figure 7A presents the results of 5 visits to sites along the barrier strip in 1977 and 1978. These data are sketchy because we were able to visit only a few sites, and periods between visits were longer than we would wish. However, they do indicate the striking increase in densities of shorebirds in these habitats. Average densities increased more than 10-fold between late June and late August. The peak densities during both years extrapolate to total shorebird populations for the northern Seward Peninsula barrier strip alone of 250,000 to 350,000 shorebirds. Other bird species noted on the transects showed the same seasonal patterns, with densities averaging about 20% of shorebird densities during each period. In late August and September the area was heavily used by flocks of Brant (Branta bernicla) which are not often recorded on our walking transects. Our estimate from an aerial survey of 6 September 1978 was of at least 15,000 Brant on the barrier strip.

These two saltmarsh and mudflat areas therefore represent very important foraging areas for large numbers of shorebirds, as well as some waterfowl species. Oil spills or other development-related activities which affect these habitats or the food resources found within them could have important negative effects on significant populations of many species at the time when shorebirds are accumulating fat reserves prior to southward migration (Connors et al 1981).

Aleutian Tern Colonies.

During the 1977 field season we located four small colonies of Aleutian Terns (Sterna aleutica) nesting in or near littoral habitats. These colonies represented northward extensions of the known range of the species. Our censuses in 1978 indicated that three of these colonies had expanded greatly (Table 9). Observations of local residents (Carrie and W.R. Uhl, pers. comm.) suggest that this species has expanded its range into the area within the last 10 to 15 years. The marked increase in numbers between 1977 and 1978

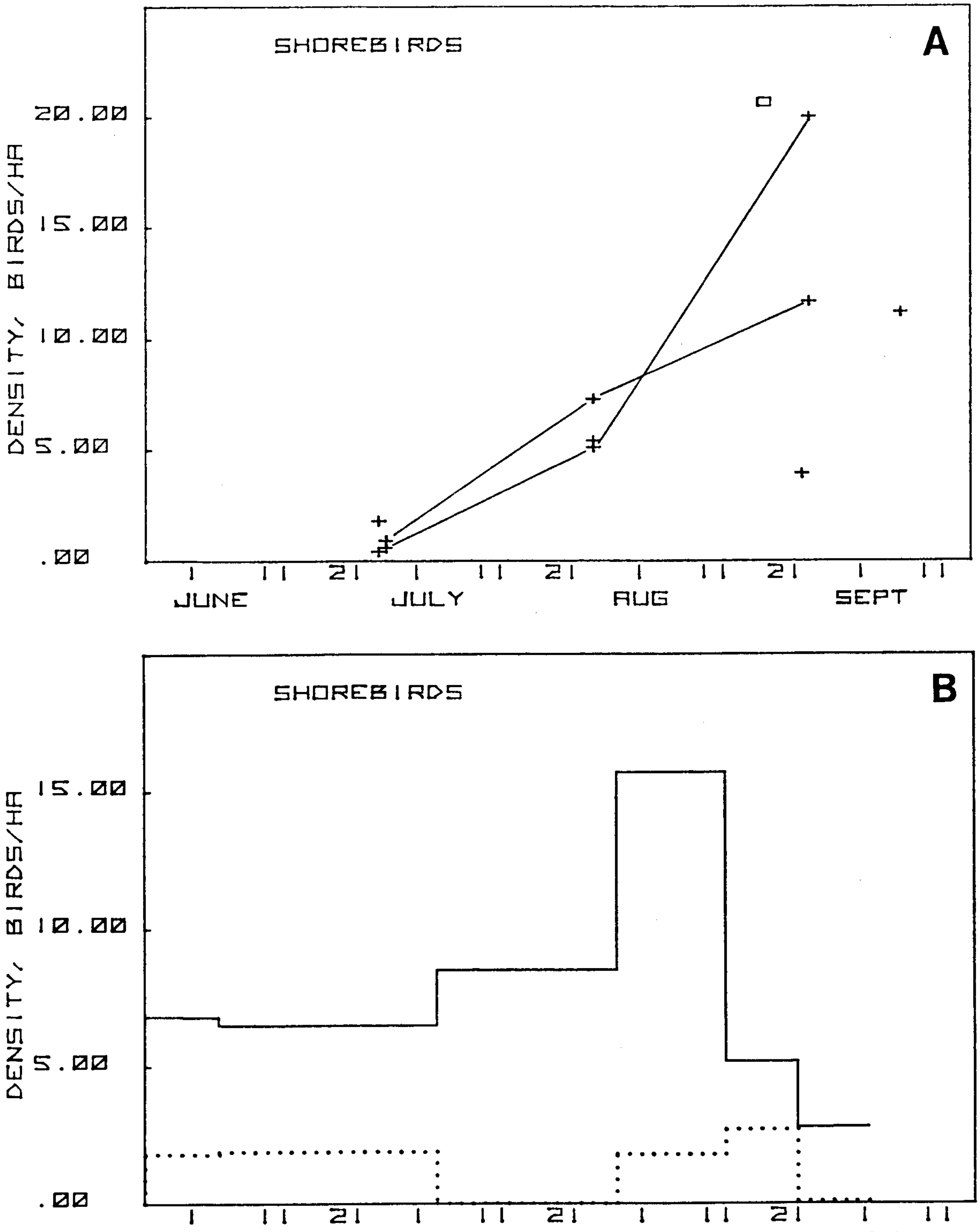

Figure 7. A. Shorebird densities at sites on barrier strip east and west of Shishmaref. (□) 1977, (+) 1978. Lines connect successive visits to 2 principal study sites.
B. Shorebird densities on transects on Sisualik Spit. Saltmarsh (solid line) and tundra (dotted line).

may be further evidence of this continuing expansion, or it may just reflect differences between years in other factors such as food supply, or predation by foxes or humans.

Table 9. Size of four northern colonies of Aleutian Terns (number of active nests).

Location Map no.[1]	Qikiqtaichaik Is. 128-001	Uhl-Williams Camp 128-002	Krusenstern North Flats 128-005	Tasaychek Lagoon 128-006
1977	5-20	c.10	c.2	c.12
1978	c.90	?	c.29	c.38

[1] Sowls _et al_. 1978

Arctic Terns (_Sterna paradisaea_) also nest in or near littoral habitats in small colonies at many sites along the southern Chukchi coast. They nested at several sites along the upper edge of the beach at Cape Krusenstern, on islands in the North Flats transect area and in Krusenstern Lagoon, and on the beaches near Tasaychek Lagoon north of Cape Krusenstern. They also nest at sites on the beaches of the Shishmaref barrier strip and at Cape Espenberg. Glaucous Gulls (_Larus hyperboreus_) also nest in some of these same habitats, especially on islands in saltmarsh and mudflat areas of the Shishmaref barrier strip and in the North Flats area near Cape Krusenstern. Colonies we noted at these sites and several other sites along the southern Chukchi coast were usually small, consisting of only ten's of nests, and some colonies are not occupied in every year. We also located one small colony of Mew Gulls (_Larus canus_) near Krusenstern Lagoon.

Seasonal Habitat Use Patterns of Selected Species.

Results of our transect density measurements have been presented as seasonal habitat density comparisons for all common species in Connors et al (1981); Connors and Risebrough (1978; 1979). In this report we will focus only on those common species which show the most notable contrasts between the Beaufort coast and southern Chukchi coast in relative habitat use or seasonal timing of movements.

Golden Plover. Connors et al (1979) classified common Barrow shorebirds in terms of their susceptibility to coastal oil development. This classification was based principally upon relative use of littoral zone vs. tundra habitats by each species. Golden Plovers were placed in the least sensitive category because the Barrow transect data showed very low use of littoral habitats by this species; almost all Golden Plovers seen were recorded on tundra transects (Figure 8A). We were therefore surprised to find a very different habitat use pattern by Golden Plovers in the southern Chukchi. Figure 8B compares tundra and littoral transect densities, combining Wales and Cape Krusenstern transects. Densities were comparable in both habitats at these sites. We can suggest at least two possible explanations for this surprising result. First, as mentioned above, the relative availability of different kinds of littoral habitat varies considerably between the southern Chukchi and Beaufort coasts. Habitats of saltmarsh with mud margins bordering tundra areas are much more extensive in the southern Chukchi and these are the habitats in which we observed Golden Plovers foraging in littoral areas. It is also quite possible that the types of prey available or the densities of prey differ in these littoral areas, with conditions in southern Chukchi marshes making them more attractive to foraging plovers. So our observations may actually represent a shift in habitat use within the species or by individual members of the species as they migrate through are differing in the relative availability or relative attractiveness of different habitats.

Alternatively, our observations may represent differences in habitat preference between two forms of Golden Plover. These two forms, previously described as subspecies, *Pluvialis dominica dominica* and *P. d. fulva*, differ markedly in relative abundance in the two areas of study (Connors, submitted). Almost all nesting birds along the Beaufort coast are *dominica* whereas *fulva* become increasingly more common in the southern Chukchi. Late summer juveniles can be readily identified, and these birds were almost all *fulva* at southern Chukchi sites, so the possibility exists that our observed difference in relative habitat use represents a real difference in ecological traits between the two forms. Elsewhere Connors (submitted) has argued that the two forms should be treated as distinct species because of lack of evidence of interbreeding. In this case a genetically determined difference in habitat preference would not be surprising. The environmental importance of this question arises from the much greater exposure to littoral zone disturbances associated with oil development for Golden Plovers in southern Chukchi areas. On the basis of our habitat use measurements, the relative sensitivity of Golden Plovers to coastal oil development must be rated higher in the southern Chukchi than along the Beaufort coast.

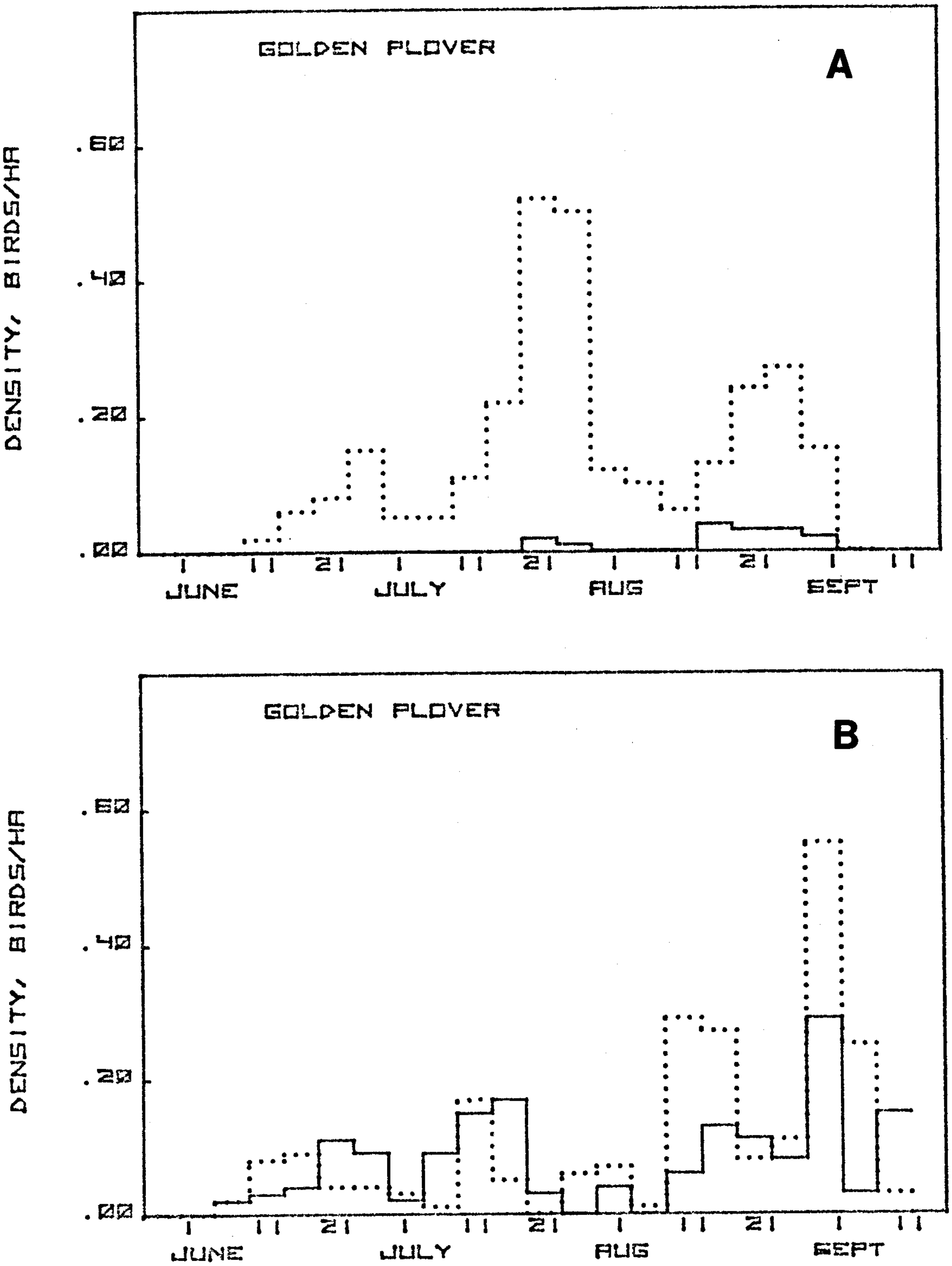

Figure 8. Transect densities, Golden Plover. A. Barrow, 1976. Littoral (solid) vs. tundra (dotted). B. Wales and Cape Krusenstern, 1977. Littoral (solid) vs. tundra (dotted).

Another aspect of the Golden Plover migrations in this region deserves comment. Our estimate of the peak species population on the Shishmaref barrier strip in August 1977 and 1978 is 13,800 birds, almost all juvenile fulva. Connors (1982) has compared that total with the production of fledged juveniles expected from the estimated nesting population of fulva occurring nearby and in all areas to the north and east. The estimate is necessarily quite rough, but the migrant juvenile population on the Shishmaref strip is about equal to the total expected production. Since juveniles also occur at other saltmarsh sites as well as on tundra, these birds may represent young produced elsewhere. We suggest that they may be Siberian in origin, crossing Bering Strait west to east in late summer to feed in the rich saltmarsh areas of Seward Peninsula, and subsequently migrating south and southwestward to wintering areas.

This surprising, indirect migration route gains plausibility when compared with an unequivocal movement of another shorebird. Sharp-tailed Sandpipers nest only in Siberia and winter in the South Pacific (New Guinea, Australia), but juveniles are fairly common in the same saltmarshes of western Alaska in early September. Numbers are much lower than for Golden Plovers, so this is not a major migration route, but neither is it a rare occurrence of out-of-range stragglers. If Siberia is the source of many of the juvenile Golden Plovers observed, as well as all the Sharp-tailed Sandpipers, the saltmarsh areas of the Alaskan coast become even more of an international resource, with birds which breed and winter on other continents dependent to some extent on resources here.

Pectoral Sandpiper. This species shows a comparable difference in relative habitat use between the two study areas, with Pectoral Sandpipers quite common on mudflats and in saltmarshes of the southern Chukchi (Figure 9), in contrast with their greater concentration in tundra areas along the Beaufort coast (Connors et al 1979).

In this species there is no question of a taxonomic difference in forms in the two areas, suggesting that the observed differences are a response to habitat conditions differing between the two regions. Again the result is a higher sensitivity of Pectoral Sandpipers in the southern Chukchi compared to their low sensitivity to oil development at Barrow.

Western Sandpiper. This species, uncommon east of Barrow but very common along the Chukchi coast, showed a consistent use of littoral habitats throughout our study, with individuals nesting on tundra but often foraging in nearby littoral areas of saltmarsh and mudflat during the breeding season and shifting heavily to these littoral habitats in late summer. Figure 10 shows the consistency of these patterns between 2 southern Chukchi study sites (Wales

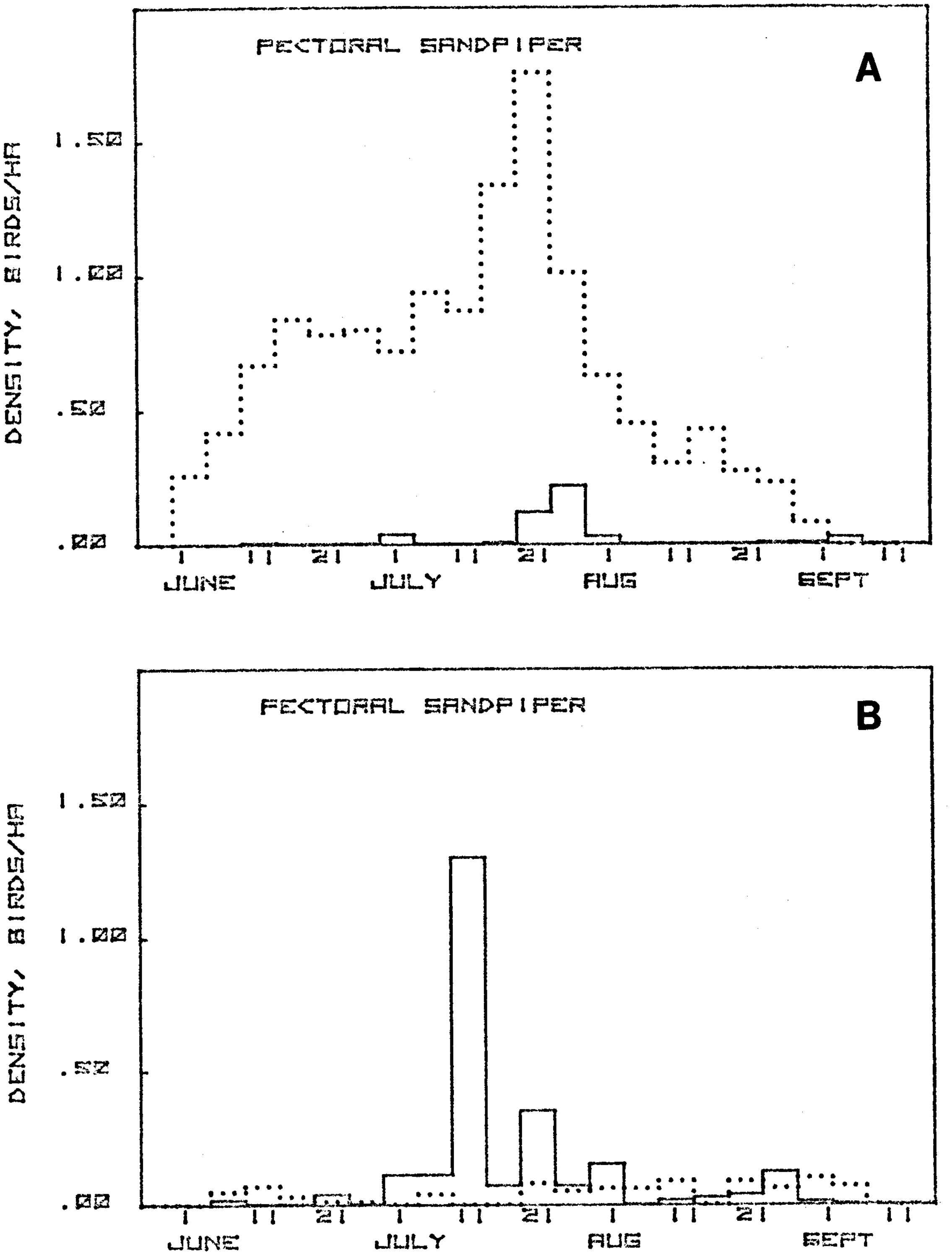

Figure 9. Transect densities, Pectoral Sandpiper. A. Barrow 1976. Littoral (solid) vs. tundra (dotted). B. Wales and Cape Krusenstern 1977. Littoral (solid) vs. tundra (dotted).

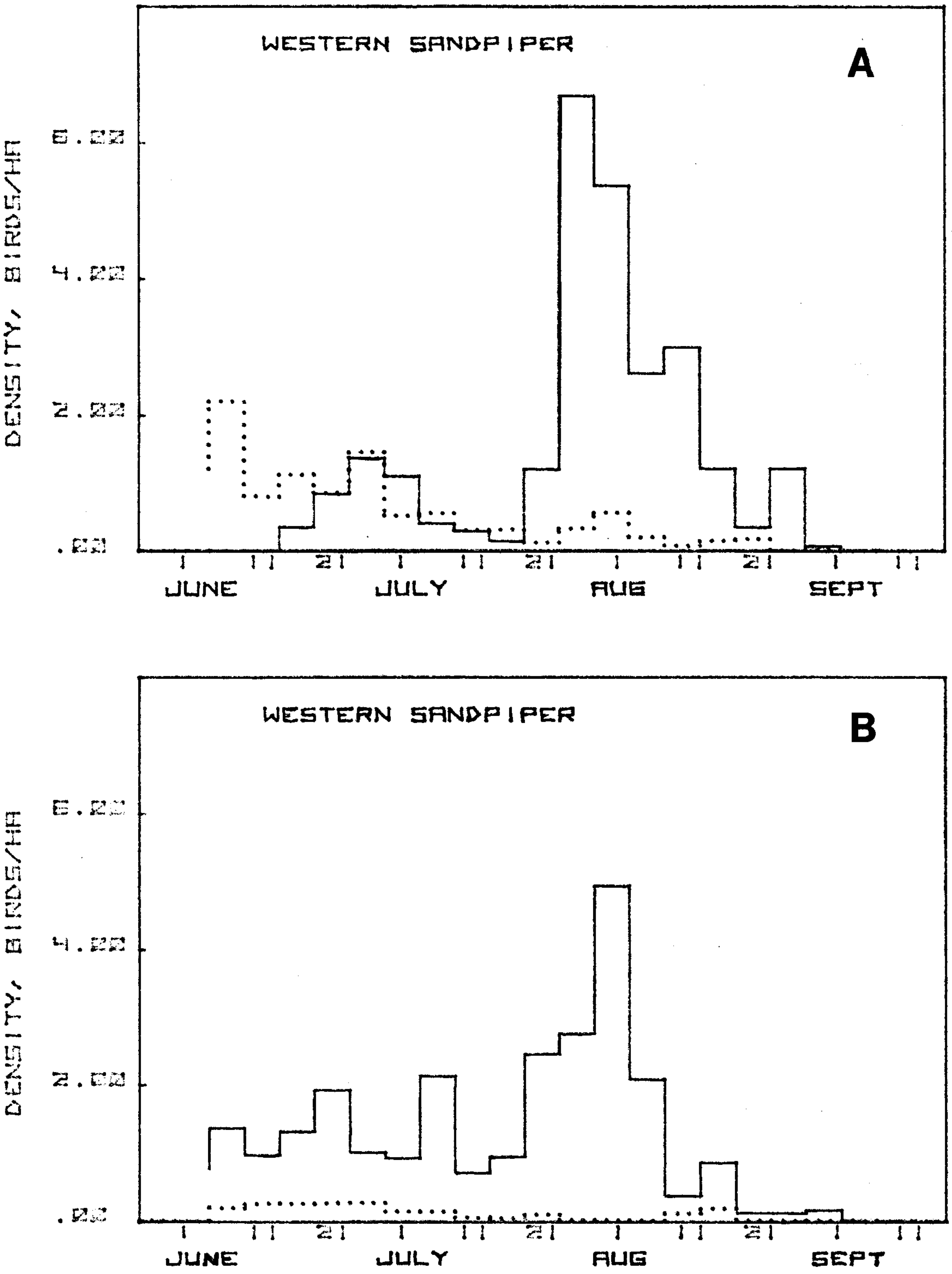

Figure 10. Transect densities, Western Sandpiper. A. Wales. Littoral (solid) vs. tundra (dotted). B. Cape Krusenstern. Littoral (solid) vs. tundra (dotted).

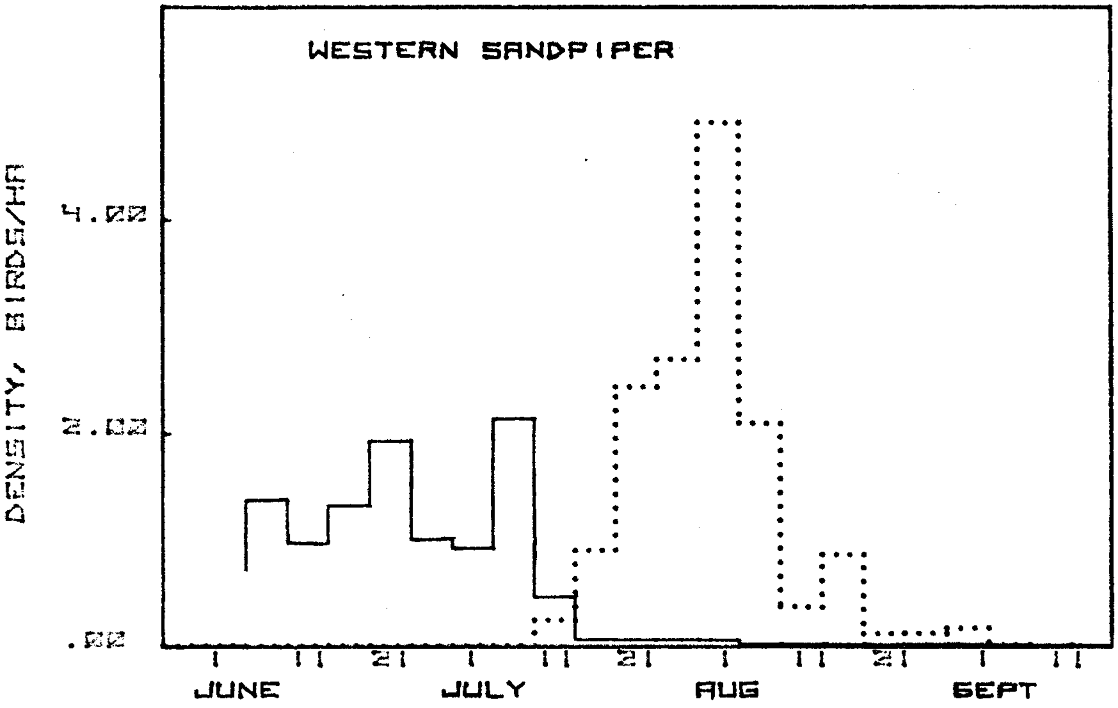

Figure 11. Western Sandpiper littoral transect densities, Cape Krusenstern, 1977. Adults (solid) vs. juveniles (dotted).

and Cape Krusenstern) in 1977. This pattern can be broken down further to show the movements of adults and young birds into littoral areas (Figure 11). Adults depart on southward migration soon after completion of nesting duties, and newly fledged young move heavily into littoral habitats in late July, where they forage prior to migration.

Semipalmated Sandpiper. This species is very similar in appearance and habitat use to Western Sandpiper, but shows a pattern of movements which contrasts more between regions than does the former species (Figure 12). At Barrow and at other sites along the Beaufort Coast, densities in littoral areas remain low throughout the breeding season, followed by a very sharp, high density movement of juveniles to the littoral zone at the end of July. At Cape Krusenstern, densities in littoral areas during the breeding season were higher than at Barrow but the movement of juveniles into the littoral zone was less marked (Figure 12B). However, both these species in both areas would be sensitive to disturbances of saltmarsh and mudflat habitat.

Semipalmated Sandpipers also show differences in timing of littoral zone movements at different sites across the arctic. Figure 13A shows the peak of juvenile Semipalmated Sandpipers on littoral transects censused in 1978 at Cape Krusenstern, Barrow and Prudhoe Bay. These movements differ in peak density, as described above, but also differ in peak timing by about 5 days between each site. This may represent differences in nesting phenology at each site, or it may represent to some extent a wave of coastal migration in this species which migrates eastward across Canada in autumn.

Another aspect of timing of littoral zone use which differs between regions depends partly upon the availability of ocean shoreline habitat, as discussed above under Phenology. At Beaufort sites large numbers of many species of shorebirds move to shorelines during August and early September, but in June these shorelines are ice-bound. At southern Chukchi sites shorelines are sometimes free of ice in June as in 1978 when northward migrating Phalaropes foraged along beaches at Cape Krusenstern. Figure 13B shows the resultant sharply contrasting difference in seasonal use of ocean shorelines between Cape Krusenstern and two Beaufort sites. Thus the timing of oil spills can have drastically different effects on shorebirds in different regions of the coast.

Red Phalarope. The extreme contrast in relative habitat use by phalaropes between the Beaufort and southern Chukchi coasts is further shown for all habitats in Figure 14. At Barrow Phalaropes are almost confined to tundra habitats until late July when the largest annual accumulations of shorebirds begin to accrue along ocean shorelines. This heavy build-up of plankton-foraging Phalaropes does not occur in late summer at Cape Krusenstern and Wales, and densities

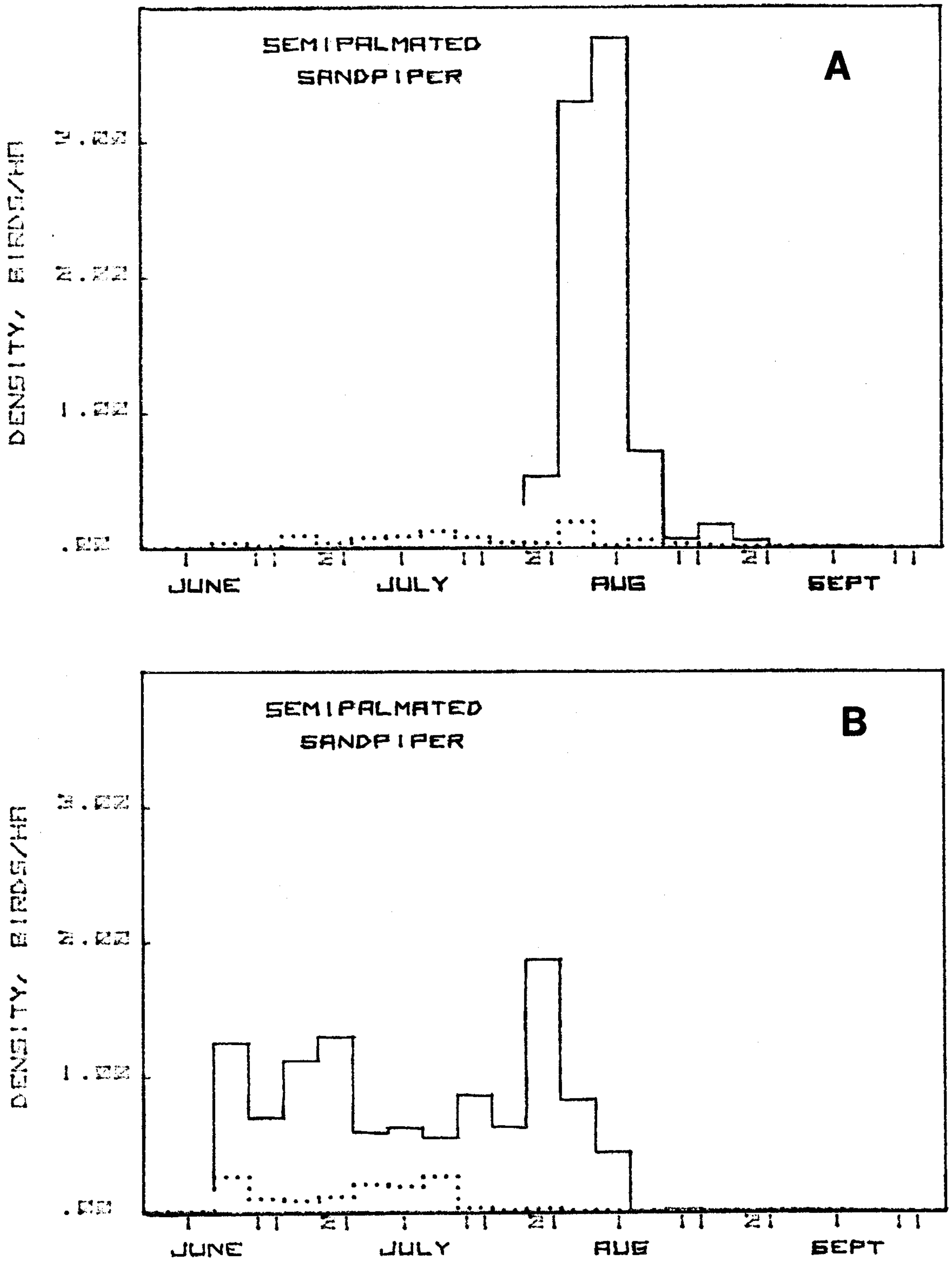

Figure 12. Transect densities, Semipalmated Sandpiper, 1977. A. Barrow. Littoral (solid) vs. tundra (dotted). B. Cape Krusenstern. Littoral (solid) vs. tundra (dotted).

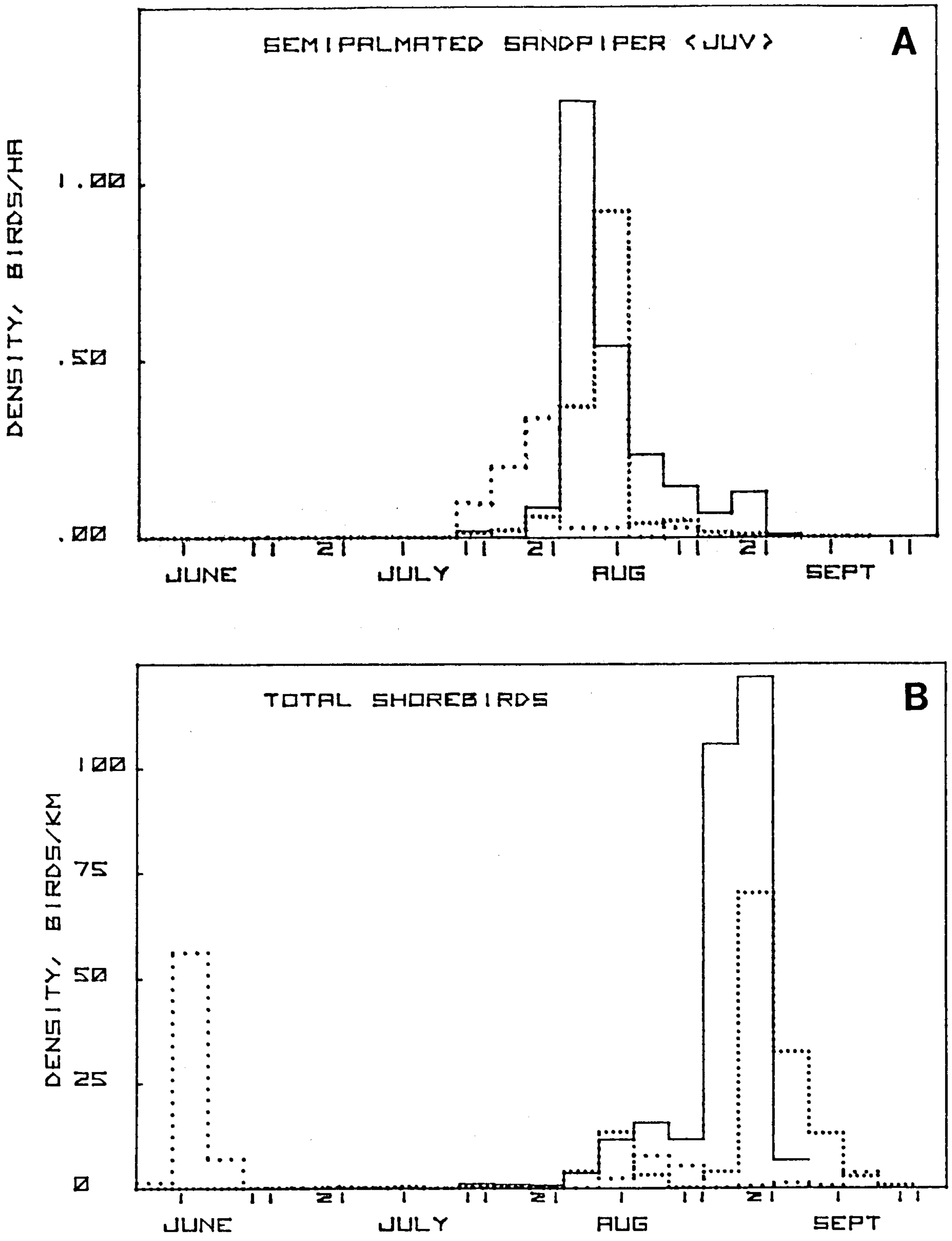

Figure 13. Shorebird densities at 3 sites: Barrow (solid line), Prudhoe Bay (short dot line), Cape Krusenstern (long dot line).

A. Juvenile Semipalmated Sandpipers on littoral transects.

B. Total shorebirds along ocean shorelines.

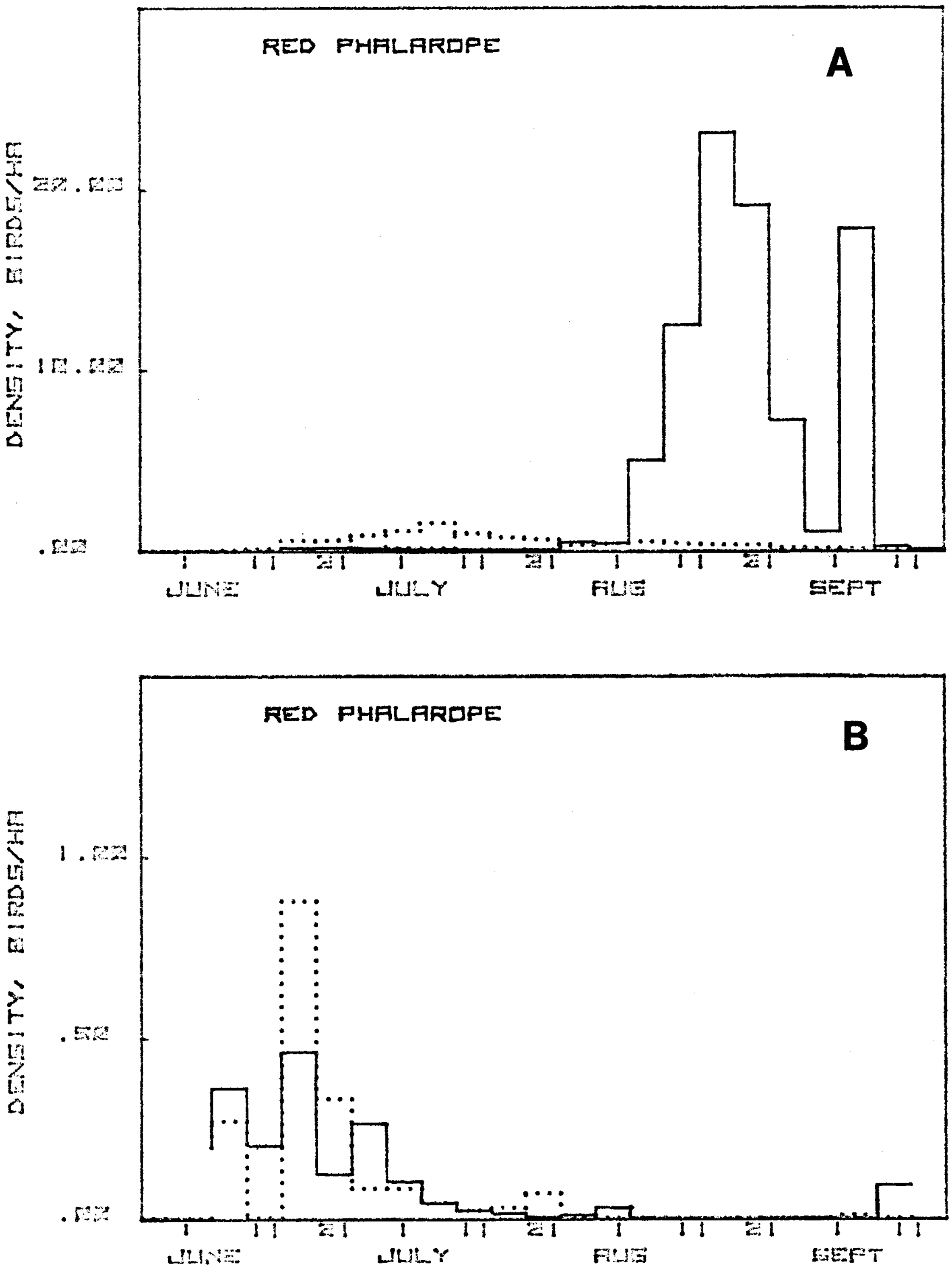

Figure 14. Transect densities, Red Phalarope. A. Barrow, 1976. Littoral (solid) vs. tundra (dotted). B. Wales and Cape Krusenstern 1977. Littoral (solid) vs. tundra (dotted).

in early summer remain low but roughly equal in littoral and tundra habitats (except 1978; see Figure 13B). Northern Phalaropes, more common as nesting birds at Cape Krusenstern than at Barrow, show a similar contrast in pattern, with birds more common in littoral habitats in early summer at Cape Krusenstern and much more common in late summer at Barrow and elsewhere on the Beaufort coast (Connors and Risebrough 1978; 1979; Connors et al 1981).

Trophic Systems.

As mentioned earlier in this report, there is a major difference in littoral zone shorebird trophics between the Beaufort coast and the southern Chukchi coast when viewed on a community level. At Barrow and elsewhere along the Beaufort coast, large numbers of several shorebird species, including principally Red and Northern Phalaropes together with Dunlins, Sanderlings, Ruddy Turnstones, and occasionally other species, forage in late summer along sand and gravel beach shorelines, especially near spits and barrier islands (Connors et al 1981, Johnson 1978). During August, the bulk of the Barrow shorebird community will be found in these habitats, where the important prey are a variety of the larger species in the zooplankton community. This zooplankton community is highly variable in time as well as space (Redburn 1974; Connors et al 1981) but densities are frequently quite high, providing an excellent food source for large numbers of shorebirds. Important organisms among these marine zooplankton include amphipods (Onisimus and Apherusa), euphausiids (Thysanoessa), copepods (Calanus), and decapod zoea, as well as other species, and along barrier lagoon shores, mysids (Mysis).

Along the beaches at Cape Krusenstern, Sisualik, Shishmaref, and Wales, we never saw comparable late summer concentrations of zooplankton foraging shorebirds. We measured shoreline plankton densities in 1977 at Barrow, Cape Krusenstern and Wales and found very little correlation in density and composition among the zooplankton communities during July and August at the 3 sites (Connors and Risebrough 1978). Densities at all 3 sites were lower than during the preceding 2 seasons at Barrow. We are not able to state whether the lower use of shoreline foraging areas by Phalaropes at southern Chukchi sites is a direct response to lower prey availablity at these sites compared with Beaufort sites. Diets of Red and Northern Phalaropes collected along lagoon and ocean shorelines at Wales and Cape Krusenstern consisted of a variety of zooplankton similar to those taken at Barrow, but total numbers of Phalaropes feeding in these habitats at the southern Chukchi sites were much lower than along the Beaufort coast (Table 10).

Table 10. Principal food items of Phalaropes at Cape Krusenstern (in order of decreasing frequency).

3 Northern Phalaropes Tundra marsh, 2 June 1978	3 Northern Phalaropes Lagoon shore, 12 June 1978	9 Red Phalaropes Ocean shore, 3-7 June 1978
chironomid larvae	mysids	copepods
other dipteran larvae	arachnids	amphipods
coleoptera	seeds	adult diptera
tiny eggs		arachnids
seeds		coleoptera
		seeds

The other major shorebird littoral zone trophic system includes the saltmarsh, mudflat and saline pool habitats which occur in scattered areas throughout the Beaufort coast, but comprise much larger areas along the southern Chukchi coast, as discussed above. In both regions and at all collection sites, the shorebird prey taken in these habitats were similar. Stomachs of almost all species contained insect larvae and adults, with chironomid fly larvae clearly the most important single prey item. Adult chironomids were taken frequently in some areas and larvae of other diptera were found occasionally. Other prey included principally oligochaetes, beetles, spiders, amphipods and seeds. In general, our samples at any one site were not sufficient to identify minor differences in diets among species. They do however show a very broad overlap in diet among many species, arising prinicipally from the widespread importance of chironomid larvae and adults to almost all shorebirds foraging in these habitats. As an example, a comparison of diets of 6 species foraging in saltmarshes at 2 sites is presented in Table 11. Of 49 individuals with identifiable prey in their stomachs, 41 birds contained larvae or adults of diptera (flies). Except for seeds or other plant material no other group of prey items occurred in more than 5 stomachs. Of the 6 species sampled, only Sharp-tailed Sandpipers had most stomachs containing prey other than diptera larvae and adults.

Table 11. Diets of shorebirds foraging in saltmarsh and mudflats at two locations in late July and August 1978.

	Number of stomachs	Number containing more than trace amounts of:						
		Fly larvae, adults	Beetles	Spiders	Amphipods Isopods	Poly-chaetes	Fish	Plant matter
A. Sisualik and Noatak Delta								
Golden Plover	3	3	0	1	1	0	0	0
Dunlin	12	9	0	1	1	0	0	8
Western Sandpiper	5	5	0	0	0	0	0	5
Pectoral Sandpiper	3	3	0	0	0	0	0	1
Sharp-tailed Sandpiper	4	1	1	3	0	0	0	4
Long-billed Dowitcher	3	3	0	0	0	1	0	3
B. Shishmaref strip								
Golden Plover	3	1	2	0	0	0	1	0
Dunlin	6	6	1	0	1	0	0	2
Western Sandpiper	5	5	0	0	0	0	0	5
Long-billed Dowitcher	5	5	0	0	0	0	0	5

This broad overlap among diets of shorebirds foraging in arctic littoral habitats appears to be the general rule. In most cases when more than 1 shorebird species was collected while foraging at the same time and place the mixture of prey found in the stomachs of all species was similar or identical (Connors and Risebrough 1976 and 1977; Connors et al 1981).

Another indication of the striking difference in importance of the southern Chukchi and Beaufort coastal trophic systems can be seen by comparing diets of all shorebirds collected during 1975 through 1977. At Barrow and Lonely on the Beaufort coast, 20 of 84 specimens (24% of shorebirds collected) had 70% or more of their stomach contents consisting of chironomid flies or larvae. Comparative figures for Wales, Cape Krusenstern, and Sisualik are 40 of 54 specimens (74%). Of course, samples of this type are inevitably biased due to the habitats sampled for shorebirds. Nonetheless, these results correspond with the bird habitat use data discussed earlier in this report and indicate in a rough way the relative importance of insects vs. marine zooplankton between the 2 regions.

Oil Development Effects Through Trophic Systems.

These differences between trophic systems may be important in determining the extent of effects on shorebirds produced by oil development disturbances. An oil slick along Beaufort gravel beaches in late summer will likely have an immediate and powerful adverse effect on large numbers of Phalaropes (Red and Northern) and a lesser effect on several other species of beach foraging shorebirds. The same oil slick along the beaches of the southern Chukchi in August would have a much reduced initial effect. Furthermore, after removal or precipitation of the oil, zooplankton communities, which are associated with the water column, may recover quickly, providing adequate foraging for shorebirds in the following season. In contrast, pollution of saltmarsh, mudflats, and brackish pools caused by on-site development or by oil slicks carried by storm surges may affect the prey densities of benthic infauna for several seasons to come. The prey base in these habitats may not recover quickly, and oil spills will therefore have a many season affect on shorebirds foraging in these habitats.

The initial, direct effect of an oil spill, however, is likely to be less severe in saltmarsh habitats because of differences in foraging modes of many species. Shorebirds walking on mudflats and in saltmarshes will not have their plumage coated with oil as readily as Phalaropes swimming on oil covered waters. There may, however, be some direct contact effects since many of these species wade in shallow water to probe for invertebrates in the mud beneath the water. In any event, the numbers of shorebirds potentially affected by pollution in saltmarshes and mudflats in the southern Chukchi is greater than that along the Beaufort coast. Thus an oil spill or other environmental disturbance will affect different species depending on whether it occurs along gravel shorelines or in saltmarshes and sloughs and its effects will differ in degree and duration depending on whether they are direct (oiling of plumage) or indirect (through prey resource) and will also differ in the extent of shorebird populations affected in different regions of the coast.

V. CONCLUSIONS

Many of the detailed conclusions of our studies have been presented in the preceding section. We summarize here our rankings of relative sensitivity to oil development for species, habitats, and seasons.

Relative Sensitivity of Shorebird Species.

Connors et al (1981) classified the common Beaufort coast shorebirds with respect to each species' relative sensitivity to littoral zone disturbances associated with oil development. The principal disturbance considered in the assessment was the threat of oil spills along the coast, and the factors employed in making this assessment included primarily habitat use patterns of the various species. Primary weight was given to the relative use of tundra vs. littoral habitats but this was modified with information on type of littoral habitat, choice of foraging microhabitat within these habitats and individual species foraging methods and behaviors. In Table 12 we present a reclassification of the relative sensitivity of common species which applies to the southern Chukchi. The several changes in this table compared with that in Connors et al (1981) take into account differences in shorebird distributions and abundance between regions as well as the differences in habitat use and behavior described above.

Relative Sensitivity of Habitats.

Since the most effective method of managing bird populations is frequently the approach of managing habitat, Connors et al (1981) summarized their results in terms of the littoral habitats studied along the Beaufort coast. We repeat this classification in Table 13 since it applies equally well to the southern Chukchi coast, although the relative amounts of these habitats in the 2 areas differ.

Sensitive Seasons.

Shorebirds are present along the southern Chukchi coast from mid-May through early October. Peak numbers of shorebirds in littoral areas are probably reached during August, but densities in some littoral habitats are also high in early summer, in marked contrast to the relative absence of shorebirds from littoral areas during the same period at Beaufort sites. Most habitat disturbances, regardless of the time of initiation, will last through many seasons. Nevertheless, the winter period, when shorebirds are absent from the arctic, is also the period when these frozen habitats are least sensitive to alteration. We therefore recommend that, whenever possible, development take place during winter months.

Table 12. Relative sensitivity of common shorebirds to littoral zone disturbances on the southern Chukchi coast.

HIGH	MODERATE	LOW
Red Phalarope	Golden Plover	Common Snipe
Northern Phalarope	Western Sandpiper	Whimbrel
	Baird's Sandpiper	
	Pectoral Sandpiper	
	Dunlin	
	Long-billed Dowitcher	
	Bar-tailed Godwit	

Table 13. Relative sensitivity of arctic littoral habitats. (Listed in order of decreasing sensitivity).

1. Littoral mudflats and saltmarsh
2. Sloughs and small lagoons (water surface and shorelines)
    1. with broad muddy margins
    2. with narrow margins
3. Spits and barrier islands
4. Mainland shorelines with broad beaches
5. Mainland shorelines with narrow beaches

VI. APPENDIX

Birds of Cape Krusenstern, Alaska, 1977-78

The following list presents the status of bird species observed in the vicinity of Cape Krusenstern, Alaska (see map, Figure 1) in 1977 between 26 May and 7 September and in 1978 between 26 May and 4 September.

RB, rare breeder: 1 or 2 nests (or broods) located in one year.
CB, common breeder: 3 or more nests or territories located in one year.
PB, probable breeder: breeding suspected, but no nests located.
CM, common migrant: present on at least 5 days; at least 10 individuals.
V, visitor: includes less common migrants and stragglers.
*: nested near Krusenstern Lagoon on Ingitakalik Mountain

The second column lists additional species reported as nesting occasionally at Cape Krusenstern in other years (W.R. Uhl and C.K. Uhl 1977).

	1977-78 Status	Additional breeders Other years (Uhl 1977)
Common Loon, *Gavia immer*	V	
Yellow-billed Loon, *G. adamsii*	V	
Arctic Loon, *G. arctica*	CB	
Red-throated Loon, *G. stellata*	CB	
Horned Grebe, *Podiceps auritus*	V	
Red-necked Grebe, *P. grisegena*	V	X
Pelagic Cormorant, *Phalacrocorax pelagicus*	V	
Whistling Swan, *Olor columbianus*	RB	
Canada Goose, *Branta canadensis*	CM	X
Brant, *B. bernicla*	CM	X
Emperor Goose, *Philacte canagica*	V	
White-fronted Goose, *Anser albifrons*	CM	X
Snow Goose, *Chen caerulescens*	CM	
Mallard, *Anas platyrhynchos*	CM	X
Pintail, *A. acuta*	CB	
Green-winged Teal, *A. crecca*	CM	X
American Wigeon, *A. americana*	CM	

Northern Shoveler, *A. clypeata*	CM	
Redhead, *Aythya americana*	V	
Ring-necked Duck, *A. collaris*	V	
Canvasback, *A. valisineria*	RB,CM	
Greater Scaup, *A. marila*	CB	
Oldsquaw, *Clangula hyemalis*	CB	
Harlequin Duck, *Histrionicus histrionicus*	V	
Steller's Eider, *Polysticta stelleri*	V	
Common Eider, *Somateria mollissima*	CB	
King Eider, *Somateria spectabilis*	V	
Spectacled Eider, *S. fischeri*	V	
White-winged Scoter, *Melanitta deglandi*	CM	
Surf Scoter, *M. perspicillata*	CM	
Black Scoter, *M. nigra*	V	X
Red-breasted Merganser, *Mergus serrator*	CM I	X
Osprey, *Pandion haliaetus*	V	
Sharp-shinned Hawk, *Accipiter striatus*	V	
Red-tailed Hawk, *Buteo jamaicensis*	V	
Rough-legged Hawk, *B. lagopus*	V*	
Marsh Hawk, *Circus cyaneus*	CM	X
Gyrfalcon, *Falco rusticolus*	V	
Peregrine Falcon, *F. peregrinus*	V*	
Willow Ptarmigan, *Lagopus lagopus*	CB	
Sandhill Crane, *Grus canadensis*	CB	
Semipalmated Plovers, *Charadrius semipalmatus*	RB	
Killdeer, *C. vociferus*	V	
American Golden Plover, *Pluvialis dominica*	CB	
Black-bellied Plover, *P. squatarola*	RB	
Ruddy Turnstone, *Arenaria interpres*	V	
Black Turnstone, *A. melanocephala*	CM	
Common Snipe, *Capella gallinago*	CB	
Whimbrel, *Numenius phaeopus*	RB,CM	
Bristle-thighed Curlew, *N. tahitiensis*	V	
Wandering Tattler, *Heteroscelus incanus*	V	
Red Knot, *Calidris canutus*	CM	
Rock Sandpiper, *C. ptilocnemis*	V	
Sharp-tailed Sandpiper, *C. acuminata*	V	
Pectoral Sandpiper, *C. melanotos*	RB,CM	

Baird's Sandpiper, *C. bairdii*	RB	
Least Sandpiper, *C. minutilla*	V	
Rufous-necked Sandpiper, *C. ruficollis*	V	
Dunlin, *C. alpina*	CB	
Sanderling, *C. alba*	CM	
Semipalmated Sandpiper, *C. pusilla*	CB	
Western Sandpiper, *C. mauri*	CB	
Stilt Sandpiper, *Micropalama himantopus*	V	
Buff-breasted Sandpiper, *Tryngites subruficollis*	CM	
Long-billed Dowitcher, *Limnodromus scolopaceus*	CB	
Bar-tailed Godwit, *Limosa lapponica*	PB,CM	
Hudsonian Godwit, *L. haemastica*	V	
Red Phalarope, *Phalaropus fulicarius*	CM	
Northern Phalarope, *Lobipes lobatus*	CB	
Pomarine Jaeger, *Stercorarius pomarinus*	CM	
Parasitic jaeger, *S. parasiticus*	CM	
Long-tailed Jaeger, *S. longicaudus*	PB,CM	X
Glaucous Gull, *Larus hyperboreus*	CB	
Glaucous-winged Gull, *L. glaucescens*	V	
Herring Gull, *L. argentatus*	V	
Thayer's Gull, *L. thayeri*	V	
Mew Gull, *L. canus*	PB,CM	X
Black-legged Kittiwake, *Rissa tridactyla*	CM	
Sabine's Gull, *Xema sabini*	CM	
Arctic Tern, *Sterna paradisaea*	CB	
Aleutian Tern, *S. aleutica*	CB	
Common Murre, *Uria aalge*)	CM	
Thick-billed Murre, *U. lomvia*)		
Black Guillemot, *Cepphus grylle*	V	
Horned Puffin, *Fratercula corniculata*	V	
Snowy Owl, *Nyctea scandiaca*	V	
Short-eared Owl, *Asio flammeus*	V	X
Common Flicker, *Colaptes auratus*	V	
Eastern Kingbird, *Tyrannus tyrannus*	V	
Say's Phoebe, *Sayornis saya*	V*	
Horned Lark, *Eremophila alpestris*	V*	

Tree Swallow, *Iridoprocne bicolor*	RB
Bank Swallow, *Hirundo rustica*	V
Cliff Swallow, *Petrochelidon pyrrhonota*	V
Common Raven, *Corvus corax*	CM*
Gray-headed Chickadee, *Parus cinctus*	V
Swainson's Thrush, *Catharus ustulatus*	V
Gray-cheeked Thrush, *C. minimus*	V
Wheatear, *Oenanthe oenanthe*	CM
Bluethroat, *Luscinia svecica*	V
Arctic Warbler, *Phylloscopus borealis*	V
White Wagtail, *Motacilla alba*	V
Yellow Wagtail, *M. flava*	CB
Water Pipit, *Anthus spinoletta*	V
Red-throated Pipit, *A. cervinus*	V
Yellow Warbler, *Dendroica petechia*	V
Wilson's Warbler, *Wilsonia pusilla*	V
Redpoll, *Acanthis* sp.	CB
Savannah Sparrow, *Passercula sandwichensis*	CB
Tree Sparrow, *Spizella arborea*	V
White-crowned Sparrow, *Zonotrichia leucophrys*	PB
Fox Sparrow, *Passerella iliaca*	V
Lapland Longspur, *Calcarius lapponicus*	CB
Snow Bunting, *Plectrophenax nivalis*	CM
Total species recorded, 1977-1978:	113

[1] Observed only in 1980.

VII. ACKNOWLEDGEMENTS

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REGIONAL PATTERNS
IN COASTAL SHOREBIRD COMMUNITIES
OF ARCTIC AND SUBARCTIC ALASKA

by

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INTRODUCTION

As a group, shorebirds (Charadriiformes: charadrii: sandpipers, plovers and their relatives) comprise a prominent and characteristic segment of the avifauna of arctic and subarctic tundra regions throughout the northern hemisphere. At most coastal tundra sites numbers of shorebird species and individuals exceed those of any other avian taxonomic group. Shorebirds nest on tundra, but frequently forage along beaches, in saltmarshes and on coastal mudflats, especially during migration. As a group they include many of the world's longest-distance migrants, with several species wintering in the southern hemisphere. The late summer period of heaviest shorebird activity in littoral habitats precedes the energetically demanding southward migration, and probably represents an interlude during which shorebird populations depend critically on resources in these coastal habitats.

Studies of shorebird nesting ecology, distribution and population densities have been conducted at many arctic sites in recent decades, and several studies have focused on ecology and movements in the littoral zone (see references by geographic region below). The following discussion will compare shorebird communities in littoral habitats from the western Canadian arctic to northeastern Siberia, extracting those features common to all regions and contrasting different regions in such factors as shorebird species composition, habitat availability, seasonal patterns of habitat use, trophic relationships and timing of movements. This exercise will point up the international nature of arctic shorebird communities and the resources on which they depend.

Shorebird communities in the Alaskan arctic and subarctic littoral zone: a general description.

The littoral zone can be defined in different ways, but for this report I shall consider all shoreline areas likely to be inundated by saline or brackish water at least once each year. Along the Beaufort coast normal lunar tides are very small, ranging over less than .25 m in most areas. Wind and atmospheric conditions can produce much larger storm tides, however, flooding low-lying areas. Those habitats subject to storm tides as frequently as every year support characteristic salt-tolerant marsh vegetation, or remain unvegetated. I consider these to be littoral zone habitats in contrast to freshwater tundra habitats above the normal flood zone. The more southern coasts of the Bering Sea have larger lunar tidal amplitudes which create a much wider primary littoral zone, but these coasts also are subject to storm flooding, creating an additional littoral (or near-littoral) zone which is salt-affected.

Shorebird use of arctic littoral habitats contrasts sharply in many respects with that of tundra habitats, where almost all species nest. In areas along the Beaufort coast, many shorelines are frozen and inaccessible to shorebirds in early summer. Activities during this period and throughout the incubation and chick-tending periods are centered on the tundra, where emerging insects, spiders and aquatic plankton provide the food source. A few species (for example, Semipalmated and Western Sandpipers) also forage along littoral sloughs and on mudflats near their nesting areas, and some species (Semipalmated Plover and occasionally Baird's Sandpiper) nest in near-littoral habitats, such as gravel beaches or gravel margins of sloughs. These exceptions, however, do not alter the general rule of much heavier use of tundra habitats during the early breeding season on the Beaufort coast. As the season progresses, two factors support a shift in shorebird activity into the littoral zone. Break-up of ice along lagoon and ocean shorelines increases the open littoral habitat, making new food sources available to foraging birds; second, as nesting activities proceed, one or both sexes of breeding birds are released from duties which had required their presence near tundra nest sites. These successful breeders join previously unsuccessful breeders along shorelines, and in late summer they are joined or replaced by fledged juveniles of many species.

The timing and magnitude of this habitat shift can be seen in Figure 1 for census transects near Barrow. The extremely high densities in late summer littoral habitats represent mainly juvenile Red Phalaropes, but a similar plot of all shorebirds except phalaropes shows the same seasonal shift, with August littoral densities approximately double the tundra densities. These patterns for the shorebird community as a whole are composites of many individual species patterns which vary in magnitude, precise timing and degree of the shift to the littoral zone.

Similar habitat shifts occur along subarctic coasts of the Bering Sea, but the season of littoral zone use is much longer, since habitats are used by some species during Spring migration, and the post-breeding period continues up to one month longer than in the arctic. In addition, several species forage to an important extent in near-littoral and littoral habitats during the breeding season in areas such as the Yukon Delta. Nevertheless, the season of heaviest shorebird use of littoral zone habitats is the post-breeding migration period in all the areas addressed in this report.

The principal prey resources in the arctic and subarctic littoral zone can be grouped broadly into two categories. Marine and estuarine zooplankton and epibenthic organisms (copepods, amphipods, euphausiids, decapod larvae, mysids, etc.) are important along ocean and lagoon shorelines, and adult and larval insects (principally fly larvae), small molluscs, and oligochaete worms provide essential resources in saltmarshes, on mudflats, and along the margins of sloughs. Zooplankton communities and densities are highly variable over time and space, but are frequently abundant, attracting principally Red and Northern Phalaropes and Sanderlings, as well as Ruddy Turnstones, Dunlins and several other shorebird species to a lesser extent. The benthic prey base of coastal mudflats and saltmarshes attracts larger numbers of Long-billed Dowitchers, Western and Semipalmated Sandpipers, and Dunlins, and almost all other species at least occasionally.

Along most of the Alaska Beaufort, Chukchi, and Bering coasts, the preceding description gives a general view of shorebird activity in the littoral zone. Several factors alter details of the picture at specific sites, however. Foremost among these are the distributional changes in local shorebird breeding communities and migratory patterns at different sites across the arctic, since these determine the species mix and relative abundances at each site. Across the Western Canadian and Alaskan arctic, many distributional changes follow a simple latitudinal or longitudinal gradient, but discontinuities in breeding distribution or

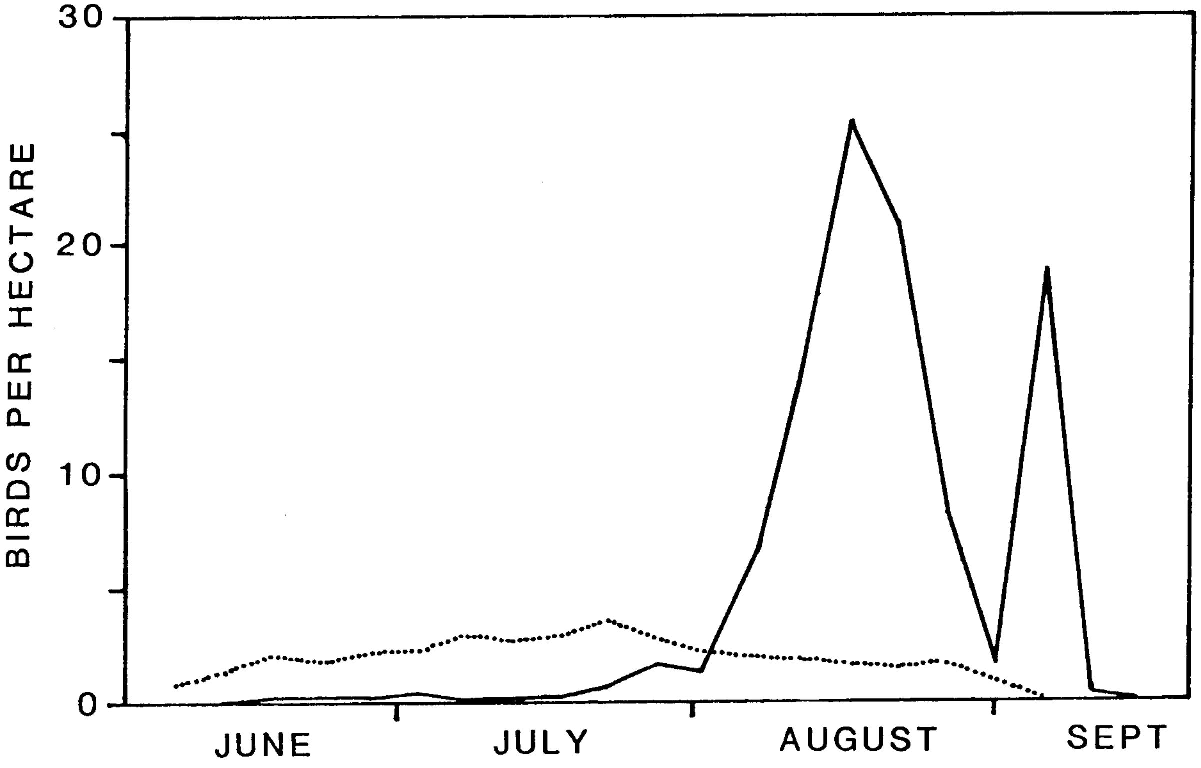

Figure 1. Seasonal changes in habitat use by shorebirds near Barrow, Alaska. Total shorebird densities on tundra (dotted line) compared to densities in littoral zone habitats (solid line). From Connors *et al.* 1981.

in migration routes complicate this. The mix of local habitats, especially of different littoral habitats, further affects the relative abundances and absolute numbers of shorebird species at different sites, by determining the availability of different types of prey and of foraging conditions. Finally, the phenology of events such as ice break-up and insect hatches in relation to migratory movements and nesting events determines the availability and attractiveness of littoral habitats in different coastal regions.

The remaining sections of this report summarize the shorebird littoral zone communities for 5 sections of coast from northwestern Canada to northeastern Siberia (see maps, figures 2,3, and 4). Breeding lists and relative abundances of littoral zone shorebirds are based on information in published references cited in each section. In some cases this has been supplemented with descriptions of broader area distribution (see Gabrielson and Lincoln 1959, Godfrey 1966, Kessel and Gibson 1978). In compiling these lists I have omitted all species which occur only rarely in the region addressed. This treatment is not intended to be exhaustive, but rather to summarize the prominent features of avian distribution and habitat use along each coast. Where species distributions are highly patchy I have tried to denote the average status across the region; where status changes markedly from one end of a region to the other, I have indicated the area and status where a species is most common. Contrasts or comparisons among sites are emphasized. This exercise is an attempt to define the major differences in shorebird littoral zone communities between areas, but it is unavoidably based on an inconsistent data base, since different studies focus on different topics at each site, and coverage of all coastal sections is neither equal nor continuous.

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REGIONAL DESCRIPTIONS OF COASTAL SHOREBIRD COMMUNITIES

Region B: Beaufort and Chukchi Coasts, Prudhoe Bay to Cape Lisburne.

The extensive arctic coastal plain north of the Brooks Range in Alaska reaches its widest and its northernmost point at Pt. Barrow (Figure 2). The Chukchi and Beaufort Sea coasts west and east of that point share many features of general geomorphology which provide similar littoral habitats of importance to shorebird populations. Areas of complex shorelines produced by spits, barrier islands, lagoons, sloughs and river deltas attract the highest density use, here as in other regions. Known concentration areas in late summer (primarily 15 July-5 September) include the islands, spits, mudflats and saltmarshes of Kasegaluk Lagoon, the spits and islands of Peard Bay, Point Barrow and the Plover Islands, the mudflats and saltmarshes of Fish Creek and Colville River Deltas, and the Simpson Lagoon area. During migration shorebirds occur in small patches of similar habitats distributed almost continuously along the coastline of the arctic coastal plain, but total numbers at most individual sites remain low compared to the main concentration areas. The principal feature which separates these sites is the total area or distance of suitable habitat available. Except at these locations, and possibly at some unstudied sites such as Dease Inlet or Smith Bay, areas of mudflat and saltmarsh are restricted in this region compared to areas farther south and west.

The mix of species characteristic of these locations varies in several ways. First, as described earlier, areas of spits and barrier islands typically attract phalaropes, turnstones, and Sanderlings preferentially, while mudflat-saltmarsh habitats support larger numbers of Long-billed Dowitchers, Dunlins, and several other species of sandpipers. (Arctic Terns, Black-legged Kittiwakes and Glaucous, Sabine's, and Ross' Gulls also congregate along spit and island shores.) Second, the distribution of breeding shorebirds varies over this region, so the mix of species in littoral habitats varies, primarily on an east-west gradient. Most noticeably, Western Sandpipers are a common breeding species on the coastal plain west of Barrow, and one of the conspicuous members of the littoral zone shorebird community in that area. East of Barrow they are rare or absent as breeders, and uncommon to rare as migrants. Stilt Sandpipers have a somewhat complementary distribution, breeding in eastern sections of the Alaska Beaufort coastal plain, but not near Barrow and westward, and occurring fairly commonly as migrants east of Barrow. Other species which are more common in eastern areas of this region include Black-bellied Plover and White-rumped Sandpiper. Red-necked Phalaropes are much more common near Prudhoe Bay than at Barrow,

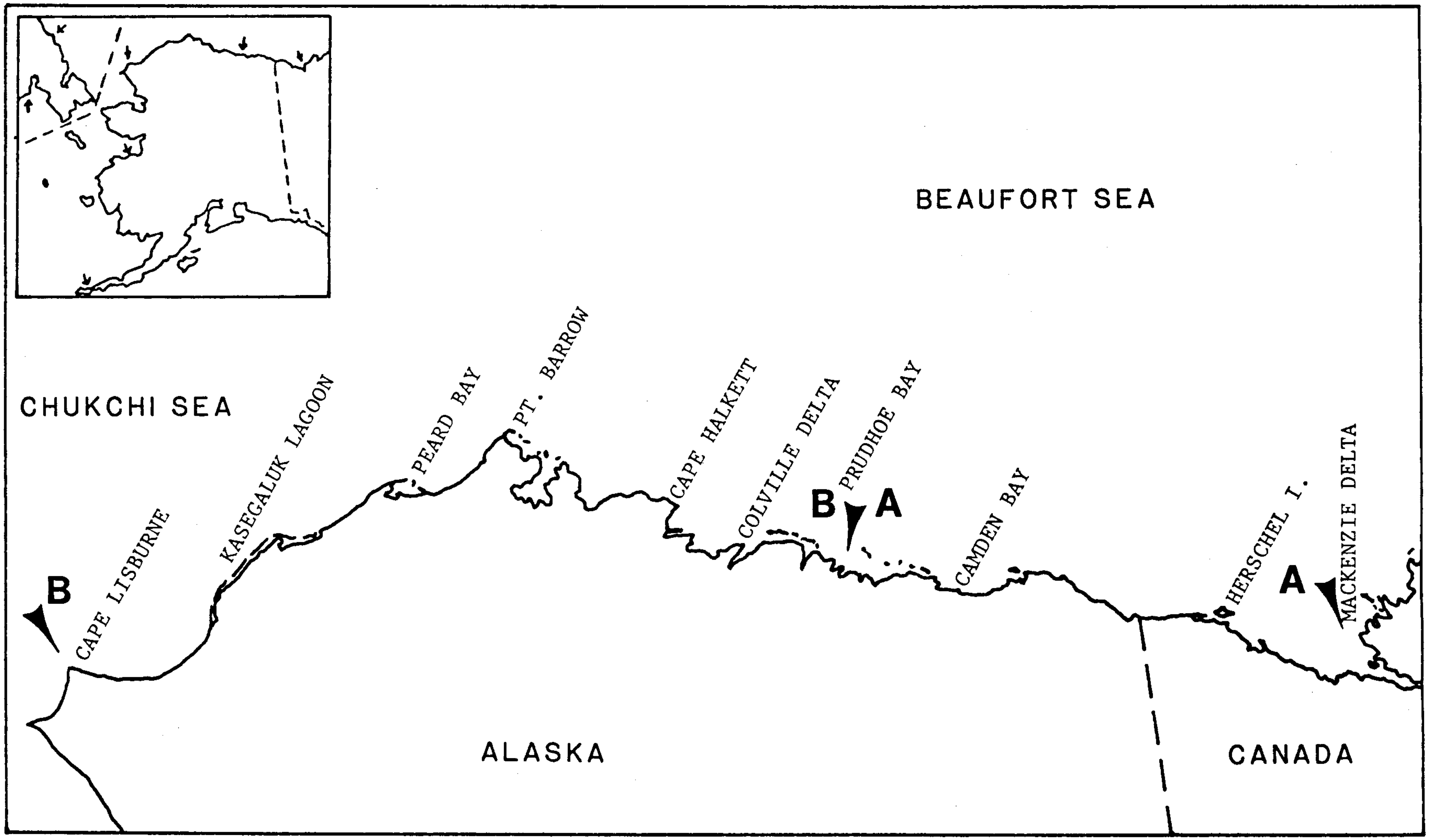

Figure 2. Coastal map of Regions A and B, Beaufort and Chukchi Seas.

Table 1. Status of shorebirds occurring regularly along the Region B coast. VC-very common; FC-fairly common; UC-uncommon; R-rare.

Species	Breeding June-July	Littoral Zone Migration July-Sept
Black-bellied Plover *Pluvialis squatarola*	FC	FC
Lesser Golden Plover *Pluvialis dominica*	VC	FC
Semipalmated Plover *Charadrius semipalmatus*	UC	UC
Whimbrel *Numenius phaeopus*	UC	R
Bar-tailed Godwit *Limosa lapponica*	R	UC
Ruddy Turnstone *Arenaria interpres*	VC	VC
Red Knot *Calidris canutus*	R west	UC
Sanderling *Calidris alba*	R	FC
Semipalmated Sandpiper *Calidris pusilla*	VC	VC
Western Sandpiper *Calidris mauri*	VC west	VC west
White-rumped Sandpiper *Calidris fuscicollis*	UC east	UC east
Baird's Sandpiper *Calidris bairdii*	FC	FC
Pectoral Sandpiper *Calidris melanotos*	VC	VC
Dunlin *Calidris alpina*	VC	VC
Stilt Sandpiper *Calidris himantopus*	FC east	FC east
Buff-breasted Sandpiper *Tryngites subruficollis*	FC east	R
Long-billed Dowitcher *Limnodromus scolopaceus*	FC	VC
Red-necked Phalarope *Phalaropus lobatus*	FC	VC
Red Phalarope *Phalaropus fulicaria*	VC	VC

but they may also occur in large migrant flocks at the western limits of this region, near Cape Lisburne (G. Divoky, pers. comm.). Several species, especially Lesser Golden Plover, Semipalmated, Baird's and Pectoral Sandpipers, Dunlin and Red Phalaropes are common throughout the region, both as breeders and migrants.

Densities of shorebirds nesting on coastal plain tundra or using littoral habitats during migration have been recorded at many sites within this region, as at Icy Cape, Peard Bay, Pt. Barrow, Atkasook, Cooper Island, Fish Creek, Simpson Lagoon, Pt. Storkersen, and Prudhoe Bay, as well as at several other sites visited only occasionally. Nesting densities of shorebirds averaged 66 territories per km^2 near Prudhoe Bay (Norton et al. 1975, Troy et al. 1983), 79 per km^2 near Barrow (Myers and Pitelka 1980) and 111 per km^2 near Atkasook, 100 km south of Barrow (Myers and Pitelka 1980). Densities of migrating shorebirds in late summer littoral habitats reach peak values much higher than these (above 100 birds per km of beach near Pt. Barrow (Connors et al. 1979), above 70 birds per km of barrier island beach at Simpson Lagoon (Johnson and Richardson 1981), and above 600 birds per km^2 of saltmarsh and mudflats on Fish Creek Delta (Connors et al. 1981). Mean densities throughout the late summer period are lower than these, however. During migration peaks, flocks of phalaropes, the most numerous shorebirds migrating along shorelines in the region, sometimes number several thousand birds at Point Barrow and at other spits and barrier islands.

The references listed below give a general indication of the effort which has been directed to studies of arctic coastal plain birds, shorebirds in particular, and also indicate the geographic distribution of those studies. The extensive coast has not yet been covered sufficiently to be confident that all important littoral areas and potential concentration areas are known.

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Region A: Beaufort Coast from Prudhoe Bay to the Mackenzie Delta.

The arctic coastal plain is narrower in this region compared with Region B, and the closer approach of the Brooks Range to the Beaufort Sea produces well-drained tundra with generally lower nesting densities of the shorebirds which are most abundant nearer Barrow. Deltas of numerous small rivers, spits, barrier islands, occasional areas of saltmarsh or flooded tundra provide littoral habitats used by migrating birds. Study coverage is patchy, but reports are available for several sites on both the Alaskan and Canadian portions of this region (Figure 2).

The geographic trends in bird distribution evident in Table 1 are continued in Table 2, with Western Sandpipers present only as rare migrants, and eastern species (Stilt Sandpiper, Buff-breasted Sandpiper) fairly common. Northern Phalaropes are common nesting species in this region in contrast to their scarcity in the western Beaufort, and they are abundant coastal migrants. Red Phalaropes continue as common breeders near the coast throughout both regions, but with densities declining in the east. As migrants, however, they are much more common in the west. This shift in relative abundance is apparent in the ratios of the two species counted at several points along the Beaufort coast (Table 3). Dunlins, one of the consistently common breeding species along the Alaskan coast from the Bering Sea north and east along most of the Alaskan Beaufort coast, is absent or rare as a breeder near Demarcation Point and along the Yukon coast, although it occurs in these areas uncommonly as a migrant.

Locations of site studies for area A are mentioned below in the list of references. Concentration areas of late summer migrant shorebirds probably correspond with areas of the more extensive littoral wetlands, spits, and barrier islands. Herschel Island is of particular significance for phalaropes (Vermeer and Anweiler 1975).

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Table 2. Status of shorebirds occurring regularly along the coast of Region A. Symbols as in Table 1.

Species	Breeding June-July	Littoral Zone Migration July-Sept
Black-bellied Plover	UC	FC
Lesser Golden Plover	VC	FC
Semipalmated Plover	UC	UC
Whimbrel	--	UC
Ruddy Turnstone	FC	FC
Sanderling	--	FC
Semipalmated Sandpiper	VC	VC
Western Sandpiper	--	UC west
White-rumped Sandpiper	UC west	UC west
Baird's Sandpiper	FC	FC
Pectoral Sandpiper	VC	FC
Dunlin	FC west	FC west
Stilt Sandpiper	FC	FC
Buff-breasted Sandpiper	FC	UC
Long-billed Dowitcher	UC	VC
Common Snipe _Gallinago gallinago_	UC east	R
Red-necked Phalarope	VC	VC
Red Phalarope	VC	FC

Table 3. Ratios of Red Phalaropes: Red-necked Phalaropes in late summer migrant foraging flocks along the Beaufort Coast.

Barrow, Alaska 156°30'W	30:1	Connors et al. (1981)
Simpson Lagoon, Alaska 149°30'W	4:1	Johnson and Richardson (1981)
Nunaluk Spit, Canada 139°40'W	1:20	Salter et al. (1980)
Herschel Island, Canada 139°10'W	1:40	Vermeer and Anweiler (1975)

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Region C: Bering and Chukchi coasts, Cape Lisburne to Norton Sound.

This coastal region is more varied in shoreline environments than is the Beaufort coast because of the greater latitudinal range, variation in coastal topography from rocky cliff headlands to coastal plains and lagoons, and the much greater range of summer ice conditions (Figure 3). Mainland rock cliffs, especially at Cape Lisburne and Cape Thompson, provide nesting habitats for large numbers of seabirds but the resultant lack of coastal wetlands in these areas makes them underutilized by shorebirds. Coastal lowland tundra nesting areas are not as extensive as on the North Slope arctic coastal plain, and the more prevalent upland tundra supports generally lower shorebird nesting densities. At some sites with wet tundra areas, however, densities are high. Shorebird nesting densities have been measured at only 47 nests/km^2 at Cape Krusenstern (Connors and Connors, 1978), but at 62 to 336 nests/km^2 at Cape Espenberg (Schamel et. al. 1979), 129 nests/km^2 near Shishmaref (Wright 1979), 100 nests/km^2 at Wales (Hirsch and Woodby 1978), and 109 to 160 nests/ km near the Akulik-Inglutalik river delta in Norton Sound (Shields and Peyton 1979). High nesting densities have also been recorded in other areas of coastal wetlands around Norton Sound (Woodby and Divoky 1983). The most common species at most of these sites are Red-necked Phalarope, Western and Semipalmated Sandpipers, and Dunlin.

Spits and barrier islands are less prominent and less heavily used by post-breeding phalaropes, Sanderlings, and Ruddy Turnstones in this region compared with the Beaufort coast. Mudflat and saltmarsh habitats are much more extensive here, however, and large numbers of several species of shorebirds, especially Semipalmated, Western and Pectoral Sandpipers, Dunlin and Long- billed Dowitchers forage in these areas in late summer. Major areas of these littoral habitats occur in Kotzebue Sound, expecially the Noatak Delta, on the north shore of Seward Peninsula, and in inner Norton Sound. Densities of migrant shorebirds on 10 coastal wetlands around Norton Sound averaged over 250 birds/km^2, with migration peaks of individual species totaling much higher (Woodby and Divoky 1983). Between these important wetlands, however, coastal beaches backed by well-drained tundra are little used by post-breeding shorebirds (Connors and Connors 1982, Woodby and Divoky 1983).

Species distributions in Region C show several contrasts with the two northern regions (Table 4). Several species seldom seen on the arctic coastal plain are regular breeders or migrants in this region, occurring over wide areas or only locally (Black Turnstone, Sharp-tailed Sandpiper, Common Snipe, Rock Sandpiper, Hudsonian Godwit, Lesser Yellowlegs). A few of the most common arctic species are local or much less common here (Ruddy Turnstone, Red Phalarope, breeding Pectoral Sandpiper). The more

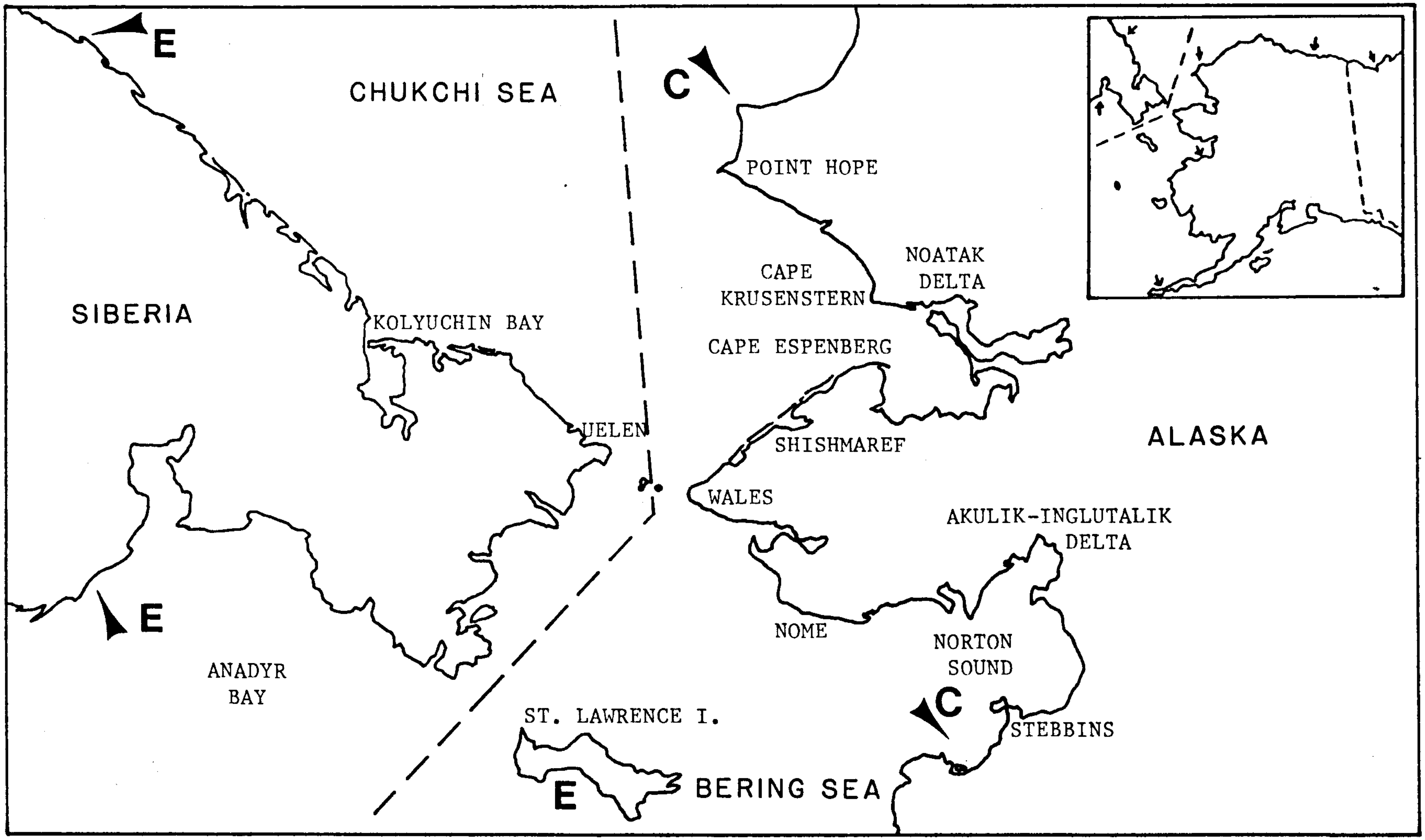

Figure 3. Coastal map of Regions C and E, Bering and Chukchi Seas.

Table 4. Status of shorebirds occurring regularly along the coast of Region C. Symbols as in Table 1.

Species	Breeding June-July	Littoral Zone Migration July-Sept
Black-bellied Plover	UC	UC
Lesser Golden Plover	VC	VC
Semipalmated Plover	UC	UC
Lesser Yellowlegs *Tringa flavipes*	R south	UC south
Whimbrel	UC	UC
Hudsonian Godwit *Limosa haemastica*	*	UC south
Bar-tailed Godwit	UC	FC
Ruddy Turnstone	UC	UC
Black Turnstone *Arenaria melanocephala*	FC south	FC south
Red Knot	R	UC
Sanderling	--	UC
Semipalmated Sandpiper	VC	VC
Western Sandpiper	VC	VC
Baird's Sandpiper	UC	UC
Pectoral Sandpiper	UC	FC
Sharp-tailed Sandpiper *Calidris acuminata*	--	UC south
Rock Sandpiper *Calidris ptilocnemis*	UC south	UC south
Dunlin	VC	VC
Long-billed Dowitcher	FC	VC
Common Snipe	FC	UC
Red-necked Phalarope	VC	VC
Red Phalarope	FC	FC

* Breeding status uncertain

eastern arctic species (White-rumped Sandpiper and Stilt Sandpiper) are rarely seen. Western Sandpipers, however, are one of the most common nesting species throughout the region, as are Red-necked Phalaropes in suitable habitat. Finally, whereas almost all golden plovers on the arctic coastal plain are the American form (Pluvialis dominica dominica), the Pacific form (P. d. fulva) is somewhat more common as a nesting species in this region and is much more common as a littoral zone migrant (Connors 1983). Some of the juvenile Pacific Golden Plovers foraging in littoral areas of this region in August may have been produced in Siberia, as is certainly the case for the Sharp-tailed Sandpipers seen fairly commonly during late summer.

Several concentration areas have been identified for post-breeding migrant shorebirds. These include the mudflats and saltmarshes of Kotzebue Sound (Noatak Delta and Cape Espenberg), the 160 km long lagoon system on the north shore of Seward Peninsula, and several Norton Sound wetlands, especially those at Stebbins and Safety Lagoon. Some areas, such as southern Kotzebue Sound and Pt. Hope have not been studied sufficiently to judge their importance.

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Region D: Bering Sea Coast, Yukon Delta to Alaska Peninsula.

In terms of total numbers of shorebirds using arctic or subarctic littoral habitats in Alaska, the Yukon Delta and southern Bering Sea coast (Figure 4) unarguably comprise the region of highest activity. Shorebird numbers total in the millions in these areas, distinguishing this region on a global as well as Alaskan perspective. The extensive littoral habitats of the Yukon River delta stand out in importance, as well as the lagoons of the Alaska Peninsula. The entire area has been discussed comprehensively by Gill and Handel (1981), and their work will be only summarized here.

This region differs importantly from more northern regions in several respects. First, as already mentioned, it differs strikingly by the sheer area of favored littoral habitats and the vast numbers of shorebirds using them. Densities of post-breeding shorebirds in Yukon Delta littoral habitats average appreciably higher in late summer than at other sites (Table 5), but the total area of littoral habitat probably differs by a much greater factor. The resultant difference in population size may be an order of magnitude for many common species (Gill and Handel 1981). Only the lagoon habitats of the north shore of Seward Peninsula, because of their relatively high shorebird densities and large area, can begin to compare with the Yukon Delta from this viewpoint (Connors and Connors 1982). Second, the season of shorebird activity in littoral habitats is greater than along the Beaufort and Chukchi coasts largely because of differences in seasonal ice conditions. Shoreline habitats are more widely available and therefore more frequently used by spring migrant shorebirds in this region. Although much of the area is still ice-bound in May, shoreline areas of Bristol Bay and the mouths of rivers are open to migrants of several species, and open nearshore waters are used by phalaropes (Gill and Handel 1981). During the nesting season, littoral habitats are used to a limited extent by shorebirds nesting on the low-lying coastal tundra. Some of this nesting tundra is near-littoral, occasionally flooded by storm tides during the late summer and fall. After nesting, adults and juveniles of many species shift to littoral habitats here as elsewhere in the arctic and subarctic, but the period of post-breeding staging lasts considerably longer than at more northern sites. From Canada to Bering Strait, the main shorebird littoral zone season extends from mid or late July to late August or early September, but at the Yukon Delta and Nelson Lagoon it begins at the same time but lasts at least one month longer (Table 5). This implies longer residency by individual birds during migration, and probably an increased dependence of the Alaska population on fewer sites during the late period. For some sites within Region D, the shorebird littoral zone season even

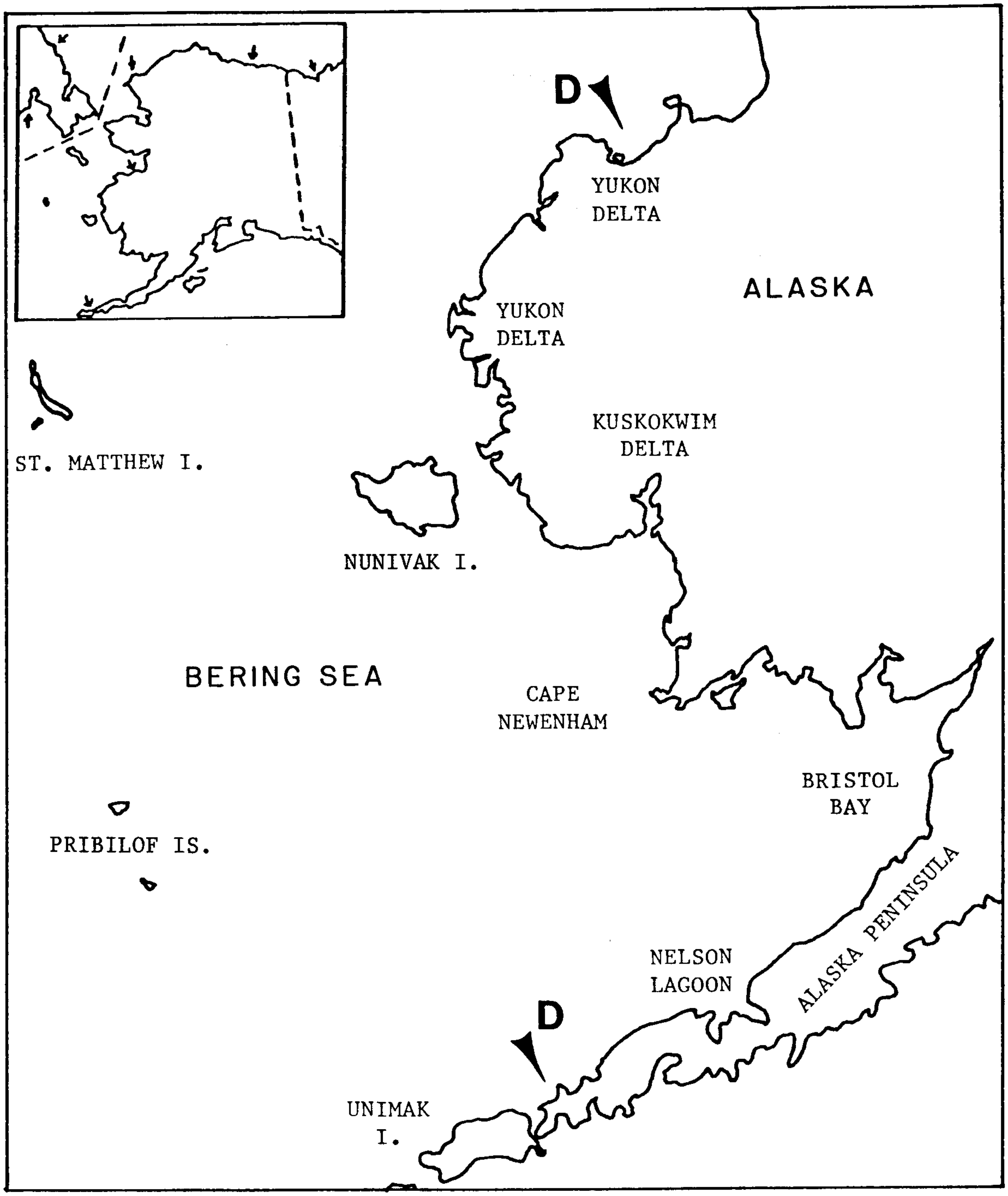

Figure 4. Coastal map of Region D, Bering Sea.

Table 5. Mean densities of post-breeding shorebirds using littoral habitats at several Alaskan sites.

Location	Major Post-breeding Period	Mean Density, Birds/ha	Reference
Canning River Delta, Region A	late July to early Sept	1.6	Martin and Moiteret 1981
Barrow, Region B	late July to early Sept	9.8*	Connors et al. 1979
Cape Krusenstern, Region C	mid July to late August	3.1	Connors and Connors 1982
Wales, Region C	late July to early Sept	3.3	Connors and Connors 1982
Yukon River Delta, Region D	late July to early Oct	10.6	Gill and Handel 1981
Nelson Lagoon, Region D	mid July to early Oct	6.6	Gill and Handel 1981

* 88% of counted shorebirds were phalaropes; density of all other shorebirds was only 1.2 birds per ha.

Table 6. Status of shorebirds occurring regularly along the coast of Region D. Symbols as in Table 1.

Species	Breeding June-July	Littoral Zone Migration July-Sept
Black-bellied Plover	FC	FC
Lesser Golden Plover	FC	FC
Semipalmated Plover	UC	UC
Greater Yellowlegs *Tringa melanoleuca*	*	FC south
Lesser Yellowlegs	*	UC
Wandering Tattler *Heteroscelus incanus*	*	UC
Whimbrel	UC	UC
Bristle-thighed Curlew *Numenius tahitiensis*	*	R
Hudsonian Godwit	--	UC
Bar-tailed Godwit	FC	VC
Ruddy Turnstone	UC	FC
Red Knot	--	VC north
Sanderling	--	FC
Semipalmated Sandpiper	FC north	FC north
Western Sandpiper	VC	VC
Least Sandpiper *Calidris minutilla*	*	UC
Pectoral Sandpiper	UC	UC
Sharp-tailed Sandpiper	--	FC
Rock Sandpiper	UC	VC
Dunlin	VC	VC
Short-billed Dowitcher *Limnodromus griseus*	UC south	VC south
Long-billed Dowitcher	UC north	FC
Common Snipe	FC	R
Red-necked Phalarope	FC	VC
Red Phalarope	FC	VC

* Breeding status uncertain

extends through the winter, clearly distinguishing this situation from areas farther north. Such shorebird use is not extensive however, being limited to occasional Rock Sandpipers and Sanderlings in ice-free areas of Bristol Bay (Gill and Handel 1981).

Another difference in the shorebird littoral zone community concerns the diversity of species involved, several of which are regular migrants at sites within this region, but rare or absent at sites farther north and east (Table 6). A few of the most abundant species (Dunlin, Western Sandpiper, Northern Phalarope) are also common in other regions; several (Hudsonian Godwit, Black Turnstone, Red Knot, Sharp-tailed Sandpiper, Rock Sandpiper) only occur regularly in one of the previously discussed regions, or are much more common in this region; a few (Greater Yellowlegs, Wandering Tattler, Least Sandpiper, Short-billed Dowitcher) are not sufficiently regular to be mentioned in discussions of other regions. The net result is a total species list which is longer for Region D than for the other Alaskan regions discussed.

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Region E: Northeastern Siberia, Bering and Chukchi Coasts.

Much less information is available to describe the littoral zone activities of migrant shorebirds along Siberian coasts. In particular, assessments of the relative importance of different coastal sites are difficult to make, but it is possible to compile a list of all common species breeding along the coasts of northeastern Siberia, together with estimates of the degree of their use of littoral zone habitats in late summer (Table 7). This information was taken principally from Portenko (1972), supplemented with other references listed below.

Published descriptions indicate, not surprisingly, that breeding and post-breeding habitats in Siberia are similar to the habitats used by each species in Alaska. Phenology of nesting and migration staging is also quite similar to that of Alaska, especially of Region C.

Table 7 clearly establishes one central fact: much of the Siberian shorebird community is continuous with the communities of western and northern Alaska. A few distinctly Siberian species (Common Ringed Plover, Rufous-necked Stint, Spoonbill Sandpiper) are rare or absent on Alaskan shores, but all other common breeders in Siberia occur regularly in Alaska. Furthermore, several species breed on one continent in populations which migrate along the shore of the other continent, as discussed further in the final section of this report.

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Table 7. Status of shorebirds occurring regularly along the coast of Region E. Symbols as in Table 1.

Species	Breeding June-July	Littoral Zone Migration July-Sept
Black-bellied Plover	FC	*
Lesser Golden Plover	FC	FC
Mongolian Plover *Charadrius mongolus*	UC	*
Common Ringed Plover *Charadrius hiaticula*	FC	FC
Eurasian Dotterel *Charadrius morinellus*	UC	*
Wandering Tattler	UC	UC
Bar-tailed Godwit	*	UC
Ruddy Turnstone	FC	FC
Red Knot	--	UC
Western Sandpiper	FC	FC
Rufous-necked Stint *Calidris ruficollis*	FC	*
Temminck's Stint *Calidris temminckii*	UC	*
Baird's Sandpiper	UC	*
Pectoral Sandpiper	FC	FC
Sharp-tailed Sandpiper	--	UC
Rock Sandpiper	FC	FC
Dunlin	VC	VC
Spoonbill Sandpiper *Eurynorhynchus pygmeus*	FC	*
Long-billed Dowitcher	FC	*
Common Snipe	FC	*
Red-necked Phalarope	FC	VC
Red Phalarope	FC	VC

* Status uncertain

DISCUSSION

This presentation of Alaskan, Canadian, and Siberian shorebird communities has spanned a range from 136° West to 180° West longitude and from 55° North to almost 72° North latitude, including shores of the Bering, Chukchi and Beaufort Seas. Such an enormous range forces our discussion to gloss over details, often ignoring smaller scale distinctions in order to search for the major trends and patterns. Several of these patterns have emerged, a number of which deal with geographic distributions of shorebird species.

First, and not surprisingly, shorebird communities vary across the regions as individual species abundances change. Species breeding distributions range from those wholly contained within part of these regions (for example, Black Turnstone) to those breeding only in the south (Short-billed Dowitcher), north (Sanderling), east (Stilt Sandpiper) or west (Spoonbill Sandpiper), but many species have distributions which include all the regions considered (for example, Lesser Golden Plover and Pectoral Sandpiper) and several species are circumpolar in distribution (Black-bellied Plover, Sanderling, both phalaropes).

Migrational distributions often overlap the more limited breeding distributions, but a similar range of littoral zone migrant distributions can be discerned, which likewise combine to produce regional differences in the potential littoral zone shorebird communities. Superimposed on these distributional limitations are species habitat preferences which determine the degree to which a species present within a region actually uses the littoral zone. Phenology of breeding and of migratory movements also plays an important role, since some species or cohorts of species either leave breeding grounds early, before chicks hatch (for example, adult female phalaropes) or migrate suddenly after breeding (Baird's Sandpipers). This limits the species' involvement in littoral habitats in two ways, by removing birds from the arctic while northern shoreline habitats are still ice-bound and by reducing the period of littoral zone occupancy when these habitats are available. Some species, in contrast, migrate very slowly (for example, Dunlin) remaining in arctic littoral habitats until early September and in subarctic areas into October.

Except for small numbers of two species which remain in the southern Bering Sea, all shorebirds migrate from these regions before winter begins. As a group, shorebirds are the longest-distance migrants among the world's birds. Of the species which occur commonly in the Alaskan arctic and subarctic each summer (Tables 1,2,4,6), 21 (of 25 species total) include the southern hemisphere as a major part of their wintering ranges; 15 of 25 regularly winter as far south as southern South America or Australia. Only one species (Rock Sandpiper) winters exclusively north of Mexico. Furthermore, these migrations are not confined to the western hemisphere. At least four species are known to migrate from Alaska to wintering areas in Asia, Australia, or the central Pacific Islands, and several species with widespread breeding and wintering areas may include populations which move westward as they migrate southward. The clearest examples of westward migrations between hemispheres consist of species or subspecies whose winter ranges do not include North or South America. Bar-tailed Godwits, the Pacific form of Lesser Golden Plover (Pluvialis dominica fulva) and the Siberian subspecies of Dunlin (Calidris alpina sakhalina) all breed in Alaska but winter only west of the Americas. Sharp-tailed Sandpipers perform an even stranger trans-Bering Sea migration, with juveniles born in Siberia foraging along Alaskan coasts in regions C and D before crossing back to winter in Micronesia and Australia. The explanation for this surprising pathway may lie in a greater availability of rich littoral zone feeding areas in Alaska compared with Siberian shores, but detailed habitat descriptions for the Siberian sea coasts are lacking. A few shorebird species (as well as Snow Geese and Sandhill Cranes) are known to perform an alternative migration across the Bering Strait area. Long-billed Dowitchers, Western Sandpipers, Baird's Sandpipers and Pectoral Sandpipers all nest in western Siberia but winter only in the Americas. This annual shifting of shorebird populations between hemispheres, east and west, north and south, creates a global aspect to questions of evolution, and a broad international aspect to questions of conservation or management of Alaska's shorebirds.

Examining these distributional patterns among the five regions we have been discussing, we can make several comparisons. The largest number of species occurring regularly in littoral zone habitats is to be found in Region D, with 26 species, compared with 18 to 22 species in other regions. The additional species are the more southerly birds which do not occur in the arctic; most arctic species also occur here, at least in migration. We can explore the similarity among regional shorebird littoral zone communities by comparing lists of core species, those species listed as Fairly Common or Very Common across each region. These core species lists can be constructed from Tables 1, 2, 4, 6, and 7, with some uncertainty for species of questionable status in Table 7. Similarities between regional lists of core species (number of species occurring on both lists divided by total number of species in two regions) are presented in Table 8. These similarity values can be placed in three groups. The only high similarity (>.70) pair is regions A and B, at similar latitude along the Beaufort coast. The three Chukchi coast regions (BC, BE, and CE pairs) form a moderate similarity group, and the remaining pairs, consisting of the southern Bering region D with A, B, C,

Table 8. Similarity coefficients between regions in shorebird littoral zone core species lists.

Region	A	B	C	D	E
A	1.0	.77	.43	.37	.33-.41
B	----	1.0	.57	.50	.50-.56
C	----	----	1.0	.41	.50-.55
D	----	----	----	1.0	.41-.47
E	----	----	----	----	1.0
Mean similarity with other regions	.49	.59	.49	.43	.47

and E and the eastern Beaufort region A with C, D, and E form the lowest similarity group. Region B has the highest average similarity and Region D has the lowest. The main trends seem to be the general similarity of migrant shorebird communities across large expanses of arctic coast, even across Bering Strait, and the somewhat lower similarity as new species are introduced in subarctic regions.

In all Alaska regions some species are more common as littoral zone migrants than they are as tundra breeders within the region. Likewise there are more species listed as fairly common or very common in the littoral zone than as fairly common or very common breeders in each of the Alaska regions. This difference is greatest in Region D, the Bering Sea coast, with 15 common migrants and only 10 common breeding species. Such a pattern emphasizes the potential for widespread effects on bird populations arising from localized disturbances. It is one of the reasons that the population effects of littoral zone disturbances are more difficult to estimate than the effects of disturbances on breeding areas. Another reason arises from the transient nature of migration use of littoral habitats. Censuses of migrant shorebirds in the littoral zone at dozens of Alaska coastal sites have been obtained over the last decade, but in almost no cases do we know the turnover rates associated with birds foraging in these areas. If individual birds remain for only short periods at a site, the total number of birds migrating through an area over a period of several weeks can be much greater than the population censused at any one time. Neither do we know the number of sites at which an individual bird may stop as it migrates from the arctic southward to wintering grounds. Both these factors have an important bearing on the problem of estimating population effects of habitat disturbances in the littoral zone. A correlary question concerns the amount of redundancy required in the location of foraging habitats within a region. How flexible are migrant shorebirds about finding alternative foraging areas when a favored area is unavailable? This question opens complex issues of food limitation, competition, energetics of migration, and relative habitat values, and is not an easy one to answer. We cannot, however, assume that all birds will be lost if habitat used by those birds is lost, and neither can we assume that such mobile animals can always go somewhere else to feed.

The shorebird community at any site is composed of species which differ in the several factors which determine a species' sensitivity to oil development effects. They range from phalaropes, which swim on the water's surface, vulnerable to spilled oil films, to upland foraging species like Bristle-thighed Curlew and Buff-breasted Sandpiper, and from localized world populations (Black Turnstone, Bristle-thighed Curlew) to species with circumpolar distributions (Black-bellied Plover, Sanderling). Factors which affect the individual's sensitivity revolve around habitat use, seasonality of movements, trophics, and foraging behaviors. These have been discussed elsewhere (Connors et. al 1979), and have been used to assign relative sensitivities of Barrow shorebirds to oil development. Additional factors which govern population vulnerability concern the numbers of birds exposed at a site compared with local, regional and worldwide populations. These factors have been included in an assessment of relative susceptibility of Bering seacoast shorebirds by Gill and Handel (1981).

This report has described the major shorebird littoral zone concentration areas within each region. Viewing the entire Bering, Chukchi and Beaufort coasts of Alaska, the outstanding area in terms of total numbers of shorebirds supported is undoubtedly the Yukon Delta. Other prime areas include Nelson Lagoon, Stebbins and Safety Lagoon in the Bering Sea, Kasegaluk Lagoon and the barrier island-lagoon system east and west of Shishmaref in the Chukchi Sea, and the Pt. Barrow-Plover Islands area in the Beaufort Sea. Along each of these coastlines, however, some areas of potential importance remain unstudied, and shorebirds are widespread in migration, occurring in many less extensive areas in high densities.

A final trend across regions can be garnered from the list of prime shorebird concentration areas just presented. Along the Beaufort and Northern Chukchi coasts, major shorebird concentrations invariably involve large numbers of phalaropes, usually near spits and barrier islands, where a major component of the prey base consists of planktonic or epibenthic organisms such as amphipods, copepods, euphausiids, and mysids. Farther south along the Southern Chukchi and Bering coasts many of the phalaropes have probably moved offshore to feed on similar prey, and the large littoral zone shorebird concentrations involve several species of sandpipers most prominently. The habitats used are principally mudflats and saltmarsh areas, and the prey are mainly benthic, especially insect larvae and small molluscs. Of course, both arctic and subarctic areas involve a similar, full range of shorebird species, habitats, and invertebrate prey, but the dominant themes in the major concentration areas show this geographic shift. It is of interest in management because the sensitivity of local avifauna to oil or other development impacts changes with shifts in shorebird communities, their trophics and their habitats.

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ENVIRONMENTAL CHARACTERIZATION AND BIOLOGICAL UTILIZATION OF PEARD BAY

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Final Report
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Research Unit 641

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CHAPTER 1

PEARD BAY ECOLOGICAL PROCESSES: CHARACTERIZATION, BIOLOGICAL UTILIZATION, AND COMPARISON OF VULNERABILITIES

1.1 SUMMARY

(1) Peard Bay is an Arctic lagoon located on the Chukchi Sea coast approximately 80 km southwest of Barrow. A scientific reconnaissance study was carried out in 1983-1984 to environmentally characterize the lagoon and to document its biological use.

(2) The Kugrua River discharges into Kugrua Bay, an inner lagoon approxiately 4 meters deep and within the Peard Bay system. Kugrua Bay tidally exchanges through a restricted entrance with Peard Bay. Peard Bay is a large (240 km^2) lagoon bounded by coastal spits and barrier islands, with shallow shelfs and a large central basin 7 meters deep. The major marine entrance to Peard Bay is at the northeast end of the Seahorse Islands. This entrance is 11 meters deep; however, it is shoaled by shallow sills 4.5 meters deep.

(3) Exchange between Peard Bay and the inshore Chukchi Sea occurs primarily through the Sea Horse Islands channel. Exchange is facilitated by tidal and meteorological forcing functions. Residence time of Peard Bay is estimated to be 15 days, with exchange being 70% tidal and 30% storm surge. Active winter exchange occurs via the deep channel under the ice with currents up to 75 cm/sec. In winter, bottom salinities of 41 ppt were measured in the deep Peard Bay basin and 48 ppt in Kugrua Bay.

(4) Within the Peard Bay system, nutrients such as ammonia (1-5 $\mu M/L$) are high as is primary productivity (10 $gC/m^2/yr$). High heterotrophic activity was also measured in the water column. Nutrients, and possibly organic materials, derived from terrestrial sources via the Kugrua River may be important to this system. The importance of this input may be enhanced by the residence time of the inner Kugrua Bay as well as that of the deep (7 meter) Peard Bay basin.

(5) Expanses of sheltered benthic habitats within the bay system provide epibenthic and infaunal food resources for higher vertebrates. Epibenthic invertebrates of Peard Bay were dominated by the same species of mysids, isopods, and amphipods as previous studies have shown to be important in Simpson Lagoon on the Beaufort Sea coast, although the relative abundances were different. Mysids (dominated by such species as *Mysis litoralis* and *Mysis relicta*) appeared less important than isopods (*Saduria entomon*) and amphipods. A comparison of the amphipod populations of Peard Bay with those of Simpson and Angun Lagoons also shows some differences. Simpson Lagoon samples were dominated in terms of biomass and numbers by *Onisimus glacialis*. Angun Lagoon samples were dominated in terms of numbers by *Corophium* sp. and *Gammarus setosus*, while *O. glacialis* dominated biomass estimates. Peard Bay dropnet samples and diver core samples were dominated in terms of abundances and wet weights by *Atylus carinatus* in the deep central section of the bay, by *Gammaracanthus loricatus* and *Onisimus litoralis*

in the shallow areas surrounding the bay, and by *Caprella carina* in the entrance to Kugrua Bay.

In comparison with previous infaunal studies the species composition sampled at Peard Bay is composed of Arctic forms and not boreal Pacific forms as found in the southern Chukchi Sea. Previous data taken in the Beaufort Sea suggest that oligochaetes, *Gammarus setosa*, *Onisimus litoralis*, *Scolecolepides arctius*, *Ampharete vega*, *Prionospio cirrifera*, *Terebellides stroemii*, *Cyrtodaria kurriana*, and *Liocyma fluctuosa* are dominant species (Carey 1978). Of the dominant infaunal species found in Peard Bay, *Spio filicornis*, *Chone duneri*, *Cylichna occulta*, *Mysella tumida*, and *Atylus carinatus* have been sampled in numerous locations in the Beaufort, indicating that the dominant species in Peard Bay are polar forms, not boreal Pacific.

Although sampling was limited, it would appear that physical factors such as sediment composition, water depth and currents, and, possibly, seasonal salinity changes are likely to be important factors in controlling the distribution of infaunal invertebrates within Peard and Kugrua Bays. The infauna of the deeper central section of Peard Bay is dominated in terms of numbers and biomass by two species of bivalves, while the shallower area of the surrounding shelf, as represented by the entrance to Kugrua Bay, may be dominated by several species of polychaetes. The shallow center of Kugrua Bay is evidently dominated by oligochaetes and polychaetes. Divers observed "bacterial mats" in the mud bottoms here during the summer. These benthic habitats thus appear to be diverse and further characterization and mapping are necessary.

(6) Vertebrate utilization of Peard Bay includes that by mammals, fish, and birds. Mammal usage was largely limited to seals (ringed and spotted), with an occasional gray whale entering the bay. Of 14 species of fish identified in Peard Bay, four marine species dominated in terms of abundance (Arctic cod, fourhorn sculpin, saffron cod, and Arctic flounder). Anadromous fish were few with little suitable habitat apparent in the Kugrua River. In terms of temporal and spatial use by birds, and in terms of prey availability and use by birds, Peard Bay appears to represent a notable transition between the estuarine systems typical of the Arctic, such as Beaufort and Simpson Lagoons, and those typical of the subarctic such as in Kotzebue and Norton Sounds. Bird use of this area for staging, migration, feeding, molting, and breeding was documented.

(7) Feeding data of the vertebrates using the Peard Bay system indicated differences from previous studies of Beaufort Sea lagoons. Oldsquaw and eiders, abundant species that exploit the benthic and epibenthic communities, and arctic terns and red phalaropes, abundant species that exploit near surface prey, were selected for feeding studies.

The single most important prey to both oldsquaw and eiders was the amphipod, *Atylus carinatus*, which accounted for over 50% of the total numbers and volume of prey consumed. The epibenthic cottid fish, fourhorn sculpin, figured prominently in the diet of the oldsquaw, but not in the diet of the eiders. Gastropods and polychaetes were the major components of the diet of eiders.

The diets of arctic terns and red phalaropes generally represented prey taken from the water column. Nektonic amphipods, particularly *Leptamphopus* sp., were the most important prey of red phalaropes, while fourhorn sculpins were the principal prey of arctic terns.

For dominant fish, qualitative data indicate mysids and fish as important in the diet of Arctic cod in Peard Bay. The diet of saffron cod is similar. Arctic flounder were found to have a diet of mysids, amphipods, and polychaetes. Fourhorn sculpin also had a varied diet of mysids, amphipods, isopods, fish, and polychaetes.

Though feeding studies were not conducted on seals, both ringed and spotted seals were observed in the bay. These seals are known to be opportunistic feeders on a variety of fish and crustaceans, including mysids and amphipods (Lowry et al. 1982).

1.2 INTRODUCTION

1.2.1 Scope of Study

The purpose of this study was to environmentally characterize and document the biological utilization of Peard Bay. Peard Bay is an Arctic coastal lagoon located on the Chukchi Sea coast approximately 80 km south of Barrow.

Alaskan OCS leasing and development activities require measures which need to be prescribed to insure protection of sensitive biological areas. For future sales in the offshore Chukchi Sea area, Peard Bay, Kasegaluk Lagoon, and Ledyard Bay were identified by NOAA/OCSEAP as areas of high biological activities. Peard Bay was selected for scientific reconnaissance in 1983-84 because of its proximity to a large population of subsistence users, and because of its protected waters which might serve as a staging area for oil and gas related activities.

Specific objectives of the Chukchi Sea coastal studies were the following:

a) Describe biological utilization of the Alaskan Chukchi Sea coast from existing data in the literature.

b) Conduct a field sampling program to describe the major physical and biological processes occurring in Peard Bay.

c) Compare the biological processes and utilization of Peard Bay with previous results obtained from lagoons along the Beaufort Sea coast (e.g., Simpson Lagoon and Beaufort Lagoon).

d) Describe the vulnerabilities of Peard Bay to possible impacts of oil and gas related activities.

Elements of these Chukchi Sea coastal studies currently underway by other contractors, include a characterization of the Chukchi Sea coast regarding sensitivity to oil spills, a study of fish resources of the Cape Lisburne to

Barrow area, a study of the coastal oceanography in the vicinity of Peard Bay, an offshore biological study from NOAA ships, and a nearshore meteorological characterization and field study of the Beaufort and Chukchi Sea coasts. None of the results of these studies was available at the time of preparing this report.

Specific methods utilized in this study included a review of the available literature and a field study of physical and biological processes within Peard Bay. Components of the field study included an analysis of the oceanography of Peard Bay with emphasis on water exchange between the lagoon and the nearshore zone. Distributions of birds and marine mammals were determined and fish utilization of the lagoon was documented. Feeding studies of birds and fish were also included. Distributions and abundances of benthic invertebrates were determined and studies were carried out on productivity mechanisms supporting the food web in Peard Bay.

1.2.2 Approach and Limitations

In order to achieve these objectives, and to comply with funding limitations, emphasis was given to the field study elements and to obtain new scientific results for the Chukchi coastal area. Since this was envisioned to be a two-year study, the final characterization of the whole coast and the vulnerability assessments were given less priority during the first year. Also, the results of the other ongoing coastal studies are not available yet.

Data on seasonal utilization by birds and marine mammals were obtained. Bird and mammal field surveys were conducted during the periods of 29 May-5 September and 31 May-28 August (1983), respectively, and aerial, ground, and boat observations were used. Field trips for the other Peard Bay study components were carried out during the periods of 26 July-1 August and 22-26 August (1983). Moorings associated with the physical oceanographic study were placed in Peard Bay during the first trip and recovered at the end of the second trip. A winter reconnaissance was carried out using a NOAA helicopter on 8 March 1984.

The major logistical limitation encountered during the study was the lack of a suitable boat for sampling in Peard Bay. Because of frequent winds and the large dimensions of Peard Bay, mobility was severely limited, particularly in the central area of the bay.

1.2.3 Presentation of Results

The results of this study are summarized here and presented in detail in subsequent chapters of this report. In Chapter 1 the Peard Bay system is characterized, the major ecological processes are described, and biological utilization of the lagoon is discussed. The vulnerability of Peard Bay to oil and gas impacts is assessed, particularly in comparison to other known Arctic lagoons.

A summary of relevant literature pertinent to the Chukchi Sea coast is included with each chapter. Results of the Peard Bay field studies are presented, and then discussed in relation to the existing data.

1.3 COASTAL REGION AND PEARD BAY

1.3.1 The Coastal Setting

The eastern Chukchi Sea coast, from the Bering Strait northward to Point Barrow (Figure 1-1), is a complex coast with major topographic features and a north/south latitudinal gradient. Influences of the Bering Sea to the south and of the Arctic Ocean to the north greatly define the oceanographic conditions along this coast.

The peninsula defined by Point Hope and Cape Lisburne divides the coast into two major sections. The southern portion comprises Kotzebue Sound and the Hope Basin geological province. At the southern end of this coast lies the Bering Strait, through which a persistent flow of Bering Sea water passes northward, with only episodic reversals (Coachman et al. 1975). From the Bering Strait northward to Cape Espenberg, Kotzebue Sound is a deep embayment with a complex coastline comprised of inner bays, islands, a large peninsula, inlets, and low-lying lakes. Among the drainages into Kotzebue Sound are two large rivers, the Kobuk and the Noatak.

The northern section of the Chukchi coast differs topographically from the Kotzebue Sound area. The Chukchi coastal region north of Point Lisburne generally trends toward the northeast to Point Barrow. This section of the coast has three large, cusp-like features delineated by Cape Lisburne, Icy Cape, and Point Franklin. Associated with these larger features are shallow, coastal lagoons formed by coastal spits and barrier islands. Peard Bay is the shallow lagoon furthest to the northeast along this coast.

1.3.2 Geomorphology of Peard Bay

Peard Bay is a large, coastal lagoon with a surface area of about 240 km^2 (Figure 1-2). The Kugrua River feeds into Peard Bay via Kugrua Bay, and a narrow connecting channel. The major inlet between Peard Bay and the Chukchi Sea is south of the Seahorse Islands. The main channel in this eastern inlet is located at the southern end of the island group. Shoals extend across the rest of this inlet. The channel is as deep as 12 m, but shoals to 4 m after entering the bay. The shoal area across the rest of this inlet is 1.5 m deep or shallower, with two sections which are about 3 m deep. A second inlet to Peard Bay is located between Point Franklin and the northern end of the Seahorse Islands. The channel in this northern inlet is 2.5 m deep and is located immediately off Point Franklin. The rest of the inlet shoals to 1.5 m or less. The large central region of Peard Bay is about 7 m deep.

Of importance to this Arctic lagoon is the proximity of the Barrow submarine canyon, which lies offshore roughly paralleling the coast (Figure 1-3). This submarine canyon is apparently a major conduit of Chukchi Sea water into the Arctic Ocean, and also of reverse flow episodes forced by large scale meteorological processes (Mountain et al. 1976).

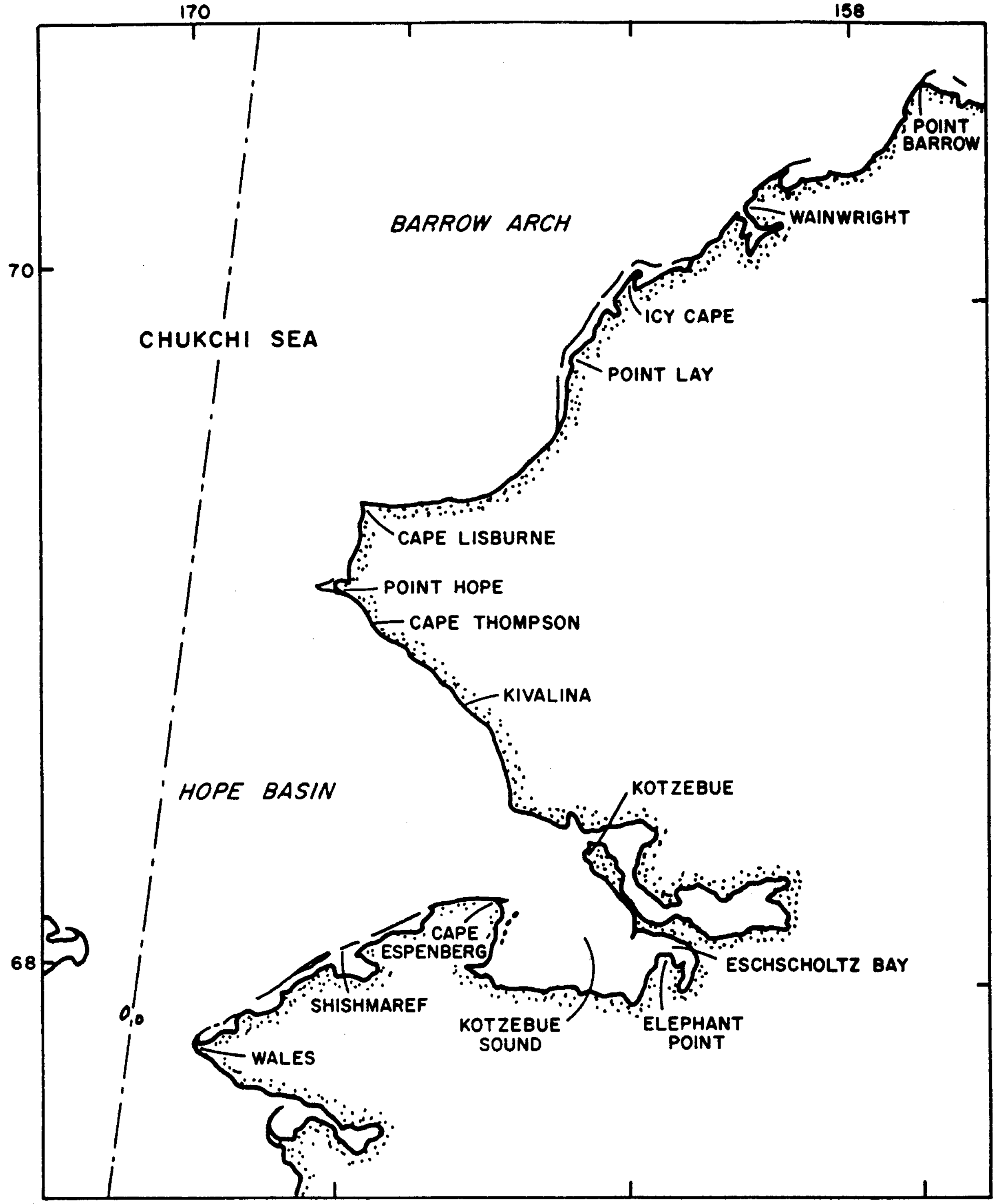

Figure 1-1. Eastern Chukchi Sea Coastline.

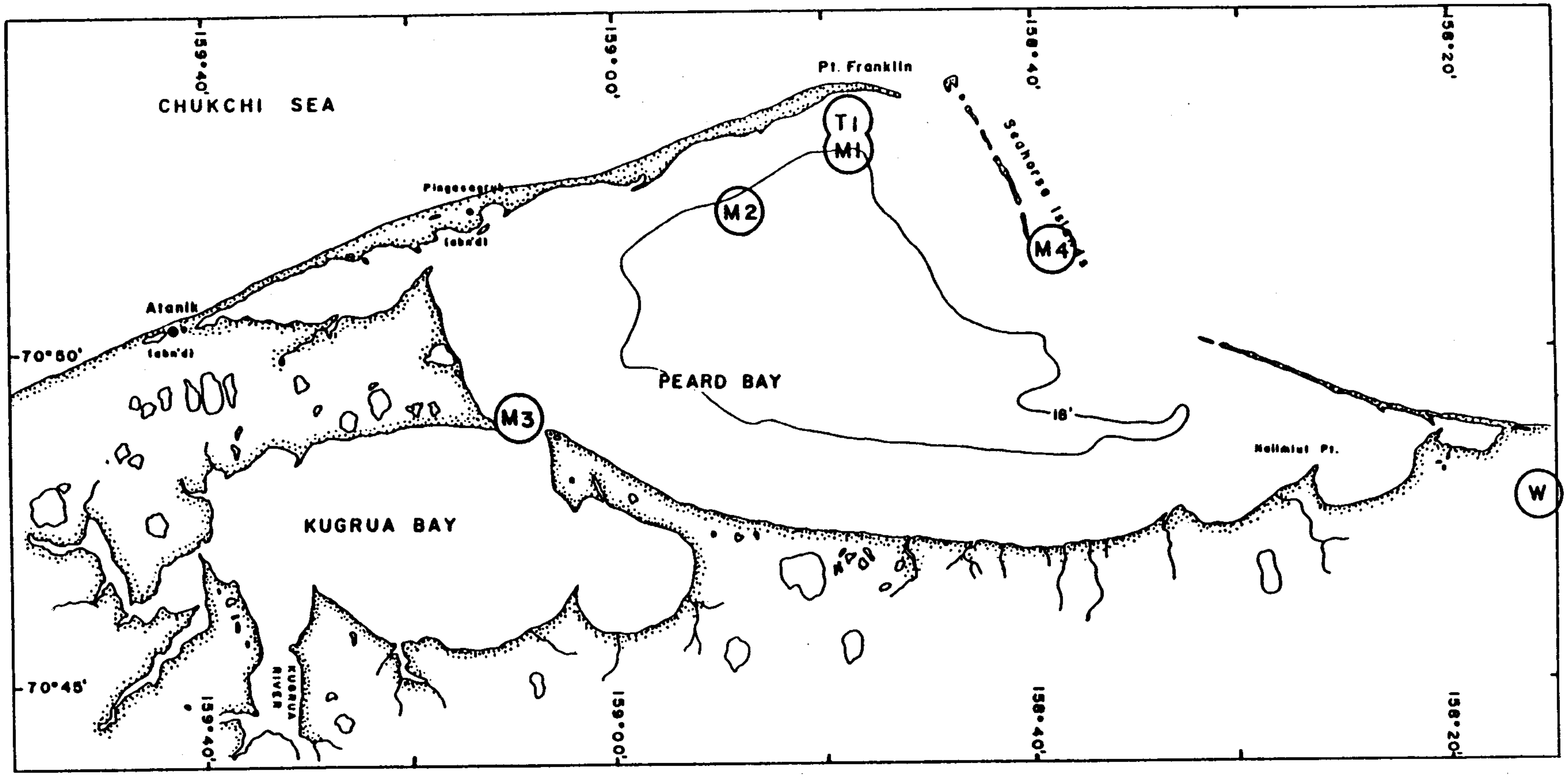

Figure 1-2. Instrument Locations in Peard Bay, Summer of 1983. Sample stations designated as M (current meters), T (tide gauge), and W (weather).

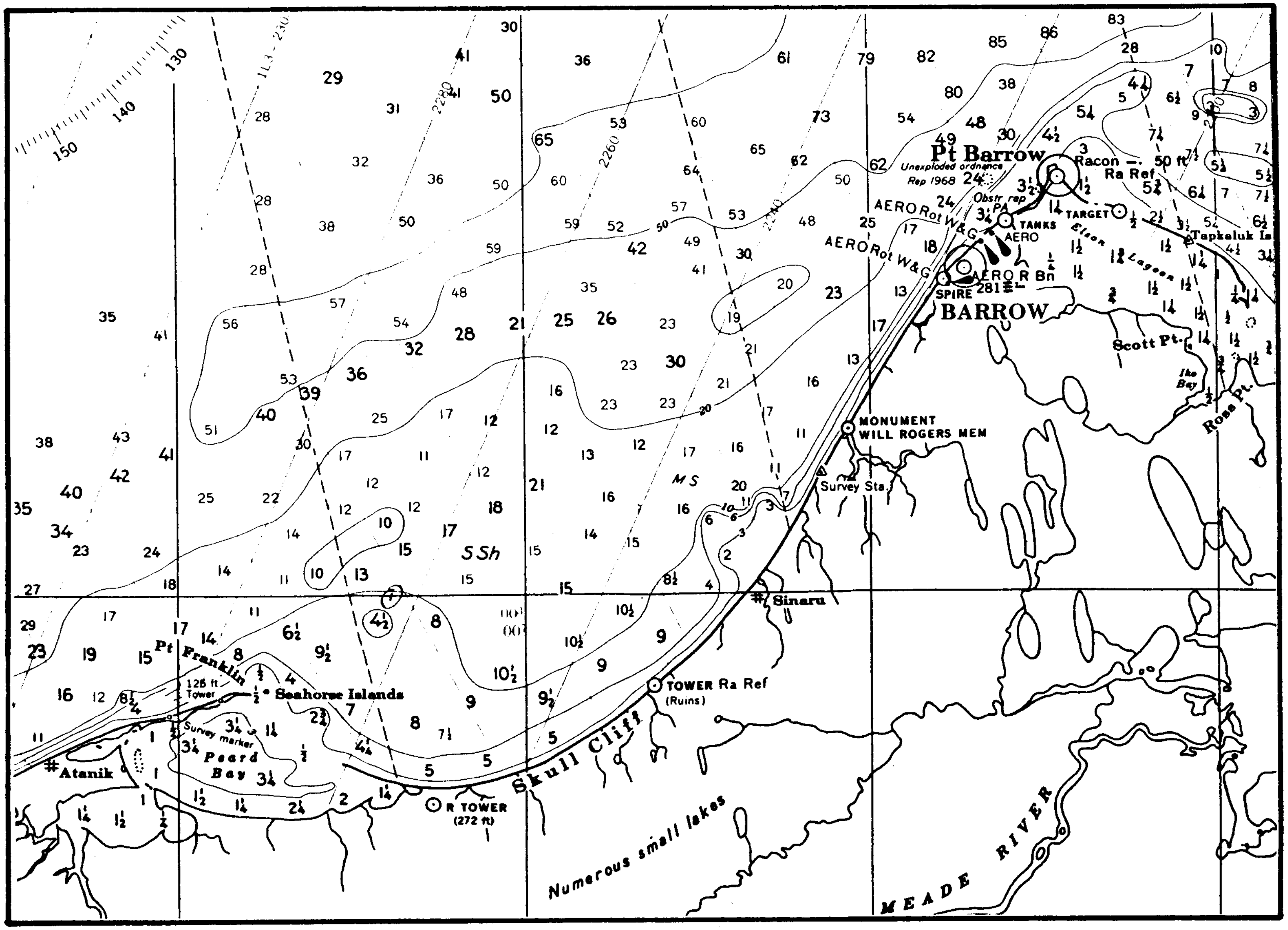

Figure 1-3. Detailed Bathymetry in the Region of Peard Bay Showing the Offshore Barrow Canyon (depth in fathoms).

1.4 PHYSICAL PROCESSES

1.4.1 Offshore Water Structure and Currents

Although there are many previous oceanographic studies in the Chukchi Sea, there have been relatively few measurements of nearshore currents. Earlier work in the Chukchi Sea, generally confined to the deeper offshore waters, was reviewed by Coachman et al. (1975). A later review, including most of the available inshore data, was given by Coachman and Aagaard (1981).

A warm current, originating in the Bering Strait, flows northeastward approximately 100 km offshore (Flemming and Heggarty 1966; Ingham and Rutland 1972; Paquette and Bourke 1974; Coachman et al. 1975). To the north, the current approaches the coast and flows through Barrow Canyon into the Beaufort Sea (Mountain et al. 1976). South of Icy Cape, there is evidence of an anticyclonic eddy separating the coast and the warm current (Flemming and Heggarty 1966; Ingham and Rutland 1972). Offshore, a pycnocline occurs between ten and fifteen meters depth because of ice melt (Ingham and Rutland 1972), but shoals to five to ten meters inshore, and becomes more intense due to freshwater runoff (Wiseman et al. 1974).

Three previous investigations are particularly relevant to the present study. Mountain et al. (1976) obtained 120-day records of currents and temperatures from two moored Aanderaa meters at 96 m and 126 m depth in 150 m of water offshore in Barrow Canyon. These records showed mean currents of 25 cm/sec toward the northeast (along the axis of the canyon which approximately parallels the shoreline). However, the records were characterized by higher speeds (commonly greater than 50 cm/sec) and large variations, including periods of reversed upcanyon motion. A close relationship was shown to exist between the measured currents and the north-south pressure gradient, such that when the pressure rose to the north, the northward flow of water through the canyon decreased.

Wiseman and Rouse (1980) obtained current-drogue track, wind measurements, and inshore hydrographic measurements near the Point Lay - Icy Cape area in 1972. They conclude that these data support the thesis of a well-developed baroclinic coastal jet.

Wilson et al. (1982) carried out a program of inshore moorings and transects along the northeast Chukchi coast during August and September of 1981 (Figure 1-4). Coastal currents measured during this study at Point Barrow and at Wainwright along the Chukchi Sea coast show both northeast (upcoast) and southwest (downcoast) flows. Speeds ranged up to 50 cm/sec and, occasionally, as much as 100 cm/sec offshore of Point Barrow in the vicinity of the Barrow submarine canyon. Although upcoast flow was predominant, downcoast flows occurred from 33 to 47 percent of the time in these different current records.

All current records taken inshore and offshore, at both Point Barrow and Wainwright, showed close similarities in directions, magnitudes, and other features such as in the times of change and in the shapes of the current vector plots. These similarities were consistent throughout the records. Statistical cross correlations of these current meter time series yielded a correlation coefficient at zero lag of 0.90 for inshore records taken at Point Barrow and at Wainwright.

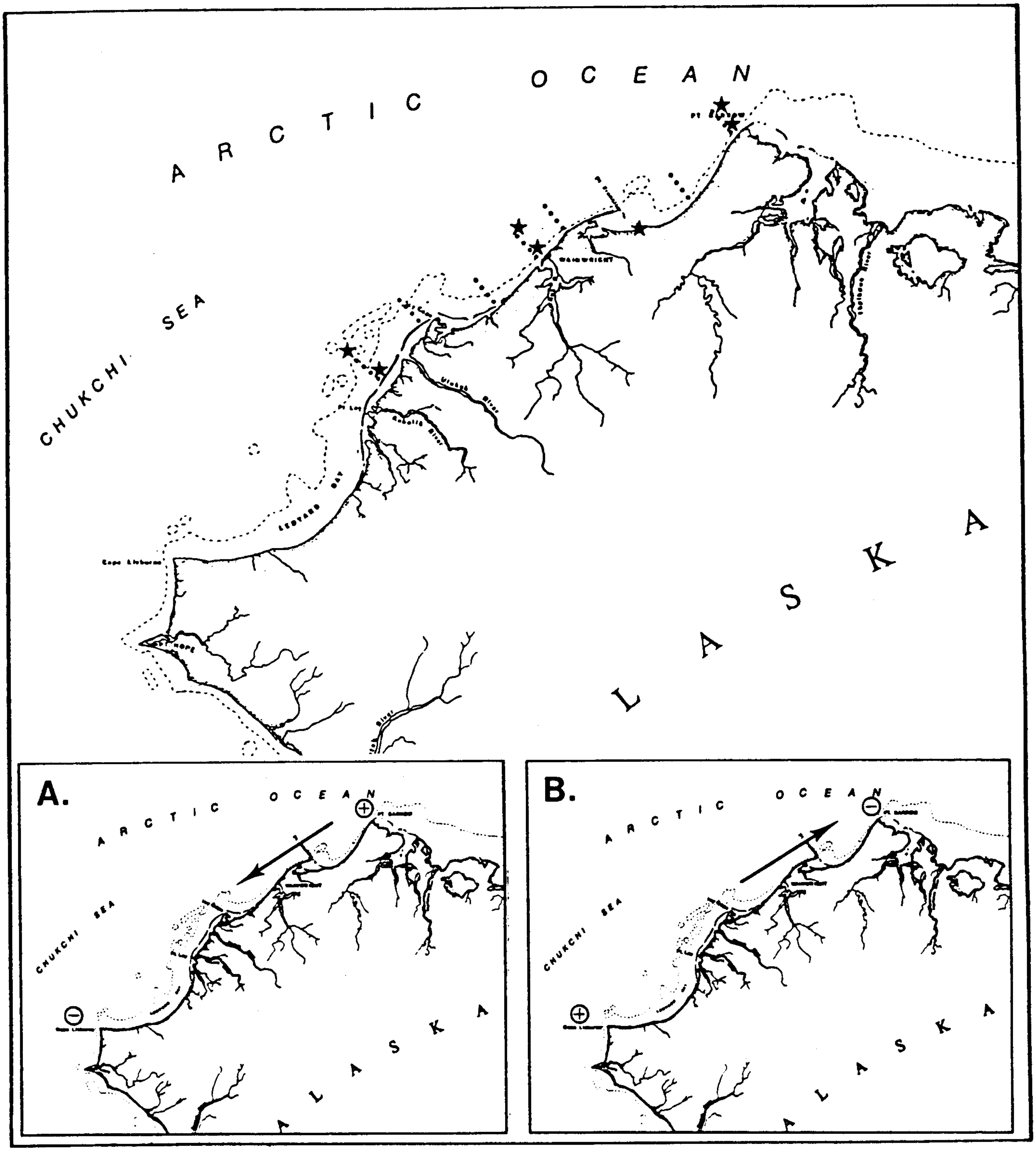

Figure 1-4. Chukchi Sea Coast Study Sites, August-September 1981 (Wilson et al. 1982).

Visual comparisons of the current meter time series data with similar plots of atmospheric pressure differences between Point Barrow and Cape Lisburne (also Pt. Barrow and Nome), show strong correlations. High pressure at Point Barrow relative to the southern stations is strongly correlated with downcoast flow. Conversely, low or negative pressure differences are strongly associated with upcoast flow.

Cross correlations of the current time series with the pressure difference series (Pt. Barrow - Cape Lisburne) indicate high negative correlation coefficients of -0.81 and -0.85, respectively, confirming the similarities observed visually.

Visual cross correlations of the local winds with the currents were not quite as evident as with the atmospheric pressures. Cross correlation coefficients of 0.65 and 0.72 were obtained for the Wainwright and Point Barrow cases, respectively. Correlation coefficients of the local winds with the pressure differences were only 0.52 and 0.56 for Wainwright and Point Barrow.

Thus, the high correlations between the individual current records, plus the high correlations of these currents with the atmospheric pressure difference along the coast, indicate that these shallow, nearcoast currents are driven by the same atmospheric pressure forcing function all along this stretch of coast. Since pressure differences are a simple index of weather systems moving through the region, the correlations, though high, are not absolute.

The hydrographic transect data, along with temperature/salinity time series data from the moorings, show highly variable temperature and salinity conditions in this nearshore area (Wilson et al. 1982). Pycnoclines are evident between 5 and 10 m depth inshore, deepening offshore to 10-15 m. Hydrographic section plots generally indicate cooler, more saline water upwelling close to shore, though not always consistent or correlated with upcoast or downcoast flow regimes. Temperatures varied from below -1.5°C up to +6°C, and salinities varied from 34 ppt down to 26 ppt. Features of sharp fronts are also evident in the time series data. The temporal and spatial patchiness in water masses is probably due to variable contributions of ice melt, upwelling, wind mixing, solar heating, and freshwater inputs modifying the source waters of the Chukchi Sea, and transported by currents driven by atmospheric forcing.

1.4.2 Dynamics of Peard Bay Circulation

1.4.2.1 Open Water Season

Current meters, temperature and salinity sensors, and a water level gauge were deployed in Peard Bay as shown in Figure 1-2. From these data, the exchange mechanisms of Peard Bay with the inshore Chukchi Sea waters and the circulation within the bay were inferred.

Results indicate that exchange of lagoon and outside waters occurs frequently, driven by meteorological forcing plus tidal forces. The moored instrument data recorded the incursion of coastal water into Peard Bay on several occasions during the 1983 season. The most direct evidence for the influx of coastal water is the rise in sea level measured at the tide station T1 on 1, 8, 18, and 26 August. Current measurments as well as temperature/salinity records from the other moored instruments indicated results consistent with such exchange.

Two conceptual circulation models adequately describe the currents that were observed during the sampling program. The first model is for northeasterly wind conditions which are typical of the Chukchi coast. The second conceptual model is for southwesterly winds; positive storm surge events.

Generalized circulation patterns are presented in Figure 1-5 for northeasterly winds. This conceptual model is based on the 1983 current meter results, and is consistent with the results of the Rand model (Liu 1983), Figure 1-6. Offshore water enters through the southern Seahorse Island entrance and circulates in the bay in a clockwise direction. Strong currents were observed entering Kugrua Bay with only weak currents exiting. The mean flow in both the southern inlet and the Kugrua Bay inlet was in the direction of flood. At Station M3 in the Kugrua Bay inlet, flow rarely reversed into Peard Bay, but instead only slowed or stopped during the ebb cycle. At Station M4 in the eastern inlet the flow did reverse in the ebb direction, but for a shorter duration than the flood flow. The tidal flow may be asymmetric, with flood flow entering principally through the channels at depth and ebb flow exiting over both the shoal area and the channel area near the surface. The ebb flow may be blocked from the location of the current meters by the sills at the ends of the channel which would direct ebb flow into the surface layer. There is evidence in the pressure record for only a small net storage within Peard Bay, about 10 cm from the beginning to end of August, so the flood flow must exit Peard Bay.

The second conceptual model, presented in Figure 1-7, is for a storm surge event during southeasterly winds as observed on 1, 8, 18, and 26 August. The northern coastline of the Chukchi Sea runs in a northeasterly-southwesterly direction with southeastern winds blowing parallel to the coast. During these conditions, surface waters are transported along the coast and to the right of the wind, causing a rise in sea level at the coast and in Peard Bay. A strong current was observed entering Peard Bay at the Seahorse Island entrance, with water probably also entering at the Point Franklin entrance. During the onset of the storm surge, currents reversed for a short period of time at M1 to a southerly direction. Currents also reversed at M2U and M2L to a southwesterly direction. At the entrance to Kugrua Bay currents were still directed into the bay. After the peak of the storm surge (18 August), currents were observed to return to the clockwise rotation. A short-lived reversal was noted at M3 due to a sudden drop in water level in Peard Bay, causing a readjustment of the water level in Kugrua Bay.

The sea level changes recorded in Peard Bay during the summer of 1983 were due to meteorologically forced events of up to 0.5 to 0.8 m in height, equivalent to about 15% of the volume of Peard Bay. Tidal analyses of the pressure data indicated a principally semidiurnal tide with a spring tide range of 18 cm, a neap range of 9 cm, and a mean range of 14 cm.

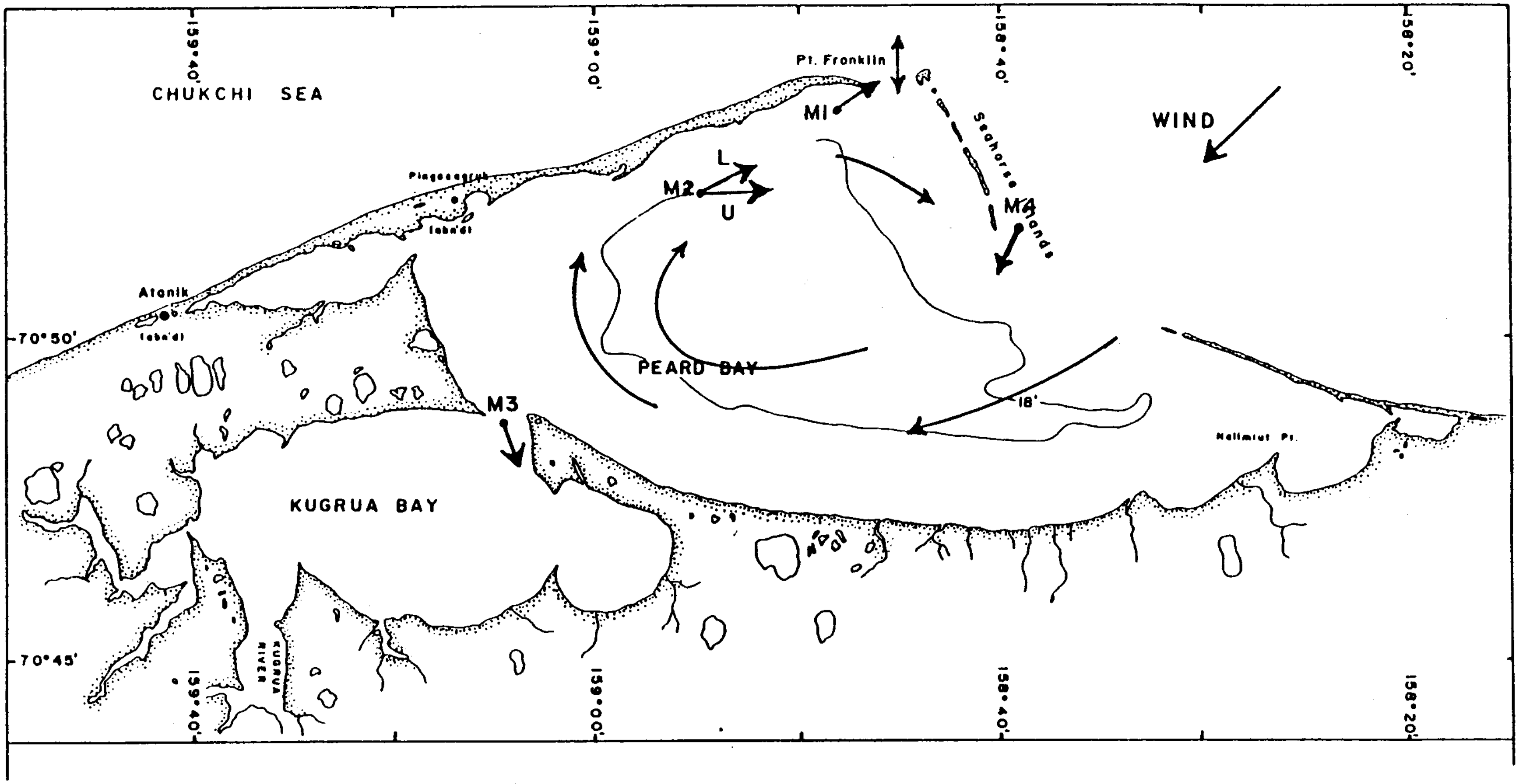

Figure 1-5. Conceptual Circulation Model in Peard Bay for NE Winds.

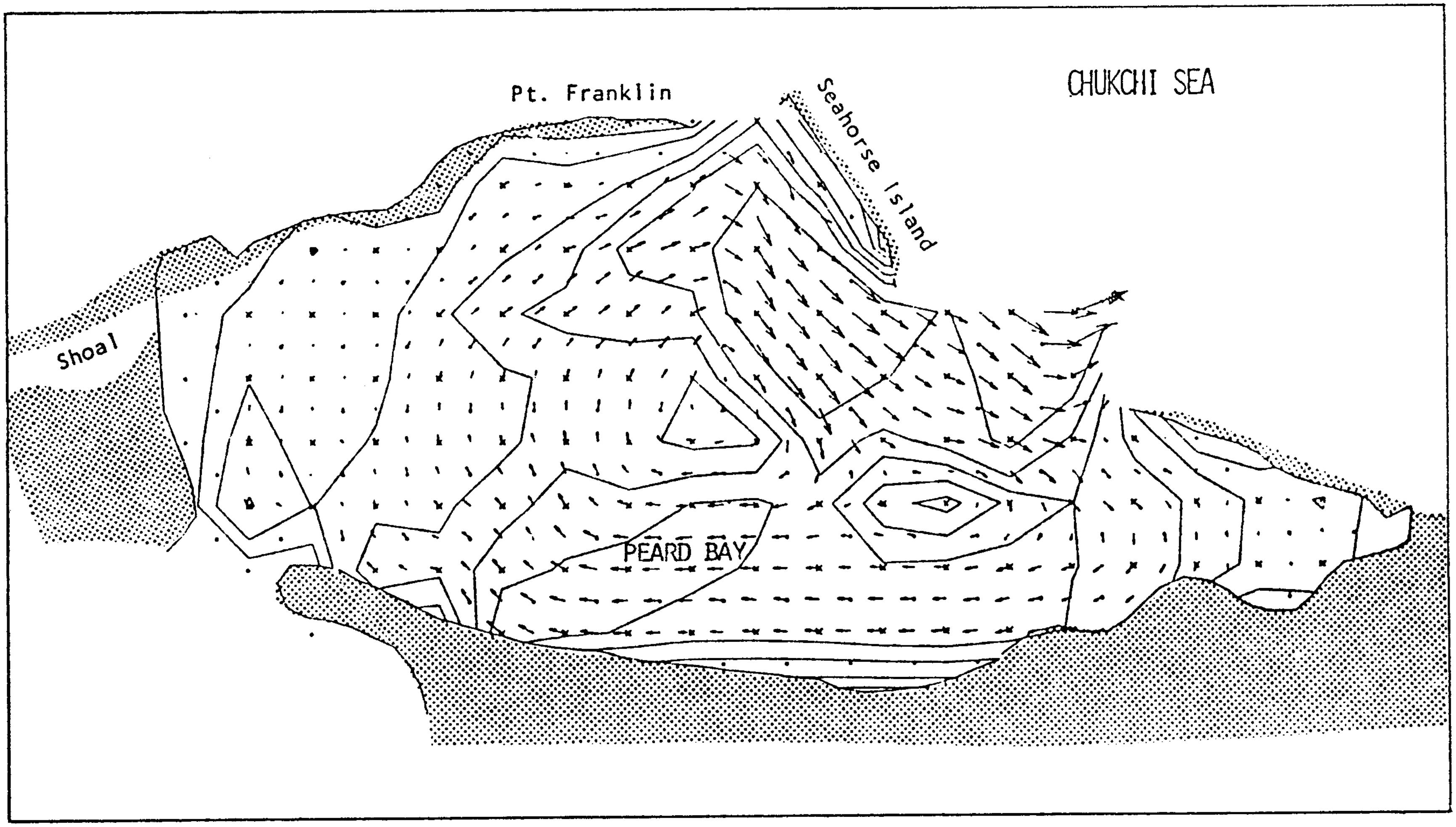

Figure 1-6. Spatial Distribution of Residual Tidal Currents in Peard Bay. The plotting scale is 4 cm/sec per grid spacing (Liu 1983).

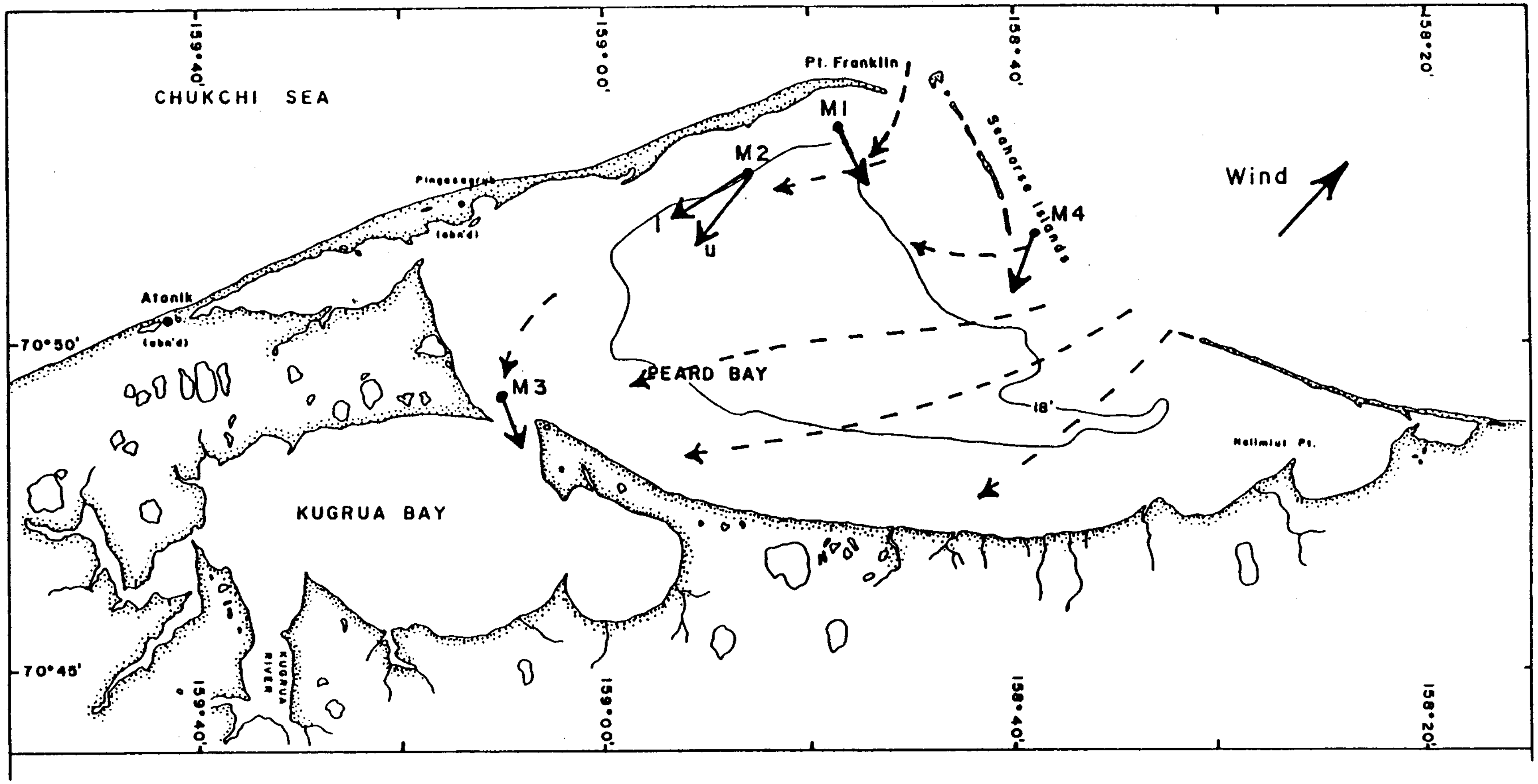

Figure 1-7. Conceptual Circulation Model in Peard Bay for a Storm Surge Event; Southwest Winds.

Initially in August, the water column in Peard Bay was well stratified at Station M2 with fresher and warmer water at the surface. However, by 8 August, the water column was vertically homogeneous. No hypersaline water was found in Peard Bay in the summer of 1983 as reported by Wiseman (1979), although profiles in the deepest portion were not obtained. Meteorological events caused corresponding events in temperature and salinity records, with their strengths and spatial coherence varying. For example, colder, saltier water was forced into Peard Bay by the 18 August surge. Being denser than bay waters, it sank, traversed across the bay, and mixed upwards in a period of about a day.

Because of the current structure near the main entrance to Peard Bay, it might be expected that the exchange coefficient would be high. Based upon volume, tide, and storm surge elevation differences, a residence time of about 15 days is estimated for Peard Bay. About 30% of this exchange is estimated to be caused by storm surges (0.5 m once every 10 days) and the rest by tidal differences (14 cm diurnal).

1.4.2.2 Winter Season

Hypersaline water was present in Peard Bay during an 8-17 March winter field trip. Vertical profiles were found to be essentially isothermal to the bottom, and isohaline down to a depth of 5 m where a sharp halocline was encountered. Water temperatures ranged from -1.9° to -1.0°C, and salinities ranged from 32.1 to 35.0 ppt in the upper layer. In central Peard Bay, at depths of 5 to 7 m, hypersaline water was found ranging from 37.66 ppt along the perimeter of the bay, to 41.79 ppt in the central bay. The highest salinity water found was in central Kugrua Bay, where salinities ranged from 38.5 ppt at the surface to 47.90 ppt at the bottom. The channel into Kugrua Bay is very restricted during the winter as a result of the 5 to 6 feet of ice cover, thus little water is exchanged with Peard Bay, resulting in high salinities. The hypersaline water in Peard Bay is not as high due to the greater volume per amount of salt extrusion, and also as a result of exchange with offshore waters. Offshore temperatures and salinities ranged from -1.7° to -1.4°C and 32.4 to 33.0 ppt, respectively.

Current speeds measured under the ice at the Pt. Franklin entrance were generally less than 5 cm/sec during both flood and ebb conditions. A number of events were observed on 9, 14, 15, and 16 March in the temperature and salinity time series data which relate to outflow conditions for the same periods, when high salinity (37 ppt) and higher temperature water exited the bay. Current speeds under the ice at the Seahorse Island entrance were very high, with speeds often exceeding 50 cm/sec and peaking up to 90 cm/sec on 9 March. Currents were mainly tidal with ebb flows being much larger than floods. This may be due to the less dense offshore water entering Peard Bay at the surface during the flood, and denser Peard Bay water exiting.

A strong NE wind blew ice offshore opening up a lead on 9 March which seems to correspond to the large ebb event. When winds slackened on 10 March, a large surge of water back into Peard Bay resulted. All other events are due to semidiurnal tides. The temperature time series is essentially isothermal in contrast to the salinity time series which fluctuates from 33 ppt during flood to 37 ppt during ebb conditions. The higher salinity Peard Bay water seems to exchange with the offshore waters even under ice-covered conditions. This is probably a result of the deep channel into Peard Bay which is in contrast to most other Arctic barrier island lagoons.

1.4.2.3 Conclusions

Exchange between Peard Bay and the inshore Chukchi Sea waters occurs primarily through the Seahorse Islands channel. Exchange is facilitated by tidal and meteorological forcing functions. Residence time in Peard Bay is estimated to be approximately 15 days (70% tidal; 30% storm surge).

Kugrua River water is introduced seasonally into Peard Bay and the active exchange occurs with inshore Chukchi waters, the latter with highly variable properties. Summer conditions within Peard Bay vary from highly stratified to vertically homogeneous, though no hypersaline waters were found within the bay during the summer of 1983. However, hypersaline waters of up to 41.8 ppt existed in the deeper portion of Peard Bay in March 1984 and up to 47.9 ppt in Kugrua Bay. Driven by tides through the Seahorse Island channel, active exchange was going on in March between Peard Bay and the Chukchi Sea. A negative storm surge event was recorded, with high salinity waters (37 ppt) ebbing from the entrance at speeds of 50-90 cm/sec under the ice.

1.5 OVERVIEW OF BIOLOGICAL UTILIZATION OF PEARD BAY

1.5.1 Mammals

1.5.1.1 Introduction

The northern Chukchi Sea is the summering ground and northernmost habitat of several migratory marine mammal species. In addition to providing summer feeding grounds, the nearshore northwestern Chukchi Sea is an important migratory pathway for species en route to and from the Beaufort Sea. Peard Bay offers a large expanse of shallow lagoon habitat at the northern end of this coastline. Eight species of marine mammals are known to frequent, at least seasonally, the vicinity of Peard Bay. These are the Pacific walrus, ringed seal, spotted seal, bearded seal, polar bear, beluga whale, gray whale, and bowhead whale. One purpose of this study was to document the utilization of Peard Bay by these marine mammals.

Since Peard Bay is close to two populations of subsistence hunters (Barrow and Wainwright), attention was also given to historic utilization of these marine mammal populations. Existing harvest records and an examination of subsistence hunting sites in Peard Bay were the basis of these determinations.

1.5.1.2 Walrus

During the 1983 field season, no live walrus were seen inside Peard Bay or Kugrua Bay. Outside the bays, however, numerous pods (1,500-2,000 animals) were present at the end of August, on grounded ice just offshore from Point Franklin.

Native hunters in Peard Bay report that they occasionally take walrus inside the bay. Several carcasses were observed along the inside shore, yet very few walrus bones were found at hunting sites within the bay. On the outside beach, however, between Point Franklin and the abandoned village of Atanik, numerous skeletal remains of walrus were observed. Walrus remains were common at both Atanik and the prehistoric village site of Pingasagaruk. It is also known that walrus are presently taken along this spit by hunters from both Wainwright and Barrow.

Field studies in the Peard Bay vicinity upon which the above conclusions are based were carried out in 1983-1984 using aerial and shore-based observations. An early aerial survey was made from Barrow to Wainwright and included transects over Peard Bay. Field studies at Peard Bay were carried out in five study periods as follows: 4-14 June, 16-20 July, 12-13 August, and 20-28 August of 1983, and 8 March of 1984. Shore-based sweep counts from a 4-m high observation tower at Pt. Franklin and mammal counts at the Pt. Franklin entrance were made. In addition, a beach survey along both sides of the Pt. Franklin spit was made, along with helicopter surveys around the perimeters of Peard and Kugrua Bays. A ground reconnaissance was also made at each spit, headland, or river mouth for examination of subsistence hunting sites and apparent harvest composition from bone debris.

The retrieved harvest of walrus by Native Alaskan subsistence hunters in recent years has averaged between 2,000 and 3,000 animals per year (Fay 1982). Historically, the bulk (80 percent) of this harvest occurs in the north Bering Sea - Bering Strait region during the spring migration in May and June, with 7 to 8 percent taken between Point Hope and Barrow during the summer months (Stoker 1983). Over the 20-year period from 1962 to 1982, the average walrus harvest taken by the village of Wainwright has been 86 animals per year, with 55 per year taken by Barrow over the same period (Stoker 1983). The success of this harvest varies greatly from year to year, largely depending on ice conditions and weather. During this 20-year period, the retrieved walrus harvest at Wainwright has ranged from 20 animals taken in 1978 to 257 taken in 1976, while that of Barrow has ranged from 7 taken in 1969 to 165 taken in 1963 (Stoker 1983).

1.5.1.3 Seals

During the field survey of Peard Bay, ringed and spotted seals were observed inside the bay as well as in adjacent waters. However, difficulties were often encountered in distinguishing ringed seals and spotted seals at a distance. Due to ice conditions, general timing, and observations, ringed seals were probably dominant in the early season through June and July. Spotted seals were certainly dominant in August, though both species were present.

Ringed seals were present within and offshore of Peard Bay during all of the 1983 field season. During the initial aerial survey of 31 May, 10 seals (probably breeding adults) were sighted at established breathing holes inside Peard Bay, along a stress crack parallel to the Point Franklin spit.

During June an average density of 0.31 seals/km^2 was recorded inside Peard Bay and 0.41 seals/km^2 outside, with complete ice cover present in both areas. During mid-July these densities were 1.6 seals/km^2 inside and 20 seals/km^2 outside. By early August and into September very low densities of seals were reported, both inside and outside of the bay. These animals were probably spotted seals.

In general, during the period of 20-28 August, spotted seals seemed to enter the bay on a rising tide or at high tide, and exit during a falling tide or at low tide. They were observed to range widely over both Peard Bay and Kugrua Bay, with several being seen far up the Kugrua River. No more than a few seals were visible at any given time. This leads to the conclusion that use of the bays by spotted seals is limited. Eskimo hunters expressed very little interest in spotted seals, and the lack of remains found in hunting camps and abandoned habitation sites indicates that they were never an important element of the subsistence economy of the vicinity.

Though some ringed seals are probably taken by Eskimo hunters within Peard Bay, they are not regularly hunted there and do not constitute a significant part of the local subsistence harvest. The paucity of seal remains in the hunting and habitation sites within Peard Bay and Kugrua Bay further suggests that they have never been of great significance to the subsistence economy of this particular locale.

No bearded seals were observed within Peard Bay or Kugrua Bay during the 1983 field season. During the aerial survey of 31 May, however, a number of bearded seals were seen in the broken pack ice seaward of shore-fast ice along the Chukchi Sea coast between Wainwright and Barrow. Bearded seal remains were also common along the outer, seaward beach of Point Franklin spit. Native hunters who were interviewed did not mention hunting bearded seals within the bays, and no remains were found at hunting sites and abandoned habitation sites within the bays.

1.5.1.4 Polar Bears

Several polar bears were seen by observers in the vicinity of Point Franklin between 4 and 14 June, including a female with two young cubs. Fresh tracks were also found on Point Franklin on 20 July. Bears were actively seeking out and feeding on walrus carcasses along the outer beach at this time, but showed no interest in entering Peard Bay itself even though a number of ringed seals were present on the ice within the bay. The spits and islands enclosing Peard Bay are known to be a regularly used route for polar bears moving back and forth along the Chukchi Sea coast. As far as is known, no polar bears den in the vicinity of Peard Bay (Jack Lentfer, ADF&G, personal communication).

At present, some 100 to 200 polar bears are taken each year by Alaskan natives for subsistence use (ADF&G open-file data). This is probably close to the sustainable yield for the population (NOAA 1979). Available records for the period 1962-1982 indicate that an average of seven bears per year are taken by hunters at Wainwright, and about the same number by hunters at Barrow (Stoker 1983).

1.5.1.5 Whales

During their northward migration into the Beaufort Sea, belugas generally pass Wainwright and Barrow during May (Seaman and Burns 1981). Other elements of the population remain in the Bering and Chukchi Seas during the summer, moving into coastal waters, particularly lagoons and river mouths. Several thousand belugas remain in Chukchi Sea coastal waters throughout the summer, primarily in Kasegaluk Lagoon (between Icy Cape and Point Lay) and in Kotzebue Sound.

No belugas were seen inside or in the vicinity of Peard Bay during the 1983 field season. Belugas probably occur in the nearshore Chukchi Sea off Point Franklin during their northward migration in April and May but, given the ice conditions observed in Peard Bay during this study, probably do not enter the bays at that time. They may occasionally enter Peard Bay and Kugrua Bay later in the summer, though the absence of sightings and of remains found in hunting and habitation sites within the bays suggests that such occurrences are infrequent.

At present, approximately 150 to 200 belugas are taken each year by Alaskan Eskimos for subsistence use (IWC 1979; NOAA 1979). Over the period 1962-1982, an average of 11 belugas per year was harvested by the village of Wainwright, and 5 per year at Barrow (Stoker 1983).

Several gray whales were seen during the 1983 field season, both within and outside of Peard Bay. From 19 July through 31 August, a total of seven gray whales were observed within the bay itself, one of them in quite shallow water (less than 3 m deep) near the inside shore of Seahorse Island. Sightings within the bay occurred on 19 July, and 11, 28, and 31 August.

During this same period, at least 30 grays were sighted in the nearshore Chukchi Sea off Point Franklin spit between Point Franklin and Barrow. Sightings occurred on 11 and 29 August, and on 2, 4, and 7 September. Most grays observed in the Chukchi Sea were probably feeding, as evidenced by their association with distinct mud plumes. On 7 September at least 20 animals were observed feeding inside the broken pack ice between Point Franklin and Barrow.

The Eskimo hunters who were contacted expressed little interest in hunting gray whales, and the lack of faunal remains in hunting and habitation sites of the vicinity points to the conclusion that grays are taken infrequently, if ever, in this locale. One adult gray whale carcass (approximately 27 feet overall length) was found on the Chukchi Sea beach near the west end of Peard Bay. It appeared to have been dead for at least a year. No external evidence of physical trauma was observed other than the post-mortem removal of a small section of skin and blubber and all of the baleen.

Though gray whales do enter Peard Bay from time to time, they seem to do so as random exploratory forays, rather than for feeding purposes. No grays were observed feeding within the bay and results of benthic studies within the bay indicate that food resources there are minimal.

There were no confirmed sightings of bowhead whales within or offshore of Peard Bay during the 1983 field season, though one possible sighting was recorded about 3 km offshore from Point Franklin on 19 July. Given the solid ice conditions normally prevalent within Peard and Kugrua Bays at the time of the spring migration and the generally shallow depth of these bays, it is unlikely that bowheads enter them.

Bowhead skeletal remains, on the other hand, were found on the beaches of the area. Two partial skeletons were found on the spit projecting into Peard Bay from the mainland, opposite the eastern entrance. One of the remains was that of an adult bowhead, the other of a subadult. Both were close to an abandoned subsistence hunting site at the end of the spit. Though it is impossible to say for certain, it seems unlikely that they were killed within the bay itself, but were towed instead there by Eskimo hunters or carried there by tides and currents. Local Eskimo hunters who were approached had no knowledge of their origin. No other marine mammal bones were evident at the hunting site, though caribou bones and antlers were numerous.

Bowhead remains in the form of scattered bones, vertebrae, jaws, and skulls are common all along the Chukchi Sea beach of Point Franklin spit. The remains of at least two whales were evident between Point Franklin and the abandoned village site of Pingasagruk at the western end of Peard Bay, and at least two more were evident between Pingasagruk and the abandoned village of Atanik. The most recent remains appeared to be several years old.

For the period 1962-1982, the average landed harvest of bowheads at major whaling villages in Alaska was 18.4 whales per year (Stoker 1983). During this same time period, an average of 1.5 bowheads was landed per year at Wainwright, with a range of 0-3 per year. An average of 10.0 whales per year was taken near Barrow during this 20-year interval, with a range of 0-23 per year (Stoker 1983).

1.5.1.6 Conclusions

Based on observations and surveys it appears that Peard Bay and Kugrua Bay do not attract large concentrations of marine mammals and are not utilized as primary marine mammal subsistence hunting locales. Conversely, Point Franklin and the nearshore Chukchi Sea adjacent to Peard Bay appear to attract significant concentrations of marine mammals for both seasonal migration and feeding purposes. Consequently, the nearshore zone is occupied seasonally by residents of both Wainwright and Barrow for subsistence use of such marine mammal resources by local hunters.

Both ringed and spotted seals frequent Peard Bay and Kugrua Bay during the summer months, though the deeper section of Peard Bay does not appear to be used by ringed seals as an overwintering habitat. Comparisons with other surveys indicate that seal densities within the bays are less than in the nearshore Chukchi Sea itself. Presumably, the seals enter Peard Bay or frequent the openings to the bays for purposes of feeding, probably on Arctic cod, saffron cod, and sculpins. Ringed seals predominate within the bays and on the shore-fast ice of the Chukchi Sea coast prior to August. Later in the open-water season spotted seals predominate in this habitat.

The only other marine mammal species to enter Peard Bay are gray whales and walrus, which do not appear to use the bays as extensively as they do the nearshore zone of the Chukchi Sea. Judging from the circumstantial evidence, the nearshore environment may host significantly greater amounts of benthic infauna fed upon by walrus, bearded seal, and gray whale than do the bays. Observations of large numbers of gray whales and walrus feeding off of Point Franklin support this conclusion.

The nearshore zone is also used by both ringed and spotted seals during spring (March-June). Ringed seals normally inhabit the shore-fast ice during this period for denning and pupping, while subadult ringed seals and bearded seals occur along polynyas.

In addition to its use as feeding grounds and pupping habitat, the nearshore Chukchi Sea is used as a migration corridor by the previously mentioned species as well as the bowhead, beluga, and gray whales, and to some extent by the spotted seal and polar bear.

Harvest data gathered over the past twenty years indicate that caribou are the single most important resource species at Wainwright and Barrow, constituting over 50% of the average annual harvest in terms of usable weight. Ranked in order of decreasing importance the other major subsistence resources are walrus, bearded seal, bowhead whale, and marine and anadromous fish (Stoker 1983).

1.5.2 Birds

1.5.2.1 Introduction

Several lagoons and embayments along the Alaska coast of the Chukchi and Beaufort seas have recently been found to be important feeding and molting areas for large numbers of water-associated birds breeding in Alaska and Canada (Divoky 1978a,b; Johnson and Richardson 1981; Lehnhausen and Quinlan 1981). Peard Bay represents one of the largest of these areas, but until 1983 only cursory information was available about the magnitude and dynamics of bird use of this bay. During 1983, a study was initiated to: 1) determine the timing and magnitude of use by birds during spring, fall, and molt migration; 2) evaluate the relative importance to birds of the various habitats in the area; 3) identify important foods taken by major species of birds using the area; 4) compare the dynamics of use of Peard Bay by birds with that of other important lagoon and estuarine systems of the Arctic coast; and 5) evaluate the susceptibility of birds to potential disturbances from petroleum-related development in the Peard Bay area.

Several sampling methods were employed to address these objectives. Migration of birds through the Peard Bay area was monitored during extensive, systematic migration watches. Bird use of the various habitats in the area was determined through aerial surveys and on-ground censuses. Finally, the food base of birds using Peard Bay and the role birds play in structuring the ecological processes in the bay were investigated.

1.5.2.2 Bird Utilization

Temporal. The first spring migrants usually pass through the area beginning in late April, and by late May migration is at its peak. During 1983, spring migration was dominated by the passage of seaducks, primarily eiders, whose migration extended into the first week of June. The migration of most other groups of birds, including shorebirds, jaegers and passerines, occurred primarily during a 3- to 4-day period in early June. No significant migration of birds was detected after 7 June, except for a return migration of pomarine jaegers in mid-June. The period between the end of spring migration and mid-July when ice left the bay was generally one of reduced bird activity. Following the opening of the bay, the first oldsquaw and eiders arrived in the area to begin molt. Numbers steadily built through August and into early September. These numbers probably peaked in late September with the arrival of seaducks and other waterbirds that had molted and staged at lagoons along the Beaufort Sea coast. The migration of many species, including arctic loons, Sabine's and glaucous gulls, and arctic terns, was much more pronounced in fall than in spring. In contrast, no passerines migrated through the area in fall and among shorebirds, only red phalaropes occurred in numbers during this period.

Spatial. In 1983 there was essentially no use of either terrestrial or aquatic habitats of the Peard Bay area by birds for staging during spring migration. Birds did not begin to make substantial use of terrestrial habitats in the Peard Bay area until the onset of the breeding season in June. At Peard Bay there was positive evidence for six species breeding on mainland tundra and it is suspected that at least six other species breed there (Table 1-1). Densities of birds using the tundra of Peard Bay during the breeding season were comparable to those found at other sites along the Beaufort and Chukchi sea coasts. At Peard Bay a total of 3.9 pairs/ha was found, which included 2.1 pairs of shorebirds per hectare.

Salt marshes, sand dunes, beaches on barrier islands, and sand spits were also used by nesting birds at Peard Bay (Table 1-2). Species nesting there were those typically found nesting in such habitats along the Beaufort and Chukchi sea coasts. Brant, common eiders, oldsquaw, semipalmated sandpipers, and lapland longspurs were found breeding in salt marshes and it is suspected that a few arctic terns, savannah sparrows and snow buntings also nested.

The most abundant species nesting on the sand dunes and beaches of the barrier islands and sandspits of the Peard Bay area was the arctic tern. This species tended to nest in clusters of 6-20 pairs and a few pairs nested singly scattered in these habitats. A total of 50-65 pairs nested in the Peard Bay area. The Peard Bay spits and barrier islands supported low numbers of nesting common eiders, glaucous gulls, and brant. The Seahorse Islands in Peard Bay were a particularly important nesting area for black guillemots. Only 15 nests with eggs or chicks were found in early August, and it is not known what proportion of the 84 adults found roosting in the nesting area may have already lost eggs or chicks.

At Peard Bay, as is typical in the Arctic, most birds left nesting areas abruptly after breeding. Some birds migrated immediately (e.g., adult semipalmated sandpipers) but most moved to other habitats to stage before migration. Birds began to use open water and shoreline habitats within the

Table 1-1. Species of birds nesting in different habitats of the Peard Bay area in 1983. (B) indicates definite breeding record and (PB) indicates probable breeding in that habitat.

Species	Sand Dunes and Beaches	Tundra	Salt Marshes
Arctic loon		B	
Brant			B
Northern pintail		PB	
Common eider	B		B
Oldsquaw	B	B	B
Long-billed dowitcher		PB	
Pectoral sandpiper		PB	
Semipalmated sandpiper		B	B
Western sandpiper		B	
Dunlin		PB	
Red phalarope		PB	
Parasitic jaeger		PB	
Glaucous gull	B	B	
Sabine's gull	B		
Arctic tern	B		PB
Black guillemot	B		
Horned puffin	PB		
Savannah sparrow			PB
Lapland longspur		B	B
Snow bunting			PB

Table 1-2. Estimates of the size of bird populations using the Peard Bay area during aerial surveys in 1983.

	Estimated Number of Birds		
Species	July 15	August 10	August 25
Greater white-fronted goose	0	350	200
Brant	0	75	600
Eiders	35	2,520	4,180
Oldsquaw	95	2,330	6,930
Northern pintail	0	200	10
Red phalarope	0	130	35
Glaucous gull	95	970	680
Black-legged kittiwake	0	3,760	10
Arctic tern	40	2,180	500
Other species	10	120	35
Total	275	12,635	13,180

bay in significant numbers beginning in mid-July, but because of the record late break-up of ice in Peard Bay in 1983, it is not known if this timing is typical. Overall densities of birds using the shore and the deeper waters of Peard Bay are summarized in Table 1-2. Estimates of numbers of birds using all of Peard Bay ranged from 275 to 13,180 birds. On the 25 August survey the majority of birds were molting oldsquaw (53%) and eiders (32%). The density of oldsquaw recorded on this survey was one of the lowest recorded for this species with respect to other studies conducted at similar lagoons along the Alaska Beaufort Sea coast.

In terms of timing and species composition, the use of shoreline areas by birds generally supported the results of aerial surveys and migration watches. The lowest lineal density (3.9 birds/km) occurred during mid-July when there was still shore-fast ice in many places. By early August densities had increased to about 40 birds/km of shoreline, and by early September, 60 birds/km of shoreline. During August about half of the birds recorded were red phalaropes (21 birds/km). This density compares favorably with those reported for this species from other Beaufort Sea lagoons. By late August/early September oldsquaw and lesser numbers of eiders and glaucous gulls accounted for most of the birds using shoreline areas of the bay and Point Franklin spit.

1.5.2.3 Conclusions

In terms of the temporal and spatial use by birds and the prey used by birds, Peard Bay appears to represent a notable transition between the estuarine systems typical of the Arctic, such as Beaufort and Simpson Lagoons, and those typical of more subarctic areas, such as in Kotzebue and Norton Sounds.

Initial findings permit only tentative conclusions to be made with regard to the relative susceptibility of avian species to disturbances resulting from petroleum exploration and/or development in the Peard Bay area. All data point to the fact that considerable variation occurs among years in the timing and extent of use of the area by birds. This may be especially true in spring, when use of the bay and nearshore waters is highly dependent on the persistence of ice that year. The present study indicates, however, that at least for 1983 the Peard Bay area was particularly important to nesting black guillemots, migrating juvenile red phalaropes, and molting oldsquaw and eiders.

1.5.3 Invertebrates

1.5.3.1 Introduction

The purpose of the present Peard Bay study was to characterize the invertebrate populations within Peard Bay in terms of community compositions and abundances and in relation to habitats within the bay. Sample locations in Peard Bay are as shown in Figure 1-8. Sampling was carried out in July and August 1983, and March 1984. Epifaunal species of mysids and amphipods were found to be key trophic components to higher consumers in Simpson Lagoon on the Beaufort Sea coast (Griffiths and Dillinger 1981). A rich assemblage of birds and fish within this lagoon is supported by these epibenthic invertebrates.

Most of the previous NOAA/OCSEAP inshore benthic studies were directed toward assessment of selected habitats in the Arctic littoral system. Local aspects of boulder patch kelp ecology were investigated by Dunton and Schonberg (1980). Assessment of the importance of detritus of terrestrial origin in the arctic food web was made by Scheider and Koch (1980) and assessment of effects of crude oil on Beaufort Sea invertebrates under the physiological stress associated with hypersaline winter conditions were made by Scheider and Koch (1980). The seasonal recolonization of shallow depths (<2 m) was made by Broad (1980), while Carey (1980) investigated nearshore populations of bivalves along the Beaufort Sea coast. Distribution and abundance data were obtained for both epifaunal and infaunal invertebrates within Peard Bay. These data were needed because such invertebrate fauna constitute the trophic link between predators (mammals, birds, fish) and primary sources of organic carbon (marine or terrestrial).

The migration and abundance of the two dominant forms of mysids, *Mysis litoralis* and *Mysis relicta*, in Simpson Lagoon were related to a flushing type of wind induced exchange of nearshore waters (Griffiths and Dillinger 1981). Conversely, the more limited type of pulsing exchange induced by storm surge as typified in the lagoons of the eastern Beaufort Sea, showed decreased importance of mysids in vertebrate diets since their seasonal migration into the lagoons was restricted (Truett 1983). In a comparison of effects of exchange, the pulsing and flushing systems differ little in mysid species composition and abundance, but differ greatly in the relative dominance of the amphipod species in the epibenthic communities (Jewett and Griffiths 1983). Amphipods are more dominant in the epibenthic communities of the pulsing system.

Four methods were used to sample the invertebrate populations in the Peard Bay area during the open water and winter seasons. During open water seasons, populations of the epibenthos were sampled with drop nets and populations of infauna were sampled with diver taken cores. Winter populations were sampled with drop nets, baited traps, and vertical zooplankton tows. Four to five replicate samples were taken per station.

1.5.3.2 Invertebrate Distributions

The dominant epibenthic species in the dropnet samples, in order of abundance, were: the isopod *Saduria entomon*, the mysid *Mysis litoralis* and many juveniles of the genus *Mysis*, the amphipods *Gammaracanthus loricatus* and *Gammarus* sp. (juv.), and *Onisimus litoralis* (Table 1-3). Juvenile *S. entomon* were found in abundance at the Kugrua Bay station, and equivalent numbers of juvenile *Mysis* sp. were noted in both the Kugrua Bay and shallow lagoon samples. The dominant amphipod species by numbers of individuals, *G. loricatus* and *L. setosus*, were both found in large numbers at the Kugrua Bay station. *Onisimus litoralis* was prevalant in the samples taken from the Chukchi Sea side of Point Franklin spit. Other species present in lesser numbers were the amphipods *Onisimus glacialis* and *Monoculopsis longicornis* and juveniles of the decapod family Crangonidae.

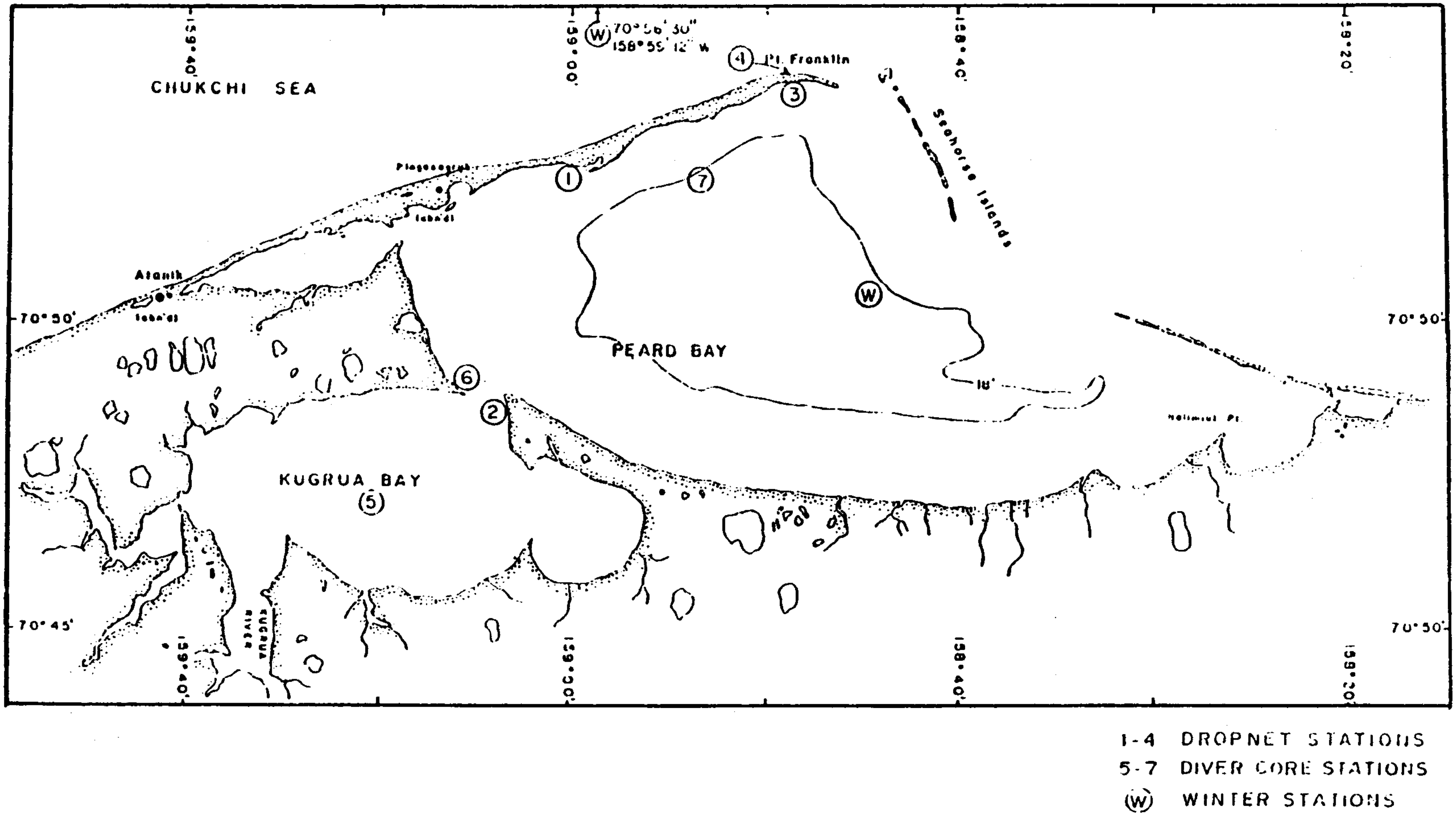

Figure 1-8. Invertebrate Sampling Stations, Summer 1983.

Table 1-3. Summary of density and biomass estimates for dominant epibenthic species taken from drop net samples (July 1983).

Crustacean Taxa	Abundance No.*	Abundance %**	Density (m^2) at occurring stations	Density (m^2) at all stations	Wet Weight (g) No.*	Wet Weight (g) %***	Biomass g/m^2) at occurring stations	Biomass g/m^2) at all stations
Mysis sp.	148	2.1	56.9	43.5	0.295	9.2	0.16	0.09
Saduria entomon	893	12.6	262.6	262.6	1.6028	49.9	0.47	0.47
Gammaracanthus loricatus	82	1.2	102.5	24.1	0.3377	10.5	0.42	0.10
Gammarus sp.	58	0.8	24.2	17.1	0.1496	4.7	0.21	0.15
Onisimus litoralis	47	0.7	19.6	13.8	0.278	8.7	0.12	0.08
Total	1,228	17.4		361.1	2.6631	83.0		0.89

* Sum of stations means.

** Percent of total abundance (7,062 individuals) of all taxa from all stations.

***Percent of total weight (3.2093 g) of all taxa from all stations.

The winter sampling period of March 1984 revealed little epibenthic acitvity at the station occupied in the central deep area of Peard Bay. Only a few amphipods and no mysids were found. The dominant species of amphipod captured in the drop nets was *Pontoporeia femorata,* while *Anonyx liljeborgi* and *Monoculodes longirostris* were the species found in the baited traps set at the water/ice interface. It was noteworthy that nothing was caught in the traps set over the bottom at the same station, indicating that the water/ice interface was the area of greater activity for at least the more predatory species of amphipods. This inference is supported by numerous observations during the CTD grid sampling. At most holes drilled in Peard Bay, numerous individuals of *Gammaracanthus loricatus* were spilled over the surface of the ice during hole completion procedures.

The zooplankton samples from the nearshore lead system and the Peard Bay station contained a typical component of copepods (Table 1-4). *Pseudocalanus* sp. dominated all samples with densities avgraging 123 individuals/m^2 from the nearshore lead system and 152 individuals/m^2 from the Peard Bay station. *Acartia* sp. was present in the lead system with an average of 4.3 individuals/m^2 and at the Peard Bay station with 8 individuals/m^2, while *Oithona* sp. was found in the lead system at densities of 5.9 individuals/m^2.

Although no drop net samples were successfully taken during the winter sampling period because of the prohibitive depth in the nearshore open lead area of the Chukchi Sea (80 feet), the results of zooplankton vertical hauls indicate the presence of mysids outside of Peard Bay (Table 1-4). Similar hauls taken within the bay contained no mysids, suggesting that they did not make use of Peard Bay as a winter habitat.

Samples taken for infauna within Peard Bay showed that a total of 80 taxa occurred at three diver core stations occupied in late August 1983, the most numerous being at the entrance to Kugrua Bay (38 taxa) and the least at the Peard Bay station (8 taxa) (Table 1-5). Of those taxa sampled, six were common to all three stations (nematodes, oligochaetes, *Terebellides stroemii, Chone duneri, Cylichna occulta,* and *Halicryptus spinulosus*). Results of cluster analysis also indicated that different species assemblages were sampled at each location.

Dominant phyletic groups and sediment particle sizes differed between stations. The annelid group tended to dominate the samples in terms of numbers of individuals at the Kugrua Bay and Kugrua Bay entrance stations, while molluscs tended to dominate the Peard Bay station.

The Peard Bay station sediments contained a large silt-clay fraction, while that at the entrance to Kugrua Bay was composed of pebbles overlain by a 7-10 cm mat of peat detritus interwoven with filamentous algae. The sediment sample from the Kugrua Bay station was lost; however, the Kugrua Bay station was observed to have a mud bottom.

Table 1-4. Summary of zooplankton net data for Peard Bay Benthic Stations Al 08 and Al 09. Data shown are mean counts for n replicates.

Station Number	Taxonomic Name	Number	Counts %	/m^3
Al 08	Anthozoa (medusae)	6	1.6	2.5
	Pseudocalanus sp.	303	81.0	128.2
	Acartia sp.	16	4.3	6.8
	Eurytemora sp.	5	1.3	2.1
	Harpacticoid sp.	27	7.2	11.5
	Harpacticoid sp.	11	2.9	4.7
	Harpacticoid sp.	3	0.8	1.3
	Harpacticoid sp.	1	0.3	0.4
	Ischyrocerus sp.	2	0.5	0.8
	Total	374		158.7
Al 09	*Pseudocalanus* sp.	1,084	91.3	110.4
	Eurytemora sp.	1	0.1	0.1
	Acartia sp.	37	3.1	3.8
	Harpacticoid sp.	8	0.7	0.8
	Harpacticoid sp.	3	0.3	0.3
	Harpacticoid sp.	1	0.1	0.1
	Oithona sp.	52	4.4	5.3
	Mysis sp.	1	0.1	0.1
	Total	1,187		120.9

Table 1-5. Summary of density and biomass estimates for dominant epibenthic and infauna species taken from diver core samples (August 1983).

	Abundance		Density (m^2)		Wet Weight (g)		Biomass g/m^2)	
Dominant Species	No.*	%**	at occurring stations	at all stations	No.*	%***	at occurring stations	at all stations
Oligochaeta	727	9.1	2,692.6	2,692.6	0.3005	0.7	1.11	1.11
Polychaeta								
Chone duneri	1,338	16.8	4,955.6	4,955.6	6.7089	15.6	24.85	24.85
Spio filicornis	632	7.9	7,022.2	2,340.7	1.8944	4.4	21.05	7.02
Scoloplos acmeceps	428	5.4	4,755.6	1,585.2	0.9063	2.1	10.07	3.36
Allia sp.	423	5.3	2,350.0	1,566.7	0.2580	0.6	1.43	0.96
Ampharete sp.	371	4.6	4,122.2	1,374.1	0.9276	2.2	10.31	3.44
Terebellides stroemii	137	1.7	507.4	507.4	0.6735	1.6	2.49	2.49
Mollusca								
Cylichna occulta	116	1.5	429.6	429.6	2.0591	4.8	7.63	7.63
Mytilus edulis	3	0.0	33.3	11.1	10.7449	24.9	119.39	39.80
Mysella tumida	463	5.8	5,144.4	1,714.8	3.0613	7.1	34.01	11.34
Liocyma fluctuosa	206	2.8	1,144.4	763.0	5.1255	11.9	28.48	18.98
Crustacea								
Caprella carina	86	1.1	955.6	318.5	0.2679	0.6	2.98	0.99
Atylus carinatus	27	0.3	150.0	100.0	0.6465	1.5	3.59	2.39
Urochordata								
Rhizomolgula globularis	10	0.1	111.1	37.0	3.1916	7.4	35.46	11.82
Total	4,967	62.4		18,396.3	36.7660	85.4		136.17

* Sum of stations means.
** Percent of total abundance (7,986 individuals) of all taxa from all stations.
***Percent of total weight (43.02 g) of all taxa from all stations.

1.5.3.3 Conclusions

On the basis of limited sampling, the epibenthic invertebrates of Peard Bay appear to be dominated by the same species of mysids and amphipods encountered in Beaufort Sea lagoons, with a few notable exceptions. The Peard Bay data indicate that mysids tend to predominate the epifauna of the shallow areas surrounding the deeper, central portion of the bay. In the deeper portions of the bay, suitable sampling was not accomplished. However, none were sampled at the deep, infaunal station where amphipods predominated, and no mysid remains were found in the gut contents of such opportunistic consumers as oldsquaws (n=26) and eider ducks (n=8) collected from the middle of the bay. Indications from sampling in Peard Bay were that mysids probably were patchy in distribution.

A comparison of biomass estimates based on wet weights and abundances of mysids illustrates the variable differences between the Peard Bay data and the previous Simpson and Angun Lagoon data sets for different years. At Simpson Lagoon, biomass estimates of 1,130 mg wet weight/m^2 and 405 mg wet weight/m^2 were recorded for both August of 1978 and 1982, while 540 mg wet weight/m^2 was noted in Angun Lagoon in late July 1982. Biomass estimates at the two drop net stations containing mysids in Peard Bay for early July 1983, were 170 and 100 mg wet weight/m^2. Such a set of comparisons shows the major differences between year data at Simpson Lagoon and between both Simpson and Angun Lagoons and Peard Bay. These differences should be viewed with caution, however, due to small sample sizes in the second year comparison of Simpson Lagoon data (Jewett and Griffiths 1983) and the limited sampling conducted in Peard Bay.

A comparison of the amphipod populations of Peard Bay with those of Simpson and Angun Lagoons illustrates the differences between the areas. Simpson Lagoon samples were dominated in terms of biomass and numbers by *Onisimus glacialis.* Angun Lagoon samples were dominated in terms of numbers by *Corophium* sp. and *Gammarus setosus,* while *O. glacialis* dominated biomass estimates. Peard Bay drop net samples and diver core samples were dominated in terms of abundances and wet weights by *Atylus carinatus*, *Gammaracanthus loricatus*, *Onisimus litoralis*, and *Caprella carina*.

Though no explanation for the differences in dominance between the Beaufort lagoons and Peard Bay is readily apparent, the differences in Peard Bay may be due in part to the depth and substrate of each location. *C. carina,* a caprellid amphipod, was found in the littoral habitat at the entrance to Kugrua Bay which contained an attached epibenthic community that was well established in a peat-algal mat. The mat covered a coarse pebble substrate in water depth of twelve to thirteen feet, well below the disruptive effects of seasonal ice formation. Conversely, *A. carinatus* was found in the deep, central area of the bay characterized by silt-clay fractions of sediment having little peat content. The deeper area was not well swept by currents as was the entrance to Kugrua Bay. This was evidenced by the occurrence of fine sediments and the lack of strong tidal currents (Chapter 2). *G. loricatus* and *O. litoralis* were found in the shallow water embayments of Peard Bay containing peat accumulations over a sandy bottom.

Amphipod biomass estimates from the shallow water drop net stations in 1983 averaged 438 mg/m^2. This estimate is similar to that given for the 1978 Simpson Lagoon study and the 1982 Angun Lagoon study (423 mg/m^2 and 493 mg/m^2, respectively). The 1982 Simpson Lagoon estimate of amphipod biomass is lower at 82 mg/m^2 but should be viewed with caution because of the small sample size (Jewett and Griffiths 1983).

Although diver core sampling was very limited, it appears that there are distinctly different benthic habitats within Peard Bay. The infauna of the deeper, central section of Peard Bay is dominated in terms of numbers and biomass by two species of bivalves, in a silt-clay bottom. Interestingly, the shallow benthic area near the entrance of Peard Bay was composed of pebbles overlain by a 7-10 cm mat of peat detritus interwoven with filamentous algae. This benthic algae may be sustained by nutrient sources from the Kugrua River. The extent of this type of bottom needs to be surveyed and the benthic primary productivity contributed by this algal mat assessed. The shallow center of Kugrua Bay itself was a mud bottom, dominated by oligochaetes. Elsewhere on the shallow shelf of Peard Bay, higher current velocities and coarser sediments in the deeper habitats of Peard and Kugrua Bays are at least 41 ppt and 48 ppt, respectively (March values), although wintertime exchange has also been documented for Peard Bay.

In comparison with previous infaunal studies, the species composition sampled at Peard Bay is composed of Arctic forms and not boreal Pacific forms found in the southern Chukchi Sea. Previous data taken in the Beaufort Sea suggest that oligochaetes, *Gammarus setosa*, *Onisimus litoralis*, *Saduria entomon*, *Scolecolepides arctius*, *Ampharete vega*, *Prionospio cirrifera*, *Terebellides stroemii*, *Cyrtodaria kurriana*, and *Liocyma fluctuosa* are dominant species (Carey 1978). Of the dominant infaunal species found in Peard Bay, *Spio filicornis*, *Chone duneri*, *Cylichna occulta*, *Mysella tumida*, and *Atylus carinatus* have been sampled in numerous locations in the Beaufort, indicating that the dominant species in Peard Bay are polar forms, not boreal Pacific.

1.5.4 Fish

1.5.4.1 Introduction

Few major fisheries studies have been conducted in the northeast Chukchi Sea. Frost and Lowry (1983) review the limited surveys which have occurred there and present offshore trawl data collected in 1977 during their survey which took place along the 40-m bottom contour between Icy Cape and Pt. Barrow. Fechhelm et al. (1983) examined the fish community composition in Ledyard Bay and Kasegaluk Lagoon during the open water period of 1983, and Peard Bay and Ledyard Bay in the winter of 1982. Quast (1972, 1974) investigated the density distribution of juvenile Arctic cod in Ledyard Bay during the open water season of 1970, while Alverson and Wilimovsky (1966) trawled north into Ledyard Bay. Mohr et al. (1957) documented fish catch information from a kelp bed located along the coast east of Peard Bay, and Craig and Schmidt (1982), Bendock (1979), and Bendock and Burr (1980) describe the anadromous fishes of the rivers flowing into the northeastern Chukchi Sea.

To date, 41 species of fish have been identified from the northeast Chukchi Sea (Morris 1981). Frequently encountered species include Arctic and saffron cod, Arctic flounder, fourhorn sculpin, capelin, rainbow smelt, herring, pink and chum salmon, at least two species of cisco, whitefish, and Arctic char.

Frost and Lowry (1983) found the Arctic cod to be the most widespread and abundant species in the northeast Chukchi Sea during the open water period, lending credence to the hypothesis that cod seasonally move north with the receding ice pack. However, their catch of cod from the Beaufort and northern Bering Seas was low. Stomach analyses revealed the cod populations in the eastern Chukchi fed heavily upon calanoid copepods such as *Calanus hyperboreus, C. glacialis, Euchaeta glacialis, Metridia longa,* and *C. cristatus* and upon the gammarid amphipod *Apherusa glacialis.* Cod populations sampled in the northern Bering consumed mostly a gammarid amphipod (*Ampelisca macrocephala*), shrimps (*Eualus fabricii* and *E. gaimardii*), and a mysid (*Neomysis rayii*). From these results and other available information the authors concluded that the Arctic cod are well adapted to living in an area where annual fluctuations in physical (ice cover) and biological (primary production) factors demand flexibility in feeding habits and abundance.

Fechhelm et al. (1983), in their investigation of Ledyard Bay and Kasegaluk Lagoon, found that marine fish species predominated in their catch results, while ciscoes, whitefish, Arctic char, and chum salmon were not in abundance presumably because of the scarcity of winter habitat afforded by large, coastal rivers. However, pink salmon and rainbow smelt were found to rely upon the smaller river systems of the Kokolik, Utakok, Kukpowruk, and Kuk along the Chukchi coast for spawning grounds. Arctic cod were the dominant species present nearshore. The winter study revealed that more feeding activity by Arctic cod took place in Ledyard Bay than in the nearshore area of Peard Bay, and a difference in the relationship of body weight to length was also apparent between the two areas. The dominant prey item by wet weight estimates (85%) for the Arctic cod in Ledyard Bay was the calanoid *Calanus glacialis,* while mysids appeared to increase in importance in the Peard Bay area. Stomach analyses indicated that the Arctic cod were foraging on *C. glacialis, A. macrocephala,* and *Diastylus rathkei* in more open waters.

Quast (1972, 1974) showed that the dominant fish in Ledyard Bay was the Arctic cod, the juveniles of which were clumped in a density structure at depth, possibly in response to predation pressure by piscivorous birds. Density estimates of 28 individuals/1,000 m^3 or 0.7 metric tons/km^2 of ocean surface were given. He further speculated that these juveniles had originated in the Chukchi Sea.

In the 1983-84 Peard Bay field study, the major purpose was to document the utilization of Peard Bay by coastal species. Peard Bay fish community composition, habitat utilization, timing of lagoon utilization, and population structure of key fish species were described. Fyke and gill nets were the sampling gear employed, with a trammel net used under the ice in winter. Stomach analyses were conducted to examine food web links between fish and the smaller pelagic or benthic fauna. Three field sampling efforts were carried out during the course of this study. Two open-water surveys were conducted in Peard Bay; one during 26 July-1 August and the other during 22-26 August. Additionally, an exploratory winter effort was carried out through the ice cover during March 1984.

1.5.4.2 Fish Utilization

Fyke and gill netting efforts produced 14 species of fish totaling 11,898 individuals (Table 1-6). Almost all (99.9%) fish were taken in fyke nets as drift gill net operations produced only one herring and one cisco.

Four marine species accounted for 99.6% of the total fyke net catch. These species were Arctic cod (69.5%), fourhorn sculpin (23.7%), saffron cod (5.7%), and Arctic flounder (0.7%). These results are comparable to those from Point Lay reported by Fechhelm et al. (1983), where ten marine species accounted for nearly 99% of the total catch, and in the almost complete absence of anadromous fish.

Only 31 anadromous fish were taken in Peard Bay in 1983. Arctic cisco, Arctic char, least cisco, and broad whitefish accounted for about 73% of the non-Arctic cod and sculpin catch in Simpson Lagoon in 1978 and over 90% in 1977 (Fechhelm et al. 1983). Conversely, whitefish and char represented less than 4% of the non-Arctic cod and sculpin catch in Peard Bay.

The Chukchi Sea coastal and/or freshwater habitats do not support major populations of anadromous fish, at least during the 1983 sample period. Whether this is caused by a lack of overwintering or breeding areas is uncertain at this time. An aerial and ground reconnaissance of the Kugrua River indicated generally poor habitat for anadromous fish.

The catch rates (CPUE) for fish taken per net hour in the fyke nets was computed for July and August as a whole for the most frequently taken species (Table 1-7). The overall catch rates are compared to the fyke net results from other Arctic areas in Table 1-8.

Several points seem clear from these data. Arctic cod and fourhorn sculpin are frequent in all catches in the Chukchi Sea and much of the Beaufort Sea, especially in estuarine and nearshore areas. Greater abundances of these species were indicated by the CPUE data taken in August compared to that of July. Lastly, anadromous species such as Arctic char and the several ciscos appear to be a much less important component of the fish fauna west of Point Barrow. In many areas they are virtually absent.

Another point of interest was apparent from the fyke net data and from the current meter measurements. If it is assumed that fish caught on one side or the other of a double fyke net indicate the direction of travel of the fish prior to entering the cod ends, then the fyke net directional catch data (Chapter 6) correlate with the current patterns described in Figures 1-5 and 1-7. In other words, these small marine fish seem to be moving consistent with the general circulation patterns of Peard Bay.

In the Peard Bay samples, small, immature individuals were the most abundant for the major marine species of Arctic cod, saffron cod, Arctic flounder, and fourhorn sculpin. The Arctic cod taken in Peard Bay ranged from 25 mm to 225 mm (TL). Unimodal length-frequency distribution was apparent between 75 and 100 mm. Immature individuals (less than 125 mm in length) composed over 87% of the total population of Arctic cod.

Table 1-6. Peard Bay fyke net fish catch data (1983).

Species	Number Caught	Percent of Catch
Arctic cod	8,270	69.5
Fourhorn sculpin	2,817	23.7
Saffron cod	680	5.7
Arctic flounder	82	<1
Least cisco	18	<1
Rainbow smelt	9	<1
Capelin	7	<1
Pacific herring	4	<1
Bering cisco	3	<1
Pacific sand lance	2	<1
Pink salmon	1	<1
Prickleback	1	<1
Eelpout	1	<1
Snailfish	1	<1
Totals	11,896	100.0

Table 1-7. Peard Bay fyke net catch per unit effort (fish/net/h) for July and August of 1983.

Fish Species	July (CPUE)	August (CPUE)	% Change
Arctic cod	3.3	31.1	+942
Fourhorn sculpin	0.6	11.1	+1850
Saffron cod	0.5	2.3	+460
Arctic flounder	0.2	0.1	-50
Others	<0.1	<0.1	0

Table 1-8. Fyke net catch rate (fish/net/h) for the four most frequently taken species in Peard Bay during summer of 1983.

Fish Species	CPUE (FISH/NET/H)
Arctic cod	17.2
Fourhorn sculpin	5.9
Saffron cod	1.4
Arctic flounder	0.1

Saffron cod from Peard Bay ranged from 54 to 294 mm (TL). The 75-100-mm size class dominated both July and August catches. This size class accounted for almost 63% of all saffron cod measured, and probably represents the Age 1 class (Craig and Haldorson 1981). The young-of-the-year size class (45-75 mm) which appeared in Point Lay catches in August (Fechhelm et al. 1983), and represented a second mode in the length/frequency display, was also present in Peard Bay, but represented only 22% of the total catch there.

Peard Bay sculpins ranged from 33 to 281 mm TL. Both July and August catches were dominated by small fish. Almost 70% of the fish were under 100 mm. These results are very similar to those of Fechhelm et al. (1983) for Point Lay, and suggest a dominance of Age 1 sculpins both in Peard Bay and at Point Lay (Craig and Haldorson 1981).

Arctic flounder ranged from 78 to 210 mm. July catches were strongly represented by 101-150-mm flounder while August catches were more evenly represented by many size classes, though the 101-150-mm cohort represented 58% of the catch, compared to 92% in July. These results compare favorably with those from Point Lay (Fechhelm et al. 1983).

1.5.4.3 Conclusions

The ichthyofauna of Peard Bay was dominated by four marine species common to the nearshore area of the northeastern Chukchi Sea. Arctic cod represented over 70% of the total catch with fourhorn sculpin, saffron cod, and Arctic flounder composing the majority of the remainder. The numbers of anadromous fish were low compared to populations of Arctic char and species of cisco and whitefish found along the Beaufort Sea coast. Suitable spawning and overwintering habitat is lacking along the northeast Chukchi coast where the extent of coastal rivers is reduced in comparison to that of the Beaufort Sea coast.

In Peard Bay the Arctic cod population was represented by immature individuals 87% of which were less than 125 mm in length. The predominance of immature individuals in the sample catch suggests that Peard Bay provides an important forage habitat and nursery area for coastal populations of Arctic cod. A similar situation existed for a number of marine species, as populations of saffron cod and fourhorn sculpin were also dominated by immature individuals.

1.6 FOOD WEB DYNAMICS OF PEARD BAY

Although many of the results of this year's Peard Bay study efforts were composed of distribution and utilization data, information was also obtained on the food web processes in Peard Bay. These results are particularly pertinent because of the physical differences and similarities of Peard Bay to lagoons previously studied by NOAA/OCSEAP.

Simpson Lagoon, an area which has been intensively studied, is a large but shallow (3 m) lagoon open to circulation at both ends as well as at the various entrances between the barrier islands. Angun Lagoon, on the eastern Beaufort coast, is a small lagoon with a restricted entrance. Driven by meteorological events, the entrance exchanges with the open sea in a pulsing manner. In contrast, Peard Bay is a large, deep lagoon (6 m throughout most of the central portion) with a wide entrance and a deep channel (4-6 m). In addition, an inner bay (Kugrua Bay) with restricted exchange with Peard Bay proper exists and the Kugrua River empties into this inner bay. Also, Peard Bay, which is located on the Chukchi Sea coast, is subject to a gradient of both Bering Sea and Beaufort Sea influences.

The present results are discussed in two sections. The first regards the primary productivity mechanisms in Peard Bay, and the second regards the data obtained on the higher trophic levels.

1.6.1 Conceptual Microbial Food Web and Carbon Sources

Carbon sources sustaining the food web in Peard Bay originate from both marine and terrestrial areas. The marine carbon is fixed by photosynthetic processes in the water column, either within Peard Bay or transported into the bay from inshore waters. The terrestrial carbon is transported into the bay from relict sources (i.e., peat) or from contemporary terrestrial production.

At this point, we have generated information about the dynamics of the microbial food web in the marine water column. Included is information on production of organic matter, as well as on the recycling of organic matter before transfer to higher trophic levels. We have also applied carbon isotope techniques to ascertain the relative contribution of terrestrial carbon to the higher trophic levels in the Peard Bay ecosystem.

1.6.1.1 Marine Microbial Web

In addition to measurements of the rate of marine primary production in Peard Bay, the dynamic processes of the microbial web in the water column responsible for this production were investigated. A schematic depiction of the microbial food web postulated to occur in Peard Bay is shown in Figure 1-9.

Knowledge of the dynamics of this food web is needed to understand the important processes and efficiencies involved in passing fixed carbon through the food web. The size fractions present in the microbial web (Figure 1-9) are also important because particles which can be grazed by macrozooplankton reside chiefly in the microplankton size range. The size fractions of interest are macroplankton (>200 μm), microplankton (20-200 μm), nanoplankton (2-20 μm), and picoplankton (<2 μm).

Productivity. The standing stocks and productivity of the phytoplankton components of the microbial web were measured, and the results are as follows:

1) Moderate phytoplankton standing stock in Peard Bay and environs ranges from 20 to 40 μg C/L and is most likely limited by nutrient availability.

2) High phytoplankton productivity (approximately 3 μg C/μg chlorophyll/h) and growth rates of about 1 division per day suggest that phytoplankton growth rates are close to the maximal rates expected to occur at the prevailing

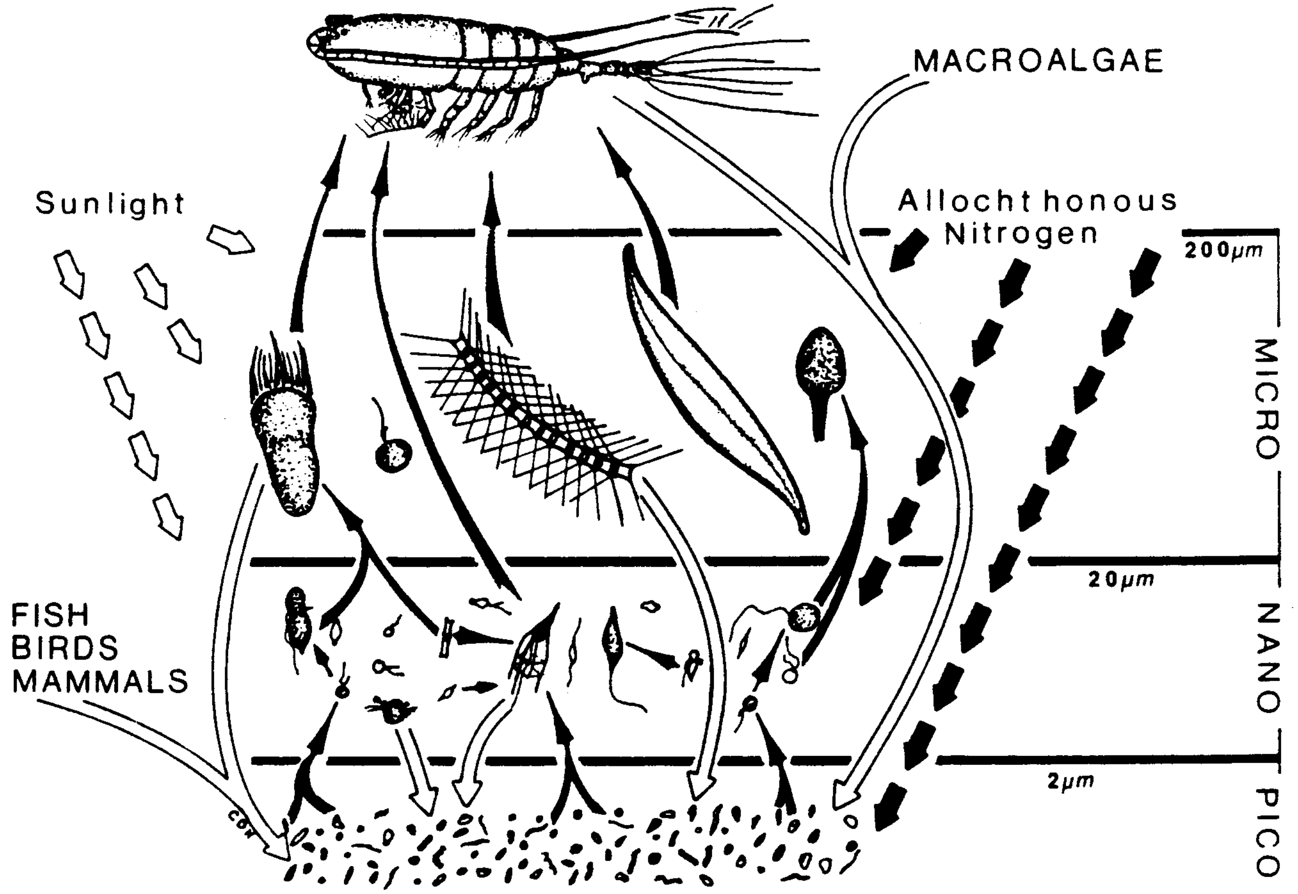

Figure 1-9. Peard Bay Microbial Food Web. Heterotrophic organisms are important in "repackaging" nanoplankton cells into particles that can be utilized by macrozooplankton. Clear unbroken arrows indicate inputs into the nutrient base; solid unbroken arrows indicate assimilatory pathways.

temperatures. Using the same assumptions as Schell et al. (1983), the annual productivity of Peard Bay would be approximately 10 g $C/m^2/yr$, slightly higher but possibly equivalent to that measured for Simpson Lagoon (6 g $C/m^2/yr$), and higher than indicated by the few measurements obtained by Schell et al. (1983) in Angun Lagoon on the eastern Beaufort coast.

Microbial Processes. Of most interest, however, is the functioning and structure of the microbial processes responsible for this productivity. The results at Peard Bay show that approximately 50% of the phytoplankton biomass and the primary productivity is contained in the nanoplankton fraction (<10 μm in diameter). Incubation experiments indicate that much of the biomass in these small cells is consumed by heterotrophic microplankton (10-200 μm in diameter).

Nutrient flux measurements indicate that there is very active nutrient regeneration occurring within the water column. This is substantiated by our documentation of large heterotrophic populations of microbial organisms which, through the combined effects of grazing and bacterioplankton activities, are largely responsible for the regeneration of ammonia and other nutrients.

Autotrophic and heterotrophic biomass for both nanoplankton and microplankton was estimated. Cyanobacteria were the most abundant autotrophic cells (approximately 10 per L), but contributed relatively little biomass by virtue of their small size. The most important group of autotrophic cells in terms of total biomass was the 5-7 μm naked dinoflagellates. Autotrophic biomass (<10 μg) was 23 ± 10 μg C/L. Heterotrophic nanoplankton biomass was rather constant at all stations (21 ± 4 μg C/L). In contrast to the nanoplankton biomass which contained 28-63% autotrophic cells, more than 80% of the microplankton consisted of protozoan biomass. Microplankton biomass was extremely high in the Chukchi Sea (210 μg C/L) as documented by microscopical examination. Estimated microzooplankton biomass for the other stations was 25-44 μg C/L. Most of the autotrophic microplankton consisted of long chains of *Chaetoceros* sp. At all stations, nanoplankton autotrophs were dominated by flagellates, with the diatom community consisting of smaller numbers of *Navicula*, *Nitzschia*, and *Amphoria* species. It was apparent from the microscopical examination of all samples that the protozoan biomass was a very important component of the plankton community.

Our results strongly suggest that the microbial portion of the food web in these waters is "unstructured" (Isaacs 1973) and that organic carbon is largely cycled between autotrophic and heterotrophic microbial organisms within the water column. This is schematically depicted in Figure 1-9. Heterotrophic organisms appear to be important in "repackaging" nanoplankton cells into particles which can be utilized by macrozooplankton.

The unstructured food web model of Isaacs (1972, 1973) has important implications regarding the fluxes and biomasses of marine organisms at differing trophic levels as well as regarding the distribution of trace materials in marine biota. Essentially, this model assumes that most creatures feed on whatever food is broadly suitable as to size and mode of feeding, with availability and abundance of food items being the major controlling parameters.

In such a system, the composition of any creature, excepting strict herbivores, is a broad mixture of material ranging from food freshly introduced into the system to a small quantity of material that has been recycled a number of times. Such material will not be an important quantity from the standpoint of food material or energy, but for some chemicals that may be concentrated at each step, such remnants may dominate. In an unstructured food web, food material passes through an infinite series of steps or conversions (with associated losses) into non-living but recoverable material.

The pyramid of a structured food web is comprised of relatively few (four to seven) steps, with specific groups of organisms rather closely restricted to a specific step. Unstructured food webs, on the other hand, can by viewed as composed of several interwoven pyramids, each with an infinite number of steps. Each successive step is occupied only by material and energy remaining from the preceding step, with living material in one pyramid and non-living but recoverable material in the other. Organisms in the unstructured food web do not occupy a small number of steps, but rather occupy broad regions which extend to infinity (except for strict herbivores). These regions differ principally in the point at which they begin with respect to the autotrophic level, and in the degree to which they are restricted to one or the other of the living or recoverable pyramids. The mathematics of an unstructured food web model yield simple expressions for the fluxes of material and energy, for the biomass at given trophic levels, and for the chemical composition of specific trophic types and materials.

There are two important aspects of this view of the food web relevant to this study: (1) Concomitant with the cycling of food materials between autotrophic and heterotrophic cells, there is the inevitable loss of energy at each transfer step. The efficiency with which primary production can be converted into biomass of utilizable trophic levels (e.g., fish) is inversely related to the number of steps in the food web (Ryther 1959). It is thus important to understand the routes and dynamics of the food web in order to relate the magnitude of primary production to the food resources available to higher trophic levels. (2) Nanoplankton cells (which are responsible for over 50% of the Peard Bay primary production) are considerably smaller than the particles ingested by most macrozooplankton. Copepod nauplii (Fernandez 1979) and copepod adults (Huntley 1981) have been shown to feed largely on particles larger than 20 µm in samples. Nauplii were observed in our samples, suggesting that macrozooplankton are an important link in the food web in these waters. These nauplii must utilize the productivity generated in the microplankton size range or that generated in the nano- plankton must be recycled into larger particles before utilization with attendant losses.

In summary, our results indicate that marine productivity in Peard Bay is relatively high for Arctic systems, and somewhat higher than measured previously in Simpson and Angun Lagoons on the Beaufort Sea coast. The microbial processes producing this productivity resemble an unstructured food web as described by Isaacs (1972, 1973). A significant fraction of the productivity is produced in the nanoplankton size range. A large amount of heterotrophic recycling occurs in this microbial food web.

Nutrients and Carbon Sources. Most striking results were obtained in Peard Bay by the very high ammonia values measured. Ammonia concentrations measured in Peard Bay were 1-3 μM/L. Values were obtained in Kugrua Bay of 5.5 μM/L and, just outside Peard Bay, of 3 μM/L. Typical ammonia concentrations in the Chukchi surface waters (Kinney et al. 1970) are at one or two orders of magnitude lower. Schell et al. (1983), however, measured comparably high values (1-7.7 μM/L) in Angun Lagoon. The highest ammonia values were measured in Kugrua Bay, perhaps indicating a terrestrial source of this nitrogen. Diver observations of the bottom of Kugrua Bay describe what appears to be a bacterial mat. Similar observations just outside Kugrua Bay indicate a benthic algal mat established on sediment of eroded peat materials, perhaps indicating a nutrient rich system. If the source of this nitrogen is terrestrial organic matter, we do not know what happens to the associated carbon. Future sampling of biota for carbon isotope measurements may resolve this point, particularly by including analysis of fixed benthic organisms for analyses.

Samples taken for carbon isotope analyses during 1983-84 include the dominant forage fish (Arctic cod and saffron cod), amphipods, isopods, mysids, peat, benthic algae, and plankton tows. These results are not yet complete. However, preliminary carbon isotope del-13 results indicate values of -21.7 for a Chukchi Sea plankton tow, a value to be expected for marine phytoplankton. A Peard Bay tow, consisting mostly of diatoms, gave a value of -19.0. A peat sample from the Point Franklin spit area gave a value of -26.6, a low value, characteristic of terrestrial organic matter. Values obtained for isopods, amphipods, and mysids were not between these extremes of terrestrial (-27) and marine (-21) carbon, but were -14.4, -16.9, and -17.2, respectively. Since marsh plants or kelp are unlikely sources of this carbon by virtue of their small biomass in Peard Bay, benthic diatoms are suspected. Further fractionation (+0.7 per trophic level) from an expected diatom value of -17 would have to be occurring. Further samples and checks are being run to verify these numbers and to explain their implications. However, peat at -27 does not seem to be the carbon source for these crustacea, which are important to the higher trophic levels of Peard Bay.

1.6.2 Higher Trophic Food Web

The ecological processes of importance in Peard Bay consist of an interplay of physical transport processes, specialized habitats within the system, and food webs of the dominant fauna. A brief synthesis of this overall system is shown schematically in Figure 1-10.

Overall, the system appears to be driven by nutrients and fixed carbon from both terrestrial and marine systems. However, the increased residence time of Kugrua and Peard Bays when compared to the other NOAA/OCSEAP studied areas, may make terrestrial carbon more important than previously realized, either as fixed carbon or as a nutrient supply for primary production in the water column. Also, within the Peard Bay/Kugrua Bay system, subhabitats are physically extensive. Indications are that areas such as the shelf and deep basin in Peard Bay, and the Kugrua Bay basin are distinctly different.

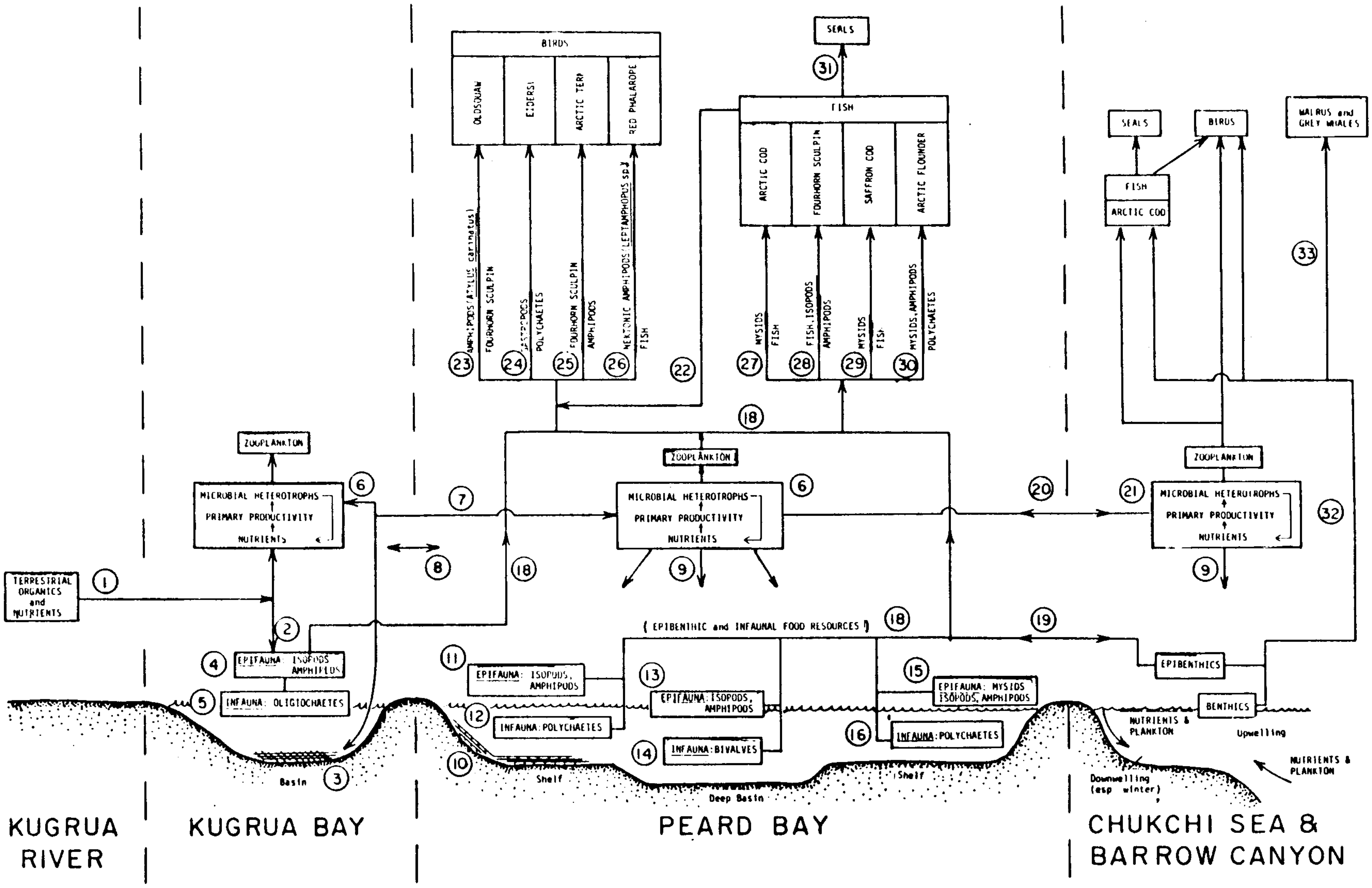

Figure 1-10. Peard Bay Ecological Processes and Food Web.

At this point in time, our synthesis should be regarded as incomplete and qualitative, because the field study could not cover all areas adequately. For example, some areas that may be classed as subhabitats within the Peard Bay system may only have been represented by a single station. Also, insufficient effort was expended on the stomach analyses of birds to clearly differentiate variations in feeding behavior versus prey availability between subhabitats. Nevertheless, an extremely interesting overall picture of the Peard Bay ecosystem is proposed, one which shows distinct differences as well as similarities to Simpson and Beaufort Lagoons.

Peard Bay Ecosystem and Trophic Structure. In the text that follows, we present a tentative synthesis of the Peard Bay ecosystem. We use the schematic of Figure 1-10, and the numbering system therein to discuss the processes, habitats, and food web inherent in the Peard Bay system.

Terrestrial organic matter and nutrients are introduced [1] into Kugrua Bay by the Kugrua River and by local erosion of tundra cliffs. The Kugrua River is estimated to drain some 406 mi^2 of tundra. Most of the discharge probably occurs in June during breakup. A comparison of the Kugrua River drainage with that of Nanavak Creek, a USGS gauged creek near Barrow, indicates that a maximum discharge of 1200 cubic feet per second (cfs) could be expected in mid-June. This flow would quickly drop off during successive weeks as is typical of tundra rivers. Given the nature of the Kugrua drainage, it seems likely that this discharge carries large quantities of particulate organics and dissolved nutrients.

Sedimentation [2] takes place in Kugrua Bay. River flow is slow at all times other than breakup. An organic rich "bacterial mat" [3] was observed by divers in summer with bubbles and strands of organic matter rising in the quiet current. In late winter, salinities under the ice were approximately 48 ppt.

Epifauna [4] in Kugrua Bay apparently were dominated by isopods (*Saduria entomon*), amphipods (*Gammaracanthus loricatus*), and juvenile mysids. Infauna [5] were dominated by large numbers of oligochaetes and biomass of polychaetes, and the gastropod *Cylichna occulta*.

Primary production [6] in the water column proceeds according to the microbial processes discussed previously, with total productivity estimated at 8-10 g $C/m^2/yr$ in Kugrua Bay. The high nutrient levels in Kugrua Bay, as shown by ammonia concentrations of 5.5 $\mu M/L$, are indirect evidence of high heterotrophic activity, probably utilizing terrestrial organic matter.

Nutrients and fixed organic matter are transported [7] out of Kugrua Bay and into Peard Bay by the net outward flow. Active tidal and surge exchange [8] occurs at the entrance of Kugrua Bay, but tidal currents are slow within, and exchange is limited.

In Peard Bay, similar levels (i.e., 10 g $C/m^2/yr$) of microbial productivity occur [6]. Ammonia values measured were also high, 1-3 $\mu M/L$, but lower than those of Kugrua Bay. Again, high heterotrophic activities were measured in the water column.

Nutrients and organic matter are also exchanged [20] between Peard Bay and the nearshore Chukchi Sea. The residence time of Peard Bay, estimated to be approximately 15 days, is driven by tidal exchange (70%) and by surge (30%) from meteorological forcing. Inshore Chukchi Sea water exhibits temporal and spatial patchiness due to variable contributions of ice melt, upwelling, wind mixing, solar heating, and freshwater inputs. Currents driven by large scale meteorological forcing are predominantly to the northeast, but with frequent reversals. Upwelling and flow through the Barrow Canyon from the Arctic Ocean occur during these reversals. Water exchange with Peard Bay thus exhibits these variable offshore events. For example, a positive storm surge (+0.8 m) measured on 18 August flooded Peard Bay with dense, cold water probably from a previous upwelling. However, ammonia values in this deeper Chukchi Sea water would not be expected to be above 1 μM/L and thus would not be the source of the high ammonia concentrations in Peard Bay (Kinney et al. 1970). On the other hand, a negative storm surge measured in March resulted in cold, high salinity (41 ppt) water leaving Peard Bay at speeds up to 1.5 knots in the Seahorse Islands entrance. This water would sink and flow along the bottom of the nearshore Chukchi Sea.

Within Peard Bay, portions of the productivity generated in the water column are passed up the food chain to zooplankton [17] or to the sediments [19], contributing food to the epibenthic and infaunal communities of Peard Bay.

Peard Bay has shallow shelf areas surrounding the deeper portions of the central basin (7 m). Just outside the entrance to Kugrua Bay, an algal benthic mat [10] exists as discussed in the above section. Epifauna [11] biomass in this area was dominated by isopods (*Saduria entomon*), amphipods (*Gammaracanthus loricatus*), and juvenile mysids. Infauna biomass [12] was dominated by polychaetes, bivalves (*Mytilus edulis*), and urochordates (*Rhizomolgula globularis*).

On the shelf near Point Franklin, epifauna biomass [15] was dominated by mysids, isopods (*Saduria entomon*), and amphipods (*Onisimus litoralis*). Infauna [16] has not yet been sampled on this shelf. Infauna biomass [14] in the deeper basin was dominated by gastropods (*Liocyma fluctuosa, Mysella tumida*, and *Cylichna occulta*) while epifauna [13] are probably composed mostly of isopods and amphipods. The amphipod *Atylus carinatus* was common in the infaunal samples, and formed a major part of the infauna biomass. The infauna and epifauna constitute a significant food resource [18] for upper trophic levels.

Five species of birds were selected for feeding studies: oldsquaw, king and spectacled eiders, Arctic tern, and red phalarope. Epifauna, infauna, and fish were found to be the primary food utilized by these species in Peard Bay.

The diet of oldsquaw [23] collected in Peard Bay (Table 1-9) was dominated by a single species of amphipod, *Atylus carinatus,* comprising over half the total numbers and volume of prey and occurring in almost half of the stomachs. Next, according to the methods of Griffiths et al. (1975) and Pinkas et al. (1971), bivalves and fish were most important. The latter consisted exclusively of fourhorn sculpins (*Myoxocephalus quadricornis*), which averaged over twice the size (24.0 mm ± 10.4) of the amphipods (11.7 mm ± 4.5) eaten. The bivalves included five different species, among which *Musculus corrugatus* and *Cyrtodaria kurriana* predominated. The rest of the diet consisted of gastropods (2.2%), polychaetes (2.8%), mysids (0.7%), and isopods (0.2%).

The amphipod *Atylus carinatus* was singularly important in the diet of eiders [24] (Table 1-10) composing over half the total numbers and volume of prey and occurring in half the stomachs. The average size taken (15.9 mm ± 4.5) was significantly larger ($p < 0.001$) than that taken by oldsquaw. Neither fish nor bivalves were particularly important to eiders; instead, gastropods, primarily *Cylichna occulta* and *Polinices pallida*, and polychaetes of the genus *Nephthys* ranked next in importance. These polychaetes were quite large, averaging 144.0 mm (±77.1) in length. Other prey of minor importance included three species of bivalves, the isopod *Saduria entomon*, mysids, the priapulid *Priapulis caudatus*, and unidentified fish and plant parts.

The diet of arctic terns [25] (Table 1-11) was heavily dominated by fish, primarily fourhorn sculpin (*Myoxocephalus quadricornis*), although Arctic cod (*Boreogadus saida*) also were taken. Fish occurred in 93% of the stomachs and comprised 70% of the numbers and 76% of the volume of the prey taken. Gammarid amphipods were second in importance as prey although those of the genera *Leptamphopus* and *Onisimus* were taken more frequently than *Atylus carinatus*. Calanoid and harpacticoid copepods, seeds, and insects (adult Diptera) formed the rest of the diet. The *Leptamphopus* averaged about 6 mm and the copepods about 1 mm in size.

In the diet of red phalaropes [26] (Table 1-12) gammarid amphipods were by far the most important prey although no *Atylus carinatus* were taken. Instead, *Leptamphopus* sp. predominated, being present in over half of the stomachs and comprising over 40% of the numbers and greater than 30% of the volume of all prey consumed. The amphipod *Onisimus glacialis* was also found in one stomach. Both species of amphipod averaged about 5.5 mm in length. Other food items included unidentified plant parts, polychaetes, mysids, bivalves, and isopods.

Only qualitative data are available at present on the diets of the four fish that make up the majority of all the fish caught in Peard Bay. Volumes and weights of prey species were available for only a few of the fish caught, thus only percent occurrence data are presented. For those stomachs studied, fresh or slightly digested prey items were not enumerated; nevertheless, the possibility of feeding while in the fyke net cannot be entirely excluded.

Table 1-13 provides the prey species ranking for Arctic cod, fourhorn sculpin, saffron cod, and Arctic flounder. Table 1-14 presents the summed prey ranking for fishes examined in 1983 from Peard Bay.

The mysid *Mysis litoralis* was the important food item in terms of number in the fish stomachs analyzed to date. Mysids ranked first in abundance 31 times, and was represented in 35.8% of all stomachs examined. Small Arctic cod, the isopod *Saduria entomon,* and amphipods (primarily *Onisimus* sp. and *Atylus* sp.) were also important in the diets of fish taken in Peard Bay.

For arctic and saffron cod [27], mysids and fish were found to be key components [29]. The Arctic flounder [30] diet consisted of mysids, amphipods, and polychaetes, while fourhorn sculpin [28] exhibited a more varied diet of mysids, amphipods, isopods, fish, and polychaetes.

Table 1-9. Percent occurrence, number and volume of taxa of prey identified in stomachs of oldsquaw collected from Peard Bay in 1983 (n = 26 stomachs).

Taxon	Number of stomachs	Number of prey	Vol. (ml)	Percent (%) No.	Percent (%) Occ.	Percent (%) Vol.
Amphipods	11	752	156.5	55.4	42.3	56.0
Atylus carinatus	11	736	155.1	54.2	42.3	55.4
Fish	14	170	66.7	12.5	53.8	23.8
Bivalves	13	222	37.9	16.3	50.0	13.6
Gastropods	9	67	6.3	4.9	34.6	2.2
Ostracods	6	80	0.6	5.9	23.1	0.2
Polychaetes	6	20	9.0	1.5	23.1	3.2
Mysids	7	31	1.5	2.3	26.9	0.5
Isopods	1	13	1.0	1.0	3.8	0.4
Hydroids	2	2	0.2	0.1	7.7	0.1
Total		1,357	279.8	99.9		99.9

Table 1-10. Percent occurrence, number and volume of taxa of prey identified in stomachs of king and spectacled eiders collected from Peard Bay in 1983 (n = 8 stomachs).

Taxon	Number of stomachs	Number of prey	Vol. (ml)	Percent (%) No.	Percent (%) Occ.	Percent (%) Vol.
Amphipods	4	188	60.1	64.8	50.0	52.3
Atylus carinatus	4	183	60.0	63.1	50.0	52.2
Gastropods	7	64	11.4	22.1	87.5	9.9
Polychaetes	2	11	32.0	3.8	25.0	27.8
Bivalves	6	10	1.3	3.5	75.0	1.1
Fish	3	8	0.3	2.8	37.5	0.3
Priapulids	1	3	7.0	1.0	12.5	6.1
Plants	2	2	1.3	0.7	25.0	1.1
Isopods	2	2	1.3	0.7	25.0	1.1
Mysids	1	1	0.1	0.3	12.5	0.1
Ostracods	1	1	0.1	0.3	12.5	0.1
Total		290	114.9	100.0		99.9

Table 1-11. Percent occurrence, number and volume of taxa of prey identified in stomachs of arctic terns collected from Peard Bay in 1983 (n = 14 stomachs).

Taxon	Number of stomachs	Number of prey	Vol. (ml)	Percent (%) No.	Percent (%) Occ.	Percent (%) Vol.
Fish	13	91	4.5	69.5	92.9	76.3
Myoxocephalus	9	83	3.8	63.4	64.3	64.4
Boreogadus	7	8	0.7	6.1	50.0	11.9
Amphipods	6	23	0.9	17.6	42.9	15.3
Copepods	3	15	0.3	11.5	21.4	5.1
Insects	1	1	0.1	0.8	7.1	1.7
Seeds	1	1	0.1	0.8	7.1	1.7
Total		131	5.9	100.2		100.1

Table 1-12. A comparison of the diets of oldsquaw in Simpson Lagoon, Beaufort Lagoon and Peard Bay.[1]

Taxon	Simpson Lagoon 1977 (n=54)	Simpson Lagoon 1978 (n=72)	Beaufort Lagoon 1982 (n=24)	Peard Bay 1983 (n=26)
Mysids	67.6	79.7	37.7	0.7
Amphipods	15.9	12.4	13.1	54.6
Fish	2.7	0.4	46.6	23.2
Bivalves	9.6	6.2	0.3	16.1
Others	4.2	1.3	2.3	5.4

[1] Expressed as percent composition wet weight (g). Data for Simpson and Beaufort Lagoons from Johnson (1983).

Table 1-13. Stomach content ranking of commonly taken fishes from Peard Bay, 1983.

Prey Item	Rank 1	2	3	Total Number of Occurrences	Frequency of Occurrence
Arctic Cod (*Boreogadus saida*)					
Mysids	20			20	64.5
Fish	3	1		4	12.9
Amphipods		1		1	3.2
Copepods		1		1	3.2
Empty	5			5	16.1
				N = 31	
Fourhorn sculpin (*Myoxocephalus quadricornis*)					
Mysids		1	1	2	7.1
Fish	3	2	3	8	28.6
Isopods		6		6	21.4
Amphipods	3	2		5	17.9
Sculpin			2	2	7.1
Worms		2		2	7.1
Empty	1			1	3.6
				N = 25	
Saffron cod (*Eleginus gracilis*)					
Mysids	8	1		9	39.1
Fish	1	1		2	8.7
Larval Fish	2			2	8.7
Empty	10			10	43.5
				N = 23	
Arctic flounder (*Liopsetta glacialis*)					
Mysids	3			3	23.1
Amphipods	1			1	7.7
Worms	2	1		3	23.1
Empty	6			6	46.2
				N = 13	

Table 1-14. 1983 Peard Bay - Prey rank summation.

Prey Item	Rank 1	 2	 3	Total Number of Occurrences	Frequency of Occurrence
Mysids	31	2	1	34	35.8
B. saida	7	4	3	14	14.7
Saduria	-	6	-	6	6.3
Amphipods	4	3	-	7	7.4
Worms	2	3	-	5	5.3
Larval fish	2	2	-	4	4.2
Copepods	-	1	-	1	1.1
Sculpin	-	-	2	2	2.1
Empty	22	-	-	22	23.2

Feeding studies were not conducted on marine mammals in Peard Bay, but sufficient data exists from other studies. As mentioned above, seals were the only marine mammal using the bay to any significant degree. Three gray whales were seen inside the bay during the summer. Benthic feeding by walrus and whales was extensive just offshore in the Chukchi Sea, but was probably not a factor inside Peard Bay.

Ringed seals appear to be opportunistic feeders on a wide range of invertebrate infauna and epifauna, zooplankton, and fish. Items known to be eaten include saffron cod, Arctic cod, rainbow smelt, sand lance, sculpin, herring, pandalid and crangonid shrimps, mysids, gammarid and hyperiid amphipods, and euphausids (Lowry et al. 1982).

Like ringed seals, spotted seals are opportunistic feeders on a wide range of marine fish and invertebrates. Their diet is known to include Arctic cod, saffron cod, sand lance, rainbow smelt, herring, sculpins, walleye pollock, capelin, flatfishes, octopus, Tanner crab, pandalid and crangonid shrimps, euphausids, and hyperiid amphipods (Lowry et al. 1982). Though the diet of spotted seal and ringed seal overlap to a considerable degree, spotted seals seem to be more reliant on fish and less on crustaceans, particularly zooplankton forms, than ringed seals.

1.6.3 Conclusions

Although our quantitative knowledge of Peard Bay is still incomplete, a very interesting picture is emerging. The Peard Bay ecosystem seems to be one in which nutrients, and possibly organic materials, derived from terrestrial sources (i.e., via Kugrua River) are important. This importance may be due largely to the residence time provided by the inner bay, Kugrua Bay, and by the deep (7 m) basin of Peard Bay. Consequently, both nutrient concentrations and productivity are high.

Benthic habitats within the bay system (shelf and deep basin) provide epibenthic and infaunal food resources for higher vertebrates, especially for birds and marine fish. Anadromous fish usage is very low, and may be due to the poor habitat in the Kugrua River. Despite high marine mammal use in the Chukchi Sea nearshore, only seals apparently make significant use of bay waters.

1.7 PRELIMINARY COMPARISON OF VULNERABILITIES TO OIL AND GAS DEVELOPMENT

1.7.1 Introduction

Extensive multi-year studies have been carried out in Simpson Lagoon on the Beaufort Sea coast both prior to and as part of the OCSEAP program (Alexander 1975; Johnson and Richardson 1980). A short comparative study of lagoons of the eastern Beaufort coast was also completed (LGL 1983).

These studies included analyses of vulnerabilities of these Arctic lagoons to oil and gas development. Other detailed analyses of impacts have been made for the Beaufort Sea coast, such as the Final Environmental Impact Statement for the Diapir Field Lease Offering (MMS 1984).

In the section that follows, we point out differences of the Peard Bay lagoon system from those of the better known Beaufort Sea lagoon systems, especially those that have a bearing on vulnerability to oil and gas development. Other physical and biological studies are ongoing in the Chukchi Sea, offshore Peard Bay, and along the Chukchi coast for which the results are not yet available. The Peard Bay study also has one year of planned field work remaining; therefore, the discussion which follows must be regarded as preliminary.

1.7.2 Peard Bay and Beaufort Sea Lagoons

Peard Bay is a large (240 km^2), semiclosed lagoon, bounded from the sea by extensive gravel spits and a small series of barrier islands called the Seahorse Islands. A deep channel exists at the east end of these islands, but a much wider shallow bar extends seaward to the east through which oil could enter. A smaller, shallow entrance exists at the end of the large Point Franklin spit. In contrast, Simpson Lagoon, which is somewhat smaller, is separated from the sea to the north by numerous barrier islands. Entrances also exist between these islands and on both of the open ends of the lagoon. Angun Lagoon is a much smaller lagoon with a restricted entrance.

An offshore oil spill would be somewhat restricted from entering Peard Bay by the spits and barrier islands. From the north and east, winds could blow surface oil into Peard Bay through the wide eastern opening. Such winds could also reverse the coastal currents to the southwest, but would be accompanied by a negative surge at Peard Bay. This surge would tend to drop the water level in the bay and possibly slow oil from entering the bay. Oil from the southwest driven by a southwesterly wind could enter the bay as a positive surge. Should Peard Bay become a staging area, it would be directly subject to complex contamination from industrial activities within the bay.

A ranking system for assessment of coastal vulnerability, based upon coastal morphology and persistence of oil in different types of coastline features, has been proposed by Hayes and Ruby (1979). The ranks range from 1 to 10, with 10 indicating the most vulnerable habitats. The gravel spits and barrier islands of Peard Bay would be assigned a moderate rank of 3 or 4. However, the interior beaches and wetlands of Peard Bay would be assigned much higher risk factors, e.g., 9 or 10, because of the higher potential residence time of oil inside the bay. Within Peard Bay the beaches are composed primarily of eroding tundra with gravel in front and support very sparse fauna. Lowlands and mudflats exist, however, in Kugrua Bay and around the river mouth.

The long potential residence time for oil is one of the major differences between Peard Bay and Simpson Lagoon. The residence time of water in Peard Bay is estimated to be about 15-20 days while that of Simpson Lagoon is 1-10 days, depending on wind conditions. Because of the enclosed geometry of Peard Bay, the differences in residence time of oil could be much greater. Angun Lagoon in the eastern Beaufort is similar to Peard Bay, but very much smaller in area.

The Peard Bay system also has two areas that are important to the ecology of the bay that may have even greater oil spill residence times. One is an inner bay system (Kugrua Bay) which is absent in the Beaufort lagoon systems. The second is the deep basin of Peard Bay which has a long hydrographic residence time, where water remains until displaced by suitably dense water flooding over the shallow sill or mixed upward with surface waters. Neither of the Beaufort Sea lagoons have such a deep basin.

Peard Bay, unlike Simpson Lagoon, has high ammonia concentrations and somewhat higher productivity. These differences may be because of the increased residence time, and terrestrial (river) inputs of nutrients and, possibly, of organic matter. Extensive benthic subhabitats exist within Peard Bay which support epibenthic and infaunal food resources for vertebrates. These benthic habitats are the shallow shelves, the deep basin of Peard Bay, and the shallow benthic area of Kugrua Bay. Mysids in these habitats are less dominant than in Simpson Lagoon, hence, amphipod, isopods, molluscs, and polychaetes are more important.

Of the higher vertebrates, birds are the most vulnerable to oil spills. In terms of the temporal and spatial use and in terms of prey available to and used by birds, Peard Bay appears to be a notable transition in estuarine systems between those typical of the arctic, such as Beaufort and Simpson Lagoons, and those typical of more subarctic areas, such as Kotzebue Sound. During 1983, Peard Bay was particularly important to nesting black guillemots, migrating juvenile red phalaropes, and molting oldsquaw and eiders, all of which are vulnerable to oil on water.

Another potential source of vulnerability to birds would be through their food supply. Major differences in diets were observed between Peard Bay and the Beaufort Sea lagoons. The diets of birds collected at Peard Bay, particularly oldsquaw and red phalaropes, were quite different from those reported for these species from Simpson and Beaufort lagoons. Although mysids figured prominently in the diets of oldsquaw at Simpson and Beaufort lagoons, they composed only a trace of the prey of oldsquaw at Peard Bay; instead, amphipods of the genus *Atylus* were the major prey eaten at Peard Bay with fish (cottids) and bivalves also important components of the diet. Only at Beaufort Lagoon did fish assume an equal importance in the diet of oldsquaw, and at neither Simpson nor Beaufort lagoons did bivalves play an important role in the diet of this species. Red phalaropes at Peard Bay consumed primarily amphipods and mysids. At Beaufort Sea sites these and other prey assumed different levels of importance in the diets of phalaropes. These inter-site differences may be real or due to annual variations in prey availability or the generally small sample size of stomachs from the various sites. The diet of eiders at Peard Bay was composed of amphipods, polychaetes, and gastropods. while the diet of Arctic terns was almost exclusively fish; some amphipods and copepods were eaten.

In spite of these differences in prey items of birds, however, their food chain is heavily dependent on the epibenthic and infaunal food resources of Peard Bay as was true in the Beaufort Sea lagoons. If the bottom sediments were oiled, the birds and fish could be affected through the food chain.

The fish composition of Peard Bay differed in one major respect from that of Simpson Lagoon. There was a very low abundance of anadromous fish noted in Peard Bay. Oil and gas development thus has less potential for impact on such resources of direct use to man.

Mammal use of Peard Bay seemed to be limited in numbers to seals. Several polar bears were seen on Point Franklin and a few gray whales were seen in the bay. However, substantial mammal resources exist just outside Peard Bay along the Chukchi Sea coast.

Subsistence use (mammals, birds, and some fish) occurs in the Peard Bay area associated with proximity to nearby population centers at Barrow and Wainwright and to the substantial mammal resources which exist just off Peard Bay in the nearshore zone. Such subsistence use could be impacted by increased human activity associated with oil and gas development.

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CHAPTER 2

PHYSICAL OCEANOGRAPHY OF PEARD BAY

2.1 INTRODUCTION

2.1.1 General

The eastern Chukchi Sea coast as a whole, from the Bering Strait northward to Point Barrow, is a complex region with major topographic features. In addition, influences of the Bering Sea to the south and of the Arctic Ocean to the north effect this coastal region. This is in contrast to the Beaufort Sea coast which lacks major topographic divisions, variable external influences, and even a north-south latitudinal gradient. The Chukchi coastal region north of Point Lisburne generally trends toward the northeast to Point Barrow. This section of coast features three large cusp-like features, delineated by Point Lisburne, Icy Cape, and Point Franklin. Associated with these larger features are shallow, coastal lagoons formed by coastal spits or offshore barrier islands. Peard Bay is the shallow lagoon furthest to the northeast along this coast. Others of interest to NOAA/OCSEAP in the region of OCS Sale No. 85 are Kasegaluk Lagoon and Ledyard Bay.

Peard Bay is a large lagoon on the Arctic coast of the Chukchi Sea with a surface area of about 240 km^2 (Figure 2-1). The Kugrua River feeds into Peard Bay via Kugrua Bay and a narrow connecting channel. The major inlet between Peard Bay and the Chukchi Sea is south of the Seahorse Islands. The main channel in this eastern inlet is located at the southern end of the island group. Shoals extend across the rest of this inlet. The channel is as deep as 12 m, but shoals to 4 m after entering the Bay. The shoal area is 1.5 m deep or shallower, with two sections which are about 3 m deep. A second inlet to Peard Bay is located between Point Franklin and the northern end of the Seahorse Islands. The channel in this northern inlet is 2.5 m deep and is located immediately off Point Franklin. The rest of the inlet shoals to 1.5 m or less. The large central region of Peard Bay is about 7 m deep.

2.1.2 Specific Objectives

The purpose of this study element was to understand the basic physical oceanographic processes operative in Peard Bay, and to support the Peard Bay ecological processes study. Specifically, current meters, water level gauges, recording temperature/salinity sensors, and CTD transects were used to measure lagoon-shelf water exchange as well as transport within the bay. The available physical oceanographic literature for the eastern Chukchi Sea coast was reviewed as a background for interpretation of the Peard Bay field studies. The Peard Bay results are used in Chapter 1 to compare Peard Bay with the lagoons of the Beaufort Sea coast.

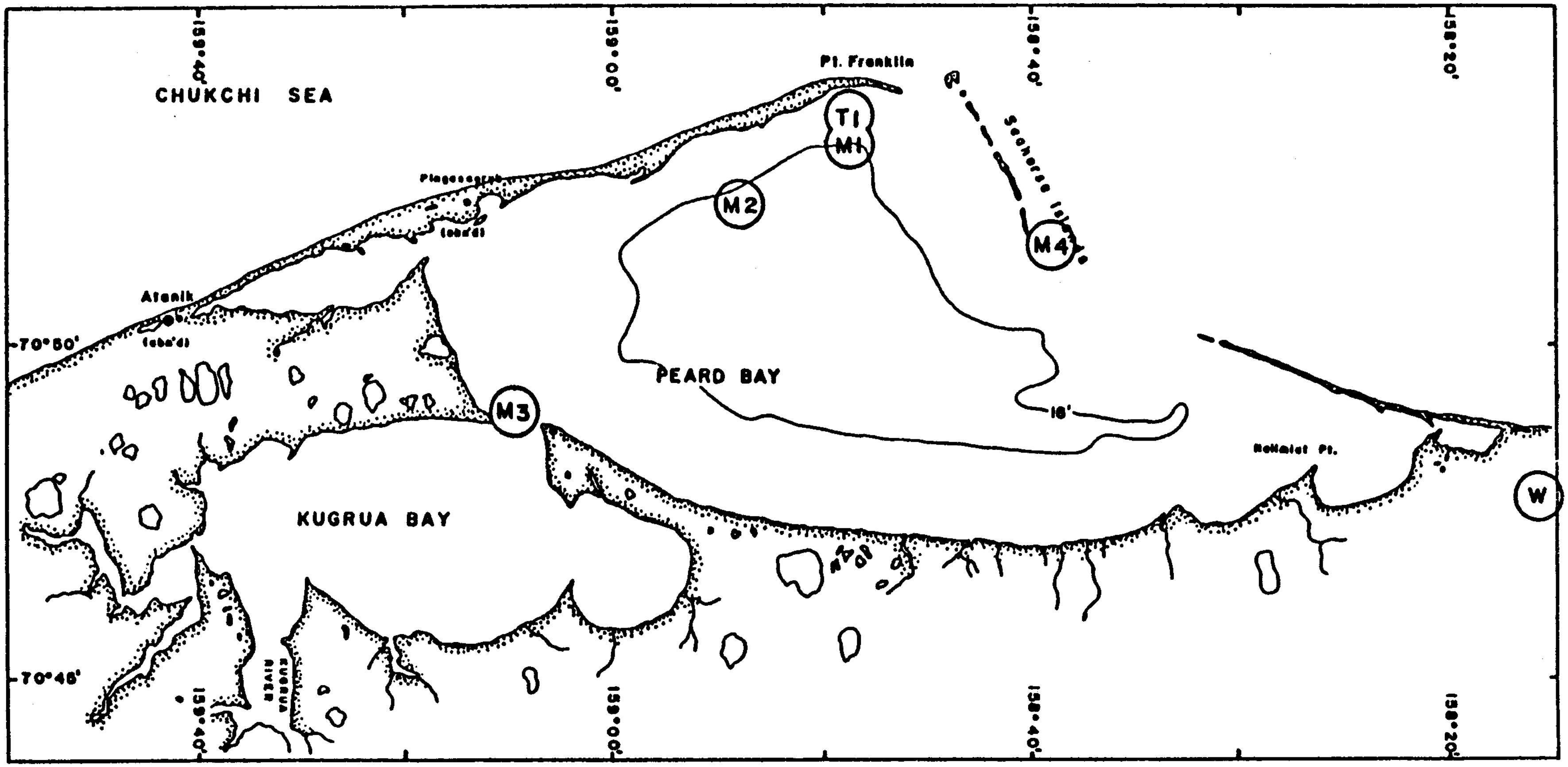


Figure 2-1. Instrument Locations, Summer of 1983. Sample stations indicated are designated as M (current meters), T (tide gauge), and W (weather).

2.2 METHODS

2.2.1 Literature

Physical oceanographic literature was compiled for the eastern Chukchi Sea. Published literature, agency files, and current research reports were used. These previous data were reviewed, and presented as background for interpretation of the specific Peard Bay results. Data from the 1983 NOAA/OCSEAP physical oceanographic study offshore from the northern Chukchi Sea coastline were not available for inclusion in this review.

2.2.2 Peard Bay Processes Study

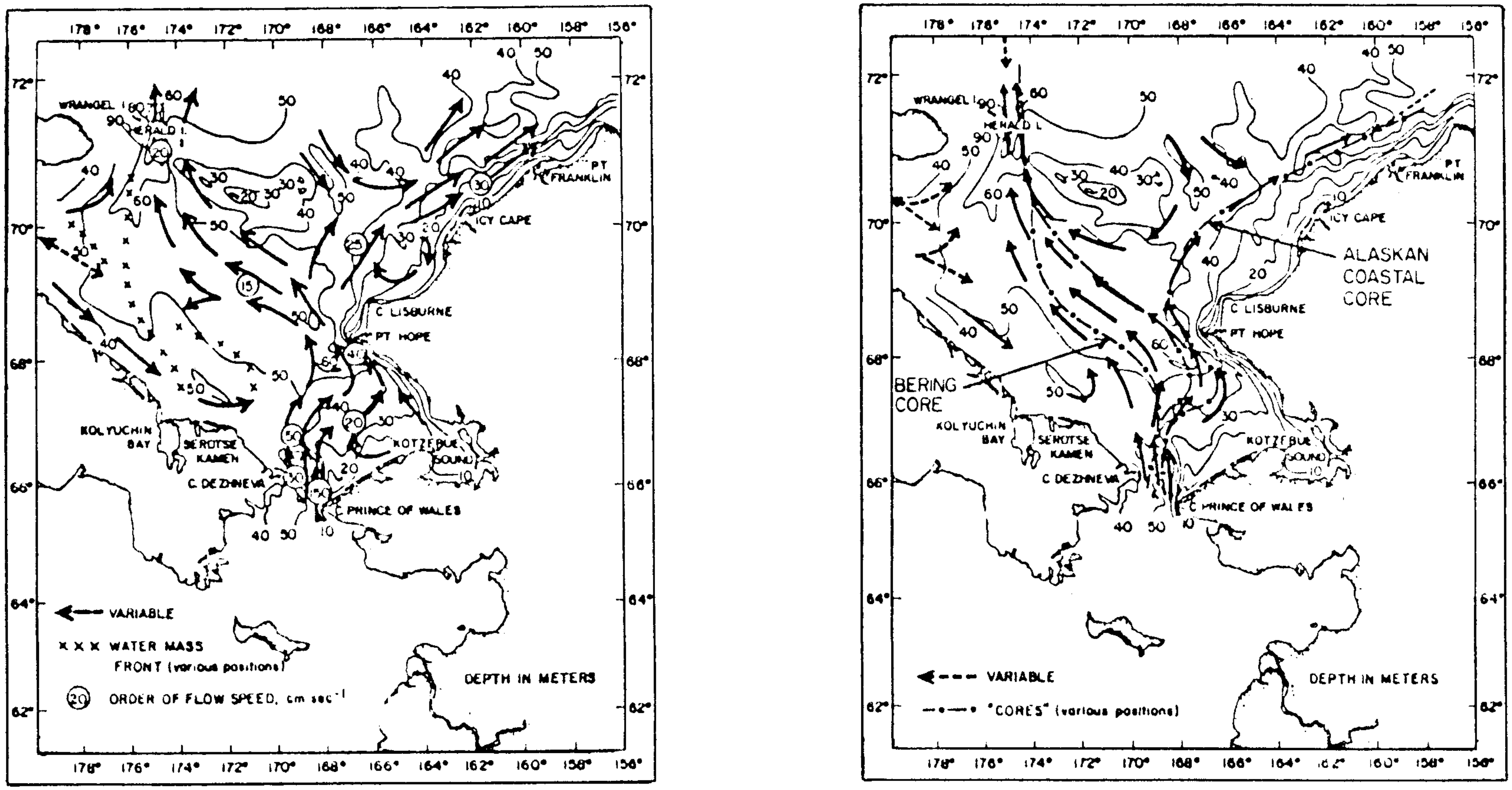
EG&G WASC Oceanographic Services deployed current meters and a tide gauge in Peard Bay to measure the circulation within the bay and in the inlet channels (Figure 2-1). NOAA/OCSEAP-supplied Aanderaa RCM-4 current meters were used to measure current speed and direction, temperature, and salinity at 15-minute intervals. The RCM-4 meters that were supplied did not have working pressure sensors. As shown in Figure 2-1, an Aanderaa TG-3 tide gauge was deployed at Station T1 off Pt. Franklin in an area protected from major currents. It measured absolute pressure at 10-minute intervals. One current meter was deployed at Station M1, near the northern inlet, at a depth of 2.3 m in 4.6 m of water. Two current meters were deployed at Station M2 in 5.2 m of water; the upper meter (M2U) at a depth of 1.7 m and the lower meter (M2L) at a depth of 3.8 m. One current meter was deployed at Station M3 in the inlet channel to Kugrua Bay at a depth of 2.1 m in 3 m of water. Ice conditions at the start of the summer measurement program prevented deployment of a current meter in the eastern inlet to Peard Bay, but Kinnetics Laboratories, Inc., deployed a General Oceanics current meter at Station M4 for nine days at the end of the summer field program. A Beckman RS5-3 was used to measure profiles of temperature and salinity at several locations within Peard Bay in order to locate Station M2 within a vertically stratified region. A Hydrolab probe was also used in the profiling to measure dissolved oxygen concentrations.

2.3 RESULTS AND DISCUSSION

2.3.1 Summary of Previous Knowledge, Eastern Chukchi Sea Coastal Area

2.3.1.1 Introduction

The Chukchi Sea is a shallow continental shelf sea bounded on the east by the Alaskan coast, on the north by the Arctic Ocean, on the west by the Siberian coast, and on the south by the Bering Strait (Figure 2-2). The depth of the central Chukchi is typically between 40 and 60 m. North of about 70°N latitude, the Chukchi is totally ice-covered or has high concentrations of ice throughout the year except for a narrow shore lead along the Alaskan coast in summer. The southern Chukchi is ice-covered for nearly eight months of the year, with the retreat of ice beginning in June in the Bering Strait (Webster 1982).



a. Upper Layer Flow: Dotted arrows indicate variable currents. Various positions of water mass fronts are indicated, and circled numbers are estimated flow speeds in cm/sec.

b. Lower Layer Flow: Dotted arrows indicate variable currents. Various positions of "cores" of Bering Sea water mass are indicated.

Figure 2-2. Circulation in the Chukchi Sea from Historical Data (from Coachman et al. 1975).

The general circulation of the Chukchi Sea in summer is described in Coachman et al. (1975), and is based on hydrographic measurements and short-term current measurements using profiling current meters and surface drifters (Figure 2-2). The description of the Chukchi Sea in this section is restricted to the eastern Chukchi Sea along the Alaskan coast. Subsurface circulation patterns are similar to surface circulation and are not discussed independently. Water from Norton Sound and the northern Bering Sea enters the Chukchi through the eastern Bering Strait. This water, named the Alaskan Coastal Water (ACW) by Coachman et al. (1975), can be traced continuously by its relative warmth and low salinity, as it moves through the eastern Chukchi Sea. The ACW continues flowing northward from Bering Strait along a shoal which extends offshore from Cape Prince of Wales. Once past the shoal the ACW veers eastward, following the shore-parallel bottom contours. Off Kotzebue Sound, the flow diverges and slows; freshwater from the sound mixes with the ACW, lowering its overall salinity and temperature slightly. (Kotzebue Sound water at times cannot be distinguished from ACW, but has characteristic temperatures and salinities in the lower range of the ACW.) Still guided by bottom topography, the ACW veers to the northwest from Kotzebue Sound towards Point Hope. At Point Hope the ACW separates into two currents - one continuing to flow northwest towards Herald Canyon, and the other veering to the northeast, following the Alaskan coast; the latter has been named the Alaskan Coastal Current (ACC) by Paquette and Bourke (1974). An anticyclonic eddy forms in the lee of the Cape Lisburne peninsula, so the ACC does not intersect the coast until it reaches Icy Cape. Along the northeastern coast of the Chukchi Sea, the ACC flows close in to shore and is responsible for opening and maintaining the shore lead. The ACC exits the Chukchi Sea along Barrow Canyon, turning eastward off Point Barrow into the Beaufort Sea.

These early measurements described in Coachman et al. (1975), relied on water mass analysis and current measurements of a few days duration to infer the circulation in the Chukchi Sea. Temperature and salinity are used successfully in the deep ocean to follow the movement of water masses. However, in the Chukchi Sea, temperature and salinity are not conservative properties and cannot be used unambiguously in identifying water masses. There are annual variations in the properties of the source water; the ACW loses heat in melting the winter ice pack and freshwater sources such as Kotzebue Sound change the properites of the ACW. The early shipboard work also suffered from a lack of synopticity and winter data coverage.

Oceanographic measurement programs since 1973 have provided current, temperature, and sea surface data for a dynamic description on the circulation in the Chukchi Sea during summer and winter. Mountain et al. (1976) deployed a current and temperature mooring in Barrow Canyon for 120 days from April through August 1973 which measured the ACC as it exited the Chukchi Sea. Coachman and Aagaard (1981) deployed current meters and water level gauges in Bering Strait and along a transect west of Cape Lisburne which measured the transport of ACW through the southeastern Chukchi Sea. These long time-series measurements have not changed our understanding of the general circulation as described by the earlier measurements, but have improved the estimates of the mean current and the seasonal variability in these currents.

Details of water masses, water transport, circulation, ice conditions, tides and waves are presented below for the southeastern Chukchi Sea (from Bering Strait to Cape Lisburne) and for the northeastern Chukchi Sea (from Cape Lisburne to Barrow Canyon).

2.3.1.2 Southeastern Chukchi Sea

Water Masses. The surface water of the southeastern Chukchi Sea, termed Alaskan Coastal Water by Coachman et al. (1975), originates on the Bering Shelf from a mixture of Bering Sea water and discharge from the Yukon River and Norton Sound. The temperature and salinity of the source waters for the ACW vary annually and the properties of the ACW are further modified as it flows through the Chukchi Sea, but it remains essentially distinct from the colder, more saline Bering Sea water in the western portion of the Chukchi. In Bering Strait, the ACW ranges in salinity from <31.0 ppt to 32.5 ppt; in summer, the temperature ranges from about 10° to 15°C. Because of the influx of water from the Bering Sea, the southeastern Chukchi Sea is about 10°C warmer than it would otherwise be (Flemming and Heggarty 1966). The salinity of the ACW increases slightly (by about 0.1 to 0.2 ppt) owing to mixing with Bering Sea water at the western boundary of the ACW; deeper layers of the ACW are cooled to a minimum of 1° to 3°C owing to mixing with Kotzebue Sound water. There is a horizontal gradient from the relatively cold, saline water to the west, to warmer, fresher water to the east.

Flemming and Heggarty (1966) reported a strong temperature-salinity front located about 20 miles offshore of the coast between Kivalina and Point Hope (northeast of Kotzebue Sound). The front was marked at the surface by convergence lines of foam and debris. The strongest gradients were located at a depth of 10 m with warmer, fresher water shoreward and colder, saltier water seaward of the front. This indicates that, as long as the front persists, nearshore circulation along this section of coastline is dominated by water from Kotzebue Sound.

At Cape Lisburne, the ACW splits into two streams, one continuing to the northwest and the other (the ACC) veering to the northeast to follow the Alaskan coastline. The mixture of Kotzebue Sound water and ACW make up the greatest fraction of the ACC north of Cape Lisburne. The stream which turns to the northwest is principally Bering Sea water (Coachman et al. 1975).

Water Transport. The transport through the southeastern Chukchi Sea was measured through the winter of 1976-77, as reported by Coachman and Aagaard (1981). Long-term current moorings were located along a transect off Cape Lisburne and in Bering Strait (Figure 2-3), to measure the inflow and outflow through the southeastern Chukchi Sea. Concurrent measurements were made at Stations NC1 through NC7 off Cape Lisburne and at Station NC10 in the Bering Strait for seven months from August 1976 through March 1977. Based on these data, they estimate the mean annual transport through the southeastern Chukchi Sea to be 0.8 + or - 0.2 Sverdrups (one Sv equals $10^6 m^3$/sec). This is much lower than previous estimates of the mean annual transport (Coachman et al. 1975) and reflects the greater occurrence of southerly current reversals in the winter. The transport actually measured from September 1976 through March 1977 was 0.3 Sv. The transport for the months of April through June 1977 was not measured directly, but was estimated from the currents as measured at Station NC10 in Bering Strait; these currents were found to be well correlated with the transports calculated at Cape Lisburne from September through March. The mean transport from September 1976 through June 1977, including the extrapolated transport estimate, was 0.6 Sv. Comparison with previous Soviet results indicated that 1976-1977 was a low transport year. Accounting for

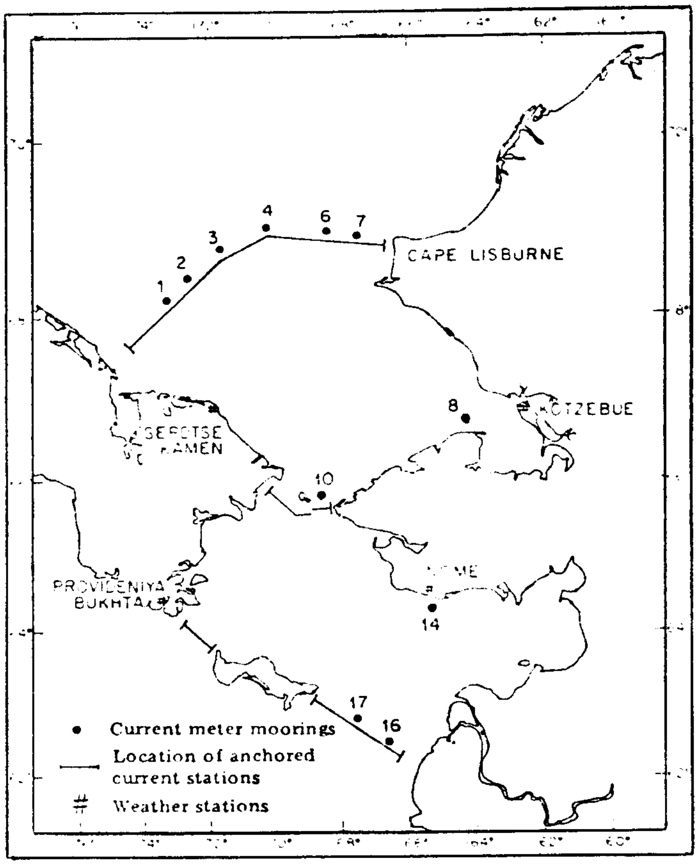


Figure 2-3. Current Meter Locations in Bering Strait and Along a Transect off Cape Lisburne (after Coachman and Aagaard 1981).

interannual variability, Coachman and Aagaard (1981) estimate 0.8 Sv as the long-term mean transport through the southeastern Chukchi Sea.

The mean transport through the Chukchi Sea is apparently driven by a mean sea surface slope to the north, i.e., the Bering Sea has a higher steric sea level than the Arctic Ocean. The reason for this difference in elevation is still unknown. The transport figure is lower than previously reported by Coachman et al. (1975; 1.5 Sv) because the earlier results were based on data taken only during open-water conditions. Seasonal variability is large, with episodes of southward current reversals occurring most often in fall and winter. These current reversals are apparently caused by major low pressure systems over the Bering Sea with strong northerly winds which force water off the shelf to the south and temporarily reverse the sea surface slope. After a lag of about one day, the transport in the southeastern Chukchi Sea responds and maximum southerly transport occurs.

Circulation. Circulation within the southeastern Chukchi Sea was well defined only in summer when large-scale quasi-synoptic measurements were taken. Flemming and Heggarty (1966) measured current profiles at 30 stations in the Bering Strait and the southeastern Chukchi Sea in 1959. Measurements were taken at 5- to 10-m intervals from the surface to the bottom. Currents showed little variation with depth. The measurement program was modified the following year to monitor depths of 5 and 20 m, reducing vertical resolution but allowing time for greater areal coverage. The horizontal structure of the near-surface and near-bottom currents based on these measurements in 1959 is shown in Figure 2-2. Water passing through the eastern Bering Strait continues northward for about 120 km, then appears to slow down and swing toward the east. In this region, the currents are guided by a shoal extending northward from Cape Prince of Wales.

The current curves to the northeast, then east toward Kotzebue Sound. There is an indication of tidal currents entering Kotzebue Sound through the southern half of the entrance and exiting through the northern half (Creager and McManus 1966), although the inferred mean circulation based on T/S distributions indicates some Kotzebue Sound water may exit to the southwest and remain trapped to the shore (Coachman et al. 1975).

Coastal currents diverge and decelerate in the area west of Kotzebue Sound. North of Kotzebue Sound to Point Hope the currents converge, accelerate, and change direction to the northwest, parallel to the bathymetry. In the area of Point Hope and Cape Lisburne the coastal current splits into two streams; one along the coast to the northeast and another to the northwest.

Ice Conditions. Creager and McManus (1966) report that freeze-up in the southeastern Chukchi Sea occurs first at Kotzebue Sound in mid- to late October. This is corroborated by the report by Ingham and Rutland (1972). Nome, Shishmaref, and Point Hope do not freeze until the middle of November and the Bering Strait may be open until early December.

Breakup occurs in Kotzebue Sound in early June, but not until late June at Point Hope and Shishmaref (Creager and McManus 1966).

Annual ice typically ranges in thickness from 100 to 120 cm. Chukchi ice is heavily deformed because of the constriction of the Siberian and Alaskan coastlines and the pressure of the expanding polar ice pack driving ice southward. Pressure ridges may be 2 to 3 m high in the interior of the sea and much higher in near-coastal shear zones where drift ice grinds against stable shorefast ice.

In the southeastern Chukchi Sea, the advance of ice breakup proceeds fastest in the interior, in contrast with the northeast Chukchi Sea where a shore lead develops early.

Tides. Currents at the entrance to Kotzebue Sound are tidal with a net inflow on the south at Cape Espenberg and net outflow on the north at Cape Krusenstern. The range of the astronomical tide along the coast is less than 0.3 m (NOS 1984), while meteorological tides can be 1.8 m (Creager and McManus 1966).

Waves. There are scant wave measurements in the southeastern Chukchi Sea. Waves are locally wind driven, with the longest fetch from the north. Waves from that direction have longer periods and larger amplitudes than from other directions.

2.3.1.3 Northeastern Chukchi Sea

Water Masses. The surface water of the northeastern Chukchi Sea, from Cape Lisburne to Point Barrow, consists largely of Alaskan Coastal Water (ACW) modified by mixing with water from Kotzebue Sound. Ingham and Rutland (1972) summarized previous hydrographic surveys in the Cape Lisburne-Icy Cape area, and also presented data from their survey of that area in 1970. Sauer et al. (1954) identified ACW (>6.6^{o}C, <30.5 ppt) near the coast at the surface and bottom in 1949. Aagaard (1964) identified ACW (>1^{o}C, <31 ppt) at Point Hope, but did not find ACW in the Cape Lisburne/Icy Cape area. The hydrographic survey of Flemming and Heggarty (1966), although principally of the southeastern Chukchi Sea, extended into the northeast Chukchi as far as Icy Cape. They did not identify the water masses they observed, but found relatively warm, freshwater near the coast which was probably ACW. They also observed an intrusion of even warmer, but more saline water (7-10^{o}C, >32 ppt) in the Cape Lisburne area which may have been related to the presence of a clockwise eddy in the lee of Cape Lisburne. Based on the observed distribution of salinity and temperature, there is a suggestion of a clockwise eddy offshore of the coast; the anomalous intrusion close inshore may have been relict from an older eddy. The water properties observed by Ingham and Rutland (1972) did not correspond exactly with temperature/salinity envelopes for ACW reported by earlier investigators. This is another indication that definition of water masses by characteristic temperature and salinity is obscured by seasonal and annual variations.

Water Transport. Hufford (1977) calculated the water transport in the Alaskan Coastal Current (ACC) off Point Franklin based on drifter measurements made during August 1976. The calculated value, 0.2 Sv, compares with the mean annual transport of 0.6 Sv for 1976-77 and the monthly mean transport of 0.46 Sv for September 1976 reported by Coachman and Aagaard (1981) off Cape Lisburne. The coastal current bifurcates at Point Hope and only a portion of the total transport flows northeastward along the Alaskan coast as the ACC.

Circulation. The general circulation in the northeastern Chukchi Sea has been determined based largely on hydrographic measurements (Flemming and Heggarty 1966; Ingham and Rutland 1972; Paquette and Bourke 1974). Drifter measurements in the vicinity of Peard Bay by Hufford (1977) and current moorings near Point Lay by Wiseman and Rouse (1980), Wiseman et al. (1974), and Wilson et al. (1982) have provided details of the dynamics of the nearshore circulation. Owing to the inherent measurement error and lack of spatial or temporal coverage, earlier current measurements using shipboard profiling current meters and drift pole techniques do not provide much useful information in determining circulation patterns.

Flemming and Heggarty (1966) performed a hydrographic survey in the area between Cape Lisburne and Icy Cape and found evidence in the temperature and salinity distribution of a clockwise eddy northeast of Cape Lisburne. Ingham and Rutland (1972) measured currents in this same area and observed weak currents, variable in direction, that were driven by the local winds. During strong northeasterly winds, the near-surface current was toward the southwest. Near-bottom currents were also influenced by the wind and in general, were in the same octant as the near-surface currents. Isobath-parallel flow was not observed in the nearshore area between Cape Lisburne and Icy Cape; the ACC is apparently positioned far offshore along this stretch of coast.

The hydrographic and current data collected by Flemming and Heggarty (1966) and Ingham and Rutland (1972) did not come within 10 km of shore. Wiseman and Rouse (1980) measured inshore currents off Icy Cape in water depth of 9.8 m. Currents were generally northward and parallel to shore with speeds as high as 70 cm/sec. Current drifters were also deployed to investigate the presence of a coastal boundary layer and to determine its offshore structure. In 1972, drifters with drogues placed at a depth of 10 m were deployed approximately 10 and 50 km offshore. The drogue closer inshore appeared to be in a coastal jet, while the drogue farther offshore was in a larger-scale coastal circulation. Aerial radiometry also suggested the presence of a coastal jet; southwest winds forced warm surface water against the coast, and northeast winds forced surface water offshore causing upwelling of colder water at the coast.

Wiseman et al. (1974) measured nearshore currents under the ice at Point Lay in April of 1972. The current meter was at mid-depth in 7.6 m water depth. The mean flow was northerly and parallel to shore with a mean speed of 2.1 cm/sec. A small, semidiurnal tidal current was observed. Currents measured in open water conditions during July and August of 1972 for 6 days, were an order of magnitude greater (21.8 cm/sec), and in the same direction. A semidiurnal tidal component was again present, but with a magnitude less than 1 cm/sec. The summer currents showed significant reversals in direction.

Paquette and Bourke (1974) defined the limits of the ACC from Icy Cape to Point Barrow based on a hydrographic survey in August of 1972. The core of the ACC was offshore in the area of Icy Cape, but moved very close inshore at Point Franklin. In this region the ACC was a well-mixed surface current flowing atop a much colder bottom layer of Chukchi winter water. A sharp temperature gradient of 7°C/m separated the two water masses. Northeast of Point Franklin the ACC moves offshore towards Barrow Canyon and exits the Chukchi Sea eastward into the Beaufort Sea. In this region the ACC migrates downward from the surface to mid-depth.

Hufford (1977) measured currents off Point Franklin using air-deployed surface current probes. Both surface current and vertically averaged currents were measured with these devices. He describes a three-banded flow regime with an inshore wind-driven flow, the Alaskan Coastal Current just a bit farther offshore flowing to the northeast, and even farther offshore, a surface current flowing to the southwest.

The inshore currents were southwesterly for most of the measurement period, at 4 to 20 cm/sec with winds from the northwest at an average of 6.9 m/sec. The wind shifted to westerly late in the record; inshore currents shifted to the northeast with no appreciable time lag.

The Alaskan Coastal Current flowed towards the northeast, just offshore of the inshore current. It was only about 20 km in width and speeds of 55 cm/sec were measured. Further north of Point Franklin the current widened to 36 km and speed lowered to 14 to 50 cm/sec. Southwesterly currents offshore of the ACC were as great as 80 cm/sec.

Wilson et al. (1982) deployed three cross-isobath transects of current meters between Point Barrow and just south of Icy Cape. Data were recovered from off Barrow and Wainwright which depicted the flow regime within 15 km of the coast during August and September 1981. The largest currents were those found within Barrow Canyon, where maximum current magnitudes approached 100 cm/sec. Off Wainwright, the maximum currents were on the order of 70 cm/sec, with 30 to 50 cm/sec values characterizing normal conditions. Although the mean current at both locations was alongshore toward the northeast, the records were dominated by current oscillations of typically five days duration capable of reversing the direction of flow. The analysis of the data indicated that the current was significantly coherent with both the alongshore component of the wind stress and the north-south atmospheric pressure gradient (correlation coefficients of 0.72 and 0.81, respectively).

Ice Conditions. Wiseman and Rouse (1980) report that the region from Cape Lisburne to Icy Cape is ice-covered from late October/early November until early July, with large annual variations in these limits. Ice cover near the coast is strongly influenced by local winds. They observed that 1972 was a light ice year and that 1975 was a heavy ice year.

Tides. Tidal heights and tidal currents in the northeastern Chukchi Sea are insignificant compared with meteorological effects on both sea surface elevation and coastal currents. Wiseman et al. (1974) measured tidal height in Kasegaluk Lagoon at Point Lay for 24 days and observed small diurnal and semidiurnal peaks. EG&G measured the tidal height in Peard Bay in 1983 and observed an average tidal range of 14 cm (Section 2.4). Meteorological tides were almost a meter in height during both measurement programs. Wiseman et al. (1974) explained the relation of storm surge height and wind stress using a simple Ekman model. Southwest winds set up a northerly nearshore current with an onshore component which causes sea level to rise at the coast and coastal lagoons to fill. Northeast winds set up southerly nearshore currents with an offshore component which causes sea level to drop at the coast and coastal lagoons to empty.

Currents were measured off Point Lay by Wiseman et al. (1974) for 7.5 days during ice-covered conditions in April 1972 and for 6 days in open-water conditions in July-August 1972. Tidal currents were only about 1 cm/sec. Ingham and Rutland (1972) had measured currents off Point Lay for 30 hours using a profiling current meter and could detect no tidal variations.

Waves. Wave measurements in the northeastern Chukchi Sea are sparse and have not included storm conditions. Wiseman et al. (1974) installed wave recording instruments off Point Lay during open-water conditions in 1972, but no major storms occurred during the measurement period. A major storm was observed visually prior to installation of equipment and estimates were made of wave height (2 m) and period (5 sec). During the period of wave measurements, significant wave height was 30 cm or less with wave periods from 2 to 3 sec. Waves were generated by the nearshore wind field and did not seem to be fetch-limited by the pack ice which was located far offshore in this light ice year. Wave direction was at a steep angle to shore, but owing to the small wave amplitude, only moderate longshore currents and sediment transport were generated.

2.3.2 Peard Bay Processes Study

2.3.2.1 Tides

The pressure record from the Aanderaa TG-3 tide gauge was analyzed using the response method of Munk and Cartwright (1966) after correction for atmospheric pressure changes. A harmonic tidal analysis according to the 29-day analysis of Shureman (1941) was also performed and the results of the two methods yielded good agreement. This tidal analysis was used to predict the tide for the record period. The predicted tide was then subtracted from the observed tide to determine the residual, or non-tidal, pressure. The total pressure, predicted tidal variations, and residual pressure are plotted in Figure 2-4. The time base for this and all other time-series plots is in GMT. The tidal fluctuations of sea level within Peard Bay are much smaller than variations due to meteorological forcing, which can be almost a meter in height. The tide in Peard Bay is principally semidiurnal with a spring range of 18 cm, a neap range of 9 cm, and a mean range of 14 cm.

Major rises in sea level occurred on 1 August, 8 August, 18 August, and 26 August, and are correlated with meteorological forcing. These periods of sea level rises, or storm surges as they are often called, occurred during either westerly or southwesterly winds. The Alaskan coastline along the northern Chukchi Sea runs in a northeasterly-southwesterly direction, so the prevailing winds blow parallel to the coast. During these conditions, surface waters are transported to the right of the wind, causing a rise in sea level at the coast and in Peard Bay during southwesterly winds and a drop in sea level during northeasterly winds.

Spectral analysis of the pressure data from Station T1 showed only a minor peak of about 1 cm at the theoretical seiche period of 50 min. Actual seiche amplitude may be somewhat higher owing to the intermittent character of the seiche, but will still be negligible.

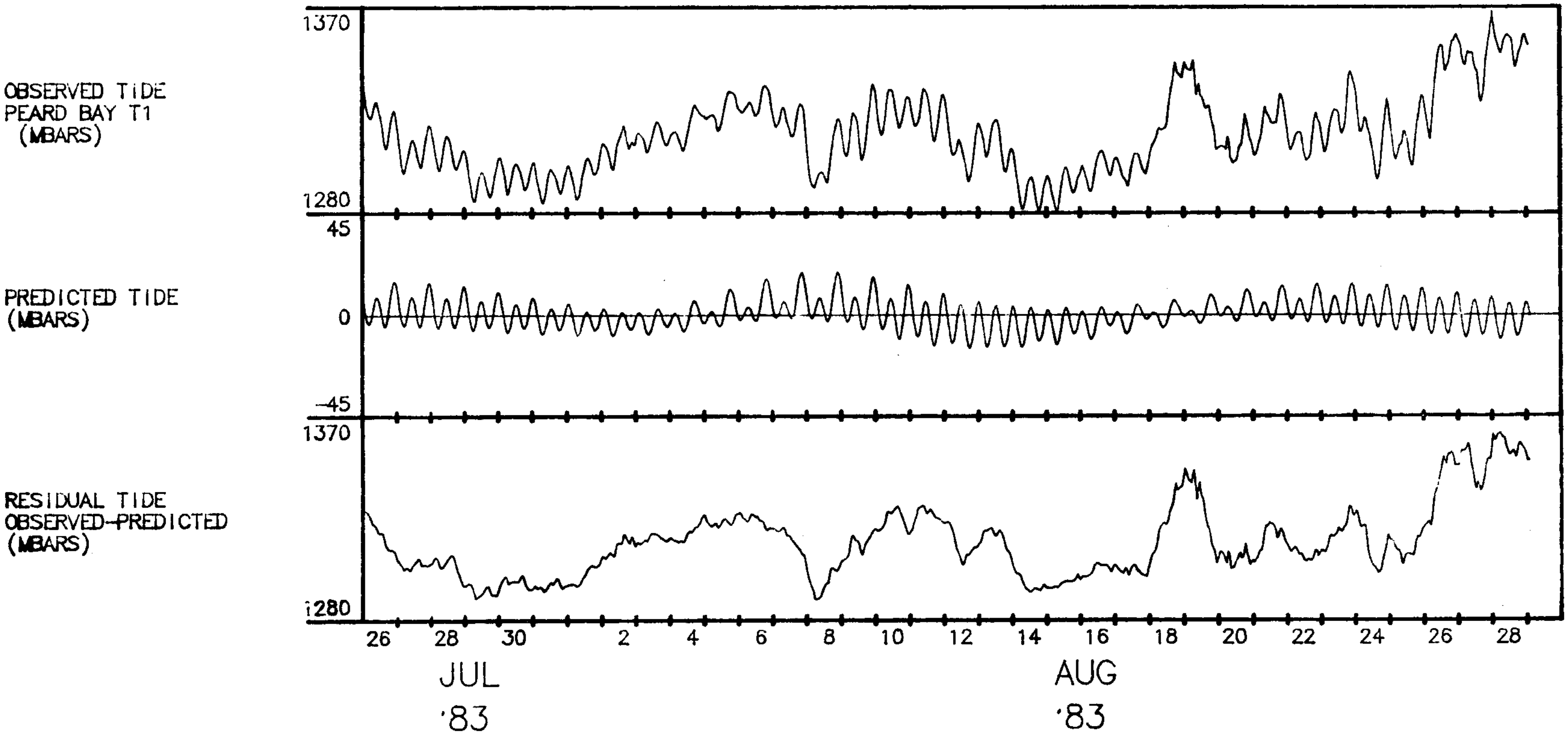


Figure 2-4. Time Series of Total Pressure and Tidal and Non-Tidal Constituents of Pressure at Station T-1.

2.3.2.2 Currents

Currents were measured from 29 July through 28 August at Stations M1 and M3 and from 1 August through 28 August at Station M2. Currents were measured at Station M4 from 21 August through 29 August. Time series plots of hourly vector currents at these stations and 3-hour winds near Peard Bay are presented in Figure 2-5. Current data were low-pass filtered using a convolution filter with a half-amplitude at 33 hours (Flagg et al. 1976). A time-series plot of the low-passed current and wind data is presented in Figure 2-6.

Flow in the inlet channels (Stations M3 and M4) is rectilinear and aligned with the axis of the channels. The unfiltered current data show strong semidiurnal tidal fluctuations, with a net inflow of about 15 cm/sec at each station. Superimposed on the mean inflow are longer-period variations at one- to two-day intervals.

Currents at Station M1, inside Point Franklin, were generally below 15 cm/sec except for isolated episodes on 18 and 27 August. On 18 August, currents increased to about 30 cm/sec while direction changed from northeast to southeast in a counterclockwise rotation. On 27 August a similar event was observed. Both events occurred during periods of strong southwest winds. The flow at Station M1 was not rectilinear as at the inlet stations. Station M1 was located near the inlet at Point Franklin, but well within the bay and away from the influence of the northern inlet channel.

Station M2 was located at the edge of the deeper central basin in Peard Bay, in water which was initially vertically stratified (see below). The flow in the upper and lower levels was in almost opposite directions during stratified conditions. From 2 to 5 August, currents were northward near the surface and southwestward near the bottom. Upper currents then shifted to the southeast and lower currents to the northwest. After 8 August, upper and lower currents were generally in the same direction and changed direction and speed roughly in phase.

Current records at Stations M1, M2U, and M2L were analyzed using the response method of Munk and Cartwright (1966) to estimate amplitude and phase of tidal constituents. Tidal currents were less than 3 cm/sec for any single constituent, consistent with the small surface tide. Tidal currents were principally semidiurnal at Stations M1 and M2U, but at Station M2L diurnal currents were nearly the same magnitude as semidiurnal currents. Tidal currents at all three stations were rectilinear rather than rotary. Upper and lower semidiurnal tidal currents at Station M2 were in phase and led the semidiurnal currents at Station M1 by about 5 hours.

2.3.2.3 Temperature and Salinity

Figure 2-7 shows time series of temperature and salinity measured at Stations M1, M2U, M2L and M3.

The last traces of the spring freshet from the Kugrua River were in evidence until early August. At Station M3 in the inlet to Kugrua Bay, there was a marked increase in salinity from 14.5 to 30.6 ppt and a concurrent

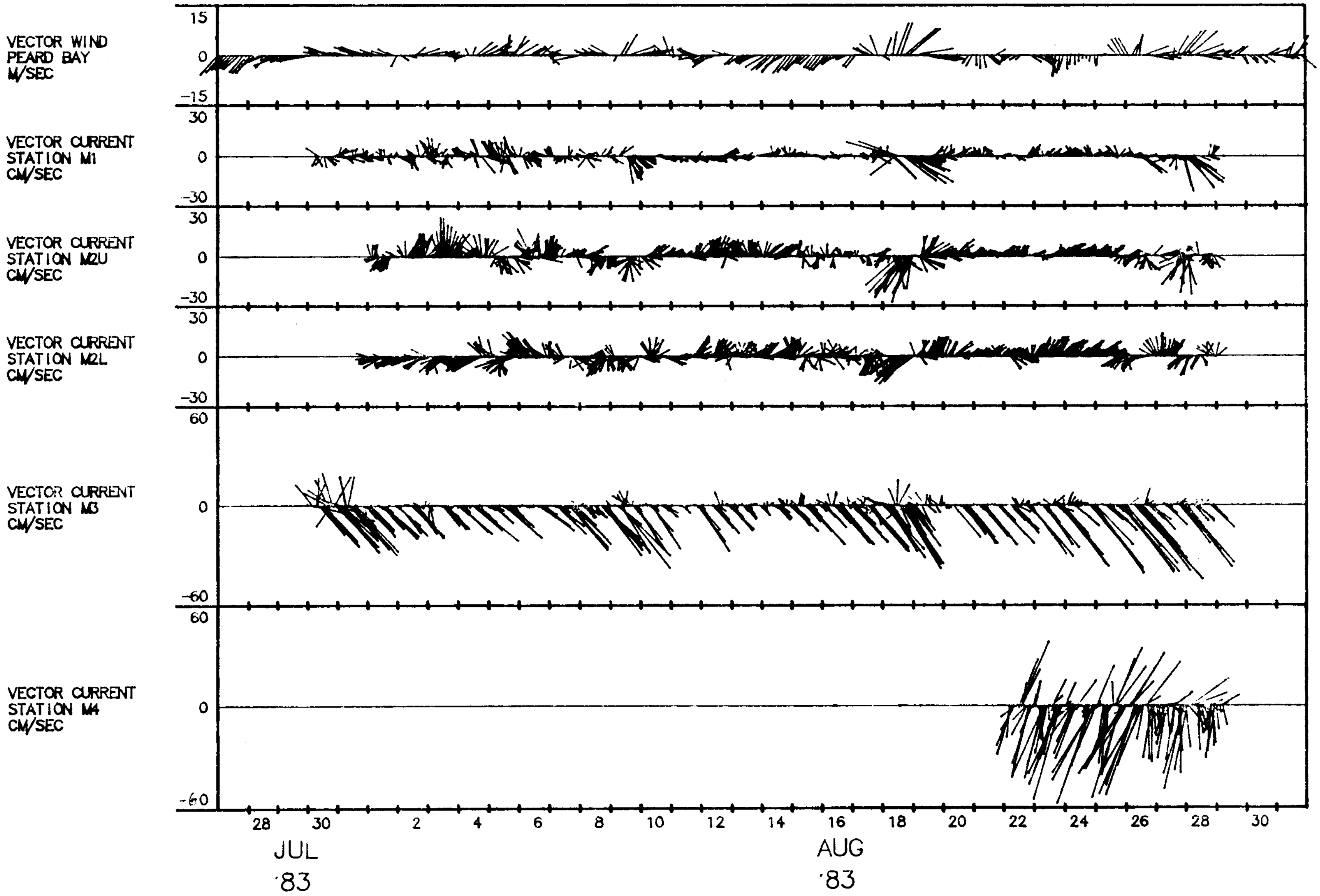


Figure 2-5. Time Series of Wind and Currents Measured at Stations M1, M2U, M2L, M3 and M4.

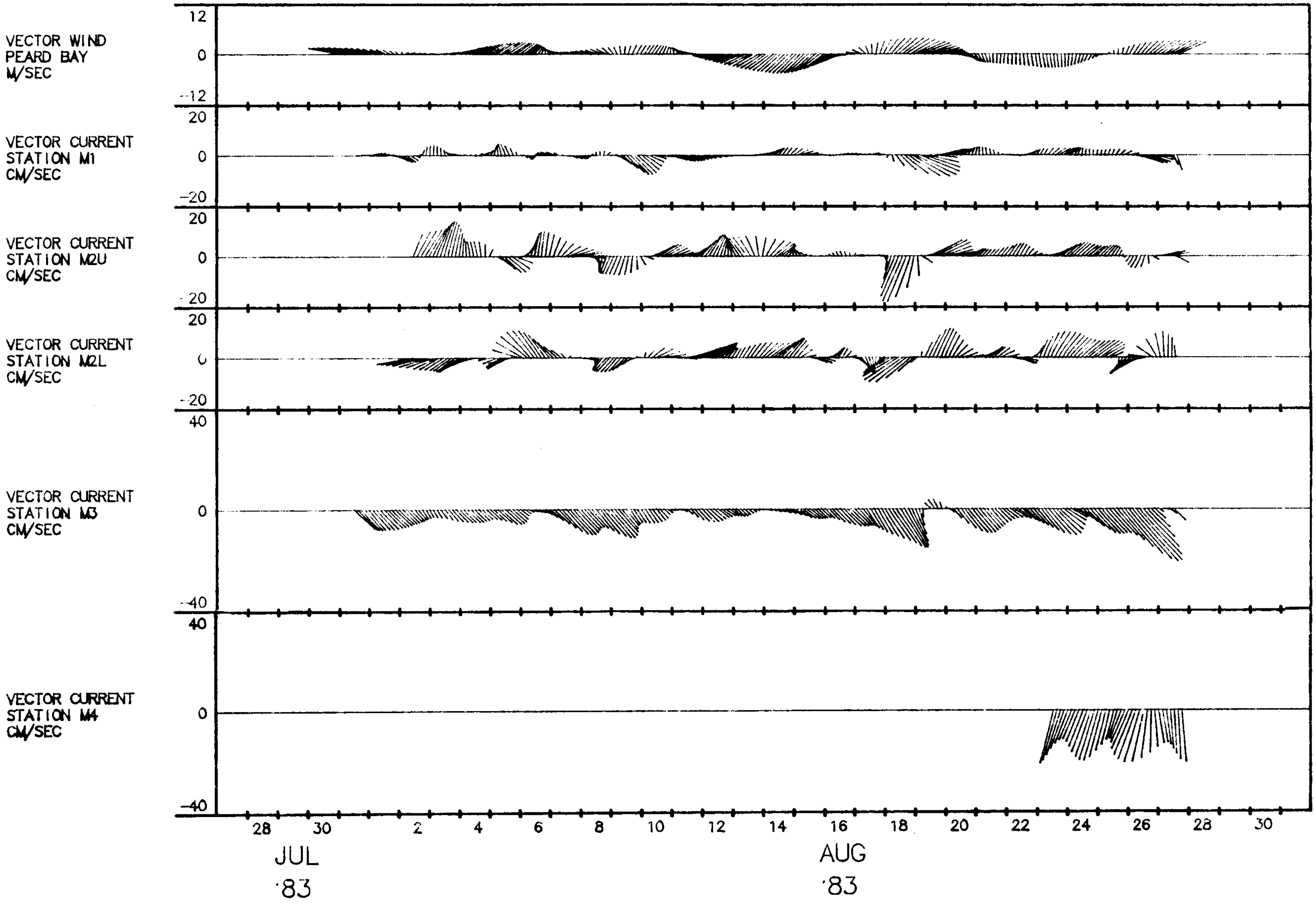


Figure 2-6. Time Series of Low-Pass Filtered Wind in the Vicinity of Peard Bay, and for Currents at Stations M1, M2U, M2L, M3, and M4.

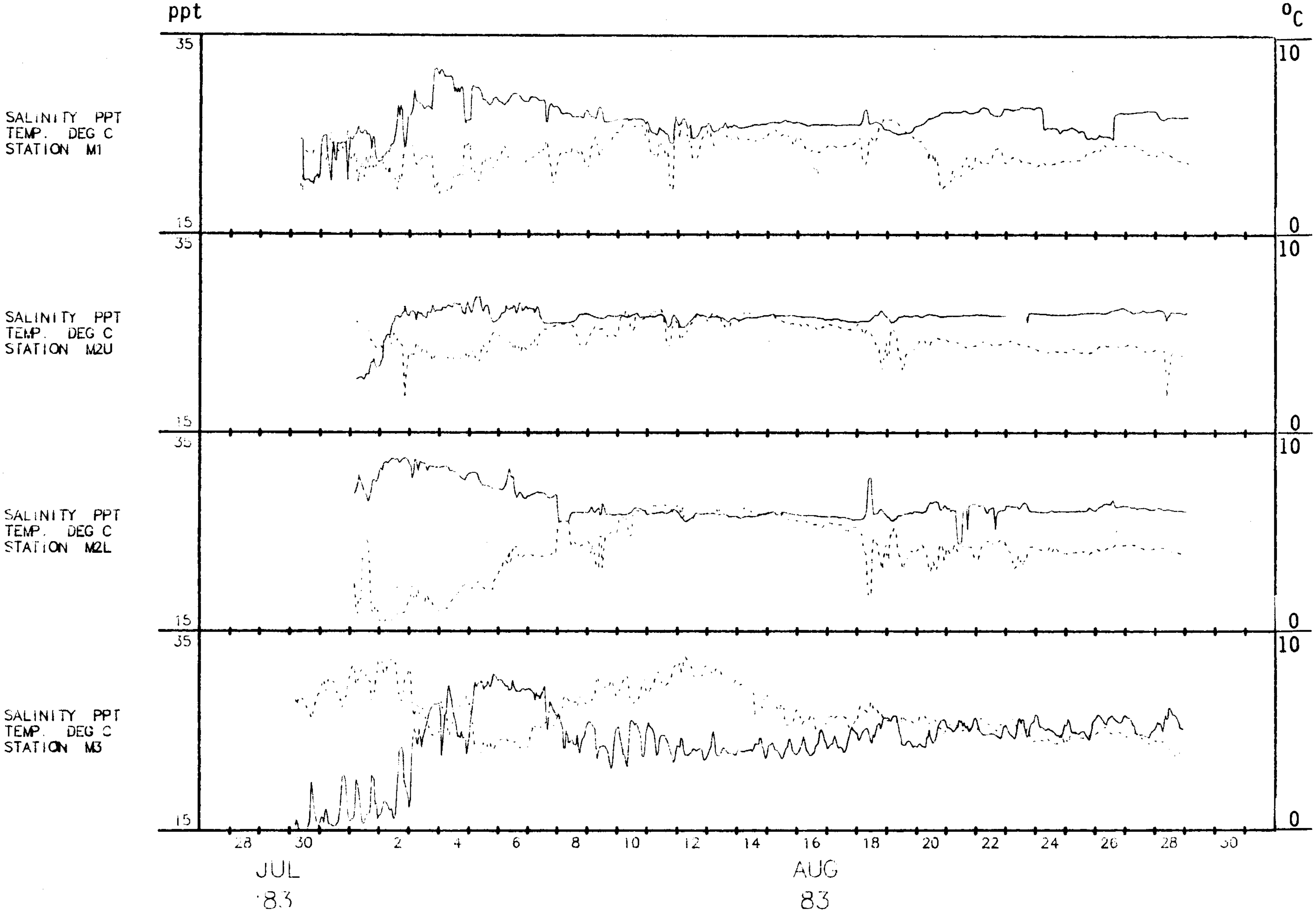


Figure 2-7. Time Series of Temperatures and Salinity at Stations M1, M2U, M2L, and M3.

decrease in temperature from 8.5 to 3.8°C during the period 30 July to 5 August. Similar rises in salinity were seen at Stations M1 and M2U, but the peaks occurred earlier, on 2 August at Station M2U and on 3 August at Station M1. This may indicate that flow from Kugrua Bay was trapped along the shore, influencing Station M1 near Point Franklin for a longer time than Station M2. Station M2 was farther from shore but nearer the inlet to Kugrua Bay.

The water column at Station M2 was well stratified during early August. On 1 August, the upper level was fresher and warmer than the lower level. The surface salinity increased and the bottom salinity decreased until the water column became vertically homogeneous on 8 August. Temperature at the lower level increased to match the upper level at the same time. Peard Bay waters were also fairly homogeneous in the horizontal on 8 August, with Station M3 having nearly the same salinity and temperature as Station M2 and Station M1 having the same salinity, but a slightly lower temperature than Station M2.

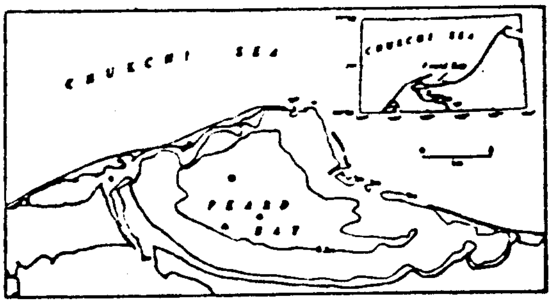
On 18 August there was a sharp perturbation in temperature and salinity at several stations in Peard Bay. Temperature dropped as salinity peaked; first at Station M1, then at Station M2L, and finally at Station M2U. No such changes in water properties were seen at Station M3. The largest temperature and salinity anomaly occurred at Station M2L which was caused by an incursion of coastal water into Peard Bay. This is described in more detail below.

Other perturbations in temperature and salinity occurred during August, but were not as spatially coherent as the event of 18 August. On 1 August, temperature rose sharply at Station M2L, accompanied by a small drop in salinity. On 28 August at Station M2U, there was a dip in both temperature and salinity. Neither event was observed at other stations.

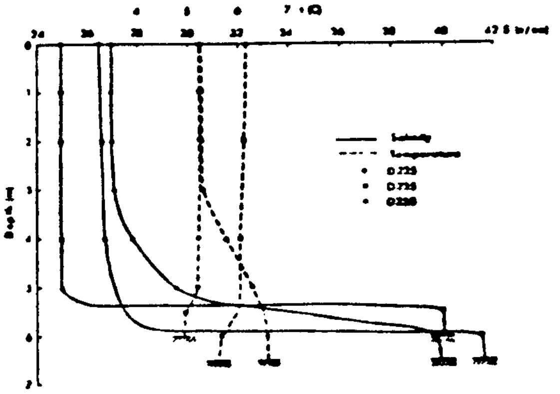
2.3.3 Summary and Conclusions

Wiseman (1979) reported finding a layer of water with a salinity of about 40 ppt in the deepest areas of Peard Bay during the summer of 1976. Such hypersaline water is formed in winter by salt rejection during the freezing of surface waters. The bottom layer persisted throughout the entire summer, although the initially sharp pycnocline was weakened by turbulent mixing due to wind stress (Figure 2-8). At the beginning of the summer, the bottom layer was colder than the upper layer. However, solar warming raised the temperature of the isolated bottom layer while the upper layer remained cold due to mixing with coastal water. The high salinity may create additional stress on benthic organisms, but the bottom layer is not so isolated as to become anoxic, since slow mixing with surface waters and solar warming during open-water conditions will allow renewal of the bottom layer with denser, oxygen-rich brine during the following winter.

Results from the 1983 study indicate that exchange of lagoon and outside waters occurs frequently, driven primarily by meteorological forcing. The moored instrument data recorded the incursion of coastal water into Peard Bay on several occasions during the 1983 season. The most direct evidence for the influx of coastal water is the rise in sea level measured at Station T1 on 1, 8, 18, and 26 August. The rise in sea level on 1 and 8 August was gradual and not associated with unusually large currents within the bay, or with large, spatially coherent perturbations in water properties. The incursions of 18



Bathymetry of Peard Bay, Alaska.



Deep temperature and salinity profiles from Peard Bay on days 225 (12 August), 235 (22 August), and 250 (6 September) of 1976. Symbols mark depths of measurements. Note the noticeable erosion of the pycnocline by day 250.

Figure 2-8. Temperature and Salinity Profiles from 12 August, 22 August, and 6 September 1976 (from Wiseman 1979).

and 25 August were marked by strong southerly flow events at Stations M1 and M2; large temperature and salinity changes were observed at Stations M1 and M2 on 18 August, but not during the incursion of 25 August. Both of these later incursions were associated with strong southwesterly winds (alongshore to the northeast), and a rise in sea level of 0.5 m or more.

For several days prior to 18 August, winds were steady from the northeast. Wind direction reversed (towards the northeast) on 18 August, and sea level in Peard Bay rose about 0.5 m over a 24-hour period. Prior to the influx of coastal water on the 18th, the water column was unstratified and horizontal gradients of temperature and salinity were also small. At Station M2 temperature was 5.2°C and salinity was 26.1 ppt at both the upper and lower levels.

Currents at Station M1 increased to 30 cm/sec on 18 August, the maximum observed at that station during the entire summer. Current direction was initially northwest, then turned to the southeast and east. At Station M2U (upper level), current speed was also 30 cm/sec during the period of flood, and direction was southwest turning toward the northeast after the storm surge. At Station M2L (lower level), current speed was at a maximum for that station, 20 cm/sec, and direction was southwest, later turning northeast.

The appearance of coastal waters was progressive among these three stations. Anomalous water was seen first at 0615 GMT at Station M1, then at 1016 GMT at Station M2L, and finally at 1816 GMT at Station M2U. The coastal waters flooding Peard Bay were colder and saltier than the bay waters; the greatest change in water properties occurred at Station M2L where salinity increased to 30.3 ppt and temperature decreased to 1.7°C. There was a smaller change in temperature and salinity at Stations M1 and M2U. Temperature dropped to 3.4 and 3.2°C, respectively, and salinity increased to 27.2 and 27.6 ppt, respectively, at those stations. The appearance of coastal water first at Station M1 is consistent with the general southward currents observed at the time in Peard Bay. The colder, saltier, coastal water was denser than bay waters and sank in the traverse across the bay, mixing upward slowly.

The coastal waters flooding Peard Bay on 18 August were colder than the typical core water of the Alaskan Coastal Current which is normally closer to 10°C and 32 ppt. In a hydrographic transect taken by Kinnetic Laboratories, Inc. (Wilson et al. 1982) in 1982, water with the characteristics observed at Station M2L was located within 5 km of shore off Point Belcher, about 35 km southwest of Point Franklin. The sustained northeast winds prior to 18 August may have induced upwelling of colder, saltier bottom waters owing to Ekman drift. The quick shift of the wind then flooded the bay with the offshore water before downwelling could be set up.

There was no change in salinity or temperature observed in the inlet to Kugrua Bay (Station M3), in contrast with the marked changes within Peard Bay. Tidal currents in the inlet were damped for a few days beginning on 19 August owing to the elevated sea level in Kugrua Bay. On 25 August there was a similar incursion of water, but with no distinctive temperature-salinity signature as there was on 18 August. Currents were southerly at Stations M1 and M2, with magnitudes almost as great as on 18 August and with sea level rising by about 0.8 m. Current data were available from the eastern inlet during this time and showed predominantly flood currents for the entire record period of 21 to 29 August.

Two conceptual circulation models are presented below which adequately describe the current patterns that were observed during the sampling program. The first model is for northeasterly wind conditions which are typical of the Chukchi coast. The second conceptual model is for southwesterly winds; the storm surge events.

Generalized circulation patterns are presented in Figure 2-9 for northeasterly winds. This conceptual model is based on the 1983 current meter results, and the results of the Rand model (Liu 1983), Figure 2-10. Offshore water enters through the southern Seahorse Island entrance and circulates in the bay in a clockwise direction. Strong currents were observed entering Kugrua Bay with only weak currents exiting. The mean flow in both the southern inlet and the Kugrua Bay inlet was in the direction of flood. At Station M3 in the Kugrua Bay inlet flow rarely reversed into Peard Bay, but instead only slowed or stopped during the ebb cycle. At Station M4 in the eastern inlet the flow did reverse in the ebb direction, but for a shorter duration than the flood flow. The tidal flow may be asymmetric, with flood flow entering principally through the channels at depth and ebb flow exiting over both the shoal area and the channel area near the surface. The ebb flow may be blocked from the location of the current meters by the sills at the ends of the channel which would direct ebb flow into the surface layer. There is evidence in the pressure record for only a small net storage within Peard Bay, about 10 cm from the beginning to end of August, so the flood flow must exit Peard Bay.

The second conceptual model, presented in Figure 2-11, is for a storm surge event during southwesterly winds as observed on 1, 8, 18, and 26 August. A strong current was observed entering Peard Bay at the Seahorse Island entrance, with water probably also entering at the Point Franklin entrance. Currents reversed for a short period of time at M1 to a southerly direction, during the onset of the storm surge. Currents also reversed at M2U and M2L to a southwesterly direction. At the entrance to Kugrua Bay currents were still directed into the bay. After the peak of the storm surge (18 August), currents were observed to return to the clockwise rotation. A short-lived reversal was noted at M3 due to a sudden drop in water level in Peard Bay, causing a readjustment of the water level in Kugrua Bay.

There were no confirmed measurements of hypersaline bottom water during the 1983 summer field program. An anomalously high salinity reading was observed during one hydrographic profile, but could not be repeated. An erroneous reading may have been caused by contact of the probe with the bottom. Because of the lack of a suitable boat, operations in the deepest parts of Peard Bay could not be accomplished safely. Program objectives were met by locating Station M2 in initially stratified waters. Monitoring of the hypersaline bottom water will require a more extensive hydrographic measurement program in the interior of Peard Bay, and deployment within the hypersaline layer of a current meter mooring designed for measurements within a meter of the bottom.

<u>Winter</u>. A 10 day winter characterization study was conducted in March in order to determine the biological utilization and governing physical processes of the bay during ice-covered conditions. A hydrographic survey was conducted on 16 March to investigate the winter salinity and temperature structure, and to determine the extent of any hypersaline water that might be present.

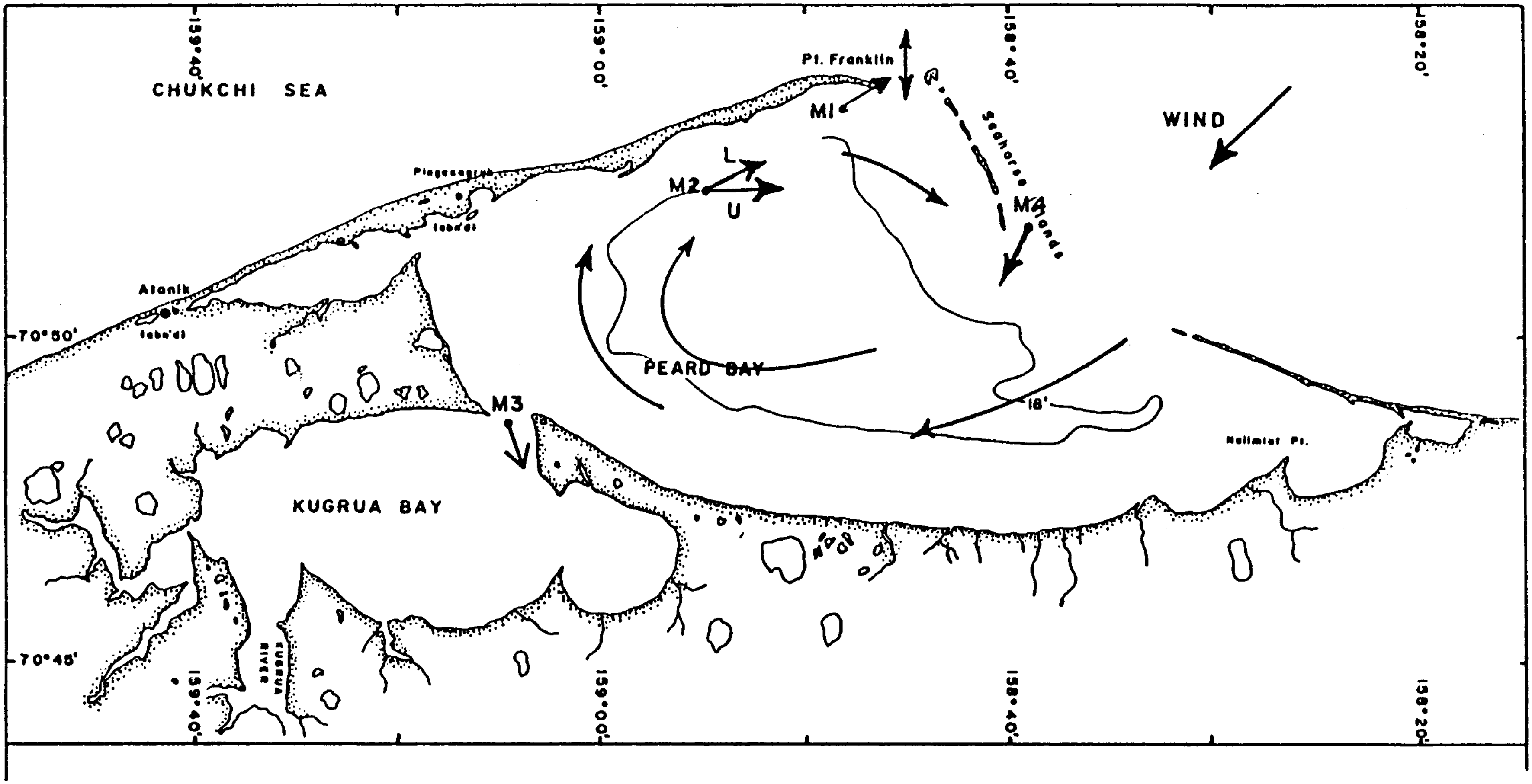


Figure 2-9. Conceptual Circulation Model in Peard Bay for Northeast Winds.

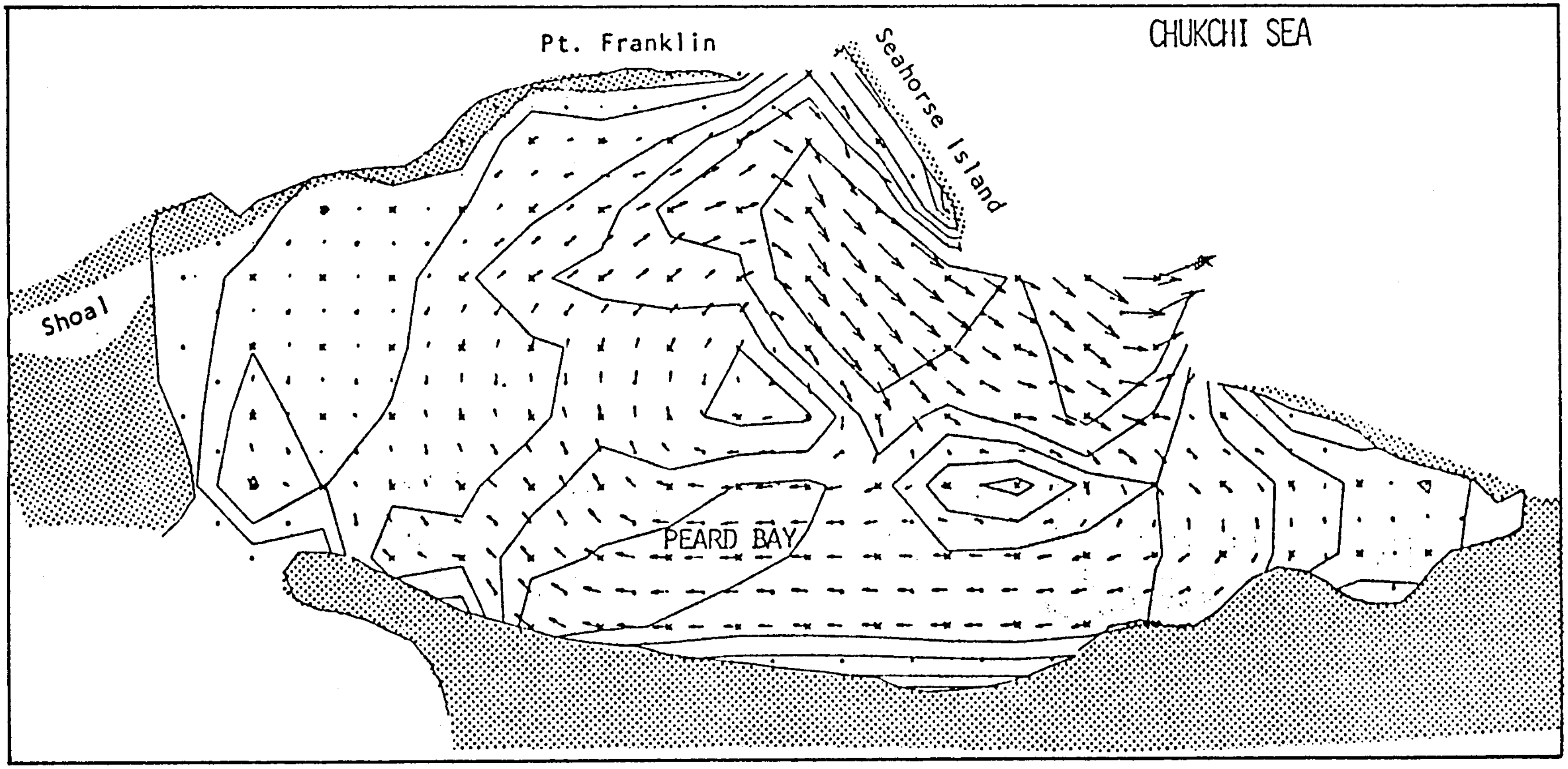


Figure 2-10. Spatial Distribution of Residual Tidal Currents in Peard Bay. The plotting scale is 4 cm/sec per grid spacing (Liu 1983).

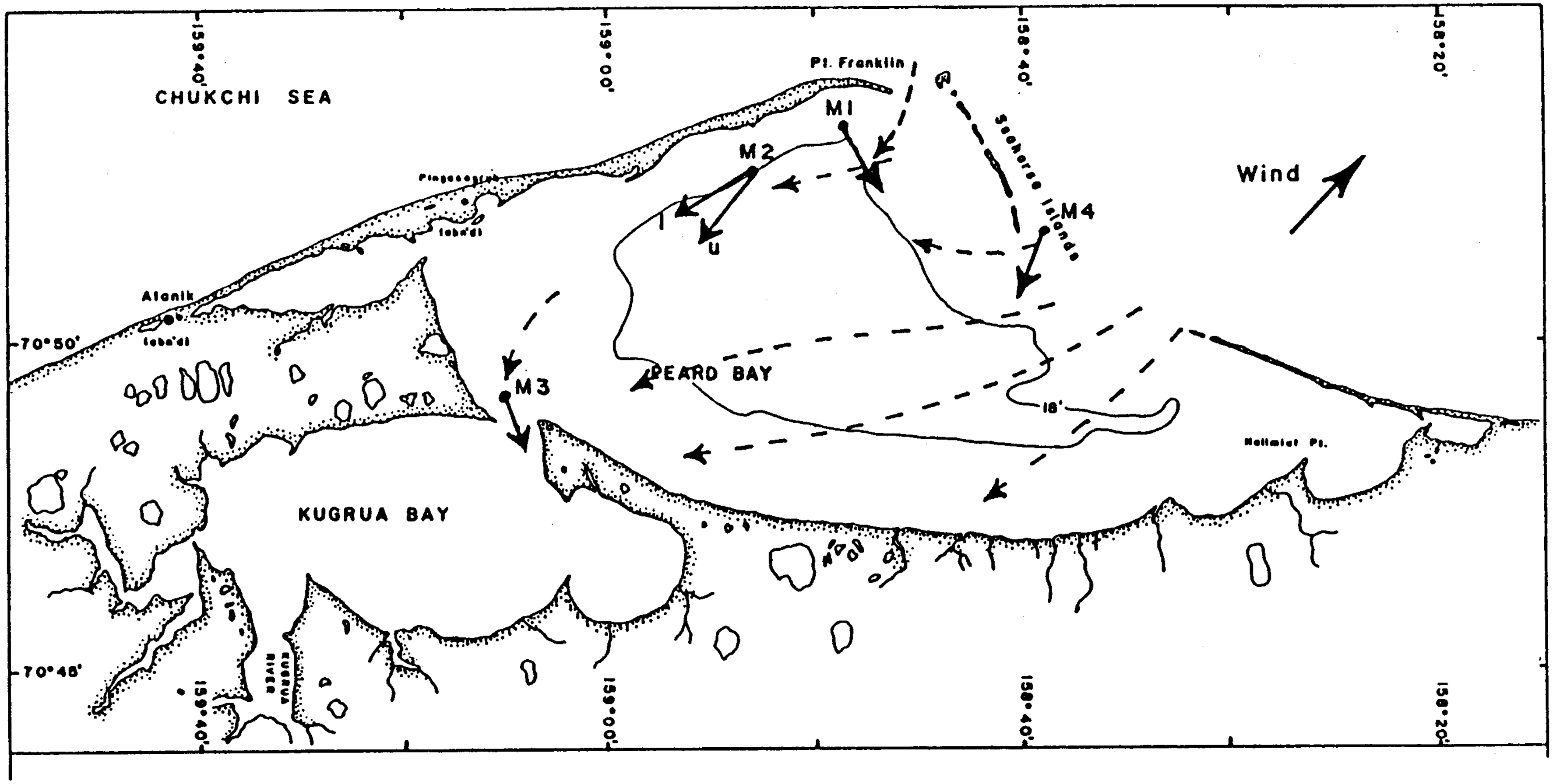


Figure 2-11. Conceptual Circulation Model in Peard Bay for a Storm Surge Event; Southwest Winds.

Vertical profiles were found to be essentially isothermal to the bottom, and isohaline down to a depth of 5 m where a sharp halocline was encountered. Water temperatures ranged from -1.9° to -1.0°C, and salinities ranged from 32.1 to 35.0 ppt in the upper layer. In central Peard Bay, at depths of 5 to 7 m, hypersaline water was found ranging from 37.7 ppt along the perimeter of the bay, to 41.8 ppt in the central bay. Water samples were taken which confirmed these measurements. The highest salinity water found was in central Kugrua Bay, where salinities ranged from 38.5 ppt at the surface to 47.9 ppt at the bottom. The channel into Kugrua Bay is very restricted during the winter as a result of the 1.2 to 1.8 m of ice cover, thus little water is exchanged with Peard Bay, resulting in high salinities. The hypersaline water in Peard Bay is not as high, due to the greater volume per amount of salt extrusion and also as a result of exchange with offshore waters. Offshore temperatures and salinities ranged from -1.7 to -1.4°C and 32.4 to 33.0 ppt, respectively.

Two Aanderaa RCM-4 current, temperature, and conductivity recorders were moored from 8 March to 17 March in the entrances to Peard Bay. Results are shown in Figure 2-12. The meters were deployed without their vanes to enable their positioning through a 10-inch auger hole. Directional data were then obtained by profiling next to the meters a number of times with a Marsh - McBirney 527 deck readout current meter, and by correlating with tide tables (NOS 1984). The meter at the Pt. Franklin entrance was deployed in 3 m of water at a depth of 2.6 m. The southern Seahorse Island mooring was in 7 m of water at a depth of 5.5 m. Ice thicknesses ranged from 1.5 to 2.0 m.

Current speeds at the Pt. Franklin entrance were generally less than 5 cm/sec during both flood and ebb conditions. A number of events can be discerned in the temperature and salinity time series which relate to outflow conditions as on 9, 14, 15, and 16 March, when high salinity (37 ppt) and higher temperature water exited the bay. Current speeds at the Seahorse Island entrance were very high, with speeds often exceeding 50 cm/sec and peaking up to 90 cm/sec on 9 March. Currents were mainly tidal with ebb flows being much larger than floods. This may be due to the less dense offshore water entering Peard Bay at the surface during the flood, and denser Peard Bay water exiting at depths near the current meter on the ebb.

A strong northeasterly wind blew ice offshore, opening up a lead on 9 March which seems to correspond to the large ebb event. When winds slackened on 10 March, a surge of water back into Peard Bay resulted in the large surge event. All other events are due to semidiurnal tides. The temperature time series is essentially isothermal in contrast to the salinity time series which fluctuates from 33 ppt during flood to 37 ppt during ebb conditions. The higher salinity Peard Bay water seems to exchange very effectively with the offshore waters even under ice-covered conditions. This is probably a result of the deep channel into Peard Bay which is in contrast to most other Arctic barrier island lagoons.

In summary, physical oceanographic measurements in Peard Bay in summer, 1983, documented the influx of large volumes of coastal water into the bay in response to strong southwesterly winds along the coast. These events occurred at intervals of 8 to 10 days and raised sea level in the Bay by 0.5 to 0.8 m. This volume represents about 15% of the total volume of Peard Bay.

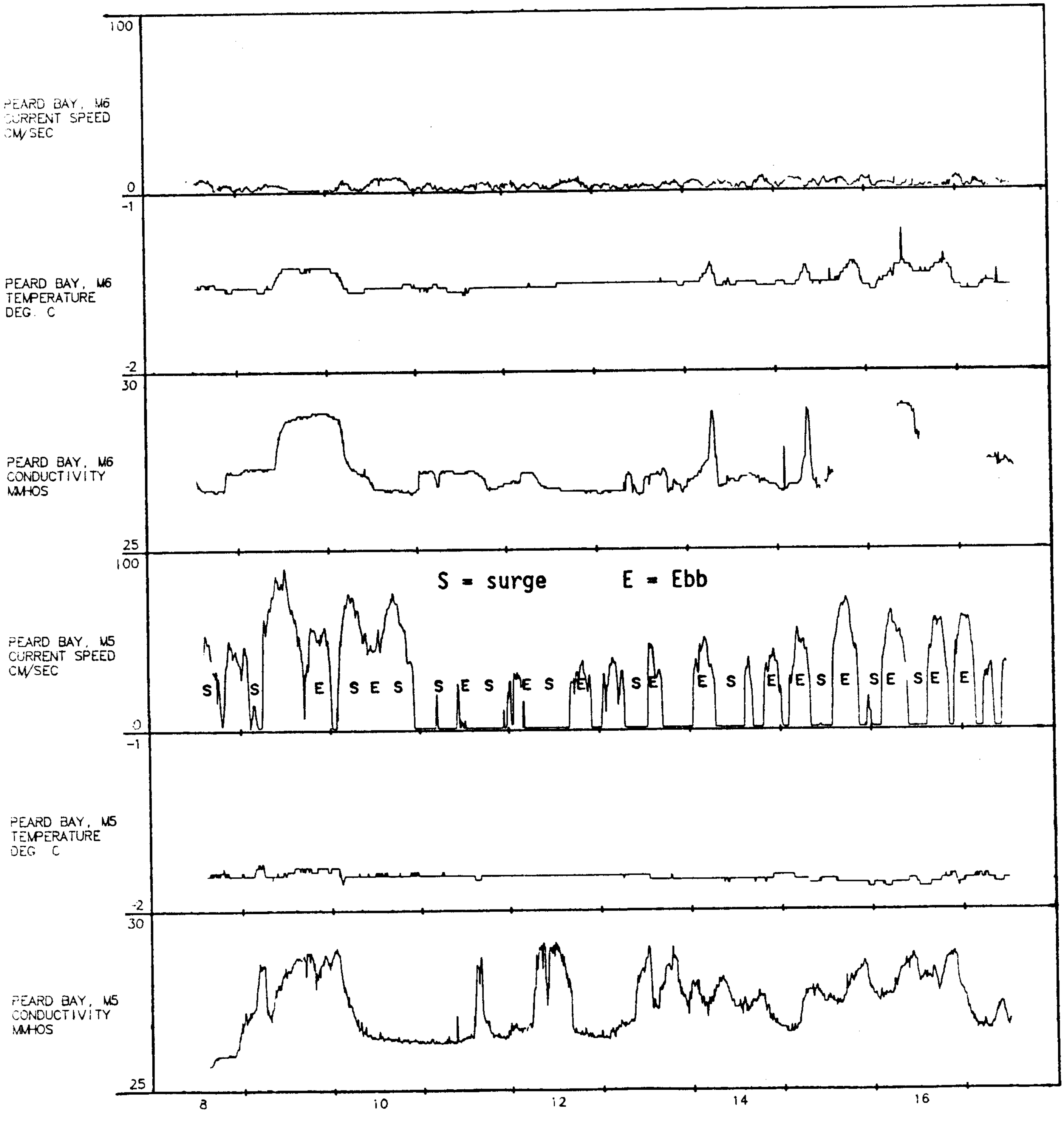


Figure 2-12. Time Series of Currents in the Seahorse (M5) and Pt. Franklin (M6) Entrances in Peard Bay During 8-17 March 1984.

The astronomical tide within Peard Bay is principally semidiurnal, but very much smaller than the meteorological tides. Mean tide height was 14 cm and the largest constituent of tidal current was less than 3 cm/sec. Tidal currents were significantly larger in the inlets.

The effects of the spring freshet of the Kugrua River were seen until about 5 August. Water in the inlet to Kugrua Bay was relatively warm and fresh, mixing horizontally across Peard Bay with colder and more saline coastal water.

There was no confirmation of the presence of hypersaline bottom water during the summer, but the measurement area did not extend to the deepest areas of Peard Bay where the bottom water was most likely to be found. Hypersaline water was found in March in both Peard and Kugrua Bays (in the bottom layer).

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CHAPTER 3

MARINE MAMMALS IN THE VICINITY OF PEARD BAY

3.1 INTRODUCTION

3.1.1 General

The northern Chukchi Sea is the summering ground and northernmost habitat of several migratory marine mammal species. In addition to providing summer feeding grounds, the nearshore northwestern Chukchi Sea is an important migratory pathway for species en route to and from the Beaufort Sea, which includes the bowhead and beluga whales, polar bear, and ringed, spotted, and bearded seals.

Peard Bay offers a large expanse (300 km^2) of shallow lagoon habitat at the northern end of the Chukchi Sea coastline. Associated with this lagoon are extensive sand and gravel spits and offshore barrier islands. In addition, a shallow inner bay (Kugrua Bay) exists as part of the Peard Bay system, into which flows the Kugrua River. It was, therefore, of particular interest to investigate the use of this lagoon system by marine mammals, especially since offshore oil and gas development and, perhaps, staging operations may occur which could have impacts on the Peard Bay ecosystem.

3.1.2 Specific Objectives

The purpose of this study was to document the utilization of Peard Bay by marine mammals and to ascertain their functions in the ecological processes operative in the bay and adjacent coastal waters. Specifically, aerial, shoreline and small boat surveys were made in Peard Bay and along the coastal spits bounding the bay. In addition, previous literature of marine mammal usage of the eastern Chukchi Sea nearshore area was to be summarized as a framework for interpretation of the results.

3.2 METHODS

3.2.1 Literature

Previous literature regarding marine mammal usage of the eastern Chukchi Sea coastal area was gathered from published literature and research reports. These results are first summarized for the larger area, then applied specifically in interpreting the present data on marine mammal usage of the Peard Bay environs.

3.2.2 Peard Bay Processes Study

A summary of marine mammal field efforts is given in Table 3-1 and sampling locations are shown in Figure 3-1. An initial aerial survey was conducted of Peard Bay and the nearshore Chukchi Sea between Barrow and Wainwright on 31 May 1983. A Cessna 185 fixed-wing, single-engine aircraft

Table 3-1. Summary of 1983 Peard Bay marine mammal field studies.

Period	Date	Field Activity
1)	31 May	Aerial survey. Transect along coast following shorefast ice edge from Barrow to Peard Bay; four transects over Peard Bay (Figure 3-1); transect down coast to Wainwright and return. Altitude 500-1000 ft; air speed 100 kts.
2)	4-14 June	Shore-based sweep counts from 4-meter high observation site at Pt. Franklin (random times each quarter day). Mammal counts at Pt. Franklin entrance to Peard Bay.
3)	16-20 July	Same as Period 2.
4)	12-13 August	Same as Period 3.
5)	20-28 August	Shorefast sweep counts for 4-meter elevation at Pt. Franklin. Beach survey along both sides of Pt. Franklin Spit using three-wheeler vehicle. Helicopter surveys around the perimeter of Peard and Kugrua Bays. Ground reconnaissance at each spit, headland, or river mouth for examination of subsistence hunting sites and apparent harvest composition from bone debris.

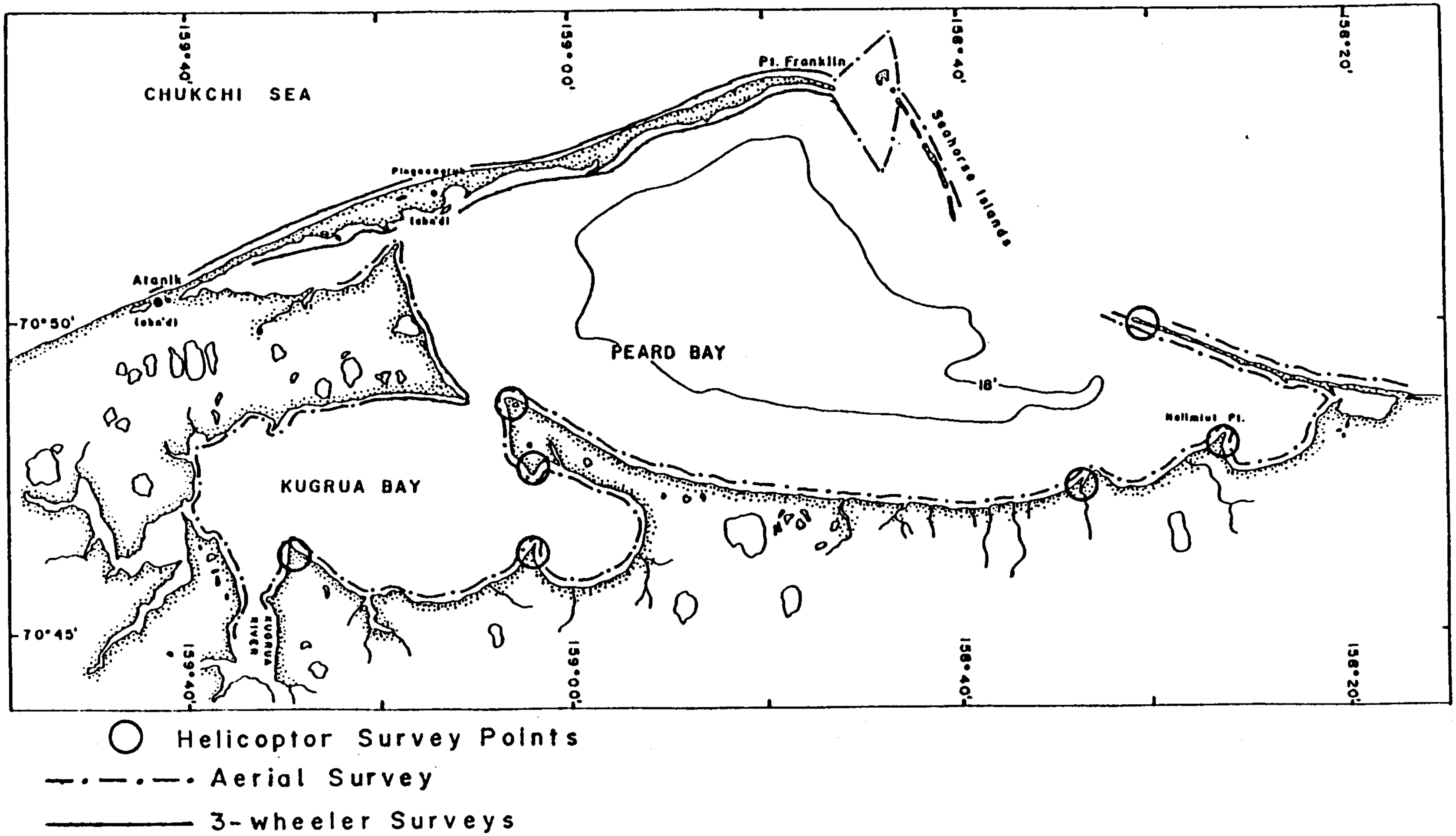

Figure 3-1. Marine Mammal Survey Areas, Summer 1983.

was used for the survey, flown at elevations varying from 500 to 1,000 feet, depending on visibility, at an average air speed of about 100 mph. Weather conditions were near optimal during this survey, with thin, broken overcast at about 3,000 feet, winds out of the north at about 15 mph, air temperature 38°F. Personnel included the pilot and an observer (S. Stoker). The survey included a single linear transect down the coast from Barrow to Peard Bay, four passes over Peard Bay, a transect down the coast to Wainwright and a return transect to Barrow. Flight transects approximately followed the edge of the shore-fast ice along the Chukchi Sea coast between Barrow and Wainwright. All sightings of marine mammals were recorded by the observer on a portable cassette recorder. Total flight time was 2 hours.

Shore-based observations were carried out from field camps at Peard Bay during 4-14 June, 16-20 July, 12-13 August, and 20 August-5 September. Observations included: 1) sweep counts of Peard Bay and of the nearshore Chukchi Sea adjacent to Point Franklin which were made from an observation site on Point Franklin, 2) counts at the entrance to Peard Bay, 3) beach surveys along both the Peard Bay side and Chukchi Sea side of Point Franklin, 4) helicopter surveys of most of the margins of Peard Bay and Kugrua Bay, and 5) reconnaissance surveys of all prominent spits and headlands within Peard Bay, Kugrua Bay, and along the Chukchi Sea side of the Point Franklin spit.

Sweep counts were conducted of Peard Bay using a standard spotting scope (Biota Consultants). Sweeps were made at randomly chosen times during each quarter of the day from a 4-m-high observation point on Point Franklin, covering a fixed 11.62 km^2 area. All marine mammals seen during these sweeps were recorded along with relevant information pertaining to ice conditions, weather, observed activity, direction of travel, etc. Similar sweep counts were conducted, from the same observation point, of a fixed 2.63 km^2 area of the nearshore Chukchi Sea adjacent to Point Franklin during 4-14 June, 16-20 July, and 12-13 August. For purposes of uniformity and comparison, counts were calculated in terms of number of animals per km^2.

During August 20-28, intermittent watches were maintained at the end of Point Franklin spit in order to assess the movements of marine mammals in and out of Peard Bay. These watches were conducted at more or less random times of day, depending on weather and visibility. They lasted for periods of from 1 to 40 hours each. Observations were made with binoculars by a single observer (S. Stoker). For each sighting, a notation was made as to species (when possible), number of individuals, apparent activity, direction of travel, time of day, weather, temperature, and tide condition. For each period, sightings were later calculated as number of animals per hour observed entering or leaving the bay. During the period of 20-29 August, several survey trips were conducted along both the Peard Bay and Chukchi Sea sides of Pt. Franklin spit to as far as the abandoned village of Atanik (Figure 3-1), using a three-wheeled all-terrain vehicle. During these surveys, notations were made of marine mammal remains found on the beaches, and obvious subsistence hunting or village sites (all presently abandoned) were reconnoitered. Notations were also made of the relative frequency of identifiable faunal remains in the vicinity.

During this same period of 20-29 August, several helicopter surveys were conducted around the perimeter of Peard Bay and Kugrua Bay and the presence of live marine mammals or visible remains was noted. In conjunction with these helicopter surveys, ground truth reconnaissance surveys were conducted at each spit, headland, or river mouth of significance within Peard Bay and Kugrua Bay. The presence and relative abundance of beached marine mammal remains were noted during these surveys, and when subsistence hunting sites were encountered, a brief assessment was made as to the apparent harvest composition based on identifiable bones or other debris found at the sites.

In addition to direct observations, informal interviews were conducted with several Eskimo subsistence hunters who visited Peard Bay from both Wainwright and Barrow. Available literature concerning marine mammals of the vicinity and subsistence harvests by villages nearby was also reviewed and the pertinent information summarized.

3.3 RESULTS AND DISCUSSION

3.3.1 Literature Summary of Marine Mammal Use of the Eastern Chukchi Sea Coastal Region

3.3.1.1 Introduction

The most recent evaluation of the marine mammals of the Chukchi Sea is by Frost et al. (1983). They made observations on the distribution of marine mammals in the coastal zone of the eastern Chukchi Sea during summer and autumn, and compiled available data on the distribution of marine mammals during the open water season in this area. Their review of data includes all sightings since 1950. They report all sightings made within 5 km of the coast, and identify haulout areas of pinnipeds in the lagoons, bays, and estuaries of the area. The reader is referred to this report for details concerning the summer and autumn distribution of marine mammals. It provides a complete (March 1983) bibliography and incorporates the data from all marine mammals surveys performed under the OCSEAP program. The distribution and biology of marine mammals in the southeastern Chukchi throughout the year are reported by Johnson et al. (1966). This study is not as geographically comprehensive as the report by Frost et al. (1983), but it provides greater seasonal coverage and details on biology of the mammals, in particular, ringed and bearded seals in the southeastern Chukchi. The aerial observations of Ljungblad (1981) and Ljungblad et al. (1982, 1983) are mainly concerned with the distribution of endangered cetaceans in the Chukchi; however, incidental observations of other marine mammals, in addition to endangered species, provide further information on spatial and temporal distributions. This chapter draws heavily upon these publications.

Each species is considered separately below. The seasonality of their distributions and occurrence at or usage of specific shoreline or nearshore areas is summarized and, where available, the feeding, breeding, and migration patterns are discussed. Geographic place names referred to in the text are shown in Figure 3-1.

Throughout the text, liberal use is made of previously published data and previously untabulated data are compiled to illustrate points. Since these are selected data sets, the primary reference should be consulted for details.

3.3.1.2 Pinnipeds

The most abundant species of pinnipeds in the Chukchi Sea-Bering Sea are the ringed seal (*Phoca hispida*) and the bearded seal (*Erignathus barbatus*). These are the only two pagophilic (ice-loving) pinnipeds which breed extensively in the Chukchi (Figure 3-2) as described by Burns (1970). These two species have also been the main subject of investigation in the southeastern Chukchi Sea by Johnson et al. (1966). Temporally and spatially extensive observations of these and other mammals in the Chukchi have been made by Ljungblad et al. (1982, 1983). Studies concerning these and other species in the northern Bering Sea have been summarized by Lowry and Frost (1981) and by Burns (1981). Aspects of these studies may be applicable to the species in the Chukchi Sea since the seals in both areas are considered one population. The Bering-Chukchi-Beaufort population of ringed seals numbers 1-1.5 million individuals, making this species the most abundant marine mammal in the northern hemisphere. Bearded seals of the Bering and Chukchi Seas number 300,000 individuals and are considered a single population (Lowry and Frost 1981).

Johnson et al. (1966) made aerial surveys and observations of marine mammals, especially ringed and bearded seals, of the southeastern Chukchi Sea and obtained specimens from hunters in the Point Hope and Kivalina areas during the summers of 1959 and 1960 and from November to June of 1961. Ringed and bearded seals were studied extensively. They examined 2,028 ringed seals and 208 bearded seals taken by hunters and lesser numbers of ribbon (7), fur (3), and harbor seals (3), walrus (2), beluga (5) and bowhead whales (3), and polar bears (3). Ringed and bearded seals generally utilize fast ice and pack ice, respectively, for breeding. As evidenced by the pattern of harvest, these seals apparently move south with the ice sheet. The seal harvest observed by Johnson et al. (1966) began with ice-in, peaked in February, and tapered off in April (Table 3-2). In general, the overflights indicated that most ringed and bearded seals remain within a few miles of shore and tend to concentrate south of Cape Thompson in spring.

Ringed Seal. Based upon the southerly shift in the geographical position of the best seal hunting from north of Point Hope (November to February) to south of this landmark (March to June), it is evident that ringed seals migrate as the ice forms. Figure 3-3 presents the April to June distribution of seals as observed from aerial surveys, and corroborates the observation from hunting returns that there is a preponderance of seals south of Point Hope after March. Although ringed seals may range widely throughout the permanent and seasonal pack ice, they utilize the shore-fast ice for breeding; therefore, they are generally found within a few miles of shore during the spring (Johnson et al. 1966). The distribution of breeding adults shown in Figure 3-4 confirms this observation. On the fast ice the ringed seals are born in lairs excavated under thick snow or in natural cavities which afford protection to the young and adults from predators. Burns (1970) concludes, on the basis of hunting success at Wainwright, that ringed seals move northward along the coast during June and early July. The incidental observations of Ljungblad et al. (1982) tend to substantiate this conclusion (Table 3-3). During mid-May (after the pupping and breeding season), ringed seals are relatively even in distribution along the nearshore areas on shore-fast ice from Point Hope to Barrow (Figure 3-5). Later in the season (early June), ringed seals are still concentrated nearshore with a preponderance observed

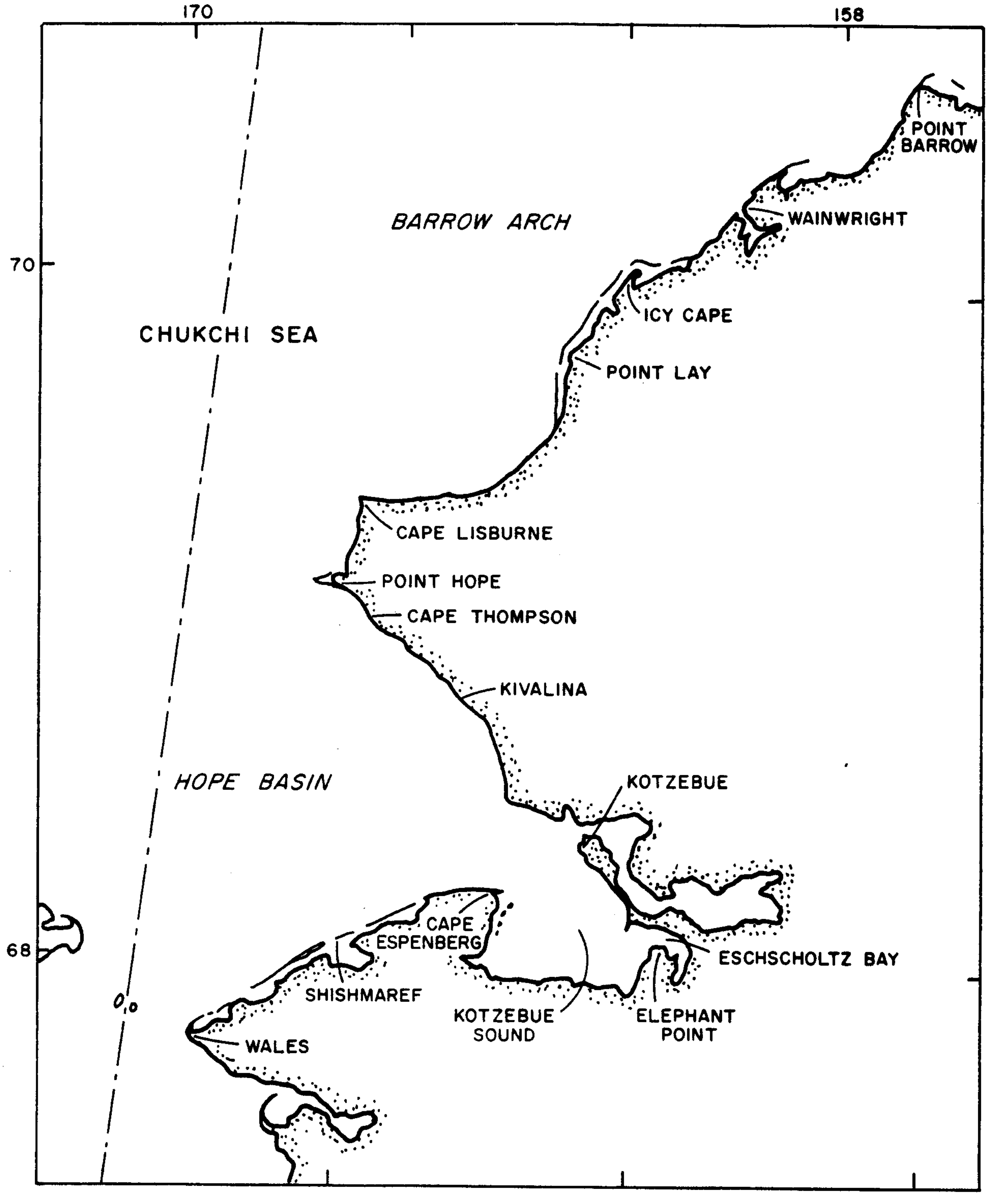

Figure 3-2. Geographic Place Names and Locations, Eastern Chukchi Sea.

Table 3-2. Numbers of bearded and ringed seals taken at Point Hope November 1960 through June 1961 by hunting area and month. Quantities in parentheses are numbers of bearded seals only.

	Hunting Area										
Month	I	II	III	IV	V	VI	VII	VIII	IX	X	Unknown	Total
November	–	–	–	58(3)	11	1	–	–	–	–	–	70(3)
December	3	11	10	60(1)	25	17	–	3	1	1	2	133(1)
January	14	37	39(1)	70	57(1)	26	13	26	10(1)	13	9	314(3)
February	1	11	–	34	329(2)	58(2)	27	29	20	3	24	536(4)
March	4	–	10(3)	38(1)	97(1)	68(1)	7	2(1)	–	–	6	232(7)
April	3(1)	6	2	21	86(8)	11	12(1)	6(1)	–	1	10(1)	158(12)
May	–	3	5	26	106(7)	13	17(1)	1	–	3	6	180(8)
June	–	–	1	18	260(84)	228(55)	2	–	–	3	268(26)	780(165)
Total	25(1)	68	67(4)	325(5)	971(103)	422(58)	78(2)	67(2)	31(1)	24	325(27)	2403(203)

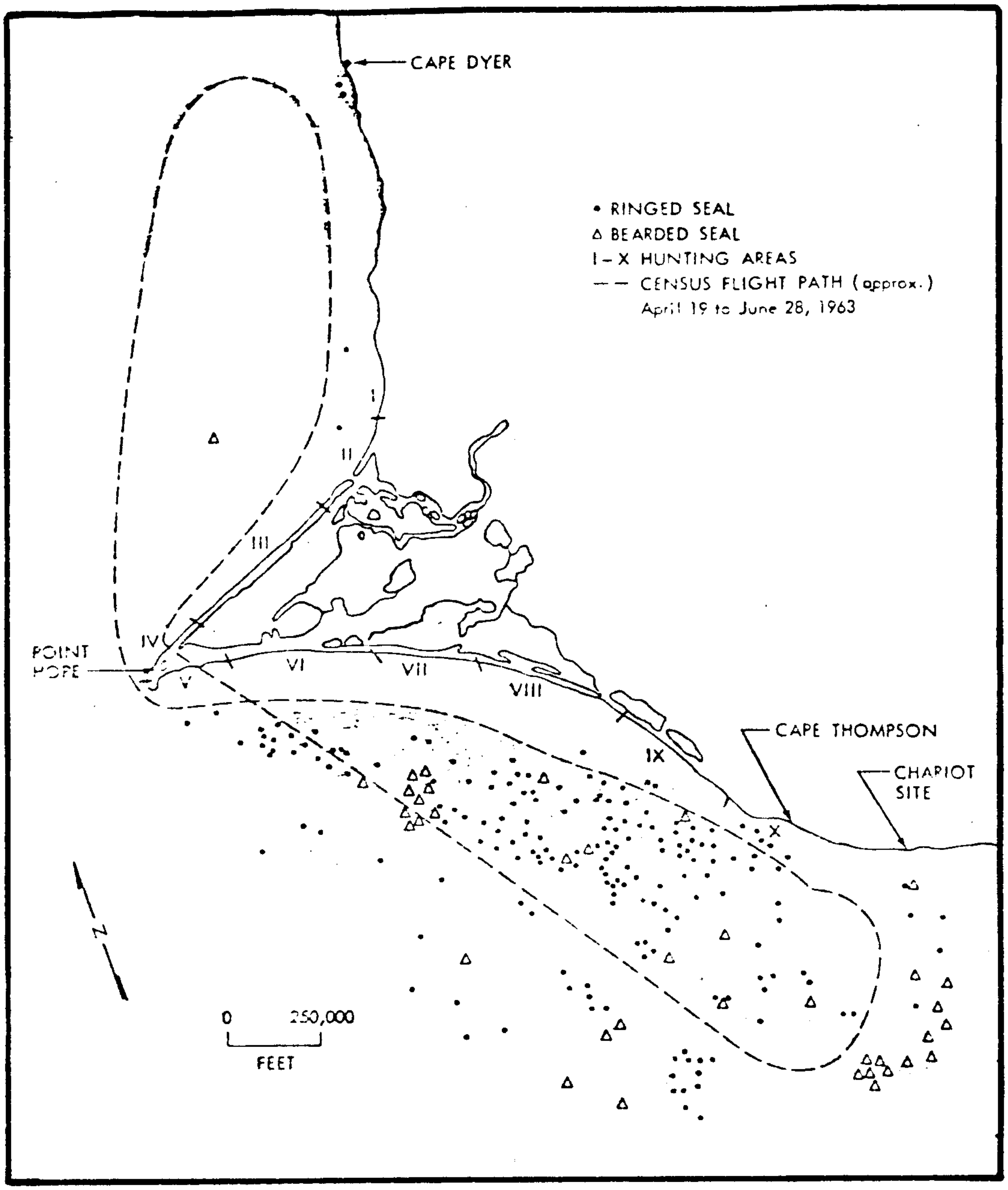

Figure 3-3. Spring Ringed and Bearded Seal Distribution and Hunting Areas Near Point Hope (after Johnson et al. 1966).

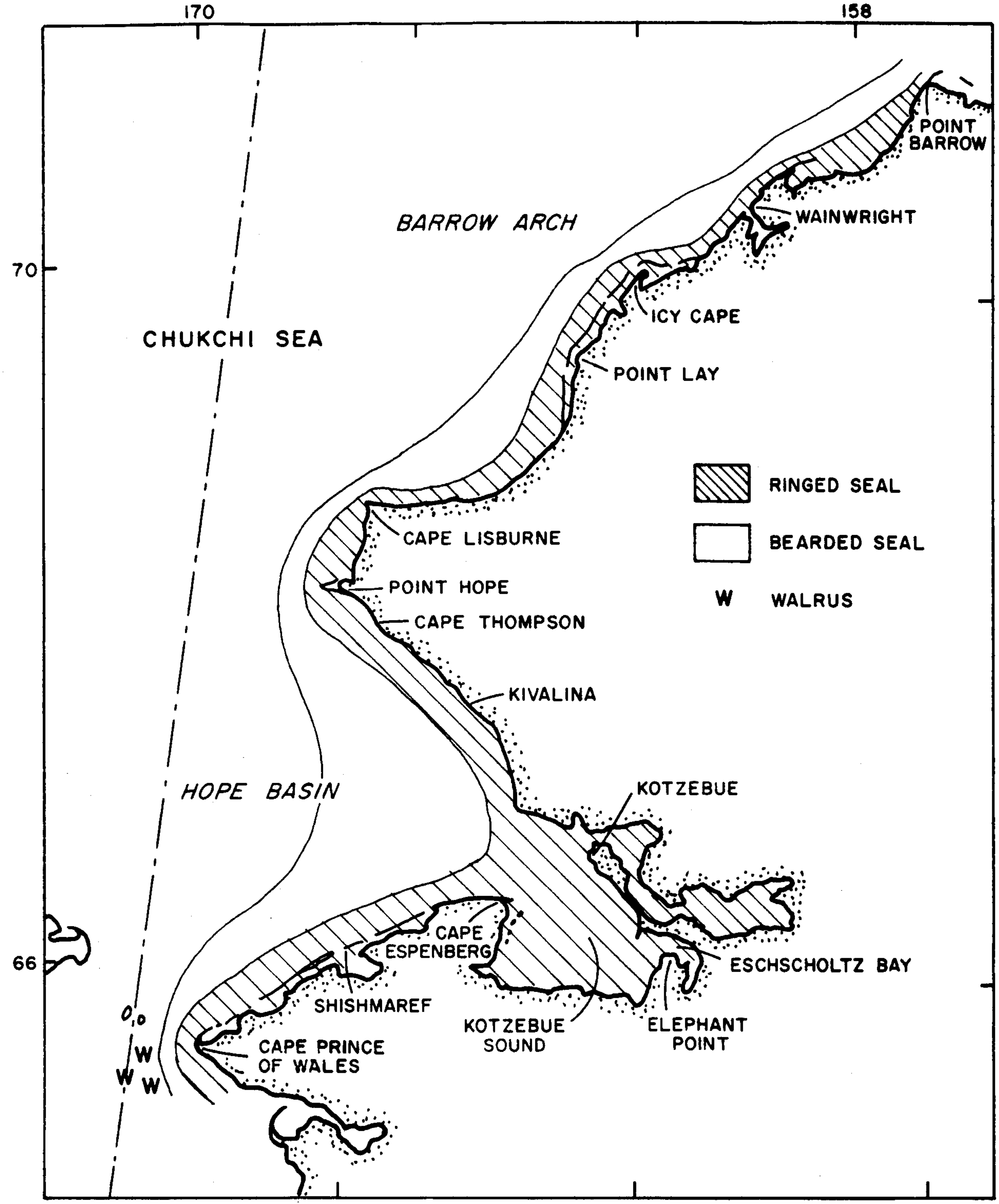

Figure 3-4. Spatial Distribution of Reproductive Adults of Pagophilic Pinnipeds in the Chukchi Sea During March and April (modified from Burns 1970).

Table 3-3. Distribution of marine mammals observed during 1981 overflights in the Chukchi Sea (from Ljungblad et al. 1982).

Date	Area	Bowhead Whale	Gray Whale	Beluga Whale	Unid. Cetacean	Spotted Seal	Ringed Seal	Bearded Seal	Unid. Pinniped	Walrus	Polar Bear	Other
4/6	Bering Straits	11	167	-	-	-	15	7	-	4	3	-
4/11	" "	35	-	134	-	-	2	2	-	4	1	-
4/17	" "	332	-	79	-	-	-	1	-	415	-	-
4/19	" "	80	-	51	-	-	-	10	-	198	-	-
4/24	Coastal (Nome to Deadhorse)	28	-	213	-	-	-	4	-	-	2	-
5/10	" "	8	-	79	-	-	94	34	-	43	-	-
6/1	" "	-	-	-	-	-	103	-	-	7	-	-
6/10	Coastal (Deadhorse to Nome)	-	15	14	-	20	12	3	-	2,126	-	-
6/11	Prince of Wales	-	5	-	-	9	-	-	2	4	-	-
6/15	Outer Kotzebue Sound	-	-	99	-	11	3	25	5	9	-	-
6/16	Coastal Point Hope	-	2	37	-	35	5	3	6	46	-	-
6/17	Inner Kotzebue Sound	-	-	-	-	42	-	-	6	-	-	-
7/7	Coastal (Nome to Kotzebue)	-	4	-	3	-	-	-	-	179(D)	-	-
7/8	Coastal Kotzebue-Point Lay	-	29	1/ 33(D)	-	-	-	-	6	6/ 4(D)	-	-
7/10	North of Cape Prince of Wales	-	1	-	-	-	-	-	1	-	-	-
7/20	Cape Prince of Wales	-	2	-	1(D)	-	-	-	3(D)	-	-	-
7/23	Coastal Nome-Kotzebue	-	1(D)	-	-	-	-	-	2	-	-	-
7/24	South of Point Hope	-	36	-	-	-	-	-	14	3/ 5(D)	-	3 Fin Whales
7/24	Coastal-Kotzebue to Deadhorse	-	34	1/ 1(D)	-	-	1	-	1	1,350/ 26(D)	-	-
8/24	Coastal-Deadhorse to Nome	-	6	-	-	-	6	9	-	-	-	-
8/28	Cape Prince of Wales and North	-	5/ 2(D)	-	1	-	-	-	2	190	-	-
8/30	Coastal-Nome to Deadhorse	-	-	4(D)	-	-	3	-	4	3(D)	-	-

D = dead

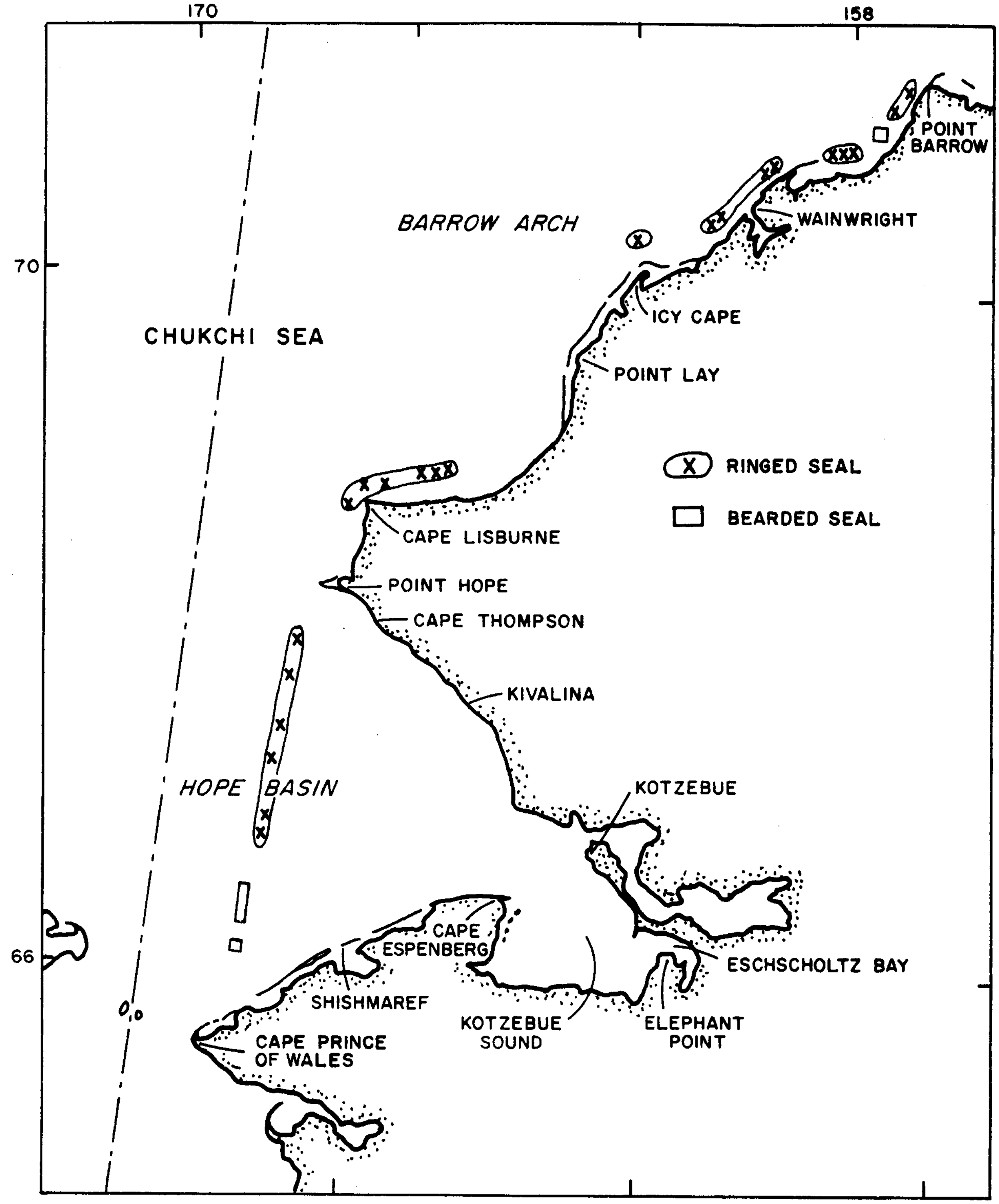

Figure 3-5. Distribution of Ringed and Bearded Seals on 16 May 1981, as Observed from Aerial Overflights (modified from Ljungblad et al. 1982).

between Point Lay and Barrow (Figure 3-6). In July, no ringed seals were observed between Kotzebue and Point Lay, and in late August they were observed only off Barrow (Figure 3-7).

Ringed seals in the Chukchi Sea congregate on shore-fast ice with a general late winter concentration in the southeastern Chukchi area south of Point Hope. It should be noted that this concentration may vary annually depending upon ice extent in the northern Chukchi. During heavy ice years, decreased densities of seals are found in the northern Chukchi with an increase above average in the southern Chukchi (Burns 1981). In March-April, they pup, nurse, and breed on the fast ice and by May can be observed along the entire Chukchi coast, still in association with fast ice. By June, they apparently disperse along the coast and, in association with floating ice, are observed along the coast in late summer.

Johnson et al. (1966) made some observations upon the biology of ringed seals on the basis of morphometric measurement, histological examination, and stomach content analysis. Measurements derived from specimens taken by hunters indicate that the mean weight of ringed seals increases from November to January and then decreases from February to June. For instance, the mean weight of males increased from 114.4 lb. in November to 152.9 lb. in January and then decreased to 92.4 lb. in June. Similar patterns were noted in non-pregnant females. Changes in blubber thickness parallel this weight change.

The observed size frequency distribution of ringed seals is presented in Figure 3-8. The fact that there were some older seals in small length categories indicates that there are dwarf populations among the ringed seals. The size distributions were bimodal, indicating an immature group and an adult group. Males were larger than females in both groups.

Stomach content analyses performed on a number of ringed and bearded seals revealed differences in food preference between species (Tables 3-4 and 3-5) and a seasonal change in diet within species (Tables 3-6 and 3-7). During fall and winter, Arctic cod are the preferred food item for the ringed seal. From December to February, Arctic cod are frequently the only species observed in the stomachs of ringed seals. Arctic cod are also among the most abundant and well distributed fish species in the southeastern Chukchi Sea. As many as 51 complete cod were found in the stomach of one seal, while fragments of 125 individual cod were found in the stomach of another specimen. During spring, the stomachs of ringed seals contained a preponderance of invertebrates, especially crabs (*Hyas* sp.) and shrimp (*Sclerocrangon boreas*). *Ampelisca* was also commonly taken during spring (up to 1,000 in one stomach). The seasonal changes in ringed seal diet are summarized by month in Table 3-7. Results of stomach content analyses on northern Bering Sea ringed seals, as summarized by Lowry and Frost (1981), reveal similar pattterns. They also found the species to be strongly piscivorous. Arctic and saffron cod, sculpin, and several crustaceans (shrimp, mysids, and gammarid amphipods) were major items. As in the Chukchi, Arctic cod were most important in winter months. During fall and spring, saffron cod were taken more often. Lowry and Frost (1981) describe dietary changes, with age, of ringed seals. As the individuals age, fish become more important in the diet and crustaceans less so. Crustaceans make up 98% of food for pups, with a progressive decline in importance to 20% of food for seals age 5 years of age and older. The authors also describe annual variability of relative abundances.

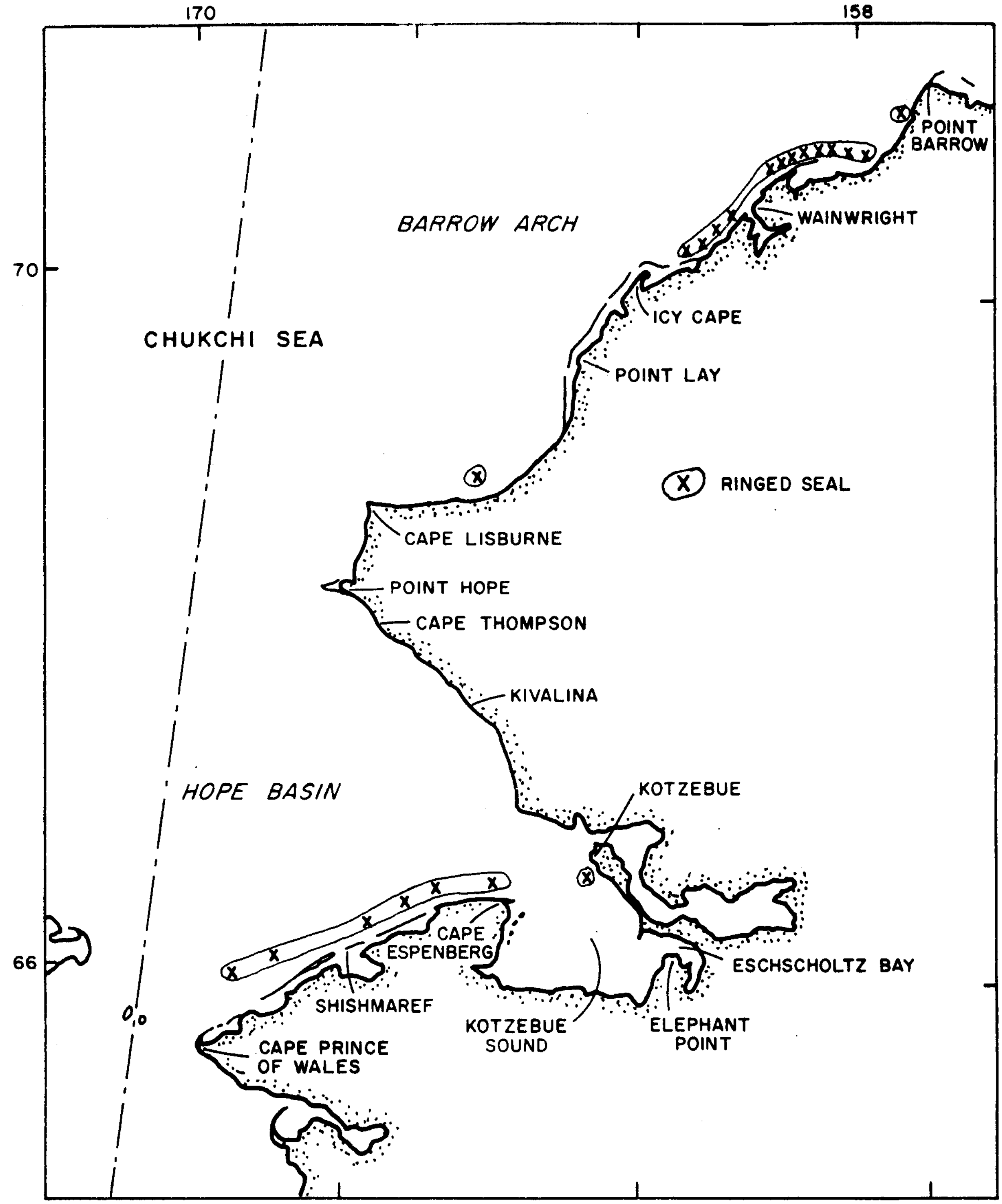

Figure 3-6. Distribution of Ringed Seals on 1 June 1981, as Observed from Aerial Overflights (modified from Ljungblad et al. 1982).

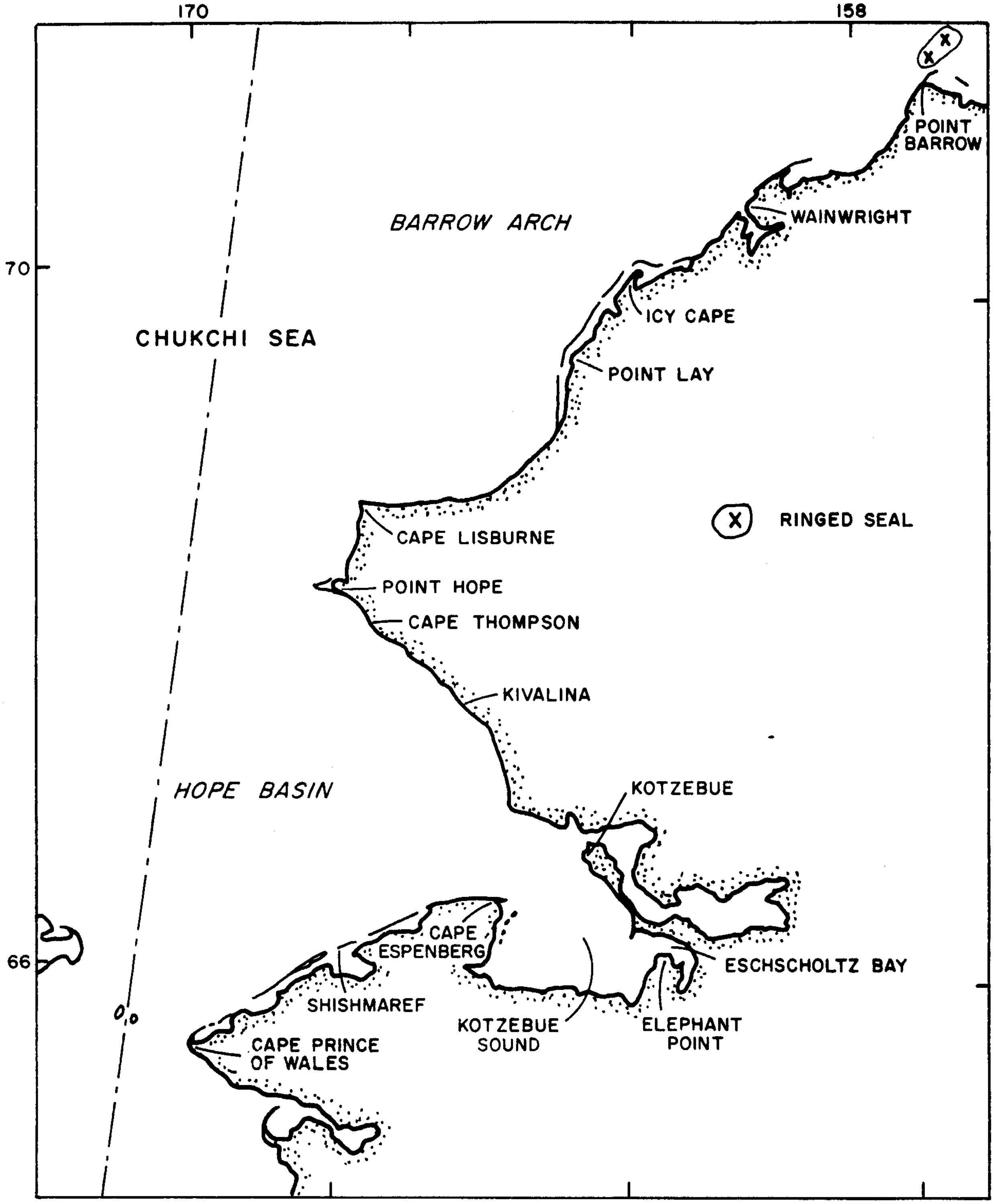

Figure 3-7. Distribution of Ringed Seals on 24 August 1981, as Observed from Aerial Overflights (modified from Ljungblad et al. 1982).

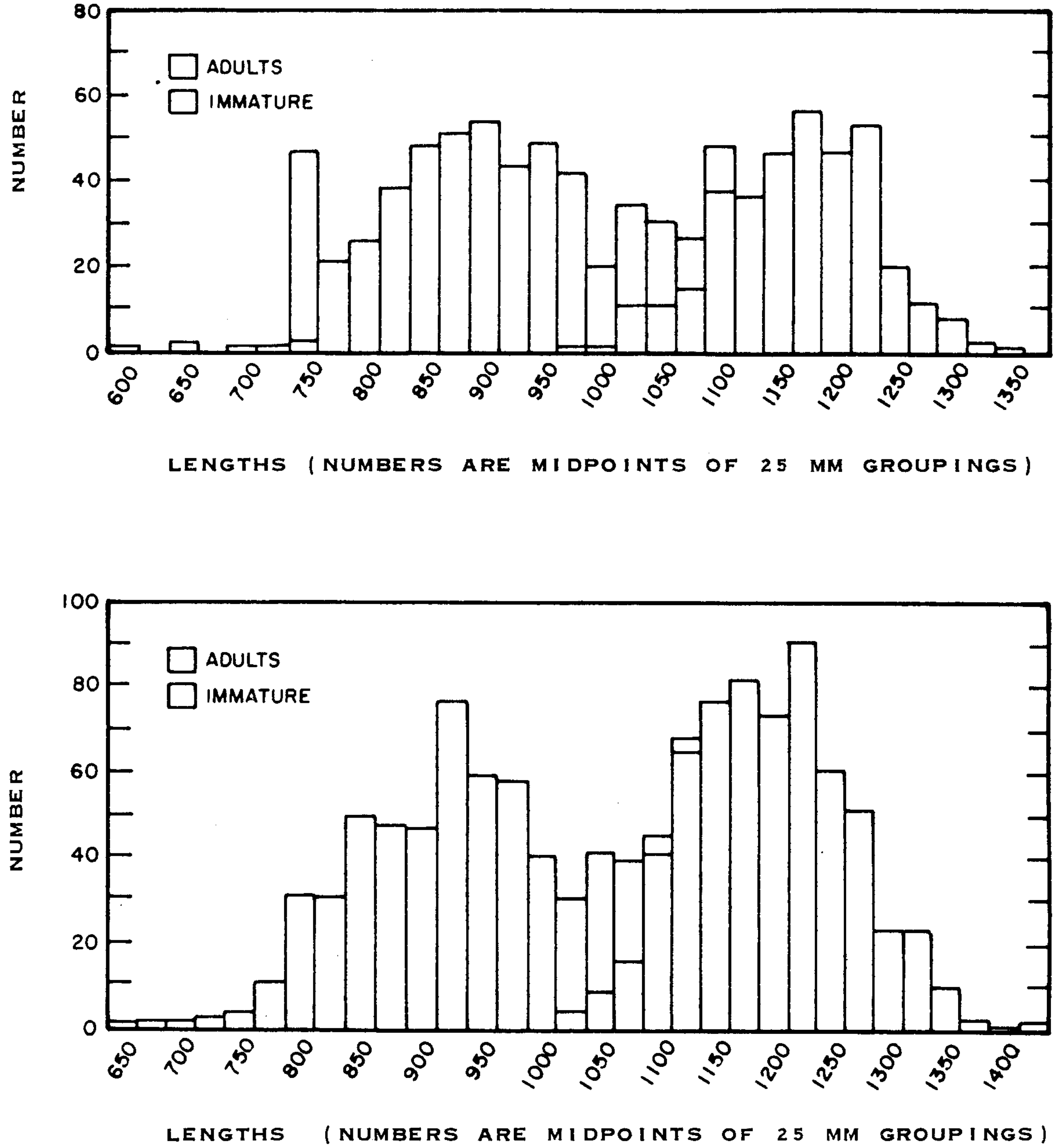

Figure 3-8. Standard Lengths of Female and Male Ringed Seals During 1960-61. Upper figure is based on 799 females and lower figure, 1139 males (after Johnson et al. 1966).

Table 3-4. Percentage of total volume of fish found in stomachs of ringed (RS) and bearded seals (BS), Point Hope, 1960-61 (from Johnson et al. 1966).

	Month															
	November		December		January		February		March		April		May		June	
Species	RS	BS	RS	BS	RS	BS	RS	BS	RS	BS	RS	BS	RS	BS	RS	BS
Herring					*		*									
Salvelinus sp.															0.5	
Capelin					*						0.1					
Smelt											0.2					
Arctic cod	26.1	*	56.4		99.0	2.0	90.2	24.1	21.7		9.1		3.6		8.4	
Saffron cod	13.9		13.9		0.4		0.1		5.4		19.2		1.9		17.7	
Stickleback	0.2		*								0.3		*		0.1	
Sculpins																
Unspecified	2.5		*						0.3	*	2.9	*	0.8		0.2	*
Artediellus sp.			0.2				*				0.1					
Gymnocanthus sp.	0.4		1.9		0.1		0.1		0.8	1.9	1.0		1.2		*	
Myoxocephalus sp.	37.9		3.8				0.3		2.4	0.5	4.7	2.9	3.8	0.5	3.5	1.9
Fourhorn			10.7										0.1			*
Shorthorn			0.9													
Triglops sp.											0.1					
Sand lance	4.9		1.2		*		1.6	2.2	6.1	7.8	1.8		1.2		3.7	
Pricklebacks			0.1				*	0.2	0.1		0.1		0.5	0.5		
Righteye flounders									*	*						
Yellowfin sole											0.1					
Starry flounder									0.6	*						
Unident. material	3.5		1.3		0.3		9.7	4.8	4.5	3.2	4.2	12.0	1.6	2.4	3.3	6.5
Invertebrates**	10.3	100.0	9.6		0.2	98.0	7.0	65.7	58.1	86.6	56.0	85.1	83.9	96.6	62.5	31.6
Stomachs with food+	30	1	99	0	248	2	439	4	168	6	119	9	100	4	229	87
Stomachs empty+	33	2	23	0	57	0	76	0	47	0	16	3	67	4	142	42

* Trace

**Percent of total stomach contents that are invertebrates (from Table 8).

+ Also included in Table 8.

Table 3-5. Percentage of total volume of invertebrates found in stomachs of ringed (RS) and bearded seals (BS), Point Hope, 1960-61 (from Johnson et al. 1966).

Species*	November		December		January		February		March		April		May		June	
	RS	BS	RS	BS	RS	BS	RS	BS	RS	BS	RS	BS	RS	BS	RS	BS
Sponges							t			1.1				t	3.0	6.4
Hydrozoa												t		t		t
Anthozoa									0.1							
Sipunculada												0.5				
Priapulida												0.5				
Echiuroidea	2.0	4.8	0.4		0.1		0.1		0.9	t	0.5	t	4.5		0.4	0.7
Annelida							t						t		0.1	0.3
Crustacea, unspec.			0.3				0.5		1.3	1.3	1.1	1.6	1.4	16.3	4.7	1.6
Mysids	0.1		0.1		t		0.3		1.9	t	4.5		27.1	t	11.7	t
Cumacea							t								t	
Isopoda			0.7				t									1.1
Amphipoda	1.3		6.2		t		0.2		24.7	0.6	25.6	2.4	15.4		6.8	t
Euphausiacea	0.1						0.1		0.8		1.2		6.1		1.6	t
Decapoda, unspec.		20.0				8.3		5.3				8.2		22.6	1.6	2.7
Shrimp	6.5	60.0			0.1	85.2	6.0	51.5	27.4	24.5	23.0	51.7	29.4	26.8	28.2	12.6
Crabs, unspec.							t									0.6
Crabs, Brachyura		5.2				t	t	1.5	1.0	2.0		13.9		24.3	3.7	24.3
Crabs, Anomura		4.5				4.5	t	2.4	t	56.3	0.2	3.8	t		0.5	1.8
Sea spider													t			
Gastropoda								6.1				t		2.3	0.2	1.6
Tectibranchiata		3.2						1.3		0.6		1.5		2.3		0.2
Octopoda									t		t			t	t	
Clams												0.7			t	37.7
Echinodermata							t									
Tunicata					t									t	0.1	t
Milk													1.4			
Unident. material	4.5		1.3		0.3		9.7	4.8	4.5	3.2	4.2	12.0	1.6	2.4	3.3	6.5
Fish**	86.2		69.1		99.5	2.0	92.3	26.5	38.6	10.2	39.7	2.9	13.1	1.0	34.1	1.9
Stomachs with food+	30	1	99	0	248	2	439	4	168	6	119	9	100	4	229	87
Stomachs empty+	33	2	23	0	57	0	76	0	47	0	16	3	67	4	142	42

* Common names are used when available.

t Trace

**Percent of total stomach contents that are fish (from Table 7).

\+ Also included in Table 7.

Table 3-6. The major prey taken by ringed seals in order of monthly importance (after Johnson et al. 1966).

Month	Prey Species	Remarks
November	Sculpins Arctic cod Saffron cod Shrimp	Approximately 90% of the volume of the stomach contents was fish.
December	Arctic cod Sculpins Saffron cod Amphipods	More than 90% of the volume of the stomach contents was fish.
January	Arctic cod	Represented 99% of the stomach contents.
February	Arctic cod Shrimp	Arctic cod made up 90% of the volume of the stomach contents.
March	Shrimp Amphipods Arctic cod Sand lance	Nearly 60% of the volume of the stomach contents was invertebrates.
April	Shrimp Amphipods Saffron cod Arctic cod	Invertebrates made up 87.2% of the stomach contents at Point Hope.
	Shrimp Crabs (Brachyura) Unid. crustacea Sculpins	Invertebrates made up 87.2% of the stomach contents at Kivalina.
May	Shrimp Mysids Sculpins	Invertebrates made up 84% of the stomach contents.
June	Shrimp Saffron cod Mysids Arctic cod	More than 62% of the volume of stomach contents was invertebrates; 56 different food species were identified from stomachs during this month.

Table 3-7. The major prey taken by bearded seals in order of monthly importance (after Johnson et al. 1966).

Month	Prey Species
November	shrimp, 60%
January	shrimp, 85%
February	shrimp, 52%; arctic cod, 24%
March	hermit crabs, 56%; shrimp, 25%
April	shrimp, 51%; crabs (Brachyura), 14%
May	shrimp, 27%; crabs, 24%; unidentified decapods, 23%
June	clams, 38%; crabs, 24%; shrimp, 13%

Upon histological examination of sperm in gonadal tissue, Johnson et al. (1966) concluded that ringed seal males are sexually mature at age 7 and females at age 6. Young are born by late March or early April in well-hidden pupping lairs in piles of drifting snow and ice. Mating takes place within one month after birth.

In summary, ringed seals are the most numerous and widespread marine mammals in the northern hemisphere, with a population conservatively estimated at 1.5 million in Alaskan waters alone (Burns 1978; NOAA 1979). Though little is known about the population history of this species, it is generally assumed to be stable at this time.

A large part of the ringed seal population is migratory, though not as strongly migratory as other marine mammal populations of the region. During summer and early autumn ringed seals are common in the vicinity of the ice edge of the Beaufort and northern Chukchi Seas. Though some of the population remains year-round in this area, most of the population shifts southward with the advance of ice in the fall, some of them to as far south as the winter ice edge in Bristol Bay.

During March and April breeding adults establish and maintain territories, generally within the shore-fast ice, where the pups are born in maintained dens. Subadults dominate the floe zone at the edge of the shore-fast ice and both adults and subadults occur in the drifting offshore ice (Lowry et al. 1982).

With the breakup of the shore-fast ice starting in April and May, seals begin their northward migration back to the Chukchi Sea. A small part of the population, mainly juveniles, remains in the ice-free waters of the northern Bering and southern Chukchi Seas through the summer, while most follow the retreating ice edge to its summer limits in the northern Chukchi and Beaufort Seas (Lowry et al. 1982). Though the timing of this migration varies from year to year depending on ice and weather conditions, in most years the majority of migrating seals pass through the Bering Strait between April and June and reach the Barrow vicinity by late June or early July (ADF&G 1976).

Aerial surveys flown in June suggest densities within the shore-fast ice of the northern Chukchi Sea of 6.2 seals per square nautical mile (i.e., 11.5 seals/km^2) (Lowry et al. 1982). It is estimated that, from 1970 through 1977, the density of ringed seals declined by 50% in the Beaufort Sea and by 35% in the northern Chukchi Sea, presumably in response to severe ice conditions. At the same time ringed seal densities underwent a corresponding increase in the southern Chukchi Sea and northern Bering Sea (U.S. Department of Commerce 1978).

Estimates of the Alaskan subsistence harvest of ringed seals range from 4,500 per year (NOAA 1979; U.S. Department of Commerce 1978) to 10,500 per year (U.S. Interagency Task Group Report 1976). This harvest seems to have declined significantly in recent years, though the population of seals has not. From estimates of 10,000 to 20,000 seals taken per year in the 1950's and 1960's, the harvest has fallen to levels of 4,000 to 5,000 in recent years (Burns and Eley 1978; J. Burns, personal communication).

Ringed seals appear to be opportunistic feeders on a wide range of invertebrate infauna and epifauna, zooplankton, and fish. Items known to be eaten include saffron cod, Arctic cod, boreal smelt, sand lance, sculpin, herring, pandalid and crangonid shrimps, mysids, gammarid and hyperiid amphipods, and euphausiids (Lowry et al. 1982).

Bearded Seal. Johnson et al. (1966) note that bearded seals do not utilize fast ice but rather prefer cracks and leads in pack ice. This is in general agreement with observations that bearded seals occur where the pack tends to disperse and form openings (Burns 1981) but away from the ice edge (Burns 1970). Aerial surveys reveal that bearded seals tend to congregate in areas south of Point Hope (Figure 3-3). Local hunters confirmed that this area is often inhabited by large numbers of bearded seals. Johnson et al. (1966) suggest that the area may be characterized by favorable bottom feeding conditions for these seals. Burns (1970) notes that, although bearded seals do not herd, they sometimes congregate in favored areas. In late to mid-spring they are commonly sighted north of the Seward Peninsula (Ljungblad et al. 1982, 1983). After breeding, and with the retreat of the ice, they begin a northward migration along the coast of the Chukchi and are observed from Cape Lisburne to west of Barrow by May (Figure 3-5). Burns (1970) has observed them at Wainwright during mid- to late July. In a series of coastal flights from Nome to Deadhorse, Ljungblad et al. (1982) report observing bearded seals along the Chukchi Sea coastline during April, May, and June. The seals are particularly concentrated in Kotzebue Sound during late May and early June. Frequency of observation of the bearded seals drops off in July (none observed) and August (nine observed). The seals apparently disperse northward with the retreating ice pack.

Johnson et al. (1966) found that bearded seals take a greater variety of foods than ringed seals (Tables 3-4 and 3-5) and concentrate upon the more sedentary benthic species. They do not take Arctic cod or any fish in appreciable amounts except in February (Table 3-7). Generally their diet comprises shrimp, hermit crabs, clams and, occasionally, gastropods and sponges. Lowry et al. (1980) examined the stomach contents of bearded seals from several village hunting takes between 1975 and 1979. Most of these seals (234 out of 397) were from the Chukchi villages of Wainwright and, particularly, Shishmaref. Table 3-8 shows the major prey species found in this study. Both age and geographical differences were noted. Clams, particularly *Serripes groenlandicus*, became more important in the diet with age (Table 3-9). Shrimp were frequently eaten (they were found in 92-100% of samples) and their volumetric importance increased with age. Geographical differences in the amount and species of shrimp taken were found in comparing Chukchi with Bering populations. At Shishmaref, 98% of shrimp taken by adults were of the family Crangonidae, while in Bering Sea samples 46-65% of shrimp were Crangonidae, 7% were Hippolytidae, and up to 51% were Pandalidae. Fish, which ranged from 7 to 11% of stomach contents, decreased in importance in adults. The major seasonal difference was that clams were more important in spring and summer than fall and winter. This parallels the observations of Johnson et al. (1966). Lowry et al. (1980) also note that in recent years the importance of clams in the diet has been declining (Table 3-10). They attribute this to the recent growth in walrus populations which feed heavily on *Serripes* in the Bering Sea. This phenomenon is not as apparent in the Chukchi (based on data from Wainwright), but may occur if the walrus population continues to grow and is forced to shift its population range. In general, they found that the

Table 3-8. Major prey species of bearded seals in the Chukchi and Bering Seas (after Lowry et al. 1980).

General Taxon	Scientific Name
Clams	*Clinocardium ciliatus* *Serripes groenlandicus* *Spisula polynyma*
Crabs	*Chionoecetes opilio* *Hyas coarctatus* *Telmessus cheiragonus*
Echiuroid worms	*Echiurus echiurus*
Fishes	*Ammodytes hexapterus* *Boreogadus saida* *Eleginus gracilis* Family Cottidae Family Pleuronectidae *Lycodes* sp.
Isopods	*Saduria entomon*
Polychaete worms	*Eunoe* sp. *Nephthys* sp. *Nereis* sp.
Shrimps	*Argis* spp. *Crangon* spp. *Eualus* spp. *Pandalus* spp. *Sclerocrangon boreas*
Snails	*Buccinum* sp. *Natica* sp. *Neptunea* sp.

Table 3-9. Major foods of bearded seals by age class. Values represent percent of total stomach contents volume for invertebrate taxa and total fish material and percent of the total number of fishes eaten for individual fish taxa (from Lowry et al. 1980).

	Shishmaref			Bering Sea		
	Pups N=38	1 and 2 Years Old N=21	≥ 3 Years Old N=91	Pups N=52	1 and 2 Years Old N=31	≥ 3 Years Old N=50
Clam	4	11	19	2	3	25
Snail	-	-	1	-	-	2
Shrimp	59	47	30	45	26	27
Brachyuran crab	6	20	24	28	38	27
Isopod	18	9	8	1	*	*
Total Fish	7	11	6	13	26	10
Saffron cod	51	18	30	41	5	4
Arctic Cod	*	*	1	5	2	6
Sculpins	28	55	25	47	89	77
Flatfish	20	25	37	*	1	1
Mean Volume (ml)	325	462	492	213	578	670

* Indicates values less than 1%.

Table 3-10. Percent of total stomach contents volume which consisted of clams in bearded seals collected at Nome, Diomede, and Wainwright between 1958 and 1979. Frequency of occurrence (no. of stomachs containing clams/total no. of stomachs in sample) is given in parentheses. Only stomachs from seals collected between May and August are included (from Lowry et al. 1980).

Year	Nome	Diomede	Wainwright
1958	-	One of two primary foods (9/17)	-
1964 - 1965	-	-	49% (5/7)
1967	-	59% (5/6)	-
1970	40% (1/2)	-	-
1975	48% (1/1)	9% (5/6)	55% (6/7)
1976	87% (4/5)	2% (2/4)	66% (6/7)
1977	44% (5/8)	0% (0/4)	75% (3/3)
1978	-	0% (0/2)	4% (2/4)
1979	* (1/6)	2% (3/8)	32% (12/16)

*Indicates values less than 1%.

reduction in clams has resulted in population shifts for the walrus, but a dietary change for the bearded seal. Females breed every other year and are mature at age 6; males are mature at age 7.

In summary, like the other phocid seals of the region, bearded seals are migratory. They can and do maintain themselves in relatively thin and broken ice but avoid shore-fast ice and heavy, unbroken pack ice. Consequently, most of the population shifts southward during the winter in response to ice conditions, largely abandoning the Chukchi and Beaufort Seas for the more favorable ice conditions of the Bering Sea (Lowry et al. 1982). Beginning in April with the breakup and retreat of the winter ice, the population moves north to summer along the margin of the fragmented ice pack of the northern Chukchi and Beaufort Seas. It is considered the most widely distributed pinniped species occurring in the drifting seasonal ice of the Bering and Chukchi Seas (Burns and Frost 1979).

Though little historical data are available, the present Bering-Chukchi-Beaufort population of approximately 300,000 bearded seals is considered near maximum carrying capacity (U.S. Interagency Task Group Report 1979) and is relatively stable.

Bearded seals are known to consume a wide variety of benthic infauna and epifauna as well as fish. Known food items include bivalve molluscs of the genera *Serripes*, *Spisula*, and *Clinocardium*, various gastropod molluscs, brachyuran and anomuran crabs of the genera *Hyas*, *Chionoecetes*, and *Pagurus*, benthic isopods, sponges, pandalid and crangonid shrimps of the genera *Argis*, *Crangon*, *Eualus*, and *Pandalus*, saffron cod, Arctic cod, walleye pollock, sculpins, and flatfish (Lowry et al. 1982). This diet overlaps to some degree with that of walrus, ringed seal, and spotted seal, and perhaps occasionally some competition for food resources occurs among these species. This may be particularly true with regard to walrus in view of the recent dramatic population increase by that species and indications of stress on its traditional food resources (Fay and Stoker 1982a,b).

The known Alaskan harvest of bearded seals since 1967 has ranged between 1,050 retrieved seals in 1968 to 4,750 in 1977 (Burns and Frost 1979). A questionable average annual retrieved Alaskan harvest of 1,500 has been estimated for recent years (NOAA 1979; U.S. Interagency Task Group Report 1976). It is felt (L. Lowry, personal communication) that the higher estimate for 1977 of 4,750 bearded seals was due to the improved monitoring effort undertaken that year rather than to an actual increase in the harvest.

Averaged over the years 1962-82, the retrieved harvest of bearded seals at Wainwright has been approximately 250 per year, with an additional 150 per year taken at Barrow (Stoker 1983). As is the case for all marine mammals, the harvest has been widely variable from year to year, depending on ice and weather conditions.

Spotted Seal. Spotted seals (*Phoca largha*) do not utilize the Chukchi in winter, but with the coming of the open water season they are common along the Chukchi Sea coast. During this time they are common in bays, river mouths, and estuaries and haul out on isolated sandy beaches and barrier islands (Burns and Morrow 1975). Frost et al. (1983) describe their distribution along the coast (Figure 3-9). They indicate that there are no major haulout areas on the

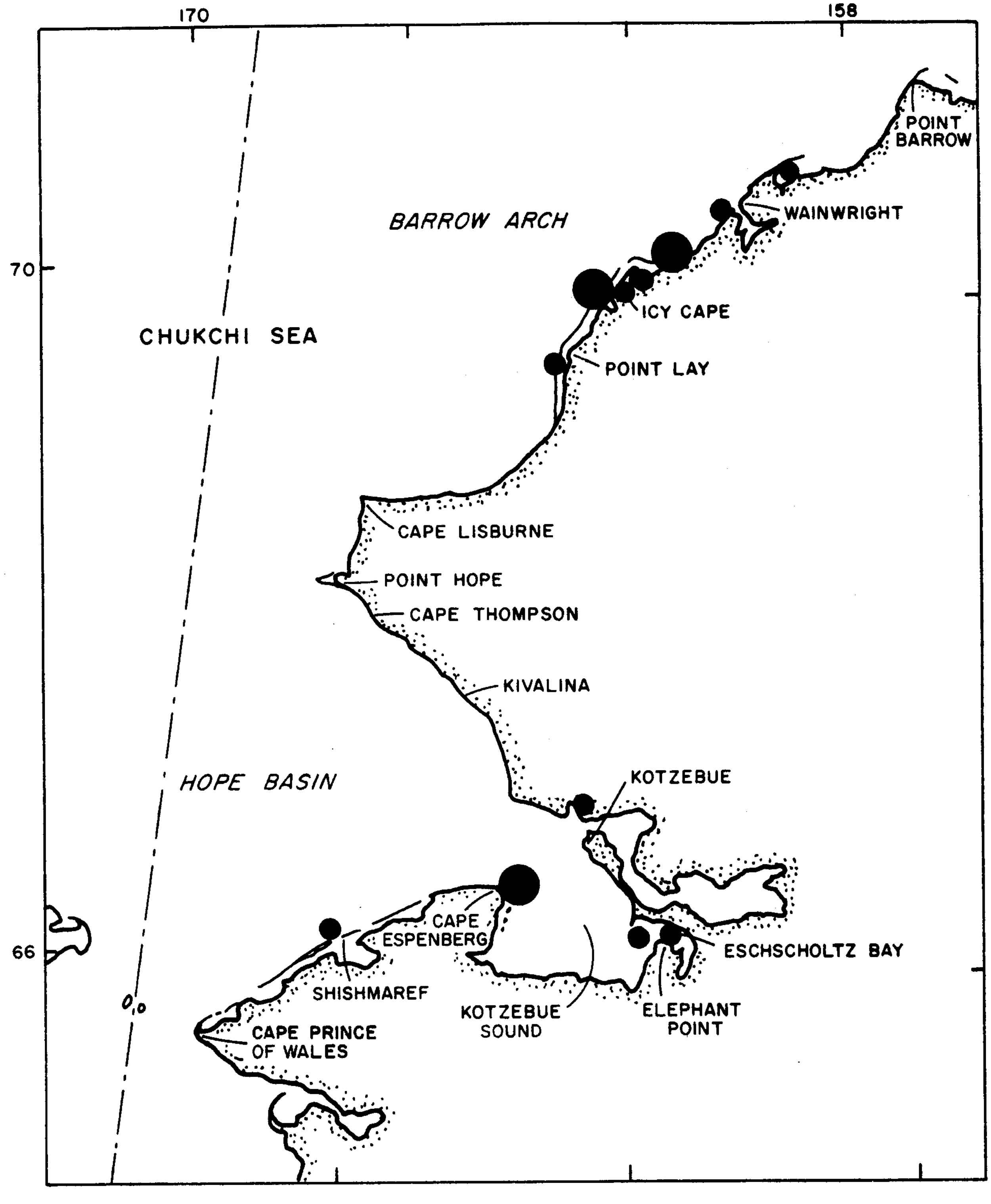

Figure 3-9. Major Haulout Areas Used by Spotted Seals. Large dots represent areas with maximum reported number of greater than 500 seals; small dots, areas with less than 500 seals (from Lowry et al. 1983).

Seward Peninsula except Cape Espenberg where over 1,000 seals have been seen hauled out in late August. These seals are present in Kotzebue Sound in various areas, as described by Frost et al. (1983), but they do not haul out there in great numbers. This is probably as a result of human activity on the north shore of the sound. In autumn, spotted seals are numerous in the Kukpuk River estuary, feeding on salmon and smelt. They have also been observed in abundance in the Kivalik Channel, apparently in response to concentrations of Arctic cod in the area (Frost et al. 1983). Along the northern Chukchi coast, spotted seals are most common in the areas of Kasegaluk Lagoon, the mouth of the Kuk River, and the mouth of the Kugrua River. Kasegaluk Lagoon is the most important of these. They are common along the entire lagoon from mid-July through September. Populations in the lagoon have been estimated at 2,500-3,000 individuals. The major haulout areas in the lagoon are the sandbars east of Utukok Pass and the spits to either side of Akoliakatat Lagoon. The seals are less common at the other two sites, but they occasionally use haulout areas in the Kuk and Kugrua Rivers. Johnson et al. (1966) make only brief reference to other pinnipeds in the southeastern Chukchi. Spotted seals were observed in considerable abundance in the Kukpuk estuary, where they occur regularly. Ljungblad et al. (1982) report the presence of spotted seals at inner Kotzebue Sound and the coastal areas off Point Hope in June (Table 3-3). Apparently, the area of Kotzebue Sound is abundantly inhabited by this species in spring and summer. Burns (1970) notes that some ribbon (*Phoca fasciata*) and, particularly, spotted seals, move through the Bering Strait after retreat of the sea ice in spring-summer, reaching Wainwright by mid-August. Ribbon seals generally remain pelagic, but spotted seals move toward the Alaskan mainland and disperse along the ice-free coast.

In summary, spotted seals, like most other marine mammals of the region, are migratory. During late winter and spring, practically the entire population is concentrated in or near the ice front in the southern and central Bering Sea (Burns 1978). With the breakup and retreat of the ice in spring, the population moves generally northward and towards the coast, with part of it following the retreat of the ice to its limits in the northern Chukchi and Beaufort Seas. Spotted seals are less dependent on, or have less affinity for, ice than are ringed seals and bearded seals; thus, a considerable part of the population summers along the ice-free coast of the Bering and Chukchi Seas. Also unlike ringed and bearded seals, no spotted seals remain in ice-covered portions of the Chukchi and Bering Seas during winter months. In most years the main northward migration passes through the Bering Strait during June, and is present in the Wainwright-Barrow vicinity from mid-August until early October, when the movement southward begins (ADF&G 1976).

The present population of spotted seals in the Chukchi and Bering Seas is estimated at between 200,000 and 330,000 (NOAA 1979; Lowry et al. 1982). This population appears to be stable and is probably near optimal for the carrying capacity of the environment (U.S. Interagency Task Group Report 1976; NOAA 1979).

The present subsistence harvest of spotted seals in Alaskan coastal waters is estimated at about 2,800 per year (Stoker 1983). This is considerably below the recommended sustained yield estimate (NOAA 1979; U.S. Interagency Task Group Report 1976). No accurate records of the number of spotted seals harvested in the Peard Bay region are currently available.

Like ringed seals, spotted seals are opportunistic feeders on a wide range of marine fish and invertebrates. Their diet is known to include Arctic cod, saffron cod, sand lance, smelt, herring, sculpins, walleye pollock, capelin, flatfishes, octopus, Tanner crab, pandalid and crangonid shrimps, euphausiid and hyperiid amphipods (Lowry et al. 1982). Though the diet of spotted seal and ringed seal overlap to a considerable degree, spotted seals seem to be more reliant on fish and less on crustaceans, particularly zooplankton forms, than are ringed seals.

3.3.1.3 Pacific Walrus (*Odobenus rosmarus divergens*)

The present walrus population of the Bering and Chukchi Seas is estimated at about 250,000-300,000 animals (Lowry et al. 1982). Due in large part to protective measures and cessation of commercial hunting, the Pacific walrus population has increased dramatically over the past several decades, and is probably now at least as large as the unexploited population prior to contact with white humans (Fay 1982). Recent analyses of reproductive organs and stomach contents from walrus taken by subsistence hunters in the north Bering Sea indicate that the population is probably at or in excess of the carrying capacity of the environment in terms of food resources, at least in the vicinity of Bering Strait, and that the productivity of the population has declined in recent years (Fay and Stoker 1982a,b). Other factors, such as increased natural mortality and a decline in the overall condition of the population (F. Fay, personal communication), indicate that the population is maximal and may decline somewhat in the near future.

The walrus population of the Bering and Chukchi Seas is, for the most part, migratory. The bulk of the population, including all of the cows, calves, and subadults, winter on feeding grounds in the central and southern Bering Sea, moving north with the retreat of the ice in late spring through the Bering Strait and into the Chukchi Sea. Though the timing of migration varies according to ice and weather conditions, the majority usually passes through the Bering Strait in June and arrives in the Peard Bay-Barrow vicinity by July. In late September the population moves southward with the advance of the winter ice, passing through the Bering Strait in October and November (Fay 1982). As a rule, the northward (spring) migration seems more well defined, predictable, and concentrated than does the fall movement southward.

Burns (1970) notes that the hunting success at Wainwright indicates walrus begin to appear near this section of the Chukchi coast in early August and generally remain on drifting ice. Ljungblad et al. (1982) report walrus heading north between Point Lay and Wainwright in mid-June (Figure 3-10). Johnson et al. (1966) also observed walrus in summer along the ice edge from 170 °W to Point Barrow. Frost et al. (1983) summarize the historical observations of Pacific walrus along the Chukchi Sea coast. Walrus migrate into the Chukchi in May or June as the ice retreats and reside either on the pack ice or at several haulout areas along the coast. In the past (1930's and 1940's), they have been observed at Point Hope, Cape Lisburne, and Icy Cape. Recently the major haulout area in the Chukchi coast has been Cape Lisburne, where as many as 200-500 walrus have been sighted in the fall. Lone walrus are occasionally sighted on the barrier islands of Kasegaluk Lagoon, although Ljungblad et al. (1982) found considerable numbers (2,126 walrus) between Icy Cape and Peard Bay.

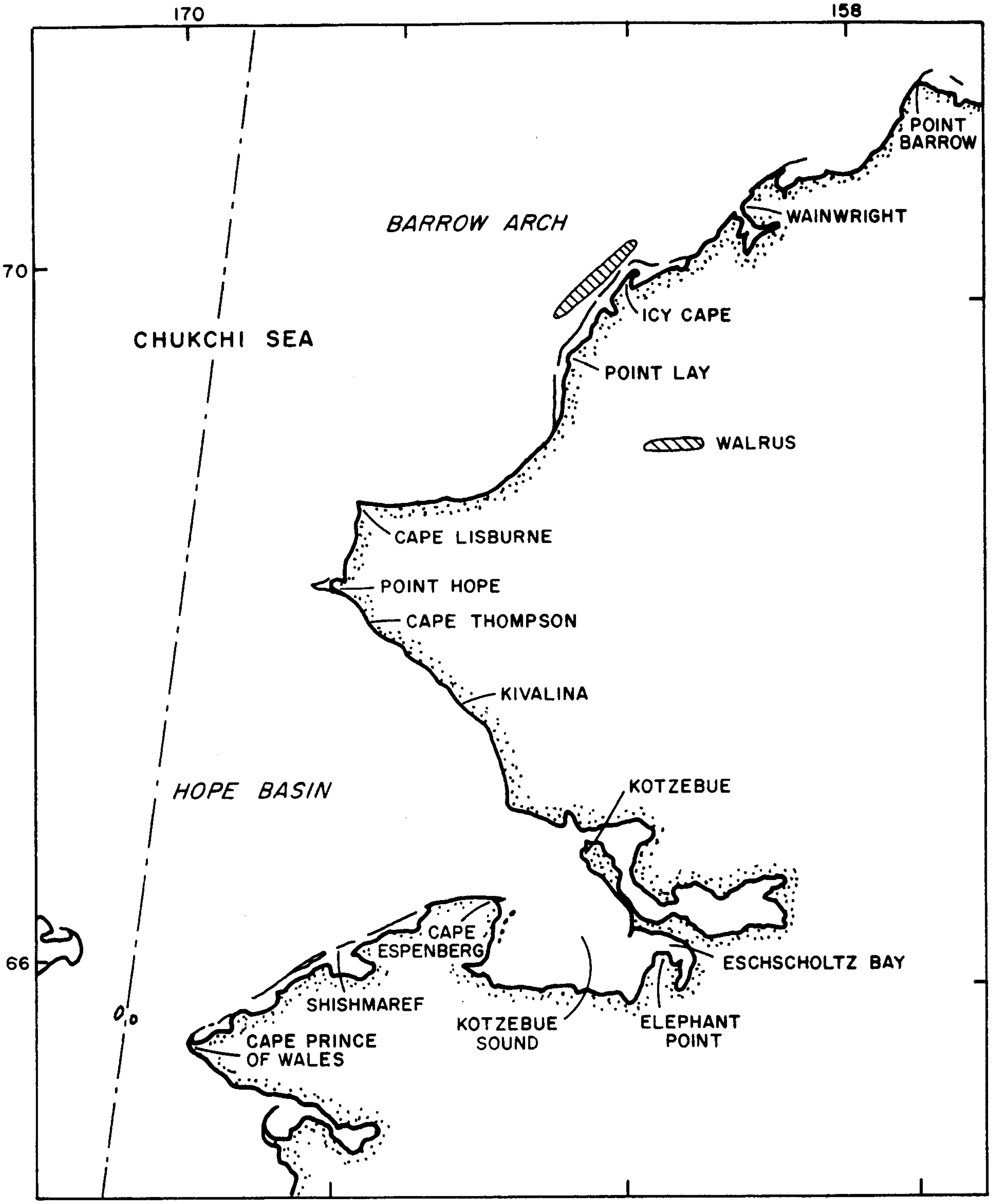

Figure 3-10. Distribution of Walrus on 10 June 1981, as Observed from Aerial Overflights (after Ljungblad et al. 1982).

The main exception to this migratory pattern is a population of between 10,000 and 20,000, all adult males, which remains in Bristol Bay during the summer months. During the winter this population of males rejoins the migratory population of females and subadults at the edge of the winter ice. Other, smaller populations of males have in recent years assumed similar patterns of behavior, dropping out along the spring migration route to summer at ice-free hauling grounds in the northern Bering Sea and in the Bering Strait, then rejoining the main population during their fall movement southward (Lowry et al. 1982).

Walruses are attracted to broken and mobile sea ice as hauling platforms but cannot cope with solid or densely packed ice. Consequently, the distribution of the summer population in the northern Chukchi Sea is determined to a great extent by wind and ice conditions and varies from year to year. Though groups of animals may be found during the summer at any point along the edge of the ice pack from Alaskan waters to Siberia, the population density is usually higher near the eastern (Alaskan) and western (Siberian) extremes of this range (J. Burns and F. Fay, personal communication). Concentrations normally occur at and within the broken edge of the ice pack, and the animals advance and retreat in response to the movements of the ice. During July and August shifts in location of the ice front may move concentrations of walrus from north of Point Barrow to as far south as Point Belcher.

Most walrus calves nurse for approximately two years (Fay 1982), after which they assume an adult diet composed primarily of benthic infaunal invertebrates. Though some 60 genera of organisms have been identified as walrus prey items from stomach analyses, bivalve molluscs constitute, on the average, over 80% of the prey consumed (Fay et al. 1977; Fay and Stoker 1982a,b; Fay and Lowry 1981). Genera constituting primary prey seem to be *Mya*, *Serripes*, *Spisula*, *Tellina*, *Hiatella*, *Macoma*, and *Astarte*. In addition, walrus are known to frequently consume large quantities of such diverse foods as Pacific sand lance, crangonid shrimps, hyoid crabs, and the flesh, skin and fat of related seals.

The retrieved harvest of walrus by Native Alaskan subsistence hunters in recent years has run between 2,000 and 3,000 animals per year (Fay 1982). Historically, 80% of this harvest occurs in the north Bering Sea-Bering Strait region during the spring migration in May and June. Seven to eight percent are taken between Point Hope and Barrow during the summer months (Stoker 1983). Over the 20-year period from 1962 to 1982, the average walrus harvest taken by the village of Wainwright has been 86 animals per year, with 55 per year taken by Barrow over the same period (Stoker 1983). The success of this harvest varies greatly from year to year, largely depending on ice conditions and weather. During this 20-year period, the retrieved walrus harvest at Wainwright has ranged from 20 animals taken in 1978 to 257 taken in 1976, while that of Barrow has ranged from 7 taken in 1969 to 165 taken in 1963 (Stoker 1983).

3.3.1.4 Polar Bear (*Ursus maritimus*)

It is believed that there are two fairly discrete populations of polar bears in Alaska waters, with the division corresponding roughly to a line drawn from about Point Lay extending to the northwest (Lentfer 1974).

Estimates of the current population vary considerably, ranging from 2,500 bears in the northeastern stock and 7,000 in the southwestern to 1,900 in the northeastern and 3,800 in the southwestern (NOAA 1979). The population is apparently stable and, if the larger total estimate of 9,000 is assumed, is near maximum carrying capacity (NOAA 1979). Bears of the northeastern stock restrict their movements to the Beaufort and northern Chukchi Seas, though some north to south population shifts occur seasonally in response to ice conditions. Bears from the southwestern stock seem to exhibit more wide-ranging migratory behavior.

At present, some 100 to 200 polar bears are taken each year by Alaskan Natives for subsistence use (ADF&G open-file data). This is probably close to the sustainable yield for the population (NOAA 1979). Available records for the period 1962-1982 indicate that an average of seven bears per year are taken by hunters at Wainwright, and about the same number by hunters at Barrow (Stoker 1983.)

Polar bears were infrequently observed along the Chukchi coast by these investigators.

3.3.1.5 Cetaceans

Three species of cetaceans are important along the Chukchi Sea coast. These species are the beluga whale, bowhead whale, and gray whale.

Beluga Whale. Frost et al. (1983) review the historical data base concerning the distribution of beluga whales (*Delphinapterus leucas*) in the coastal Chukchi Sea (Figure 3-11). This species tends to be found in the coastal Chukchi in spring and summer, especially in Kotzebue Sound and the passes and channels of Kasegaluk Lagoon. They are most abundant in early spring and summer and are less frequently observed in late summer. Beluga whales are in great abundance in leads and polynyas of the Bering Strait in early April (Ljungblad et al. 1982, 1983). Depending upon ice conditions, they are found just north of the Seward Peninsula (Ljungblad et al. 1982) or as far north as Point Hope (Ljungblad et al. 1983) in late April. Frost et al. (1983) report that they are common along the coast of the Seward Peninsula from March to June. They are very common in Kotzebue Sound from May to June. Frost et al. (1983) report large concentrations (1,000 individuals) in Eschscholtz Bay in June 1973 and Ljungblad et al. (1982) found them common in Kotzebue Sound near Elephant Point in May and Eschscholtz Bay in June 1981. In late June-July, belugas were abundant nearshore of Kasegaluk Lagoon (2,000-2,500 individuals). Frost et al. 1983 (Tables 3-3 and 3-11) substantiate this observation. The abundance of beluga whales in Kotzebue Sound is probably due to the runs of prey species such as smelt, herring, char, salmon, and saffron cod which occur there (Seaman and Burns 1981). Calving also occurs in the sound as it does near Kasegaluk Lagoon (Frost et al. 1983).

Though the total size of the beluga population of the Bering, Chukchi, and Beaufort Seas is poorly known, a minimum estimate of 9,000 to 9,500 animals is generally accepted (IWC 1979; NOAA 1979). The population is thought to be stable at this time. Belugas spend the winter months in offshore waters covered by mobile, fractured ice, and along the edge of the winter ice pack (Lowry et al. 1982). As the ice recedes in spring, a large part of the

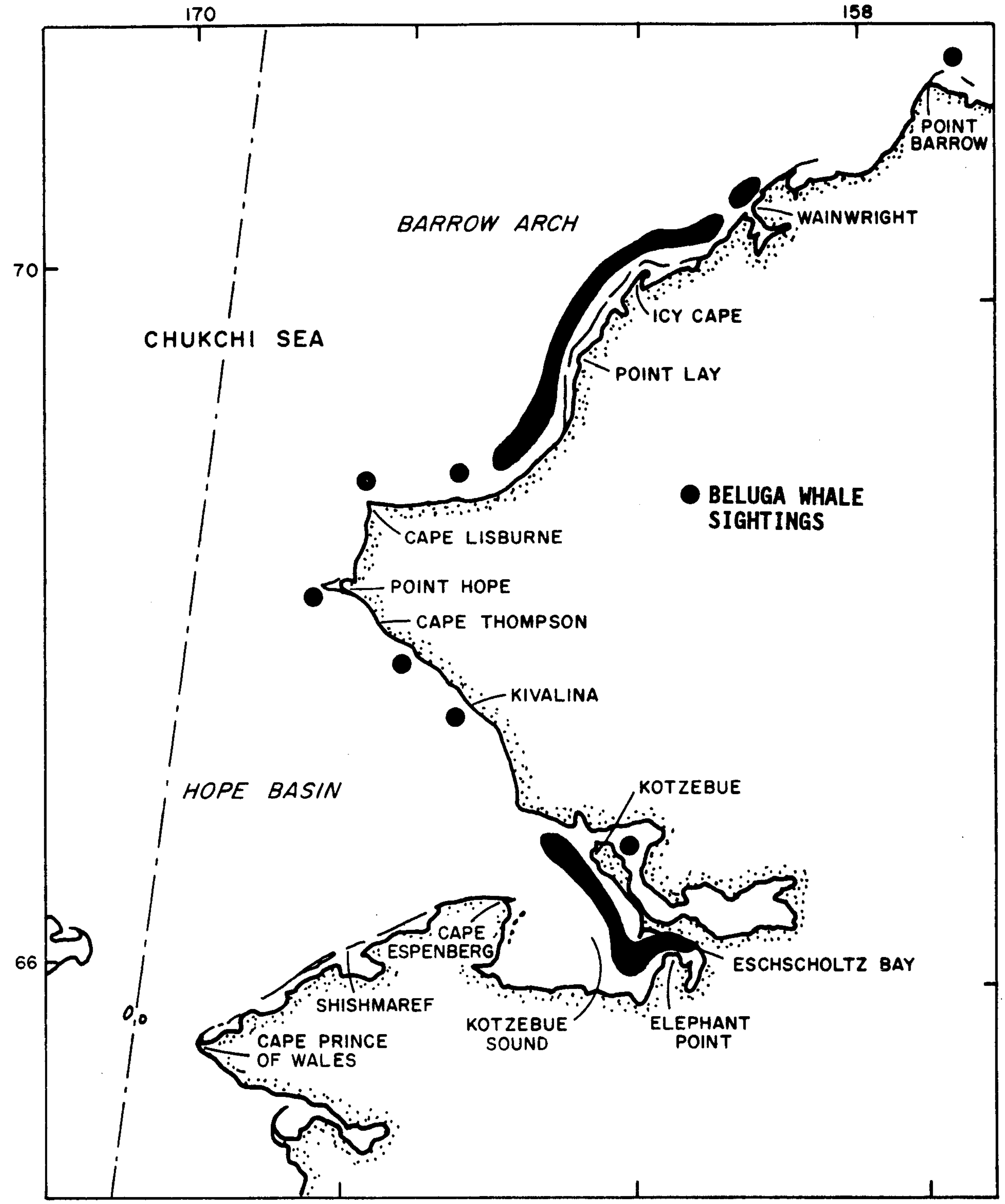

Figure 3-11. Sightings of Beluga Whales in the Coastal Zone (from Frost et al. 1983).

Table 3-11. Distribution of marine mammals observed during 1982 overflights in the Chukchi Sea coastal areas (abstracted from Ljungblad et al. 1983).

Date	Area	Bowhead Whale	Beluga Whale	Gray Whale	Narwhale	Unid. Cetacean	Walrus	Bearded Seal	Ringed Seal	Unid. Pinniped	Polar Bear
4/23	Bering Strait	–	9	–	–	–	89	3	1	–	–
4/26	South Chukchi	28	156	–	2	–	177	2	–	–	–
4/27	South Chukchi	1	93	–	–	–	–	1	–	–	–
5/1	Nome to Point Barrow	3	161	–	–	–	2	24	11	–	–
5/4	Point Barrow	33	4	–	–	–	–	–	–	–	–
5/7	Point Barrow-Nome	13	45	–	–	–	–	1	1	–	–
5/9	Cape Lisburne-Point Barrow	5	1	–	–	–	–	1	–	–	–
6/22	Wainwright-Nome	3	4	–	–	–	1	17	1	–	–
7/31	Kotzebue-Barter Islands	–	–	111	–	–	100	–	–	49	–

population, perhaps as many as 7,000 animals, moves north along the Chukchi coast and through lead systems in the Beaufort Sea to summering grounds in the vicinity of Banks Island and the Mackenzie River estuary. They remain there until August (Sergeant and Hoek 1974; Fraker 1980). During this northward migration, belugas generally pass Wainwright and Barrow during May (Seaman and Burns 1981). Other elements of the population remain in the Bering and Chukchi Seas during the summer, moving into coastal waters, particularly lagoons and river mouths. Several thousand belugas remain in Chukchi Sea coastal waters throughout the summer, primarily in Kasegaluk Lagoon (between Icy Cape and Point Lay) and in Kotzebue Sound.

Belugas are known to feed on a wide range of anadromous and marine fishes and invertebrates, including all five species of salmon (both adults and smolt), smelt, flounder, saffron cod, sole, sculpins, blennies, lampreys, char, squid, herring, Arctic cod, octopuses, walleye pollock, and crangonid shrimps (Lowry et al. 1982).

At present, approximately 150 to 200 belugas are taken each year by Alaskan Eskimos for subsistence use (IWC 1979; NOAA 1979). Over the period 1962-1982, an average of 11 belugas per year was harvested by the village of Wainwright. This figure was five per year for Barrow (Stoker 1983).

Bowhead Whale. Bowhead whales (*Balaena mysticetus*) are not common in the Chukchi Sea (Figures 3-12 and 3-13). They move rapidly through the Chukchi in early spring during their northward migration to the Beaufort Sea. They have been observed to migrate from the Bering Strait to Barrow in 11 days along narrow leads (Ljungblad et al. 1982). Ljungblad et al. (1982, 1983) observed that they tend to pass the Bering Strait in two distinct pulses. In 1981, the first group was sighted north of the Bering Strait during 6-11 April, and the second group passed through the strait on 18 April. This two-pulse activity had been seen previously (Marquette and Braham 1982). Subsequent to passage through the Bering Strait, bowheads have been sighted in early spring (April-May) in the nearshore areas of the Chukchi near Cape Lisburne, Icy Cape, Point Barrow, Point Hope, and off Kasegaluk Lagoon in 1981 and 1982 (Ljungblad et al. 1982, 1983).

Because bowheads are migratory, most or all of the population shifts south into the central and southern Bering Sea in advance of the winter sea ice. Beginning in late March, the bowheads begin their northward migration, following lead systems through the Bering Strait and along the Chukchi Sea coast to Point Barrow. From there they move more or less directly across the Beaufort Sea to the vicinity of Banks Island. The peak of this spring bowhead migration, when virtually all subsistence hunting occurs, is in April and May at Wainwright and from April through mid-June at Barrow (Stoker 1983). Though details of the southward (fall) migration are poorly known, whales probably move back through the northern Chukchi Sea in November and early December. They remain well offshore during this fall migration, and are essentially unavailable for harvesting.

The present population status of the bowhead is controversial. The 1978 population estimate, derived from shore counts during the spring whaling season at Barrow, was 1,783 to 2,864 animals. In 1981 the estimate was raised to 2,025 to 2,459, using the same basic survey design. During the 1982 spring season at Barrow, observations resulted in an estimate of between 3,125 and

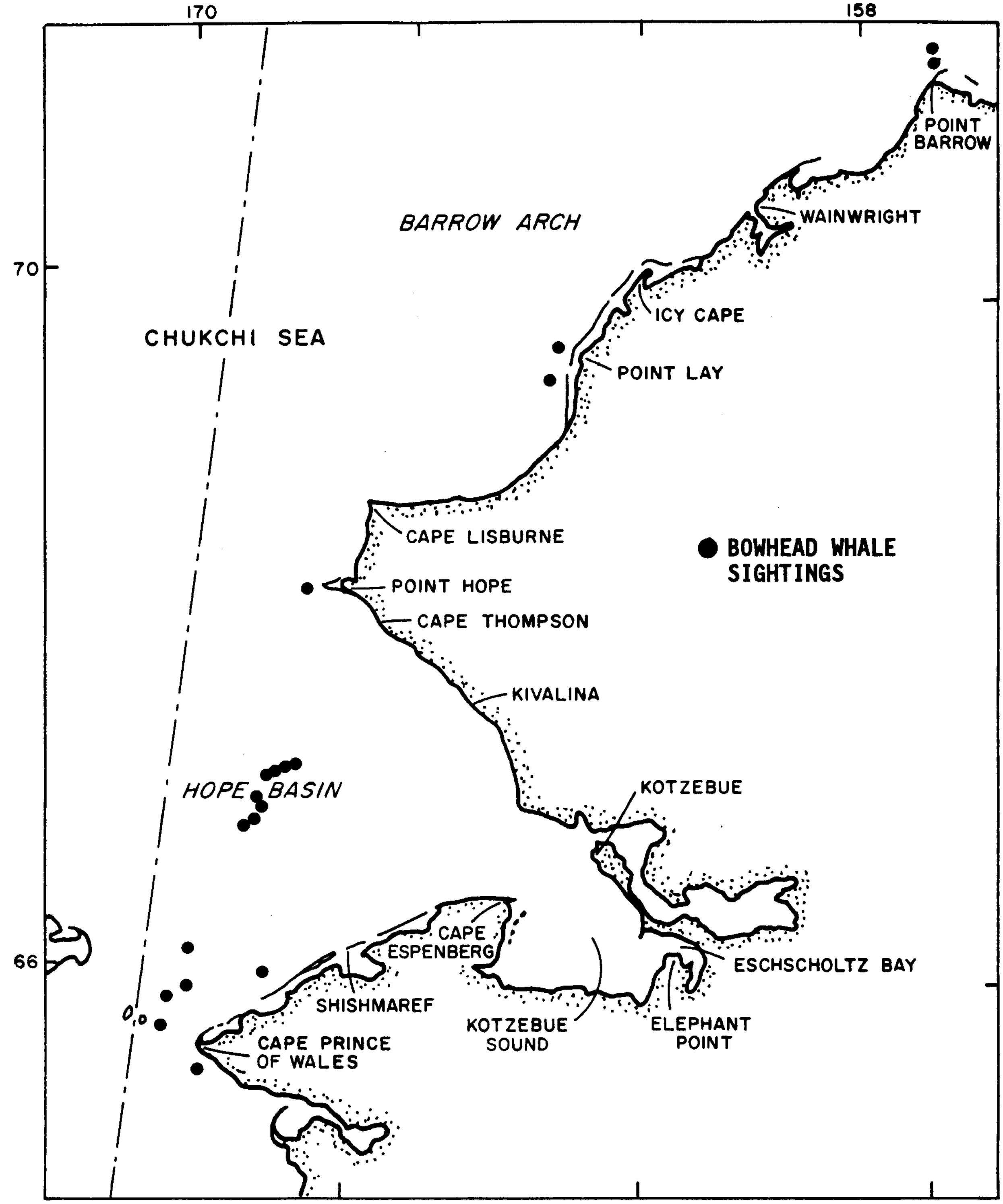

Figure 3-12. Distribution of Spring Bowhead Whale Sightings in the Chukchi Sea During 1981 (from Ljungblad et al. 1982).

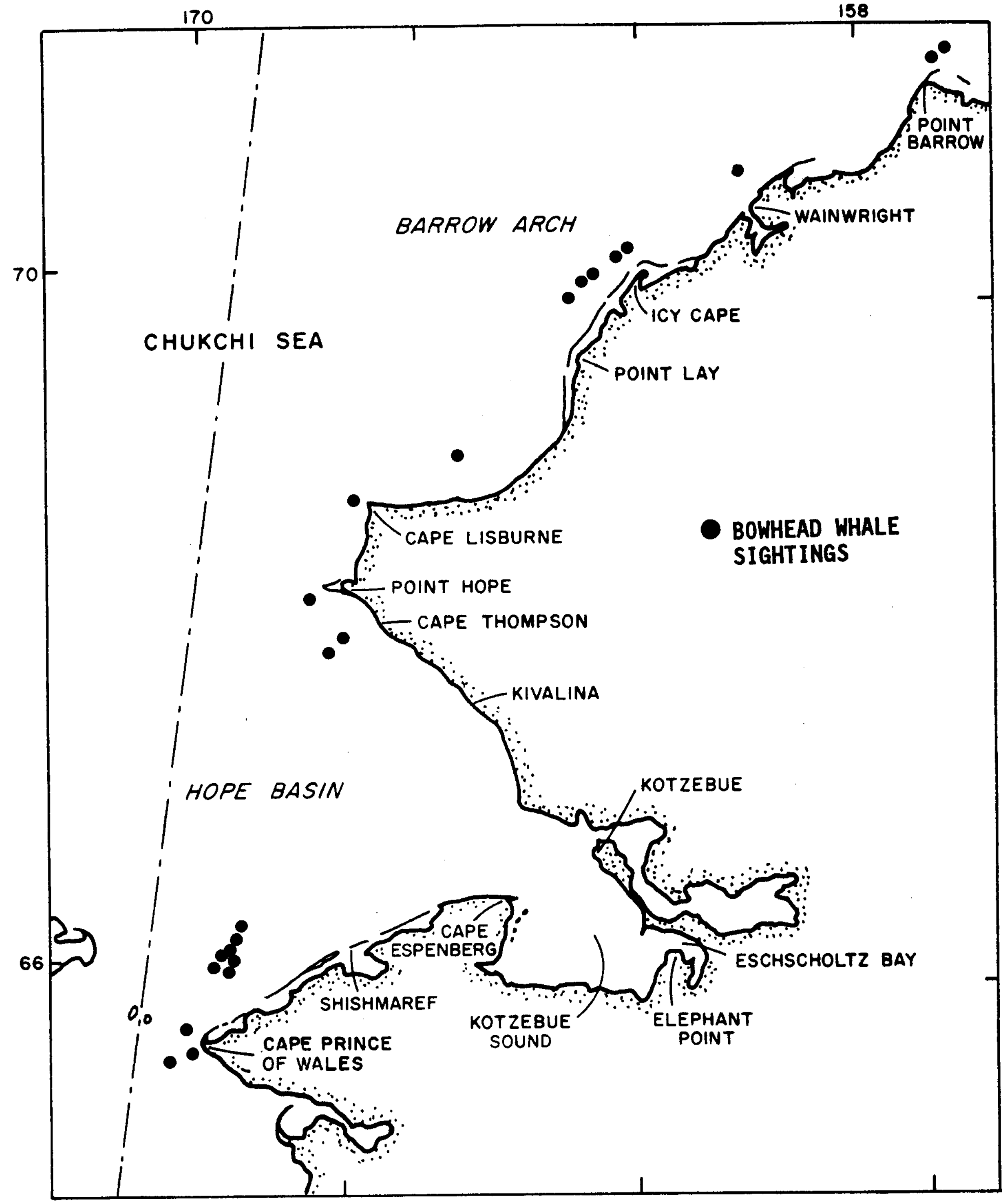

Figure 3-13. Distribution of Spring Bowhead Whale Sightings Between 24 April and 25 May 1982 (from Ljungblad et al. 1983).

3,987 animals (Dronenburg et al. in press). Though these estimates may be low (Lowry et al. 1982), they are still far below the pre-exploitation estimate of 14,000-26,000 (Breiwick et al. 1981). On the other hand, they are considerably above the minimum population of 600+ estimated in 1912 (Eberhardt and Breiwick 1980). Recent estimates indicate a fairly slow but steady increase in numbers of bowhead whales.

Between 1962 and 1982, the average landed harvest of bowheads at major whaling villages in Alaska was 18.4 whales per year (Stoker 1983). During this same period, an average of 1.5 bowheads was landed per year at Wainwright, with a range of 0-3 per year. An average of 10.0 whales per year was taken by Barrow during this interval, with a range of 0-23 per year (Stoker 1983).

Gray Whale. Gray whales (*Eschrichtius robustus*) are strongly migratory, spending their summers in ice-free waters of the Bering and Chukchi Seas and moving south in the fall and winter to calving and breeding grounds in the sheltered coastal lagoons of Baja California, Mexico. Gray whales enter the Bering Sea through Unimak Pass between March and June, arrive in the vicinity of St. Lawrence Island in May or June, and disperse to feeding grounds throughout the northern Bering and Chukchi Seas until about October. They then begin to move south in advance of the seasonal sea ice (Lowry et al. 1982). Though the bulk of the population does not continue so far north, some animals appear in the coastal waters of the Chukchi Sea in the vicinity of Wainwright and Barrow in late June or early July.

Frost et al. (1983) report that gray whales are often sighted within 1-2 km of shore in the Chukchi Sea in May through July. Although there are no obvious areas of concentration, they are most common from Icy Cape to Barrow, with the highest reported sightings near Wainwright (50-100 in August 1953) and Point Franklin (200 in August 1982). They are also reported in Kotzebue Sound in substantial numbers and along the coast from Kivalina to Cape Lisburne.

Ljungblad et al. (1982, 1983) report that gray whale sightings in the coastal Chukchi are often associated with feeding plumes (85% in July 1981). Their observations of gray whale distributions for 1981 and 1982 (Figures 3-14 and 3-15) substantiate the observations that they are most commonly observed in the Chukchi off Point Franklin and Wainwright, and apparently not in Peard Bay.

Gray whales feed on benthic infauna and epifauna, and rely heavily on ampeliscid amphipods of the genera *Ampelisca*, *Lembos*, *Anonyx*, and *Pontoporeia* (Lowry et al. 1982).

Like the walrus, the gray whale population has undergone a rapid recovery in recent decades, from a low of about 4,000 animals in 1875 to approximately 17,000 at present (Reilly et al. 1980). The present population level is probably similar to that of the pre-exploited stock, and is considered stable and probably near the carrying capacity of the environment.

Grays are less desirable for subsistence use and are harder to hunt than other available marine mammals (bowhead and beluga whales, seals, and walrus) and so are not pursued to any great extent by Alaskan Eskimos (U.S. Department

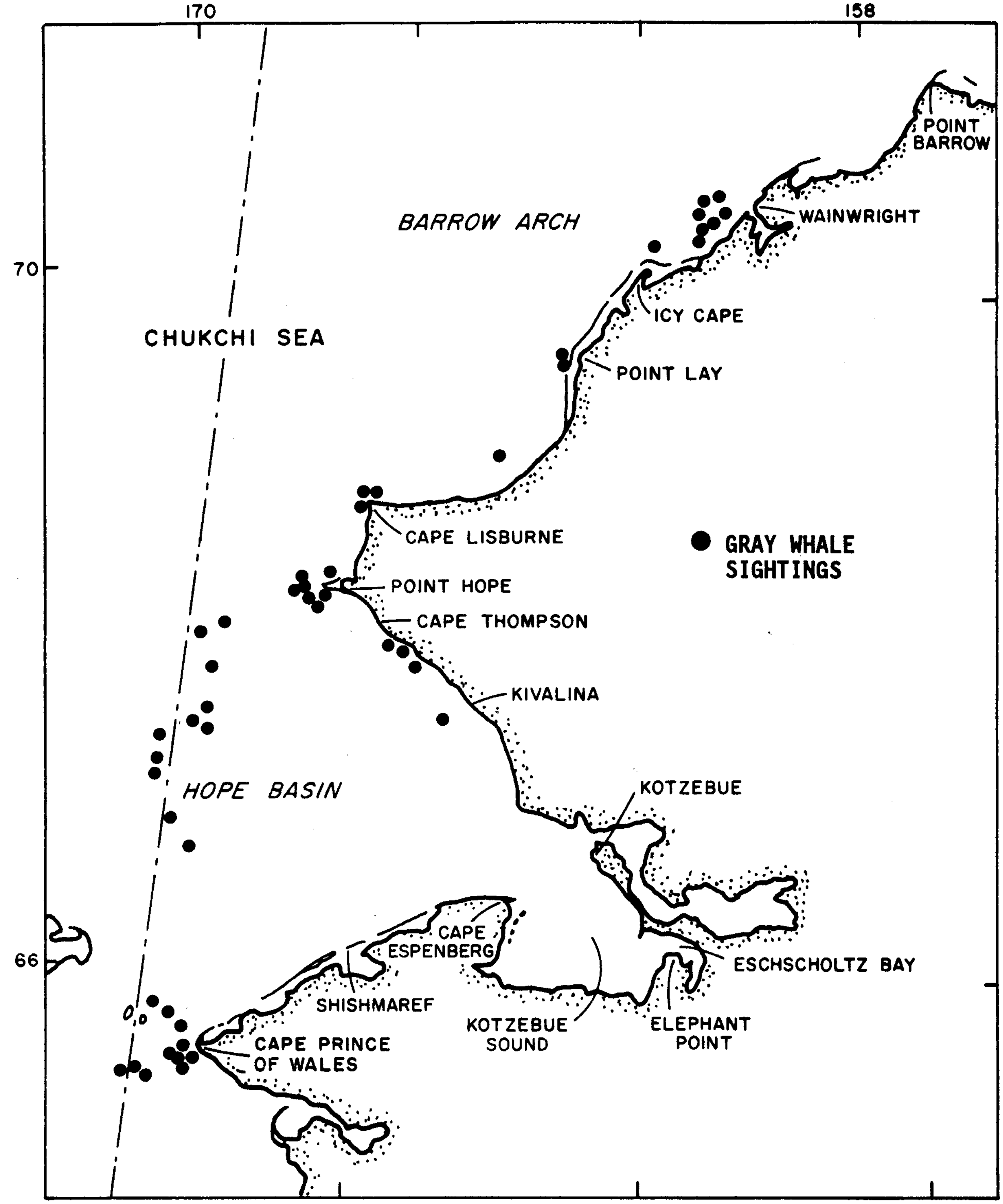

Figure 3-14. Distribution of Gray Whale Sightings in the Chukchi Sea During 1981 (from Ljungblad et al. 1982).

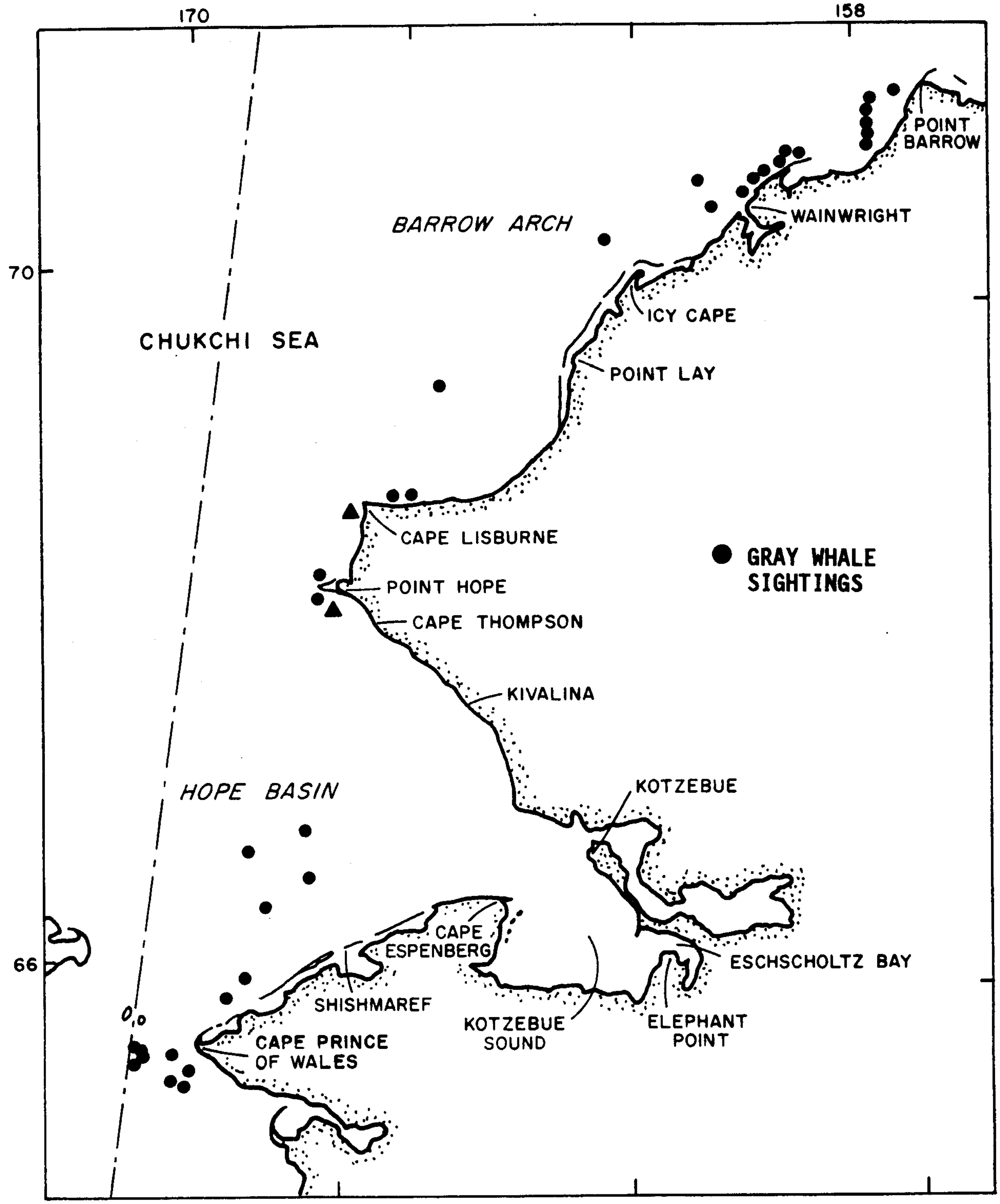

Figure 3-15. Distribution of Gray Whale Sightings in the Chukchi Sea During 1982. Locations of two carcasses are denoted by a triangle (from Ljungblad et al. 1982).

of Commerce 1977, 1978; IWC 1979; U.S. Dept. Interior 1980; J. Burns, personal communication). Between 37 and 49 gray whales have been taken in Alaska for subsistence use since 1950 (Braham 1980; Marquette and Braham 1982). Of this number, an estimated 86% were landed at the villages of Gambell, Wainwright, and Barrow (Braham 1980).

Other Cetaceans. Frost et al. (1983) indicate that killer whales (*Orcinus orca*) are widely distributed in the coastal Chukchi in summer and that minke whales (*Balaenoptera acutorostrata)* are rarely sighted.

3.3.2 Marine Mammal Use of Peard Bay and Adjacent Coast

3.3.2.1. Ringed Seal

Eight species of marine mammals are known to frequent, at least seasonally, the vicinity of Peard Bay. These are the Pacific walrus, ringed seal, spotted seal, bearded seal, polar bear, beluga whale, gray whale, and bowhead whale. Results of our marine mammal field sightings are given in Table 3-12. These new data and pertinent background material are then discussed for each species.

Ringed seals appeared to be present within and offshore of Peard Bay during all of the 1983 field season. During the initial aerial survey of 31 May, 10 seals were sighted at established breathing holes inside the bay. All of the seals and all identified breathing holes were found along a stress crack parallel to Point Franklin spit about 400-500 m offshore. In most instances the seals seemed to be in pairs; possibly breeding adults. It is likely that they overwintered within the bay. The densities of seals observed within Peard Bay and outside the bay are summarized in Table 3-13.

During June 4-14, 135 seals were observed in 38 sweeps with a spotting scope from a fixed position. The area surveyed within the bay was 11.62 km^2 per sweep, or 441.56 km^2 total. The average density of seals within the bay during this period was 0.31 seals/km^2, in comparison to an average density of 0.41 seals/km^2 outside the bay. During this time the bay and the nearshore Chukchi Sea were completely covered with ice, though minor fractures and leads existed. Since these and subsequent observations could not clearly distinguish between ringed seals and spotted seals, the results are lumped as "seals." However, considering the ice conditions during this first observation period, it is probable that most or all of the seals observed were ringed seals.

During the period of 16-20 July, an average density of 1.58 seals/km^2 was observed inside the bay in comparison to 19.77 seals/km^2 outside of the bay. Ice coverage inside the bay during this period averaged 30-40%, while in the nearshore Chukchi Sea it averaged 70-80% coverage. It is probable that at least some of these animals were spotted seals.

During 12-13 August, only one seal was seen in four sweeps of the bay, while none were observed outside the bay. Ice was absent from the bay, with about 10% coverage in the nearshore Chukchi Sea.

Table 3-12. Sightings of Unidentified Seals - Point Franklin, 1983. (Data Supplied By Biota Consultants)

Area 1 - Peard Bay Sweep Count (120^0 to 250^0)

Date	Time	Ice Cover	No. of Seals
June 4	0430	8	0
	0600	8	0
	1000	8	2
	1430	8	3
	2145	8	0
	2300	8	0
June 5	0100	8	0
	0645	8	0
	2345	8	0
June 7	0315	8	0
	0815	8	3
	1200	8	5
	1415	8	7
June 8	0915	8	12
June 9	1000	8	2
	1430	8	2
	1615	8	2
	2100	8	0
June 10	0000	8	0
	0345	8	2
	1645	8	10
	2130	8	7
June 11	1000	8	7
	1700	8	8
	2015	8	0
June 12	0400	8	2
	0930	8	8
	1200	8	0
	1815	8	9
	2015	8	8
June 13	0315	8	3
	0930	8	3
	1715	8	4
	2130	8	8
June 14	0515	8	4
	0915	8	6
	1745	8	7
	2230	8	1
July 16	2100	4	4
July 17	0135	4	1
	0234	4	0
	0251	4	0
	0545	4	9
	0805	4	3
	0830	4	2
	1100	4	10
	1215	4	2
	1430	4	21
	1504	4	21
July 18	0800	2	1
	1129	2	57
	1200	2	40
	1641	0	1
July 19	0001	3	66
	0030	2	48
	0232	2	29
	0338	2	47
	0356	2	45
	0700	2	52
	0936	2	9
	1030	2	1
	1700	2	28
	1805	2	6
	2115	2	1
	2300	2	2
July 20	0000	2	0
	2013	1	0
Aug 12	0200	0	0
	0250	0	1
Aug 13	1105	0	0
	2206	0	0
Aug 26	0853	0	0
	1055	0	0
	1145	0	0
	1325	0	0
	1615	0	0
	1700	0	1
	1745	0	1
	1830	0	0
	2100	0	0
Aug 28	0745	0	0
	0915	0	0
	1015	0	0
	1140	0	0
	1445	0	0
	1525	0	0
	1645	0	0
	1745	0	0
	1815	0	0
	1915	0	0
	2015	0	0
Aug 30	0715	0	1
	0815	0	0
	0915	0	1
	1015	0	0
	1215	0	0
	1245	0	0
	1415	0	0
Aug 30	1515	0	0
	1815	0	0
	2145	0	0
Sept 1	0645	0	0
	0730	0	0
	0845	0	0
	1015	0	0
	1345	0	1
Sept 1	1415	0	0
	1545	0	0
	1815	0	0
	1905	0	1
	2015	0	0
Sept 3	0600	0	0
	0915	0	1
	1145	0	0
	1215	0	0
	1255	0	0
	1615	0	0
Sept 5	0645	0	0
	0815	0	1
	1045	0	1
	1145	0	0
	1445	0	0
	1515	0	2
	1715	0	0
	1745	0	0

Area 2 - Chukchi Sea Sweep Count (320^0 to 050^0)

Date	Time	Ice Cover	No. of Seals
June 4	0445	8	0
	0615	8	0
	1015	8	1
	1445	8	1
	2130	8	2
	2315	8	2
June 5	0115	8	0
	0630	8	0
	1330	8	0
June 7	0300	8	0
	0800	8	2
	1215	8	2
	1400	8	1
June 8	0900	8	1
June 9	1015	8	2
	1445	8	0
	1600	8	0
	2115	8	0
June 10	0015	8	0
	0330	8	1
	1630	8	1
	2145	8	0
June 11	1015	8	0
	1715	8	1
	2000	8	0
June 12	0415	8	2
	0945	8	2
	1215	8	0
	1800	8	2
	2000	8	3
June 13	0300	8	1
	0945	8	3
	1700	8	2
	2145	8	3
June 14	0500	8	2
	0900	8	3
	1730	8	3
	2245	8	1
July 16	2115	7	18
July 17	0158	7	12
	0215	7	13
	0309	7	11
	0530	7	18
	1200	7	15
	1450	4	18
	1525	7	24
July 18	0820	6	83
	1110	7	96
	1220	2	90
	2006	6	87
	2030	7	102
	2330	6	91
July 19	0000	6	--
	0303	7	105
	0321	7	--
	0630	6	91
	1001	7	89
	1017	7	--
	1720	6	56
	1747	7	59
	2140	4	47
	2230	6	44
July 20	0031	7	26
	2038	5	0
	2212	5	3
Aug 12	0000	1	0
	0220	1	1
	0235	1	0
	2000	1	0
Aug 13	2230	1	0

Table 3-13. Density of seals in the Peard Bay environs during 1983.

	Peard Bay			Chukchi Sea Nearshore		
Observation Period	Mean per km^2	Range per km^2	Peak Density per km^2	Mean per km^2	Range per km^2	Peak Density per km^2
4-14 June	0.31	0-1.03	0.42	0.41	0-1.15	0.79
16-20 July	1.58	0-5.68	2.37	19.77	0-40.07	29.58
12-13 August	0.02	-	-	0	-	-
26 August- 2 September	0.03	-	-	-*	-	-

*Not sampled

Between 26 August and 5 September, the observed density of seals inside Peard Bay averaged 0.03/km^2. No observations were made of the nearshore Chukchi Sea. Ice was absent from the bay, and it is probable that most of the animals seen were spotted seals.

During 20-28 August, observations were also made from the end of Point Franklin spit to assess movements of mammals into and out of the bay. An average of 3.7 seals per hour was observed entering or leaving the bay. Seals seemed to enter the bay during a rising tide and to exit during a falling tide or at low tide. Although most of the seals observed were spotted seals, often in groups of two or three swimming and diving synchronously, it was not possible to be certain of their identity.

Though some ringed seals are probably taken by Eskimo hunters within Peard Bay, they are not regularly hunted there and do not constitute a significant part of the local subsistence harvest. The paucity of seal remains in hunting and habitation sites within Peard Bay and Kugrua Bay further suggest that they have not been of significance to the subsistence economy of this locale.

3.3.2.2 Bearded Seal

No bearded seals were observed within Peard Bay or Kugrua Bay during the 1983 field season. During the aerial survey on 31 May, however, a number of bearded seals were seen in the broken pack ice seaward of shore-fast ice along the Chukchi Sea coast between Wainwright and Barrow. Bearded seal remains were also common along the outer, seaward beach of Point Franklin spit. Eskimo hunters who were interviewed did not mention hunting bearded seals within the bays, and no remains were found at hunting sites and abandoned habitation sites within the bays.

3.3.2.3 Spotted Seal

During field observations at Peard Bay, it was often difficult to distinguish between ringed seals and spotted seals so recordings were generally lumped as "seals." Both species were present in the vicinity during 20-28 August, though spotted seals were almost certainly dominant in terms of numbers. Due to ice conditions and season, it is likely that the reverse was true during June and July, when ringed seals were probably numerically dominant.

During 20-28 August, spotted seals seemed to enter the bay on a rising tide or at high tide, and exit during a falling tide or at low tide. They were observed to range widely over both Peard Bay and Kugrua Bay, several being seen far up the Kugrua River. Since few seals were visible at any given time, use of the bays by spotted seals is probably limited. Eskimo hunters expressed little interest in spotted seals, and the lack of remains found in hunting camps and abandoned habitation sites indicates that they are not an important element of their subsistence economy.

3.3.2.4 Pacific Walrus

During the 1983 field season, no live walrus were seen inside Peard Bay or Kugrua Bay. Eskimo hunters say that they occasionally take a few walrus inside the bay, and several carcasses were observed along the inside shore. Whether these remains were of animals killed inside the bay or of animals killed outside and which either drifted or were towed in is unknown. Very few walrus bones were found at hunting sites inside the bay, which indicates that they are probably not taken there with any regularity or in any significant numbers. Also, judging from the apparent paucity of large sessile invertebrates inside the bay (Chapter 5), it is doubtful that they utilize the bays for forage grounds, though a few may wander in at random from time to time.

Judging from the large numbers of shelled molluscs found on the outer Chukchi Sea beaches, the nearshore zone off Point Franklin may provide attractive forage grounds. Shells identified from this outer beach include representatives of the bivalve genera *Mya*, *Serripes*, *Spisula*, *Siliqua*, *Tellina*, *Clinocardium*, *Hiatella*, *Macoma*, and *Astarte*, all of which are known to be fed on extensively by walrus (Fay et al. 1977; Fay and Stoker 1982a,b). On 29 August 1983, numerous pods of walrus were observed on broken ice between 5 and 10 miles offshore from Point Franklin during a return flight to Barrow. Later on that same day 36 pods totaling approximately 1,500-2,000 animals were seen on grounded ice just offshore from Point Franklin.

Numerous skeletal remains of walrus were observed along the Chukchi beach between Point Franklin and the abandoned village of Atanik. Whether these animals were killed in the vicinity by Eskimo subsistence hunters or were carried there by winds and currents is uncertain. It is known that walrus are taken in the vicinity by hunters from both Wainwright and Barrow. Walrus remains were common at both Atanik and at the prehistoric village site of Pingasagaruk, indicating major importance as a subsistence resource.

3.3.2.5 Polar Bear

Several polar bears were seen by observers in the vicinity of Point Franklin between 4 and 14 June, including a female with two young cubs. Fresh tracks were also found on Point Franklin on 20 July. Bears were actively seeking out and feeding on walrus carcasses along the outer beach at this time, but showed no interest in entering Peard Bay itself even though a number of ringed seals were present on the ice within the bay. The spits and islands enclosing Peard Bay are knownto be a regularly used route for polar bears moving back and forth along the Chukchi Sea coast. No polar bears are known to den in the vicinity of Peard Bay (J. Lentfer, ADF&G, personal communication).

3.3.2.6 Beluga Whale

No belugas were seen within or in the vicinity of Peard Bay during the 1983 field season. Belugas probably occur in the nearshore Chukchi Sea off Point Franklin during their northward migration in April and May but, given the ice conditions observed in Peard Bay during this study, probably do not enter the bays at that time. They may occasionally enter Peard Bay and Kugrua Bay later in the summer, though the lack of sightings and of remains found in hunting and habitation sites within the bays suggest that such occurrences are infrequent.

3.3.2.7 Bowhead Whale

There were no confirmed sightings of bowhead whales within or offshore of Peard Bay during the 1983 field season, though one possible sighting was recorded about 3 km offshore from Point Franklin on 19 July. Given the solid ice conditions normally prevalent within Peard and Kugrua Bays at the time of the spring migration and the generally shallow depth of these bays, it is unlikely that bowheads enter the bays.

Bowhead skeletal remains, on the other hand, were found on the beaches of the area. Two partial skeletons were found on the spit projecting into Peard Bay from the mainland, opposite the eastern entrance. One of the remains was that of an adult bowhead, the other that of a subadult. Both were close to an abandoned subsistence hunting site at the end of the spit. Though it is impossible to say for certain, it is unlikely that they were killed within the bay, but were probably towed there by Eskimo hunters or carried there by tides and currents. Local Eskimo hunters had no knowledge of the origin of these bowhead remains. No other marine mammal bones were evident at the hunting site.

Substantial bowhead skeletal remains, including jaws and partial skull of an adult animal, were found at a prehistoric house pit site located on the bank of the Kugrua River near its mouth. A brief survey of the site yielded numerous traces of caribou, but no other marine mammal remains.

Bowhead remains in the form of scattered bones, vertebrae, jaws and skulls are common all along the Chukchi Sea beach of Point Franklin spit. The remains of at least two whales were evident between Point Franklin and the abandoned village site of Pingasagruk at the western end of Peard Bay, and at least two more between Pingasagruk and the abandoned village of Atanik. The most recent remains appeared to be several years old.

3.3.2.8 Gray Whale

Several gray whales were seen during the 1983 field season, both within and outside of Peard Bay. From 19 July through 31 August, a total of seven gray whales were observed within the bay, one of them in quite shallow water (less than 3 m depth) near the inside shore of Seahorse Island. Sightings within the bay occurred on 19 July and 11, 28, and 31 August.

At this time, at least 30 grays were sighted in the nearshore Chukchi Sea off Point Franklin spit between Point Franklin and Barrow. Sightings occurred on 11 August, 29 August, and on 2, 4, and 7 September. Most grays observed in the Chukchi Sea were feeding, as evidenced by presence of distinct mud plumes. On September 7 at least 20 animals were observed feeding inside the broken pack ice between Point Franklin and Barrow.

The Eskimo hunters who were contacted expressed little interest in hunting gray whales, and the lack of faunal remains in hunting and habitation sites of the vicinity suggests that grays are taken infrequently, if ever, in this locale. One adult gray whale carcass (approximately 8.2 m in overall length) was found on the Chukchi Sea beach near the west end of Peard Bay. It appeared to have been dead for at least a year. No external evidence of physical trauma was observed other than the post-mortem removal of a small section of skin and blubber and all of the baleen.

Though gray whales obviously do enter Peard Bay, they probably do so at random, on exploratory forays, rather than for feeding purposes. No grays were observed feeding within the bay and results of benthic studies within the bay indicate that appropriate food resources there are minimal.

3.3.3 Summary and Conclusions

Judging from observations of marine mammal distributions during the 1983 field season and taking into account available information concerning biological and physical aspects of Peard and Kugrua Bays, it seems unlikely that either of these bays are used extensively by the marine mammal populations of the region.

Both ringed and spotted seals frequent the bays during summer months, and a certain number of ringed seals may overwinter in the deeper sections of Peard Bay. Comparisons of sightings inside and outside of Peard Bay during the summer of 1983, however, and comparison with other seal density surveys conducted in the area (Lowry 1982) indicate that seal densities within the bays are less than in the nearshore Chukchi Sea. Presumably, both ringed and spotted seals enter the bays for purposes of feeding, probably on Arctic cod, saffron cod, sculpins, and perhaps salmon. Ringed seals are probably the dominant species both within the bays and on the shore-fast ice of the Chukchi Sea prior to August. After this time spotted seals are more common.

The only other marine mammal species known to enter Peard Bay are gray whales and an occasional walrus. Considering the shallow depth of the bays and the probable low density of the benthic macrofauna as compared with the nearshore Chukchi Sea, it seems likely that these forays are primarily exploratory in nature. It is doubtful that either species feeds extensively inside the bays or stays there for any length of time.

The nearshore Chukchi Sea off Point Franklin, on the other hand, probably provides important habitat for numerous species. Judging from the large number of bivalve and gastropod molluscs found on the outer beaches, the nearshore Chukchi Sea in this vicinity is rich in those benthic forms fed upon by walrus, bearded seal, and probably ringed seal and gray whale. Observations of large numbers of walrus and gray whales feeding off Point Franklin during the field period support this conclusion. This nearshore zone is probably also used fairly extensively by both ringed and bearded seals in spring (March-June). Ringed seal adults normally inhabit the shore-fast ice during this period for denning and pupping, while subadult ringed seals and bearded seals occur along the fracture zone and in the offshore pack ice.

In addition to its use as feeding grounds and pupping habitat, the nearshore Chukchi Sea is used as a migration corridor by the above-mentioned species as well as by the bowhead, beluga and gray whales, and to some extent, by the spotted seal and polar bear.

Harvest data over the past 20 years indicate that caribou are the single most important subsistence resource species at both Wainwright and Barrow, constituting over 50% of the average annual harvest in terms of usable biomass (Stoker 1983). Ranked in order of decreasing importance, the other major subsistence resources are walrus, bearded seal and bowhead whale at Wainwright, and bowhead whale, marine and anadromous fish, and walrus at Barrow (Stoker 1983).

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CHAPTER 4

BIRD UTILIZATION OF PEARD BAY AND VICINITY

4.1 INTRODUCTION

Several lagoons and embayments along the Alaska coast of the Chukchi and Beaufort seas have recently been found to be important feeding and molting areas for large numbers of water-associated birds breeding in Alaska and Canada (e.g., Divoky 1978a,b; Johnson and Richardson 1981; Lehnhausen and Quinlan 1981; Johnson 1983). Peard Bay, which lies between Icy Cape and Barrow, represents one of the largest of these areas, but until 1983 only cursory information was available about the magnitude and dynamics of bird use of this bay. Because of recent petroleum-related interests in the eastern Chukchi Sea there existed a need to establish baseline information on the natural resources of the area. This chapter presents results of research on the use of Peard Bay by birds during 1983. Six basic methods were used to assess avian utilization of the bay area; literature review, migration watches, ground sweep counts, aerial surveys, shoreline transects, and feeding studies.

4.2 METHODS

4.2.1 Review of the Literature

All literature pertinent to the study of bird populations at Peard Bay is reviewed. A brief history and synopsis of the research effort along the Arctic coast of Alaska is presented and the results are discussed in relation to findings of our study at Peard Bay. Mention is also made of recent, unpublished results.

4.2.2 Peard Bay Process Study

4.2.2.1 Migration Watches

Migration watches were conducted on a daily basis from 29 May to 13 June, 16-20 July, 10-14 August, and every other day from 26 August to 5 September. Watches were conducted from atop a 4-m high (above mean tide level) sand dune near the base of a RACON tower about 2 km from the tip of Point Franklin spit (Figure 4-1). Each census day was divided into 6-hour quarters (00:00-05:59, 06:00-11:59, 12:00-17:59, 18:00-23:59 AST), and four 30-minute census periods within each quarter were randomly selected. The 30-minute census periods were further divided into two 15-minute watches: one to monitor migration of birds along the nearshore waters of the Chukchi Sea side of the spit and the other to monitor birds migrating across Peard Bay. Thus, given a day on which weather permitted all counting periods, migration over each area was sampled for a total of 4 hours. By late August the decreased day length reduced this to approximately 2.5 h/day.

Each migration watch was conducted by one observer using a 20x spotting scope set at a fixed compass bearing. Bearings for the Chukchi Sea and Peard

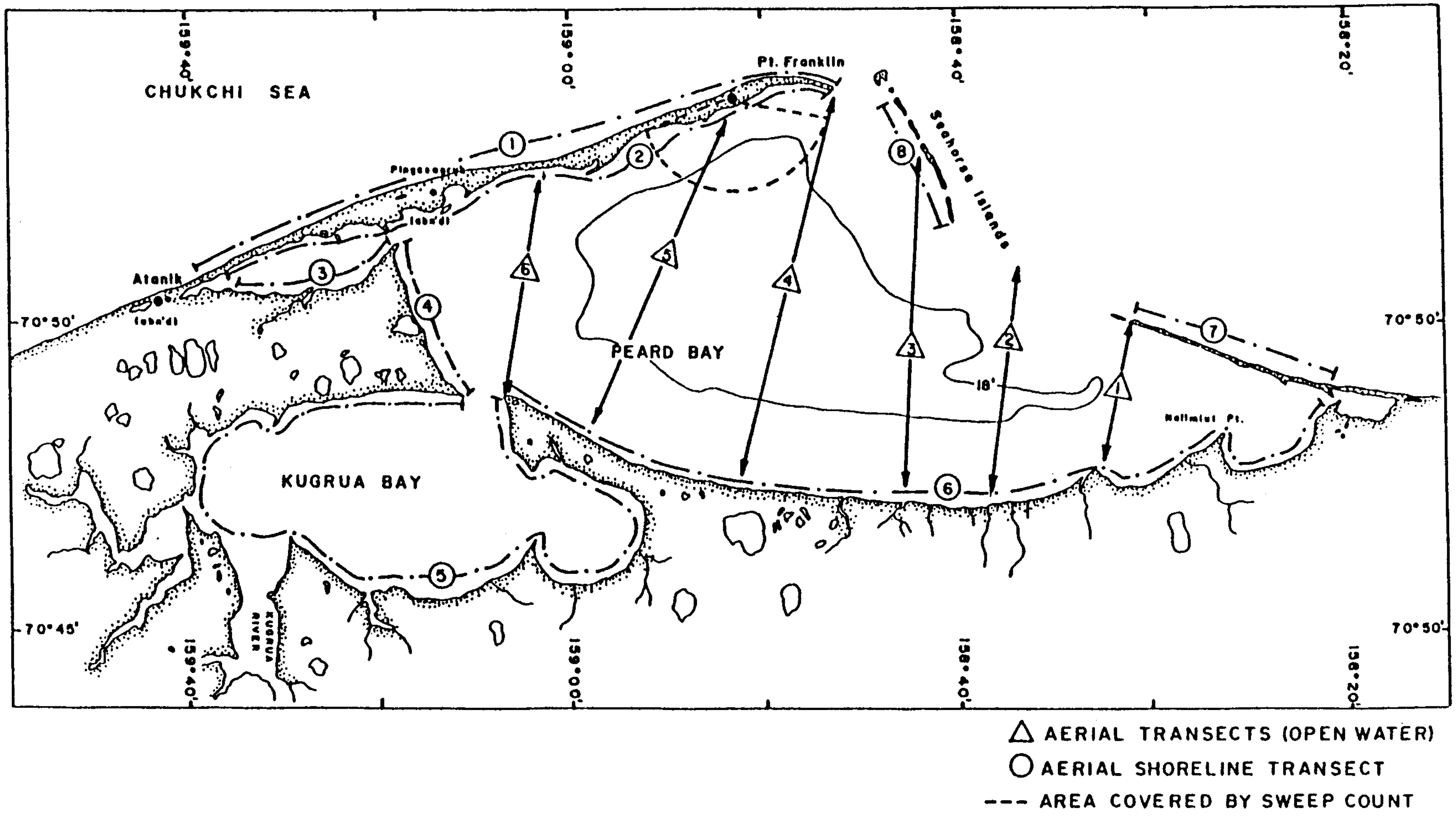

Figure 4-1. Transects Employed in Peard Bay Bird Study.

Bay watches were 340^0 and 180^0, respectively (true north). For each watch the observer first recorded the weather and observing conditions, and then (when possible) recorded the species, number, age and sex, flight direction, and behavior of each bird or flock observed. This information was recorded onto a portable tape recorder, and transcribed onto coding forms for computer processing.

4.2.2.2 Habitat Use

Censuses of Terrestrial Habitats. Censuses were conducted throughout the breeding season to assess the timing of breeding and the relative importance of terrestrial habitats to birds in the Peard Bay area. Because bird densities were found to be very low compared to those in aquatic habitats, less effort was expended in this aspect of the study.

Censuses on tundra habitat were conducted by counting all birds that occurred on a strip transect with a width of 50 m or 100 m. On 9 June, at the east end of Peard Bay near the landing strip, where the habitat consisted mainly of high-center polygons and interspersed with *Carex* sp. marshes, two transects (totaling 0.16 km^2) were censused. On 17 July at the west end of Peard Bay (on the peninsula north of Kugrua Bay) a 100-m-wide transect (1.13 km^2) was run over habitat that consisted of dry sedge-grass tundra, low-center polygon tundra, and *Carex-Eriophorum* marshes.

On 19 July and 27 August, the vegetated areas on Point Franklin spit were censused completely by two observers walking a series of parallel transects. One salt marsh began 5.6 km from the base of the spit and covered 0.3 km^2, and the vegetation was dominated by *Carex subspathacea* and *Elymus arenarius*. The next major vegetated area began 10 km from the base of the spit and encompassed a triangular patch (0.3 km^2) of salt marsh of similar vegetation but bordering a 0.3 km^2 ridge of tundra. This area was censused on 16 July. Sand dunes, sparsely vegetated with *Elymus arenarius* and scattered up and down the spit, were searched periodically throughout the season for nests.

The Seahorse Islands were examined only on 13 August to assess the status of breeding birds. The dunes, vegetated primarily by *Elymus arenarius*, were searched for burrows and nests. A count (20x spotting scope) was made of the numbers of arctic terns (*Sterna paradisaea*) tending eggs or young on the rest of the island, which was low in relief and largely unvegetated.

The only estimates of the number of birds breeding on the spit at the east end of Peard Bay were those that we could obtain during aerial surveys.

Sweep Counts. During 16-20 July, 12-13 August, and 26 August-5 September, visual sweep counts of Peard Bay were conducted to assess waterbirds. Sweep counts were performed in conjunction with migration watches and were normally done at the beginning or end of a 30-minute census period. Using a 20x spotting scope the observer scanned a fixed area of the bay in a single sweep from left to right, recording all birds present. The area censused was about 11.5 km^2 (Figure 4-1). The same type of information recorded during migration watches was recorded during sweep counts.

Aerial Surveys. Aerial surveys of Peard Bay were flown on 8 June, 15 July, and 10 and 25 August. A reduced number of tracklines were flown on 8 June and 15 July due to shore-fast ice. Surveys were designed to estimate density indices of all birds using the Peard Bay study area. These areas included the nearshore and open-water areas of Peard Bay, immediate shoreline habitats of Peard and Kugrua Bays and the Chukchi Sea side of the two spits enclosing Peard Bay, and areas on and adjacent to the Seahorse Islands. The Seahorse Island area was not surveyed until early August so as not to interfere with traditional native subsistence hunting camps located on the islands.

Surveys on 8 June, 15 July, and 10 August were flown in a Cessna 185 and the 25 August survey was flown in a DeHavilland Beaver. Surveys were flown at 90-100 m altitude and at an air speed of 100-120 knots. Two observers conducted each survey, one in the right front seat and the other in the left rear seat. Each observer counted all birds seen within a 200-m wide transect on his side of the aircraft. During shoreline counts the aircraft was positioned about 200 m from the shoreline. Observations were recorded into portable tape recorders and included information on species, flock size, age, relative position of the birds along the transect, habitat, and weather conditions.

Because birds were concentrated along the shoreline we used a stratified sampling scheme, censusing birds along the shore and in open waters separately. The six open-water aerial transects ran roughly north to south across the bay and totaled 57 km in length and 23 km^2 in area. The eight aerial shoreline transects covered the entire shoreline of the bay and totaled 142 km in length and 57 km^2 in area (Table 4-1, Figure 4-1).

Shoreline Transects. Shoreline, ground-based censuses were designed to derive measures of seasonal use, distribution, and densities of waterbirds along beaches and adjacent nearshore waters. Transects were established in mid-July when the majority of shoreline was free of shore-fast ice and birds were beginning to use these habitats. Because of logistical problems in getting around the Peard Bay area, shoreline transects were limited to the Point Franklin spit from Atanik to Point Franklin. Twelve transects were established, six on each side of the spit, and varied in length from 2 to 10 km (Figure 4-2, Table 4-2). The beginning and end of each transect was fixed and easily located by prominent physiographic features. Each transect encompassed the beach and nearshore waters out to a distance of 50 m. Transects were run from a three-wheeled Honda with the observer recording observations into a portable tape recorder. Information recorded during each survey included:

1) The date, transect number, observer, start and stop time of the survey, direction of travel, and weather, water, and ice conditions.

2) The number of birds of each species seen on transect, and their age and sex when discernible.

3) The location of each bird on the transect (e.g., beach, water, or ice).

4) The behavior of each bird or group of birds on the transect.

Table 4-1. Length (km) and area (km^2) of aerial transects conducted at Peard Bay in 1983.

Survey area			Length (km)	Area (km^2)
Open water:	1		4.9	2.0
	2		7.9	3.2
	3		11.4	4.6
	4		13.0	5.2
	5		11.7	4.7
	6		7.6	3.0
		Subtotal	56.5	22.7
Shoreline:	1		22.9	9.2
	2		24.4	9.7
	3		7.7	3.1
	4		5.0	2.0
	5		36.0	14.4
	6		29.5	11.8
	7		6.5	2.6
	8		6.7	2.7
	9		3.2	1.3
		Subtotal	141.9	56.8
		Total	198.4	79.5

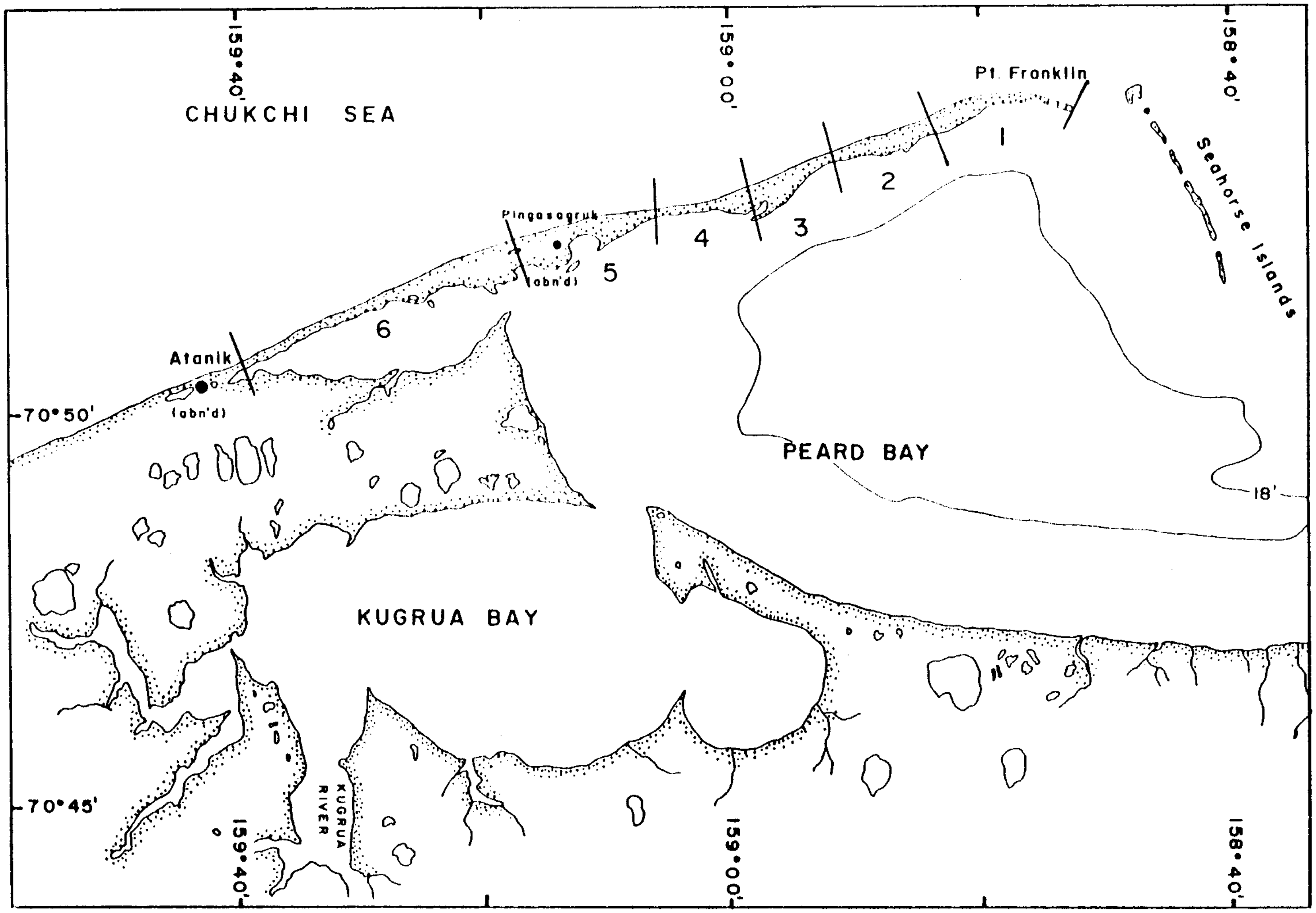

Figure 4-2. Location of Transects Along Pt. Franklin Spit.

Table 4-2. Seasonal sampling effort for shoreline censuses of the Point Franklin spit during 1983.

Transect No.	15-22 July		10-14 August		26 August-7 Sept		Total	
	No.	(total km)[1]	No.	(total km)	No.	(total km)	No.	(total km)
Peard Bay Side								
1 (4.0)[2]	4	(16.0)	2	(8.0)	5	(20.0)	11	(44.0)
2 (2.1)	3	(6.3)	1	(2.1)	1	(2.1)	5	(10.5)
3 (3.7)	3	(11.1)	1	(3.7)	2	(7.4)	6	(22.2)
4 (2.0)	3	(6.0)	1	(2.0)	2	(4.0)	6	(12.0)
5 (2.4)	1	(2.4)	1	(2.4)	0		2	(4.8)
6 (9.8)	2	(19.6)	1	(8.2)	1	(9.8)	4	(37.5)
Subtotal	16	(61.4)	7	(26.3)	11	(43.3)	34	(131.0)
Chukchi Sea Side								
1 (4.2)	4	(16.8)	2	(8.4)	5	(21.0)	11	(46.2)
2 (2.0)	5	(10.0)	1	(2.0)	6	(12.0)	12	(24.0)
3 (3.4)	5	(17.0)	1	(3.4)	6	(20.4)	12	(40.8)
4 (1.7)	5	(8.5)	1	(1.7)	5	(8.5)	11	(18.7)
5 (2.1)	3	(6.3)	1	(2.1)	2	(4.2)	6	(12.6)
6 (9.0)	2	(18.0)	1	(7.5)[3]	2	(10.9)	5	(36.4)
Subtotal	24	(76.6)	7	(25.1)	26	(77.0)	57	(178.7)
TOTAL	40	(138.0)	14	(51.4)	37	(120.3)	91	(309.7)

[1] Number of times each transect was run and the total km censused.
[2] Length (km) of each transect.
[3] Partial transect run during this period.

4.2.2.3 Feeding Studies

Studies of the feeding ecology of birds using Peard Bay were conducted to determine important prey organisms in the diets of those bird species most abundant in the bay. The species examined were: oldsquaw (*Clangula hyemalis*), king and spectacled eiders (*Somateria spectabilis* and *S. fischeri*), arctic tern, and red phalarope (*Phalaropus fulicarius*). To assess the relative importance of each taxa of prey found in the stomachs we used the quantitative assessment methods of Pinkas et al. (1971) and Griffiths et al. (1975). These methods take into account such things as differential digestion rates of hard- and soft-bodied prey, and the potential shortcomings of using only percent or percent frequency of occurrence to assess the importance of prey to a predator.

Collections. Between 12 August and 5 September, 68 specimens of the five principal avian species were collected from Peard Bay and along the Chukchi Sea side of Point Franklin spit (Table 4-3, Figure 4-3). Oldsquaw, with the exception of eight birds shot on 12 August, were collected from flocks in which the birds were observed diving and presumed to be feeding. The eight birds collected on 12 August were from a flock of molting and flightless males near the mouth of Kugrua Bay. Eiders could not be collected from large flocks. Those collected were usually from groups of two to six birds and their feeding behavior prior to collection was often difficult to assess. All red phalaropes were collected while feeding within 3 m from shore along the distal 2 km of Point Franklin spit. Arctic terns were collected from flocks of 20 to 100 birds that appeared to be actively feeding by plunge-diving and surface-seizing. All terns were collected from Peard Bay 4-7 km south of the end of Point Franklin spit. All birds were collected with a shotgun, the phalaropes from shore and all other birds from a 4-m Zodiac boat.

One to five minutes after being shot, each bird was weighed, labeled, and injected down the esophagus with a 10% solution of buffered formalin. The esophagus was plugged with cotton. Within 24 hours of collection data were taken on molt, sex, age, subcutaneous and abdominal mesenteric fat, gonadal condition and size, and measurements of culmen and wing length. At this time the esophagus and gut were removed as a single unit, slit lengthwise and placed in Whirl-Pak bags filled with a 10% solution of buffered formalin. Stomach contents were allowed to fix in this solution for at least 24 hours, then were washed and placed in a 50% solution of isopropyl alcohol.

Laboratory Analysis. An estimate was made of the relative volume of each major prey taxon and the fullness of the stomach (relative to the fullest stomach) using the "points" method of Hynes (1950) and Griffiths et al. (1975). A full stomach was given 20 points (25 points if gorged), 3/4 full 15 points, 1/2 full 10 points, 1/4 full 5 points, 1/8 full 2.5 points, and empty 0 points. Unlike the methods described by Griffiths et al. (1975), the total volume and relative fullness of each stomach were assessed after the contents had been removed from the stomach. For each stomach we measured total wet weight (g) and displaced volume (ml) of all stomach contents. Measurements were made for wet weight and displaced volume of each prey item (subsamples or aliquots of abundant prey). The total weight (g) of non-food items was also determined. Additionally, when whole prey items from the stomachs were found, length (mm) measurements were taken.

Table 4-3. Number, age and sex of birds collected for studies of avian feeding ecology at Peard Bay in 1983.

Date	Oldsquaw	Eiders	Arctic tern	Red phalarope
August 12-13	8 AHY-M	3 AHY-F	9 AHY-M 4 HY-F	1 AHY-M 7 HY-M 11 HY-F 1 HY-U
August 29	6 AHY-M 3 AHY-F		1 AHY-M	
August 31	4 AHY-M	2 HY-M 3 HY-F		
September 5	4 AHY-M 1 HY-F			
Total by Type	22 AHY-M 3 AHY-F 1 HY-F	3 AHY-F 2 HY-M 3 HY-F	10 AHY-M 4 HY-F	1 AHY-M 7 HY-M 11 HY-F 1 HY-U
Total Individuals	26	8	14	20

Age: AHY = After hatching-year, HY = Hatching-year.

Sex: F = female, M = male, U = unknown.

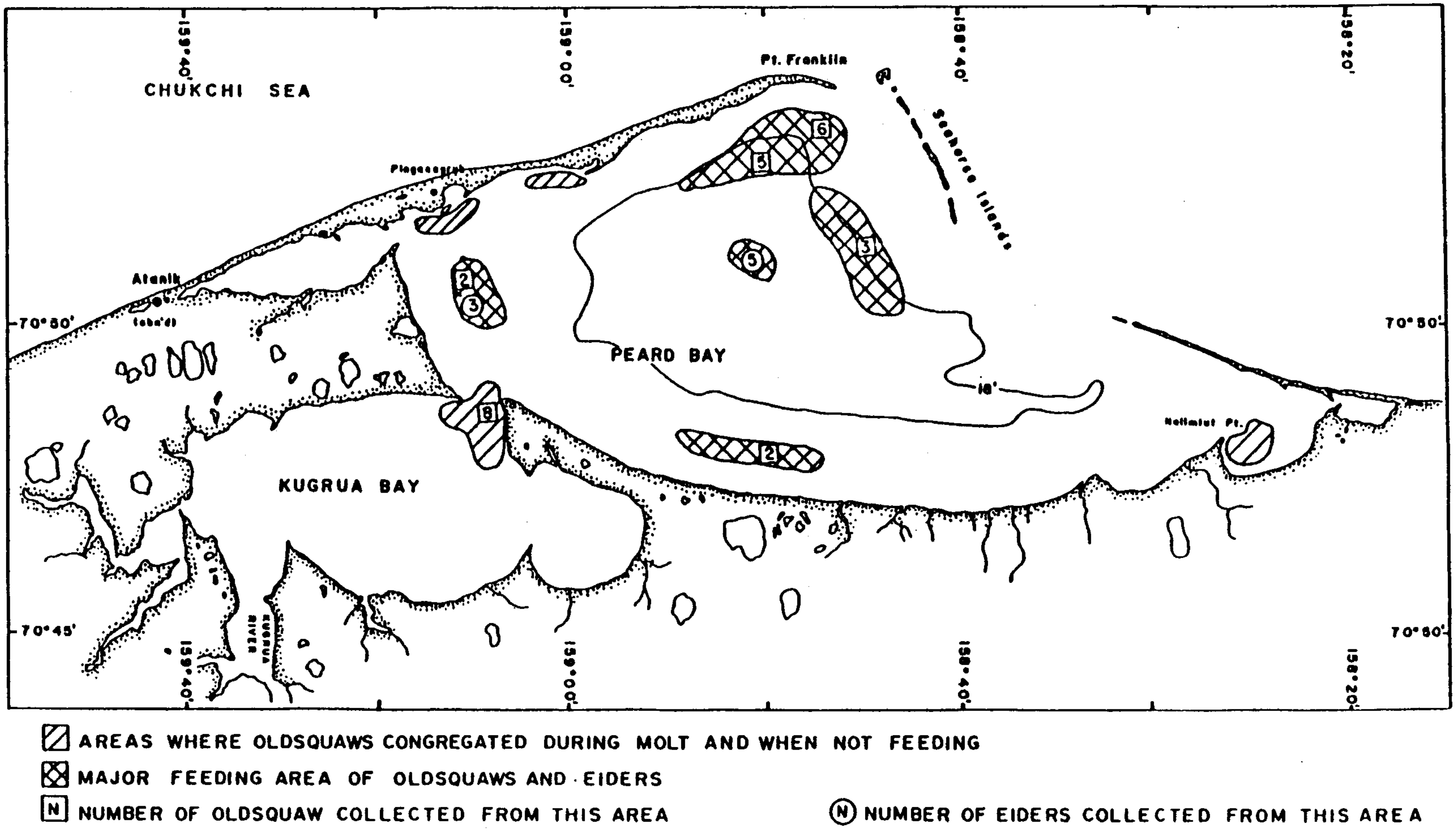

Figure 4-3. Major Feeding and Molting Areas of Seaducks in Peard Bay.

Besides the method described by Griffiths et al. (1975) to determine the importance of various prey to each species of bird, the method of Pinkas et al. (1971) was used to determine the "Index of Relative Importance" (IRI) for each major prey taxon. IRI was computed using the equation;

$$\text{IRI value} = \%FO * (\%V + \%N), \text{ where}$$

%FO (% frequency of occurrence) = the percentage of the stomachs in which the prey taxon occurred;
%V (% volume) = the percentage that the prey taxon composed of the total volume of prey from all stomachs; and
%N (% numbers) = the percentage that the prey taxon composed of the total number of prey items from all stomachs.

Depending on the size of the three percentages (rounded to the nearest 0.1%), IRI values can range from a low of 0.02, to a high of 20,000. A higher value for a particular prey taxon indicates a greater importance to that species of bird relative to other prey items. IRI values for all prey were summed for each species of bird and the percentage that each prey taxon contributed to the total IRI was calculated. This permitted a direct comparison of the results of Pinkas' IRI method and Hynes'-Griffiths' point method.

The equations presented by Horn (1966), Levins (1968), and Pielou (1974) were used to calculate the amount of overlap in the diets of these species of birds, niche breadth, and prey species diversity (= trophic diversity) to determine how much the birds may have been competing with each other for prey.

4.3 RESULTS

4.3.1 Review of the Literature

4.3.1.1 Introduction

Peard Bay is situated on the northeastern coast of the Chukchi Sea within the physiographic unit of the Arctic Slope defined by Payne et al. (1951) as the Arctic Coastal Plain Province. Kessel and Cade (1958) demonstrated that distinctive floral, faunal, and ecological features separate this province from foothill tundra and alpine tundra, the other two distinct physiographic provinces of the Arctic Slope. They noted that the avifauna of the coastal tundra was dominated by species (primarily shorebirds and waterfowl) that were strongly associated with surface waters, including marine littoral and fresh or brackish lacustrine waters. Passerines formed a minor component in terms of species diversity.

Pitelka (1974) pointed out in his review of the Barrow region avifauna that it was important to consider more detailed changes in topography and habitats when analyzing the distribution of birds in relation to biogeography. According to his delineation, Peard Bay lies at the western fringe of the northern triangular tip of the Arctic Coastal Plain, which he termed the "Barrow region." This area was delineated because of its general uniformity in faunal ecosystem although he noted that some differences between coastal and inland areas were pronounced in summer because of maritime influences (Pitelka 1974).

4.3.1.2 History of Ornithological Studies in Arctic Alaska

Investigations of Arctic Slope avifauna region began in 1825 when the H.M.S. Blossom, with naturalist George Lay aboard, sailed to the Arctic Ocean and Point Barrow was named. Bailey (1948) gives a historical sketch of the expeditions to the Alaskan coast of the Chukchi Sea and western Beaufort Sea during this exploratory period. Most naturalists during this time were occupied with only the collection of specimens and reporting of the distributions of species at the locales they visited (Vigors 1839; Harting 1869, 1871; Bean 1882; Nelson 1883, 1885; McLenegan 1887, 1889; Townsend 1887a,b; Seale 1898; Stone 1900; Anderson 1913, 1915, 1917; Brooks 1915; Anderson and Taverner 1919; Dixon 1943). Notable exceptions were Grinnell (1900), who conducted intensive studies of birds in the Kobuk River region of Kotzebue Sound, and Murdoch (1885a,b,c, 1887, 1898, 1899).

These studies were the most complete for the Alaskan Arctic until Bailey recorded detailed observations of birds along the entire Chukchi Sea coast, from Cape Prince of Wales to Barrow (Bailey 1923, 1924a,b,c, 1925, 1926a,b, 1928, 1929a,b, 1930a,b, 1931, 1932, 1933a,b, 1934, 1939, 1942, 1943, 1947, 1948; Bailey and Bishop 1934; Bailey et al. 1933). He is the first ornithologist to have reported visiting the Peard Bay area, albeit in winter (Bailey 1948).

Subsequent studies of the avifauna of Alaska's Arctic Slope have increased greatly in number and narrowed in scope. Research interests blossomed largely through the establishment of the Naval Arctic Research Laboratory near Barrow in 1947 (Pitelka 1974). Research efforts were expanding on other fronts simultaneously. The Alaska Cooperative Wildlife Research Unit was established at the University of Alaska; the Arctic Health Research Center (later to become the Institute of Arctic Biology) supported substantial avian research; Federal Aid funds became available to support systematic waterfowl surveys throughout the state; and the Arctic Institute of North America was established (Gabrielson and Lincoln 1959; Handel et al. 1981). In the late 1950's the Atomic Energy Commission funded a major interdisciplinary study of the biological resources of the Cape Thompson area (Hines 1963; Swartz 1966; Williamson et al. 1966). Miscellaneous other studies were conducted with funding from other sources (Bee 1958).

Two major, recent events have caused further expansion of Arctic avian research: establishment of the International Biological Program and discovery of oil at Prudhoe Bay (Pitelka 1974). When the responsibility for management of the National Petroleum Reserve - Alaska was transferred to the Department of the Interior in 1976, a number of studies in coastal and inland areas of the slope were initiated by the U.S. Fish and Wildlife Service (Derksen et al. 1981). Much of the work to date remains unpublished in the scientific literature. It was also at this time that the Outer Continental Shelf Environmental Assessment Program began to fund large, interdisciplinary studies at several locations along the Arctic coast.

Contemporary investigations (since the late 1940's) do not simply focus on determining the distribution of birds, but emphasize a better understanding of the avian species through the analyses of complex interrelationships of ecological communities. The need for such a change in studies of the Arctic tundra communities has been voiced by Pitelka (1969).

It is primarily these later studies, rather than the distributional treatises of earlier eras, that are key in the analysis of the importance and vulnerabilities of Peard Bay. Since Peard Bay lies on the edge of the "Barrow region," it is fortunate that so many of the studies have been centered at Point Barrow. These studies permit a comparison of Peard Bay with the core of the "Barrow region." If comparisons show similarities, one can then extrapolate from the results of the more detailed, intensive studies of the community and individual species at Barrow. More intensive studies can then be focused on the areas of dissimilarity.

4.3.1.3 Review of Most Recent Ornithological Research

Several investigators have reported on the timing and magnitude of migration, especially of waterfowl in fall, past Point Barrow. Thompson and Person (1963) monitored migration of king and common eiders from July through September 1953. Johnson (1971) also reported on migration of loons and waterfowl for the same period in 1970. Timson (1976) monitored fall migration of all birds past Barrow from late August to mid-September in 1975, and analyzed the influence of factors such as wind conditions and time of day on the magnitude of migration. That same year Densley (1977, 1979) monitored the fall migration of Ross' gulls (*Rhodostethia rosea*) past Barrow in late September. Flock (1973) used radar to monitor fall migration of waterfowl at Barrow and has also performed comparative studies at other sites along the Arctic coast from Barter Island to Point Lay. His most intensive radar monitoring was at Tin City and Cape Prince of Wales (Flock 1972, 1976; Flock and Hubbard 1979).

Largely because of the influence of Pitelka, a solid basis of knowledge has been built on the ecology of shorebirds nesting in the Barrow region. Most studies have involved shorebirds of the Scolopacidae but subjects have ranged widely from basic breeding biology to the ecological interactions of shorebirds with prey and energetics (Pitelka 1959; Holmes 1964, 1966a,b,c, 1970, 1971; Holmes and Pitelka 1964, 1968; MacLean 1969, 1974; Norton 1970, 1971, 1972a,b, 1973; MacLean and Holmes 1971; MacLean and Pitelka 1971; Norton and Safriel 1971; Pitelka et al. 1974; Safriel 1975; Ashkenazie and Safriel 1979a,b; Myers 1979, 1981, 1982; Myers and Pitelka 1979, 1980). Schamel and Tracy (1977) have examined the breeding system of the red phalarope, and Dodson and Egger (1980) studied this species' prey preferences and feeding rates. Connors has conducted investigations on the dependence of shorebird species on the littoral areas of Barrow and at several other sites along the Arctic coast, including a cursory visit to Peard Bay (Connors and Risebrough 1976, 1977, 1978, 1979; Connors et al. 1979; Connors 1981, 1983). A related study was conducted by Jones (1980) at Prudhoe Bay to analyze the patterns of habitat selection by shorebirds throughout the summer. Schamel et al. (1979) studied shorebirds, as well as other waterbirds present at two sites on the Espenberg Peninsula in Kotzebue Sound.

Barrow has been the site for studies of jaegers and owls nesting on the coastal plain. Those by Pitelka et al. (1955a,b) looked primarily at the relationship between pomarine jaegers (*Stercorarius pomarinus)*, snowy owls (*Nyctea scandiaca*), short-eared owls (*Asio flammeus*), and a major prey species, the brown lemming (*Lemmus trimucronatus*). Maher (1962, 1970, 1974) has examined several aspects of the nesting ecology of all three species of jaegers including the pomarine jaeger, the parasitic jaeger (*Stercorarius parasiticus*), and the long-tailed jaeger (*Stercorarius longicaudus*), and expanded his study to include Cape Sabine, Wainwright, and Barrow. The most abundant passerine, the lapland longspur (*Calcarius lapponicus*), has received detailed study at Barrow (Custer 1973, 1974; Custer and Pitelka 1977, 1978; MacLean and Seastedt 1979; Seastedt and MacLean 1979). The less common snow bunting (*Plectrophenax nivalis*) has received less attention (Custer and Pitelka 1975).

The most significant studies of waterfowl, both nesting and staging, have not come from the Barrow area but from other sectors of the Arctic Coastal Plain. Particularly important are avifaunal studies of the wetlands of the National Petroleum Reserve - Alaska and other parts of the coastal plain adjacent to potential oil-producing areas. These include Storkersen Point (Howard 1974; Bergman and Derksen 1977; Bergman et al. 1977); Teshekpuk, Island, and East Long Lakes--important goose molting areas (Derksen et al. 1979a,b; Derksen and Eldridge 1980); and the Arctic National Wildlife Refuge (Andersson 1973). Results of the most recent studies in these areas and at Prudhoe Bay are presently unpublished.

Aerial surveys have also been used to determine the distribution of waterbirds over large tracts of the Arctic Coastal Plain (King 1970, 1979). Other studies have focused on particular species. Schamel (1974, 1977) studied the breeding biology of the common eider (*Somateria mollissima*) nesting on a barrier island just west of Prudhoe Bay, and Myres (1959) described behaviors and interactions between king eiders and common eiders at Barrow.

Seabird colonies are almost nonexistent along the Arctic coast (Sowls et al. 1978) because of the relatively low relief north of the Brooks Range. The most substantial seabird colony close to Peard Bay is at Cape Thompson, where nearly half a million birds have been recorded (Sowls et al. 1978). The breeding and feeding ecology of seabirds nesting in this colony have been studied intensively by Swartz (1966) and Springer (Springer and Roseneau 1977, 1978; Springer et al. 1979, 1980).

Farther north along the coast colonies of marine birds generally consist of small numbers of common eiders, glaucous gulls (*Larus hyperboreus*), arctic terns, and black guillemots (*Cepphus grylle*) nesting on barrier islands, sand dunes, and beaches (Sowls et al. 1978). These species have been intensively studied in Arctic Alaska only at Point Barrow (MacLean and Verbeek 1968; Divoky 1976a, 1978b; Divoky et al. 1974; Boekelheide 1980); at Egg Island near Storkersen Point (Schamel 1974, 1976, 1977, 1978); and at Icy Cape (Quinlan and Lehnhausen 1982). Useful information on the distribution of marine birds at sea has been presented by Jaques (1930), Swartz (1967), Frame (1973), and Harrison (1977, 1979). Divoky and colleagues have examined the importance of ice in determining the distribution of birds in the Chukchi and Beaufort seas (Divoky 1972, 1976a,b, 1977, 1978a, 1979; Watson and Divoky 1972, 1974,; Divoky and Good 1979).

Important studies have been recently conducted to examine the dynamics of coastal bays and lagoons along the Arctic coast. These studies have looked at the seasonal occurrence of birds in lagoon habitats in relation to physical and biotic factors. Most of these have been concentrated along the Beaufort Sea coast: Beaufort Lagoon (Johnson 1983); smaller lagoons along the coast of the Arctic National Wildlife Refuge (Bartels 1973); Simpson Lagoon (Johnson 1977, 1978, 1979); and Elson Lagoon, near Barrow (Divoky 1976, 1978b; Divoky and Good 1979).

Several other avifaunal studies recently conducted by the U.S. Fish and Wildlife Service have not yet been published. The most pertinent of these to the Peard Bay study is that conducted by Lehnhausen and Quinlan (1981) at Icy Cape and Kasegaluk Lagoon, about 125 km southwest of Peard Bay. They collected information primarily on migration and the use of various habitats available to birds. Peard Bay lies midway between Point Barrow and Icy Cape, so comparison of avian ecology at the three sites would help establish the importance of Peard Bay to birds in the northeastern Chukchi Sea. However, certain limitations exist which limit such a comparison. Lehnhausen and Quinlan (1981) were at Icy Cape for only a single year. Because of the marked annual fluctuations in avian populations that are typical in the Arctic, direct comparisons of observations at Peard Bay and Icy Cape must be viewed with caution since data were gathered at the two sites in two different years. In addition, studies at Kasegaluk Lagoon did not include investigations of other abiotic and biotic factors that might influence bird populations in the area. For example, there is no information from that area on feeding ecology of birds, prey abundance, or currents within the lagoon.

As more studies are conducted and published, a better understanding of areas critical to avian populations will be achieved.

4.3.2 Bird Use of Peard Bay and Vicinity

4.3.2.1 Migration Watches

Migration watches were conducted on 30 of the 44 field days between 28 May and 7 September. A total of 223 watches, representing about 112 hours of observation, were conducted during this period. Primarily due to weather, but also because of conflicts with other activities and decreasing day length, only 47% of the scheduled watches were conducted (Table 4-4). However, 58% of the scheduled watches were conducted in spring and 78% were conducted in fall, when migration could be expected to be most intense.

Loons. All three species of loons--red-throated (*Gavia stellata*), arctic (*G. arctica*), and yellow-billed (*G. adamsii*)--were recorded on migration watches. The yellow-billed loon was the only species of loon observed in spring and only on 31 May did the species migrate past the area in numbers (averaging about 10 birds/h; Figure 4-4). The fall migration of loons began in late August and was still increasing when we departed on 7 September. No yellow-billed loons were identified in fall. During the peak migration on 5 September arctic loons comprised the majority of loons seen migrating along both the Chukchi Sea shore (80%, 23 birds/h) and across Peard Bay (95%, 67 birds/h).

Procellarids. No procellarids were observed during migration watches until 26 August. On that date there was a pronounced net easterly movement of shearwaters (*Puffinus* sp.) averaging 1,565 birds/h along the Chukchi Sea side, with flocks ranging in size from 16 to 3,500 birds. On the Peard Bay side (26 August) an average of 185 birds/h moving east and simultaneously 146 birds/h moving west were recorded. On subsequent days shearwaters were

Table 4-4. Number of 30-minute migration watches conducted during 29 May - 5 September 1983.

		Migration watch period (Alaska Standard Time)			
Date	00:00-05:59	06:00-11:59	12:00-17:59	18:00-23:59	Total
May 29	0	4	4	1	9
30	0	3	4	4	11
31	3	3	0	0	6
Jun 1	4	4	4	4	16
2	4	4	2	0	10
3	0	0	0	0	0
4	1	4	4	4	13
5	2	2	2	1	7
6	0	0	0	0	0
7	3	2	3	1	9
8	0	2	0	0	2
9	0	1	4	3	8
10	2	2	1	3	8
11	1	2	2	2	7
12	2	2	2	3	9
13	2	2	2	2	8
14	2	2	1	2	7
Jul 16	0	0	0	1	1
17	4	3	3	0	10
18	0	2	2	3	7
19	3	3	2	3	11
20	1	0	0	2	3
Aug 12	3	0	0	1	4
13	0	0	0	1	1
26	dark	3	5	3	11
28	dark	4	4	3	11
30	dark	4	4	2	10
Sep 1	dark	4	3	3	10
3	dark	3	3	0	6
5	dark	4	4	dark	8
Total	37	69	65	52	223

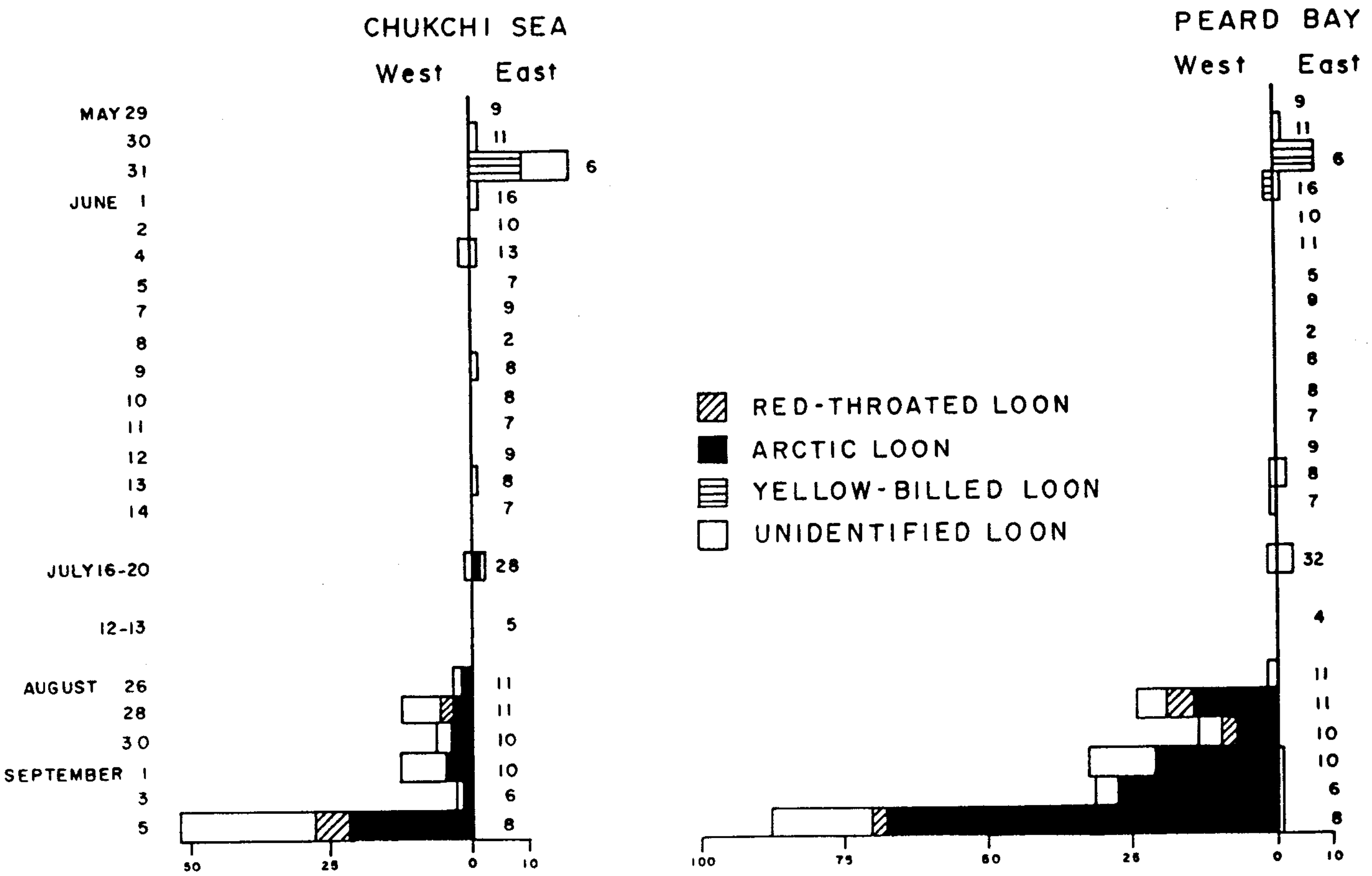

Figure 4-4. Mean Number of Loons Migrating Per Hour. Numbers to the right of each bar represent the number of counts that day.

recorded regularly but in much lower numbers. The magnitude of movement was approximately equal in both directions, and evenly split between Peard Bay and the Chukchi Sea coast. These movements appeared to be local, large scale, and directed. Southward migration did not appear to have begun before staff departure from the area. All closely observed shearwaters appeared to be short-tailed shearwaters (*P. tenuirostris*) and all eight shearwaters found dead on the beach during this period were of this species. Northern fulmars (*Fulmarus glacialis*) were recorded moving through Peard Bay and along the Chukchi Sea coast, but at much lower rates. Westerly movements of this species peaked on 28 August at an average of 18 birds/h.

Waterfowl. By 26 May the eastward migration of eiders past Barrow was well underway. The nearshore lead at Barrow was only 2 km offshore and many flocks of birds were migrating within 0.5 km of shore as they passed Barrow. Since the lead opposite Peard Bay during late May and early June was never observed to be closer than 10 km from shore, the majority of eiders and oldsquaw probably migrated offshore.

A significant migration of waterfowl to the east was recorded between 30 May and 4 June. This was most intense on 4 June when over 500 birds/h, mostly eiders (63% common, 33% king), were observed (Figure 4-5). No easterly migration of waterfowl was observed over Peard Bay in spring. Migration of waterfowl across Peard Bay and along the Chukchi Sea coast during summer was sporadic and probably represented birds moving to molting areas.

Beginning in late August a substantial increase in waterfowl migration was detected. Unlike spring when mostly eiders were observed, oldsquaw composed the majority of waterfowl passing along the coast. Over the nearshore waters of the Chukchi Sea the migration peaked at 525 birds/h to the west on 1 September, and on 3 September over Peard Bay a high of 1,350 oldsquaw/h passed to the west (Figure 4-5). The large numbers of oldsquaw recorded moving to the east across Peard Bay in fall (Figure 4-5) were probably local birds moving directly between different feeding or roosting areas in the bay (see Sweep Counts).

Shorebirds. Eleven species of shorebirds were identified during migration watches, but only four--sanderling (*Calidris alba*), semipalmated sandpiper (*C. pusilla*), dunlin (*C. alpina*), and red phalarope--were observed in large numbers. Shorebird migration in spring past Peard Bay was very compressed and occurred over a 7-day period between 29 May and 4 June, with the peak occurring on 31 May. On this date about 150 birds/h passed to the east across both the bay and along the Chukchi Sea coast (Figure 4-6). Fall migration of shorebirds was well underway by 26 August and decreased steadily into the first week of September (Figure 4-6). Red phalaropes comprised 95% of all shorebirds migrating during this period and during peak passage on 26 August, when migration occurred at a rate of 200 birds/h along the Chukchi Sea shore and 28 birds/h across Peard Bay (Figure 4-6).

Jaegers. The eastward migration of jaegers in spring was underway by late May. Pomarine jaegers comprised about 95% of all jaegers observed during late May and early June, passing over Peard Bay at peak rates of 42 birds/h on 30 May and 18 birds/h along the Chukchi Sea shore on 2 June (Figure 4-7). A small passage (4-5 birds/h) of parasitic jaegers occurred to the east along the Chukchi Sea shore on 4-5 June. Beginning on 2 June a few pomarine jaegers

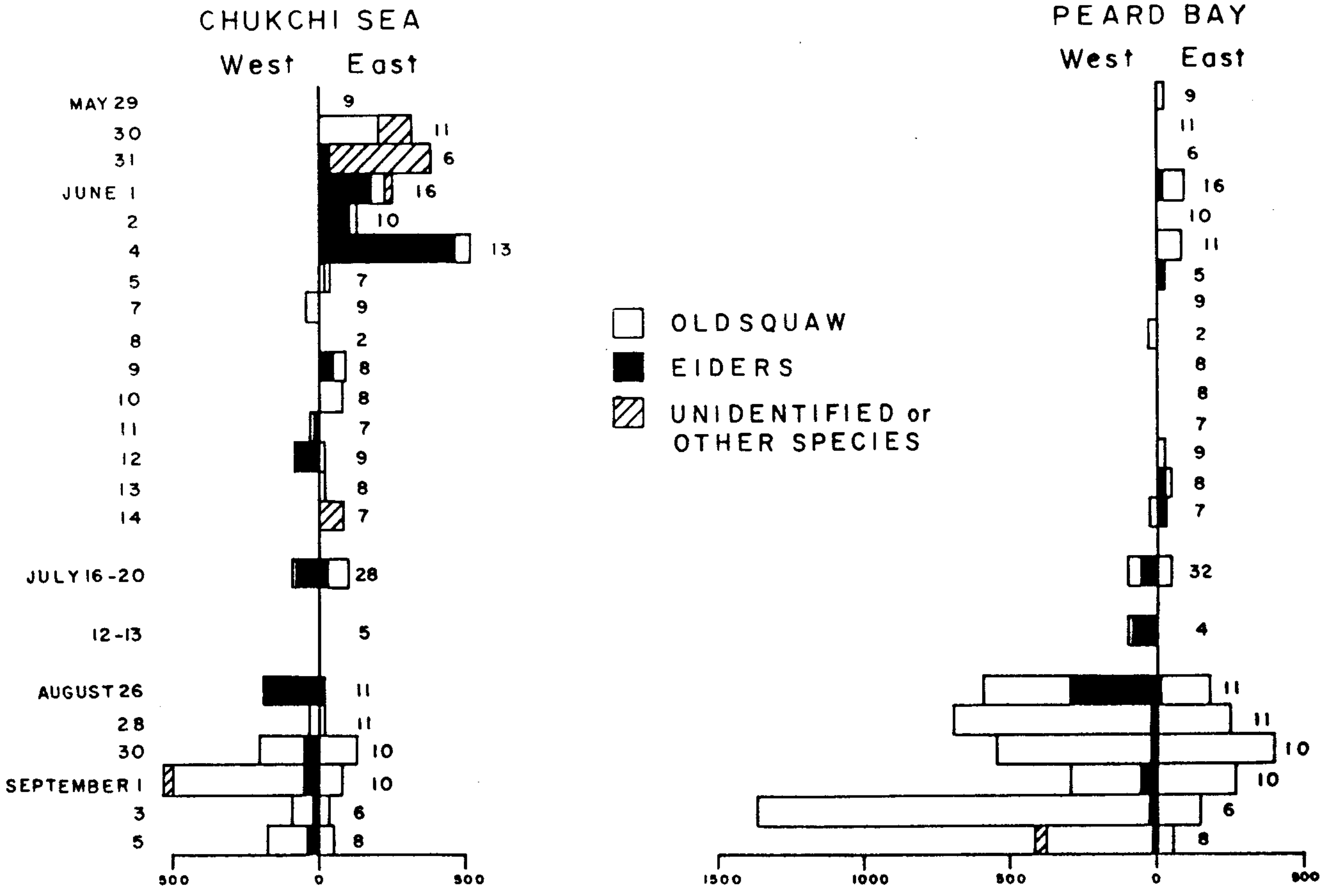

Figure 4-5. Mean Number of Waterfowl Migrating Per Hour. Numbers to the right of each bar represent the number of counts that day.

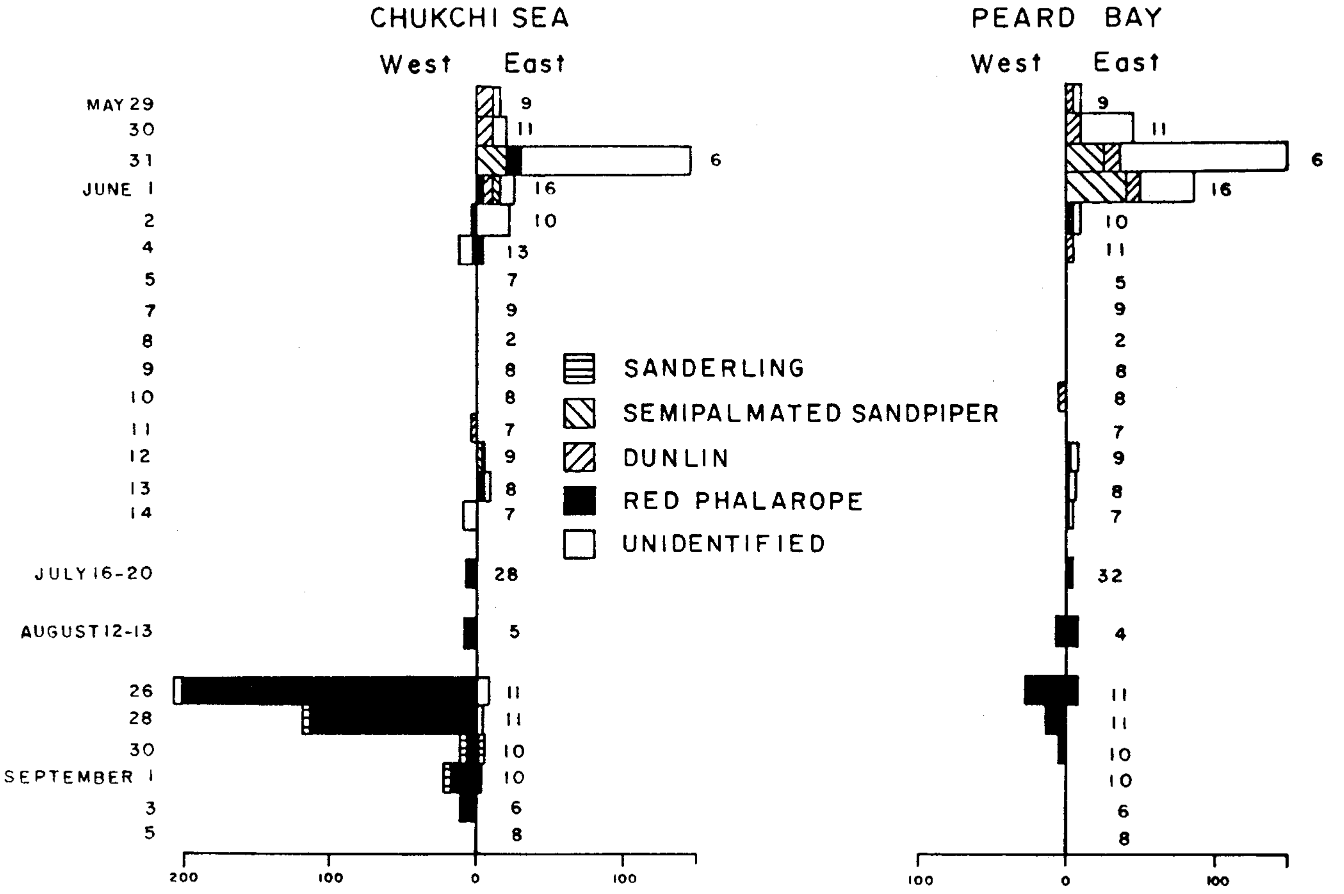

Figure 4-6. Mean Number of Shorebirds Migrating Per Hour. Numbers to the right of each bar represent the number of counts that day.

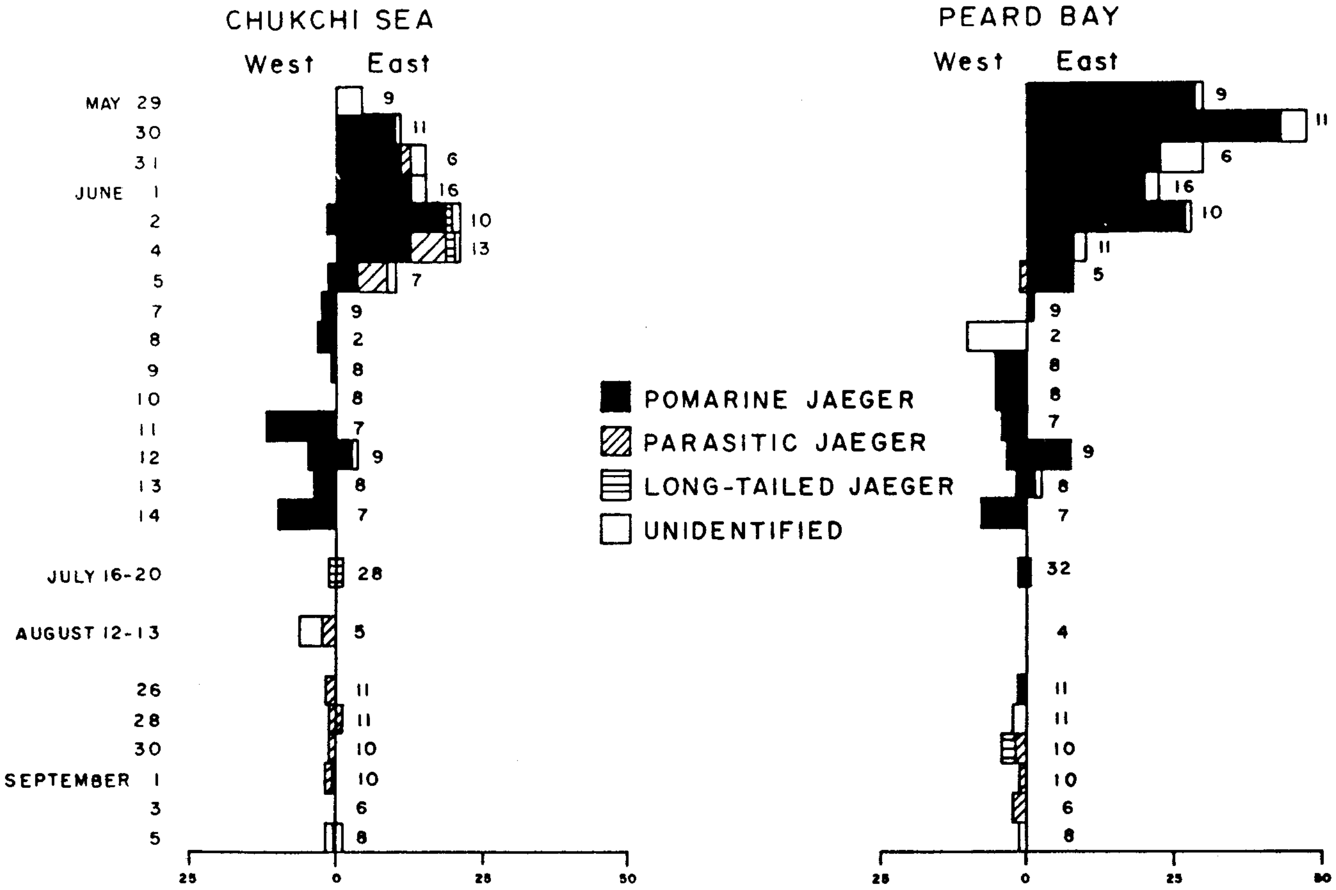

Figure 4-7. Mean Number of Jaegers Migrating Per Hour. Numbers to the right of each bar represent the number of counts that day.

were seen migrating to the west, and by the second week in June a very pronounced westerly migration of pomarine jaegers was in progress over Peard Bay and along the nearshore waters of the Chukchi Sea. At neither migration watch area were major fall migrations of jaegers detected; instead, small numbers of predominantly parasitic jaegers passed to the west at rates of less than 3 birds/h during late August and early September (Figure 4-7).

Gulls and Terns. Five species of gulls and terns (glaucous gull, Sabine's gull (*Xema sabini*), Ross' gull, black-legged kittiwake (*Rissa tridactyla*), and arctic tern) were recorded during migration watches. Only glaucous gulls were observed migrating in spring (2-15 birds/h between 29 May and 5 June; Figure 4-8). Most of these were moving to the east, with smaller numbers seen moving west, and probably represented local, direct movements of birds using the area.

In mid- to late August, westerly fall migration became quite pronounced, with the rate along the Chukchi Sea coast being about seven times greater than that within Peard Bay. Westward migration was fairly steady from 26 August through 3 September, peaking on 28 August (>300 birds/h). Arctic terns were the predominant species, with a maximum rate on 1 September at about 170 birds/h. Black-legged kittiwakes were second most numerous; their westward migration reached a high on 28 August (average 68 birds/h). Peak movement of Sabine's gulls occurred on 3 September, averaging 45 birds/h. During this period there was also a net westerly movement of glaucous gulls (maximum rate of 21 birds/h on 28 August). By 5 September the numbers of gulls and terns migrating west had decreased to 55 birds/h, and the majority of birds appeared to have left the Peard Bay area.

Passerines. Only in spring was there a substantial passage of passerines. During the rest of the season no passerine migration was recorded (Figure 4-9). In spring, 99.6% of the passerines observed were lapland longspurs, whose migration peaked markedly on 31 May. Migration rates on this day averaged about 600 birds/h along the Chukchi Sea coast and about 475 birds/h along the Peard Bay shore. Snow buntings and a varied thrush (*Ixoreus naevius*) were the only other passerines recorded migrating in spring.

4.3.2.2 Habitat Use

Censuses of Terrestrial Habitats. Upon arrival at the study area on 26 May the tundra and salt marsh habitats were approximately 95% snow-covered. By 2 June only 2% of the snow cover remained, streams were flowing, and there were large areas of standing meltwater on the tundra. Lakes were still frozen solid but were covered with meltwater. Notable concentrations of staging birds were not observed on the tundra on this day. A flock of ten Sabine's gulls, two pairs of common eiders, two brant (*Branta bernicla*), and a dozen oldsquaw were recorded on one large meltwater-covered lake. Pectoral sandpipers (*Calidris melanotus*), dunlin, western sandpipers (*C. mauri*), red phalaropes, and semipalmated sandpipers were scattered over the tundra.

On 9 June the most abundant species using tundra habitat on the east side of Peard Bay was the lapland longspur, with densities of 335 birds/km^2 (Table 4-5). Shorebirds as a group were next highest in abundance followed by pectoral sandpipers (124 birds/km^2), semipalmated sandpipers (99 birds/km^2), dunlin (87 birds/km^2), and western sandpipers (62 birds/km^2). Long-billed

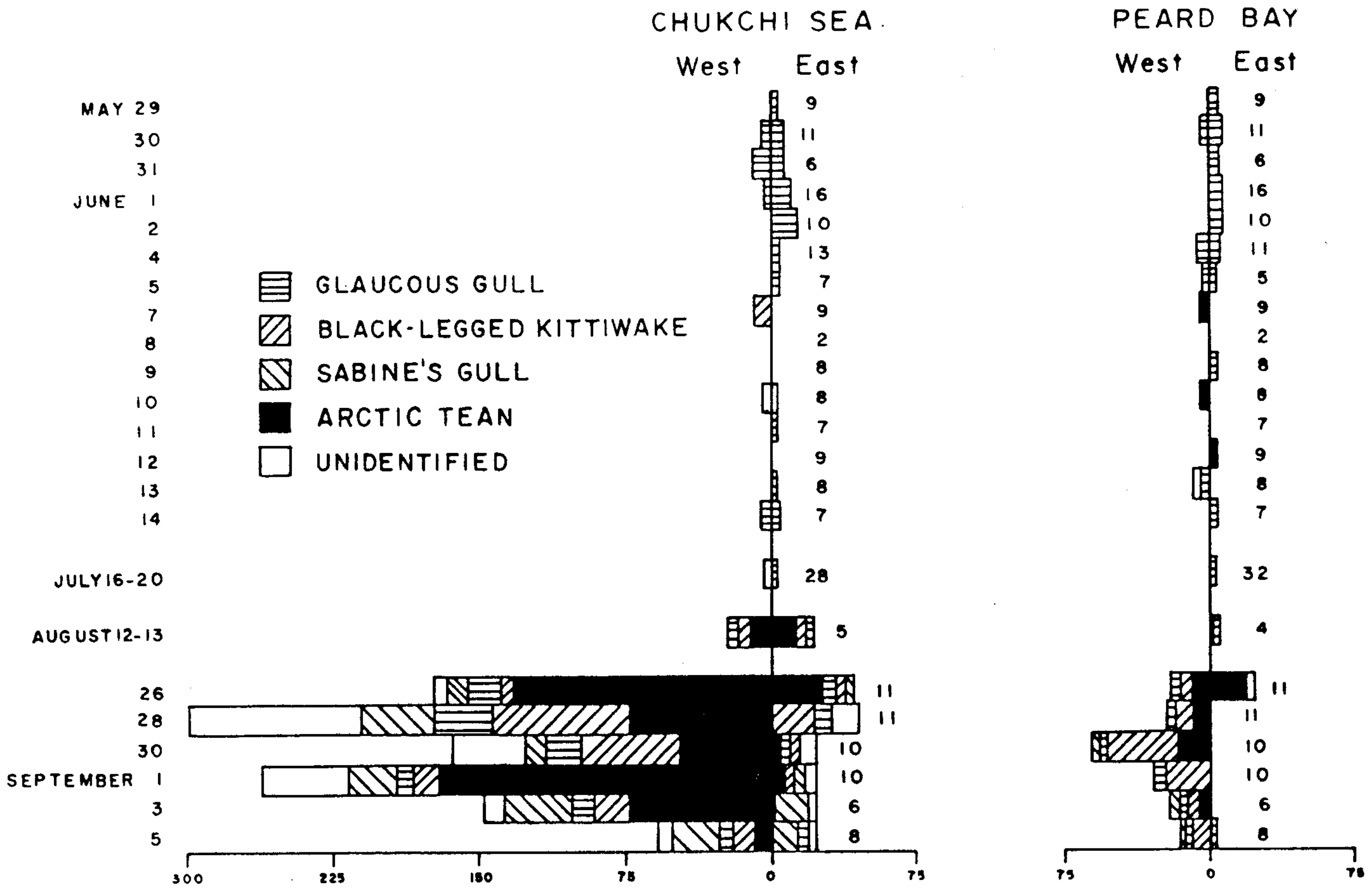

Figure 4-8. Mean Number of Gulls and Terns Migrating Per Hour. Numbers to the right of each bar represent the number of counts that day.

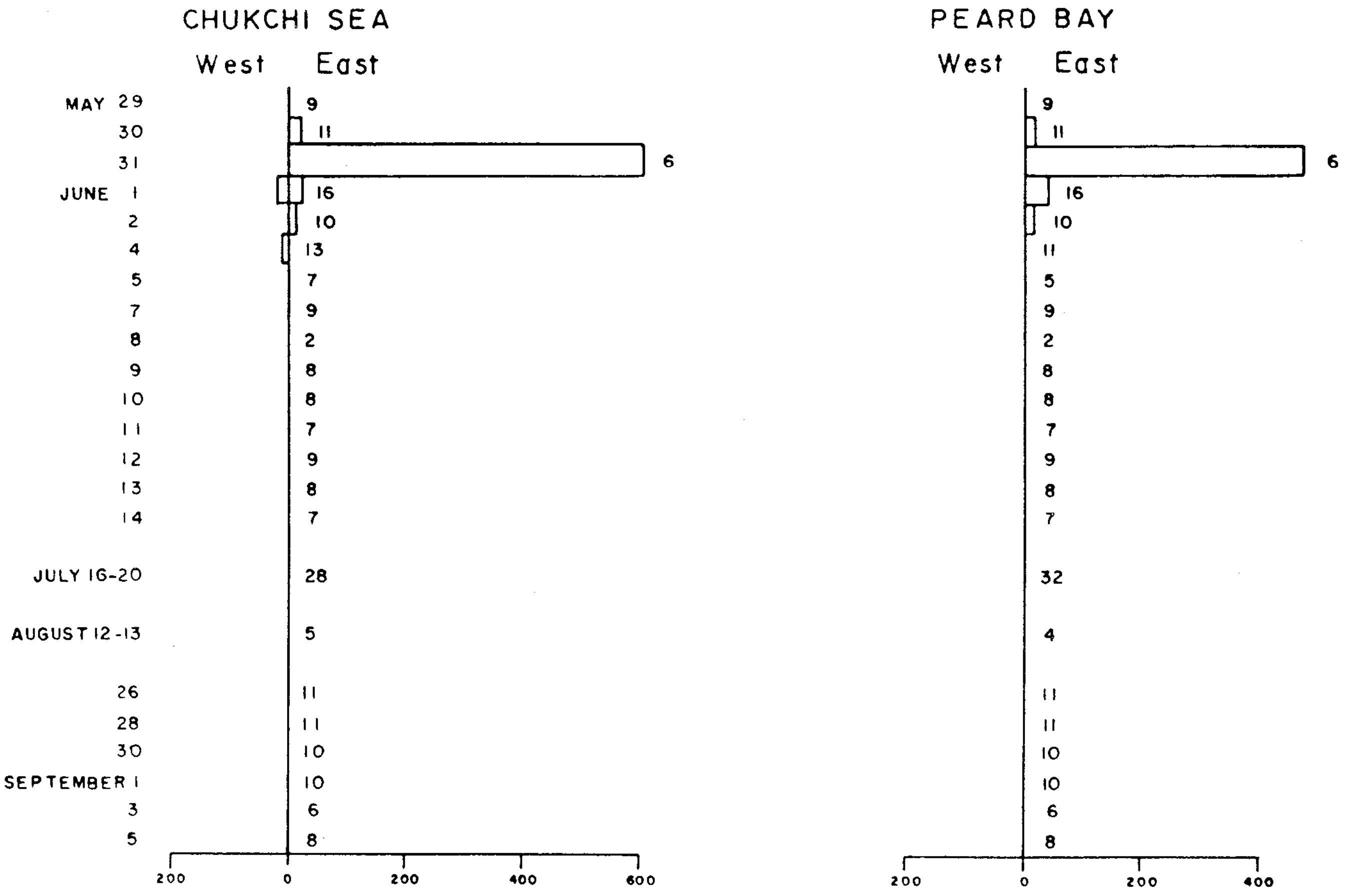

Figure 4-9. Mean Number of Passerines Migrating Per Hour (99.6% Lapland longspurs. Numbers to the right of each bar represent the number of counts that day.

Table 4-5. Densities of birds (/km^2) on tundra and salt marshes of Peard Bay area in 1983. (B) indicates definite breeding record and (PB) indicates probable breeding in that habitat. "Off" indicates species was recorded only off the transect.

Species	Tundra[1]		Salt Marsh I[2]	Salt Marsh II[3]	
	9 Jun	17 Jul	16 Jul	19 Jul	27 Aug
Red-throated loon		off			
Arctic loon		off (B)			
Tundra swan		off			
Brant			4.9 (B)		1,452
Northern pintail	12.4 (PB)	off	3.3		
Common eider			47.5	19.4 (B)	
King eider			8.2		
Steller's eider			8.2		
Oldsquaw	12.4 (PB)	3.6 (B)		135.5 (B)	
Lesser golden plover		off			
Long-billed dowitcher	12.4 (PB)				
Pectoral sandpiper	124.2 (PB)	12.7 (PB)	1.6		
Semipalmated sandpiper	99.4 (B)	0.9 (B)	19.7(B)		
Western sandpiper	62.2 (PB)	6.3 (B)	4.9		6.5
Dunlin	87.0 (PB)	8.2 (PB)	50.8	29.0	
Red phalarope	24.8 (PB)	7.3 (PB)	1.6		
Long-tailed jaeger		off			
Parasitic jaeger		1.8 (PB)			
Glaucous gull		off (B)	3.3		3.2
Arctic tern				58.1 (PB)	3.2
Savannah sparrow			4.9 (PB)		
Lapland longspur	335.4 (B)	31.8 (B)	19.7 (B)		
Snow bunting			6.6 (PB)	3.2	
Total	770.2	71.7	185.2	245.2	1,464.9

[1] On 9 June, 0.16 km^2 of tundra surveyed at east end of Peard Bay near landing strip. On 17 July, 1.1 km^2 of tundra surveyed on peninsula between west end of Peard Bay and Kugrua Bay. Note that to obtain breeding pairs per km^2, numbers must be divided by two.

[2] Salt marsh (0.61 km^2) on Point Franklin spit 10 km west of its base.

[3] Salt marsh (0.31 km^2) on Point Franklin spit 5.6 km west of its base.

dowitchers (*Limnodromus scolopaceus*), red phalaropes, oldsquaw, and northern pintail (*Anas acuta*) were also observed and were suspected of breeding. This information provides an index of breeding densities for this particular area but may differ from those in other parts of the bay.

Two semipalmated sandpiper nests, each with two eggs, and one lapland longspur nest with three eggs were found during this 9 June census. This indicates the beginning of laying for these species. The balance of the birds observed were exhibiting territorial behavior.

On 17 July densities of birds using tundra habitat on the west side of the bay on the peninsula north of Kugrua Bay were much lower than those reported above. On this date the tundra was being used by the first wave of post-breeding birds, adults tending young, and late-nesting species that were incubating eggs. The most abundant species was the lapland longspur, but densities had decreased 10-fold to 31.8 birds/km^2 (Table 4-5). About half (17 of 35) of the birds recorded were young of the year. Densities for all other species were about ten times lower than those recorded on 9 June. Pectoral sandpipers were still second in abundance (12.7 birds/km^2), followed by dunlin, red phalaropes, and western sandpipers. One pair of western sandpipers was tending newly hatched young. Only one semipalmated sandpiper, an adult, was observed, indicating that most of the breeding adults had already departed on southward migration. Low densities of paired red-throated and arctic loons were also observed. One arctic loon nest was found with two eggs being incubated. Scattered female oldsquaw were recorded, including one incubating six eggs, and an adult glaucous gull tending its 3-5 day-old young. Postbreeding flocks of six adult tundra swans (*Cygnus columbianus*) and eight lesser golden plovers (*Pluvialis dominica*) were observed, but off the transect. Female northern pintail and a single long-tailed jaeger were also observed, but off the transect.

By comparison, the two salt marshes on Point Franklin spit supported densities of birds 2-3 times higher than those on the tundra in mid-July (Table 4-5). There was evidence of breeding for brant, common eiders, oldsquaw, semipalmated sandpipers, and lapland longspurs in this habitat. Savannah sparrows (*Passerculus sandwichensis*) and snow buntings were probably breeding, but were not observed doing so. Three adult brant with four downy young (7-10 days old) were observed; three semipalmated sandpiper pairs had young ranging in age from 1-2 days to newly fledged; lapland longspur adults were tending bob-tailed fledglings; and oldsquaw and common eiders were found on eggs. Postbreeding flocks of female eiders (both common and king), male and female oldsquaw, and adult dunlin were also using the salt marshes in mid-July.

By late August the density of birds using the salt marsh had increased dramatically to almost 1,500 birds/km^2, primarily due to the presence of 450 brant. Throughout August and early September this marsh was used steadily by brant, while the numbers of other birds present varied daily. This fluctuation suggests that brant may have been moving through the Peard Bay area to other staging areas.

The sand dunes and beaches of Point Franklin spit, the Seahorse Islands, and the southeastern spit of the bay were also used by nesting birds of a few species (Table 4-6). On Point Franklin spit 20 to 30 pairs of arctic terns were nested, concentrated in small enclaves wherever there were dunes. Egg laying

Table 4-6. Minimum numbers of pairs of major species nesting on sand dunes and beaches of sandspits and barrier islands of the Peard Bay area in 1983.

Species	Point Franklin Spit	Seahorse Islands	Peard Bay Spit[1]
Common eider	2-5	8	UA
Oldsquaw	2-5	0	UA
Glaucous gull	1	0	UA
Arctic tern	20-30	15-20	15
Black guillemot	0	15-40	UA
Sabine's gull	1	UA	UA
Horned puffin	0	1-3	UA

[1] Note that the Peard Bay Spit was surveyed only by air and many species could have been overlooked if they nested in small numbers (UA = unable to assess).

was estimated to have taken place from 23 June to 15 July, by back-dating from the timing of hatch and the age of chicks observed in August and September. An estimated 2 to 5 pairs of oldsquaw and common eiders were observed nesting on the vegetated dunes and in the beachdrift of the spit. Evidence of nests from previous years suggests that at times several dozen eiders may nest on the spit. A single glaucous gull pair nested on the long, narrow protrusion from the spit on the Peard Bay side and one pair of Sabine's gulls may have nested in some dunes with arctic terns.

Although not visited until 13 August to avoid interfering with subsistence activities, the Seahorse Islands were found to be quite productive. On that date 15 to 20 pairs of arctic terns were incubating eggs or tending chicks (up to 14 days old). They were concentrated among debris on a flat sandy area west of the prominent dunes on the island. A flock of about 200 adults was roosting on the tip of the island, and some young may have already fledged from the nests on the island prior to our visit. There was a flock of 26 adult and 30 hatching-year Sabine's gulls on the island, but no adults were observed with eggs or chicks and no evidence was found of breeding. A total of 84 adult black guillemots were observed on the island and a cluster of 15 active nests was found in a 150 m^2 area of driftwood. Of these nests, one had two eggs, one was hatching, and the others all had newly hatched young. The mean clutch or brood size was 1.8 young per nest (sd = 0.56, n = 15). Three prominent burrows in a large dune in the vicinity of the guillemot colony were noted, but activity was not noted. Adult horned puffins *(Fratercula corniculata)* were seen flying about the north portion of the bay throughout the summer (cf. Divoky 1978b) and it is suspected that these burrows might have been used by the puffins.

A cluster of eight nests of common eiders was also found in the dunes. All but one of them had been deserted even though all contained eggs. The clutch size ranged from 3 to 6 eggs with a mean of 4.4 ± 1.3 eggs per nest. It is not known why or when the nests were deserted.

Table 4-7. Mean numbers and behaviors of birds recorded during sweep counts of Peard Bay, 16-20 July 1983.

Species	No./Count		Percent of Birds			
	Mean	S.D.	Fly	Mill	Rest	Feed
Arctic loon	10.4	15.03	7.2	3.6	89.2	-
Yellow-billed loon	0.3	0.68	-	-	100.0	-
Total loons	10.7	15.04	7.0	3.5	89.3	-
Common eider	3.5	7.05	0.8	-	92.9	6.3
King eider	22.3	57.97	72.6	-	6.6	20.8
Spectacled eider	0.1	0.55	-	-	100.0	-
Steller's eider	0.2	0.87	-	-	100.0	-
Oldsquaw	49.1	80.53	14.7	14.5	70.8	-
Total eiders	52.9	96.97	66.6	-	24.2	9.1
Total waterfowl	181.0	172.42	26.2	3.9	67.1	2.7
Red phalarope	1.3	3.30	-	17.0	4.9	78.1
Long-tailed jaeger	<0.1	0.18	100.0	-	-	-
Glaucous gull	2.8	4.64	18.2	24.0	44.4	12.4
Sabine's gull	0.1	0.71	-	-	-	100.0
Arctic tern	3.4	3.97	0.9	6.4	27.6	65.3
Total gulls & terns	6.3	7.54	8.4	14.0	34.3	42.7
Black guillemot	0.5	1.57	6.3	50.0	43.7	-
Total birds	199.8	180.89	24.5	4.4	66.8	4.3

Counts taken from Point Franklin spit (n = 32 counts).

S.D. = standard deviation.

Table 4-8. Mean numbers and behaviors of birds recorded during sweep counts of Peard Bay, 12-13 August 1983.

Species	No./Count		Percent of Birds			
	Mean	S.D.	Fly	Mill	Rest	Feed
King eider	0.5	0.58	-	-	50.0	50.0
Oldsquaw	47.0	31.35	-	-	100.0	-
Total eiders	0.5	0.58	-	-	50.0	50.0
Total waterfowl	47.5	31.10	-	-	99.5	0.5
Red phalarope	5.8	8.88	87.0	8.7	4.3	-
Glaucous gull	11.5	13.67	-	-	100.0	-
Black-legged kittiwake	0.8	0.96	100.0	-	-	-
Sabine's gull	2.3	2.06	-	-	100.0	-
Arctic tern	87.0	120.93	1.7	0.6	62.9	34.8
Total gulls & terns	101.8	109.41	2.2	0.5	67.5	29.7
Thick-billed murre	0.3	0.50	-	-	100.0	-
Black guillemot	0.3	0.50	-	-	100.0	-
Total alcids	0.5	0.58	-	-	100.0	-
Total birds	155.3	90.99	4.7	0.6	75.0	19.6

Counts taken from Point Franklin spit (n = 4 counts).

S.D. = standard deviation.

On 15 July during the aerial survey, a colony of approximately 15 pairs of arctic terns was recorded nesting near the Peard N Base benchmark on the spit at the southeastern end of the bay. It is not known if other species nested in this area because of an inability to census the area from the ground.

<u>Sweep Counts</u>. Beginning in mid-July, when the ice was beginning to leave Peard Bay and birds were beginning to use the open waters, all sweep censuses (11.5 km^2) were conducted. These sweeps were performed to assess seasonal changes in waterbird densities, species composition, and behavior. In mid-July an average of 200 birds per sweep was attained (Table 4-7). In mid-August the mean was lower, 155 birds per sweep, but not significantly so, because of the large variation in the numbers of birds recorded during each count (Table 4-8). In late August and early September, an average of over 550 birds per sweep was recorded (Table 4-9), significantly higher than the mean in either mid-July or mid-August ($p<0.001$).

During all three periods most of the birds in this area (60-75%) were involved in resting or maintenance behaviors, e.g., preening, swimming, and roosting (Tables 4-7, 4-8, 4-9). In mid-July about equal numbers (4%) were recorded milling in the area and actively feeding (Table 4-7). In mid-August the proportion feeding increased to about 20%, mainly because of the regular

Table 4-9. Mean numbers and behaviors of birds recorded during sweep counts of Peard Bay, 26 August to 5 September 1983.

Species	No./Count		Percent of Birds			
	Mean	S.D.	Fly	Mill	Rest	Feed
Arctic loon	0.8	1.92	80.0	-	20.0	-
Yellow-billed loon	0.1	0.39	-	-	100.0	-
Total loons	1.7	2.76	82.6	-	17.8	-
Northern fulmar	0.3	0.73	78.6	-	21.4	-
Short-tailed shearwater	30.7	125.58	93.0	1.1	5.1	0.8
Total procellarids	31.0	125.57	92.8	1.1	5.3	0.8
King eider	4.9	9.13	10.4	-	89.6	-
Spectacled eider	0.2	0.98	70.0	-	30.0	-
Oldsquaw	497.3	576.19	8.9	27.2	63.9	<0.1
Total eiders	16.6	55.55	65.5	-	34.1	0.4
Total waterfowl	529.1	584.03	10.4	23.2	57.0	<0.1
Red phalarope	1.0	2.43	79.0	-	21.0	-
Total shorebirds	1.3	2.84	82.5	-	17.5	-
Pomarine jaeger	0.1	0.30	100.0	-	-	-
Parasitic jaeger	<0.1	0.19	100.0	-	-	-
Total jaegers	0.1	0.43	100.0	-	-	-
Glaucous gull	1.1	1.33	36.1	27.5	31.0	5.4
Black-legged kittiwake	0.9	1.83	98.0	-	2.0	-
Sabine's gull	0.4	1.30	91.3	4.4	-	4.4
Arctic tern	1.7	5.74	69.2	-	-	30.8
Total gulls & terns	4.2	6.34	69.6	7.4	8.3	14.3
Thick-billed murre	0.2	0.74	100.0	-	-	-
Total birds	567.8	575.77	16.8	24.0	59.0	0.2

Counts taken from Point Franklin spit (n = 55 counts).

S.D. = standard deviation.

occurrence of feeding flocks of arctic terns in the area (Table 4-8). In late August the proportion of birds recorded milling in the area increased to 24% largely because of the influx of oldsquaw (Table 4-9).

When the behaviors of individual species during the three periods are compared (Table 4-10), it becomes apparent that for most species the percent of the birds spending time in the area (i.e., not actively migrating through) decreased as the season progressed. This was particularly apparent for loons, phalaropes, gulls, terns, and alcids. In contrast, however, the proportions of sedentary eiders and oldsquaw increased as the season progressed and as the numbers of individuals within the bay increased (Table 4-10).

When densities of various species are compared for the three periods (Table 4-10), patterns similar to those found from the aerial surveys, migration counts, and shoreline counts become evident. Densities of loons were highest in mid-July, when they often gathered in substantial numbers near the distal end of Point Franklin spit. During late August and early September an influx of short-tailed shearwaters and northern fulmars into the bay was recorded but only 7% of these were feeding, resting, or milling in the area.

Waterfowl by far dominated in numbers during all three periods, peaking at the end of the season. Red phalaropes showed a peak in numbers in mid-August, when juveniles were passing through in large numbers. Jaegers of all three species were observed sporadically in very low numbers. Gulls and terns showed a characteristically marked peak in mid-August, with arctic terns dominating in numbers. Finally, very few alcids were recorded using the area, black guillemots early on and thick-billed murres later in the season. Combining all species of birds, densities averaged 17.4, 13.5, and 49.4 birds/km^2 during mid-July, mid-August, and early September, respectively. This was mainly due to the increase in numbers of oldsquaw using the bay.

<u>Aerial Surveys</u>. Aerial surveys were conducted four times during the season to determine the timing of ice breakup in the bay and to correlate the densities and distribution of birds using the area with observations from the land-based studies.

During the 8 June aerial survey, Peard and Kugrua Bays were completely ice-covered except for a narrow, discontinuous band of open water along the south side of Point Franklin spit. No birds were recorded using the bays. By 15 July Peard Bay was still 90% ice-covered, but meltwater had begun to form on the surface and there were extensive open-water areas along the shore of both Peard and Kugrua Bays. Only a few oldsquaw (0.2 birds/km^2) were observed on transects across Peard Bay (Table 4-11), but several species had begun to use the open waters along the shore, particularly glaucous gulls, oldsquaw, arctic terns, and eiders (Table 4-12). Kugrua Bay, which was 40-60% ice-free, supported the greatest number of birds and had the second highest lineal density of birds using the shoreline of the study area (Table 4-12). The spit at the southeastern end of Peard Bay supported the highest lineal density (4.6 birds/km) on the survey because arctic terns were concentrated there. For all areas an average of 1.57 birds/m^2 was recorded on 15 July (Table 4-12). Based on densities of birds using the center of the bay and the shoreline, a population of 275 birds was estimated to be using Peard and Kugrua Bays on 15 July (Table 4-13).

Table 4-10. Mean densities of birds recorded during sweep counts of Peard Bay from Point Franklin spit and the percentage of the birds not actively migrating during each survey period. Number of sweep counts during the three survey periods were 32, 4 and 55.

Species	Mean density (No./km^2)		Percent of Birds not Migrating			
	16-20 July	12-13 Aug	26 Aug -5 Sep	16-20 July	12-13 Aug	26 Aug -5 Sep
Arctic loon	0.90	-	0.07	92.8	-	20.0
Yellow-billed loon	0.02	-	0.01	100.0	-	-
Total loons	0.92	-	0.15	93.0	-	17.4
Northern fulmar	-	-	0.02	-	-	21.4
Short-tailed shearwater	-	-	2.67	-	-	7.0
Total procellarids	-	-	2.69	-	-	7.2
Common eider	0.31	-	-	99.2	-	-
King eider	1.94	0.04	0.43	27.4	100.0	89.6
Spectacled eider	0.01	-	0.02	-	-	30.0
Steller's eider	0.02	-	-	100.0	-	-
Oldsquaw	4.27	4.09	43.24	85.3	100.0	91.1
Total eiders	4.60	0.04	1.45	33.4	100.0	34.5
Total waterfowl	15.74	4.13	46.00	73.8	100.0	89.6
Red phalarope	0.11	0.50	0.09	100.0	13.0	21.0
Total shorebirds	0.11	0.50	0.11	100.0	13.0	17.5
Pomarine jaeger	-	-	<0.01	-	-	0
Parasitic jaeger	-	-	0.01	-	-	0
Long-tailed jaeger	<0.01	-	-	0	-	-
Total jaegers	<0.01	-	0.01	0	-	0
Glaucous gull	0.24	1.00	0.09	81.8	100.0	63.9
Black-legged kittiwake	-	0.07	0.08	-	0	2.0
Sabine's gull	0.01	0.22	0.04	-	100.0	8.7
Arctic tern	0.30	7.56	0.15	99.1	98.3	30.8
Total gulls & terns	0.55	8.85	0.36	91.6	97.8	30.4
Thick-billed murre	-	0.02	0.02	-	100.0	0
Black guillemot	0.04	0.02	-	93.7	100.0	-
Total alcids	0.04	0.04	0.02	93.7	100.0	0
Total birds	17.37	13.50	49.37	75.5	95.3	83.2

Table 4-11. Numbers and densities (birds/km^2) of birds recorded during aerial survey of open waters of Peard Bay on 15 July 1983.[1]

Species	Transect Number						Total	
	1	2	3	4	5	6	No.	Density
Oldsquaw	5	0	0	*	*	0	5	(0.2)
Total	5	0	0			0	5	(0.2)

[1] Peard Bay was 90% ice-covered this date.

*Transect not surveyed.

Table 4-12. Number of birds recorded during aerial survey of the shoreline of Peard Bay on 15 July 1983. Numbers in parentheses represent birds per km of shoreline.

Species	Shoreline Census Area								Total	
	1	2	3	4	5	6	7	8	No.	No./km
Arctic loon		3							3	(0.02)
Unidentified eider		1		5	29				5	(0.25)
Oldsquaw					35	2	6		43	(0.30)
Glaucous gull		8		1	74	2	9		94	(0.67)
Arctic tern		1			1		37		39	(0.27)
Black guillemot							8		8	(0.06)
Total No.	0	13	0	6	139	4	60	0	222	(1.57)
No./km		(0.5)		(1.2)	(3.9)	(0.1)	(4.6)			

Table 4-13. Estimates of the size of the bird populations using the Peard Bay area during aerial surveys in 1983.

Species	Estimated Number of Birds		
	July 15	August 10	August 25
Greater white-fronted goose	0	350	200
Brant	0	75	600
Eiders	35	2,520	4,180
Oldsquaw	95	2,330	6,930
Northern pintail	0	200	10
Red phalarope	0	130	35
Glaucous gull	95	970	680
Black-legged kittiwake	0	3,760	10
Arctic tern	40	2,180	500
Other species	10	120	35
Total	275	12,635	13,180

During the survey on 10 August, when Peard Bay was totally ice-free, birds were recorded on five of six open-water transects of the bay, averaging 19.8 birds/km^2, or about 1,700 birds using the bay. Of the birds observed on the open-water transects, 84% were unidentified brown eiders, 5% arctic terns, and 5% oldsquaw (Table 4-14). On the shoreline transects 17 species, representing about 10,000 birds, were recorded. An average of 72 birds/km was recorded for all shoreline census areas (Table 4-15). The majority of these were black-legged kittiwakes (37%), oldsquaw (22%), and arctic terns (20%). Large flocks of black-legged kittiwakes, arctic terns, and glaucous gulls were found roosting at the distal end of Point Franklin spit, on the spit at the southeastern end of the bay, and along the Seahorse Islands. Oldsquaw were most concentrated near small points of land projecting from the southeastern shore of Peard Bay. Oldsquaw were also found in Kugrua Bay and along the south side of Point Franklin spit, where king eiders concentrated (Table 4-15). A flock of 350 greater white-fronted geese (*Anser albifrons*) and lesser numbers of brant and northern pintail were observed using Kugrua Bay.

By late August a noticeable increase was detected in the number of birds using the open waters of Peard Bay. On the 25 August survey an average of 86.5 birds/km^2 was recorded (Table 4-16), projecting to about 7,500 birds using the open waters of the bay. The majority of these were oldsquaw (61%) and eiders (38%). The increase in bird use of open waters in late August coincided with a marked decrease in bird use of shoreline areas of Peard and Kugrua Bays (Table 4-17). On the 25 August survey 2,200 birds were recorded along the shoreline for an average of 16 birds/km of shore, approximately 20%

Table 4-14. Numbers and densities (birds/km^2) of birds recorded during aerial survey of open waters of Peard Bay on 10 August 1983.

Species	Transect number						Total	
	1	2	3	4	5	6	No.	Density
Arctic loon		6					6	(0.3)
Unid. loon			2				2	(0.1)
Unid. eider		11	6		350		367	(16.2)
Oldsquaw		20					20	(0.9)
Red phalarope			3			1	4	(0.2)
Glaucous gull				2	3		5	(0.2)
Arctic tern				19		4	23	(1.0)
Thick-billed murre						9	9	(0.4)
Total number	0	37	11	21	353	14	436	(19.8)
Density		(11.6)	(2.4)	(4.1)	(75.3)	(4.6)		

of the lineal density found on 10 August. This was not simply a seasonal movement of birds from the shoreline to open waters, but instead mainly reflected a change in the composition of species using Peard Bay and different habitat use. Although the total number of birds in the Peard Bay area was 12,000-13,000 on both 10 and 25 August, the dominant species varied greatly. Large numbers of black-legged kittiwakes and arctic terns were found in nearshore areas on 10 August while on 25 August oldsquaw and eiders dominated (Table 4-13).

<u>Shoreline Transects</u>. Ninety-one transects, totaling about 310 km, were run during late summer (Table 4-2). Primarily due to difficult access at high tide, about 40% fewer transects were run along the Peard Bay side (n = 34) of Point Franklin spit than along the Chukchi Sea side (n = 57). During the three observation periods, noticeable changes occurred in the numbers of birds using the area, both in species composition and in spatial distribution (Table 4-18).

The shore and nearshore waters of the Peard Bay side of the spit supported moderate densities of birds (24-28 birds/km) in both mid-July and late August - early September, and peaked in use in mid-August (43 birds/km; Table 4-18). In contrast, use of the Chukchi Sea side of the spit was very low in mid-July (4 birds/km), when the pack ice still covered most of the offshore areas and the shoreline was sometimes inundated with brash ice. After the ice cleared from the area, the density of birds using the Chukchi Sea side steadily increased, reaching a density about equal to that on the Peard Bay side in mid-August (40 birds/km), and far surpassing densities on the Peard Bay side in fall (60 birds/km).

Table 4-15. Number of birds recorded during aerial survey on the shoreline of Peard Bay on 10 August 1983. Numbers in parentheses represent birds per km of shore.

Species	Shoreline Census Area								Total	
	1	2	3	4	5	6	7	8	No.	No./km
Red-throated loon	1								1	(0.01)
Arctic loon					11				11	(0.08)
G. white-fronted goose					350				350	(2.47)
Brant			3	10	60				75	(0.53)
Common eider	1				2	40			43	(0.30)
King eider	2	150							152	(1.07)
Unidentified eider	4	12	8			1	250		275	(1.94)
Northern pintail					116	90			206	(1.45)
Oldsquaw	3	370			542	1307			2222	(15.66)
Black-bellied plover					1				1	(0.01)
Red phalarope	93	2		2			7	3	107	(0.75)
Unid. shorebird					1				1	(0.01)
Glaucous gull	179	139	94	1	29	13	435	51	941	(6.63)
Black-l. kittiwake	26		20				2180	1529	3755	(26.46)
Sabine's gull	4								4	(0.03)
Arctic tern	427	42	4	1	3		301	1276	2054	(14.48)
Thick-billed murre						7			7	(0.05)
Black guillemot								4	4	(0.03)
Total No.	740	715	131	14	1115	1458	3173	2863	10,209	(71.95)
No./km.	(32.3)	(29.4)	(16.9)	(2.9)	(31)	(49.5)	(242)	(889.1)		

Table 4-16. Numbers and densities (birds/km^2) of birds recorded during aerial survey of open waters of Peard Bay on 25 August 1983.

Species	Transect number						Total	
	1	2	3	4	5	6	No.	Density
Arctic loon		3	1	1			5	(0.2)
Unid. eider	350	363			34		747	(32.9)
Oldsquaw				400	806		1206	(53.1)
Red phalarope			1				1	(0.1)
Glaucous gull					2		2	(0.1)
Arctic tern			2				2	(0.1)
Total number	350	366	4	401	842	0	1963	(86.5)
Density	(175.0)	(114.3)	(0.8)	(77.1)	(179.1)	(0)		

Table 4-17. Number of birds recorded during aerial survey of the shoreline of Peard Bay on 25 August 1983. Numbers in parentheses represent birds per km of shore.

Species	Shoreline Census Area								Total	
	1	2	3	4	5	6	7	8	No.	No./km
Arctic loon				1	2	2			5	(0.04)
Yellow-billed loon						3			3	(0.02)
G. white-fronted goose			4		195				199	(1.40)
Brant		151			426	19	6		602	(4.24)
King eider				5					5	(0.04)
Unidentified eider		2			5				7	(0.05)
Northern pintail					9				9	(0.06)
Oldsquaw		75			8	30	90		203	(1.43)
Red phalarope						1	12	15	28	(0.20)
Unid. shorebird						2			2	(0.01)
Glaucous gull	336	219		38	21	2	58		674	(4.75)
Black-l. kittiwake							9	3	12	(0.08)
Arctic tern	8	51	3	1	50	2	364	11	490	(3.45)
Total No.	344	498	7	45	716	61	539	29	2239	(15.78)
No./km	(15)	(20.4)	(0.9)	(9)	(19.9)	(2.1)	(41.1)	(9.6)		

Table 4-18. Mean number of birds observed per km of shoreline during transects of the Peard Bay (PB) and Chukchi Sea (CS) sides of Point Franklin spit, 15 July-7 September 1983.

	Census Period					
	15-20 Jul		10-14 Aug		25 Aug-7 Sep	
Species	PB	CS	PB	CS	PB	CS
Red-throated loon					.02	.01
Arctic loon	2.69	.31			.02	.09
Yellow-billed loon	.02				.07	
Unidentified loon	.02					
Short-tailed shearwater					.02	.09
Brant	.24		4.41		1.85	.01
Common eider	2.31	.60		.04		
King eider	2.65	.12	5.51		5.36	10.50
Spectacled eider						.06
Steller's eider		.13				
Unidentified eider	.81				2.84	
Oldsquaw	5.96	.65	.49	.04	1.99	25.90
Red-breasted merganser	.03				.02	
Unidentified waterfowl		.10				
Golden eagle						.01
Peregrine falcon				.04		
Gyrfalcon						.01
Black-bellied plover		.01				
Sanderling		.01	.08	.29	.21	.30
Semipalmated sindpiper	.02					
Western sandpiper			1.48	.24	.05	
Pectoral sandpiper	.07					
Dunlin	.42	.03	5.55	1.08	1.04	.26
Red phalarope	1.07	1.34	7.57	20.84	.83	2.68
Parasitic jaeger		.01	.08			.04
Long-tailed jaeger	.03					
Herring gull						.01
Slaty-backed gull						.01
Glaucous gull	10.83	.33	6.39	3.43	5.08	8.89
Black-legged kittiwake			.27	6.57	.07	.44
Ross' gull						.01
Sabine's gull	.41		.27	.52	2.87	4.08
Arctic tern	.39	.17	9.51	7.17	1.29	6.07
Thick-billed murre					.02	
Black guillemot		.09	.11			
Lapland longspur			.57		.05	.10
Snow bunting	.02					
Total for All Species	27.99	3.91	42.29	40.26	23.70	59.57

These seasonal changes primarily reflected variances in species composition. In spring, glaucous gulls, oldsquaw, king eiders, and common eiders comprised about 80% of the birds along the Peard Bay shore of the spit. By mid-August there was a marked influx of red phalaropes (primarily juveniles), arctic terns, and black-legged kittiwakes using both sides of the spit about evenly. By late August most of the red phalaropes and black-legged kittiwakes had left the area and densities of arctic terns had decreased. The abrupt increase in use of the Chukchi Sea shoreline during this period was mainly due to an increase in oldsquaw, king eiders, and Sabine's gulls. Densities of glaucous gulls increased slightly, although their numbers remained fairly steady throughout the summer.

4.3.3 Feeding Studies

4.3.3.1 Oldsquaw

Between 12 August and 5 September, 26 oldsquaw (22 adult males, three adult females, and one juvenile female; Table 4-3) were collected from five sites scattered throughout Peard and Kugrua Bays (Figure 4-3). Among the stomachs eight (31%) were full, three (12%) were 3/4 full, four (15%) were 1/4 full, and 11 (42%) were less than 1/4 full. A total of 27 taxa of prey was identified from all stomachs (Appendix 4-A). All stomachs contained one or more identifiable taxa of prey and averaged 4.0 ± 3.0 (range = 1-13) taxa per stomach.

The diet of oldsquaw collected in Peard Bay was dominated by a single species of amphipod, *Atylus carinatus*, comprising over half the total numbers and volume of prey and occurring in almost half of the stomachs (Table 4-19). Next in importance according to both the point-method of Griffiths et al. (1975) and the IRI method of Pinkas et al. (1971) were bivalves and fish (Table 4-20). The fish were exclusively fourhorn sculpins (*Myoxocephalus quadricornis*), and were over twice the size (24.0 mm ± 10.4) of the amphipods (11.7 mm ± 4.5) eaten (Table 4-21). The bivalves were represented by five different species (Appendix 4-A), and were dominated by *Musculus corrugatus* and *Cyrtodaria kurriana*. The rest of the diet consisted of gastropods (2.2%), polychaetes (2.8%), mysids (0.7%), and isopods (0.2%).

4.3.3.2 Eiders

Three king and five spectacled eiders were collected between 12 and 31 August at two feeding sites within Peard Bay (Figure 4-3; Table 4-3). Because so few birds were collected and their prey selection was very similar, the two eider species were treated as a group. Equal numbers (2, 25%) of the stomachs were full, 1/2 full, 1/4 full, and less than 1/4 full. A total of 18 taxa was identified (Appendix 4-A). All stomachs contained identifiable foods and they averaged 4.6 ± 2.1 (range = 2-8) taxa per stomach.

As with oldsquaw, the amphipod *Atylus carinatus* was singularly important, comprising over half the total numbers and volume of prey and occurring in half the stomachs (Table 4-22). The average size taken (15.9 mm ± 4.5) was significantly larger ($p < 0.001$) than those taken by oldsquaw (Table 4-21). Neither fish nor bivalves were particularly important to eiders; instead,

Table 4-19. Percent occurrence, number and volume of taxa of prey identified in stomachs of oldsquaw collected from Peard Bay in 1983 (n = 26 stomachs).

Taxon	Number of stomachs	Number of prey	Vol. (ml)	Percent (%) No.	Percent (%) Occ.	Percent (%) Vol.
Amphipods	11	752	156.5	55.4	42.3	56.0
Atylus carinatus	11	736	155.1	54.2	42.3	55.4
Fish	14	170	66.7	12.5	53.8	23.8
Bivalves	13	222	37.9	16.3	50.0	13.6
Gastropods	9	67	6.3	4.9	34.6	2.2
Ostracods	6	80	0.6	5.9	23.1	0.2
Polychaetes	6	20	9.0	1.5	23.1	3.2
Mysids	7	31	1.5	2.3	26.9	0.5
Isopods	1	13	1.0	1.0	3.8	0.4
Hydroids	2	2	0.2	0.1	7.7	0.1
Total		1,357	279.8	99.9		99.9

Table 4-20. A comparison of two methods to estimate the relative importance of different prey in the diets of oldsquaw, eider, arctic tern and red phalarope at Peard Bay during 1983.

Taxa	Oldsquaw n=26		Eiders n=8		Arctic tern n=14		Red phalarope n=20	
	Vol.[1] (%)	IRI[2] (%)	Vol. (%)	IRI (%)	Vol. (%)	IRI (%)	Vol. (%)	IRI (%)
Amphipods	54.3	53.9	58.7	58.2	24.7	9.2	56.3	85.7
Atylus carinatus		53.0		57.3		<0.1		0.0
Leptamphopus sp.								41.0
Fish	17.7	22.4	0.3	1.2	61.7	88.3	14.5	4.1
Myoxocephalus		22.4				53.5		
Boreogadus						5.9		
Bivalves	21.7	17.1	4.2	3.4			2.0	0.2
Gastropods	2.2	2.8	9.4	27.8				
Polychaetes	2.8	1.2	20.2	7.9			8.3	1.8
Priapulids			4.3	0.9				
Mysids	0.7	0.9	0.1	0.1			6.0	0.6
Ostracods	0.3	1.6	<0.1	<0.1				
Isopods	0.2	0.1	0.7	0.4			0.5	0.2
Copepods					9.0	2.3		
Insects					1.8	0.1	7.3	5.3
Hydroids	<0.1	<0.1						
Seeds					2.7	0.1	4.0	2.0
Plants			1.1	<0.1			1.0	0.2
Total	99.9	100.0	99.9	99.9	99.9	100.0	99.9	100.1

[1] Percent estimated volume after Griffiths et al. (1975). Total points for oldsquaw = 258, for eiders = 92.5, for arctic terns = 92.5, for red phalaropes = 125.

[2] IRI values after Pinkas et al. (1971). Total points for oldsquaw = 8,738; for eiders = 10,056; for arctic terns = 5,342; for red phalaropes = 10,153.

Table 4-21. Length (mm) of measurable prey items found in stomachs of oldsquaw and eiders collected in Peard Bay in 1983. S.D = Standard Deviation.

		Oldsquaw			Eider	
Prey	n	Mean±S.D.	range	n	Mean±S.D.	range
Polychaeta						
Nephthys sp.				5	144.0±77.1	90.0-280.0
Gastropoda						
Bittium sp.	11	4.1±2.0	1.8-7.8			
Colus sp.				5	6.1±1.1	4.6-7.2
Oenopota sp.	6	4.3±1.2	3.2-6.2			
Polinices sp.				3	11.5±3.6	7.8-15.0
Cylichna occulta				35	3.8±0.9	1.3-5.2
Bivalvia						
Mysella tumida	13	2.1±1.1	1.0-4.2	1	2.2	
Liocyma fluctuosa	25	2.1±1.6	0.6-1.4			
Musculus corrugatus	93	5.2±1.4	1.8-8.4			
Cyrtodaria kurriana	12	15.1±2.1	12.0-17.5			
Mysidae						
Mysis sp.	12	12.7±5.6	9.1-28.6	1	19.0	
Isopoda						
Saduria entomon	7	3.6±0.3	3.1-3.9	1	24.8	
Amphipoda						
Atylus carinatus	250	11.7±4.5	4.6-26.0	101	15.9±4.5	3.8-24.7
Pontoporeia femorata				2	5.9±0.9	5.2-6.5
Priapulidae						
Priapulis caudatus				3	53.3±2.9	50.0-55.0
Osteichthyes						
Myoxocephalus quadricornis	64	24.0±10.4	16.9-70.0			

Table 4-22. Percent occurrence, number and volume of taxa of prey identified in stomachs of king and spectacled eiders collected from Peard Bay in 1983 (n = 8 stomachs).

Taxon	Number of stomachs	Number of prey	Vol. (ml)	Percent (%) No.	Percent (%) Occ.	Percent (%) Vol.
Amphipods	4	188	60.1	64.8	50.0	52.3
Atylus carinatus	4	183	60.0	63.1	50.0	52.2
Gastropods	7	64	11.4	22.1	87.5	9.9
Polychaetes	2	11	32.0	3.8	25.0	27.8
Bivalves	6	10	1.3	3.5	75.0	1.1
Fish	3	8	0.3	2.8	37.5	0.3
Priapulids	1	3	7.0	1.0	12.5	6.1
Plants	2	2	1.3	0.7	25.0	1.1
Isopods	2	2	1.3	0.7	25.0	1.1
Mysids	1	1	0.1	0.3	12.5	0.1
Ostracods	1	1	0.1	0.3	12.5	0.1
Total		290	114.9	100.0		99.9

gastropods (primarily *Cylichna occulta* and *Polinices pallida*) and polychaetes of the genus *Nephthys* ranked next in importance (Table 4-20). The polychaetes were quite large, averaging 144.0 mm (±77.1) in length (Table 4-21). Other prey of minor importance included three species of bivalves, the isopod *Saduria entomon*, mysids, the priapulid *Priapulis caudatus*, and plant parts.

4.3.3.3 Arctic tern

Ten adult males and four juvenile females of this species were collected on 13 and 29 August (Table 4-3). All were collected from flocks of birds actively feeding within a 3-km radius of Point Franklin. Among the stomachs one (7%) was 3/4 full, three (21%) were 1/2 full, seven (50%) were 1/4 full, and three (21%) were less than 1/4 full when collected. A total of nine taxa comprised identifiable prey. Each stomach contained an average of 2.1 ± 0.9 (range = 1-4) taxa.

The diet of arctic terns was heavily dominated by fish, primarily fourhorn sculpin, although Arctic cod (*Boreogadus saida*) were also eaten (Table 4-20). Fish occurred in 93% of the stomachs and comprised 70% of the numbers and 76% of the volume of the prey taken (Table 4-23). Gammarid amphipods were second in importance as prey (Table 4-20), although those of the genera *Leptamphopus* and *Onisimus* were taken more frequently than *Atylus carinatus*. Calanoid and harpacticoid copepods, seeds, and insects (adult Diptera) formed the rest of the identifiable diet. *Leptamphopus* averaged about 6 mm and the copepods about 1 mm (Table 4-24).

Table 4-23. Percent occurrence, number and volume of taxa of prey identified in stomachs of arctic terns collected from Peard Bay in 1983 (n = 14 stomachs).

Taxon	Number of stomachs	Number of prey	Vol. (ml)	Percent (%) No.	Percent (%) Occ.	Percent (%) Vol.
Fish	13	91	4.5	69.5	92.9	76.3
Myoxocephalus	9	83	3.8	63.4	64.3	64.4
Boreogadus	7	8	0.7	6.1	50.0	11.9
Amphipods	6	23	0.9	17.6	42.9	15.3
Copepods	3	15	0.3	11.5	21.4	5.1
Insects	1	1	0.1	0.8	7.1	1.7
Seeds	1	1	0.1	0.8	7.1	1.7
Total		131	5.9	100.2		100.1

4.3.3.4 Red phalarope

All 20 red phalaropes were collected from flocks feeding along the shore of Point Franklin spit between 12 and 13 August. Only one was an adult (Table 4-3). When collected, four (20%) of the stomachs were 3/4 full, four (20%) were 1/2 full, one (5%) was 1/4 full, and the remainder (55%) were less than 1/4 full. A total of 13 prey taxa were identified (Appendix 4-A). Each stomach, averaging 1.8 ± 1.0 (range = 1-4) taxa, contained food.

Gammarid amphipods were the most important prey although no *Atylus carinatus* were identified (Table 4-20). Instead, *Leptamphopus* sp. predominated, being counted in over half of the stomachs, and comprised over 40% of the numbers and greater than 30% of the volume of all prey consumed (Table 4-25). The amphipod *Onisimus glacialis* was identified in one stomach. Amphipod species averaged 5.5 mm in length (Table 4-24). Other prey included unidentified plant parts, polychaetes, mysids, bivalves, and isopods (Table 4-20).

4.4 DISCUSSION

4.4.1 Migration

Three major studies, using methods similar to this investigation, have assessed spring and fall migration of waterbirds along the Alaska coast of the Chukchi and Beaufort Seas (Timson 1976; Johnson and Richardson 1981; Lehnhausen and Quinlan 1981). The area covered by these studies extends from Icy

Table 4-24. Length (mm) of measurable prey items found in stomachs of arctic terns and red phalaropes collected in Peard Bay in 1983. S.D. = Standard Deviation.

Prey	Arctic Terns n	Arctic Terns Mean±S.D.	Arctic Terns range	Red Phalaropes n	Red Phalaropes Mean±S.D.	Red Phalaropes range
Calanoid copepod	13	1.0±0.4	0.7-2.1			
Harpacticoid copepod	2	0.8±0.01	0.78-0.80			
Leptamphopus sp.	2	6.2±1.3	5.3-7.1	14	5.5±1.1	4.0-7.2
Onisimus sp.				4	5.4±1.7	4.1-7.8

Table 4-25. Percent occurrence, number and volume of taxa of prey identified in stomachs of red phalaropes collected from Peard Bay in 1983 (n = 20 stomachs).

Taxon	Number of stomachs	Number of prey	Vol. (ml)	Percent (%) No.	Percent (%) Occ.	Percent (%) Vol.
Amphipods	16	39	2.0	60.0	80.0	48.8
Leptamphopus	11	27	1.4	41.5	55.0	34.1
Insects	5	6	0.5	9.2	25.0	12.2
Fish	4	7	0.4	10.8	20.0	9.8
Seeds	3	4	0.3	6.2	15.0	7.3
Polychaetes	3	3	0.3	4.6	15.0	7.3
Mysids	1	3	0.3	4.6	5.0	7.3
Isopods	1	1	0.1	1.5	5.0	2.4
Plants	1	1	0.1	1.5	5.0	2.4
Bivalves	1	1	0.1	1.5	5.0	2.4
Total		65	4.1	99.9		99.9

Cape (162° W) in the northern Chukchi Sea to Simpson Lagoon (150° W) in the central Beaufort Sea, with sites in between at Peard Bay (159° W) and Point Barrow (156° 30'W). It is not the intent of this discussion to present a detailed comparison of migration past all sites, but instead to assess the importance of Peard Bay to birds migrating along the Arctic Coast of Alaska, particularly along the Chukchi Sea coast. In this regard some comparison must be made among the four sites, especially with Icy Cape which lies only 125 km southwest of Peard Bay. However, the reader is cautioned that while results from these studies were derived using similar methods, migration was not studied in both spring and fall at all sites and no two studies were conducted during the same year. Nevertheless, sufficient information exists for most species or groups of species to establish periods of peak seasonal passage and, in many instances, the magnitude of their migration over the area encompassed by these studies.

4.4.1.1 Loons

The spring migration of loons past Peard Bay was typical of that reported from the other areas in that very small numbers of red-throated, arctic, and yellow-billed loons were recorded. During 600 hours of observation conducted over 102 days in spring 1977, 1981, and 1983 at Simpson Lagoon, Icy Cape, and Peard Bay, respectively, only 175 red-throated loons, 103 arctic loons, and 54 yellow-billed loons were recorded (Johnson and Richardson 1981; Lehnhausen and Quinlan 1981; this study). The numbers of yellow-billed loons seen at these sites in spring are generally in keeping with the low nesting densities reported for this species on the North Slope. However, the numbers of recorded red-throated and arctic loons are much less than the nesting populations reported from northern Alaska (Sage 1974; Bergman et al. 1977; Derksen et al. 1981). Thus, in spring red-throated and arctic loons are probably migrating directly overland in spring to breeding areas from subarctic wintering or staging areas, or they are migrating too far offshore to be observed during migration watches.

Fall migration of loons, particularly arctic loons, past Peard Bay was spectacular by comparison to spring migration, and typical of that reported from Icy Cape (Lehnhausen and Quinlan 1981) and Point Barrow (Timson 1976). Migration past all three sites began in late August and was most intense in mid-September (numbers at Peard Bay were still increasing upon our departure on 7 September). The ratio of arctic, red-throated, and yellow-billed loons passing each site was approximately 85:12:1. Rates of passage of all loons at Icy Cape, Peard Bay, and Point Barrow during fall averaged 46, 23, and 57 birds/h, respectively, with rates of peak passage at all sites exceeding 100 birds/h. A common observation at all three sites was that during good weather loon migration was steady with few birds stopping at the study areas, but during foggy periods large numbers of loons stopped migrating and congregated on open waters until the fog lifted.

4.4.1.2 Waterfowl

During spring at Peard Bay, Icy Cape, Simpson Lagoon, and areas to the east, waterfowl composed the vast majority of migrants. Migration at all sites occurred over a broad front with the timing and intensity of passage reported at these sites often being a function of the proximity of ice leads and other physical barriers to the observers (for a discussion see Johnson and Richardson 1981; and Lehnhausen and Quinlan 1981). For example, the lead at Peard Bay was over 10 km offshore. In addition, a 5-10 m high pressure ridge, formed by grounded ice, occurred the length of the Point Franklin spit about 3 km offshore from our observation site. This ridge frequently prevented our staff from counting large flocks of eiders and oldsquaw. Bird presence was detected, but only when portions of the flock rose above the horizon. It is hypothesized that there was a zone beyond the ridge of about 2 km in which most of the birds migrating low over the ice were missed.

The tundra swan, four species of geese, and seven species of ducks were identified during spring migration watches at Peard Bay. The single recorded swan is consistent with the low numbers of this species recorded elsewhere along the Chukchi Sea coast (Bailey 1948; King 1979; Lehnhausen and Quinlan 1981) and is supportive of Sladen's (1973) contention that swans migrate to and from the North Slope via an interior route. Of the four species of geese recorded in spring, only greater white-fronted geese and brant exhibited a true migration along the coast. Canada geese (*Branta canadensis*), in flocks of three and five birds, were seen on 30 May and 1 June, and snow geese (*Chen caerulescens*), totaling 12 birds, were seen on only five days between 29 May and 14 June. Greater white-fronted geese were recorded daily between 29 May and 4 June with a peak passage of 3.3-7.6 birds/h to the east on 29-30 May. Lehnhausen and Quinlan (1981) also recorded a peak passage of greater white-fronted geese on 29 May 1980 at Icy Cape when 18 birds/h passed their observation site. Numbers observed at both Icy Cape and Peard Bay represent less than 3% of the North Slope breeding population (King 1970) and strongly suggest an interior spring migration route in northern Alaska.

Brant were the most numerous species of goose migrating past Peard Bay in spring (261 observed between 30 May and 2 June), but the numbers recorded were insignificant compared to those recorded for the North Slope (Derksen et al. 1979b). All evidence so far supports an inland migration route for this species in spring with birds moving inland south of Icy Cape and cutting across the coastal plain to breeding and molting areas east of Point Barrow (Lehnhausen and Quinlan 1981). Lehnhausen and Quinlan (1981) also recorded a second and larger (12,000 observed; 37,000 estimated) passage of brant inland and to the north of Icy Cape between late June and mid-July. These were presumed to be birds on their molt migration to Teshekpuk Lake, which lies between Smith and Harrison Bays east of Point Barrow (Derksen et al. 1979a). Lehnhausen and Quinlan (1981) estimated that during the last two weeks of June about 20% of the brant migrating past Icy Cape were stopping to use the marshes in the area. No observations were made at Peard Bay during this same period in 1983 and thus there is no direct evidence that some brant migrating at this time were stopping briefly at Peard Bay. Brant did use the marshes along the north and west sides of Peard Bay in late August and September (section on Habitat Use, this chapter); however, no fresh goose droppings were found in these marshes during the mid-July field effort. Nevertheless, it is still possible that during some years brant may use these areas during their molt-migration in June and July.

Although there was a noticeable increase in use of the marshes of Peard Bay by brant in August and early September, essentially no fall migration of this species past Peard Bay was recorded for this period. According to numerous other studies (Johnson and Richardson 1981) conducted along the Beaufort Sea coast during the above period (but during different years), brant should have passed Peard Bay in numbers. At Icy Cape, just southwest of Peard Bay, the fall migration of brant began on 4 September and was still in progress when Lehnhausen and Quinlan departed the site on 23 September 1980. A possible explanation for the apparent lack of a fall migration of brant past Peard Bay is that birds either passed beyond view along the south shore of the bay or else were migrating inland. That most brant may have migrated inland along this section of the Chukchi Sea coast is suggested by 1) the considerably fewer numbers of birds seen passing Point Barrow (Johnson 1971; Timson 1976) compared to numbers of westbound brant recorded migrating past sites east of Point Barrow (Johnson and Richardson 1981; Johnson 1983), and 2) observations on 2 September along the coast 20 km southwest of Point Franklin, of flocks of 250 and 75 brant seen flying from several kilometers inland toward the coast. Upon reaching the coast the flocks turned 90 degrees and proceeded to migrate to the south about 1 km offshore.

The peak period and rate of passage of oldsquaw at Peard Bay (1-4 June; 37.8 birds/h) coincided with that found at Icy Cape in spring 1980 (Lehnhausen and Quinlan 1981). However, because spring migration of oldsquaw along the coast takes place primarily over open leads of sea ice and such leads at Icy Cape and Peard Bay were well offshore in 1980 and 1983, respectively, the magnitude of oldsquaw migration along the Chukchi Sea coast remains largely unknown. During the period of molt-migration of oldsquaw (late June through July) migration was only monitored over a 5-day period (16-20 July). During this time, birds had a net easterly movement of 50.3 birds/h along the Chukchi Sea coast. At Icy Cape in 1980, Lehnhausen and Quinlan (1981) recorded a net northerly movement of 71.8 birds/h during peak passage on 10 July and at Simpson Lagoon the molt migration was primarily westerly and peaked during the first week of July 1977 and 1978 (Johnson and Richardson 1981). Lehnhausen and Quinlan (1981) speculated that, based on their information and that available from Simpson Lagoon (Johnson and Richardson 1981) and Point Barrow (Thompson and Pearson 1963; Johnson 1971), there was comparatively little molt-migration of oldsquaw along the Beaufort Sea coast into the Chukchi Sea area. Instead, they believed that molt-migrants using the Chukchi Sea coast came from areas south of Icy Cape or from western parts of the North Slope.

Oldsquaw is one of the latest of all birds to migrate from the Arctic in the fall. The peak passage does not usually occur until late September when ice begins to form on the bays and lagoons (Bailey 1948; Johnson 1971; Timson 1976; Johnson and Richardson 1981). At Peard Bay the fall migration of oldsquaw began in late August and appeared to be still building into the second week of September (1,350 birds passing/h). At Icy Cape the fall passage of oldsquaw was increasing into the third week of September 1980 at over 2,900 birds/h to the south (Lehnhausen and Quinlan 1981).

Eiders, treated here as a group because of problems in identification due to distance of observation and mixed-species flocks, were the most abundant spring migrant recorded at Peard Bay. Migration of eiders along this stretch of the Chukchi Sea coast begins in early May and is well underway by the third week of May (Lehnhausen and Quinlan 1981). A steady movement of eiders was recorded from 29 May through 14 June. The most intense passage occurred between 30 May and 5 June (a mean rate of 188 birds/h). Of those birds which we could identify to species during this period (n=1,226), 57% were common eiders, 41% king eiders, 2% spectacled eiders, and less than 1% Steller's eiders (*Polysticta stelleri*). Between 11 and 14 June a mean passage of 21 birds/h was occurring to the east past Peard Bay. Lehnhausen and Quinlan (1981) recorded a rate of 97.2 eiders/h past Icy Cape between 25 May and 5 June 1980. Of those birds which they could identify to species, 84% were common eiders, 7% spectacled eiders, 4% king eiders, and less than 1% Steller's eiders. Owing to our overall small sample sizes and the tremendous variation in ratios of species we recorded within mixed-species flocks, we do not believe the differences in species composition of eiders recorded at the two sites to be real. At Simpson Lagoon in 1977 Johnson and Richardson (1981) recorded a somewhat later period of peak passage of eiders (4-14 June), with common and king eiders migrating at rates of 27.0 and 13.4 birds/h, respectively.

The molt-migration of eiders, while found to be major past Simpson Lagoon (Johnson and Richardson 1981) and Point Barrow (Johnson 1971) and less so past Icy Cape (Lehnhausen and Quinlan 1981), essentially went undetected past Peard Bay. This is most probably the result of only studying the area for a 5-day period (16-20 July) during the time when molt-migration usually occurs (late June-early August). A small net westerly movement of eiders was recorded between 16 and 20 July (about 53 birds/h), but this was well below the over 1,500 birds/h recorded passing Icy Cape to the south in late July 1980 and 114 birds/h passing Simpson Lagoon to the west between 26 June and 25 July 1977.

Unlike oldsquaw, for which there are distinct periods for molt-migration and fall migration, the migration of eiders from the Arctic in fall appears to peak with the molt-migration and steadily decline thereafter until most birds have departed the area by late September. The passage of eiders (99% king, 1% spectacled) declined at Peard Bay throughout late August and early September. Of the eiders identified to species as they migrated past Point Barrow in 1975, 97% were king eiders. That year the rate of eider migration had declined by almost two-thirds between the last week of August and the third week of September (Timson 1976). Lehnhausen and Quinlan (1981) also recorded a steady decline in the rate of eider migration past Icy Cape between late August and late September 1980.

4.4.1.3 Shorebirds

The passage of shorebirds at Peard Bay in spring was very similar to that recorded by Lehnhausen and Quinlan (1981) at Icy Cape. Migration at both sites began in late May and was essentially over by the second week of June. During this period there were one or two days in which waves of migrants passed. The species were mostly dunlin, red phalaropes, and semipalmated sandpipers, although at Icy Cape numbers of lesser golden plovers, Baird's (*Calidris bairdii*) and pectoral sandpipers, and long-billed dowitchers were recorded. Considering the total number of shorebirds seen passing Icy Cape (1,300) and Peard Bay (600) in relation to the numbers reported breeding on the North Slope, only the smallest fraction of the North Slope breeding population migrates along the Chukchi Sea coast in spring. Apparently, once shorebirds leave major subarctic staging sites such as in southcentral Alaska in spring, migration becomes very direct and large movements along coastal areas become less common (Gill and Handel 1981; Woodby and Divoky 1983).

The fall migration of shorebirds past the Peard Bay area was similarly disappointing, but typical of most arctic sites where shorebird migration has been studied. Migration in the usual sense of large numbers of birds passing in discrete periods is generally not found. Instead, there appears to be a gradual shift of most species to littoral areas following breeding (Connors and Risebrough 1978; Connors et al. 1979) and then a slow drift of birds along the coast or a direct overland migration to wintering areas. During the periods 15-22 July, 10-14 August, and 26 August-7 September nine species of shorebirds were recorded but, with exception of red phalaropes and dunlin, none numbered more than a few score individuals. The fall shorebird migration at Icy Cape in 1980 included half again as many species and comparatively more individuals of most species, especially red phalaropes and dunlin (Lehnhausen and Quinlan 1981). Dunlin using Kasegaluk Lagoon were recorded in flocks of over 1,000 birds in mid-August. The majority of the over 10,000 phalaropes seen were red phalaropes. At Peard Bay fewer than 300 dunlin and only 3,500 red phalaropes were observed during similar census efforts.

4.4.1.4 Gulls and Terns

During 1983 there was no pronounced spring migration of gulls and terns (Figure 4-8). Such is probably the case in most years as few gulls and terns were recorded passing Icy Cape in spring 1980 (Lehnhausen and Quinlan 1981) and at Simpson Lagoon in spring 1977 and 1978 (Johnson and Richardson 1981). At Icy Cape in spring 1980 a total of 1,800 gulls and terns (84% glaucous gulls and 13% arctic terns) was recorded during 417 hours of observation between 25 May and 14 July. At Simpson Lagoon only 437 gulls and terns (85% glaucous gulls and 8% arctic terns) were observed during daily migration watches between 17 May and 14 June. The timing of spring migration at Peard Bay coincided with that found at Icy Cape and Simpson Lagoon, with glaucous gulls passing during late May and into the first week of June and arctic terns not moving through until the second and third weeks of June.

The fall migration of gulls and terns past Peard Bay was much more pronounced than in spring and, with a few exceptions, was typical of that recorded at Icy Cape, but differed considerably from that recorded at Point Barrow (Timson 1976) and Simpson Lagoon (Johnson and Richardson 1981). The total numbers of gulls and terns recorded during fall at Icy Cape, Peard Bay, Point Barrow, and Simpson Lagoon was 16,000, 3,100, 430, and 400, respectively. Over the duration of fall migration watches at these sites the mean rate of passage was 43, 110, 6, and 10 birds/h. The absence or considerably reduced numbers of glaucous and Sabine's gulls recorded at Simpson Lagoon and Point Barrow in fall may be due to a more offshore migration of these species along the Beaufort Sea coast (Johnson and Richardson 1981), but once birds move into the Chukchi Sea a larger proportion of the population may migrate closer to shore.

4.4.1.5 Jaegers

The migration of jaegers, particularly pomarine jaegers, at Peard Bay was one of the most seasonally contrasting of any group of birds. A major easterly passage of pomarine jaegers occurred during the first week of June (17 birds/h) and was almost immediately followed by a very pronounced westerly passage during the period 11-14 June (7.9 birds/h). This westerly movement represented 16% of approximately 800 pomarine jaegers recorded during spring. Maher (1974), in particular, mentioned this phenomenon of reverse migration in pomarine jaegers and attributed it to birds either not breeding or failing in breeding attempts because of low levels of prey populations on the breeding grounds. While we conducted no systematic censuses of small rodent populations in the area, we failed to see a single lemming or microtine during hikes over some 50 km of adjacent tundra. Farther north near Barrow and east near Cooper Island, Divoky (G. Divoky, personal communication) also observed an absence of small rodents during spring 1983.

The timing and magnitude of jaeger migration in spring at Peard Bay was generally similar to that recorded at Icy Cape in 1980 (Lehnhausen and Quinlan 1981). The major difference between the two sites was that a somewhat greater proportion of parasitic jaegers was recorded at Icy Cape than at Peard Bay. Long-tailed jaegers comprised less than 2% of all jaegers recorded at either site.

The fall migration of jaegers past Peard Bay was sporadic and only 22 birds were observed (15 parasitic, 6 pomarine, 1 long-tailed). In contrast, a major fall migration of jaegers was recorded at Icy Cape in 1980 when some 2,500 birds were observed. Of these, 69% were pomarine and 27% parasitic jaegers; periods of peak movement for these species were 25 August-4 September and 25 August-15 September, respectively. It is possible that a significant migration of jaegers occurred past Peard Bay after 7 September, but our migration data indicated no such buildup was occurring. Timson (1976) recorded no passage of jaegers at Point Barrow between 3 and 16 September 1975 and Johnson and Richardson (1981) recorded only two jaegers passing Simpson Lagoon between 21 August and 22 September 1977. Gollop and Davis (1974) reported somewhat greater numbers passing along the Yukon coast in 1972, but over half of their observations were of birds moving east; of those seen moving west, the majority had passed prior to September. Thus, the migration of jaegers in fall from North Slope breeding grounds may include both offshore (Watson and Divoky 1972; Harrison 1977; Divoky 1978) and overland components (Pitelka 1974). Birds using overland migration routes in fall may not reach the coast until south of Peard Bay. Such a migration would account for the much larger numbers of jaegers recorded in fall at Icy Cape.

4.4.1.6 Passerines

Eleven species of passerines were recorded from the study area; only four species--snow bunting, lapland longspur, redpoll (*Carduelis* sp.), and savannah sparrow--were seen on more than two occasions during the study. Of these, only lapland longspurs migrated in numbers, and only in spring (31 May). Among the other study sites which were used to monitor spring migration, only at Icy Cape (Lehnhausen and Quinlan 1981) was a significant passerine migration recorded (26 May). A comparatively smaller reverse migration of longspurs occurred past Icy Cape in mid-August. Since observations of migration at Peard Bay were confined to the Point Franklin spit area, it is not known to what extent passerines migrated through other areas of the study area, e.g., along the south shore of Peard Bay. However, since not even a single small movement along the spit in fall was recorded, it is probable that no significant migration of longspurs or other passerines occurred in fall anywhere in the Peard Bay area.

4.4.2 Habitat Use

4.4.2.1 Spring Staging

In 1983 there was essentially no use of either terrestrial or aquatic habitats of the Peard Bay area by birds for staging during spring migration. During the aerial survey on 8 June both Peard and Kugrua Bays were completely ice-covered except for a narrow shorelead on the south side of Point Franklin and no birds were recorded. The closest offshore lead was 10 km from shore, so essentially there was no open water available in early June. In 1980, however, during a flight from Barrow to Wainwright on 20 May, Lehnhausen and Quinlan (1981) recorded about 10,000 king and common eiders, most of which were concentrated in a large open lead in the Peard Bay area. Their observation demonstrates that the importance of Peard Bay to migrant birds in spring can be quite variable and that ice conditions influence habitat use.

4.4.2.2 Breeding Season

Birds did not begin to make substantial use of terrestrial habitats in the Peard Bay area until the onset of the breeding season in June. Densities of birds using the tundra of Peard Bay during the breeding season were comparable to those found at other sites along the Beaufort and Chukchi seacoasts. At Peard Bay a total of 3.9 pairs/ha, which included 2.1 pairs of shorebirds/ha, was found. Connors and Risebrough (1978) found that breeding densities at five sites along the Arctic coast in 1977 ranged from 1.1 pairs/ha at Barrow to 2.7 pairs/ha at Meade River. At all sites shorebirds also predominated as a group, ranging from 0.5 pairs/ha at Cape Krusenstern to 1.5 pairs/ha at Meade River. At Icy Cape in 1980, Lehnhausen and Quinlan (1981) recorded only 1.8 birds (not pairs)/ha for all birds using the tundra on 13 June. Shorebirds predominated, being recorded at a density of 1.2 birds/ha. Nesting densities on the tundra-covered portions of Pingok Island at Simpson Lagoon in 1977 and 1978 (Johnson and Richardson 1981) were much lower (0.2-0.4 pairs/ha) than those found on mainland tundra at Peard Bay. Even densities on one mainland plot surveyed at Simpson Lagoon in 1978 were markedly lower (0.6 pairs/ha) than those at Peard Bay. Part of this discrepancy may be accounted for by the difference in method of censusing. Researchers at Simpson Lagoon based their counts only on the total number of nests they located on the plot. They may have missed some active nests and others may have been lost already or not yet established. Their comparison of counts of nests and counts of territorial males show discrepancies in both directions (Johnson and Richardson 1981). We and the other investigators cited above based our calculations of density on a combination of nests actually found and the number of additional territorial pairs observed, recognizing that all nests would not be located.

At Peard Bay positive evidence was found for six species breeding on mainland tundra and it is suspected that at least six other species may breed there (Table 4-5). By comparison, the number of species nesting on tundra at five sites along the Chukchi and Beaufort seacoasts in 1977 ranged from 9 at Wales to 18 at Meade River and averaged 12 (Connors and Risebrough 1978). At Simpson Lagoon only 9 species were recorded nesting on tundra in 1977 and 10 in 1978 (Johnson and Richardson 1981). In 1978, just southwest of Peard Bay at Icy Cape Lehnhausen and Quinlan (1981) found evidence of 21 species nesting on tundra but diversities cannot be directly compared because their census plots covered approximately eight times the area censused by us and by the other investigators cited above. One must view with caution, however, any comparisons of breeding densities and diversity among Arctic sites studied in different years because of the large annual variations that typically occur. For example, at two plots near Barrow, studied between 1975 and 1980, densities ranged from 1.00 and 0.99 to 1.67 and 1.71 pairs/ha, respectively, and the number of species recorded breeding varied from a low of 10 n to a high of 17 at each site (Myers and Pitelka 1975; Meyers et al. 1977, 1978, 1979, 1980, 1981).

The overall composition of species at Peard Bay was very similar to that found at Icy Cape. At both sites lapland longspurs, pectoral sandpipers, and dunlin were very abundant among small birds and oldsquaw and northern pintail were the most abundant among larger birds. For only two species did relative abundance differ markedly between the two sites. At Icy Cape red phalaropes and red-necked phalaropes (*Phalaropus lobatus*) comprised 31% and 8%, respectively, of the birds recorded on a 13 June census of the tundra. Both were much higher than the proportions recorded at Peard Bay on 9 June, where red phalaropes comprised only 3% of the birds recorded and no red-necked phalaropes were found on the tundra.

At Peard Bay salt marshes, sand dunes, beaches on barrier islands, and sandspits were also used by nesting birds. Species nesting there were those typically found nesting in such habitats along the Beaufort and Chukchi seacoasts. Brant, common eider, oldsquaw, semipalmated sandpipers, and lapland longspurs were found breeding in salt marshes and it is suspected that a few arctic terns, savannah sparrows, and snow buntings also nested there. In similar marshes at Icy Cape, Lehnhausen and Quinlan (1981) reported evidence of breeding only for common eiders, arctic terns, and possibly oldsquaw. Such marsh habitat either does not exist at Beaufort and Simpson Lagoons, or Johnson and Richardson (1981) and Johnson (1983) did not report results of breeding bird use of these areas.

The most abundant species nesting on the sand dunes and beaches of the barrier islands and sandspits of the Peard Bay area was the arctic tern. This species tended to nest in clusters of 6 to 20 pairs although a few pairs nested singly scattered in these habitats. An estimated 50 to 65 pairs nested in the Peard Bay area. Divoky (1978b) found two-thirds fewer arctic tern nests at Peard Bay during a brief visit in 1976. Elsewhere along the Chukchi Sea coast, 96 nests of arctic terns were found in 1976 on barrier islands of Kasegaluk Lagoon to the south (Divoky 1978b). Along the Beaufort Sea coast at Cooper Island just east of Barrow, Divoky (1978b) found an average of 55 nests from 1975 to 1977. Farther east at Simpson Lagoon, only three arctic tern nests were found on Jones Island, and adjacent spits and bars (Johnson and Richardson 1981).

At Kasegaluk Lagoon Divoky (1978b) found a remarkable concentration of nesting common eiders (586 pairs in eight colonies), which he estimated to comprise 58% of the total nesting population along the Chukchi Sea coast. In contrast, the highest concentration found in the present study was in a small colony of eight nests on the Seahorse Islands, of which all but one had been deserted. Divoky (1978b) did not report any nests on the Seahorse Islands during visits in 1972, 1975, and 1976. In 1983 only two to five pairs were estimated to have bred elsewhere around Peard Bay in barrier island habitat, although the presence of several dozen empty nest bowls on Point Franklin spit suggests that in some years eiders may nest in higher densities. At Simpson Lagoon in 1977 and 1978 only two common eider nests were found on barrier islands and spits (Johnson and Richardson 1981), but in 1972 on Egg Island in the eastern part of Simpson Lagoon, Schamel (1978) found a colony of 39 pairs of common eiders nesting.

Although Peard Bay spits and barrier islands supported low concentrations of nesting common eiders, glaucous gulls, and brant in comparison with the barrier islands of Kasegaluk Lagoon, 125 km to the southwest, the Seahorse Islands in Peard Bay were a particularly important nesting area for black guillemots. Only 15 nests with eggs or chicks were found during the early August field effort. It is not known what proportion of the 84 adults found roosting in that nesting area may have already lost eggs or chicks. This colony was unusual in that all of the birds nested in natural driftwood debris. Black guillemots were first suspected of nesting in the vicinity of the Seahorse Islands by Bailey (1948). During visits to the Seahorse Islands in 1972, 1975, and 1976 Divoky and co-workers found 6, 5, and 4 black guillemot nests, respectively, placed in the same sand dunes and driftwood pile (Divoky et al. 1974; Divoky 1978b). The nearest large concentrations of black guillemots are at Cape Lisburne (85 pairs) to the south and Cooper Island (21 pairs) near Point Barrow (Sowls et al. 1978). Divoky (1978b) postulated that the availability of nest sites was the major factor that determined the distribution of black guillemots along the Beaufort and Chukchi seacoasts. It is interesting that the number of guillemots nesting on the Seahorse Islands has increased so markedly between 1976 and 1983 although no change has occurred in the nest site availability there. Our sighting of a color-banded adult on the Seahorse Islands that was banded on Cooper Island (G. Divoky, personal communication) indicates that the Seahorse Island population deserves more study to determine the relative importance of different nesting areas and the interchange among them.

The presence of three recently dug burrows in the dunes of the Seahorse Islands is also important. Because it could not be discerned whether or not the deep burrows were active without causing major disruption, confirmation of the presence of breeding horned puffins on the island could not be made. If breeding puffins were present, this would constitute a northern nesting limit. It is possible that one or more of these burrows was used by black guillemots since Divoky (1978b) found them nesting in one and two burrows, respectively, in 1972 and 1975. We did, however, observe adult horned puffins consistently in the area between mid-July and early September and suspect that they nested in the area. Divoky (1978b) also observed horned puffins flush from the sand dunes in 1972 and circle the island as though they had been scared off a nest.

4.4.2.3 Fall Staging

At Peard Bay, as is typical in the Arctic, most birds left nesting areas on the tundra abruptly after breeding. Some birds migrated immediately (e.g., adult semipalmated sandpipers) but most moved to other habitats to stage before migration. Birds began to use other habitats within the bay in substantial numbers beginning in mid-July and continued to increase as the season progressed. During the aerial survey on 25 August it was estimated that there were about 13,000 birds using the Peard Bay area, a seasonal high, and upon departure from the area on 7 September, these numbers had not declined perceptibly. It is thus not possible to pinpoint when use of the bay peaked or when it was finally abandoned by birds in the fall. Over 80% of the birds present in the bay on 25 August were eiders and oldsquaw, whose numbers had steadily been increasing throughout the summer. Since fall migration of both species along the Arctic coast generally extends into late September and early October (Bailey 1948; Divoky 1978a; Johnson and Richardson 1981; Lehnhausen and Quinlan 1981) it is probable that use of Peard Bay continued to be high throughout most of this period.

In many respects the timing and patterns of avian use of various habitats within Peard Bay were similar to those found at other lagoons along the Beaufort and Chukchi coasts. The shift from the tundra resulted in a marked increase in densities of birds using waters in and out of the bay, the barrier islands, sandspits, and salt marshes for both feeding and roosting in fall (Table 4-26).

The most abundant groups staging in the Peard Bay area included loons, shearwaters, waterfowl, shorebirds, gulls, and terns.

Loons. Loons as a group (predominantly arctic) comprised less than 1% of the birds recorded using the bay or nearshore waters between mid-July and early September. Similarly, other studies (Divoky 1978a; Johnson and Richardson 1981; Lehnhausen and Quinlan 1981) recorded only a small percentage of loons stopping during migration to use lagoons or bays. Most of those using the Peard Bay area concentrated along the distal end of Point Franklin spit, on both the bay side and the ocean side, and at the entrance between Point Franklin spit and the Seahorse Islands. During July (when densities were highest), about 90% of the observed loons were resting on the water. Many may have been diving for prey concentrated by the current at the entrance.

Shearwaters. Short-tailed shearwaters have been found to occur regularly in pelagic waters of the Chukchi Sea from late August through mid-September (Jaques 1930; Watson and Divoky 1972; Harrison 1977; Divoky 1978a). Our observations of shearwaters in the Peard Bay area are notable in that flocks of up to 200 birds each were recorded every day within the bay itself from late August until departure in early September. Some of these shearwaters were observed feeding within the bay.

Waterfowl. Small numbers of geese were recorded using the Peard Bay area in 1983. However, sampling did not occur from mid-June to mid-July, and a large eastward molt-migration of brant may have been missed. At Icy Cape in 1980, Lehnhausen and Quinlan (1981) recorded a large movement of brant during this period, and also observed that substantial numbers stopped to use waters of the lagoon and salt marshes on the barrier islands. During August brant were recorded using both Kugrua Bay (over 400 birds on 25 August) and similar salt marsh habitat on Point Franklin spit (over 400 on 27 August), thus it is known that brant use these habitats. At Icy Cape during August and September 1980, flocks of over 2,000 brant (totaling up to almost 6,000 birds) were regularly observed in the lagoon or in the salt marsh (Lehnhausen and Quinlan 1981). This is approximately 10 times the maximum number recorded at Peard Bay (600 birds, 25 August). Their observations at Icy Cape included that of one bird that had been banded three weeks earlier at a staging area on East Long Lake.

Table 4-26. Major habitats used within the Peard Bay area by the most abundant species of birds in 1983.

Species	Nesting	Feeding	Roosting
Loons	Tundra	Entrance to bay	-
Short-tailed shearwater	-	Nearshore waters and within bay	-
Brant	Salt marshes	Salt marshes	Salt marshes
Eiders	Barrier islands, sand spits	Waters of bay (molt) Ocean (after molt)	Gravel beaches
Oldsquaw	Tundra, sand spits	Waters of bay (molt) Nearshore waters of spits (after molt)	Gravel beaches at points inside bay
Red phalarope	Tundra	Nearshore waters of spits and barrier islands (oceanic and within bay)	Sandspit beaches
Other shorebirds	Tundra	Salt marshes, oceanside beaches	Salt marsh, ocean beaches
Glaucous gull	Tundra	Chukchi Sea and Peard Bay	Barrier islands, sandspits, gravel spits within bay
Black-legged kittiwake	-	Oceanic nearshore waters	Sandspits and barrier islands
Sabine's gull	Tundra	Oceanic waters near brash ice, tide rips at entrance	Sandspits and barrier islands
Arctic tern	Sandspits and barrier islands	Oceanic waters near brash ice and throughout bay	Sandspits and barrier islands

Since significant numbers of brant have not been recorded stopping at Elson Lagoon during fall migration (Divoky 1978a), Peard Bay may be the first staging area for brant heading south from Island Lake and East Long Lake, where nonbreeders and failed breeders from Canada, western Alaska, and Wrangel Island, U.S.S.R., congregate to molt (Derksen et al. 1979). In comparison, no significant numbers of brant were recorded stopping at either Simpson Lagoon (Johnson and Richardson 1981) or Beaufort Lagoon (Johnson 1983).

Almost all greater white-fronted geese observed in the Peard Bay area were along the shoreline of Kugrua Bay, and the maximum seen was 350 on 10 August. This species was also seen regularly using salt marsh areas at Icy Cape in fall 1980 (Lehnhausen and Quinlan 1981), but was not recorded at Simpson Lagoon (Johnson and Richardson 1981) or Beaufort Lagoon (Johnson 1983) in fall. Unlike brant, most greater white-fronted geese do not move to coastal wetlands after molting near Teshekpuk Lake (Derksen et al. 1979). The greater white-fronted geese in Kugrua Bay in August may have been those from local breeding areas. Alternately, they may represent a small proportion of molters from the Teshekpuk Lake area that do not follow the typical migration route, inland through Canada to wintering areas in the south central United States (Bellrose 1976).

Eiders and oldsquaw were similar to each other in their timing of build-up and use of habitats within Peard Bay. The numbers of both increased steadily from mid-July until 7 September, although oldsquaw outnumbered eiders by almost two to one on the last aerial survey on 25 August, reaching a peak of almost 7,000 birds. Oldsquaw flocks were composed almost exclusively of molting males until late August, when an influx of females was recorded. At Icy Cape oldsquaw outnumbered eiders, but the timing of peak use was quite different (Lehnhausen and Quinlan 1981). The numbers of both oldsquaw (13,000) and eiders (600) peaked there in early August. Numbers of oldsquaw were low in late August (1,400) and then increased again slightly in mid-September (1,900), whereas numbers of eiders continued to decline. At Simpson Lagoon, Johnson and Richardson (1981) found the timing and densities of peak numbers of oldsquaw were quite variable between years, sometimes showing peaks in both July and August and sometimes not peaking until late September. In comparison with peak densities recorded at several sites along the Beaufort Sea coast (Johnson 1983), the peak density of oldsquaw recorded at Peard Bay on 25 August (38 birds/km^2) was one of the lowest recorded (range 35-212 birds/km^2 at five sites). Densities of oldsquaw at Peard Bay may well have increased after 7 September, since in past years peak numbers of almost 13,000 were recorded in Elson Lagoon (Divoky 1978a) and over 100,000 in Simpson Lagoon (Johnson and Richardson 1981) in early and late September, respectively. Eiders largely bypassed Beaufort, Simpson, and Elson Lagoons during fall migration (Divoky 1978a; Johnson and Richardson 1981; Johnson 1983), suggesting that Peard Bay may be the first important stop during coastal southward migration.

Oldsquaw were found in August feeding mainly in nearshore areas of Peard Bay near the distal end of Point Franklin spit, but they were also scattered throughout the bay, within 1-3 km of shore. Birds roosted along gravel beaches of Point Franklin spit on the Peard Bay side and along various other promontories around the shore of the bay. Feeding eiders were found feeding dispersed more widely throughout the bay, but roosted in similar areas, particularly along Point Franklin spit. In late August and early September, following molt, there was a pronounced shift of both eiders and oldsquaw to nearshore feeding areas on the Chukchi Sea side of Point Franklin spit. Whether this reflected a change in availability of prey or just a change in mobility remains unknown. Such a change in habitat use was also noted for oldsquaw at Icy Cape in mid-August in 1980 (Lehnhausen and Quinlan 1981).

Shorebirds. Red phalaropes dominated within the shorebird group in terms of numbers during fall at Peard Bay, as they did at other Arctic lagoons and estuaries (Connors and Risebrough 1978; Divoky 1978a; Connors et al. 1979; Johnson and Richardson 1981; Lehnhausen and Quinlan 1981; Johnson 1983). At Peard Bay as at Point Barrow (Connors et al. 1979), phalaropes' extreme reliance on littoral habitats in conjunction with their tendency to concentrate in high densities makes them the most susceptible of all shorebirds to any hazards of oil development in the area, including oil spills and littoral zone disturbances. Their timing of use of the area was typical of that found at other Arctic sites. Adult male phalaropes began to congregate along the beaches of Point Franklin spit in mid-July but by the mid-August survey very few adults remained. Thus it is not known at what levels the population of adults peaked within Peard Bay, but the peak is likely to have occurred in late July as it did at Icy Cape in 1980 (Lehnhausen and Quinlan 1981) and at Elson Lagoon in 1976 and 1977 (Divoky 1978a; Connors et al. 1979). Connors and Risebrough (1978) found that at Barrow the peak movement of adult males to littoral areas was about two weeks earlier in 1977 than in 1976. This was apparently in response to earlier availability of foraging sites because of mild ice conditions. It is likely that timing and extent of use of Peard Bay by adult males is also governed in some years by the timing of ice breakup in the bay.

The buildup of juvenile red phalaropes in littoral areas of Peard Bay in mid-August was typical of that observed at other sites along the Arctic coast. At Simpson Lagoon lineal densities of phalaropes peaked in both mid- and late August in 1978. At Beaufort Lagoon, densities of phalaropes (including both reds and northerns) were markedly lower, being less than 6/km in early August and about 10/km in late September along barrier island shorelines. At Elson Lagoon near Cooper Island red phalaropes reached peak concentrations of more than 8,000 birds in 1976 and about 3,500 birds in 1977 (Divoky 1978a). Connors and Risebrough (1978) reported peak lineal densities of about 100/km of shoreline in mid- to late August, about four times higher than densities recorded in late July and far greater than the densities of red phalaropes (14/km) found along the shoreline of Peard Bay in mid-August by the present study. However, because of the possibly tremendous annual variation in reproductive success and recruitment common among Arctic nesting shorebirds it is difficult to determine the relative importance of Peard Bay as a staging area for juvenile red phalaropes based solely on comparisons of studies conducted in different years. At Icy Cape in 1980, for example, there was no peak of juveniles recorded in mid-August, but Lehnhausen and Quinlan (1981) could not determine if this reflected poor production that year or a real difference in habitat use. Densities there peaked in early August at 67 phalaropes/km, also far greater than the numbers recorded in mid-August by the present study.

The patterns of habitat use in Peard Bay by red phalaropes was similar to patterns found at other sites. The numbers feeding on the bay side and the ocean side of Point Franklin spit in mid-July were approximately equal, but in August and September there was a marked shift to the ocean side, where birds were observed feeding among the brash ice that had shifted close to shore. At

Simpson Lagoon (Johnson and Richardson 1981) such a shift also occurred in late August. At Elson Lagoon, Divoky (1978a) found that in both 1976 and 1977 the largest concentrations of feeding red phalaropes occurred where *Apherusa glacialis*, an under-ice amphipod, was the dominant prey available. As at Elson Lagoon, red phalaropes at Peard Bay roosted on unvegetated areas of barrier islands and spits when not feeding.

In comparison with red phalaropes, other shorebirds using Peard Bay occurred in low numbers and frequented different habitats. Dunlin were the second most abundant shorebird but their numbers did not approach those found at Icy Cape to the south. At Peard Bay an average of 40 dunlin/km^2 used salt marshes in mid-July and none were present in late August. Densities of dunlin using salt marshes at Icy Cape steadily increased in July and remained high throughout August, averaging 172 birds/km^2 in one marsh and 57 birds/km^2 in another. At both sites dunlin also foraged along the exposed mudflats. Several other species, including lesser golden plovers, black-bellied plovers (*Pluvialis squatarola*), ruddy turnstones (*Arenaria interpres*), Baird's, western, semipalmated and pectoral sandpipers, and sanderlings also occurred at Peard Bay but none in the densities found at either Barrow (Connors and Risebrough 1978) or at Icy Cape (Lehnhausen and Quinlan 1981). In a comparative study of total shorebird use of littoral habitats at six sites between Oliktok and Wales in 1977, Connors and Risebrough (1978) found densities of shorebirds at Peard Bay to be about equal to those at most other sites in early August (27/km), lower than those at the Beaufort and Chukchi sea sites in mid-August (19/km), and intermediate among all sites in early September (5/km).

Gulls and Terns. Although barrier islands and spits were important to a few species for nesting, they were used far more heavily by postbreeding birds. Gulls and terns were found roosted in large flocks on flat, unvegetated areas of beaches and sandspits. The numbers of birds roosting in these habitats peaked in early August. During an aerial survey on 10 August almost 1,000 glaucous gulls, about 3,800 black-legged kittiwakes, and over 2,000 arctic terns were observed along the shoreline of Peard Bay, 98% of which were concentrated in large flocks on the Seahorse Islands and the two major spits. These numbers decreased as fall progressed and the kittiwakes and terns departed. The numbers of Sabine's gulls roosting on the sandspits and barrier islands in Peard Bay increased as fall progressed.

The presence of large roosting flocks of gulls and terns on barrier islands is a common phenomenon along the Arctic coast in fall, with the magnitude of use quite variable among sites. Beaufort Lagoon supported very low numbers of glaucous gulls, with peak numbers recorded in early August when a flock of 44 birds roosted on brackish lakes near the coast (Johnson 1983). At Simpson Lagoon, however, numbers peaked in late September in both 1977 and 1978 when high counts of over 3,000 and over 250 birds were recorded, respectively (Johnson and Richardson 1981). At Cooper Island, Divoky (1978a) observed buildups of glaucous gulls, particularly in September, whenever euphausids and copepods washed onto shallow beaches, but numbers never exceeded 400 birds. At Icy Cape, peak counts in mid-September (1,000 birds) were quadruple the numbers recorded there during August (Lehnhausen and Quinlan 1981). Thus it is likely that the number of glaucous gulls using Peard Bay greatly exceeded 1,000 birds in late September, making the area an important one for staging glaucous gulls. Although glaucous gulls roosted primarily along the barrier islands and major sandspits, they also concentrated along the gravel promontories throughout Peard Bay, particularly in Kugrua Bay. In late August there was a noted shift of feeding birds to the Chukchi Sea side of Point Franklin spit as was observed for eiders, oldsquaw, and phalaropes.

The concentration of black-legged kittiwakes using Peard Bay in early August was notable because such congregations have not been reported for any other site between Beaufort Lagoon and Icy Cape. At Icy Cape in 1980 small flocks (of less than 100 birds) were recorded roosting on barrier islands and feeding in the lagoon during July and August, but when numbers peaked during migration in late August and September the birds no longer stopped (Lehnhausen and Quinlan 1981). This seasonal pattern was similar to that observed at Peard Bay but the numbers using Peard Bay were much higher. Kittiwakes fed throughout the bay and in nearshore waters of the Chukchi Sea. At other sites kittiwakes did not stop in any significant numbers during migration (Connors and Risebrough 1978; Divoky 1978a; Johnson and Richardson 1981; Johnson 1983).

The numbers and timing of arctic terns staging at Peard Bay were similar to those found at other sites along the Arctic coast. Numbers peaked in mid-August at about 2,000 birds in Peard Bay (34 birds/km of shoreline). Terns fed mainly in shallow waters of Peard Bay (within 3-4 km of shore) and in nearshore waters of the Chukchi Sea among brash ice. At Simpson Lagoon peaks of 33 and 2 terns/km were recorded in mid-August in 1977 and 1978, respectively (Johnson and Richardson 1981). At Cooper Island numbers of terns peaked during the first two weeks of August (maximum of 2,500 birds on 5 August); there too, large numbers roosted on barrier islands and fed in shallow waters (Divoky 1978a). At Icy Cape numbers peaked in mid-August within the lagoon, along barrier islands, and in salt marshes (Lehnhausen and Quinlan 1981). Peak density along barrier island beaches at Icy Cape (64/km) was about double that recorded at Peard Bay during the same period although in different years. By early September densities had greatly decreased, but some adults were still tending newly fledged local young.

As arctic terns left the area, Sabine's gulls, predominantly juveniles, moved in to roost on barrier islands and spits, feeding in the same habitats used by terns (primarily nearshore waters with brash ice). Sabine's gulls did not exceed a few hundred birds in Peard Bay, however. At Cooper Island Sabine's gulls were present in substantial numbers throughout August and peaked at about 1,000 birds in late August (Divoky 1978a). There too, feeding habits were similar to those of arctic terns, dipping, surface-seizing and pecking on beaches (Divoky 1978a). Lehnhausen and Quinlan (1981) recorded a substantial migration of Sabine's gulls past Icy Cape in August and September but very few birds stopped to use the area. No fall migration of Sabine's gulls was recorded at Simpson or Beaufort Lagoons (Johnson and Richardson 1981; Johnson 1983).

4.4.3 Feeding Studies

To assess the feeding ecology of birds using Peard Bay, species that exploited benthic and epibenthic prey organisms (oldsquaw and eiders) and those that fed at or near the surface of the water (arctic terns and red phalaropes) were studied. Results of these investigations clearly point to the different prey communities used by these two bird groups in Peard Bay. The single most important prey to both oldsquaw and eiders was the epibenthic amphipod *Atylus carinatus*, which accounted for over 50% of the total number and volume of prey consumed (Tables 4-19, 4-20 and 4-22). The epibenthic cottid fish *Myoxocephalus quadricornis* figured prominently in the diet of oldsquaw but not in the diet of eiders, while gastropods and polychaetes were major components in the diet of eiders but not in the diet of oldsquaw (Tables 4-19, 4-20, and 4-22). Despite these differences, when Horn's (1966) calculations, which compare both the taxa shared by the two species and the total number of prey consumed of each taxa, were applied, the correlation coefficient of dietary overlap between oldsquaw and eiders at Peard Bay was found to be very high (0.91).

The diets of arctic terns and red phalaropes generally represented prey taken from the water column (Table 4-20). Nektonic amphipods, particularly *Leptamphopus* sp., were the most important prey of red phalaropes (Tables 4-20, 4-25), and *Myoxocephalus* sculpins were the principal prey of arctic terns (Tables 4-20, 4-23). The origin of the sculpins found in the tern stomachs is uncertain since all terns were collected in water greater than 3 m in depth and no whole fish were found in the stomachs, only well digested fragments. Considering the limited depth to which arctic terns can dive (<0.5 m) and the epibenthic habitats of *Myoxocephalus*, terns had probably taken these fish in shallow nearshore areas during previous feedings and not in the open, deeper waters of the bay. The dietary coefficient of overlap (Horn 1966) between arctic terns and red phalaropes was 0.30. This is considerably less than that between oldsquaw and eiders, but markedly greater than that between any other two species (range = 0.03-0.11) when paired combinations among all four species were considered.

When the diets of the four species were looked at in terms of prey species diversity (Shannon-Weiner Index, Pielou 1974), oldsquaw were found to have had the most diverse diet (1.46) followed by red phalaropes (1.42), eiders (1.19), and arctic terns (0.91). When the foraging niche breadth of the four species was calculated according to Levins (1968) the same trend was found to persist.

Comparisons of studies on the feeding ecology of birds at Peard Bay with other Alaska Beaufort Sea lagoons must be prefaced with a few comments about the limitations placed on such comparisons. These limitations are due primarily to differences in types of analysis, interpretation of results, varying physical and ecological parameters inherent among the sites, differences in sample sizes, and annual variations in prey availability.

The major studies available for comparison with Peard Bay are those from Simpson Lagoon (Johnson and Richardson 1981) and Beaufort Lagoon (Johnson 1983). The primary method used by Johnson and Richardson (1981) to assess the importance of prey to avian predators was the modified Hynes (1950) point-method, in which the percent volume and percent number of prey are considered together when determining the value of a particular taxon of prey. The same method was reportedly used by Johnson (1983); however, he only presented his results as percent volume by wet weight, which does not allow the use of the Hynes method for a comparison with results at Peard Bay and Simpson and Beaufort Lagoons. This aside, the major shortcoming of the Hynes method is that it does not consider the percent frequency of occurrence of a prey taxon, and as a result the method is very sensitive to biases resulting from 1) large numbers or volume of a taxon of prey occurring in only one or two stomachs, and 2) lesser numbers or volume of prey occurring in the majority of the stomachs in a sample. For these reasons the IRI method of Pinkas et al. (1971), which considers all three parameters (percent of number, percent frequency of occur- rence, and percent volume) to assess prey taxa, is a more accurate predictor of the importance of various prey items in the diet of a predator. For instance, among the eider stomachs from Peard Bay (Tables 4-20, 4-22) the polychaete, *Nephthys* sp., occurred in only one stomach but accounted for over 25% of the total volume of all prey. Using the Hynes method polychaetes were three times as important as indicated by the IRI method. Likewise, mysids in the diet of red phalaropes analyzed by the Hynes method were given ten times the importance of the IRI method. In this instance, one of 20 phalarope stomachs contained three fresh mysids which accounted for 7% of the total volume of all prey. When percent wet weight alone is used to compare the relationship between mysids and other taxa in phalarope stomachs, the importance of mysids was 58 times greater than that produced by the IRI method and six times greater than that produced by the Hynes method (Table 4-27). Among arctic tern stomachs, fish were ranked noticeably lower using the Hynes method instead of the IRI method (Table 4-20), yet fish occurred in 93% of all tern stomachs (Table 4-23). In this particular instance none of the fish were whole and the total stomach volume was reduced from what it could have been if the fish were newly caught.

Tables 4-28 and 4-29 present a comparison of the diets of oldsquaw and red phalaropes collected at Simpson Lagoon, Beaufort Lagoon, and Peard Bay. Comparisons could only be made by expressing the values for each prey taxon as percent composition by wet weight. When the diets of oldsquaw among the three sites are examined, the most obvious difference is for oldsquaw at Peard Bay; amphipods were extremely important but mysids were absent from the diet, while at both Simpson and Beaufort Lagoons mysids were the predominant prey. Oddly, fish were important to oldsquaw at both Peard Bay and Beaufort Lagoon, but assumed a very minor role at Simpson Lagoon, which lies between the two sites.

The comparison of phalarope diets among the three sites (Table 4-29) shows more variation than that found in the diets of oldsquaw from these sites. The proportion of mysids and amphipods in stomachs of Peard Bay phalaropes was most similar to that found at Beaufort Lagoon. At Simpson Lagoon, in 1977 only were copepods present in the diets of phalaropes. This extreme annual variation in prey selection by phalaropes in the Arctic is further evidenced from studies done by Connors and Risebrough (1977) at Barrow. From small samples (n=8) of juvenile red phalaropes collected during August 1975 and 1976, eight major prey taxa, only two of which were taken both years, were identified.

4.5 SUMMARY AND CONCLUSIONS

Studies were conducted at Peard Bay between late May and early September 1983 to assess the importance of the area to water-associated birds in comparison with that of other embayments and lagoons along the Alaska coast of the Chukchi and Beaufort Seas. The specific objectives of these studies were to 1) determine the timing and magnitude of use of the area by birds during spring, fall, and molt migration, and 2) evaluate the relative importance to

Table 4-27. A comparison of three methods for evaluating the relative importance of prey to oldsquaw and red phalaropes at Peard Bay.

Taxon	Oldsquaw Vol.[1] (%)	Oldsquaw IRI[2] (%)	Oldsquaw Wet wt.[3] (%)	Red phalarope Vol.[1] (%)	Red phalarope IRI[2] (%)	Red phalarope Wet wt.[3] (%)
Amphipods	54.3	53.9	54.6	56.3	85.7	49.1
Fish	17.7	22.4	23.2	14.5	4.1	4.2
Bivalves	21.7	17.1	16.1	2.0	0.2	0.1
Gastropods	2.2	2.8	2.3	0.0	0.0	0.0
Polychaetes	2.8	1.2	2.8	8.3	1.8	7.0
Mysids	0.7	0.9	0.7	6.0	0.6	35.1
Ostracods	0.3	1.6	0.1	0.0	0.0	0.0
Isopods	0.2	0.1	0.1	0.5	0.2	0.1
Hydroids	0.1	0.1	0.1	0.0	0.0	0.0
Insects	0.0	0.0	0.0	7.3	5.3	3.2
Seeds	0.0	0.0	0.0	4.0	2.0	0.1
Plants	0.0	0.0	0.0	1.0	0.2	0.1
Total	99.9	100.0	99.9	99.9	100.1	100.0

[1] Method of Hynes (1950), modified by Griffiths et al. (1975), in which % volume and % number are considered but not % frequency of occurrence (see Johnson and Richardson 1981).

[2] Method of Pinkas et al. (1971) in which % volume, % number and % frequency of occurrence are considered.

[3] Only % wet weight is considered (see Johnson 1983).

birds of disturbances from petroleum-related development in the Peard Bay area. Field observations were conducted for a total of 44 days (28 May-14 June, 15-22 July, 10-14 August, and 26 August-7 September). During these periods the following tasks were performed: 1) 112 hours of "migration watches" of birds migrating over Peard Bay and along the nearshore waters of the Chukchi Sea during spring and fall, 2) 91 "sweep counts" of an 11.5-km^2 area of Peard Bay between mid-July and early September, 3) four aerial surveys recording birds seen on fixed transects across Peard Bay and along the shoreline of the bay and the Chukchi Sea side of Point Franklin spit, 4) six on-ground censuses of birds using tundra, salt marsh, and barrier island habitats, 5) 91 on-ground shoreline transects, totaling 310 km, to assess bird use of the shoreline along the Peard Bay and Chukchi Sea sides of Point Franklin spit, and 6) the collection of 68 specimens of five principal avian species to determine the feeding ecology of birds using Peard Bay.

Table 4-28. A comparison of the diets of oldsquaw in Simpson Lagoon, Beaufort Lagoon and Peard Bay.[1]

Taxon	Simpson Lagoon 1977 (n=54)	Simpson Lagoon 1978 (n=72)	Beaufort Lagoon 1982 (n=24)	Peard Bay 1983 (n=26)
Mysids	67.6	79.7	37.7	0.7
Amphipods	15.9	12.4	13.1	54.6
Fish	2.7	0.4	46.6	23.2
Bivalves	9.6	6.2	0.3	16.1
Others	4.2	1.3	2.3	5.4

[1] Expressed as percent composition wet weight (g). Data for Simpson and Beaufort Lagoons from Johnson (1983).

Table 4-29. A comparison of the diets of red phalaropes in Simpson Lagoon, Beaufort Lagoon and Peard Bay.[1]

Taxon	Simpson Lagoon 1977 (n=46)	Simpson Lagoon 1978 (n=26)	Beaufort Lagoon 1982 (n=10)	Peard Bay 1983 (n=20)
Mysids	8.1	2.3	32.6	35.7
Amphipods	20.2	95.8	34.9	49.1
Copepods	65.3	0.0	0.0	0.0
Fish	0.0	0.0	31.9	4.2
Pteropods	4.0	1.9	0.3	0.0
Others	2.4	1.9	0.3	11.6[2]

[1] Expressed as percent composition wet weight (g). Data for Simpson and Beaufort Lagoons from Johnson (1983).

[2] Composed of 7.0% polychaetes, 3.2% insects, and 1.1% seeds.

When the study began on 27 May, Peard Bay was 100% ice-covered and the nearshore lead in the Chukchi Sea was 10 km offshore. Spring migration of eiders and oldsquaw was estimated to have been in progress for about a week prior to this date. During the period 30 May - 4 June an average of 500 waterfowl/h (primarily eiders) passed to the east, mostly over the nearshore waters of the Chukchi Sea. Spring migration of all species had essentially ceased by 7 June, being most apparent for loons, shorebirds, and passerines on 31 May, and for jaegers (90% pomarine) between 2 and 4 June. No pronounced migration of gulls or terns was noted in spring.

Fall migration for many species had begun just prior to the 26 August survey. Migration of loons (80% arctic) was still building by 7 September (23 - 67 birds/h). Migration of waterfowl occurred at a mean daily rate of 500 to 1,400 birds/h and consisted primarily of oldsquaw, unlike the spring migration which was dominated by eiders. Migration of jaegers consisted mostly of parasitic jaegers passing in low numbers throughout the season. Migration of black-legged kittiwakes, arctic terns, and Sabine's gulls peaked on 28 August, 1 September, and 3 September, respectively. There was no migration of passerines in fall. The shorebird migration consisted of mostly juvenile red phalaropes with lesser numbers of dunlin and sanderlings.

Densities and composition of breeding birds on the tundra were similar to those found at other coastal sites in the Arctic, with shorebirds and lapland longspurs predominating. Birds were also found nesting in salt marshes, on sand dunes and beaches of the barrier islands and sandspits. The most abundant species in these habitats was the arctic tern (60-85 pairs). A colony of black guillemots nesting on the Seahorse Islands was particularly significant, having increased from 4-5 pairs to 15-40 pairs during the last 10 years even though no major change in nesting habitat has occurred.

Significant bird use of open-water portions of Peard Bay did not begin until late July. Because of the record late breakup of ice in Peard Bay in 1983, it is not known if this timing is typical of waterbird use of the area. Overall densities of birds using deeper waters of the bay during the 15 July and 10 and 25 August aerial surveys were 0.2 birds/km^2, 19.8 birds/km^2, and 86.5 birds/km^2, respectively. The densities of birds along the shore were 3.9 birds/km^2, 179.9 birds/km^2, and 39.5 birds/km^2. When extrapolated, these densities project an estimate of 275, 12,635, and 13,180 birds using all of Peard Bay on the above respective dates. On the 25 August survey the majority of birds were molting oldsquaw (53%) and eiders (32%). The density of oldsquaw recorded on this survey was one of the lowest for this species as compared to studies conducted at other lagoons along the Alaska Beaufort Sea coast.

In terms of timing and species composition, use of shoreline areas by birds generally reflected that found during aerial surveys and migration watches. The lowest lineal density (3.9 birds/km) occurred during mid-July when there was still shore-fast ice in many places. By early August, densities had increased to about 40 birds/km of shoreline and, by early September, 60 birds/km of shoreline. During August about half of the birds reported were red phalaropes (21 birds/km). This density compares favorably with those reported for this species from other Beaufort Sea lagoons. By late August through early September oldsquaw, with lesser numbers of eiders and glaucous gulls, accounted for most of the birds using shoreline areas of the bay and Point Franklin spit.

The diets of birds collected at Peard Bay, particularly oldsquaw and red phalaropes, were quite different from those reported for the same species at other sites along the Beaufort Sea coast. While mysids figured prominently in the diets of oldsquaw at Simpson and Beaufort Lagoons, they composed only a trace of oldsquaw prey at Peard Bay. Amphipods of the genus *Atylus* were the major prey eaten at Peard Bay with fish (cottids) and bivalves also important components of the diet of oldsquaw. Only at Beaufort Lagoon did fish assume an equal importance in the diet of oldsquaws and at neither Simpson Lagoon nor Beaufort Lagoon did bivalves play an important role in their diet. Red phalaropes at Peard Bay consumed primarily amphipods and mysids. At Beaufort Sea sites these and other prey assumed different levels of importance in the diets of phalaropes. These inter-site differences may be real or due to annual variations in prey availability or the generally small sample size of stomachs from the various sites. The diet of eiders at Peard Bay was composed of amphipods, polychaetes, and gastropods, while the diet of arctic terns was almost exclusively fish with some amphipods and copepods eaten.

From our initial findings we can draw only tentative conclusions about the relative susceptibility of different species to potential disturbances resulting from petroleum exploration or development in the Peard Bay area. All our data point to the fact that considerable variation occurs among years in the timing and extent of use of the area by birds. This may especially be true in spring, when use of the bay and nearshore waters is highly dependent on the ice conditions persisting that year. We have found, however, that at least for 1983 the Peard Bay area was particularly important to nesting black guillemots, migrating juvenile red phalaropes, and molting oldsquaw and eiders. Considering the record late breakup of ice in Peard Bay in spring 1983, we need to determine if the phenology of migration and use of the area that we witnessed is typical. It is also important that we determine the extent to which brant use the area during their molt-migration, which we missed during our absence between late June and early July. Lastly, our data strongly suggest that peak use of the bay by birds, particularly oldsquaw and eiders, occurs in late September. Since most studies in the Arctic have neglected this period, there are few data from which we can predict the importance of this Arctic embayment in late fall. This point is emphasized by the fact that the avian food base in Peard Bay is completely different from that found for any other Arctic lagoon. Thus it is important that we determine when peak populations of birds occur in the area, how long they persist, and what effects they have on the prey base.

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Appendix Table 4-A. Taxa of prey identified in stomachs of oldsquaw, eiders, arctic terns and red phalaropes collected at Peard Bay in 1983.

Taxa[1]	Oldsquaw n=26	Eider n=8	Arctic Tern n=14	Red Phalarope n=20
Hydrozoa				
Hydroid colony	x			
Rhynchocoela	x			
Polychaeta				
Polynoidae	x	x		x
Phyllodocidae				x
Anaitides sp.				x
Nephthys sp.		x		
Pectinaria sp.	x			
Unid. fragments	x			
Gastropoda				
Alvinia sp.	x			
Bittium sp.	x	x		
Colus sp.		x		
Oenopota sp.	x			
Polinices pallida	x	x		
Cylichna occulta	x	x		
Unid. gastropod	x	x		
Bivalvia				
Mysella sp.				x
Mysella tumida	x	x		
Mytilus edulis	x			
Musculus corrugatus	x			
Liocyma fluctuosa	x	x		
Cyrtodaria kurriana	x	x		
Unid. bivalve	x	x		
Ostracoda	x	x		
Copepoda				
Calanoid			x	
Harpacticoid			x	
Mysidae				
Mysis spp.	x	x		x
Isopoda				
Saduria entomon	x	x		x

Appendix Table 4-A. Taxa of prey identified in stomachs of oldsquaw, eiders, arctic terns and red phalaropes collected at Peard Bay in 1983. (continued)

Taxa[1]	Oldsquaw n=26	Eider n=8	Arctic Tern n=14	Red Phalarope n=20
Amphipod - Gammaridae				
Leptamphopus sp.			x	x
Onisimus sp.			x	x
Monoculodes sp.	x			
Anonyx sp.	x			
Atylus carinatus	x	x	x	
Apherusa glacialis	x			
Pontoporeia femorata		x		
Pleusymtes subglaber	x			
Paradulichia spinifera	x			
Acanthostepheia sp.	x			
Pleustus sp.	x			
Unid. Gammaridae			x	x
Amphipod - Hyperiidae				
Caprella carina	x			
Priapulidae				
Priapulis caudatus		x		
Insecta				
Diptera (adult)			x	x
Unid. (winged)				x
Osteichthyes		x		x
Gadidae				
Boreogadus saida			x	
Cottidae				
Myoxocephalus quadricornis	x		x	
Unid. fish vertebrae	x	x		x
Unid. fish otolith	x	x		
Unid. fish egg				x
Vegetative matter				
Unid. algae		x		
Unid. seed			x	x
Unid. vascular plant parts		x		x
Total taxa	27	18	9	13

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[1] Lowest identifiable level.

CHAPTER 5

INVERTEBRATES OF PEARD BAY

5.1 INTRODUCTION

5.1.1 General

Previous NOAA/OCSEAP studies have relied upon the construction and testing of conceptual ecological models to predict the potential impacts of oil and gas development. The concept of pulsing and flushing types of Arctic lagoons has been of central importance to the modeling of these systems. In the past a rich assemblage of birds and fish was discovered to have been supported by the seasonal migration and productivity of several epibenthic species of invertebrates. The migration and abundance of the two dominant forms of mysids, *Mysis litoralis* and *Mysis relicta*, in Simpson Lagoon, were related to a flushing type of wind-induced exchange of nearshore waters (Griffiths and Dillinger 1981). Conversely, the more limited type of pulsing exchange induced by storm surge as typified in the lagoons of the eastern Beaufort Sea showed decreased importance of mysids in vertebrate diets since their seasonal migration into the lagoons was restricted (Truett 1983). In a comparison of effects of exchange, the pulsing and flushing systems differ little in mysid species composition and abundance, but differ greatly in the relative dominance of the amphipod species in the epibenthic communities (Jewett and Griffiths 1983). Amphipods are more dominant in the epibenthic communities of the pulsing system.

In terms of biomass, the epifauna communities of both systems were equivalent, and were not a limiting factor as a food resource to the populations of the higher trophic consumers of fish and birds.

Since the epifaunal species of mysids and amphipods were the key trophic components to the higher consumers to the Simpson Lagoon food web by virtue of the relatively large abundances, no attempts have been made to compare flushing and pulsing lagoon systems with their infaunal communities. Instead, most of the previous NOAA/OCSEAP benthic studies were directed toward assessment of selected habitats in the Arctic littoral system. Local aspects of boulder patch kelp ecology were investigated by Dunton and Schonberg (1980). Assessment of the importance of detritus of terrestrial origin in the arctic food web was made by Scheider and Koch (1980) and assessment of effects of crude oil on Beaufort Sea invertebrates under the physiological stress associated with hypersaline winter conditions was made by Scheider (1980). The seasonal recolonization of shallow depths (<2 m) was studied by Broad (1980), while Carey (1980) investigated nearshore populations of bivalves along the Beaufort Sea coast.

5.1.2 Specific Objectives

The purpose of this study was to characterize the invertebrate populations of the Peard Bay environment, to compare the results with those of previous studies in the Alaskan Arctic, and to evaluate the potential impact of oil and gas development over part of Lease Sale No. 85, the Chukchi Sea. This involved the compilation and and review of all pertinent literature available for both the Chukchi and Beaufort Sea environments.

5.2 METHODS

5.2.1 Literature

Previous literature regarding invertebrate populations of the eastern Chukchi and Beaufort Seas was gathered from published literature and research reports. These data were reviewed and presented as background for interpretation of the specific Peard Bay results.

5.2.2 Peard Bay Process Study

5.2.2.1 Field Sampling

Four methods were used to sample the invertebrate populations in the Peard Bay area during the winter and open-water seasons. Populations were assessed by sampling the epibenthos with drop nets and the infauna with diver cores during open-water season. Winter populations were sampled with drop nets, baited traps, and zooplankton tows. Both sets of methods are effective in obtaining distribution and abundance data for comparison with similar sets of information from previous NOAA/OCSEAP lagoonal studies. The drop net used in this study was identical to that used in the Simpson and Beaufort Lagoon studies (i.e., 50 cm dia., 1.0 m length, 1.0 mm mesh, 0.2 m^2 sampling area). This net is adequate for sampling macroinvertebrates such as mysids and amphipods within 10 cm of the lagoon bottom (Griffiths and Dillinger 1981). During the sampling operation the open net is forced by pole or dropped by weight onto the substrate from the side of a small boat or ice hole. Four to five replicate samples per station were taken to assess the distribution and abundance of the dominant species.

The sampling devices used in the diver coring were No. 10 coffee cans, each being 15 cm in diameter, 20 cm in length, and 0.018 m^2 in sampling area. Prior to sampling, one end of each can was fitted with a cover of 1.0-mm-mesh netting to prevent escape of the more motile forms. During the sampling operation the diver randomly inserted the open end of the core into the substrate, recovered the core sample intact, and then capped the core with a fitted lid. The cores were then lifted to the boat for transport ashore and sample processing.

Baited minnow traps were set at ice holes located both within and outside Peard Bay. At each station they were set at the ice/water interface and at the bottom to ascertain the presence of amphipod species during the winter season.

The zooplankton tows were performed with 0.5-m conical nets constructed of 200-μm mesh netting hauled vertically through ice holes during the winter sampling. Two replicates were taken per station at the nearshore and Peard Bay station, and were preserved in a sea water solution of 10% buffered formalin.

Frequency and location of drop net samples were designed to define differences in distribution and abundance of the epibenthic fauna. In addition to determining how secondary producers such as mysids and amphipods were distributed, periods and locations of sampling would resolve any local concentrations of organisms resulting from the effects of flushing or intrusion of nearshore water. The July, August, and March samplings were coordinated with hydrographic sampling.

5.2.2.2 Laboratory Procedures

Sample processing of diver cores involved sieving and preserving on site, prior to transportation to laboratory facilities for identification, enumeration, weighing, and construction of voucher collections. Beach sieving occurred before samples froze and post-sample predator-prey interactions occurred. Samples were sieved with sea water through a nested array of 1.0-mm and 0.5-mm-mesh sieve screens. All specimens were relaxed in propylene phenoxitol before preservation. After relaxation all samples were fixed in a 10% formalin solution of buffered sea water. On arriving at the laboratory, the samples were transferred to a 70% ethanol solution for preservation. They were then identified to the lowest taxonomic level possible, enumerated, and weighed wet. Wet weights were taken after the specimens were rinsed with fresh water and blotted dry. In the event of fragmentation, specimens were identified and enumerated by the total number of whole organisms plus the number of separate telsons and abdomens, and telson of mysids and amphipods, respectively. The total number of polychaetes consisted of the number of whole organisms plus the number of anterior pieces. Voucher collections were made for purposes of verifying species identifications, cataloguing type specimens, and aiding in the identification of fish and bird stomach contents. As requested, the complete voucher collection and documentation will be submitted to the California Academy of Science for processing and storage.

Drop net samples were processed in an identical manner with the addition of length measurements of the mysid species. Following enumeration and identification of each species, individual lengths of the mysid species were measured to the nearest 0.1 mm, and weighed to the nearest 0.01 mg.

Zooplankton and baited trap samples were processed directly, since no splitting was necessary. Individuals were enumerated and identified to the lowest possible taxon.

All raw data were entered on files in NODC specifications to facilitate statistical analysis. NODC format No. 132 was used to store the epibenthic and benthic information on nine-track tape.

5.2.2.3 Statistical Analysis

The results from both sets of samples were analyzed statistically in a similar manner for purposes of comparison among and between stations. Bartlett's test for homogeneity was applied to the species enumerations of each station before the analysis of variance tests were run ($p<0.05$) (Sokal and Rohlf 1969). Significant differences in abundance, diversity, mean species richness, and dominance were analyzed with a Duncan's Multiple Range Test to determine where the significant differences occurred. The community parameter diversity was calculated using the Shannon-Weiner formula (H'), while the dominance index was estimated from Odum (1980). Qualitative comparisons of species assemblages at each station were made using both Jaccard's Coefficient of Community Index (Greig-Smith 1964) and the Dice Index of Similarity (Boesch 1977). All sets of values were clustered using an unweighted pair-group method outlined by Boesch (1977). The similarity between clusters was calculated as the mean similarity in a matrix between all possible pairs of the assemblages composing the clusters. Clustering is valuable because it usually clarifies the affinities between each of the assemblages present in a similarity matrix.

5.3 RESULTS AND DISCUSSION

5.3.1 Summary of Previous Knowledge

5.3.1.1 Zooplankton Distribution

With the exception of a study of plankton volumes of major species conducted by English (1966), and a survey by Cooney (1977), little data exist concerning the zooplankton of the southeastern Chukchi Sea from Cape Prince of Wales to Point Lisburne. English (1966) measured plankton volumes on an extensive number of net tows in 1959 and 1960 (Figures 5-1 and 5-2). The figures reveal clear differences in plankton volumes between onshore and offshore stations and in a south-north direction. Plankton volumes were generally lower in inshore areas and in Kotzebue Sound. Also, there was a general decrease in plankton volumes in a north-south direction. Differences in species composition were also found. Table 5-1 shows the major species found in the nearshore and offshore areas.

Cooney (1977) also observed this offshore-nearshore differentiation in species composition. He noted a low-diversity nearshore community which is continuous from Cape Prince of Wales to Point Hope. The dominants were those observed by English and included the cladocerans *Evadne* and *Podon*, as well as copepods of the genera *Acartia*, *Pseudocalanus*, and *Centropages*. Also paralleling English's earlier observations, Cooney found *Calanus plumchrus* and *Eucalanus bungii* offshore. During favorable conditions these dominant species enter the Beaufort coastal areas where they are known as expatriate species from the Bering Sea (Horner 1978). Although previous data gathered during the CGC Glacier cruise of August to September 1976 indicated that calanoids were the dominant forms at stations located along the 40-m contour from west of Icy Cape to north of Point Barrow (Horner 1981a,b), little is known of the dominant forms from the northeast Chukchi region, because species composition information was not completed from those sets of samples.

The known distribution of species in the Chukchi parallels that described by Cooney (1981) for the oceanic and nearshore communities of the Bering Sea. In that area, there is an additional region referred to as a middle shelf

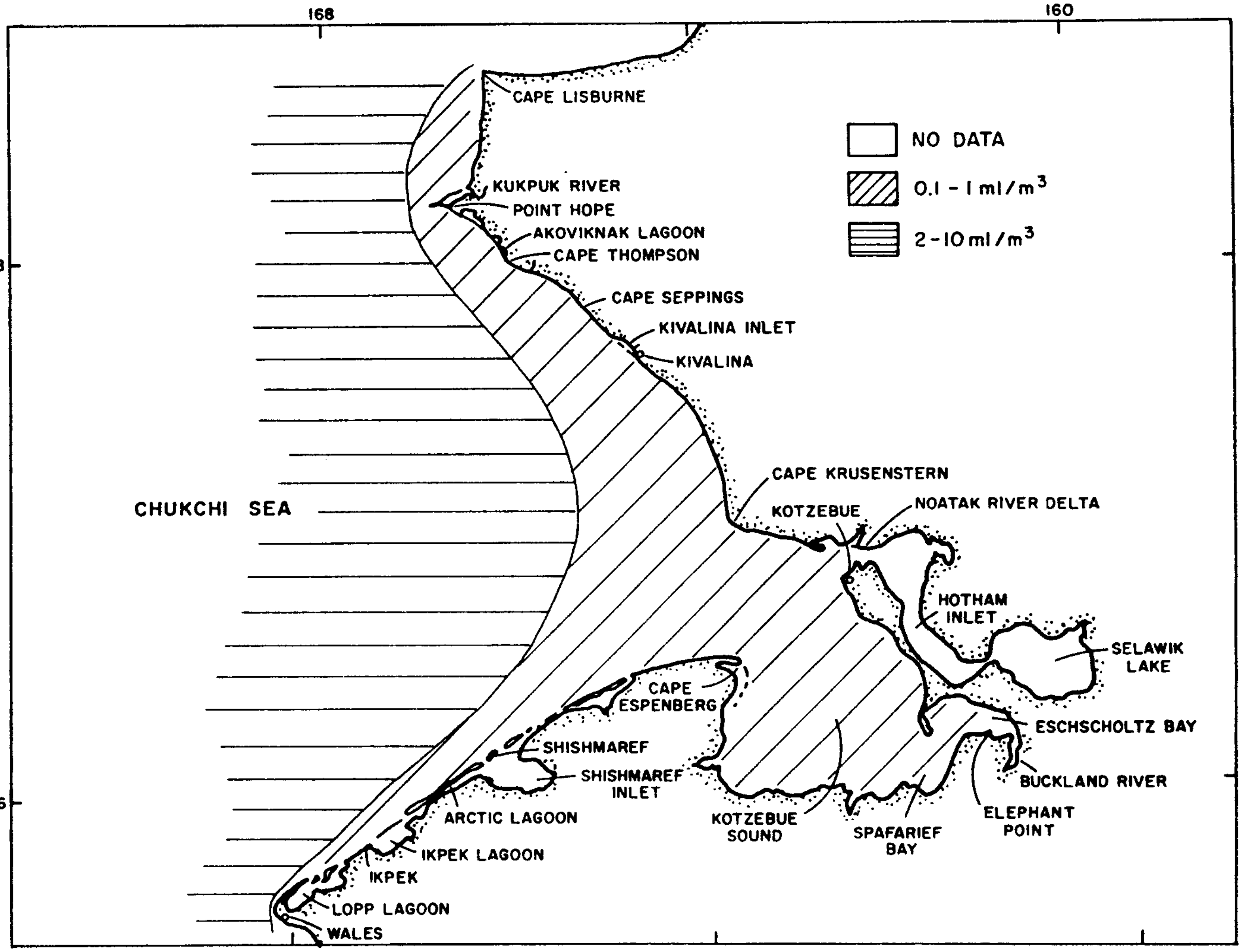


Figure 5-1. Plankton Volumes From Samples in the Chukchi Sea Taken on the Cruise of the M.V. Brown Bear in 1959 (from English 1966).

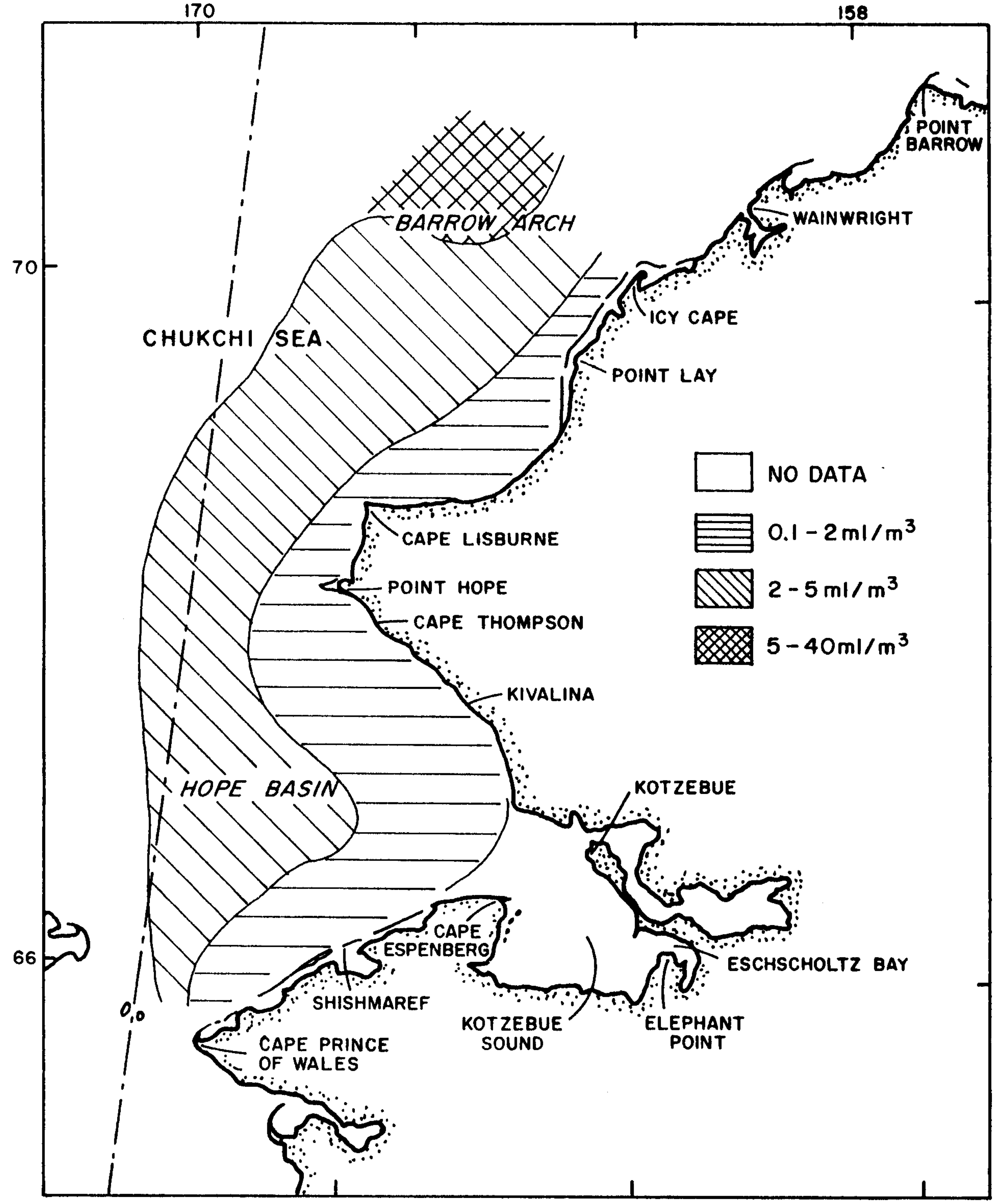


Figure 5-2. Plankton Volumes From Samples in the Chukchi Sea Taken on the Cruise of the M.V. Brown Bear in 1960 (from English 1966).

Table 5-1. Major zooplankton species found in the offshore and nearshore areas of the Chukchi Sea from Cape Prince of Wales to Point Lisburne (from English 1966).

Nearshore Species	Offshore Species
Eurytemora pacifica	*Metridia lucens*
Acartia clausii	*Calanus plumchrus*
Evadne nordmani	*Eucalanus bungii*

community which results from the presence of a hydrographic front separating the middle shelf from the outer shelf. This strong hydrographic differentiation apparently does not occur in the Chukchi, and so is not reflected in the distribution of zooplankton communities. There are two communities in the Chukchi: an inshore community which occurs in the relatively well-mixed nearshore region, and an offshore community which occurs in the stratified offshore waters. This differentiation in species distribution occurs also in the phytoplankton (Chapter 7).

Lagoon Zooplankton. The coastline of the Chukchi Sea from Cape Prince of Wales to Barrow is characterized by numerous enclosed or semi-enclosed lagoons. These lagoons represent a transitional area between marine and freshwater environments. In August 1959, Johnson (1966) investigated the zooplankton species composition of nine of these lagoons between Cape Prince of Wales and Point Lisburne. Two of these were located north of Cape Thompson and seven were located south of the cape (Figure 5-3). Samples were taken from about the middle of each of the lagoons in 1.3-3.0 m depth. The salinity and temperature data indicated that lagoons were unstratified (Table 5-2). The species compositions in the lagoons were dissimilar from each other (Table 5-3); possibly reflecting the differences in salinity occurring as a result of influx of fresh versus salt water, the height of the lagoon above sea level, and effectiveness of the berm as a barrier to the percolation of water out of the lagoon. The dominant zooplankton species in the lagoons were either brackish or freshwater. The most saline lagoon, 2S, had more marine fauna than any of the others. It was dominated by *Acartia bifilosa*, a brackish water species; however, neritic and offshore species such as *Calanus finmarchicus*, *Pseudocalanus minutus*, and *Acartia longiremis* were relatively common. Lagoon 4S, which also had a relatively high salinity although not as saline as 2S, displayed species of the genera *Evadne* and *Podon* which are common to the nearshore zone of the Chukchi Sea. The source of these species is obviously the nearshore and offshore Chukchi. Their presence and persistence in the lagoons is probably determined by the extent and frequency of saltwater intrusion to these environments, and the degree to which the above-mentioned mechanisms for determining salinity are effective in individual lagoons. The plankton of the other lagoons are generally freshwater species. Johnson (1966) discusses the evolutionary and taxonomic significance of these species.

In addition to their obvious geological significance, the lagoons are transitional areas between the marine and freshwater zooplankton fauna of the

Table 5-2. Water temperature and salinity in coastal lagoons immediately south and north of Cape Thompson, August 1959* (after Johnson 1966).

Lagoon	Bottom Depth (m)	Temperature (^{o}C)	Salinity (ppt)
1S, August 12	1.5		
Surface		11.0	0.83
Bottom		11.0	0.83
2S, August 12	1.3		
Surface		11.2	14.31
Bottom		11.1	15.96
3S, August 12	1.3		
Surface		11.0	0.16
Bottom		10.4	0.17
4S, August 13	1.3		
Surface		12.3	6.42
Bottom		12.1	7.16
5S, August 13	1.3		
Surface		13.6	0.83
Bottom		13.6	0.83
6S, August 13	2.4		
Surface		12.6	0.73
Bottom		12.4	0.73
7S, August 13	2.0		
Surface		12.6	3.58
Bottom		12.1	3.58
1N, August 14	3.0		
Surface		13.5	0.18
Bottom		13.0	0.18
2N, August 15	2.5		
Surface		13.8	0.46
Bottom		13.0	0.55

*The lower sample was taken just above the bottom depth indicated.

Arctic. As such, they may be excellent indicators of recent past geological processes, if the relationship between the frequency of salt water intrusions into the lagoons and the species composition (i.e., marine versus freshwater) of the zooplankton could be determined. Such a relationship could then be used to predict the frequency of intrusion on the basis of an examination of the zooplankton.

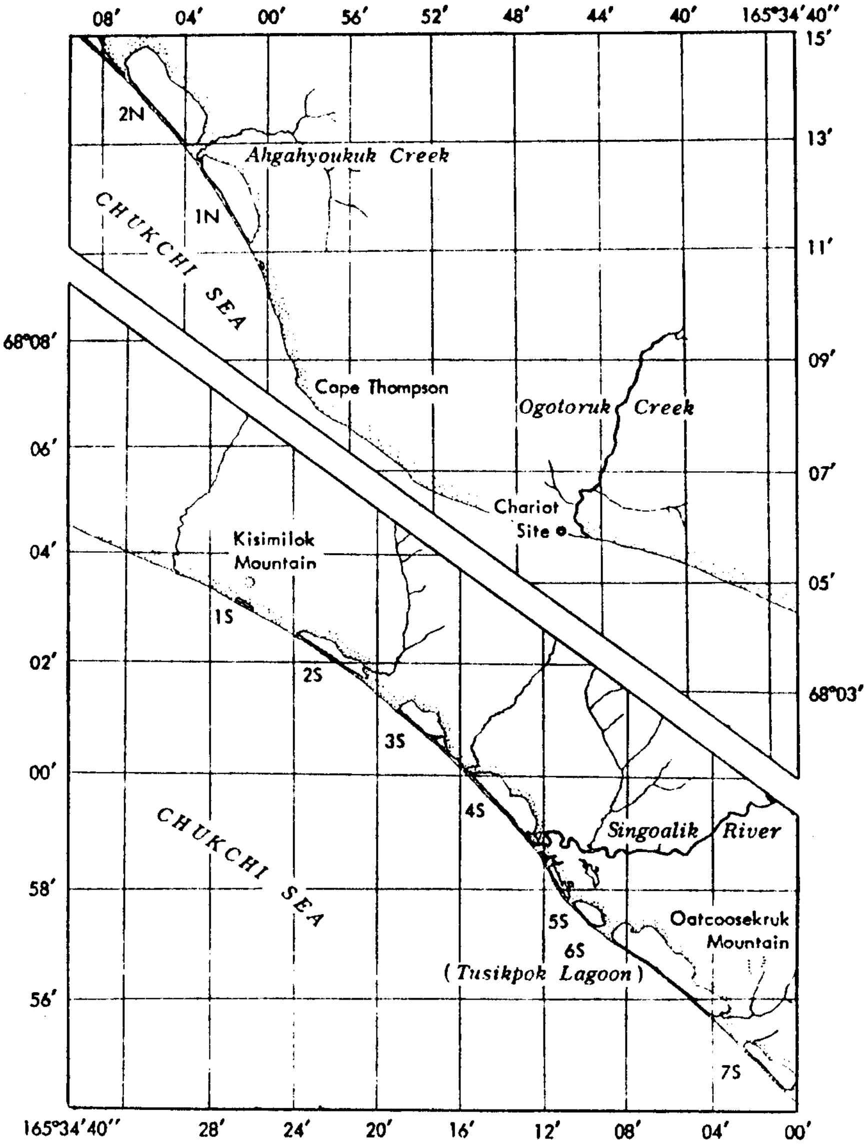


Figure 5-3. Location of the Lagoons Sampled in the Cape Thompson Area. Based on U.S. Coast and Geodetic Survey Topographic Map T-9425 Alaska (after Johnson 1966).

5.3.1.2. Benthic Distribution

The coastal benthos of the Chukchi Sea has been partitioned between two major environments: the nearshore/littoral subject to seasonal disturbance by ice, and the offshore areas which are not. Both areas have been characterized by Pacific-boreal fauna which are apparently recruited to the Chukchi via northerly flowing currents from the Bering Sea. There is a general paucity of

Table 5-3. Percentage composition of zooplankton in coastal lagoons in the Cape Thompson area of the Chukchi Sea (after Johnson 1966).

	Lagoons South														Lagoons North			
	1		2		3		4		5		6		7		1		2	
Date of Sampling: (August 1959)	6	12	6	12	6	12	6	13	6	13	6	13	6	13	14	15	5	15
Surface or Bottom:	S	B	S	B	S	B	S	B	S	B	S	B	S	B	S	B	S	B
Acartia bifilosa			78	90			90	12	c									
Acartia clausi			2						+									
Acartia longiremis			18	8														
Calanus finmarchicus			+															
Centropages abdominalis			c	+														
Cyclops sp.	65	12				+	+	4	c	c	2	c	+	+	c	1	1	+
Eurytemora canadensis	3					1		+	+	+	3		c	3				
Eurytemora herdmani			c	c														
Eurytemora pacifica			+	+														
Eurytemora forcola, n.sp.											95	90			99	98	57	28
Limnocalanus grimaldi															c	c		
Limnocalanus johanseni	28	81			c	1	+		96	38		+	14	17	c	c	1	15
Pseudocalanus minutus			1	+														
Tortanus discaudatus			c	c														
Harpacticoids			+	1	+	+	5	72	+	+								
Daphnia	2	6			99	97	+		c	37	+	85	80				40	57
Podon			+	+			1	12										
Evadne			+				+	+										
Clam shrimp	2	1			+				3	25								
Fairy shrimp (Anostraca)	c																	
Ostracods		+		+		+	+				+							+
Neomysis (juvenile)								+										
Sagitta			+															
Fish larvae (total found)				3				7										
Rotifer												9						

Plankton not present in sufficient numbers to constitute 1% of the population are indicated as follows: c = common; + = present.

Arctic forms in both regimes (Stoker 1981). Within two miles of the beach, gravel bottoms dominate and the fauna in these environments reflect this bottom type (Sparks and Pereyra 1966). Additionally, this nearshore/littoral fauna is depopulated annually by ice scour (Broad et al. 1978), and as a result, populations are sparse and species are poor.

Further offshore, the infauna is part of a continuous community along most of the shelf from Cape Krusenstern to Barrow. Biomass is higher in the southern Chukchi than it is in the northern Chukchi (Stoker 1981). Epifauna dominates the benthos (Sparks and Pereyra 1966), and in the southeastern Chukchi epifaunal invertebrate biomass comprises 87-93% of the catch per unit effort of trawls (Wolotira et al. 1977). The remaining biomass is composed largely of fish. Molluscs are the most diverse group, while echinoderms dominate in terms of biomass.

Nearshore Benthic Environments. MacGinitie's (1955) early reconnaissance of benthic communities in the region of Point Barrow indicated the presence of a relatively depauperate faunal assemblage in the nearshore zone out to a depth of 3 to 6 m. The tunicate *Rhizomolgula globularis*, and the bryzoan *Alcyonidium disciforme*, were the dominant fauna in the coarse sand and gravel substrate of the littoral zone. Several species of annelid and a dorid were also found in this zone.

More recently the nearshore benthic community of the coastal Chukchi was addressed by Broad et al. (1978) and Sparks and Pereyra (1966). Broad made a survey of the littoral zone of the coast from Cape Prince of Wales to Point Barrow. Broad et al. (1978) defined the littoral zone as the area extending from the shoreline to a depth of 2 m. In this area, macroalgae were unimportant and relatively species poor (<35 species). The faunal elements were also sparse and species poor with higher diversity and biomass south of Point Hope than in more northerly areas. He found 23 species south of Point Hope which did not occur north of the point. The most abundant genera in this group of 23 included the bivalves *Cryptomya* sp., *Mytilus edulis*, and *Mysella* sp., and the shrimps *Crangon septemspinsoa* and *Neomysis* spp., and chironomid larvae. With the exception of enchytraeid worms and chironomid larvae, there were few permanent faunal residents north of Point Hope. In this area, the littoral community is probably depopulated annually by ice scouring.

Sparks and Pereyra (1966) also observed a generally impoverished littoral zone (within 7 m of the beach) in the southeastern Chukchi Sea which they attribute to ice scour. They also examined the lagoons and found low populations of mysids and occasionally numerous *Lipidurus* sp. In the immediate offshore area (within 2 miles of the beach), they found small populations of organisms which were apparently adapted to the gravel-bottom environments which occur extensively from Cape Krusenstern to east of Cape Lisburne (Figure 5-4). The fauna in this environment included cumaceans, an alcyonarian, crangonid shrimp, small sponges, starfish, amphipods, bryozoans, tunicates, and small barnacles.

Offshore Benthic Environments. In his survey of the benthic fauna of the Point Barrow region, MacGinitie (1955) also provided qualitative assessments of the communities of the offshore benthic environment. Two unique communities were identified from the mud bottom zone extending from 6 to about 30 m in depth. The first of the assemblages was located at the shoreward edge of

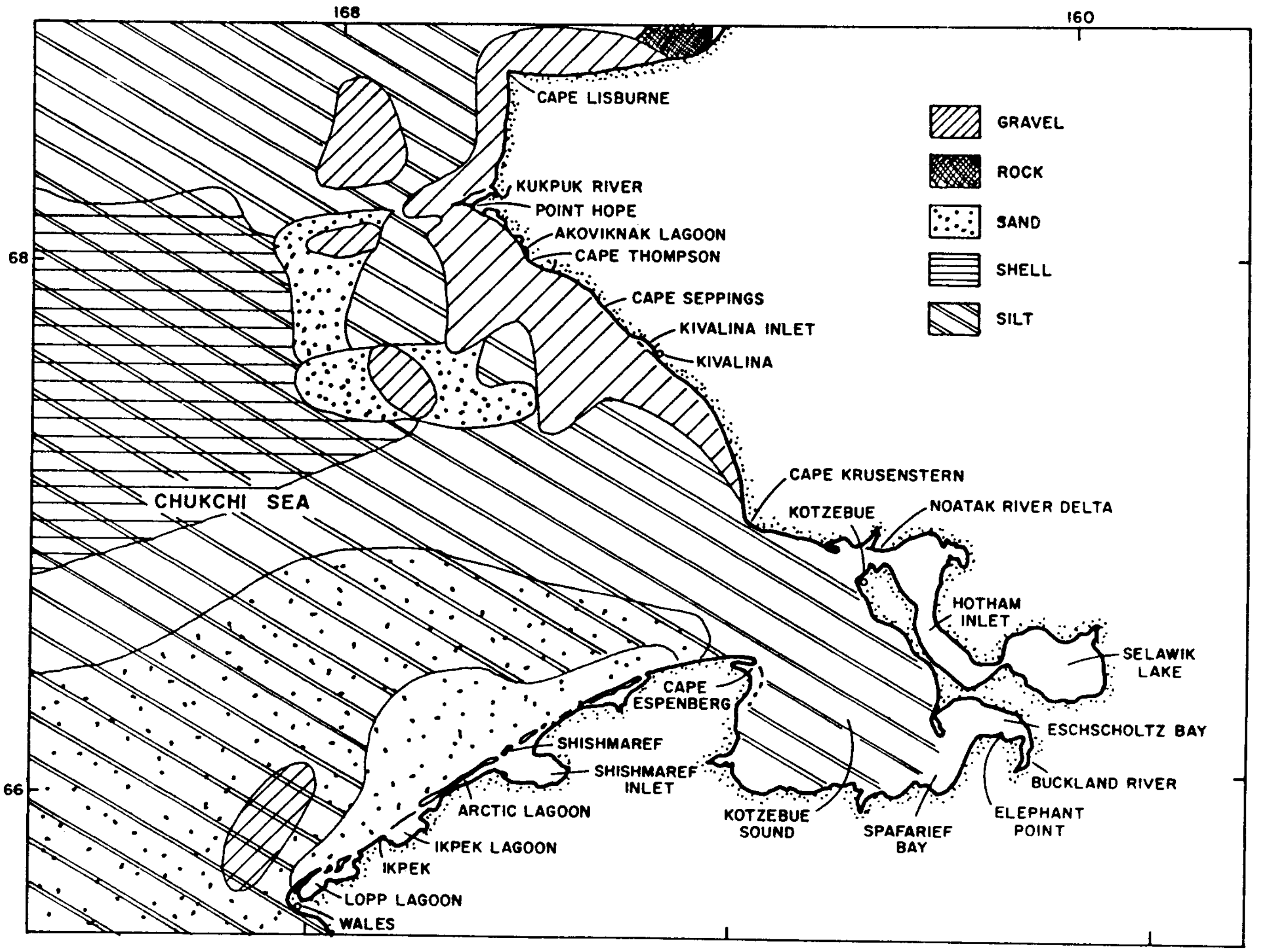


Figure 5-4. Bottom Types in the Southeastern Chukchi Sea (after Sparks and Pereyra 1966).

the mud zone and was dominated by the echiuroid *Echiurus echiurus*, the lugworm *Arenicola glacialis*, and a sea cucumber *Myciotrochus rinki*. Several polychaetes and another echiuroid were also relatively abundant in this community. In the deeper areas of the mud zone a burrowing anemone and numerous species of molluscs including *Macoma calcarea, Astarte montagui, Musculus* spp., *Nuculana* sp., and *Macoma moesta* were the dominant fauna of the benthic community.

Stoker (1981) reviewed the distribution of infaunal macrofauna in the Bering-Chukchi shelf, and found a generally interrelated community extending over the entire shelf. The infauna in the Chukchi appears to be dependent upon Bering Sea populations for food and recruitment. The southern Chukchi is higher in biomass than the northern Chukchi. The entire shelf area was dominated by boreal-Pacific forms rather than high Arctic species, probably as a result of the northerly flow of currents in the area. A suite of cluster analyses revealed a single group extending parallel to the shore from Cape Krusenstern to Point Barrow (Stoker 1981). This group was dominated by *Maldane sarsi, Ophiura sarsi, Golfingia margaritacea,* and *Astarte borealis.* Station coverage did not permit characterization of the infauna from Cape Prince of Wales to Cape Krusenstern.

Sparks and Pereyra (1966) made the first extensive inventory of the trawlable epifauna in the southeastern Chukchi. They noted that the fauna is boreal-Pacific, and found almost a complete absence of Arctic fauna. The authors suggested that the stocks are probably repopulated by Bering Sea stocks which are carried into the area by northerly flowing currents. They also found a wide variety of bottom types in the offshore Chukchi from Kotzebue Sound to north of Cape Lisburne. They suggest that the diversity of the epifauna may be due to the variety of bottom types and to the sharp temperature gradients in offshore-onshore transects. Wolotira et al. (1977) extended the studies of Sparks and Pereyra (1966) in the southeastern Chukchi Sea. They also found high diversity and relatively high biomass in this area. Table 5-4 presents the biomass of the major invertebrate groups in the southeastern Chukchi. Echinoderms formed the major phyla by weight, and molluscs were the most diverse phyla represented. Among the arthropods, decapod crustaceans, particularly Crangonidae, Hippolytidae, and Pandalidae, were most dominant. It should be noted that these shrimp are often important prey items in the diets of bearded and ringed seals. More recently, Jewett and Feder (1981) summarized the results of surveys of the southeastern Chukchi epifauna as part of the assessment of the Alaskan continental shelf. They found a generally high invertebrate biomass north of Cape Espenberg. The majority of species were molluscs (Table 5-5), while echinoderms composed the highest biomass (Table 5-6).

Dominant Species. Jewett and Feder (1981) found *Neptunea heros* concentrated in waters of 0-40-m depth off Cape Lisburne, Cape Krusenstern, and in Kotzebue Sound. Wolotira et al. (1977) found this species in relatively low concentrations nearshore, although they also found high concentrations in inner Kotzebue Sound and in areas south of Cape Krusenstern. In contrast, Sparks and Pereyra (1966) did not find any gastropods, including *N. heros*, widely distributed in Kotzebue Sound.

Wolotira et al. (1977) reported maximum catch rates of echinoderms in outer Kotzebue Sound between Cape Espenberg and Cape Krusenstern, where they

Table 5-4. Apparent biomass (metric tons) of major invertebrate taxonomic groups in the southeastern Chukchi Sea (abstracted from Wolotira et al. 1976).

Taxa	Hope Basin	Kotzebue Sound
Gastropods	8,649	1,253
Pelecypods	191	40
Shrimp	1,171	175
Chionoecetes sp.	3,879	3,597
Paralithodes sp.	76	13
Telmessus sp.	1,199	217
Starfish	38,842	17,252
Other echinoderms	4,221	42
Other invertebrates	31,337	4,804

Table 5-5. Average density (individual/km) of dominant epifaunal species at 0-40 m in the southeastern Chukchi Sea (after Jewett and Feder 1981).

Species	Density/km
Neptunea ventricosa	9.80
Neptunea heros	51.41
Pagurus trigonocheirus	49.01
Paralithodes camtschatica	0.02
Paralithodes platypus	0.01
Hyas coarctatus alutaceus	12.21
Chionoecetes opilio	100.37
Asterias amurensis	59.94
Asterias rathbuni	5.82
Evasterias echinosoma	2.19
Leptasterias polaris acercata	21.79
Lethasterias nanimensis	8.92
Strongylocentrotus droebachiensis	4.10
Gorgonocephalus caryi	1.28
Chelyosoma spp.	5.04
Styela rustica macrenteron	14.56
Halocynthia aurantium	0.05

Table 5-6. Biomass of dominant epifaunal species at 0-40 m in the southeastern Chukchi Sea (after Jewett and Feder 1981).

Species	Mean Biomass (g/m^2)	% Total Biomass
Neptunea ventricosa	0.049	1.78
Neptunea heros	0.373	13.39
Pagurus trigonocheirus	0.067	2.40
Paralithodes camtschatica	<0.001	0.03
Paralithodes platypus	<0.001	0.02
Hyas coarctatus alutaceus	0.036	1.30
Chionoecetes opilio	10.203	7.29
Asterias amurensis	0.889	31.91
Asterias rathbuni	0.094	3.40
Evasterias echinosoma	0.096	3.45
Leptasterias polaris acercata	0.151	5.42
Lethasterias nanimensis	0.197	7.08
Strongylocentrotus droebachiensis	0.023	0.83
Gorgonocephalus caryi	0.020	0.74
Chelyosoma spp.	0.048	1.76
Styela rustica macrenteron	0.033	1.21
Halocynthia aurantium	<0.001	0.01
Total	2.281	82.02

contributed 55% of the total catch rate. Jewett and Feder (1981) found that the most commonly occurring echinoderm in shallow (<40 m) water was *Asterias amurensis.* They found concentrations of the species off Cape Krusenstern. *Evasterias echinosoma,* another important echinoderm (Table 5-6), was concentrated off the area of Cape Krusenstern in nearshore areas. In outer Kotzebue Sound, *Lethasterias nanimensis* represented 6.4% of the biomass in 0-40 m of water. Among the other echinoderms, Sparks and Pereyra (1966) found ophiuroids concentrated only in silty areas between Cape Thompson and Kivalina. There were no ophiuroids north of Cape Lisburne. Sea urchins were widely distributed and concentrated off Cape Thompson, and sand dollars were less frequent with a concentration north of Point Lisburne.

Areas of relatively high biomass of *Chionoecetes opilio* (Tanner crab) were found off Capes Krusenstern and Espenberg (Jewett and Feder 1981); however, the species does not occur in enough quantity to provide a commercial fishery.

In the northeastern Chukchi, Frost and Lowry (1983) report brittle stars (usually *Ophiura sarsi*) as dominant in offshore (<40 m) water.

5.3.2 Peard Bay Process Study

The sampling regime shown in Figure 5-5 reflects the areas accessible to the scientific crew during the field effort of the open-water season. Though

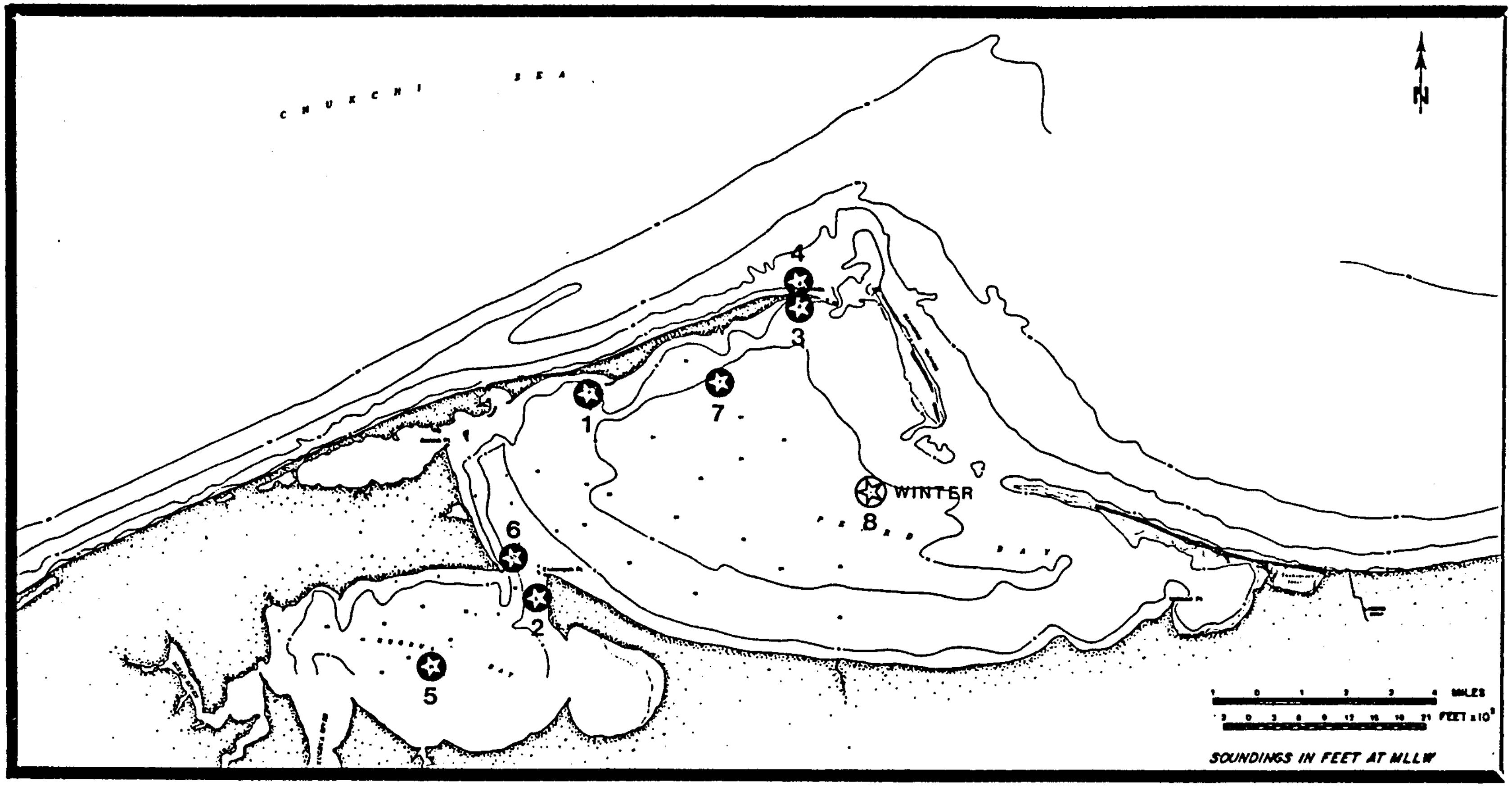


Figure 5-5. Invertebrate Sampling Stations, Summer-Winter 1983-84. Stations 1-4 are summer drop net stations, 5-7 summer diver core stations, and 8 is a winter station.

the intentions of the planned sampling design were not realized due to adverse ice conditions and logistical difficulty, sufficient information of the Peard Bay invertebrates was gathered for a comparison with other arctic systems. Numbers of replicates taken at each station appeared to be adequate for estimating the abundances of the dominant species. Drop net samples of four to five replicates per station did not substantially change the number of taxa found past the third replicate (Figure 5-6). The same trend appeared to be true for the five diver core replicates at each of the three stations examined. The number of taxa and the running mean (pooled abundances) did not substantially change past the fourth replicate (Figure 5-6).

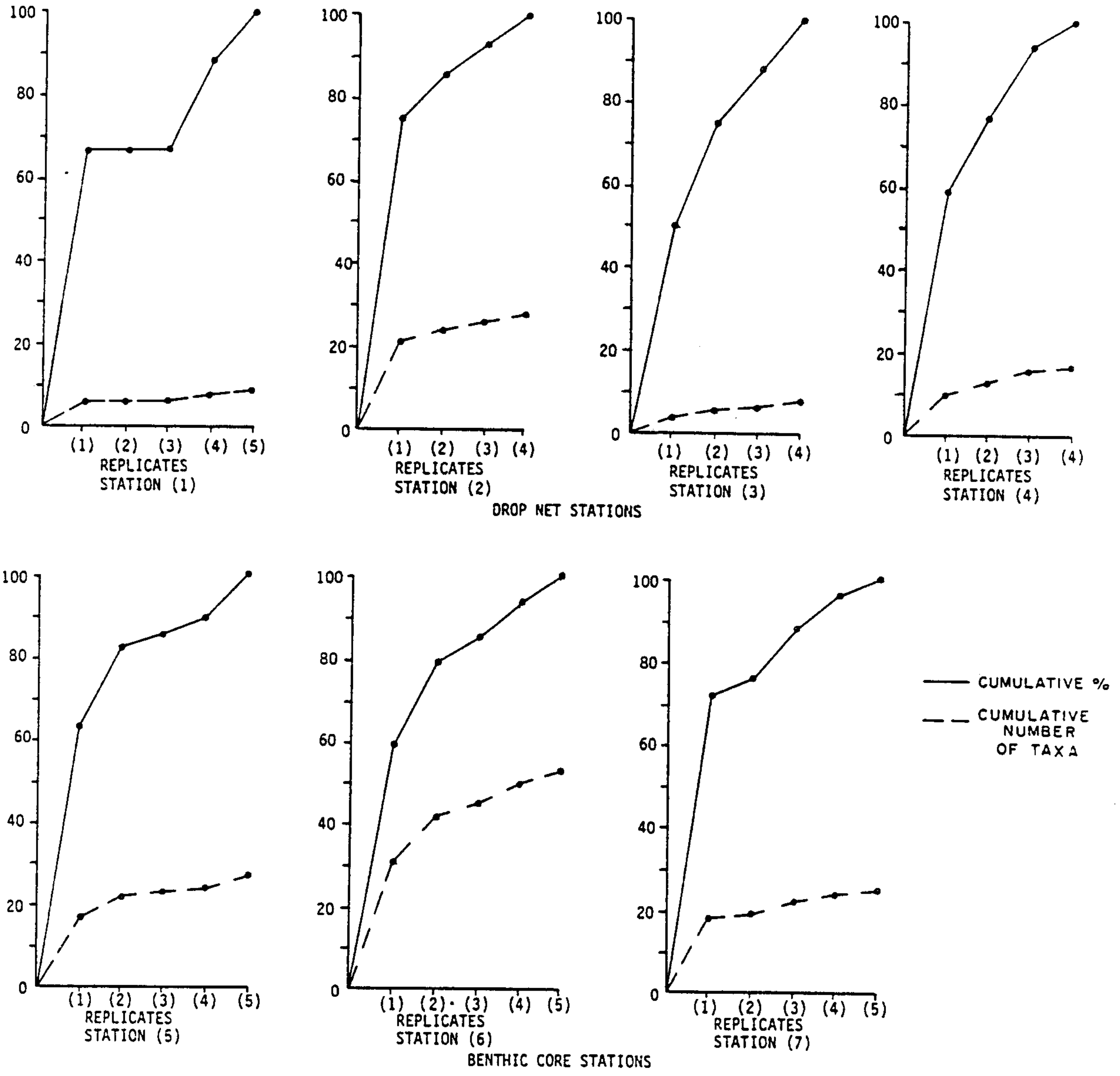


Figure 5-6. Cumulative Number of Taxa (dashed line) and Percent of Total (solid line) per Replicate at All Open-Water Drop Net and Diver Core Stations in Peard Bay, 1983.

It should be noted, however, that relatively few stations were sampled. Thus, the benthic habitats within Peard Bay are insufficiently sampled with respect to spatial variability. The descriptions of these habitats within Peard Bay which result must therefore be considered as preliminary at this time.

5.3.2.1 Epibenthic Samples

Of the four drop net stations occupied during July 1983, a total of 55 taxa were sampled (Tables 5-7a thru 5-7f). The highest number of taxa were found at the entrance to Kugrua Bay (34 taxa) and the fewest occurred on the Peard Bay side of Point Franklin spit (9 taxa) (Figure 5-7). The other two stations sampled, a shallow lagoon within Peard Bay, and the Chukchi Sea side of Point Franklin spit, Stations 2 and 3, respectively, had 14 and 15 taxa, respectively. Of those taxa sampled only two were found common to all four stations (*Saduria entomon* and an unidentified harpacticoid copepod), indicating that a range of species assemblages was sampled at all drop net

Table 5-7a. Summary of drop net data for Peard Bay Benthic Station Al 01. Data shown are mean counts or mass for n replicates.

	Counts			Weight (Grams)		
Taxonomic Name	Number	%	/m^2	Number	%	/m^2
Nematoda	7	2.9	7.1	-	-	-
Pygospio elegans	7	2.9	7.1	-	-	-
Liocyma fluctuosa	1	0.4	1.0	-	-	-
Calanus glacialis	1	0.4	1.0	-	-	-
Pseudocalanus sp.	1	0.4	1.0	-	-	-
Metridia longa	1	0.4	1.0	-	-	-
Eurytemora sp.	15	6.4	15.3	-	-	-
Harpacticoid sp.	4	1.7	4.1	-	-	-
Harpacticoid sp.	73	30.9	74.5	-	-	-
Cirripedia (nauplii)	1	0.4	1.0	-	-	-
Mysis sp. (juv.)	84	35.6	85.7	0.1700	68.4	0.17
Lamprops sp.	1	0.4	1.0	-	-	-
Saduria entomon	36	15.3	36.7	0.0739	29.7	0.08
Onisimus glacialis	4	1.7	4.1	0.0046	1.9	0.00
Total	236		240.8	0.2485		0.25

Table 5-7b. Summary of drop net data for Peard Bay Benthic Station A1 02. Data shown are mean counts or mass for n replicates.

	Counts			Weight (Grams)		
Taxonomic Name	Number	%	/m^2	Number	%	/m^2
Nematoda	3,027	48.9	3,783.8	-	-	-
Pygospio elegans	325	5.2	406.3	-	-	-
Capitella capitata	1	0.0	1.3	-	-	-
Chone sp.	2	0.0	2.5	-	-	-
Chone duneri	1	0.0	1.3	-	-	-
Oligochaeta	7	0.1	8.8	-	-	-
Macoma balthica	136	2.2	170.0	-	-	-
Halacaridae	5	0.1	6.3	-	-	-
Podocopa E	15	0.2	18.8	-	-	-
Calanus glacialis	1	0.0	1.3	-	-	-
Pseudocalanus sp.	7	0.1	8.8	-	-	-
Eurytemora sp.	22	0.4	27.5	-	-	-
Acartia clausi	70	1.1	87.5	-	-	-
Harpacticoid sp. D	77	1.2	96.3	-	-	-
Harpacticoid sp. C	2	0.0	2.5	-	-	-
Harpacticoid sp. B	837	13.5	1,046.3	-	-	-
Harpacticoid sp. A	501	8.1	626.3	-	-	-
Cyclopoid sp. B	21	0.3	26.3	-	-	-
Cyclopoid sp. A	35	0.6	43.8	-	-	-
Mysis sp. (juv.)	63	1.0	78.8	0.1250	5.6	0.16
Mysis litoralis	1	0.0	1.3	0.0342	1.5	0.04
Mysis relicta	1	0.0	1.3	0.0202	0.9	0.03
Lamprops sp.	1	0.0	1.3	-	-	-
Saduria entomon	854	13.8	1,067.5	1.5250	67.9	1.91
Gammaracanthus loricatus	82	1.3	102.5	0.3377	15.0	0.42
Gammarus sp. (juv.)	46	0.7	57.5	0.0353	1.6	0.04
Gammarus setosus	7	0.1	8.8	0.0573	2.6	0.07
Onisimus glacialis	17	0.3	21.3	0.0886	3.9	0.11
Onisimus litoralis	3	0.0	3.8	0.0106	0.5	0.01
Monoculodes latimanus	2	0.0	2.5	0.0002	0.0	0.01
Monoculopsis longicornis	19	0.3	23.8	0.0034	0.2	0.00
Halicryptus spinulosus	1	0.0	1.3	-	-	-
Larvacea	1	0.0	1.3	-	-	-
Cottidae	1	0.0	1.3	0.0081	0.0	0.01
Total	6,191		7,738.8	2.2455		2.81

Table 5-7c. Summary of drop net data for Peard Bay Benthic Station A1 03. Data shown are mean counts or mass for n replicates.

Taxonomic Name	Counts			Weight (Grams)		
	Number	%	/m^2	Number	%	/m^2
Nematoda	5	27.8	6.3	-	-	-
Harpacticoid sp. A	1	5.6	1.3	-	-	-
Cirripedia (nauplii)	2	11.1	2.5	-	-	-
Mysis relicta	1	5.6	1.3	0.0115	17.5	0.01
Saduria entomon	2	11.1	2.5	0.0026	4.0	0.00
Pontogeneia inermis	1	5.6	1.3	0.0008	1.2	0.00
Gammarus sp.	1	5.6	1.3	0.0013	1.2	0.00
Onisimus litoralis	4	22.2	5.0	0.0205	31.3	0.03
Monoculodes latimanus	1	5.6	1.3	0.0288	43.9	0.04
Total	18		22.5	0.0655		0.08

Table 5-7d. Summary of drop net data for Peard Bay Benthic Station A1 04. Data shown are mean counts or mass for n replicates.

Taxonomic Name	Counts			Weight (Grams)		
	Number	%	/m^2	Number	%	/m^2
Anthozoa (medusae)	25	4.1	31.3	-	-	-
Polychaeta (larvae)	17	2.8	21.3	-	-	-
Harmothoe sp. (juv.)	1	0.2	1.3	-	-	-
Spio filicornis	19	3.1	23.8	-	-	-
Poecilochaetidae	1	0.2	1.3	-	-	-
Gastropoda (unident.)	4	0.6	5.0	-	-	-
Polinices pallida	1	0.2	1.3	-	-	-
Calanus hyperboreus	14	2.3	17.5	-	-	-
Calanus glacialis	11	1.8	13.8	-	-	-
Pseudocalanus sp.	146	23.7	182.5	-	-	-
Metridia longa	75	12.2	93.8	-	-	-
Eurytemora sp.	4	0.6	5.0	-	-	-
Acartia clausi	3	0.5	3.8	-	-	-
Cirripedia (nauplii)	179	29.0	223.8	-	-	-
Mysis sp. (juv.)	1	0.2	1.3	-	-	-
Lamprops sp.	1	0.2	1.3	-	-	-
Saduria entomon	1	0.2	1.3	0.0013	0.2	0.00
Apherusa glacialis	1	0.2	1.3	0.0030	0.5	0.00
Apherusa megalops	2	0.3	2.5	0.0075	1.2	0.01
Gammarus sp. (juv.)	11	1.8	13.8	0.1130	17.4	0.14
Gammarus setosus	8	1.3	10.0	0.2079	31.9	0.26
Onisimus litoralis	40	6.5	50.0	0.2469	37.9	0.31
Acanthostephia sp. (juv.)	13	2.1	16.3	0.0649	9.9	0.08
Amphipoda, Hyperiidea (juv.)	1	0.2	1.3	0.0004	0.1	0.00
Paguridae (larval)	16	2.6	20.0	0.0038	0.6	0.01
Sagitta elegans	16	2.6	20.0	-	-	-
Stichaeidae	1	0.2	1.3	0.0010	0.2	0.00
Total	617		771.3	0.6455		0.79

Table 5-7e. Summary of drop net data for Peard Bay Benthic Station Al 08. Data shown are mean counts or mass for n replicates.

	Counts			Weight (Grams)		
Taxonomic Name	Number	%	/m^2	Number	%	/m^2
Anthozoa (medusae)	8	0.1	10.0	-	-	-
Nematoda	5,706	95.1	7,132.5	-	-	-
Capitella capitata	44	0.7	55.0	-	-	-
Ampharete arctica	1	0.0	1.3	-	-	-
Ampharete sp.	8	0.1	10.0	-	-	-
Chone sp.	2	0.0	2.5	-	-	-
Oligochaeta	21	0.3	26.3	-	-	-
Tachyrynchus erosus	3	0.0	3.8	-	-	-
Cylichna occulta	5	0.1	6.3	-	-	-
Cylichnella harpa	1	0.0	1.3	-	-	-
Mysella tumida	14	0.2	17.5	-	-	-
Liocyma fluctuosa	3	0.0	3.8	-	-	-
Odostomia sp.	1	0.0	1.3	-	-	-
Musculus niger	18	0.3	22.5	-	-	-
Pseudocalanus sp.	23	0.4	28.8	-	-	-
Acartia clausi	1	0.0	1.3	-	-	-
Harpacticoid sp.	10	0.2	12.5	-	-	-
Gammaracanthus loricatus	1	0.0	1.3	0.1233	14.9	0.15
Pontoporeia femorata	84	1.4	105.0	0.4897	59.5	0.61
Monoculodes longirostris	14	0.2	17.5	0.2103	25.5	0.26
Priapulida (juv.)	35	0.6	43.8	-	-	-
Total	6,003		7,503.8	0.8233		1.02

Table 5-7f. Peard Bay benthic station data.

Station Number	Number of Replicates	Sample Date	Sample Depth (m)	Latitude DDMMSS	Longitude DDDMMSS
Al 01	5	7/29/83	1.0	705223N	1590630W
Al 02	4	7/31/83	1.3	704903N	1590524W
Al 03	4	7/31/83	1.5	705422N	1585000W
Al 04	4	7/31/83	1.7	705434N	1585000W
Al 08	4	3/15/84	6.0	705020N	1584200W

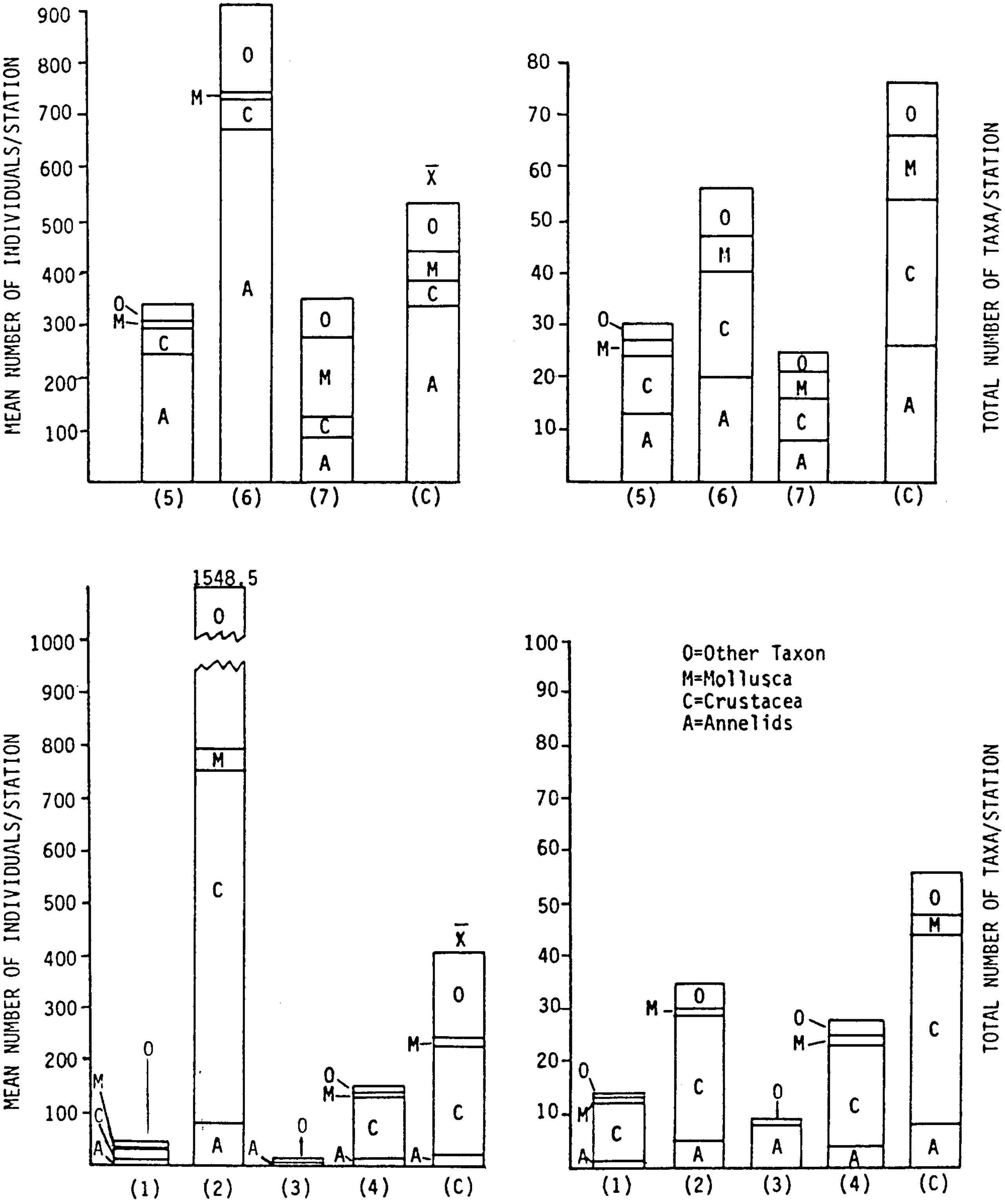


Figure 5-7. Mean Phyletic Comparisons of Abundance and Numbers of Taxa per Station for Drop Nets (Stations 1-4) and Cores (Stations 5-7) in Peard Bay, August 1983.

stations. Cluster analysis also indicated that different species assemblages were sampled at each location (Figure 5-8). Station similarities were lowest between Stations 1 and 3 and highest between Stations 2 and 3.

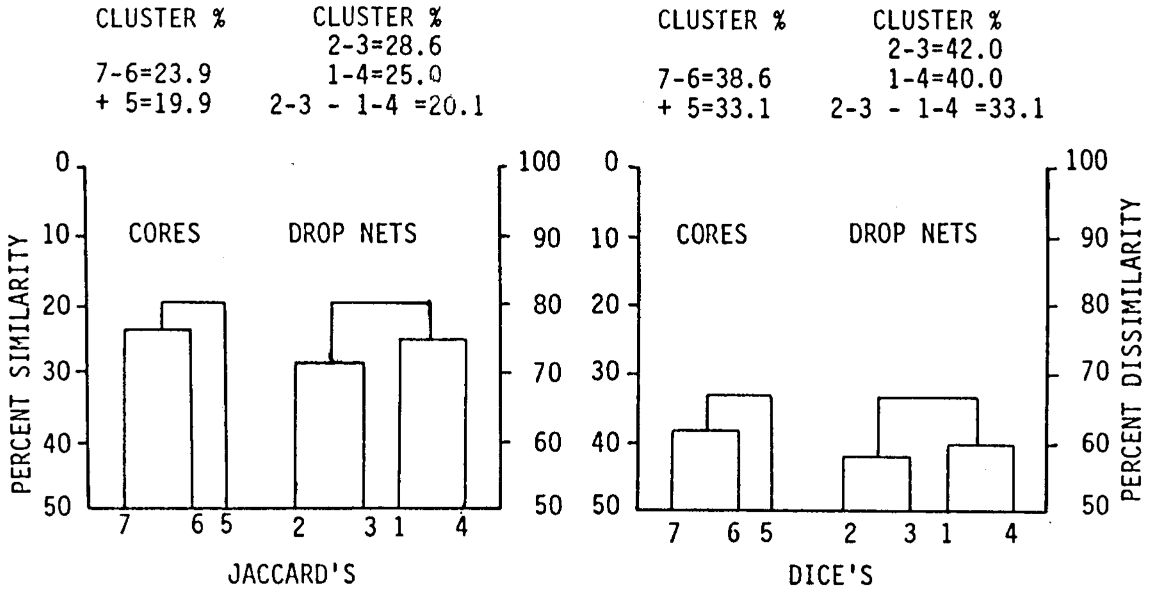
Estimates of species richness, abundance, diversity (H'), and dominance reinforced the trend seen for the numbers of taxa. Values of species richness and abundance were greatest at the entrance to Kugrua Bay and least at the Peard Bay side of Point Franklin spit (Figures 5-7 and 5-9). Higher diversity values were shared by the stations at the entrance to Kugrua Bay and the Chukchi Sea side of Franklin spit (Figure 5-9), while the Peard Bay side of Franklin spit had lower diversity and higher dominance values (Figure 5-9). The results of the ANOVA and Duncan's Test for the total abundances of epibenthic species showed that the samples from the shallow lagoon within Peard Bay and the Chukchi Sea side of Franklin spit were significantly different ($p<0.05$) from the higher value at the entrance to Kugrua Bay and the lower value at the Peard Bay side of Franklin spit (Table 5-8). Other significant differences for the parameters of mean species richness and diversity also reflect the general trend seen between stations (Table 5-8). It appeared that the shallow protected lagoon at the entrance to Kugrua Bay was the most productive of stations sampled in terms of numbers of taxa present and abundance of epifaunal standing stocks, and that the unprotected shelf of the Peard Bay side of Franklin spit was the least productive of the areas sampled.

Only the biologically important epibenthic taxa were included in the biomass analyses while all organisms were included in the previous community parameters discussed. The epibenthic taxa chosen for biomass were considered important based on previous studies conducted in the Chukchi and Beaufort Seas. The drop net is not an effective sampler of the infaunal community because it mainly samples the water column adjacent to the sediment/water interface. Drop nets do not penetrate into all sediment types equally, if at all, and are inappropriate in estimating benthic population parameters.

The dominant epibenthic species in the drop net samples were, in order of decreasing abundance, the isopod *Saduria entomon,* the mysid *Mysis litoralis* and many juveniles unrecognizable at the species level of the genus *Mysis,* the amphipods *Gammaracanthus loricatus* and *Gammarus* sp. (juv.), and *Onisimus litoralis* (Table 5-9). Juvenile individuals of *Saduria entomon* were found in abundance at the Kugrua Bay station, while equivalent numbers of juvenile *Mysis* spp. were noted in both the Kugrua Bay and shallow lagoon samples. The dominant amphipod species by numbers of individuals, *G. loricatus* and *L. setosus*, were both found in abundance at the Kugrua Bay station, while *O. litoralis* was prevalent in the samples taken from the Chukchi Sea side of Point Franklin spit. Other species present in lesser numbers were the amphipods *Onisimus glacialis* and *Monoculopsis longicornis* and juveniles of the family Crangonidae.

Mysid juveniles too immature to be accurately identified to the species level (K. Coyle, personal communication) were found at three of the four stations sampled. The mean density and biomass of these mysids at the lagoon station and Kugrua Bay stations were 84 individuals/m^2 (170 mg wet weight/m^2), and 80 individuals/m^2 (125 mg wet weight/m^2), respectively. Only one mysid was found at the station located on the Chukchi Sea side of Point Franklin spit. The density and biomass estimates are not significantly different between the two protected embayments, Stations 1 and 2 ($p<0.05$). The length

UNWEIGHTED GROUP AVERAGE DENDROGRAMS



SIMILARITY-DISSIMILARITY RESEMBLANCE MATRIX

JACCARD'S COEF.
DIVER CORES (%)
DISSIMILARITY

	5	6	7
5		76.5	83.7
6	23.5		76.1
7	16.3	23.9	

SIMILARITY

JACCARD'S COEF.
DROP NETS (%)
DISSIMILARITY

	1	2	3	4
1		78.6	88.9	75.0
2	21.4		71.4	73.7
3	11.1	28.6		78.6
4	25.0	26.3	21.4	

SIMILARITY

DICE'S COEF.
DIVER CORES
DISSIMILARITY

	5	6	7
5		61.9	71.9
6	38.1		61.4
7	28.1	38.6	

SIMILARITY

DICE'S COEF.
DROP NETS
DISSIMILARITY

	1	2	3	4
1		64.7	80.0	60.0
2	35.3		58.0	58.3
3	20.0	42.0		64.7
4	40.0	41.7	35.3	

SIMILARITY

$$\text{JACCARD'S} = \frac{A}{A+B+C} \times 100$$

$$\text{DICE'S} = \frac{2A}{2A+B+C} \times 100$$

WHERE: A = No. SPP. IN COMMON BETWEEN COLLECTION a AND COLLECTION b

B = No. SPP. IN b BUT NOT a

C = No. SPP. IN a BUT NOT b

Figure 5-8. Clustering by Jaccard's and Dice's Coefficient of Similarities for the Infauna and Epifauna Species Sampled in Peard Bay, August 1984.

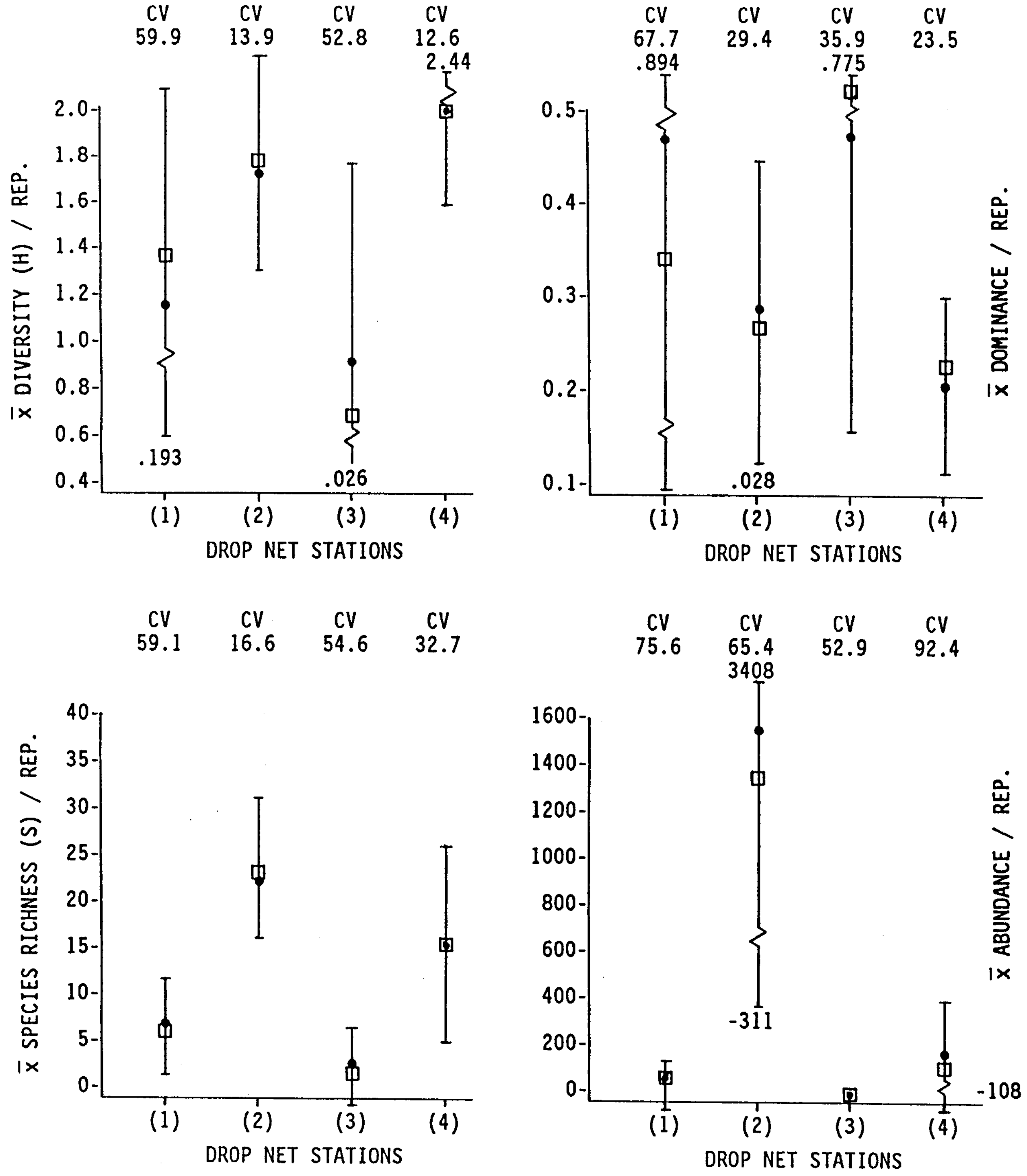


Figure 5-9. Mean Values of Diversity, Dominance, Species Richness and Abundance at Drop Net Stations. Error bars are 95% confidence limits. CV = Coef. of Var. (%)>

Table 5-8. Single-factor analysis of variance (F) for drop net community parameters. Duncan's multiple range test used for mean separation. Underlining indicates a non-significant difference ($p<0.05$).

Parameter	Station Ranking*	F value	Probability
Individuals	2 4 1 3	31.75	0.0002
Species	2 4 1 3	22.97	0.0007
Diversity	4 2 1 3	4.85	0.0176
Dominance	3 1 2 4	2.11	0.1475

*Rankings are from highest to lowest.

Table 5-9. Summary of density and biomass estimates for dominant epibenthic species taken from drop net samples (July 1983).

Crustacean Taxa	Abundance		Density (m^2)		Wet Weight (g)		Biomass g/m^2)	
	No.*	%**	at occurring stations	at all stations	No.*	%***	at occurring stations	at all stations
Mysis sp.	148	2.1	56.9	43.5	0.295	9.2	0.16	0.09
Saduria entomon	893	12.6	262.6	262.6	1.6028	49.9	0.47	0.47
Gammaracanthus loricatus	82	1.2	102.5	24.1	0.3377	10.5	0.42	0.10
Gammarus sp.	58	0.8	24.2	17.1	0.1496	4.7	0.21	0.15
Onisimus litoralis	47	0.7	19.6	13.8	0.278	8.7	0.12	0.08
Total	1,228	17.4		361.1	2.6631	83.0		0.89

* Sum of stations means.
** Percent of total abundance (7,062 individuals) of all taxa from all stations.
***Percent of total weight (3.2093 g) of all taxa from all stations.

frequency measurements, although taken from only 135 individuals, indicate that 48% and 38% of those measured were within the 6-8 mm and 8-10 mm length range, respectively. The average mysid wet weight was 2.0 and 1.5 mg per individual at Stations 1 and 2 (Table 5-10).

Amphipod species dominated the epifauna community in terms of abundance and biomass at two of the four stations sampled. Total amphipod densities were highest at the Kugrua Bay entrance station (162.5 individuals/m^2) and the seaward side of Point Franklin spit (78.8 individuals/m^2). Wet weights were similar at both Stations 2 and 4 (832.8 mg/m^2 and 834.5 mg/m^2, respectively). Dominant species at these stations were *Gammarus* sp. juveniles--most likely *Gammarus setosus*--and adult *G. setosus*, *Onisimus glacialis*, *O. litoralis*, and *Monoculopsis longicornis*. Average wet weights per individual were 17.7 mg for *G. setosus* (adults), 5.1 mg for *O. glacialis*, and 6.1 mg for *O. litoralis*.

It was remarkable how many atypical epibenthic species of calanoid copepods were caught in the shallow depths of the seaward side of the Point Franklin spit during the late July sampling period. The dominant species caught were *Pseudocalanus* sp. and *Metridia longa*. One other species of possible ecological significance was *Calanus hyperboreus*, a large deep water calanoid endemic to the Beaufort Sea and a staple item in the diet of migrating Bowhead whales.

The winter sampling period of March 1984 revealed little epibenthic activity at the station occupied in the central deep area of Peard Bay. Only a few amphipods and no mysids were found. The dominant species of amphipod captured in the drop nets was *Pontoporeia femorata*, while *Anonyx liljeborgi* and *Monoculodes longirostris* were the species found in the baited traps set at the water/ice interface. It was noteworthy that nothing was caught in the traps set over the bottom at the same station, indicating that the water/ice interface was the area of greater activity for at least the more predatory species of amphipods. This inference is supported by numerous observations during the CTD grid sampling. For example, at most holes drilled in Peard Bay, numerous individuals of *Gammaracanthus loricatus* were spilled over the surface of the ice during hole completion procedures.

The zooplankton samples from the nearshore lead system and the Peard Bay station contained a typical component of copepods (Tables 5-11a,b). *Pseudocalanus* sp. dominated all samples with densities averaging 123 individuals/m^3 from the nearshore lead system and 152 individuals/m^3 from the Peard Bay station. *Acartia* sp. was present in the lead system with an average of 4.3 individuals/m^3 and at the Peard Bay station with 8 individuals/m^3. One species of harpacticoid was present only in the bay at 14 individuals/m^3, while *Oithona* sp. was found in the lead system at densities of 5.9 individuals/m^3.

Although no drop net samples were successfully taken in the nearshore area during the winter sampling period because of the prohibitive depth (80 feet), the results of zooplankton vertical hauls indicated the presence of mysids outside Peard Bay (Table 5-11a). Similar hauls taken within the bay contained no mysids, suggesting that they may not make use of Peard Bay as a winter habitat.

Table 5-10. Length frequency of *Mysis* sp. from Peard Bay, 28 July 1983. Length measurements were converted from telson lengths according to Griffiths and Dillinger (1980).

Converted Total Lengths (mm)	Number of Individuals Measured/Station				Total	%
	1	2	3	4		
4.7	-	1	-	-	1	0.7
5.4	7	6	-	-	13	9.6
6.0	9	5	-	-	14	10.4
6.7	12	5	-	-	17	12.6
7.3	9	7	-	-	16	11.9
7.9	12	6	-	-	18	13.3
8.6	16	13	-	-	29	21.5
9.2	10	7	-	-	17	12.6
9.9	6	1	-	-	7	5.2
10.5	2	-	-	-	2	1.5
11.2	-	1	-	-	1	0.7
Total measured	83	52			135	100.0
% measured	98.8	82.5				

Table 5-11a. Summary of zooplankton net data for Peard Bay Benthic Stations Al 08 and Al 09. Data shown are mean counts for n replicates.

Station Number	Taxonomic Name	Number	Counts %	/m^3
Al 08	Anthozoa (medusae)	6	1.6	2.5
	Pseudocalanus sp.	303	81.0	128.2
	Acartia sp.	16	4.3	6.8
	Eurytemora sp.	5	1.3	2.1
	Harpacticoid sp.	27	7.2	11.5
	Harpacticoid sp.	11	2.9	4.7
	Harpacticoid sp.	3	0.8	1.3
	Harpacticoid sp.	1	0.3	0.4
	Ischyrocerus sp.	2	0.5	0.8
	Total	374		158.7
Al 09	*Pseudocalanus* sp.	1,084	91.3	110.4
	Eurytemora sp.	1	0.1	0.1
	Acartia sp.	37	3.1	3.8
	Harpacticoid sp.	8	0.7	0.8
	Harpacticoid sp.	3	0.3	0.3
	Harpacticoid sp.	1	0.1	0.1
	Oithona sp.	52	4.4	5.3
	Mysis sp.	1	0.1	0.1
	Total	1,187		120.9

Table 5-11b. Peard Bay zooplankton station data.

Station Number	Number of Replicates	Sample Date	Sample Depth (m)	Latitude DDMMSS	Longitude DDDMMSS
Al 08	2	3/15/84	6.0	705020N	1584200W
Al 09	2	3/15/84	25.0	705630N	1585912W

5.3.2.2 Infauna Samples

A total of 80 taxa were identified at three diver core stations occupied in late August 1983, the most numerous occurring at the entrance to Kugrua Bay (38 taxa) and the least at the Peard Bay station (8 taxa) (Tables 5-12a thru 5-12d). Of those taxa sampled six were common to all three stations (Nematodes, Oligochaetes, *Terebellides stroemii*, *Chone duneri*, *Cylichna occulta* and *Halicryptus spinulosus*.. The results of the cluster analysis also indicated that different species assemblages were sampled at each location. Jaccard's Coefficient of Similarity gave low values of cluster percentages (23.9 and 19.9) for Stations 7-6 and 5, respectively (Figure 5-8). Dice's Coefficient of Similarity resulted in the same pattern of low species affinities between sampling locations (Figure 5-8).

Dominant phyletic groups differed between stations. The annelid group tended to dominate the samples in terms of numbers of individuals at the Kugrua Bay and Kugrua Bay entrance stations, while molluscs tended to dominate the Peard Bay station (Figure 5-7).

Particle size analysis of a single sediment sample taken from the Peard Bay station revealed a large silt-clay fraction (Table 5-13). Sediment at the entrance to Kugrua Bay was composed of pebbles overlain by a 7-10-cm mat of peat detritus interwoven with filamentous algae (Table 5-13). The sediment sample taken at the Kugrua Bay station was lost.

Levels of abundance between stations showed that the station at the entrance to Kugrua Bay contained the highest densities and that densities at the Kugrua Bay and Peard Bay stations were very similar to one another (Figres 5-7 and 5-10). The results of the ANOVA and Duncan's Test for the numbers of individuals per sample indicates that the standing stocks at the station near the entrance to Kugrua Bay are significantly higher ($p<0.05$) than the two mid-bay stations (Table 5-14). In terms of standing stocks of numbers of individuals and numbers of species, the results suggest that the shallower shelf area of Peard Bay is more productive than either of the two mid-bay stations.

The dominant benthic species in the diver core samples were in the following order of decreasing abundance: the polychaete *Chone duneri*, nematodes, the polychaete *Spio filicornis*, oligochaetes, the polychaete *Scoloplos acmeceps*, the bivalve *Mysella tumida*, the polychaetes Ampharete sp., *Allia* sp., and *Capitella capitata*, and the bivalve *Liocyma fluctuosa* (Table 5-15). The polychaetes dominant at the Kugrua Bay entrance station were: *C. duneri* (14,166/m^2), *S. filicornis* (7,022/m^2), *S. acmeceps* (4,755/m^2), and *C. capitata* (2,433/m^2), while the Kugrua Bay station was dominated by oligochaetes (4,855/m^2) and the polychaete *Allia* sp. (3,100/m^2). In contrast, the Peard Bay station was dominated by the bivalves *M. tumida* (5,144/m^2) and *L. fluctuosa* (2,200/m^2), and the polychaete *Ampharete* sp. (4,122/m^2). Other species conspicuously present in lesser numbers were the amphipods *Atylus carinatus* (288/m^2) at the Peard Bay station, and *Caprella carina* (922/m^2) at the entrance to Kugrua Bay, and the priapulid *Halicryptus spinulosus* (377/m2) at the Peard Bay station. No mysids were captured in the diver core samples at any of the three stations.

Biomass estimates were highest at the entrance to Kugrua Bay (343.9 g/m^2) and lowest at the Kugrua Bay station (16.7 g/m^2). Biomass estimates selected by phyla show Peard Bay to be high for amphipods and bivalves, while

Table 5-12a. Summary of diver core data for Peard Bay Benthic Station Al 05. Data shown are mean counts or mass for n replicates.

	Counts			Weight (Grams)		
Taxonomic Name	Number	%	/m^2	Number	%	/m^2
Kinorhyncha	1	0.1	11.1	-	-	-
Nematoda	157	9.3	1,744.4	-	-	-
Microphthalmus sp.	2	0.1	22.2	0.0000	0.0	0.00
Nephthys cornuta	118	6.9	1,311.1	0.0832	4.1	0.92
Sphaerodoropsis sp.	4	0.2	44.4	0.0046	0.2	0.05
Allia sp.	279	16.5	3,100.0	0.2110	10.4	2.34
Pygospio elegans	49	2.9	544.4	0.0116	0.6	0.13
Chaetozone setosa	69	4.1	766.6	0.0167	0.8	0.19
Capitella capitata	1	0.1	11.1	0.0000	0.0	0.00
Ampharete arctica	126	7.5	1,400.0	0.0749	3.7	0.83
Terebellidae	89	5.3	988.9	0.4976	24.6	5.53
Terebellides stroemii	4	0.2	44.4	0.0647	3.2	0.02
Chone sp.	5	0.3	55.6	0.0012	0.1	0.01
Chone duneri	48	2.8	533.3	0.0030	0.1	0.03
Oligochaeta	437	25.9	4,855.6	0.1843	9.1	2.05
Gastropoda	3	0.2	33.3	0.0076	0.4	0.42
Cylichna occulta	46	2.7	511.1	0.4183	20.7	4.65
Cylichnella harpa	6	0.4	66.7	0.0016	0.1	0.02
Podocopa F	41	2.4	455.6	0.0135	0.7	0.15
Podocopa A	1	0.1	11.1	0.0006	0.0	0.01
Pseudocalanus sp.	1	0.1	11.1	-	-	-
Eurytemora sp.	176	10.4	1,955.6	-	-	-
Harpacticoid sp.	1	0.1	11.1	-	-	-
Cirripedia (nauplii)	3	0.2	33.3	-	-	-
Cumella sp.	1	0.1	11.1	-	-	-
Saduria entomon	5	0.3	55.6	0.1358	6.7	1.51
Corophium sp. (juv.)	3	0.2	33.3	0.0000	0.0	0.00
Corophium sp.	1	0.1	11.1	0.0001	0.0	0.00
Pontoporeia femorata	2	0.1	22.2	0.0081	0.4	0.09
Halicryptus spinulosus	10	0.6	111.1	0.2812	13.9	3.12
Total	1,689		18,766.7	2.0200		22.44

Table 5-12b. Summary of diver core data for Peard Bay Benthic Station Al 06. Data shown are mean counts or mass for n replicates.

	Counts			Weight (Grams)		
Taxonomic Name	Number	%	$/m^2$	Number	%	$/m^2$
Tubularia	8	0.2	88.9	-	-	-
Anthozoa (medusae)	1	0.0	11.1	-	-	-
Rhynchocoela	13	0.3	144.4	-	-	-
Nematoda	814	17.9	9,044.4	-	-	-
Harmothoe sp. (juv.)	1	0.0	11.1	0.0006	0.0	0.01
Pholoe minuta	158	3.5	1,755.6	0.0739	0.3	0.82
Eteone longa	7	0.2	77.8	0.0597	0.2	0.66
Microphthalmus sp.	35	0.8	388.9	0.0007	0.0	0.01
Sphaerodoropsis	2	0.0	22.2	0.0006	0.0	0.01
Dorvillea sp.	1	0.0	11.1	0.0004	0.0	0.00
Scoloplos acmeceps	428	9.4	4,755.6	0.9063	3.2	10.07
Allia sp.	144	3.2	1,600.0	0.0470	0.2	0.52
Spio filicornis	632	13.9	7,022.2	1.8944	6.6	21.05
Chaetozone setosa	13	0.3	144.4	0.0795	0.3	0.88
Travisia forbesii	1	0.0	11.1	0.1008	0.4	1.12
Capitella capitata	219	4.8	2,433.3	0.3904	1.4	4.37
Mediomastus sp.	15	0.3	166.7	0.0115	0.0	0.13
Arenicola glacialis	1	0.0	11.1	0.8188	2.9	9.10
Ampharete arctica	38	0.8	422.2	0.0451	0.2	0.50
Terebellidae	2	0.0	22.2	0.0616	0.2	0.68
Terebellides stroemii	132	2.9	1,466.7	0.6087	2.1	6.76
Chone duneri	1,275	28.0	14,166.7	6.6836	23.4	75.37
Oligochaeta	246	5.4	2,733.3	0.0769	0.3	0.85
Polinices pallida	1	0.0	11.1	0.0133	0.1	0.15
Oenopota sp.	1	0.0	11.1	0.0756	0.3	0.84
Cylichna occulta	6	0.1	66.7	0.0337	0.1	0.37
Mytilus edulis	3	0.1	33.3	10.7449	37.6	119.39
Montacuta dawsoni	21	0.5	233.3	0.0117	0.0	0.13
Macoma balthica	8	0.2	88.9	0.0570	0.2	0.63
Liocyma fluctuosa	8	0.2	88.9	0.0290	0.1	0.32
Cyrtodaria kurriana	1	0.0	11.1	0.0037	0.0	0.04
Halacaridae	23	0.5	255.6	-	-	-
Podocopa F	27	0.6	300.0	0.0047	0.0	0.05
Podocopa D	1	0.0	11.1	0.0000	0.0	0.00
Podocopa C	43	0.9	477.8	0.0044	0.0	0.05
Podocopa B	33	0.7	366.7	0.0127	0.0	0.14
Podocopa A	20	0.4	222.2	0.0106	0.0	0.12
Calanus hyperboreus	1	0.0	11.1	-	-	-
Pseudocalanus sp.	6	0.1	66.7	-	-	-
Eurytemora sp.	8	0.2	88.9	-	-	-
Harpacticus sp.	6	0.1	66.7	-	-	-
Harpacticoid sp.	1	0.0	11.1	-	-	-
Harpacticoid sp.	16	0.4	177.8	-	-	-
Saduria entomon	6	0.1	66.7	0.0113	0.0	0.13
Atylus carinatus	1	0.0	11.1	0.1201	0.4	1.33

Table 5-12b. Summary of diver core data for Peard Bay Benthic Station Al 06. Data shown are mean counts or mass for n replicates. (cont'd)

	Counts			Weight (Grams)		
Taxonomic Name	Number	%	/m^2	Number	%	/m^2
Eusiridae	1	0.0	11.1	0.0006	0.0	0.01
Boeckosimus affinis	1	0.0	11.1	0.0065	0.0	0.07
Onisimus glacialis	1	0.0	11.1	0.0182	0.1	0.20
Monoculodes longirostris	8	0.2	88.9	0.0260	0.1	0.29
Stenothoidae	3	0.1	33.3	0.0001	0.0	0.00
Caprella carina	86	1.9	955.6	0.2679	1.0	2.98
Priapulus caudatus	4	0.1	44.4	0.7923	2.8	8.80
Halicryptus spinulosus	8	0.2	88.9	0.6704	2.3	7.45
Rhizomolgula globularis	10	0.2	111.1	3.1916	11.2	35.46
Leptocottus armatus	1	0.0	11.1	0.4864	1.7	17.86
Total	4,550		50,555.6	28.5524		329.70

Table 5-12c. Summary of diver core data for Peard Bay Benthic Station Al 07. Data shown are mean counts or mass for n replicates.

	Counts			Weight (Grams)		
Taxonomic Name	Number	%	$/m^2$	Number	%	$/m^2$
Anthozoa (medusae)	10	0.6	111.1	-	-	-
Nematoda	325	18.6	3,611.1	-	-	-
Pholoe minuta	1	0.1	11.1	0.0000	0.0	0.00
Allia sp. a	5	0.3	55.6	0.0005	0.0	0.01
Allia sp. b	1	0.1	11.1	0.0000	0.0	0.00
Chaetozone sp.	1	0.1	11.1	0.0001	0.0	0.00
Ampharete sp.	371	21.2	4,122.2	0.9276	7.5	10.31
Terebellides stroemii	1	0.1	11.1	0.0001	0.0	0.01
Chone duneri	15	0.9	166.7	0.0223	0.2	0.25
Oligochaeta	44	2.5	488.9	0.0392	0.3	0.44
Tachyrynchus erosus	24	1.4	266.7	0.3258	2.6	3.62
Polinices pallida	1	0.1	11.1	0.0004	0.0	0.00
Cylichna occulta	64	3.7	711.1	1.6071	12.9	17.86
Mysella tumida	463	26.5	5,144.4	3.0613	24.6	34.01
Liocyma fluctuosa	198	11.3	2,200.0	5.0965	40.9	67.74
Podocopa F	145	8.3	1,611.1	0.0288	0.2	0.32
Podocopa C	1	0.1	11.1	0.0000	0.0	0.00
Amphiascus sp.	3	0.2	33.3	-	-	-
Atylus carinatus	26	1.5	288.9	0.5264	4.2	5.85
Pontoporeia femorata	7	0.4	77.8	0.0102	0.1	0.11
Ischyrocerus sp.	2	0.1	22.2	0.0027	0.0	0.03
Anonyx sp. (juv.)	1	0.1	11.1	0.0091	0.1	0.10
Monoculodes longirostris	1	0.1	11.1	0.0009	0.0	0.01
Priapulus caudatus	3	0.2	33.3	0.1611	1.3	1.79
Halicryptus spinulosus	34	1.9	377.8	0.6308	5.1	7.01
Total	1,747		19,411.0	12.4509		138.34

Table 5-12d. Peard Bay diver core station data.

Station Number	Number of Replicates	Sample Date	Sample Depth (m)	Latitude DDMMSS	Longitude DDDMMSS
Al 05	5	8/27/83	4.0	704750N	1591130W
Al 06	5	8/29/83	4.0	704909N	1590622W
Al 07	5	8/29/83	7.0	705255N	1585124W

Table 5-13. Grain size analysis of sediment taken at station Al 07 in Peard Bay, August 1983.

Size Class (mm)	Cumulative Fractional Percent
over 1.000	2.0
1.000 - 0.707	2.8
0.707 - 0.500	2.8
0.500 - 0.350	2.8
0.350 - 0.250	2.8
0.250 - 0.180	2.8
0.180 - 0.125	2.8
0.125 - 0.088	2.8
0.088 - 0.062	2.8
0.062 - 0.031	7.7
0.031 - 0.016	13.4
0.016 - 0.008	29.0
0.008 - 0.004	37.8
0.004 - 0.002	57.1
0.002 - 0.001	82.4
<0.001	100.0

Total organic carbon*	4.9 %
Percent carbonate*	2.9 %
Percent moisture*	50.7 %

*percent by weight

Table 5-14. Single-factor analysis of variance (F) for benthic core community parameters. Duncan's multiple range test for mean separation. Underlining indicates a non-significant difference (p<0.05)).

Parameter	Station Ranking*	F value	Probability
Individuals	$6\quad \underline{5\quad 7}$	16.84	0.00054
Species	$6\quad \underline{5\quad 7}$	28.74	0.00009
Diversity	$\underline{6\quad 5\quad 7}$	3.36	0.0684
Dominance	$\underline{5\quad 7\quad 6}$	0.64	0.5463

*Rankings are from highest to lowest.

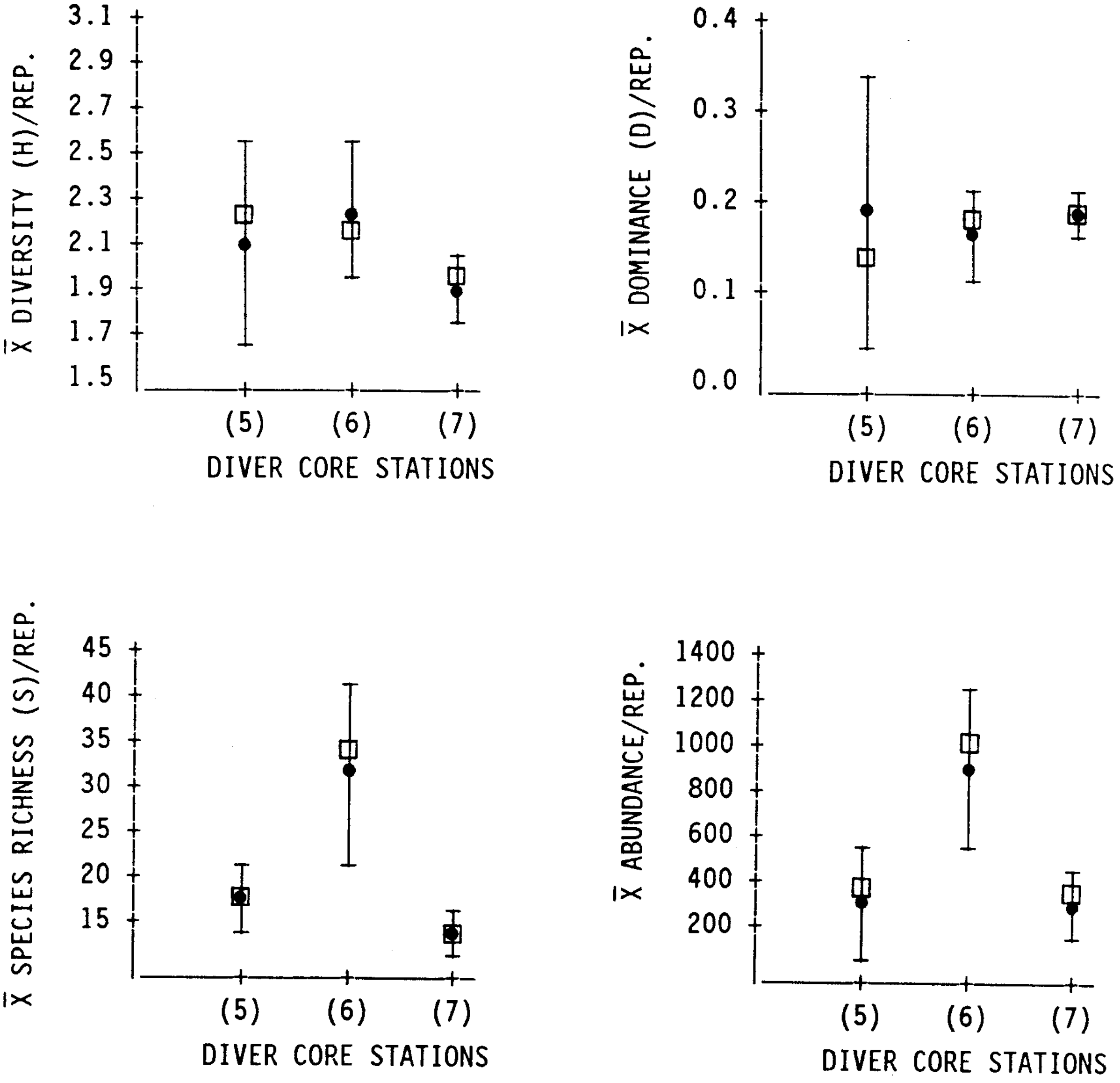


Figure 5-10. Mean Values of Diversity, Dominance, Species Richness and Abundance at Diver Core Stations. Error bars are 95% confidence limits.

Table 5-15. Summary of density and biomass estimates for dominant epibenthic and infauna species taken from diver core samples (August 1983).

Dominant Species	Abundance		Density (m^2)		Wet Weight (g)		Biomass g/m^2)	
	No.*	%**	at occurring stations	at all stations	No.*	%***	at occurring stations	at all stations
Oligochaeta	727	9.1	2,692.6	2,692.6	0.3005	0.7	1.11	1.11
Polychaeta								
Chone duneri	1,338	16.8	4,955.6	4,955.6	6.7089	15.6	24.85	24.85
Spio filicornis	632	7.9	7,022.2	2,340.7	1.8944	4.4	21.05	7.02
Scoloplos acmeceps	428	5.4	4,755.6	1,585.2	0.9063	2.1	10.07	3.36
Allia sp.	423	5.3	2,350.0	1,566.7	0.2580	0.6	1.43	0.96
Ampharete sp.	371	4.6	4,122.2	1,374.1	0.9276	2.2	10.31	3.44
Terebellides stroemii	137	1.7	507.4	507.4	0.6735	1.6	2.49	2.49
Mollusca								
Cylichna occulta	116	1.5	429.6	429.6	2.0591	4.8	7.63	7.63
Mytilus edulis	3	0.0	33.3	11.1	10.7449	24.9	119.39	39.80
Mysella tumida	463	5.8	5,144.4	1,714.8	3.0613	7.1	34.01	11.34
Liocyma fluctuosa	206	2.8	1,144.4	763.0	5.1255	11.9	28.48	18.98
Crustacea								
Caprella carina	86	1.1	955.6	318.5	0.2679	0.6	2.98	0.99
Atylus carinatus	27	0.3	150.0	100.0	0.6465	1.5	3.59	2.39
Urochordata								
Rhizomolgula globularis	10	0.1	111.1	37.0	3.1916	7.4	35.46	11.82
Total	4,967	62.4		18,396.3	36.7660	85.4		136.17

* Sum of stations means.
** Percent of total abundance (7,986 individuals) of all taxa from all stations.
***Percent of total weight (43.02 g) of all taxa from all stations.

the entrance to Kugrua Bay was high for polychaetes, amphipods and bivalves. The Kugrua Bay station was dominated by oligochaetes and polychaetes.

Total amphipod biomass estimates indicated that the Peard Bay station was the highest per unit area. Biomass estimates for amphipods showed 6.10 g/m^2 at the Peard Bay station as compared to 4.88 g/m^2 and 0.09 g/m^2 at the Kugrua Bay entrance and Kugrua Bay stations, respectively. Significant contributions to those totals were contributed by *Atylus carinatus* at the Peard Bay and entrance to Kugrua Bay stations (5.85 g/m^2 and 1.33 g/m^2, respectively) and by *Caprella carina* (2.98 g/m^2) at the entrance to Kugrua Bay.

Total mollusc biomass estimates indicated that the entrance to Kugrua Bay was as high per unit area as the Peard Bay station. Biomass estimates for bivalves at the Peard Bay station were 90.6 g/m^2, while the entrance to Kugrua Bay station was 120.5 g/m^2. The difference in station total weights was due to that of one large individual of *Mytilus edulis* at the entrance of Kugrua Bay. No bivalves were sampled in Kugrua Bay. Gastropod biomass was highest at Peard Bay (21.5 g/m^2), abundant in Kugrua Bay (4.8 g/m^2), and present at the entrance to Kugrua Bay (1.4 g/m^2). The Peard Bay station bivalve biomass estimates were comprised of *Mysella tumida* and *Liocyma fluctuosa*, which contributed 34.0 g/m^2 and 56.6 g/m^2 to the total, while *Mytilus edulis* composed the bulk of the biomass at the entrance to Kugrua Bay (119.4 g/m^2). Gastropod biomass at Peard Bay was dominated by *Cylichna occulta* and *Tachyrynchus erosus* (17.9 g/m^2 and 3.6 g/m^2, respectively). Kugrua Bay was dominated by *C. occulta* (4.7 g/m^2).

Polychaete biomass was highest at the entrance to Kugrua Bay and Kugrua Bay station, and in evidence at the Peard Bay station. Total biomass values were 132.0 g/m^2, at the entrance to Kugrua Bay, 10.8 g/m^2 at the Kugrua Bay station, and 10.6 g/m^2 at the Peard Bay station. The entrance to Kugrua Bay biomass was dominated by *Pholoe minuta* (75.4 g/m^2) and *Spio filicornis* (21.1 g/m^2). The Kugrua Bay station was dominated by *Allia* sp.(2.3 g/m^2), while the Peard Bay samples were dominated by an unidentified species of polychaete, *Ampharete* sp. (10.3 g/m^2).

The ascidian *Rhizomolgula globularis* (Pallas) contributed 35.5 g/m^2 for an average of 3.6 g/individual at the Kugura Bay entrance station.

5.3.3 Summary and Conclusions

On the basis of the limited sampling accomplished this year, the epibenthic invertebrates of Peard Bay appear to be dominated by the same species of mysids and amphipods encountered during previous NOAA/OCSEAP-sponsored studies, with a few notable exceptions; and seem to conform to the model of a pulsing lagoon, where reduced exchange of bay waters with nearshore waters presumably limits the potential for seasonal migration of the dominant mysid species, *Mysis litoralis* and *Mysis relicta*, commonly found in abundance in Simpson Lagoon, the flushing ecotype. From the limited sampling carried out in Peard Bay, mysids tend to dominate the fauna of the protected shallow embayments surrounding the margins of the area. Little is known about their abundances in the deeper central areas of Peard Bay, except that none were caught at the infaunal stations where amphipods predominated, and no mysid remains were found in the gut contents of such opportunistic consumers as oldsquaw (n=26) and eider ducks (n=8) collected from the middle of the bay, suggesting that mysids were not present in the deeper central area of the bay when the samples and birds were taken. Conversely, mysids appear to be the dominant food item of Arctic cod (and other opportunistic fish species) caught in fyke nets along the shallow shelf regions of the bay, indicating mysid predominance in the epifauna of the shallow reaches of the bay.

Since only one of the two open-water sampling periods was successfully sampled with drop nets, temporal information of habitat use by mysids is lacking, making conclusions tenuous. Other information such as the diver core and fyke net catch data indicates that mysid distribution in the shallow areas of the bay is patchy. Mysids were not found in any of the diver core station data, and only on one occasion, at one of the Point Franklin Spit fyke net stations early in July. Evidently, a school of *Mysis litoralis* moving north toward the tip of Franklin spit was intercepted by the fyke net located 0.25 miles south of the western entrance to Peard Bay. Length measurements of those individuals retained in the half-inch stretch mesh cod end of the net averaged 23.0 mm for 150 individuals measured, and though the data are obviously biased toward the larger individuals, those captured were of an older year class than those caught in the shallow-water embayments with drop nets during the same time period. The average size of mysids at the two shallow drop net stations was 7.6 mm (n=83) and 7.8 mm (n=56) (Table 5-9), indicating that young of the year populate the shallow, protected embayments within the bay.

While these interpretations are based on small sample sizes from a localized area within Peard Bay, the data available on length and wet weight measurements show similarities with previous data for mysids in arctic lagoonal systems. The majority of mysids collected in both the Simpson Lagoon study and the eastern Beaufort Lagoon study measured between 6 and 8 mm in length (Jewett and Griffiths 1983), agreeing well with the average measurements of the young-of-the-year mysids caught in two of the drop net stations in Peard Bay. Similarly, the average wet weights measured at the two drop net stations are similar to those measured in 1982 at Angun Lagoon in the eastern Beaufort. Wet weights of mysids at Peard Bay were 2.0 mg/individual and 1.5 mg/individual at the two stations, while the average Angun Lagoon wet weight was 2.7 mg/individual for *Mysis litoralis* (Jewett and Griffiths 1983). Some differences in wet weights exist between the Simpson Lagoon data of 1978 and 1982 and the Peard Bay information. Wet weights of *M. litoralis* at Simpson Lagoon averaged 3.6 mg in 1978 and 4.3 mg in 1982 as compared to lower averages for Peard Bay. As mentioned in Jewett and Griffiths (1983), differences in wet weights may be due to differences in catch dates during rapid periods of mysid summer growth. In a comparison of seasonal catch dates, the Peard Bay data were collected in early July, three to four weeks prior to typical Simpson Lagoon and Angun Lagoon data. Had it been possible to collect late summer data in August and September as originally planned, perhaps similar wet weight information to the previous studies would have been available for a more direct comparison of mysid standing stocks and growth rates.

A comparison of biomass estimates based on wet weights and abundances of mysids illustrates some differences between the Peard Bay data and the previous Simpson and Angun Lagoon data sets for different years. At Simpson Lagoon, biomass estimates of 1,130 mg wet weight/m^2 and 405 mg wet weight/m^2 were recorded for August of both 1978 and 1982, while 540 mg wet weight/m^2 was noted in Angun Lagoon in late July 1982. Biomass estimates at drop net

Stations 1 and 2 in Peard Bay for early July 1983 were 170 and 100 mg wet weight/m^2. Such a comparison shows the major differences between year data at Simpson Lagoon and between both Simpson and Angun Lagoons and Peard Bay. Both differences should be viewed with caution, however, due to small sample sizes in the second year comparison of Simpson Lagoon data (Jewett and Griffiths 1983) and the limited sampling conducted in Peard Bay.

Assuming that similar mysid population decreases did not occur in either Simpson Lagoon or Angun Lagoon during the 1983 open-water season, and that mysids are not as abundant in the deeper regions of Peard Bay as they are in the shallows, the mysid population of this system may not be as important to higher level consumers as are the populations present in Simpson and Angun Lagoons. Mysids found to predominate the gut contents of Arctic cod taken from fyke net sets of the shallow shelf surrounding Peard Bay may not accurately reflect the situation of prey consumption by the dominant fish species (Chapter 6). Mysids were not dominant in the gut samples of the major bird species examined from the deep, central area of Peard Bay (Chapter 4).

A comparison of the amphipod populations of Peard Bay with those of Simpson and Angun Lagoons also shows some differences between areas. Simpson Lagoon samples were dominated in terms of biomass and numbers by *Onisimus glacialis*. Angun Lagoon samples were dominated in terms of numbers by *Corophium* sp. and *Gammarus setosus*, while *O. glacialis* dominated biomass estimates. Peard Bay drop net samples and diver core samples were dominated in terms of abundances and wet weights by *Atylus carinatus* in the deep central section of the bay, by *Gammaracanthus loricatus* and *Onisimus litoralis* in the shallow embayments surrounding the bay, and by *Caprella carina* in the entrance to Kugrua Bay. The observed differences in Peard Bay may be due in part to the depth and substrate of each location. *C. carina*, a caprellid amphipod, was found in the littoral habitat at the entrance to Kugrua Bay which contained an attached epibenthic community that was well established in a peat-algal mat. The mat covered a coarse pebble substrate in water depth of 12-13 feet, well below the disruptive effects of seasonal ice formation. Conversely, *A. carinatus*, a circumpolar subarctic species (Dunbar 1954), was found in the deep central area of the bay characterized by silt-clay fractions of sediment having little peat content. The deeper area was not as well swept by currents as was the entrance to Kugrua Bay, as evidenced by the occurrence of fine sediments and the lack of strong tidal currents (Chapter 2). *G. loricatus* and *O. litoralis*, both circumpolar, shallow-water subarctic species (Dunbar 1954), were found in the shallow-water embayments of Peard Bay containing peat accumulations over a sandy bottom.

The differences between amphipod species dominances at Simpson Lagoon, Angun Lagoon, and Peard Bay may be due in part to differences in sources of available carbon for invertebrates as previously suggested by Jewett and Griffiths (1983) in their analysis of differences between epifaunal standing stocks of Simpson and Angun Lagoons. Although adequate temporal and spatial data are lacking, the tropic structures of Simpson and Angun Lagoons may be different. Schell et al. (1983) found that modern terrestrial sources of carbon which were unimportant in Simpson Lagoon relative to modern marine sources were apparently important in the Angun Lagoon ecosystem. In Angun Lagoon rates of primary productivity were one-fourth those measured in Simpson Lagoon, and radiocarbon experiments revealed that the food webs of the two ecosystems reflected the relative contributions of carbon available. The

Angun Lagoon invertebrates apparently have land-based production as one of their major sources of available carbon, while the Simpson Lagoon mysids and amphipods are solely reliant upon modern marine-based production as their major carbon source. These differences of carbon sources are reflected in the relative dominance of the amphipod species in Angun Lagoon by *Gammarus setosus*, which has been demonstrated to assimilate detritus as a nutrient source (Scheider 1980). *G. setosus* was not dominant in the Peard Bay samples, and was only conspicuous in samples from areas where accumulations of detritus were evident. One such area was the drop net station at the entrance to Kugrua Bay, which is protected from physical disturbance of wind and waves.

The total amphipod biomass of Peard Bay is difficult to compare with those of Simpson Lagoon and Angun Lagoon, because of the restricted drop net sampling in Peard Bay during 1983 and 1984 and Simpson Lagoon in 1982. Drop net samples were taken only in the shallow shelf of Peard Bay during 1983 and not in the deeper central region of the bay. A single station was sampled in the deeper central region of the bay during the winter of 1984. Amphipod biomass estimates taken from the shallow-water drop net stations in 1983 averaged 438 mg/m^2. This estimate is similar to that given for the 1978 Simpson Lagoon study and the 1982 Angun Lagoon study (423 mg/m^2 and 493 mg/m^2, respectively). The 1982 Simpson Lagoon estimate of amphipod biomass is lower at 82 mg/m^2 but should be viewed with caution because of the small sample size (Jewett and Griffiths 1983). An assessment of the comparability of diver core samples with drop net samples for amphipod biomass in Peard Bay would have been made if it had been possible to take parallel sets of samples at the same locations.

No comparison with the invertebrate fauna of the nearshore area to Peard Bay was possible from the limited amount of sampling completed for this study. However, it is interesting to note the occurrence of two species of calanoid copepod and one of hydromedusae in the net samples taken from the Chukchi Sea side of Point Franklin spit. Both *Metridia longa* and *Calanus hyperboreus* are vertically migrating species endemic to Arctic Ocean depths of 200 meters (Brodskii 1950). *Calanus glacialis*, *C. hyperboreus*, and *M. longa* are the dominant calanoids found in the Beaufort Sea (Horner 1981a,b; Grainger 1965). The narcomedusae is also a deep water form not usually found in shallow coastal waters (K. Coyle, personal communication). Their appearance in the shallow waters of the Chukchi Sea would indicate that they were most likely transported from the deeper areas of the Beaufort Sea northwest of Point Barrow. Subsequent to their appearance in the samples on 28 July 1983, wind conditions conducive to coastal upwelling were recorded. Winds of approximately 8-16 knots from 35-80° true north were recorded from 24 to 28 July (T. Kozo, personal communication). Though corroborative information from the offshore physical oceanographic study is not available, upwelled water which appeared in the nearshore region during the study is believed to have moved from out of the Barrow canyon (L. Hackmeister, personal communication). Previous studies have documented strong down-coast (northeast to southwest) currents (Coachman and Aagaard 1981; Mountain et al. 1976; Wilson et al. 1982).

Although diver core sampling was limited, it would appear that physical factors such as sediment composition, water depth and currents, and, possibly, seasonal salinity changes are likely to be important factors in controlling the distribution of infaunal invertebrates within Peard and Kugrua Bays. The infauna of the deeper central section of Peard Bay is dominated in terms of numbers and biomass by two species of bivalves, while the shallower area of the surrounding shelf, as represented by the entrance to Kugrua Bay, may be dominated by several species of polychaetes. The shallow center of Kugrua Bay is evidently dominated by oligochaetes. The center of Peard Bay is characterized by low current velocities and a large silt-clay sediment fraction. Conversely, the shelf may be characterized by higher current velocities and a much coarser fraction of sediments. Though there are no current or sediment data from the center of Kugrua Bay, diver observations indicate that the sediments are not rippled by currents or composed of the coarser fractions, suggesting a condition similar to that of the center of Peard Bay. Winter salinity data indicate that the centers of Kugrua Bay and Peard Bay do not provide similar habitats to infaunal constituents. Evidently, Kugrua Bay is not as well flushed during the winter as is Peard Bay, because bottom salinities were found to be 7-10 ppt higher in Kugrua Bay.

In comparison with previous infaunal studies the species composition sampled at Peard Bay is composed of Arctic forms and not boreal Pacific forms found in the southern Chukchi Sea. Previous data taken in the Beaufort Sea suggest that oligochaetes, *Gammarus setosa, Onisimus litoralis, Saduria entomon, Scolecolepides arctius, Ampharete vega, Prionospio cirrifera, Terrebellides stroemi, Cyrtodaria kurriana*, and *Liocyma fluctuosa* are dominant species (Carey 1978a,b). Of the dominant infaunal species found in Peard Bay, *Spio filicornis, Chone duneri, Cylichna occulta, Mysella tumida,* and *Atylus carinatus* have been sampled in numerous locations in the Beaufort, indicating that the dominant species in Peard Bay are polar forms, not boreal Pacific.

The similarity of the major physical conditions in the northern Chukchi and the Beaufort probably accounts for the similarities in species compositions. The physical processes responsible for hypersalinity stress in the winter and ice gouging of the nearshore sediments in the open-water season are both present as well as the effect of sediment accumulation of fines and detritus within the lagoons and embayments along both coasts. Additionally, occasional current reversals down coast probably supply Peard Bay with larval forms and food from the Beaufort Sea.

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CHAPTER 6

FISH UTILIZATION OF PEARD BAY

6.1 INTRODUCTION

6.1.1 General

Peard Bay provides extensive shallow lagoon and estuarine habitat for numerous species of marine fish. The coastline and near vicinity is characterized by low relief sand spits, barrier islands, and sandy gravel beaches in exposed areas, much like the shores of the Beaufort Sea. However, the physiography is subjected to latitudinal gradients with Bering Sea influences in the south to those of the Arctic Ocean in the north. The eastern Chukchi coastline also displays major topographical features such as steep cliffs at Point Lisburne. The entire Kotzebue Sound exhibits different coastal and oceanographic conditions than those of the northeastern Chukchi region.

Pertinent scientific literature of the Chukchi coast is briefly reviewed as background for interpreting our field data, since many species are wide ranging or transitory and move along the entire sea coast. Data herein are presented on the utilization of Peard Bay by inshore species of fish.

6.1.2 Specific Objectives

Using fyke and gill nets as the primary sampling methods, we attempted to describe 1) fish community composition, 2) habitat utilization, 3) timing of lagoon utilization, and 4) population structure of key fish species. Stomach analyses were conducted to examine food web links to smaller pelagic or benthic fauna.

6.2 METHODS

6.2.1 Literature

The results of previous work on the fish of the eastern Chukchi Sea were compiled from published literature and available research reports. The literature was summarized, first for the southeastern coastal area as background, then for the northeastern area adjacent to Peard Bay.

6.2.2. Peard Bay Fish Utilization Study

Three field sampling efforts were carried out during the course of this study. Two open-water surveys were conducted in Peard Bay; one during July 26-August 1 (1983) and the other from August 22 to August 26 (1983). An additional exploratory effort was carried out through the ice cover during March 1984.

Fyke and gill nets were the primary fish sampling gear. Gill nets were 45.8 m long by 1.2 m deep with equally sized monofilament stretch mesh panels of 2.54, 3.81, 5.08, 6.35, and 8.89 cm. Gill nets were rigged for floating or sinking by using varying amounts of cork and lead line. Fyke nets were nearly identical to those used in Simpson Lagoon (Craig and Haldorson 1981) and consisted of a 61.1-m-long by 1.2-m-deep lead with 15.3-m-long by 1.2-m-deep wings leading to two, 1.2-m by 1.8-m stainless steel framed cod ends (Figure 6-1). The fyke nets were set with the cod ends offshore in about 1 m of water while the lead line was secured to the shore. Fyke and gill net set locations are shown in Figure 6-2.

During the winter sampling, trammel nets were used because of the limited amount of field time and because previous efforts using gill nets and fyke nets had proved difficult and even unsuccessful under the seasonally thick ice of Peard Bay (Fechhelm et al. 1983). The trammel nets used during the winter study were 150 feet long by 8 feet deep, and were constructed of inside panels of #69 monofilament 3/4-inch stretch mesh. Outside panels were of #139 nylon 4-inch stretch mesh. The nets were rigged to sink with #30 lead core lead line and a 1/2-inch polyfloat head rope.

Fyke nets were deployed continuously during the sampling periods and were checked on a 24-h cycle, weather permitting. Gill nets, which are known for causing significant fish mortalities, were fished as drift nets from boats for periods ranging from 30 min to 2h. During this time the nets were examined continuously in order to remove freshly caught fish for tagging and subsampling.

Catch rates or catch per unit effort (CPUE) for fyke nets were determined for each major species by the following equation:

$$\text{CPUE} = 1/n \sum_{i=1}^{n} N_i / A_i \qquad (1)$$

where N is the number of fish caught at Station i, A is the effort in hours at Station i, and n is the number of nets used.

Food habits of major species sampled were determined by examination and subsequent identification of all prey items. Comparisons of food items were made between species by ranking food items both by number and frequency of occurrence. Similarity and dietary overlap were also compared on a species by species basis.

6.3 RESULTS AND DISCUSSION

6.3.1 Literature Summary, Eastern Chukchi Sea Coastal Area

6.3.1.1 Introduction

This section discusses the previous literature of the southeastern and the northeastern Chukchi Sea coast. This division is made at Cape Lisburne

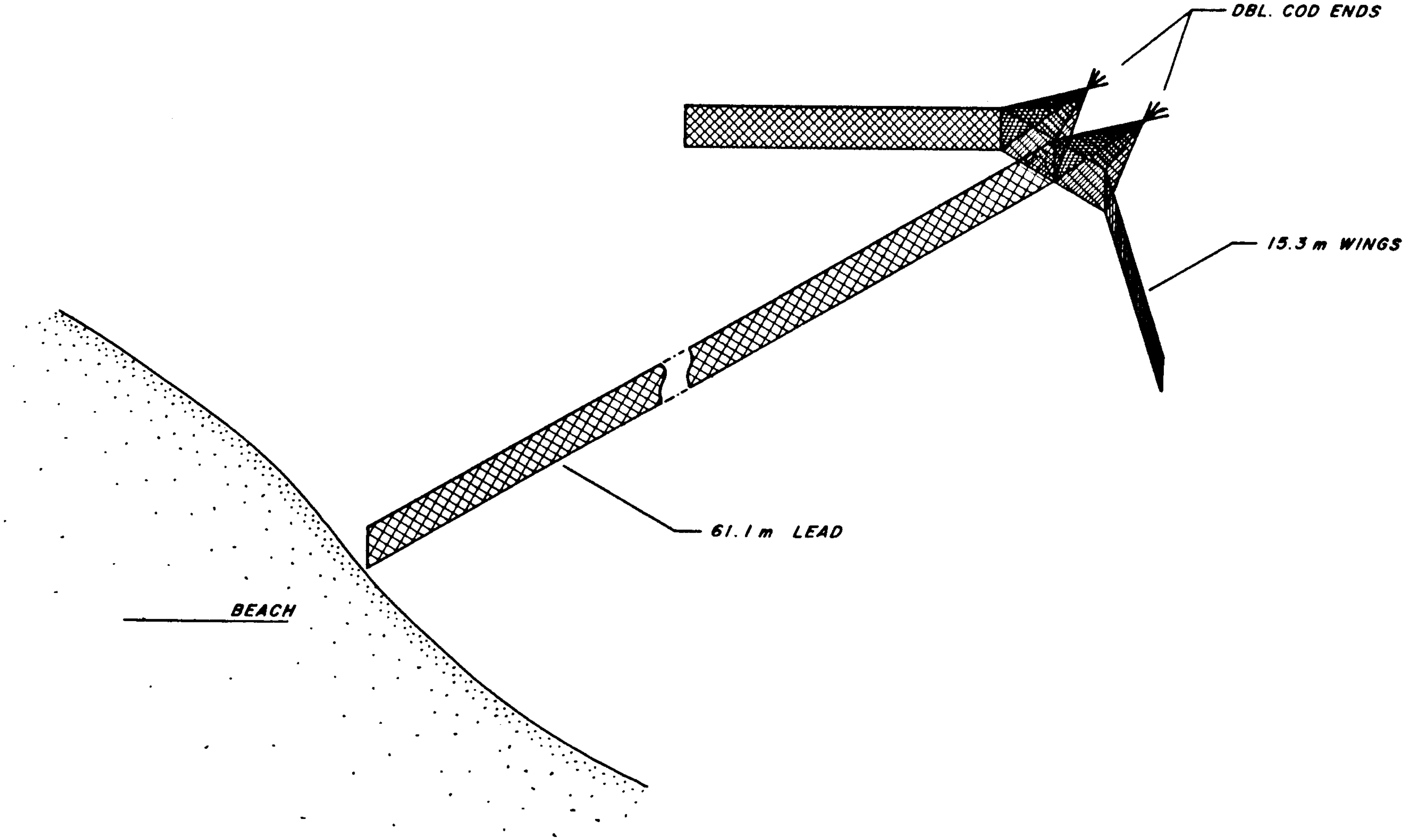

Figure 6-1. Fyke Net Configuration Used in Peard Bay.

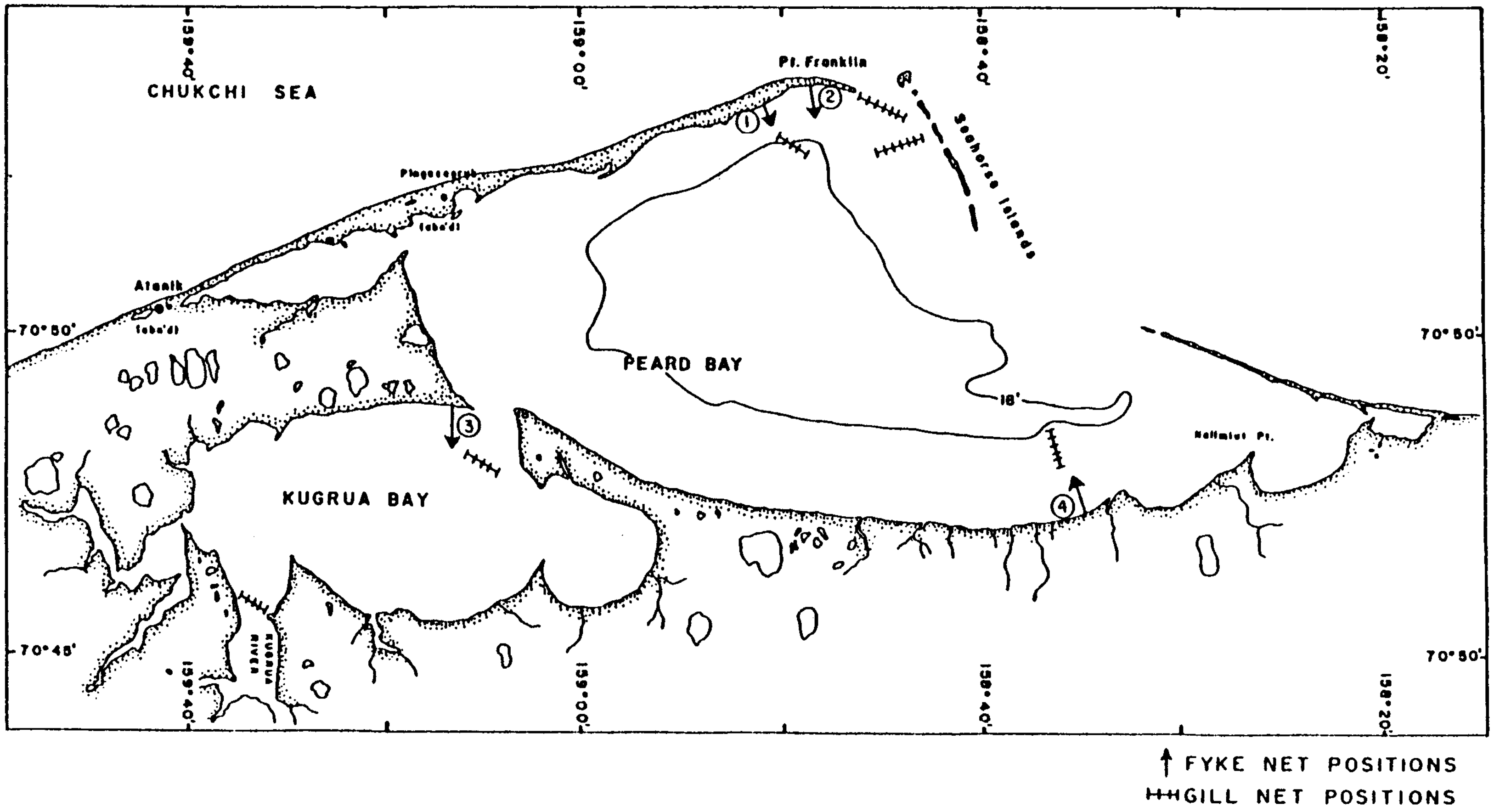

Figure 6-2. Locations of Fyke and Gill Nets Used in Peard Bay Fish Study, Summer 1983.

between the north and south coastal areas because of their existing major geographical differences.

Three major sources of information characterize the fish communities of the southeastern area. One reference (ADF&G 1983) deals exclusively with the concerns of the nearshore anadromous fisheries. The other two studies (Alverson and Wilimovsky 1966; Wolotira et al. 1977) describe the demersal or bottomfish resources of the southeastern Chukchi Sea and include data from offshore as well as nearshore stations. Although Alverson and Wilimovsky (1966) concentrated their sampling around Point Hope, they included stations from as far south as Cape Prince of Wales and from northeast of Cape Lisburne. Wolotira et al. (1977) geographically expanded the sampling grid and level of detail of Alverson and Wilimovsky (1966). The sampling grid of the later study was evenly distributed from Cape Prince of Wales to Point Hope. Though they did not sample as far north as the previous study, they did cover the Kotzebue Sound area. Kotzebue Sound, particularly its associated river and estuarine systems, was also the object of a study by the Alaska Department of Fish and Game (ADF&G 1983) in which they assessed the commercial and subsistence anadromous fisheries in this area.

There was no planned continuity between the above studies and each had different objectives. However, in total, the studies provide a broad-scale description of the fisheries in the southeastern Chukchi Sea. Obviously, little can be said of the seasonality of the fish resources or of the annual variability with such a temporally limited data base. Wolotira et al. (1977) made an effort to compare their data with that of Alverson and Wilimovsky (1966) by reducing the latter's data set to conform with their own presentation format. In the present work, the two data sets are presented separately, but are compared where appropriate.

Several sources of information aid in characterizing the northeast section of the Chukchi Sea. Recent investigations in the Chukchi and Beaufort Seas have strongly suggested that nearshore areas provide habitat important to both marine and anadromous fish species (Bendock 1977; Craig and Griffiths 1981; Craig and Haldorson 1981; Lowry and Frost 1981; Griffiths and Gallaway 1982; Griffiths et al. 1983; Frost and Lowry 1983). Several other investigators have studied fishes specific to the Barrow area and the subsistence fishing patterns of coastal villages (Cohn 1954; MacGinitie 1955; McPhail 1966; Wilimovsky 1956; Ivie and Schneider 1979; Schneider and Bennett 1979; and Pedersen et al. 1979).

To date 41 species of fish have been identified from the northeast Chukchi Sea (Morris 1981). Frequently encountered species include Arctic and saffron cod, Arctic flounder, fourhorn sculpin, capelin, rainbow smelt, herring, pink and chum salmon, at least two species of cisco, whitefish, and Arctic char.

6.3.1.2 Southeastern Chukchi Sea

Demersal Fish. Alverson and Wilimovsky (1966) conducted the first large-scale comprehensive survey of demersal fish in the southeastern Chukchi Sea during July-August 1959. The stations they occupied are presented in Figure 6-3. This survey resulted in 52 species (Table 6-1), most of which (44) the

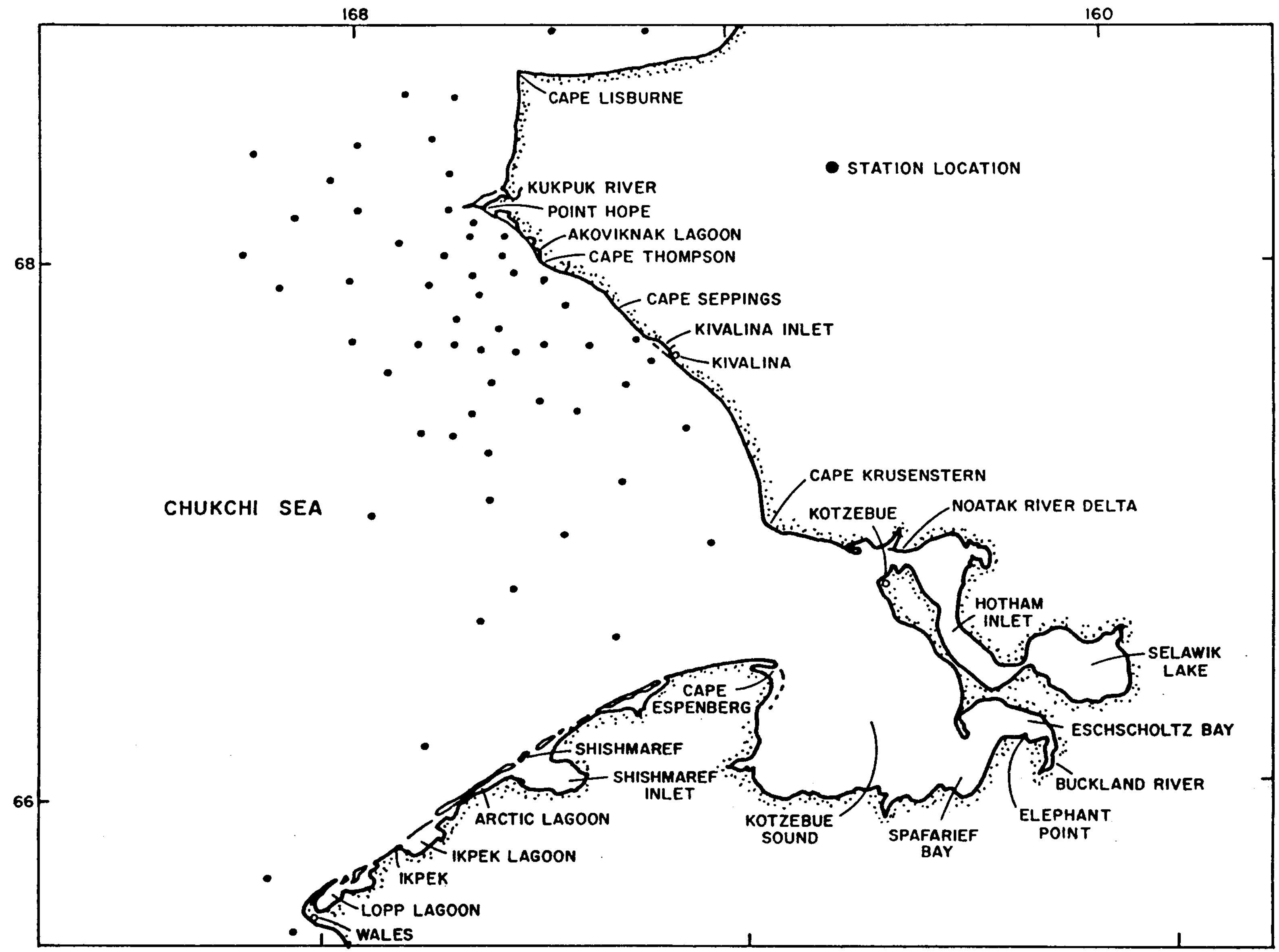

Figure 6-3. Station Locations (after Alverson and Wilimovsky 1966).

Table 6-1. List of marine and freshwater fishes taken during Chukchi Sea investigation (after Alverson and Wilimovsky 1966).

MARINE FISHES	
Clupeidae	
Clupea harengus pallasi	Pacific herring
Salmonidae	
Oncorhynchus gorbuscha	Pink salmon
Oncorhynchus keta	Chum salmon
Salvelinus alpinus	Arctic char
Salvelinus malma	Dolly varden
Osmeridae	
Mallotus villosus	Capelin
Osmerus mordax	Rainbow smelt
Gadidae	
Boreogadus saida	Arctic cod
Eleginus gracilis	Saffron cod
Zoarcidae	
Gymnelis viridis	Fish doctor
Lycodes palearis arcticus	Wattled eelpout
Lycodes raridens	Eelpout
Lycodes sp.	Eelpout
Stichaeidae	
Eumesogrammus praecisus	Fourline snakeblenny
Lumpenus fabricii	Slender eelblenny
Lumpenus medius	Stout eelblenny
Stichaeus punctatus	Arctic shanny
Ammodytidae	
Ammodytes hexapterus	Pacific sand lance
Hexagrammidae	
Hexagrammos stelleri	Whitespotted greenling
Cottidae	
Artediellus scaber beringianus	Hamecon
Enophyrs lucasi	Leister sculpin
Gymnocanthus tricuspis orientalis	Arctic staghorn
Hemilepidotus sp.	Irish loard sp.
Icelus spatula	Spatulate sculpin
Megalocottus platycephalus	Belligerent sculpin
Microcottus sellaris	Brightbelly sculpin
Myoxocephalus jaok	Plain sculpin
Myoxocephalus quadricornis	Fourhorn sculpin
Myoxocephalus scorpioides	Arctic sculpin
Myoxocephalus scorpius	Shorthorn sculpin
Myoxocephalus stelleri	Stellate sculpin
Nautichthys pribilovius	Eyeshade sculpin
Triglops pingeli	Ribbed sculpin
Agonidae	
Aspidophoroides olriki	Arctic alligator fish
Podothecus acipenserinus	Sturgeon poacher
Cyclopteridae	
Liparis herschelinus	Bartail snailfish
Liparis sp.	Snailfish
Pleuronectidae	
Atheresthes stomias	Arrowtooth flounder
Hippoglossoides robustus	Bering flounder
Limanda aspera	Yellowfin sole
Liopsetta glacialis	Arctic flounder
Platichthys stellatus	Starry flounder
Pleuronectes quadrituberculatus	Alaska plaice

FRESHWATER FISHES	
Salmonidae	
Salvelinus alpinus	Arctic char
Salvelinus malma	Dolly varden
Coregonus autumnalis	Arctic cisco
Coregonus larvaretus pidschian	Humpback whitefish
Coregonus sardinella	Least cisco
Thymallus arcticus	Arctic grayling
Cottidae	
Cottus cognatus	Slimy sculpin
Gasterosteidae	
Gasterosteus aculeatus	Threespine stickleback
Pungitius pungitius	Ninespine stickleback

authors consider to be benthic or demersal. Table 6-2 presents the most abundant species in order, and Table 6-3 presents the most abundant species by frequency of occurrence within their station pattern. The most common species found was Arctic cod (*Boreogadus saida*). Arctic cod are of particular interest because they are a major prey item in the diet of ringed seals. Figure 6-4 presents the distribution of this species throughout their sampling grid. Arctic cod was the most abundant (59% of fish taken) and most frequently observed (72% of trawl stations) species in the study area. Arctic cod were particularly abundant from south of Point Hope to north of Cape Lisburne. South of Kivalina, abundance and frequency dropped off precipitously. In general, the species was less abundant and frequent nearshore, than offshore.

Alverson and Wilimovsky (1966) note correlations between temperature, salinity, and distribution of some species of flatfish and cod. In the warmer nearshore waters south of Kivalina, Arctic cod were replaced by saffron cod which prefer warmer temperatures. Yellowfin sole (*Limanda aspera*) prefer relatively warm and shallow waters when compared to Bering flounder (*Hippoglossoides robustus*) which prefer deeper and colder waters. Fourhorn sculpin (*Myoxocephalus quadricornis*) and starry flounder (*Platichthys stellatus*) were found in nearshore areas of lower salinities. The commercial species of flatfish were generally low in abundance and were smaller than those taken in commercial quantities in other areas. In total, only 283 individual flounder were taken in the entire survey. The authors compare this catch to commercial fisheries where the catch runs to approximately 455 kg of commercial flatfish per hour of trawling. The flatfish were relatively small in comparison to those taken in commercial fisheries in the eastern Bering Sea (Table 6-4). For instance, *H. robustus* taken in commercial fisheries averaged 37-48.5 cm in length, while the same species taken in the southeastern Chukchi ranged from 14 cm to 26 cm. Alverson and Wilimovsky (1966) conclude that both growth rate and population levels in the Chukchi are depressed. Although population levels are certainly depressed, it is not clear from their data whether it is growth rate or maximum size of the individual which is depressed (Wolotira et al. 1977 found that this was species specific). These authors conclude that the area in question could not provide a commercially successful fishery for groundfish, nor could it provide a commercially successful crab fishery on the basis of incidental catches of benthic species.

Building upon the work of Alverson and Wilimovsky (1966), Wolotira et al. (1977) conducted a demersal and shellfish resource study of the northern Bering and southeastern Chukchi Seas. The subareas considered in their study include northern and southern Hope Basin, outer Kotzebue Sound, and inner Kotzebue Sound (Figure 6-5). They obtained length, weight, sex, age, abundance, biomass, and growth characteristics. Table 6-4 shows the principal fish species, abundance, and biomass by subarea determined by these investigators. Most of the species (74%) were benthic. The fish species fell into three general groups: 1) a cold water group indigenous to Arctic marine waters with species such as Arctic cod, longhead dab, and Arctic flounder, 2) a subarctic-boreal group whose center of abundance is well south of the Chukchi in the Bering Sea, or in areas of the eastern or western Pacific, and which includes saffron cod, yellowfin sole, Alaska plaice, starry flounder, and Pacific herring, and 3) an anadromous fresh water group which includes several char, whitefish, and smelt. They estimated that there is a relatively low fish biomass in the southeastern Chukchi and northern Bering Seas (47,000

Table 6-2. Rank order of marine fish species.

Species	Order of Abundance	Frequency of Occurrence
Boreogadus saida	1	1
Clupea harengus pallasi	2	-
Gymnocanthus tricuspis	3	2
Artediellus scaber	4	8
Mallotus villosus	5	-
Hippoglossoides robustus	6	3
Osmerus mordax	7	9
Myoxocephalus scorpius	8	4
Triglops pingeli	9	5
Eleginus gracilis	10	-
Podothecus acipenserinus	-	6
Lumpenus fabricii	-	7
Lycodes sp.	-	10

Table 6-3. Size distribution of common species of fish taken in Chukchi Sea during July-August 1959 (after Alverson and Wilimosky 1966).

Length (cm)	*Boreogadus saida*	*Hippoglossoides robustus*	*Limanda aspera*	*Clupea harengus pallasi*	*Osmerus mordax*
7			1		
8			1		
9	5		1		
10	18		2		1
11	36				1
12	17		2		1
13	10				16
14	7	1	1		9
15	33	4	6		2
16	42	7	1		
17	58	3	1		1
18	52	7		1	
19	35	26	2	7	
20	17	26		21	
21	6	19		39	
22	3	5		53	
23	1	7		30	
24	1	4		42	
25		1		18	
26		1		6	
28	1			1	
30	1				
Mean length (cm)	15.9	19.9	13.5	22.4	13.4
Range (cm)	9-30	14-26	7-19	18-26	10-17
Total Number	343	111	18	218	31

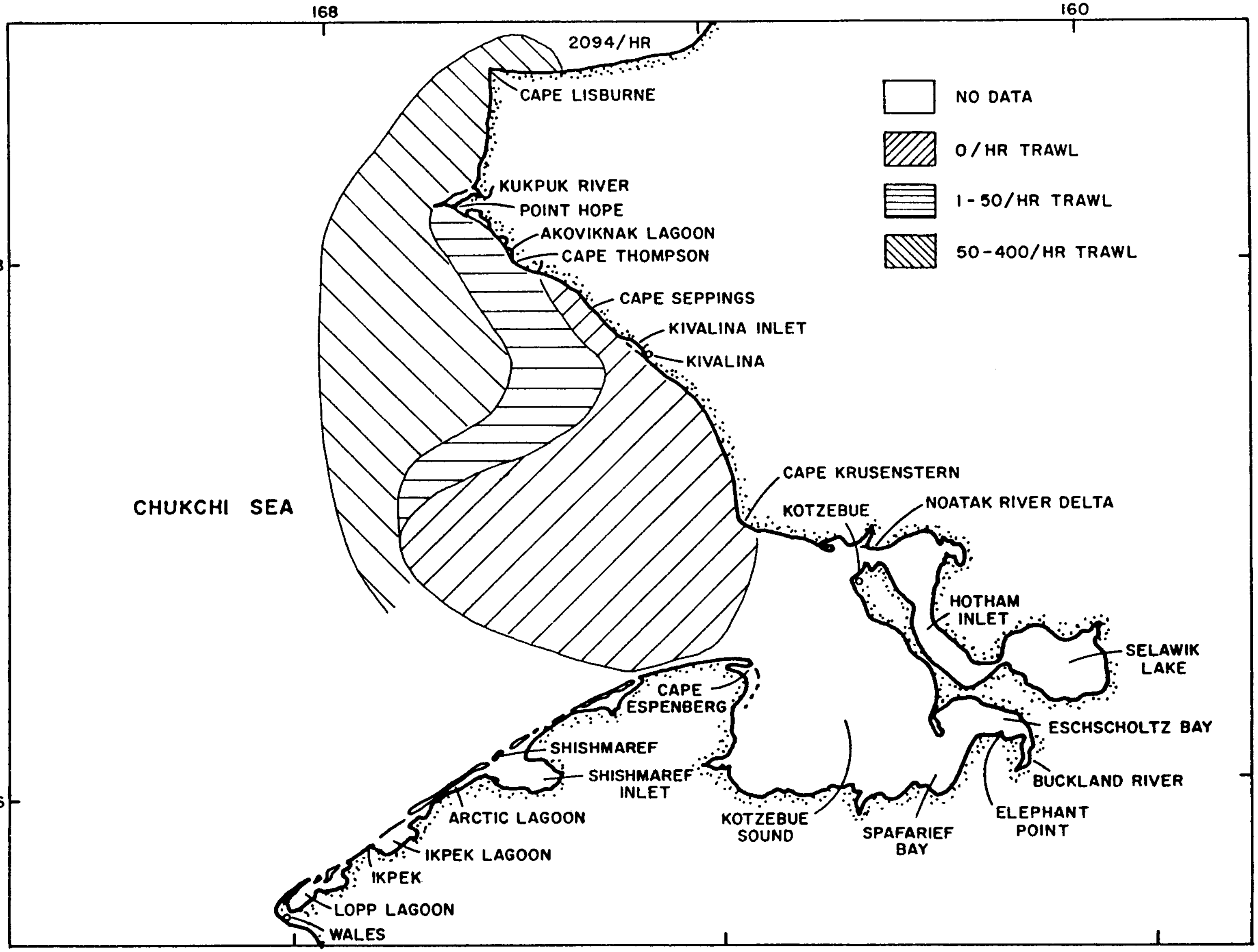

Figure 6-4. Distribution of Catch Rates by Numbers of Arctic Cod During 1959 (after Wolotira et al. 1977).

Table 6-4. Biomass (metric tons) and population (number of individuals x 1000) in the southeastern Chukchi Sea and Kotzebue Sound during September-October 1976 (abstracted from Wolotira et al. 1977).

Species	Sample Areas							
	1N		1S		20		2I	
	Population	Biomass	Population	Biomass	Population	Biomass	Population	Biomass
Saffron cod	43,660	188	31,948	520	43,802	735	6,937	83
Starry flounder	167	84	1,185	1,156	96	55	68	62
Shorthorn sculpin	10,462	196	6,317	230	288	15	11	<1
Pacific herring	2,832	255	4,376	357	14,902	1,331	133	15
Rainbow smelt	3,540	145	1,699	96	25,762	591	1,802	37
Alaska plaice	365	118	2,117	244	589	78	786	74
Yellowfin sole	-	-	1,415	75	361	26	3,728	86
Arctic cod	25,270	353	8,774	149	3,149	67	344	6
Walleye pollock	279	5	804	?	25	1	36	2
Bering flounder	2,077	173	193	11	307	25	-	-
Longhead dab	-	-	220	8	176	10	29	4
Arctic flounder	19	1	27	8	39	1	325	4
Capelin	3,206	64	706	13	344	4	-	-

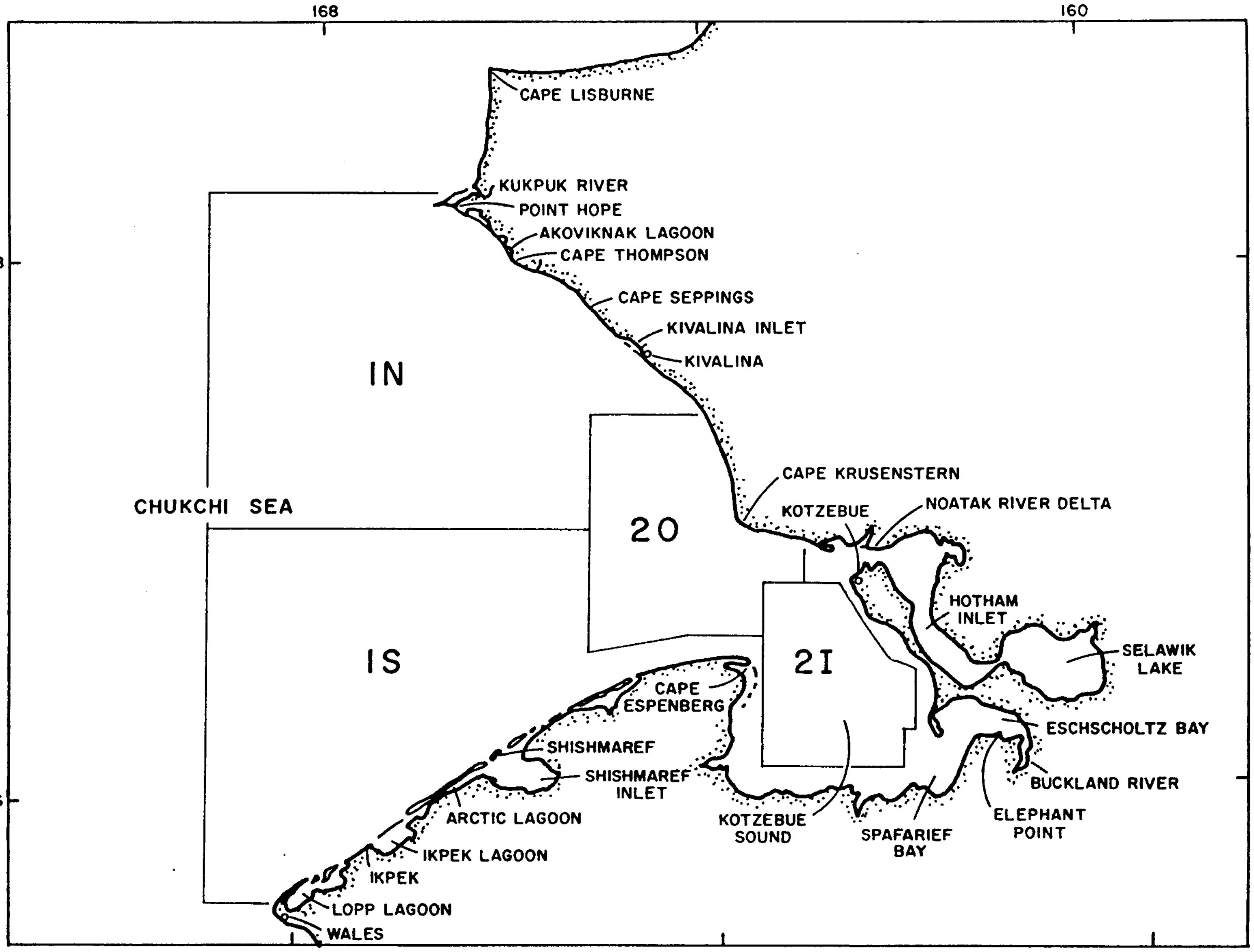

Figure 6-5. Sampling Areas and Strata Used for Biomass Analysis in 1976 (after Wolotira et al. 1977).

metric tons) in comparison to the eastern Bering Sea which supports a fish biomass 60 times greater. Of this total in the Chukchi, 6,601 metric tons occur in Hope Basin and 3,980 metric tons in Kotzebue Sound. Although lower in total biomass, Kotzebue Sound contained a greater density of fish than Hope Basin (12.7% of the catch per unit effort versus 6.9% of the catch per unit effort). Benthic invertebrates accounted for most of the biomass. Table 6-5 presents the most abundant fish species in each of the subareas.

Among nearshore areas the densest populations (expressed as kg/km trawled) of saffron cod occurred between Cape Espenberg and Cape Krusenstern, with the greatest concentration (20.6 kg/km) caught just north of Cape Krusenstern. In the offshore direction, or in Kotzebue Sound proper, the catch generally declined (Figure 6-6). The size of saffron cod was smaller on average in the Chukchi than in the northern Bering Sea. In the Bering Sea, the average length ranged from 11.5 to 13.31 cm in various subareas, while in the Chukchi the average ranged from 7.74 cm in northern Hope Basin to 10.34 cm in outer Kotzebue Sound.

Rainbow smelt were concentrated in Kotzebue Sound, particularly between Cape Espenberg and Cape Krusenstern. (Alverson and Wilimovsky (1966) did not sample the sound, but did find rainbow smelt most abundant just west of Cape Krusenstern.) Populations decreased in an offshore direction in the Chukchi (Figure 6-7). Average size ranged from 13.77 cm in outer Kotzebue Sound to 16.87 cm offshore of Seward Peninsula where fish were generally older. It was estimated that rainbow smelt north of the Bering Strait grew faster than fish south of the strait, although the maximum size at age was less.

Yellowfin sole did not occur on the northern shore of Hope Basin from north of Cape Krusenstern to Point Hope (Figure 6-8). Appreciable concentrations occurred only in Kotzebue Sound southeast of Cape Espenberg where they were more numerous, although smaller, than in offshore areas. In general, this species attained a smaller maximum size in the Chukchi Sea than in areas south of the Bering Strait. Alverson and Wilimovsky (1966) noted that in 1959 yellowfin sole occurred only in nearshore, shallow areas.

Alaska plaice were most abundant along the north coast of the Seward Peninsula (Figure 6-9), and are among the most common species in Kotzebue Sound.

Pacific herring were mainly concentrated in outer Kotzebue Sound northwest of Cape Espenberg (Figure 6-10). Relatively few were found in the inner sound and along coastal areas of Seward Peninsula and from Cape Krusenstern to Point Hope. Alverson and Wilimovsky (1966) encountered very few Pacific herring, and did not encounter a relatively high abundance off Point Hope. It should be noted that during spawning season when the Pacific herring moves inshore to spawn on nearshore vegetation, the distribution will be different than that observed by Wolotira et al. (1977) during summer/autumn.

Although among the most frequently encountered species in the southeastern Chukchi (74% of stations in Kotzebue Sound and 84% of stations in Hope Basin), the Arctic cod accounted for a surprisingly small percentage of the biomass (1.2%) in these areas. Small areas of concentration of Arctic cod occurred north of Cape Espenberg and in waters north of Cape Prince of Wales (Figure 6-11). Very few were noted in Kotzebue Sound. This may be explained by the

Table 6-5. The most abundant species of fish found in the subareas of the southeastern Chukchi Sea during September-October 1976 (after Wolotira et al. 1977).

Species	Inner Kotzebue	Outer Kotzebue	Northern Hope Basin	Southern Hope Basin
Saffron cod	+	+	+	+
Rainbow smelt	+	+	-	-
Yellowfin sole	+	-	-	-
Alaska plaice	+	-	+	-
Pacific herring	-	+	-	+
Arctic cod	-	+	+	+
Shorthorn sculpin	-	-	+	+

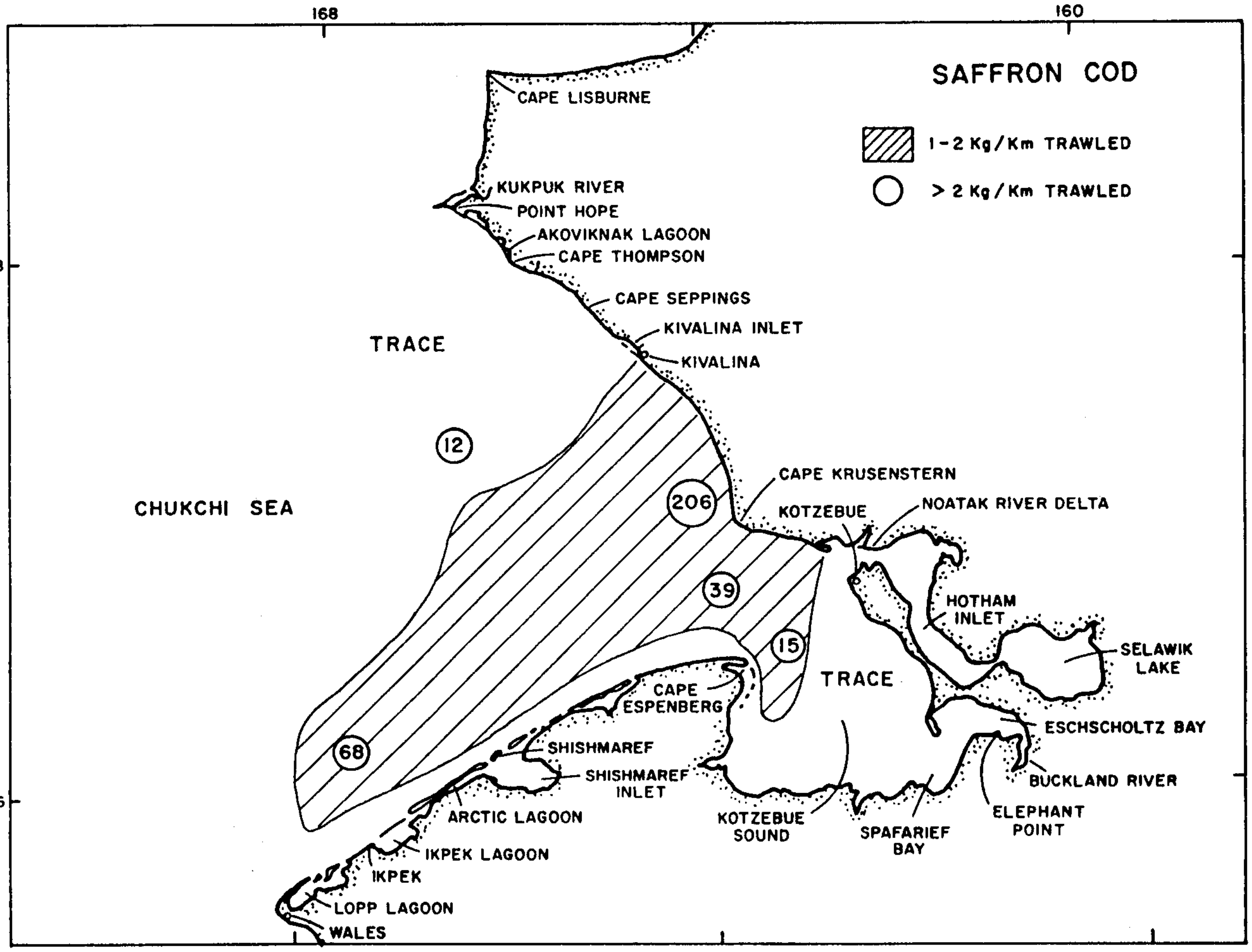

Figure 6-6. Distribution of Catch Rates by Weight of Saffron Cod (after Wolotira et al. 1977).

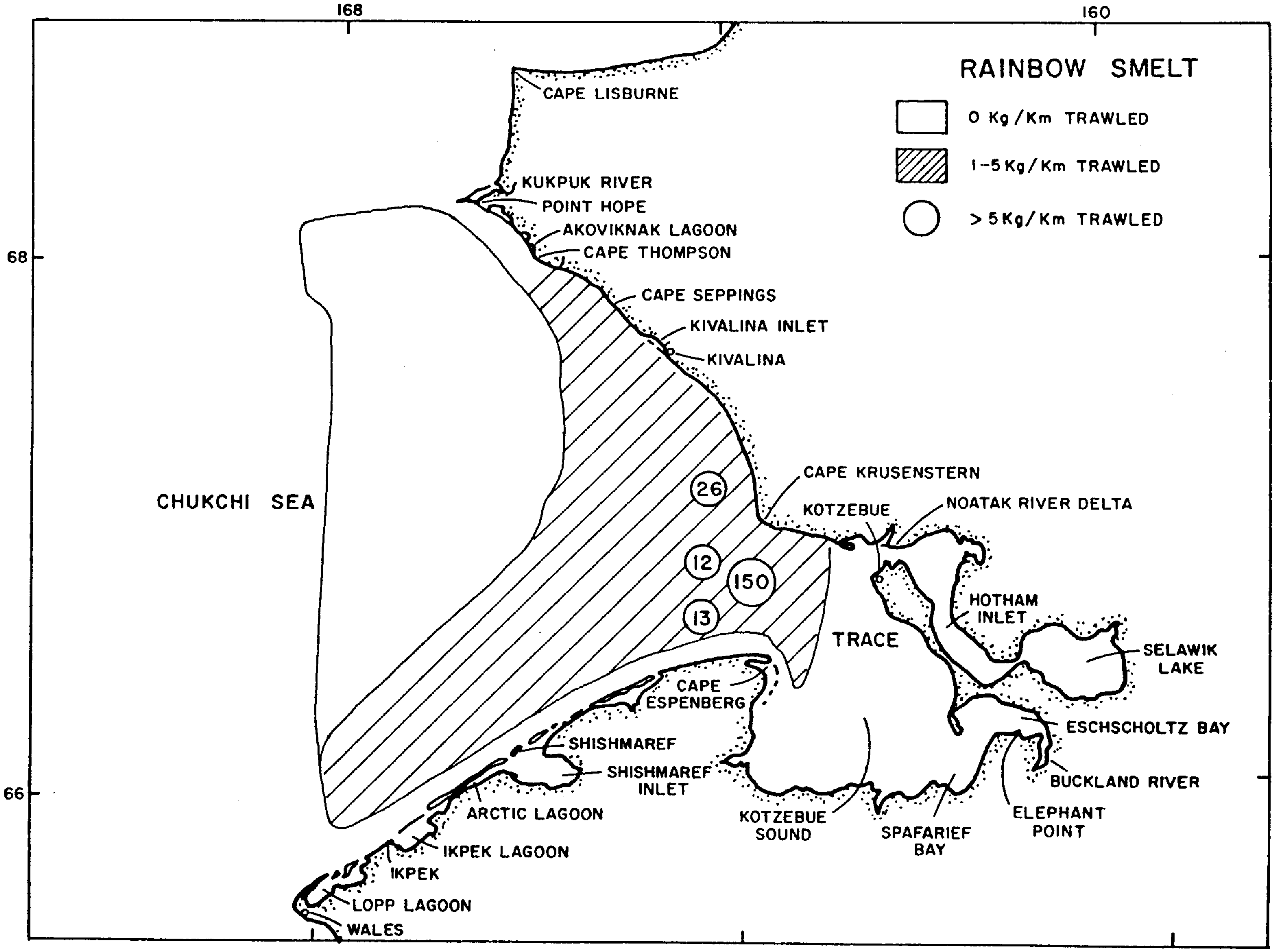

Figure 6-7. Distribution of Catch Rates by Weight of Rainbow Smelt (after Wolotira et al. 1977).

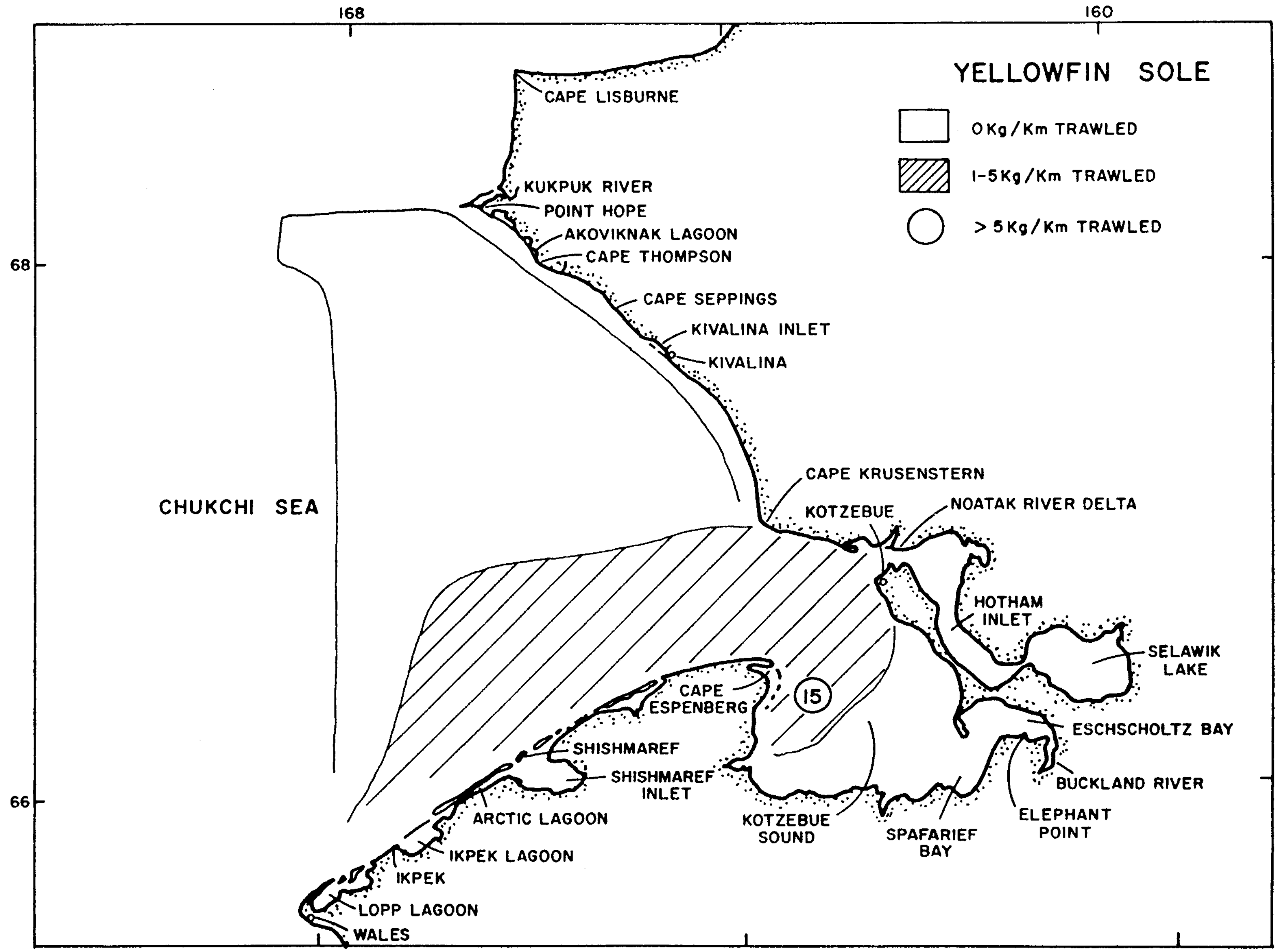

Figure 6-8. Distribution of Catch Rates by Weight of Yellowfin Sole (after Wolotira et al. 1977).

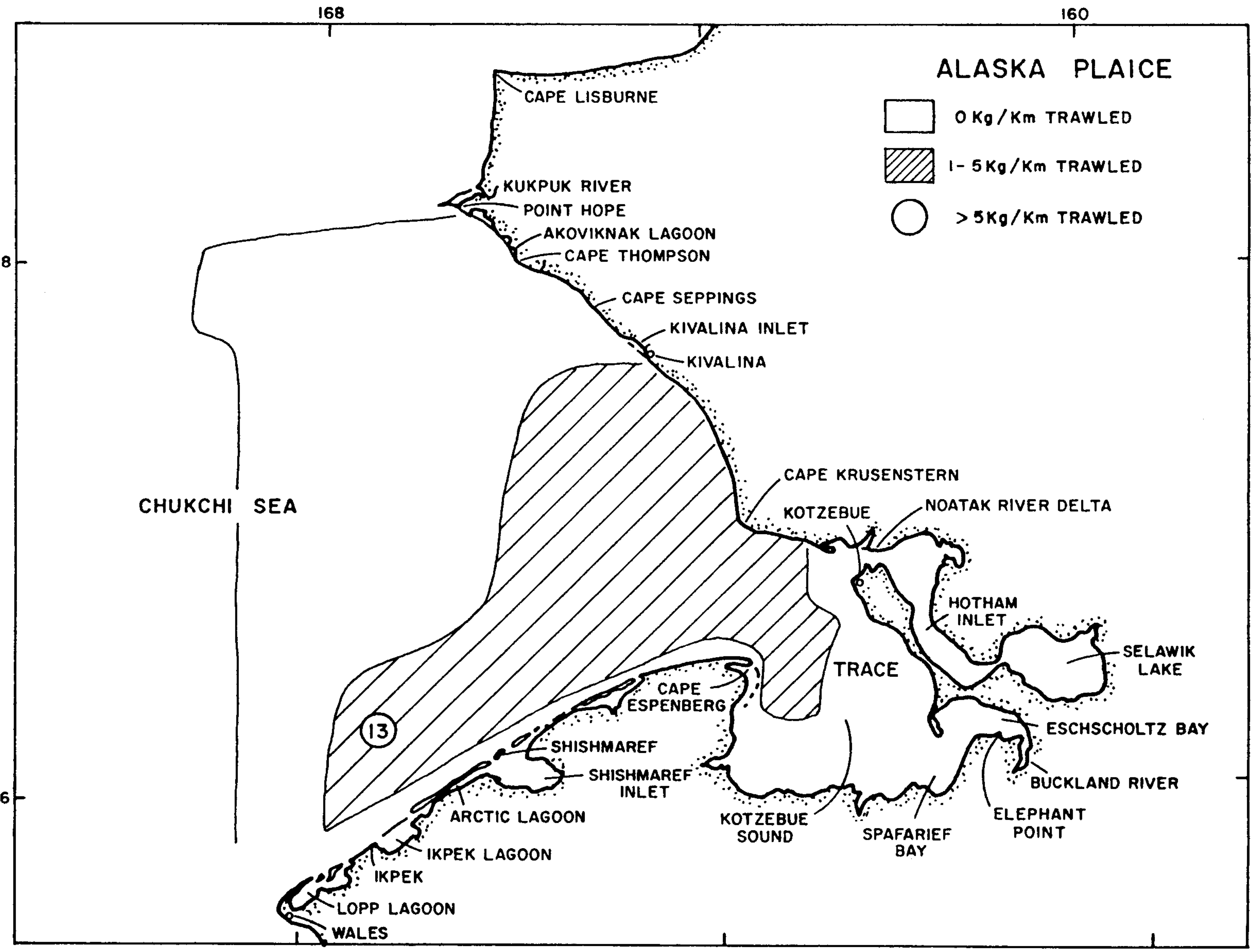

Figure 6-9. Distribution of Catch Rates by Weight of Alaska Plaice (after Wolotira et al. 1977).

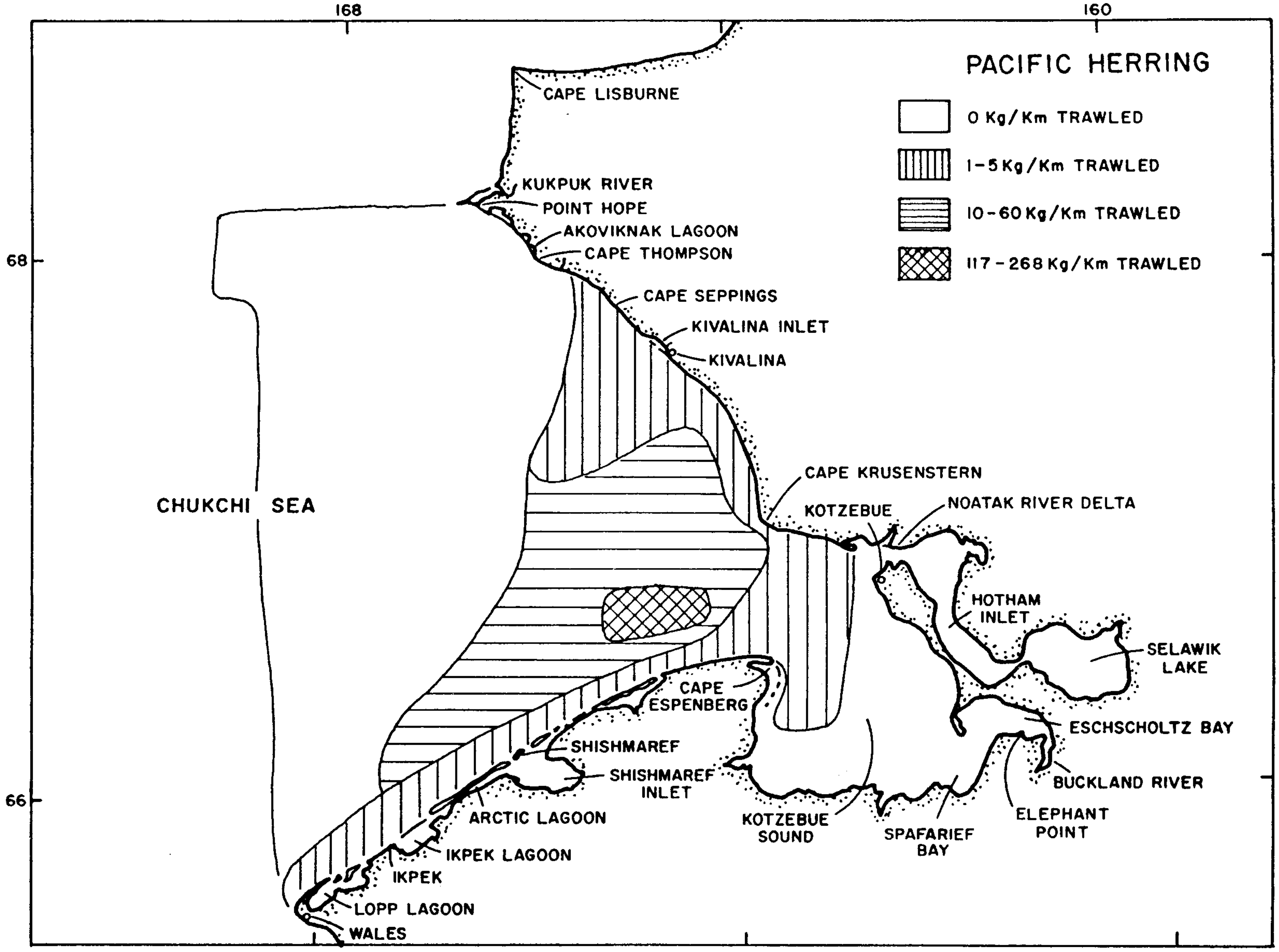

Figure 6-10. Distribution of Catch Rates by Weight of Pacific Herring (after Wolotira et al. 1977).

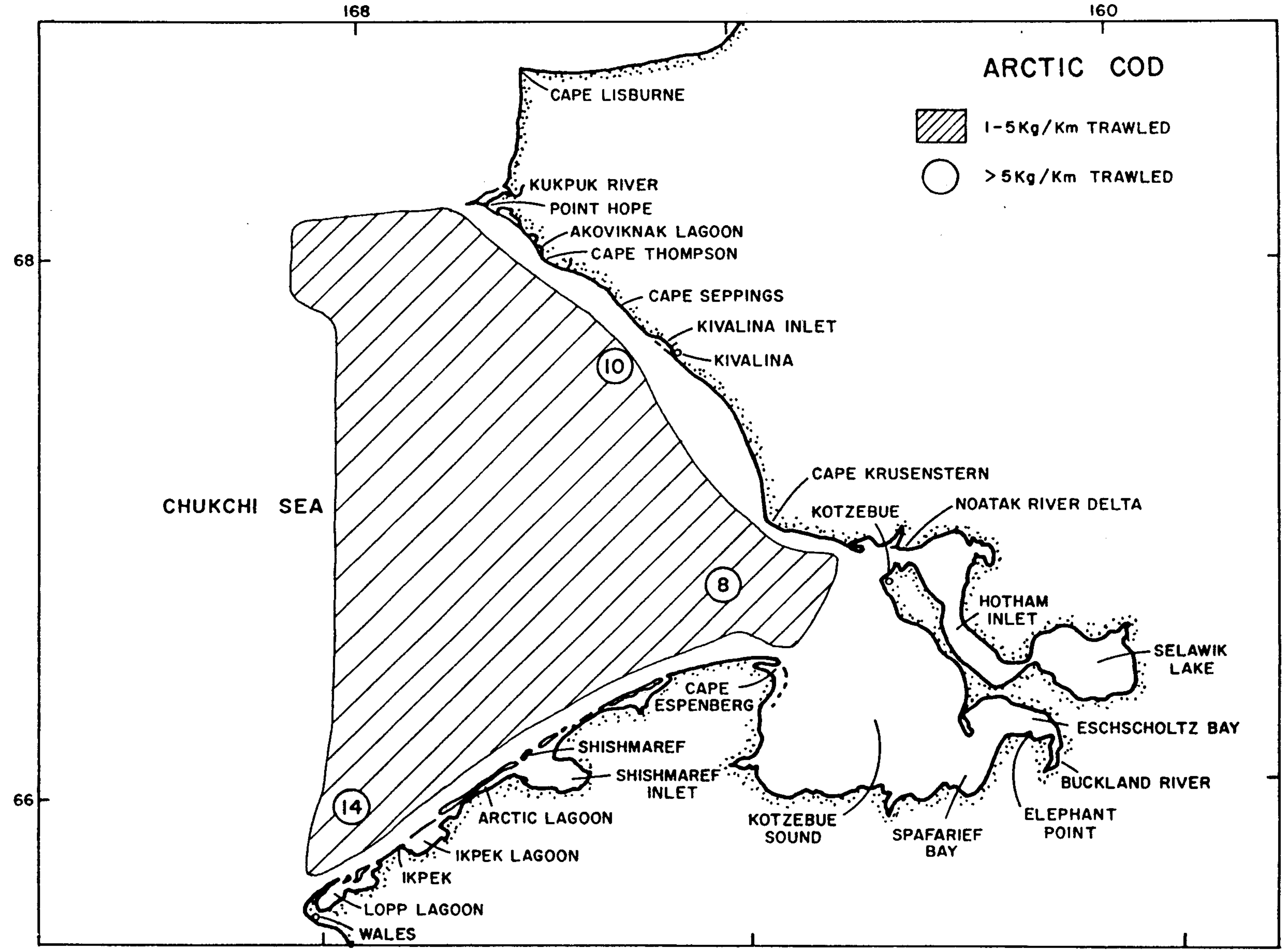

Figure 6-11. Distribution of Catch Rates by Numbers of Arctic Cod During 1959 (after Wolotira et al. 1977).

fact that Arctic cod are semi-pelagic and are very abundant in mid-waters (Quast 1974). As noted above, Alverson and Wilimovsky (1966) also found this species most abundant in offshore areas north of Kivalina. The authors note that the warm temperature during summer may have accounted for their results. Shorthorn sculpin were generally abundant only in offshore waters north of Cape Prince of Wales.

Anadromous Fish. Although Alverson and Wilimovsky (1966) and Wolotira et al. (1977) indicate that the southeastern Chukchi probably does not support enough demersal fish to constitute a commercial fishery, there is a locally important fishery for salmon. Smith et al. (1966) first reported upon the salmon fishery in the region. All five species of Pacific salmon occur at least as far north as Point Hope; however, only Kotzebue Sound, particularly the Noatak and Kobuk Rivers, support an active salmon fishery. The most commonly caught species in these rivers is the chum salmon. Pink salmon were observed in more northerly rivers, such as the Singoalik and Kukpuk. Smith et al. (1966) speculate that the restriction on salmon in the coastal Chukchi may be related to the irregular periods characterizing the opening and closing of the coastal lagoons. Recent statistics which are updated annually regarding the salmon fishery in Kotzebue Sound are provided by the Alaska Department of Fish and Game (ADF&G 1983). Their aerial survey escapement data support earlier observations that the major salmon-producing systems are the Noatak and Kobuk Rivers. Straty (1980) presents estimates of the relative abundance of salmon in producing areas along the Alaskan coast. These data for Kotzebue Sound are presented in Table 6-6.

These estimates indicate that Kotzebue Sound produces only 1.5% of the Pacific salmon in western Alaska. Chum salmon is clearly the most important Pacific salmon species in this area.

ADF&G (1983) also provides information on several other species of anadromous coastal fish in Kotzebue Sound. Sheefish (*Stenodus leucichthys*) overwinter in the Hotham Inlet-Selwik Lake area and migrate into the Kobuk-Selwik River drainages after ice breakup. This species spawns relatively late in life (5-7 years for males and 1-11 years for females), and so is easily subject to overharvest. Because of this and its importance as a subsistence species, the commercial fishery for the sheefish is controlled by ADF&G. Arctic char (*Salvelinus alpinus*) are also taken in the area of Kotzebue Sound, often as incidental in the salmon catch. This species emerges in the spring and migrates to the ocean in summer. The areas of heaviest catches occur in the Noatak, Kivalina, and Wulik Rivers. Hotham Inlet is also the site of a fishery comprised mainly of whitefish. The term whitefish includes several species of the genus *Coregonus* (*C. nasus, C. pidschian, C. sardinella, C. autumnalis, C. laurettae*) and *Prosopium cylindraceum.*

Summary. The southeastern Chukchi does not support a commercially viable bottomfish fishery. Fish biomass is very low compared to major fishery areas to the south such as the eastern Bering Sea. The percentage of demersal biomass as fish versus invertebrates is low (approximately 6.9%-12.7%) compared to commercially valuable fisheries in other regions of Alaska.

There is not sufficient time series data to address the problem of annual variability of fish distribution and biomass in the southeastern Chukchi Sea.

Table 6-6. Relative abundance (in thousands of fish) of Pacific salmon produced in river tributary systems of Kotzebue Sound as indicated by average of U.S. commercial catches during 1962-1977 and available Soviet data (from Straty 1980).

Species	Relative Abundance (thousands)
Sockeye salmon	0.006
Chum salmon	168.100
Pink Salmon	0.004
Chinook salmon	0.003

Based on existing data, however, it appears that Arctic cod (an important item in the diet of ringed seals) are generally distributed north of Kivalina and offshore in summer, while saffron cod (another diet item for ringed seals) inhabit the nearshore waters south of Kivalina in greater abundance than further north.

It should also be noted that the Kotzebue Sound and the area between Cape Espenberg and Cape Krusenstern are areas of concentration for saffron cod, rainbow smelt, yellowfin sole, Alaska plaice, Pacific herring, the anadromous species of Pacific salmon, sheefish, Arctic char, and the various species collectively referred to as whitefish. This is a particularly germane observation since this area (Kotzebue Sound and environs) is also an important feeding and/or haulout area for various species of marine mammals.

6.3.1.3 Northeastern Chukchi Sea

Few major fisheries studies have been conducted in the northeast Chukchi Sea. Frost and Lowry (1983) review the limited surveys which have occurred there and present offshore trawl data collected in 1977 during their survey which took place along the 40-m bottom contour between Icy Cape and Point Barrow. Fechhelm et al. (1983) examined the fish community composition in Ledyard Bay and Kasegaluk Lagoon during the open-water period of 1983, and Peard Bay and Ledyard Bay in the winter of 1982. Quast (1972, 1974) investigated the density distribution of juvenile Arctic cod in Ledyard Bay during the open-water season of 1970, while Alverson and Wilimovsky (1966) originally trawled north into Ledyard Bay. Mohr et al. (1957) documented fish catch information from a kelp bed located along the coast east of Peard Bay, and Craig and Schmidt (1982), Bendock (1979), and Bendock and Burr (1980) describe the anadromous fishes of the rivers flowing into the northeastern Chukchi Sea.

To date, 41 species of fish have been identified from the northeast Chukchi Sea (Morris 1981). Frequently encountered species include Arctic and saffron cod, Arctic flounder, fourhorn sculpin, capelin, rainbow smelt, herring, pink and chum salmon, at least two species of cisco, whitefish, and Arctic char.

Frost and Lowry (1983) found the Arctic cod to be the most widespread and abundant species in the northeast Chukchi Sea during the open-water period, lending credence to the hypothesis that the cod seasonally move north with the receding ice pack. Their catch data for cod from the Beaufort and northern Bering Seas indicated the least abundance. Stomach analyses revealed the cod populations in the eastern Chukchi fed heavily upon the calanoid copepod species of *Calanus hyperboreus, C. glacialis, Euchaeta glacialis, Metridia longa*, and *C. cristatus* and upon the gammarid amphipod *Apherusa glacialis,* while the populations sampled in the northern Bering consumed mostly a gammarid amphipod (*Ampelisca macrocephala*), shrimps (*Eualus fabricii* and *E. gaimardii*), and a mysid (*Neomysis rayii*). From these results and other available information the authors concluded that the Arctic cod are well adapted to living in an area where annual fluctuations in physical (ice cover) and biological (primary production) factors demand flexibility in feeding habits and abundance.

Fechhelm et al. (1983), in their investigation of Ledyard Bay and Kasegaluk Lagoon, found that marine fish species predominated in their catch results, while ciscoes, whitefish, Arctic char, and chum salmon were not in abundance presumably because of the scarcity of winter habitat afforded by large coastal rivers. However, pink salmon and rainbow smelt were found to rely upon the smaller river systems of the Kokolik, Utakok, Kukpowruk, and Kuk along the Chukchi coast for spawning grounds. Arctic cod were the dominant species present nearshore. The winter study revealed that more feeding activity by Arctic cod took place in Ledyard Bay than in the nearshore area of Peard Bay, and a difference in the relationship of body weight to length was also apparent between the two areas. The dominant prey item by wet weight estimates (85%) for the Arctic cod in Ledyard Bay was the calanoid *Calanus glacialis,* while mysids appeared to increase in importance in the Peard Bay area. Stomach analyses indicated that the Arctic cod were foraging on *C. glacialis, A. macrocephala,* and *Diastylus rathkei* during the open-water period.

Quast (1972, 1974) showed that the dominant fish in Ledyard Bay was the Arctic cod, the juveniles of which were clumped in a density structure at depth possibly in response to predation pressure by piscivorous birds. Density estimates of 28 individuals/1,000 m^3 or 0.7 metric tons/km^2 of ocean surface were given. He further speculated these juveniles had originated in the Chukchi Sea.

Table 6-7. Peard Bay fyke net fish catch data (1983).

Species	Number Caught	Percent of Catch
Arctic cod	8,270	69.5
Fourhorn sculpin	2,817	23.7
Saffron cod	680	5.7
Arctic flounder	82	<1
Least cisco	18	<1
Rainbow smelt	9	<1
Capelin	7	<1
Pacific herring	4	<1
Bering cisco	3	<1
Pacific sand lance	2	<1
Pink salmon	1	<1
Prickleback	1	<1
Eelpout	1	<1
Snailfish	1	<1
Totals	11,896	100.0

6.3.2 Peard Bay Fish Utilization

6.3.2.1 Introduction

This report contains the results and interpretation of fish data gathered during the 1983 study. It provides an appraisal of fish community structure within the waters of Peard Bay. The 1983 fish utilization study was designed to examine marine and anadromous fish usage and to incorporate the results into a comprehensive report dealing with the physical and biological systems of Peard Bay.

6.3.2.2 Study Area

Peard Bay, located on the Chukchi Sea coast between Point Barrow and Wainwright, is a moderately deep (7 m) embayment encompassing about 300 km^2 of surface area. A brief survey of the Kugrua River (approximately 2 miles) showed the bottom to be mostly sand or silt with very little current.

6.3.2.3 Field Data

Fyke and gill netting efforts produced 14 species of fish totaling 11,898 individuals (Table 6-7). Almost all fish were taken in fyke nets. Only two were taken during drift gill net operations: one herring and one least cisco.

Four marine species accounted for 99.6% of the total fyke net catch. These species were Arctic cod (69.5%), fourhorn sculpin (23.7%), saffron cod

(5.7%), and Arctic flounder (0.7%). These results are comparable to those from Point Lay obtained by Fechhelm et al. (1983), where 10 marine species accounted for nearly 99% of the total catch. Also similar to the Fechhelm et al. (1983) study is the almost complete absence of anadromous fish.

Only 31 anadromous fish were taken in Peard Bay in 1983 from both fyke and gill nets. While Arctic cisco, Arctic char, least cisco, and broad whitefish accounted for about 73% of the nonArctic cod and sculpin catch in Simpson Lagoon in 1978 and over 90% in 1977, ciscoes, whitefish, and char represented less than 4% of the non-Arctic cod and sculpin catch in Peard Bay.

The Chukchi Sea coastal and/or freshwater habitat is not attractive to populations of anadromous fish, at least during the 1983 sampling period. Whether this is caused by a lack of overwintering or breeding areas is uncertain at this time.

6.3.2.4 Catch Rates

The catch rates (CPUE) for fish taken per net hour in the fyke nets were computed for July and August as a whole for the most frequently taken species (Tables 6-8 and 6-9). The overall catch rates are compared to the fyke net results from other Arctic areas in Table 6-10.

Two points seem clear from these data. Arctic cod and fourhorn sculpin are frequent in all catches in the Chukchi Sea and much of the Beaufort Sea, especially in estuarine and nearshore areas. Secondly, anadromous species such as Arctic char and the several ciscoes appear to be a much less important component of the fish fauna west of Point Barrow; in many areas they are virtually absent.

No fish were caught in Peard Bay by nets during the winter survey.

6.3.2.5 Trophic Comparisons

The stomachs of 76 fish taken at Peard Bay were examined from those four species which make up the majority of all fish caught. Stomachs were examined from fish taken in fyke nets; however, all fresh or slightly digested prey items likely to have been taken from the fyke nets were not enumerated or identified.

Table 6-11 provides the prey species ranking (after Frost and Lowry 1983) for Arctic cod, fourhorn sculpin, saffron cod, and Arctic flounder. Table 6-12 presents the summed prey ranking for fishes examined in 1983 from Peard Bay.

Mysids, primarily *Mysis litoralis*, represented an important food item to the fish examined. They ranked first in abundance 31 times and were represented in 35.8% of all stomachs examined. Small Arctic cod, the isopod *Saduria entomon*, and amphipods (primarily *Onisimus* sp. and *Atylus* sp.) were also numerically important in the diets of fish taken in Peard Bay.

Table 6-8. Peard Bay fyke net catch per unit effort (fish/net/h) for July and August of 1983.

Fish Species	July (CPUE)	August (CPUE)	% Change
Arctic cod	3.3	31.1	+942
Fourhorn sculpin	0.6	11.1	+1850
Saffron cod	0.5	2.3	+460
Arctic flounder	0.2	0.1	-50
Others	<0.1	<0.1	0

Table 6-9. Fyke net catch rate (fish/net/h) for the four most frequently taken species in Peard Bay during summer of 1983.

Fish Species	CPUE (FISH/NET/H)
Arctic cod	17.2
Fourhorn sculpin	5.9
Saffron cod	1.4
Arctic flounder	0.1

Table 6-10. Comparative fyke net catch rates (CPUE) for common species in Peard Bay and other Arctic lagoon areas.

Fish Species	Peard Bay[1] 1983	Simpson Lagoon[2] 1977	Simpson Lagoon[2] 1978	Prudhoe Bay[3] 1981	Point Lay[4] 1983
Arctic cod	17.2	0.27	66.9	8.2	7.6
Fourhorn sculpin	5.9	2.5	15.3	3.6	3.9
Arctic char	0	0.13	0.77	0.35	<0.1
Arctic cisco	0	0.52	0.68	2.3	0

[1] This study.
[2] Craig and Haldorson 1981.
[3] Griffiths and Galloway 1982.
[4] Fechhelm et al. 1983.

Table 6-11. 1983 Peard Bay - Prey rank summation.

Prey Item	Rank 1	Rank 2	Rank 3	Total Number of Occurrences	Frequency of Occurrence
Mysids	31	2	1	34	35.8
Boreogadus saida	7	4	3	14	14.7
Saduria	-	6	-	6	6.3
Amphipods	4	3	-	7	7.4
Worms	2	3	-	5	5.3
Larval fish	2	2	-	4	4.2
Copepods	-	1	-	1	1.1
Sculpin	-	-	2	2	2.1
Empty	22	-	-	22	23.2

Table 6-12. Stomach content ranking of commonly taken fishes from Peard Bay, 1983.

Prey Item	Rank 1	2	3	Total Number of Occurrences	Frequency of Occurrence
Arctic Cod (*Boreogadus saida*)					
Mysids	20			20	64.5
Fish	3	1		4	12.9
Amphipods		1		1	3.2
Copepods		1		1	3.2
Empty	5			5	16.1
				N = 31	
Fourhorn sculpin (*Myoxocephalus quadricornis*)					
Mysids		1	1	2	7.1
Fish	3	2	3	8	28.6
Isopods		6		6	21.4
Amphipods	3	2		5	17.9
Sculpin			2	2	7.1
Worms		2		2	7.1
Empty	1			1	3.6
				N = 26	
Saffron cod (*Eleginus gracilis*)					
Mysids	8	1		9	39.1
Fish	1	1		2	8.7
Larval fish	2			2	8.7
Empty	10			10	43.5
				N = 23	
Arctic flounder (*Liopsetta glacialis*)					
Mysids	3			3	23.1
Amphipods	1			1	7.7
Worms	2	1		3	23.1
Empty	6			6	46.2
				N = 13	

6.3.2.6 Fish Movements As Indicated by Fyke Catches

Assuming that fish caught on one side or the other of a double fyke net indicate the direction of travel of the fish prior to entering the cod ends, the following results suggest that the general movements of Arctic cod follow the predominant directions of the currents in Peard Bay. During July, 90% of Arctic cod taken at Station 2 were moving in a southerly direction along the northern end of Point Franklin spit, while during the August sampling period, 65% of the Arctic cod taken were moving in a northerly direction (Table 6-13). The predominant direction of the catch at the Franklin spit station is in general correspondence with the direction of current flow as recorded from the nearby current meter station at M1 (Chapter 2). During the first sampling period of the fyke net surveys the currents recorded from station M1, though somewhat mixed, show a strong down-spit (north to south) component, while the dominant current direction during the August fyke net sampling period proceeds up the spit (Figure 6-2).

Directional catch data from other fyke net stations support the contention that the general movements of Arctic cod correspond with the direction of the local currents in Peard Bay. At Station 4 located on the southeast side of Peard Bay 88% of the catch of Arctic cod was recovered from the cod end on the eastern side of the net, corresponding to the general clockwise circulation of water within Peard Bay (Figure 2-10). The storm event immediately following this period produced similar results when 66% of the estimated total catch of 5,450 Arctic cod were recovered from the east side of Station 4 (Table 6-13). Although no direct current measurements were taken to confirm the general circulation patterns predicted for Kugrua Bay, detailed field notes verify the correlation between directional catch data and local current flow. Drift accumulation of macrophytic plants on the same side of the fyke net lead as the majority of the Arctic cod catch at Station 3 further suggests that local currents probably dictate the movements of cod in the Peard Bay study area.

6.3.2.7 Species Accounts

Arctic cod (*Boreogadus saida*). Circumpolar in distribution from the Beaufort Sea south to the Bering Sea in Alaskan waters (Pereyra et al. 1977; Lowry and Frost 1981; Frost and Lowry 1983), Arctic cod appear to be very common and abundant, especially in the Chukchi and western Beaufort Seas (Alverson and Wilimovsky 1966; Quast 1974; Craig and Haldorson 1981; Lowry and Frost 1981; Frost and Lowry 1983; Griffiths et al. 1983).

Arctic cod was the most abundant species of fish taken in Peard Bay during open water in 1983. A total of 8,270 Arctic cod were taken in the fyke nets (they are not vulnerable to gill netting). This represented 69.5% of all fish taken (Table 6-7). More Arctic cod were taken per net hour (CPUE) during August (31.1 fish/h) than in July (3.3 fish/h); however, no daily environmental correlations such as temperature or salinity were taken at the fyke net stations, so their influence on the CPUE cannot be investigated.

Arctic cod taken in Peard Bay ranged from 25 mm to 225 mm (TL). Unimodal length-frequency distribution was apparent between 75 and 100 mm (Figure 6-12). When the July Arctic cod length-frequency data were plotted separately

Table 6-13. Directional fyke net catch data (numbers of individuals) for Arctic cod from Peard Bay during 1983.

	Fyke Net Sample Number							
	1		2		3		4	
Sample Date	L	R	L	R	L	R	L	R
7-28	10	5	71	4				
7-29			20	2				
7-30			22	4	57	50		
7-31			22	2	85	132		
8- 1			13	4	95	192		
8-22			49	99	6	65		
8-23			115	127				
8-24			63	178	171	1329	313	2868
8-25			29	143	9	801	132	340
8-26			244	396				
8-27**								
8-28**								
8-29					45*	915*	1850*	3600*

L - left side of net, looking seaward.
R - right side of net looking seaward.
* - estimated catch
**- weather day

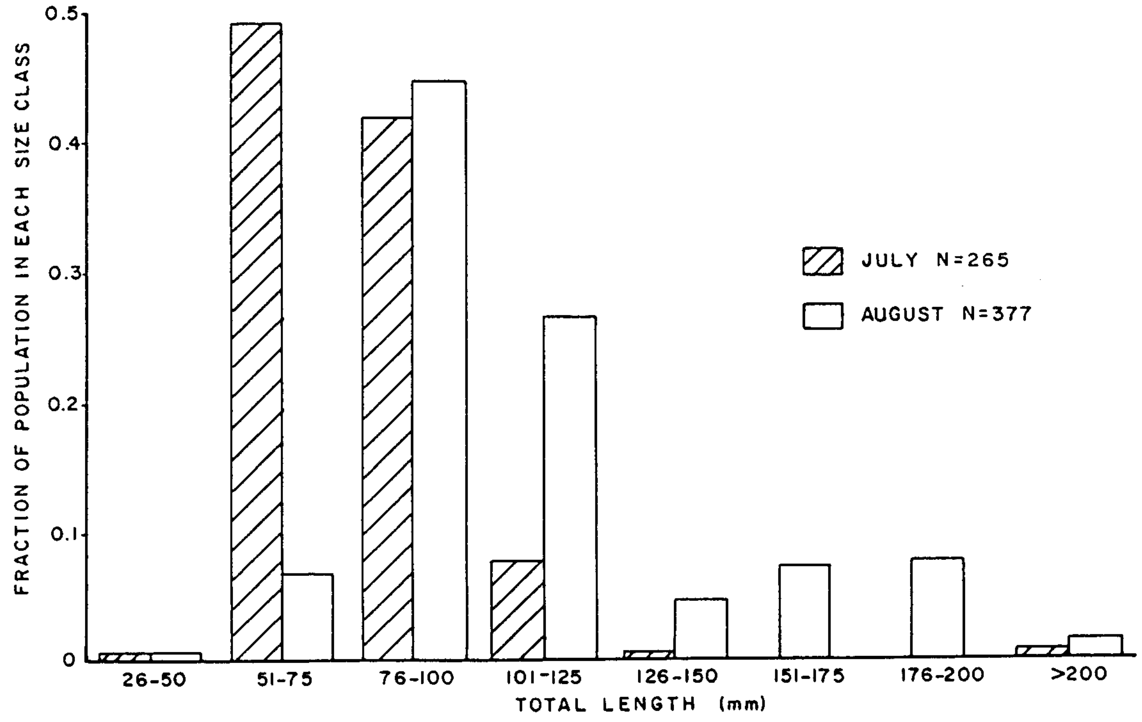

Figure 6-12. Length-Frequency Distribution of Arctic Cod Taken by Fyke Nets in Peard Bay, Summer 1983.

from data recorded in August (Figure 6-12), a noteworthy reduction in the August 51-75-mm size class was apparent. The almost 86% reduction in this size class of Arctic cod (from 49.1% of those measured in July to 6.9% in August (N=164)) may be due to predation or changes in growth. Increases in mean weight of Arctic cod caught in August versus July are shown in Table 6-14. If growth were primarily responsible, however, one might expect to see a definite increase in the next larger classes, the 76-100-mm and 101-125-mm classes. As noted in Figure 6-12, both these classes did show increases; the 76-100-mm class increase from 41.9% in July to 44.8% in August and the 101-125-mm class increase from 7.9% in July to 26.5% in August. However, these values do not indicate that predation is unimportant in this system.

While Fechhelm et al. (1983) found that winter-caught Arctic cod in Peard Bay had fed mostly on copepods (57% occurrence) and less on mysids (38%) and amphipods (<10%), samples from the open-water season (N=24) suggest that mysids, especially *Mysis litoralis*, predominate as summer food with a 64.5% occurrence rate. Fish (12.9%) and amphipods (3.2%) were of much less importance. Of the Arctic cod stomachs examined, 16.1% were empty.

Fourhorn Sculpin (*Myoxocephalus quadricornis*). With a distribution similar to the Arctic cod, i.e., circumpolar, and with a tolerance to low salinity waters (Kendel et al. 1975; Pearcy 1975; Craig and Haldorson 1981), this fish was the second most abundant species caught in Peard Bay.

A total of 2817 fourhorn sculpin were taken in fyke nets during July and August. This species has proven common in most other nearshore Alaskan Arctic fish studies (Griffiths et al. 1975, 1977; Bendock 1979; Craig and Haldorson 1981). An average of 5.9 of these sculpin were caught during each hour of fyke net effort. However, that figure is misleading because the catch rate was much higher in August (11.1 fish/h) than for July (0.6 fish/h).

Peard Bay sculpin ranged from 33 to 281 mm TL (Figure 6-13). Both July and August catches were dominated by small fish. Almost 70% of the fish were under 100 mm. These results are very similar to those of Fechhelm et al. (1983) for Point Lay, and suggest a dominance of Age 1 sculpin both in Peard Bay and at Point Lay (Craig and Haldorson 1981).

As noted in Table 6-12, fourhorn sculpin stomachs from Peard Bay contained a variety of foods, with small (<50 mm) fish and the isopod *Saduria entomon* occurring in 50% of the stomachs. Amphipods, principally of the genera *Onisimus* and *Atylus*, were found in almost 18% of the stomachs examined. Empty stomachs were infrequent and represented only 3.6% of those examined. These results are somewhat different from those reported for Point Lay (Fechhelm et al. 1983), principally in frequency of occurrence and not in prey species. The results from Peard Bay compare favorably to those from the Beaufort Sea in terms of foods eaten, but vary with regard to frequency of occurrence (Griffiths et al. 1975, 1977; Kendel et al. 1975; Pearcy 1975; Craig and Haldorson 1981).

Saffron Cod (*Eleginus gracilis*). Annual nearshore winter spawners, saffron cod are apparently limited to the western sector of the Alaska Beaufort Sea in addition to the Chukchi and Bering Seas and North Pacific (Percy 1975; Bendock 1977; Morrow 1980).

Table 6-14. Weight changes in four species of marine fish commonly taken in Peard Bay during summer 1983.

Species	N	July Mean Weight (g)	August Mean Weight (g)	% Increase
Arctic cod	670	2.9	9.5	380
Saffron cod	211	2.6	9.6	369
Fourhorn sculpin	240	7.6	18.6	244
Arctic flounder	47	18.8	33.7	179

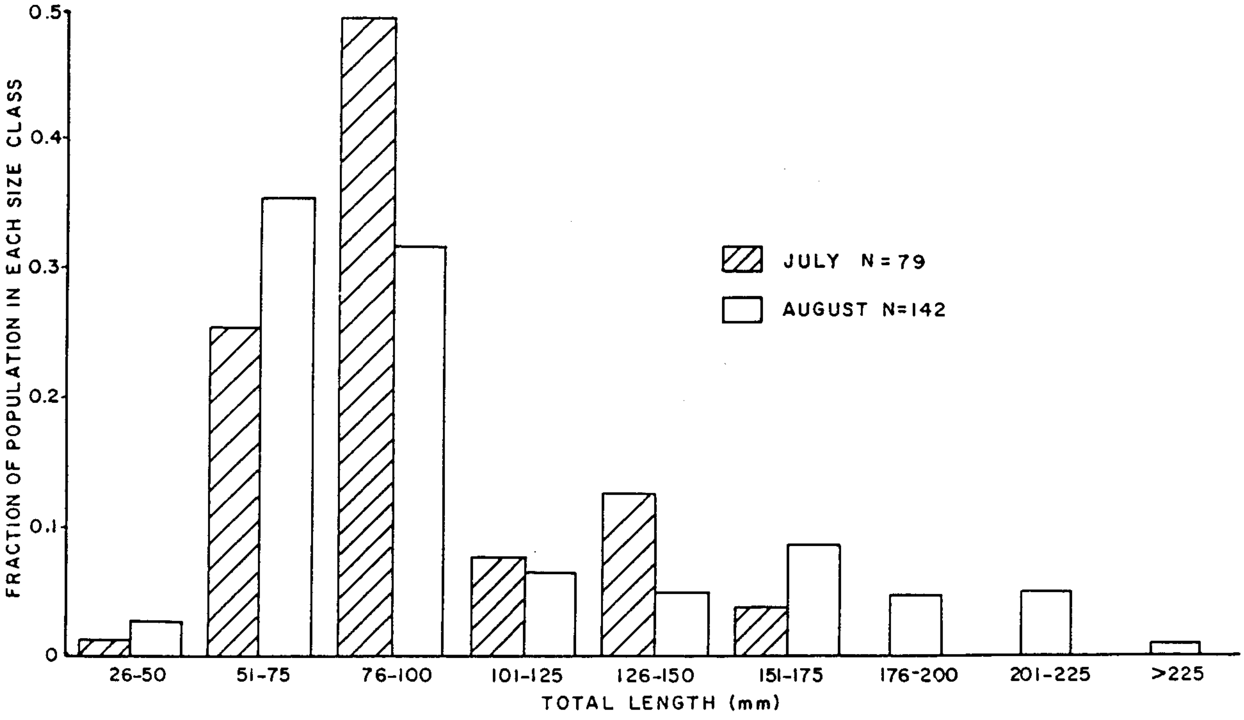

Figure 6-13. Length-Frequency Distribution of Fourhorn Sculpin Taken by Fyke Nets in Peard Bay, Summer 1983.

Saffron cod from Peard Bay ranged from 54 to 294 mm TL. The 75-100-mm size class dominated both July and August catches (Figure 6-14). This size class accounted for almost 63% of all saffron cod measured, and probably represents the Age 1 class (Craig and Haldorson 1981). The young-of-the-year size class (45-75 mm) which appeared in Point Lay catches in August (Fechhelm et al. 1983), and represented a second mode in the length/frequency display, was also present in Peard Bay, but represented only 22% of the total catch there.

Saffron cod ate mostly mysids in Peard Bay (39.1% frequency of occurrence) with small and larval fish present in about 17% of the stomachs examined. Results of stomach examination of saffron cod taken near Kotzebue by jigging suggest that fish and mysids are also important in that area (Craig and Haldorson 1981).

<u>Arctic Flounder</u> (*Liopsetta glacialis*). This small, typically nearshore flatfish is found in the Canadian and Alaskan Beaufort Seas, through the Chukchi and Bering Seas south to Bristol Bay (Fechhelm et al. 1983).

During the summer of 1983 a total of 82 Arctic flounder were taken in fyke nets set in Peard Bay (0.7% of total catch). They were the fourth most abundant fish taken; however, the catch rate was low (0.1 fish/net/h) compared to Arctic cod, fourhorn sculpin, and saffron cod. Arctic flounder demonstrated a 50% decrease in the catch rate from July to August.

Arctic flounder ranged from 78 to 210 mm. July catches were strongly represented by 101-150-mm flounder (Figure 6-15) while August catches were more evenly represented by many size classes, though the 101-150-mm cohort represented 58% of the catch, compared to 92% in July. These results compare quite favorably with those from Point Lay (Fechhelm et al. 1983).

Empty stomachs were quite common in Arctic flounder from Peard Bay (46.2%). While this is lower than the 78% found in Point Lay samples, it seems quite high nevertheless. Of those stomachs containing food, 23.1% had eaten mysids, 23.1% contained worms, and 7.7% amphipods. Again, these findings are similar to those of Point Lay with the exception of those samples collected after 22 July in which worms were predominant (83%).

<u>Other Fish</u>. The preceeding four species of fish represented all but 42 (0.4%) of the almost 12,000 fish taken in Peard Bay in 1983. The 42 other fish were of 10 species. Least cisco (*Coregonus sardinella*) and Bering cisco (*C. laurettae*) made up half of the remaining catch; 21 individuals. In addition, rainbow smelt (*Osmerus mordax*), capelin (*Mallotus villosus*), herring (*Clupea harengus pallasi*), and sand lance (*Ammodytes hexapterus*) were represented by from two to nine individuals (Table 6-7). One pink salmon (adult female) was taken, as were a single prickleback (*Lumpenus* sp.), an eelpout (*Lycodes* sp.) and a snailfish (*Liparis* sp.)

These results are similar, in terms of species composition, to those reported from Point Lay (Fechhelm et al. 1983). An exception is the catch of three Arctic char (*Salvelinus alpinus*) taken at Point Lay. No char were caught in Peard Bay.

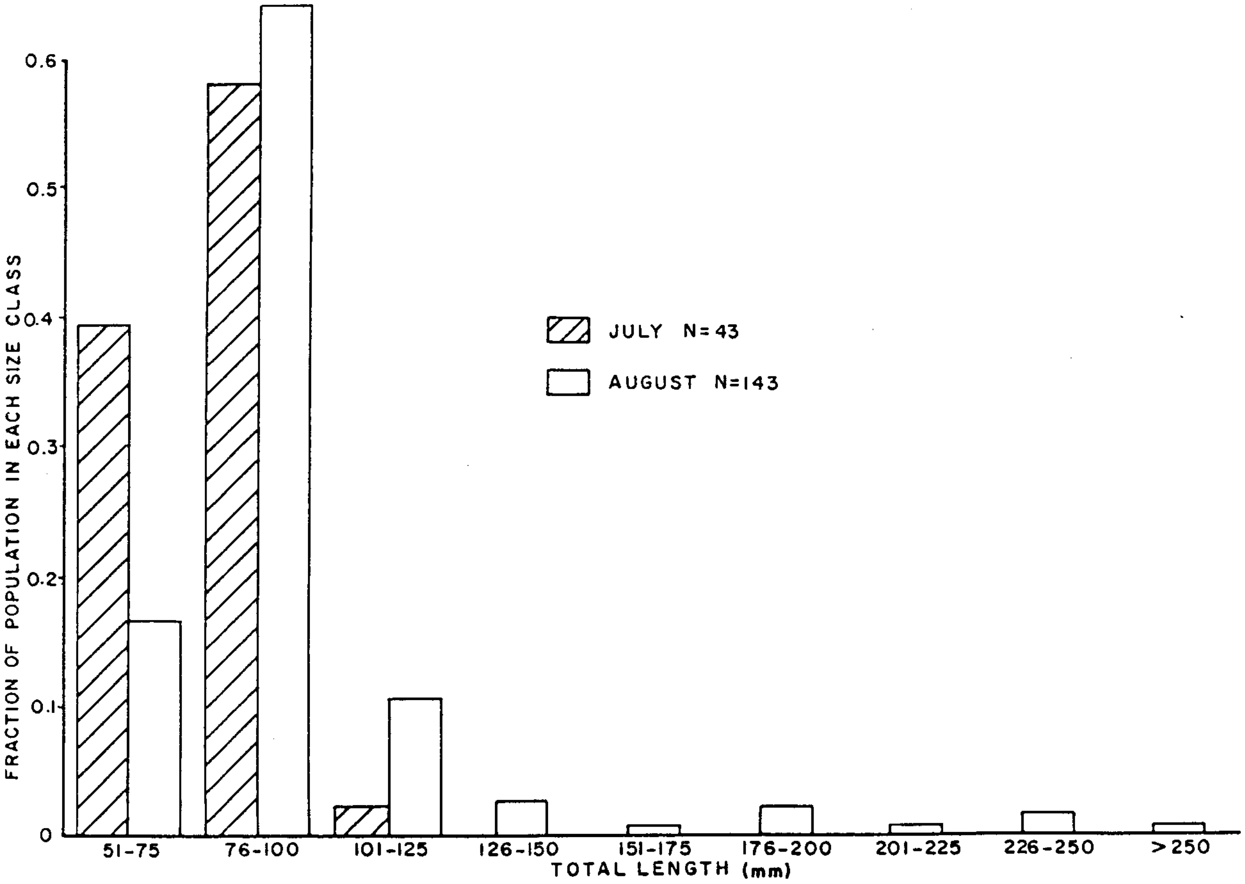

Figure 6-14. Length-Frequency Distribution of Saffron Cod Taken by Fyke Nets in Peard Bay, Summer 1983.

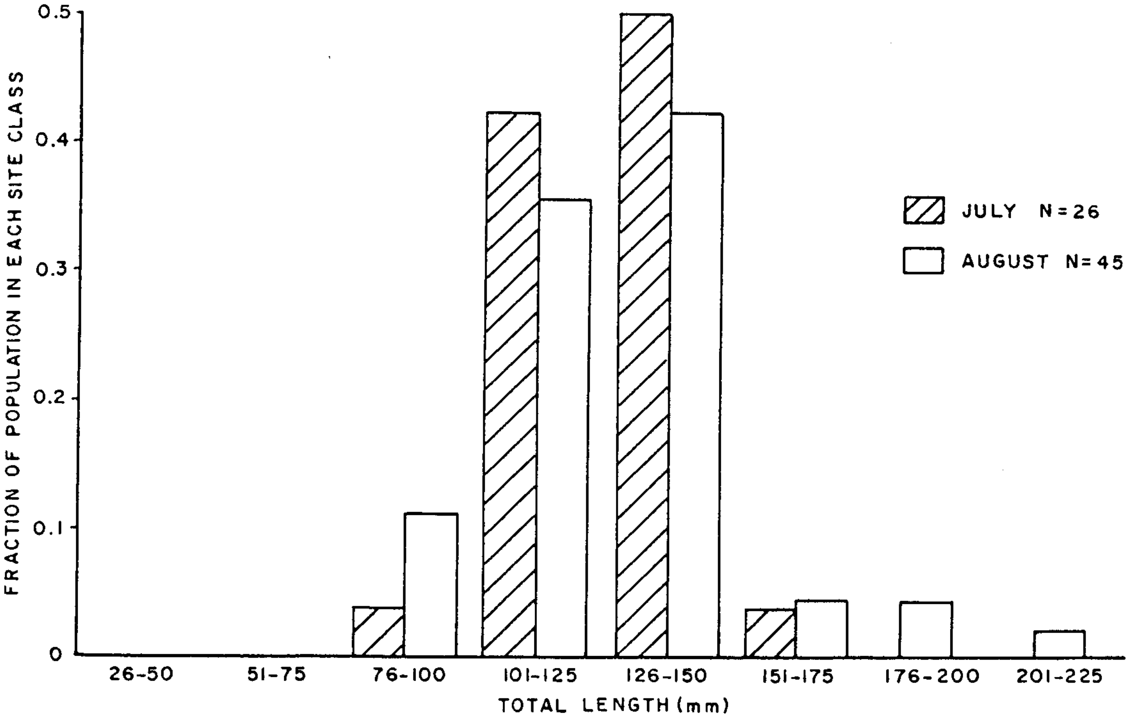

Figure 6-15. Length-Frequency Distribution of Arctic Flounder Taken by Fyke Nets in Peard Bay, Summer 1983.

6.3.3 Summary and Conclusions

As in other recently sampled nearshore areas of the Chukchi Sea, the fish fauna from Peard Bay was dominated by marine species, principally Arctic cod, fourhorn sculpin, saffron cod, and Arctic flounder. Catches of anadromous fish were much reduced compared to those from Simpson Lagoon, Prudhoe Bay, and the Beaufort Lagoon areas. It is suspected that suitable spawning and overwintering habitat is much reduced in the Chukchi Sea coastal rivers in comparison to the much larger river systems east of Point Barrow.

Arctic cod, a major prey item for many birds and marine mammals, represented almost 70% of the total catch. Of the Arctic cod measured, over 87% were less than 125 mm TL and were, therefore, likely to be immature. This predominance of young Arctic cod suggests that Peard Bay provides important forage and/or nursery habitat for young Arctic cod. Saffron cod and fourhorn sculpin catches were dominated by immature individuals as well, and may use Peard Bay as a forage area also.

Catch rates of Arctic cod, saffron cod, and fourhorn sculpin in fyke nets were comparable to, or higher than, those from Point Lay, Prudhoe Bay, Beaufort Lagoon, and the 1977 Simpson Lagoon rates. Only the 1978 Simpson Lagoon catchs of Arctic cod and fourhorn sculpin exceeded 1983 Peard Bay values.

In 1983, mysids (mostly *Mysis litoralis*) were important prey items for fishes sampled. Amphipods, small fish, especially Arctic cod, worms, and the isopod *Saduria entomon* were also commonly found in fish stomachs.

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CHAPTER 7

PRIMARY PRODUCTIVITY AND NUTRIENTS

7.1 INTRODUCTION

7.1.1 General

The base of Peard Bay ecosystem processes lies in marine primary productivity, supplemented by terrestrial input from both local erosional (peat) sources and the Kugrua River. This terrestrial input includes not only fixed organic carbon and nitrogen (particulate and dissolved), but also dissolved nutrients which are important to marine primary productivity mechanisms.

Previous studies on productivity in Arctic lagoons include two multi-year studies of Simpson Lagoon along the Beaufort Sea coast (Alexander et al. 1975; Schell et al. 1982; Schell 1983). Marine primary productivity within the lagoon averaged about 6 g C/m^2/yr. Terrestrial carbon was found to be unimportant in marine trophic energetics, since the carbon content of invertebrates and higher trophic levels was shown by isotopic studies to be essentially of marine origin. Nutrients derived from terrestrial sources, particularly nutrient regeneration and nitrification processes occurring in the winter, were felt to be important to inshore marine productivity. A few primary productivity measurements along with isotopic measurements of three fish were obtained in Angun Lagoon on the eastern Beaufort coast (Schell et al. 1983) during the summer of 1983. The authors caution against comparing these few results with those of Simpson Lagoon due to 1) low sample size, 2) high natural variability in primary productivity measurements, and 3) the unknown movements of fish. They do observe, however, that their results show lower primary productivity (about 2 g C/m^2/year) than found in Simpson Lagoon and that up to 50-80% of the carbon of the two Arctic cisco and one Arctic flounder was of terrestrial rather than marine origin.

Peard Bay, which lies along the northeast Chukchi coast south of Point Barrow, is semi-enclosed by a system of spits and offshore barrier islands. Knowledge of the physical and ecological processes operating within this lagoon are needed prior to the proposed offshore oil and gas development. Primary productivity mechanisms in the bay were studied and compared with the results obtained for the Beaufort and Simpson lagoons.

Emphasis in the present Peard Bay productivity studies included work on the efficiency with which marine productivity was manifested in microplankton-sized particles large enough to be grazed by higher organisms. Heterotrophic activity of the smaller nano- and picoplankton, which work within the water column to recycle organic carbon and regenerate nutrients, was also investigated. If such a dynamic microbial food web is operative in these inshore Arctic areas, the present concept of lower food chain dynamics would have to be modified. The current viewpoint is that the production of organic carbon is by microplankton (mostly diatoms). The carbon produced settles to the bottom, and serves as the food base for organisms living within or close to the sediments. These two contrasting views of the food web also would present different scenarios in regard to the possible uptake, transfer, and effect of pollutants (metals and hydrocarbons) on marine organisms.

7.1.2 Specific Objectives

The purpose of the present work in Peard Bay was to describe the primary production and nutrient dynamics of the lagoon. Specifically the objectives included (1) the determination of the total microbial biomass which serves as the "base" of the food web and which supports all higher trophic levels, (2) the determination of the rate of production of organic matter by phytoplankton, and (3) the determination of the factors which limit the rate of primary production so that an estimate of its availabilty as food to vertebrate populations can be made.

7.2 METHODS

7.2.1 Literature

The literature on primary production measurements along the eastern Chukchi Sea coast was gathered and summarized according to NOAA requirements. The other pertinent literature for the Beaufort Sea coast and lagoons was gathered, and is discussed in the context of the study results.

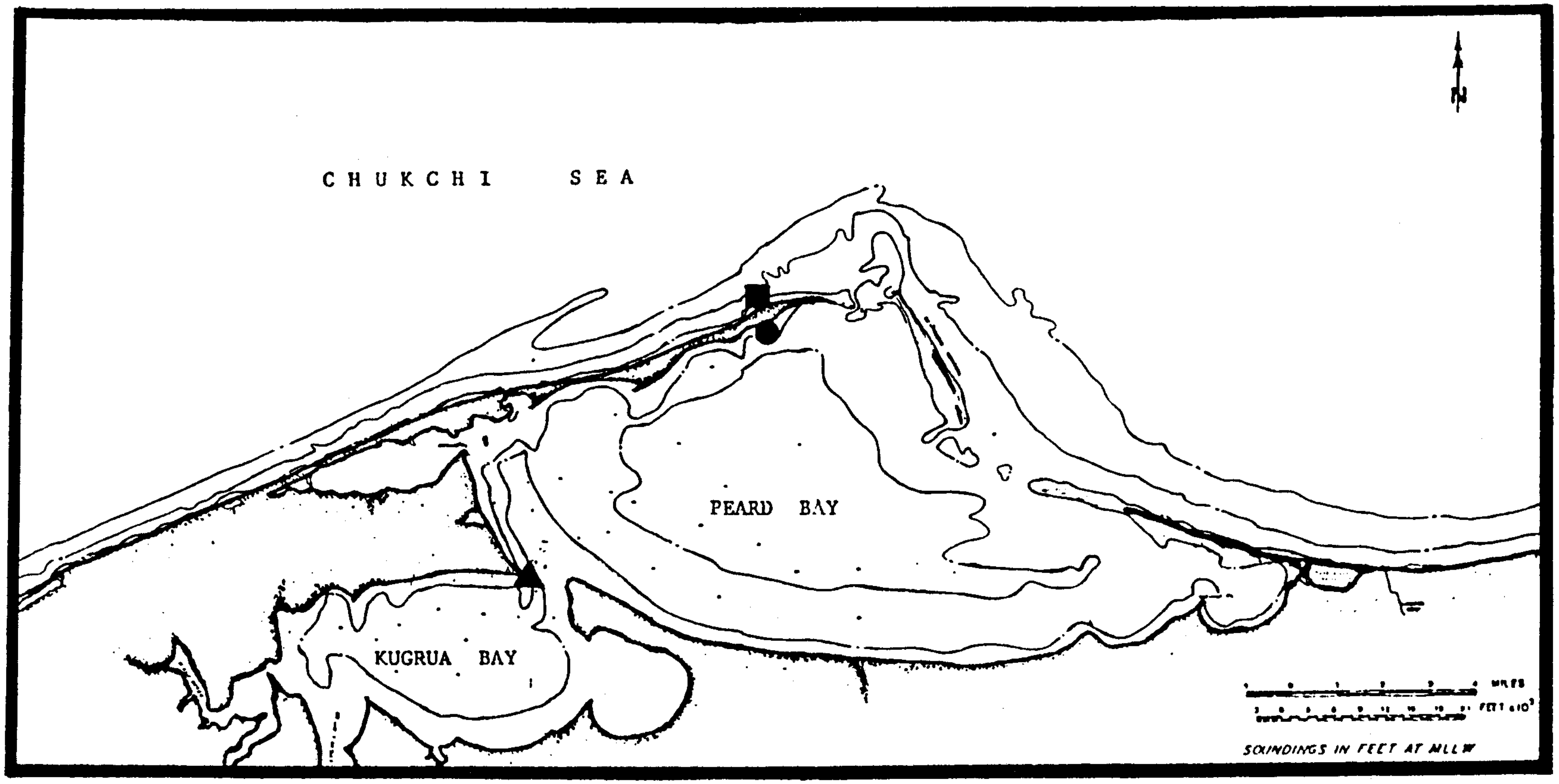
7.2.2 Food Web Dynamics in Peard Bay

Samples were obtained and processed during three field trips to Peard Bay. In the spring, shortly after breakup (29-31 July 1983), stations were run in the Chukchi Sea just outside the Point Franklin spit (CS) and inside Peard Bay (PB-I) as shown in Figure 7-1. These samples consisted of surface water within 10 m of shore. In the summer (23-25 August 1983), samples were taken from PB-II (same location as PB-I) and from Kugrua Bay (KB). In the winter, ice cores and water samples were again taken from Peard Bay and the Chukchi Sea.

7.2.2.1 Sample Processing

The work performed on water samples is outlined in Table 7-1 and the procedures are diagrammed in Figure 7-2.

Water was first passed through a 202-μm Nitex mesh to remove macrozooplankton. This was designated as the "experimental" fraction. Half of this water was then passed through a 10-μm Nitex mesh and was designated the "ungrazed" fraction (due to the exclusion of the microzooplankton component). These two fractions were incubated under identical physical conditions. At several intervals during the course of the experiment, aliquots were taken from each for analysis. In addition, the water in the "experimental" fraction was passed through a 10-μm Nitex mesh for analysis so that a comparison could be made with the "ungrazed" fraction. Thus, an assessment of the grazing pressure upon the 10-μm micro-organisms by protozoans might be obtained. The techniques used are described as follows.

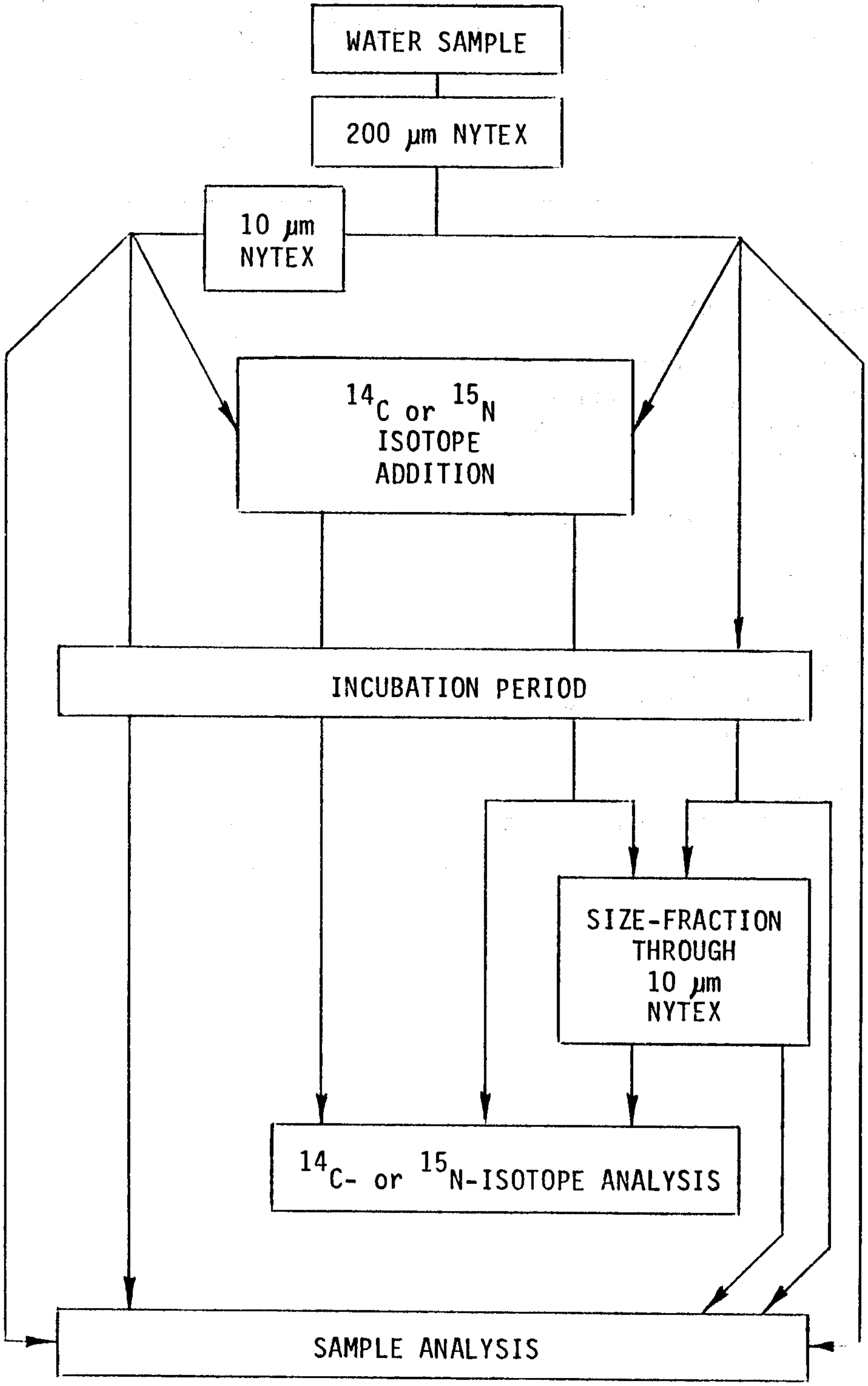


Microbial Sampling Stations: ■ Chukchi Sea ● Peard Bay ▲ Kugrua Bay

Figure 7-1. Microbial Sampling Stations in Peard Bay.

Table 7-1. Experimental work conducted on samples obtained from Peard Bay and environs. Sampling times included Spring (A), Summer (B), and Winter (C). (+) indicates samples taken for that analysis.

Sample Analysis	Sampling Time A	B	C
Water Samples			
Inorganic nutrients	+	+	+
Chlorophyll	+	+	+
Adenosine triphosphate	+	+	-
Particulate organic C and N	+	+	-
Floristic/faunistic analysis	+	+	+
Grazing experiments	+	+	-
Primary production	+	+	-
15N-substrate assimilation	+	-	-
Ice Core Samples			
Chlorophyll	-	-	+
Adenosine triphosphate	-	-	+
Floristic/faunistic analysis	-	-	+
Particulate organic C and N	-	-	+
Particulate Material			
Carbon and nitrogen isotope values	+	-	-



Chemical: POC, PON, POP
Biochemical: Chl, ATP
Microscopical: On-Site Observations
Preserved Water Samples

Figure 7-2. Procedures Followed to Elucidate Microbial Trophodynamics in the Peard Bay Area.

Inorganic nutrients. Water samples were filtered through a combusted glass fiber filter (Whatman, GF/C), frozen in acid-washed 250-ml polyethylene bottles, and shipped to Scripps Institute of Oceanography (SIO) for analysis. Nitrate, phosphate, silicate, and ammonia were determined by autoanalyzer using standard methodology (Strickland and Parsons 1972).

Chlorophyll. Chlorophyll concentration was determined from particulates retained on glass fiber filters. The filters were wrapped in aluminum foil to exclude light. They were kept frozen until processed at SIO. The particulate material on the filters was extracted in absolute methanol and the chlorophyll measured fluorometrically (Holm-Hansen and Reiman 1978).

Adenosine triphosphate (ATP). Samples were filtered through micro-fine glass fiber filters (Whatman GF/F), and the ATP extracted in boiling Tris buffer (Holm-Hansen and Booth 1966). The extract was frozen and returned to SIO where the ATP was determined by measurement of bioluminescence utilizing firefly lantern extract (Holm-Hansen 1973).

Organic carbon and nitrogen. Particulates were concentrated onto combusted glass fiber filters (25 mm, Whatman GF/C), frozen and shipped to SIO, where particulate organic carbon (POC) and nitrogen (PON) were determined using a Hewlett-Packard 185B CHN gas analyzer (Sharp 1974).

Floristic/faunistic analysis. Preliminary microscopical examination of all water samples was made on location to determine success of size-fractionation, and to determine the relative extent of the size range of phytoplankton and protozooplankton cells. Gluteraldehyde-preserved water samples were frozen until epifluorescent microscopy could be made to determine trophic relationships. Microscopical analysis involved obtaining cell size and density of autotrophic nanoplankton (Hewes and Holm-Hansen 1983; Hewes et al. 1984b), and converting these data into biomass using the equation developed by Strathmann (1967).

Microbial biomass. Biomass was estimated in three ways: (1) Phytoplankton biomass was estimated from chlorophyll concentrations when approximate ratios of organic carbon/chlorophyll were known; (2) ATP data was used to estimate total microbial biomass (Hewes et al. 1984a); and (3) Direct microscopical determination of autotrophic and heterotrophic biomass. The microscopical analysis yielded the best estimate; however, it was a very time-consuming technique.

Primary production. Water samples were incubated in 125-ml glass screw-cap bottles containing 5 μCi 14C-bicarbonate. The bottles were wrapped with neutral density screening which passed only 38% of the incident radiation. Time and materials did not permit determination of the rate of photosynthesis as a function of different light intensities. The bottles were incubated under water at temperatures which ranged from 2 to 9°C. After incubation (4-24 hours), the particulates were concentrated onto glass fiber filters and the radiocarbon measured by standard scintillation techniques.

Light. During primary production experiments ambient sunlight was monitored with a submersible, integrating, scalar irradiance quantum meter (Booth 1976).

Nitrogen uptake experiments. 15N-enriched nitrate of ammonia was added to water samples which were incubated in 4-L polycarbonate bottles under the same conditions used for the radiocarbon experiments. The 15N/14N ratio was determined, by emission spectroscopy, using standard methodology (Dugdale and Goering 1967; Ronner et al. 1983).

Biological material was collected for carbon isotope analyses. These materials were frozen until laboratory processing. Representative samples collected included peat, zooplankton, phytoplankton, mysids, isopods, benthic algae, fish, and birds.

7.3 RESULTS

7.3.1 Summary of Eastern Chukchi Sea Productivity

7.3.1.1 Introduction

This section addresses phytoplankton and benthic micro-algae production and species distribution in the nearshore region of the Chukchi Sea. With the exception of a study by Hameedi (1978), there is a general paucity of primary production measurements in the Chukchi Sea, particularly in the nearshore area. Matheke and Horner (1974) have made some measurements in the nearshore Chukchi off Barrow. There is more extensive, although hardly comprehensive, coverage of the distribution and seasonal succession of phytoplankton species in the Chukchi Sea. Saito and Taniguchi (1978) discuss the distribution of species and chlorophyll-a in the offshore Chukchi. Bursa (1963) describes the succession of nearshore phytoplankton off Barrow, and Matheke and Horner (1974) describe seasonal changes in phytoplankton chlorophyll-a near Barrow.

The existence of a kelp community offshore and northeast of Peard Bay has also been reported by Mohr et al. (1957).

7.3.1.2 Primary Production and Standing Stock in the Chukchi Sea

Relative to other Arctic marine environments, the Chukchi Sea is moderately productive. Carey (1978) reviewed the literature and concluded that the primary production in the northeast Chukchi ranged from 18 to 28 g C/m^2/yr. Hameedi (1978) investigated summer production in the marginal ice zone of the Chukchi Sea in summer. He found low to moderate levels of production (0.077-0.97 g C/m^2/half-day). Although none of Hameedi's stations can be considered nearshore, those closest to the American shore of the Chukchi (Figure 7-3) are presented in Table 7-2. (The data have been reduced from Hameedi's Table 1 to reflect integrated production over the euphotic zone.) Hameedi concluded that primary production is nutrient-limited in the Chukchi Sea as a result of the highly stratified water during summer. Stratification occurs due to melting ice. Vertical diffusion of nutrients is thus retarded. This condition appears to apply throughout the Chukchi Sea, with the exception of the southwestern Chukchi Sea on the Siberian coast where there is a large-scale divergence of surface water. In this area the water column was relatively well mixed and production and chlorophyll-a were higher by more than an order of magnitude than anywhere else in the Chukchi Sea. This observation is corroborated by the relatively high July phytoplankton

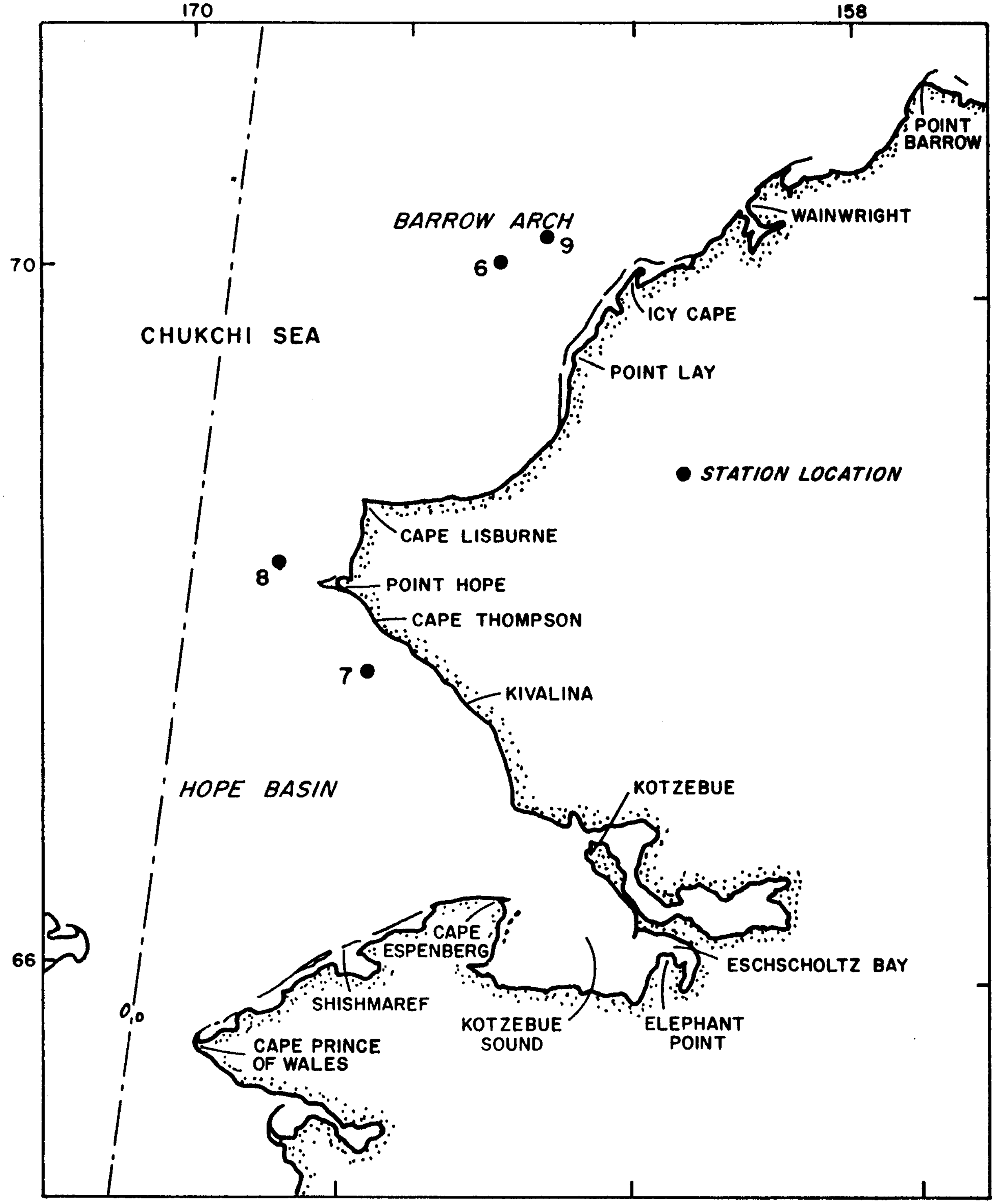


Figure 7-3. Nearshore Primary Productivity Stations (from Hameedi 1978).

Table 7-2. Production (mg C/m^2/h) and chlorophyll-a μg/m^3 found at Hameedi's stations nearest the American Chukchi shore, July 1974 (modified from Hameedi 1978).

Station	Production	Chlorophyll-a
7	12.0	16.8
8	20.9	26.5
6	6.2	6.8
9*	285.4	143.2

*Ice edge station

Table 7-3. Primary production (mg C/m^2/h) of phytoplankton, benthic algae, and ice algae in the nearshore Chukchi Sea near Barrow, Alaska (abstracted from Matheke and Horner 1974).

Primary Producer	May	June	July	August
Phytoplankton	<1	3-9	2-4	2-24
Benthic algae	0	<1-2	14-22	2-57
Ice algae	<1-5	<1	-	-

Table 7-4. Plankton groups in the Chukchi Sea (adapted from Saito and Taniguchi 1978).

Group	
Ice plankton	Diatom: *Achnanthes tacniata, Fragilaria crotonensis, F. islandica, F. striatula, Gyrosigma fasciola, Navicula directa, N. distans, Nitzschia closterium, N. cylindrus, N. frigida, N. grunowii, Pleurosigma intermedium, P. normanii.*
Spring species	Diatom: *Thalassiosira baltica, T. condensata, T. decipiens, T. gravida, T. hyalina, T. nordenskioldii, T. pacifica, T. polychorda, T. subtilis.*
Summer species	Diatom: *Chaetoceros compressus, C. concavicornis, C. convolutus, C. danicus, C. debilis, C. decipiens, C. furcellatus, C. mitra, C. radicans, C. subsecundus.* Dinoflagellata: *Ceratium lineatum, C. longipes, C. macroceros, Dinophysis acuta, D. ovum, D. vanhoeffenii, Prorocentrum* sp., *Gonyaulax catenata, C. heighleii, Peridinium conicoides, P. conicum, P. crassipes, P. depressum, P. islandicum, P. roseum, P. trochoideum.*

cell abundance and by the chlorophyll-a concentrations found in this area by Saito and Taniguchi (1978). It appears that coastal production along the Siberian coast is relatively high. However, no such similar observations have been made along the American coast of the Chukchi Sea.

Enhancement of production along ice edges is a commonly observed phenomenon in the Bering Sea. Blooms along melting ice edges occur as a result of the development of frontal structure in the Bering Sea (Alexander and Niebauer 1981). In the Chukchi, at all ice edge stations, Hameedi (1978) observed a subsurface accumulation of chlorophyll-a within the stratified waters along the ice edge. He suggests that this concentration of chlorophyll-a may be a result of the release of epontic algae during melt. It is uncertain how important the epontic contribution is in the Chukchi Sea. Horner and Alexander (1972) found that epontic cells sloughed off the ice did not contribute to the phytoplankton bloom. However, Saito and Taniguchi (1978) suggest that cells from the ice edge may make a significant contribution to the spring blooms. Alexander and Chapman (1981) hypothesize that the difference in primary production between the Chukchi and Bering Seas may be due to either nutrient or light limitation in the Chukchi Sea. Their discussion concerning these differences is speculative and vague. This, in itself, suggests that a sufficient time series data base does not exist to determine with certainty the importance of the ice edge system to primary production in the Chukchi Sea.

Matheke and Horner (1974) present data on seasonal changes in primary production of the phytoplankton at inshore areas. Table 7-3 presents this data. A comparison of this data with that of Hameedi (1978) for the more offshore Chukchi (Table 7-2) shows that during July, offshore water column production is greater than nearshore. However, if the contributions of inshore benthic micro-algae are added, the inshore areas are considerably more productive than offshore areas. In August there is a considerable increase of inshore phytoplankton production over that in July, and the contribution by benthic micro-algae triples the total inshore primary production (exclusive of epontic algae). There are no August data available for the offshore Chukchi Sea. There is probably no benthic contribution to the deeper light-limited offshore areas. Therefore, even if the inshore August increase in phytoplankton production is paralleled offshore, the total inshore production (per m^2) is probably much higher. A detailed investigation of the relative contributions of offshore and nearshore areas in the Chukchi Sea is warranted to obtain a more complete understanding of the role of nearshore areas in the ecosystem. Specifically, it should be determined whether the phytoplankton at inshore areas are actually more productive through the summer, and, as suggested by Matheke and Horner (1974), the importance of benthic algae to higher trophic levels should be evaluated.

7.3.1.3 Seasonal Succession of Phytoplankton Species

Saito and Taniguchi (1978) have addressed the problem of species succession in the Chukchi Sea. They observed three seasonal components of the phytoplankton during the ice-free period (Table 7-4): 1) ice plankton (mostly pennate diatoms) which probably grow in the ice and are common in plankton after the ice melts; 2) spring plankton dominated by *Thalassiosira* species in the surface layers during the vernal bloom; and 3) summer species consisting of *Chaetoceros* species and dinoflagellates which are probably transported into the area by northward-flowing currents. In terms of species, this series of successional events closely parallels northern hemisphere temperate events. However, the spatial scales are considerably shorter due to the prolonged period of ice cover in the Chukchi Sea.

Saito and Taniguchi (1978) suggest that a series of hydrographic and current conditions drives the seasonal species changes in phytoplankton. The initial event, ice melt, releases ice algae to the surface waters and simultaneously stabilizes the upper water column by lowering salinity. Ice plankton in the surface layer apparently sink shortly after ice melt and the spring plankton begin to dominate in the stratified surface water while ice plankton dominate the subsurface water. Finally, summer species dominate as surface waters warm and/or as surface currents from the south intrude. Spring species sink from the surface, and vertical segregation of summer, spring, and ice species is observed from surface to bottom. These three phases start in June in the middle Chukchi Sea and in late July in the northern Chukchi Sea. The last phase, dominance by summer species, is strongly delayed in the middle and northern Chukchi Sea when the influence of the northward current is small relative to the Bering Strait area. This suggestion of delayed summer species appearing in the middle Chukchi is supported by the data of Bursa (1963) who found *Chaetoceros compressus* and *C. lacinosus*, as well as some spring species (*Thalassiosira gravida, Thalassionema nitzschioides)* dominant or common in late summer (29 August-7 September) in areas 1.3-1.6 km offshore Barrow.

Bursa (1963) also investigated the summer phytoplankton of nearshore areas (91 m to 3,200 m off Barrow) in the Chukchi Sea. Surface drift and wind action result in unstable hydrographic conditions in this area and keep the water relatively turbid with organic debris and silt. *Chaetoceros* species, common offshore during late July-August, were rare or absent from inshore stations. Freshwater species (chiefly *Phytomonadiana*) were common. Marine species included *Gonyaulax tamarensis* and *Gymnodimium* species which were selectively grazed by zooplankton. Bursa (1963) suggests that the turbid inshore water near Barrow with its fluctuating temperature and salinity is not favorable for the growth of phytoplankton, a statement not supported by the production measurements made at the same site by Matheke and Horner (1974) presented above.

7.3.1.4 Kelp Beds

In the depositional environment of the nearshore Chukchi Sea, the existence of kelp communities is generally precluded by lack of suitable substrate. However, strandings of seaweeds have been reported, leading to the idea that isolated areas of kelp do occur. Mohr et al. (1957) documented the existence of at least one kelp community in the Chukchi Sea in 13 m of water northeast of Peard Bay (70°51'30"N, 158°08'30"W). This was the only kelp bed reported by Mohr et al. (1957) in a relatively extensive dredge survey of the Chukchi and Beaufort (Dunton et al. 1982). The species identified are presented in Table 7-5.

The authors conclude that the Chukchi is generally poor in macro-algae due to the depositional nature of the area. It is probably safe to assume that seaweeds are not important contributors to nearshore production in the American Chukchi Sea.

Table 7-5. Algal species found in a dredge haul over a kelp bed in the nearshore Chukchi Sea (after Mohr et al. 1957).

Macro-algae
Phaeophyceans
Phyllaria dermatodea
Desmarestia viridis
Rhodophyceans
Turnerella pennyi
Phyllophora interrupta
Antithamnion americanum
Phycodrys sinuosa
Polysiphonia arctica
Odonthalia dentata
Rhodomela lycopodiodes

7.3.2 Food Web Dynamics in Peard Bay

7.3.2.1 Introduction

A schematic depiction of a microbial food web postulated to occur in Peard Bay is shown in Figure 7-4. The emphasis of this first year's effort was placed upon the dynamics of this food web, as a basis for understanding the important processes and efficiencies involved in passing fixed carbon up the food web. Such efforts were meant to add to previous results of productivity and carbon isotope work in the Beaufort Sea lagoons. Some work with these latter techniques was included in the present Peard Bay work to characterize this Chukchi lagoon and facilitate its comparison with Beaufort lagoons. More emphasis on isotope techniques is proposed for second year efforts.

The size fractions present in the microbial food web (Figure 7-4) are also important because particles which can be grazed by macrozooplankton are mostly in the microplankton size range. These size fractions of interest are macroplankton (>200 μm), microplankton (20-200 μm), nanoplankton (2-20 μm), and picoplankton (<2 μm).

7.3.2.2 Field and Laboratory Results

The concentrations of chlorophyll-a and ATP measured during the summer field trips are shown in Table 7-6. Phytoplankton biomass in Peard Bay and Kugrua Bay was low and was dominated by nanoplankton (<10 μm in diameter). The Chukchi Sea sample had comparable chlorophyll concentrations for both the <10 and >10 μm size fractions. In contrast to the chlorophyll concentrations, the

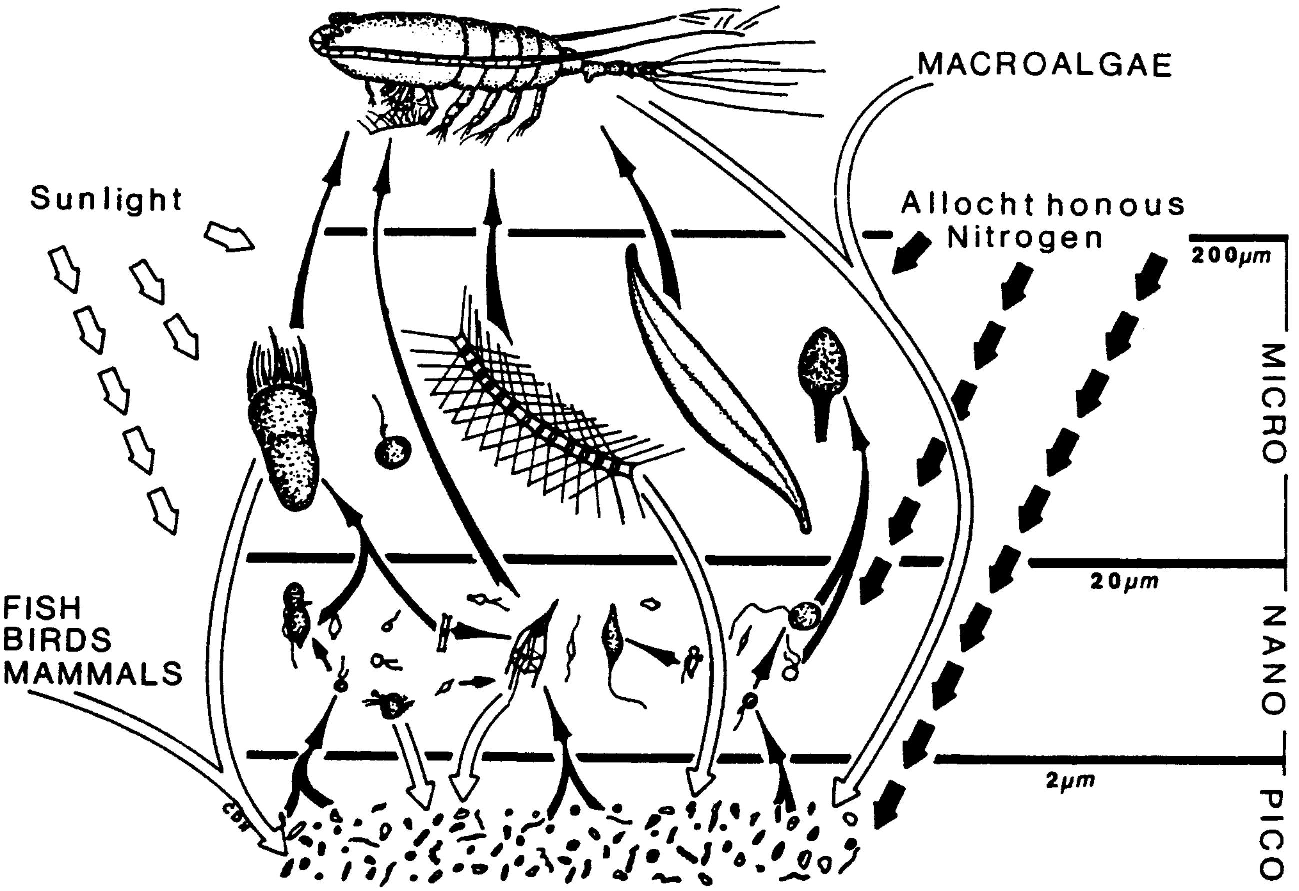


Figure 7-4. Peard Bay Microbial Food Web. Heterotrophic organisms are important in "repackaging" nanoplankton cells into particles that can be utilized by macrozooplankton. Clear unbroken arrows indicate inputs into the nutrient base; solid unbroken arrows indicate assimilatory pathways.

>10 μm size fractions contained significantly greater ATP concentrations than the <10 μm size fractions in all but the Kugrua Bay sample.

In order to estimate phytoplankton biomass from chlorophyll data, it is necessary to know the approximate ratio of cellular carbon to chlorophyll. The carbon content of autotrophic nanoplankton was determined by use of the FTF technique (Hewes and Holm-Hansen 1983) and cell enumeration by epifluorescence microscopy. The carbon/chlorophyll ratios varied from 63 to 143 with a mean of 102, which is similar to those found in Antarctic phytoplankton (Hewes et al. 1984a). This ratio was then used to estimate autotrophic and heterotrophic biomass for both nanoplankton and microplankton (Table 7-7). Cyanobacteria were the most abundant autotrophic cells (approximately 10 per liter) in our samples, but they contributed relatively little biomass by virtue of their small size. The most important group of autotrophic cells in terms of total biomass was the 5-7 μm naked dinoflagellates. Autotrophic biomass (<10 μg) was 23 ± 10 μg C/L. Heterotrophic nanoplankton biomass was rather constant at all stations (21 ± 4 μg C/L). In contrast to the nanoplankton biomass which contained 28-63% autotrophic cells, more than 80% of the microplankton consisted of protozoan biomass. Microzooplankton biomass was extremely high in the Chukchi Sea (210 μg C/L) as documented by microscopical examination (Figure 7-5). Estimated microzooplankton biomass for the other stations was 25-44 μg C/L. Most of the autotrophic microplankton consisted of long chains of *Chaetoceros* sp. (Figure 7-6). At all stations, nanoplankton autotrophs were dominated by flagellates, with the diatom community consisting of smaller numbers of *Navicula, Nitzschia,* and *Amphoria* species. It was apparent from microscopical examination of all samples that the protozoan biomass was a very important component of the plankton community (Figures 7-5 and 7-6).

Table 7-6. Cell contents of chlorophyll-a (CHL) and adenosine triphosphate (ATP) in cells <10 μm and >10 μm from the Chukchi Sea, Peard Bay, and Kugrua Bay.

Sample Site	Season	CHL (μg/L) <10 μm	CHL (μg/L) >10 μm	ATP (μg/L) <10 μm	ATP (μg/L) >10 μm
Chukchi Sea	Spring	0.21	0.22	0.32	2.03
Peard Bay	Spring	0.1	0.06	0.17	0.30
Peard Bay	Summer	0.4	0.12	0.27	0.43
Kugrua Bay	Summer	0.3	0.05	0.28	0.25

Table 7-7. Estimates of autotrophic and heterotrophic biomass in nanoplankton (<10 μm) and microplankton (>10 μm) based on chlorophyll and ATP concentrations.

Location	Season	C/chl	Autotrophic <10** μg/C/L	Autotrophic >10 μg/C/L	Heterotrophic* <10 μg/C/L	Heterotrophic* >10 μg/C/L	Total Biomass <10 μg/C/L	Total Biomass >10 μg/C/L	Percent Autotrophic <10	Percent Autotrophic >10
Chukchi Sea	Spring	143	30	32	22	210	52	242	58	13
Peard Bay	Spring	102	10***	6	26	30	36	36	28	17
Peard Bay	Summer	63	25	8	19	44	44	52	57	15
Kugrua Bay	Summer	100	30	5	18	25	48	30	63	17

* Using the equation:
Total Biomass + Chl x F + {{ATP - (Chl x F) / 250} x 110}, where F = C/Chl. Carbon was estimated from microscopical estimates of cell size and density (Strathmann 1967) and chlorophyll determined fluorometrically.

** Values derived from microscopical analysis of FTF-prepared samples.

***This value was obtained from chlorophyll data and assuming a mean C/Chl ratio of 102.

Figure 7-5.

Micrographs of Spring Plankton Samples From the Chukchi Sea. The microzooplankton biomass at this station was very high as evidenced by these pictures. A and C are 160x, and B and D are 260x. For all micrographs, ciliates, c; diatoms, d; zooflagellates, middle graphs, and chlorophyll concentrations in the lower graphs. Zero time represents time at which meter sample was obtained (1330 for A and 1630 for B).

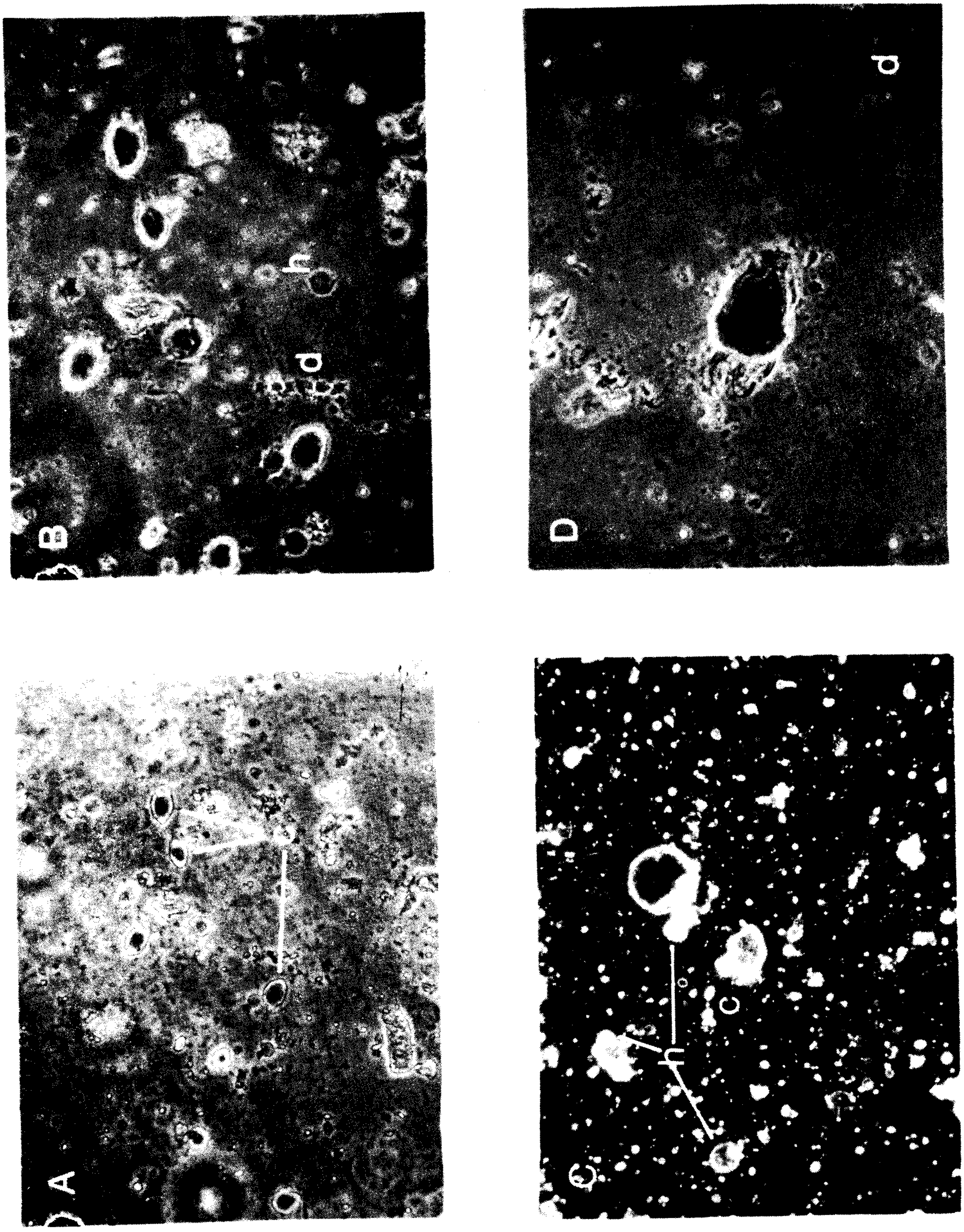
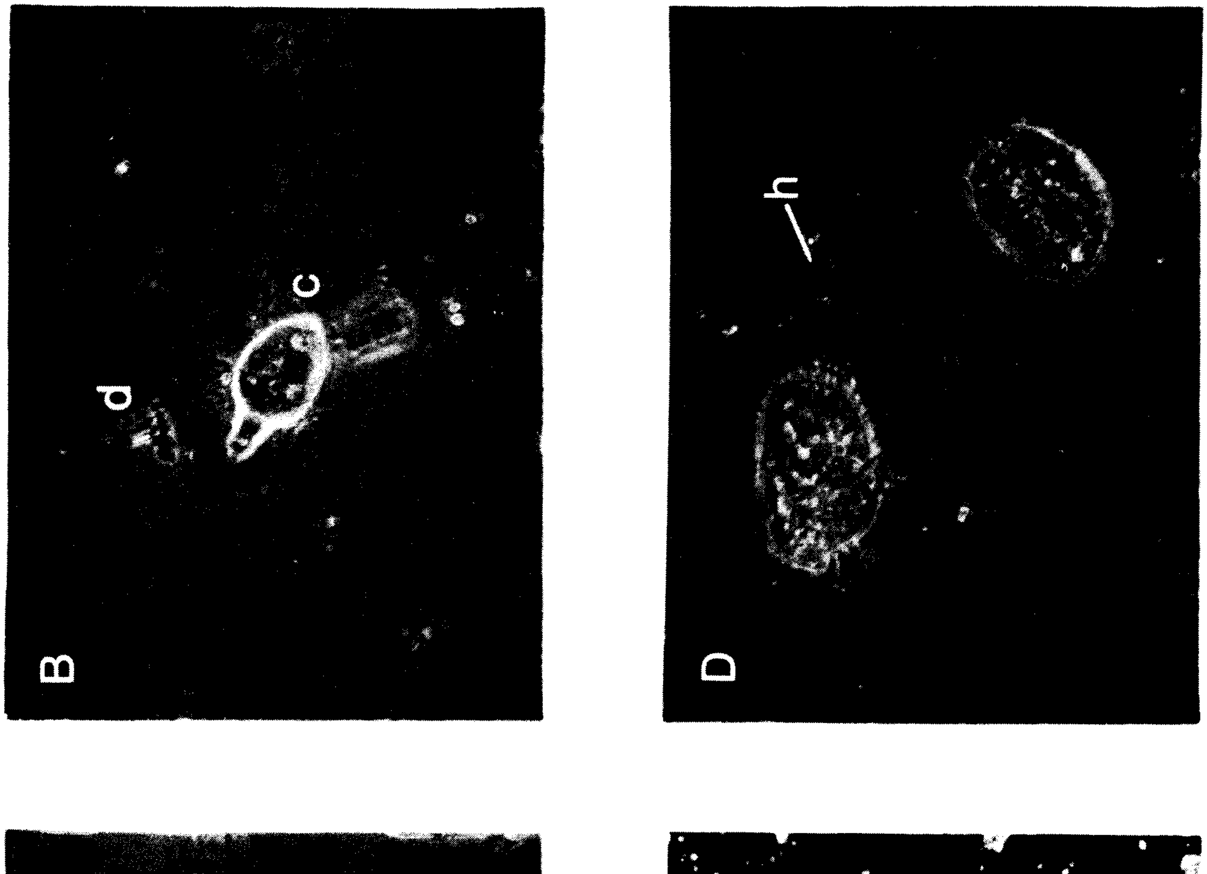

A
B
h
d
C
c
h
D
d

Figure 7-6.

Micrographs of Spring Plankton Samples From Peard Bay in July 1983. *Chaetocerus* sp. chains were the most abundant autotrophic microplankton, and their size may be compared with that of ciliates and copepod naupulii. A and C are 160x, and B and D are 260x. For all micrographs, ciliates, c; diatoms, d; zooflagellates, h.


A
c
d
c
B
d
c
C
c
c
D
h

The biomass data presented above show that the standing stock of phytoplankton in Peard Bay and environs is low as compared to coastal waters in temperate areas, but considerably higher than in the oligotrophic central gyres. The concentrations of the three mineral elements which most often limit primary production (N, P, Si) are also seen to be intermediate between oligotrophic and eutrophic waters (Table 7-8). The Chukchi Sea, as expected, has the highest concentrations of nitrate, phosphate, and silicate. Nitrate and silicate are relatively low in concentration as compared to the phosphate concentrations, and are in the range where they might be limiting the rate of primary production. In contrast to the above three nutrients, ammonium is not found in deep ocean water, and its presence in surface waters generally indicates in situ formation by biological processes. Ammonium was very high in all waters sampled during our study. As Kugrua Bay feeds into Peard Bay, it is not surprising that the nutrients sampled at these points in the summer are quite similar. It is seen that ammonia is very high (3.3 and 5.4 μM), indicating either that mineralization is occurring in these waters at a rapid rate, or that ammonia may be introduced by terrestrial inputs.

The results from the incubation experiments are shown in Figures 7-7 and 7-8. It can be seen from these figures that much of the primary productivity in Peard Bay samples was contained in the microplankton size fraction, in spite of the fact that most of the chlorophyll was found in the nanoplankton fraction. This enhanced incorporation of radiocarbon by the microplankton size fraction was not seen, however, in the Chukchi Sea or Kugrua Bay samples. Data in Figures 7-7 and 7-8 also show that the concentrations of ATP and chlorophyll either remain approximately the same or decrease during the incubation periods, in sharp contrast to the accumulation of radiocarbon in particulate material. This may represent the combined effects of grazing and various bottle effects, including possible death of some of the larger heterotrophic organisms.

Various ways in which to express photosynthetic rates in the Peard Bay samples are shown in Table 7-9. Phytoplankton assimilation numbers (AN) averaged 3.46 μgC fixed/μg Chl-a/hour, indicating fairly high growth rates. Growth rates in doublings per day averaged 0.83, which is close to the value predicted by Eppley's temperature-response equation (1972). Primary production averaged 22 mgC/m^3/day, with nanoplankton and microplankton contributing approximately equal amounts to the total (with the exception of Kugrua Bay, where nanoplankton dominated).

Radiocarbon data from our incubation experiments (Figures 7-7 and 7-8) indicate that the phytoplankton are reproducing at a fast rate. Such an increase in organic particulate material would be expected to deplete nutrient concentrations if there were not active regeneration of nutrients by biological processes. Data in Figure 7-9 show that there is a sharp reduction in nutrients during our incubation periods. It is seen, however, that ammonia is not completely stripped from the medium, but remains at approximately 1.0 μM. This suggests active microbial heterotrophic processes are occurring in our incubation bottles. These results indicate that there must be nutrient input(s) into the Peard Bay-Kugrua Bay environment to maintain the observed nutrient levels. Although there does appear to be extensive regeneration of nutrients occurring, there must be some nutrients input to "balance out" the organic material which sinks to the sediments and is lost to the euphotic zone (Eppley and Peterson 1979). The major possibilities in this context are (1)

Table 7-8. Nutrient levels occurring during Spring (Chukchi Sea and Peard Bay) and Summer (Peard Bay and Kugrua Bay).

Sample Site	Season	CONCENTRATION $[NH_4^+]$	$[NO_3^-]$	$[PO_4^{-3}]$	[Si]
Chukchi Sea	Spring	2.9	5.3	1.48	19.9
Peard Bay	Spring	0.94	0.12	0.52	2.6
Peard Bay	Summer	3.35	0.60	0.71	2.0
Kugrua Bay	Summer	5.46	0.60	1.08	1.3

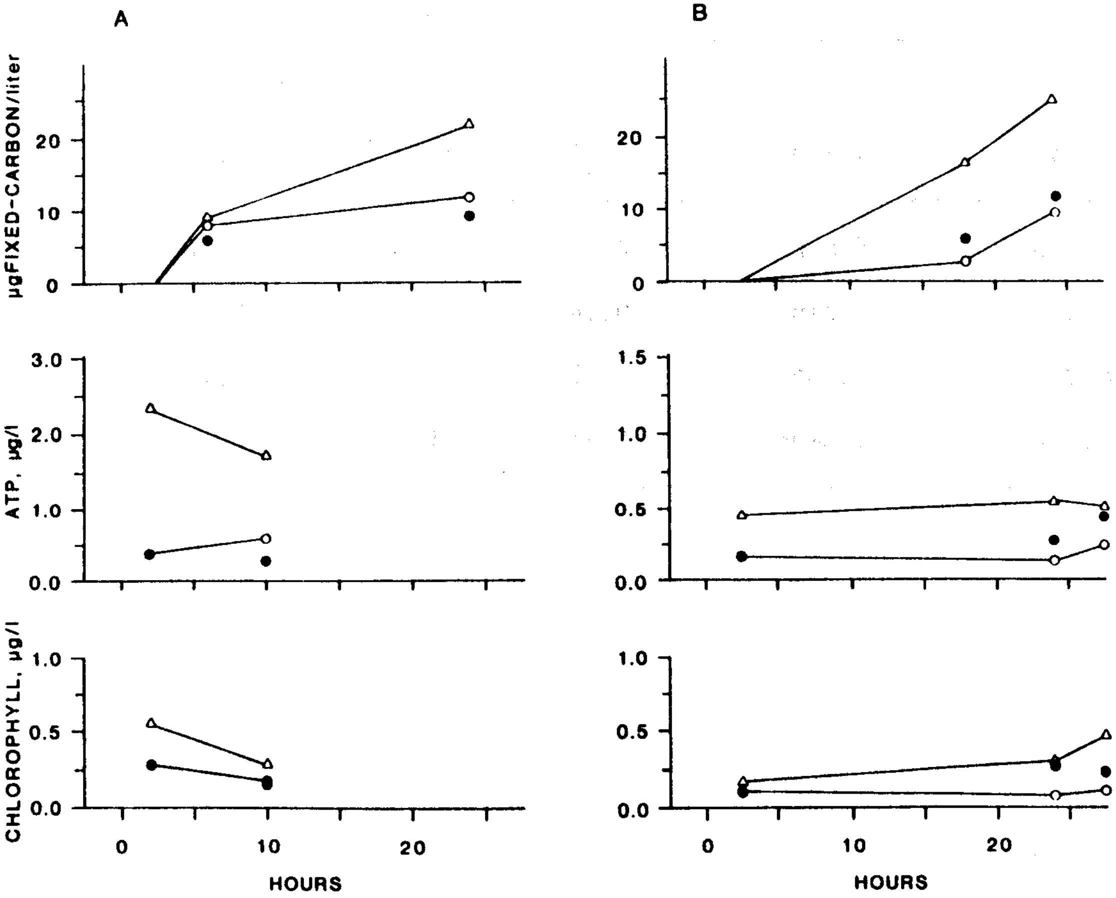


Figure 7-7.

Primary Production and Effects of Grazing During the Spring Sampling Period in the Chukchi Sea (A) and in Peard Bay-I (B). Solid circles represent the nanoplankton population in the "ungrazed" fraction. Open circles are from the "grazed" fraction, where triangles represent the total and circles the nanoplankton component. Primary productivity is shown in the top graphs, ATP concentrations in the middle graphs, and chlorophyll concentrations in the lower graphs. Zero time represents time at which the water sample was obtained (1130 for A and 1630 for B). The total light flux in A between two and six hours was 12.6 E/m^2 and between 6 and 24 hours 14.1 E/m^2; in B between 2 and 18 hours it was 22.4 E/m^2, and between 18 and 24 hours it was 17.1 E/m^2. Note that there was no night during this time of year.

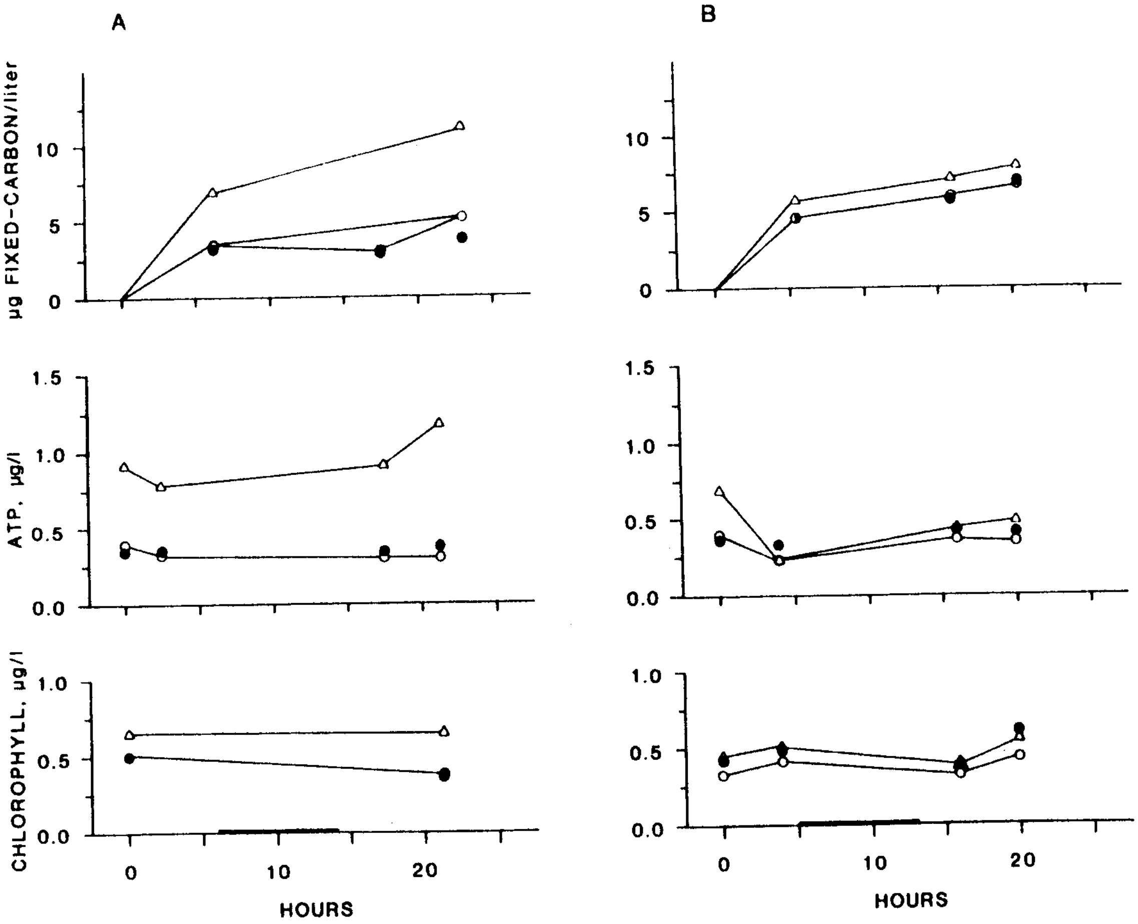


Figure 7-8.

Primary Production and Effects of Grazing During the Summer Sampling Period in Peard Bay-II (A) and in Kugrua Bay (B). Solid circles represent the nanoplankton population in the "ungrazed" fraction. Open circles are from the "grazed" fraction, where triangles represent the total and circles the nanoplankton component. Primary productivity is shown in the top graphs, ATP concentrations in the middle graphs, and chlorophyll concentrations in the lower graphs.

Table 7-9. Photosynthetic rates of nanoplankton and microplankton in Peard Bay and environs.

		Incubation Period	Light flux	Nanoplankton			Microplankton			Total		
Location	Season	(hours)	(E/m^2)	PP*	AN**	μ***	PP	AN	μ	PP	AN	μ
Chukchi Sea	Spring	16.5	26.5	11.9	2.36	0.48	9.9	1.88	0.39	21.8	2.16	0.43
Peard Bay	Spring	24	39.5	9.7	3.92	0.98	21.0	14.6	2.17	30.7	7.99	1.5
Peard Bay	Summer	23	39.1	10.6	1.10	0.53	11.7	4.06	1.35	22.3	1.83	0.78
Kugrua Bay	Summer	20.5	-	13.2	1.83	0.62	2.5	2.08	0.68	15.7	1.87	0.63

* Phytoplankton Productivity in μg C/liter/24 hour day.

** Assimilation Number = μg C fixed/μg Chl-a/hour.

***μ = Growth Rate, in doublings per day. See Neori and Holm-Hansen (1982) for equations.

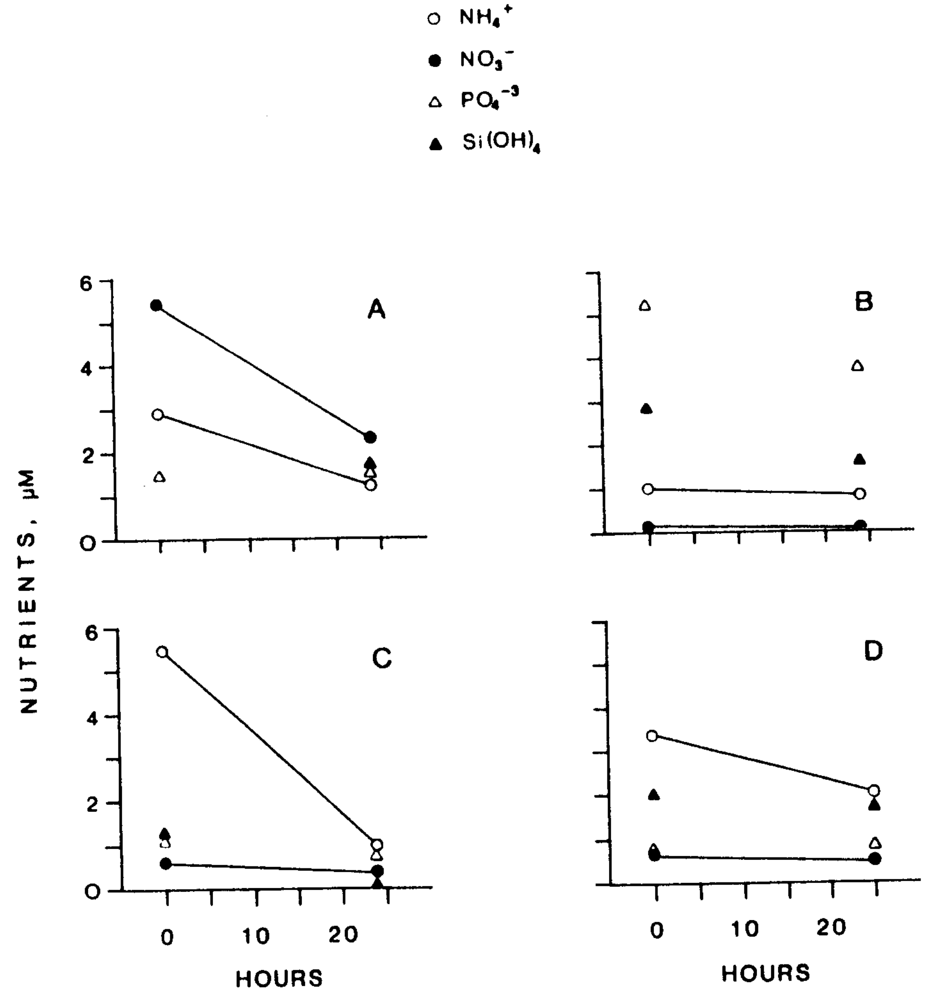


Figure 7-9. Changes in Nutrient Concentrations During Incubation Experiments. A, Chukchi Sea; B, Peard Bay-I; C, Kugrua Bay; D, Peard Bay-II.

advection from the Chukchi Sea, and (2) terrestrial runoff of nutrient-enriched waters.

The ratio of chlorophyll to ATP in our samples is of interest in that a high value (around 2.5-4.0) indicates a predominance of autotrophic cells, and a ratio of about 0.5-1.5 indicates that heterotrophic cells may compose at least 30% of the total microbial biomass. The Chl/ATP values obtained for the incubation samples are shown in Figure 7-10. In general, the <10 μm size fractions contain higher values than those of >10 μm size fractions. This indicates that the populations of the larger micro-organisms at these stations do not contain as much chlorophyll as ATP, or, in other words, there is significantly greater heterotrophic activity in the microplankton size fraction. This is substantiated by microscopical observations (Figures 7-5 and 7-6) and by autotrophic and heterotrophic biomass estimates (Table 7-7). It was found that Chl/ATP values for nanoplankton of the prescreened incubations are generally slightly higher than those of the "grazed fraction" at the end of the incubation periods. This indicates that less grazing of autotrophic phytoplankton <10 μm by protozoans occurred for the prescreened incubation samples.

Funds for carbon isotope laboratory analyses were curtailed for this first year by an initial funding cut at the beginning of the program. However, because of his interest in polar isotopic studies, arrangements were made with Dr. I. Kaplan at University of California, Los Angeles to run these samples at UCLA. Samples taken for carbon isotope analyses during 1983-84 include the dominant forage fish (Arctic cod and saffron cod), amphipods, isopods, mysids, peat, benthic algae, and plankton tows. These results are not yet complete. However, preliminary carbon isotope del-13 results indicate values of -21.7 for a Chukchi Sea plankton tow, a value to be expected for marine phytoplankton. A Peard Bay tow, consisting mostly of diatoms, gave a value of -19.0. A peat sample from the Point Franklin spit area gave a value of -26.6, a low value, characteristic of terrestrial organic matter. Values obtained for isopods, amphipods, and mysids were not between these extremes of terrestrial (-27) and marine (-21) carbon, but were -14.4, -16.9, and -17.2, respectively. Since marsh plants or kelp are unlikely sources of this carbon by virtue of their small biomass in Peard Bay, benthic diatoms are suspected. Further fractionation (+0.7 per trophic level) from an expected diatom value of -17 would have to be occurring. Further samples and checks are being run to verify these numbers and to explain their implications. However, peat at -27 does not seem to be the carbon source for these crustacea, which are important to the higher trophic levels of Peard Bay.

7.3.2.3 Discussion and Conclusions

The central goal of the present work is to understand the processes regulating the origin of the food base which supports the higher trophic levels in Peard Bay and environs. The results obtained thus far give us an interesting insight into the structure and dynamics of the microbial food web in Peard Bay and in adjacent nearshore Chukchi Sea waters.

Our results strongly suggest that the microbial portion of the food web in these waters is "unstructured" (Isaacs 1973) and that there is much cycling of organic carbon between autotrophic and heterotrophic microbial organisms

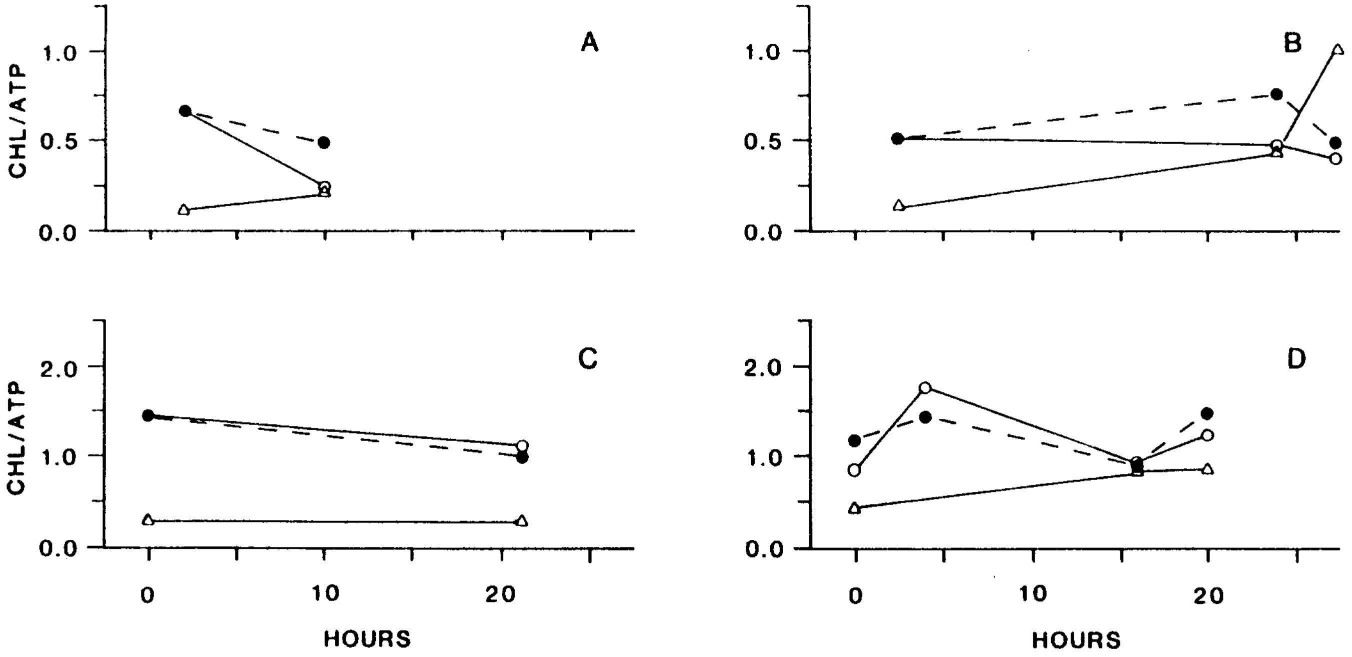


Figure 7-10.

Chlorophyll/ATP Ratios During the Incubation Periods in Samples from the Chukchi Sea (A), Peard Bay-I (B), Peard Bay-II (C), and Kugrua Bay (D). Nanoplankton values from the "ungrazed" fraction are shown by solid circles. Open symbols represent the "grazed" fraction, with triangles showing values for the microplankton and circles showing values for the nanoplankton.

within the water column. This is schematically depicted in Figure 7-4. Heterotrophic organisms appear to be important in "repackaging" nanoplankton cells into particles which can be utilized by macrozooplankton.

The unstructured food web model of Isaacs (1972, 1973) has important implications regarding the fluxes and biomasses of marine organisms at differing trophic levels as well as regarding the distribution of trace materials in marine biota. Essentially, this model assumes that most creatures feed on whatever food is broadly suitable as to size and mode of feeding, with availability and abundance of food items being the major controlling parameters. For example, stomach contents of tunas and salmon do not differ from the catch of nekton nets towed in the intermediate waters they occupy. Similarly, both filter and particulate feeders consume a heterogeneity of zooplankton, eggs and larvae, detritus, and phytoplankton, and may themselves become food for the organisms whose eggs, larvae, and detritus they consume. In such a system, the composition of any creature, excepting strict herbivores, is a broad mixture of material ranging from food freshly introduced into the system to a disappearingly small quantity of material that has been recycled a number of times. Such material will not be of important quantity from the standpoint of food material or energy, but for content of some chemical materials that are concentrated at each step, such remnants may dominate. In such an unstructured food web, food material passes through an infinite series of steps and conversions (with associated losses), partly and successively into non-living but recoverable material.

The pyramid of a structured food web is composed of relatively few (4 to perhaps 7) steps, with specific groups of organisms rather closely restricted to a specific step. Unstructured food webs, on the other hand, can be viewed as composed of a pair of interwoven pyramids, each of an infinite number of steps. Each successive step is occupied only by material and energy remaining from the preceeding step, with living material in one pyramid and non-living but recoverable material in the other. Organisms in the unstructured food web do not occupy a small number of steps, but rather occupy broad regions that always extend to infinity (except for strict herbivores), and that differ principally in the point at which they begin in respect to the autotrophic level, and in the degree to which they are restricted to one or the other of the living or recoverable pyramids. The mathematics of an unstructured food web model yield simple expressions for the fluxes of material and energy, for the biomass at given trophic levels, and for the chemical composition of specific trophic types and materials.

For our present Peard Bay results with regard to the microbial food web, there are two important aspects of this view of the food web. First, concomitant with the cycling of food materials between autotrophic-heterotrophic cells, there is the inevitable loss of energy at each transfer step. The efficiency with which primary production can be converted into biomass of utilizable trophic levels (e.g., fish) is inversely related to the number of steps in the food chain/web (Ryther 1959). It is thus important to understand the routes and dynamics of the food web in order to relate the magnitude of primary production to the food resources available to higher trophic levels. Second, nanoplankton cells (which are responsible for over 50% of the Peard Bay primary production) are considerably smaller than the size spectrum of particles ingested by most macrozooplankton. Copepod nauplii (Fernandez 1979) and copepod adults (Huntley 1981) have been shown to feed largely on particles larger than 20 μm (Figure 7-5). Nauplii observed in samples from this study suggest that macrozooplankton are an important link in the food web in these waters. These nauplii must utilize the productivity generated in the microplankton size range or that generated in the nanoplankton must be recycled with attendent losses into larger particles before utilization.

The full significance of our results on the microbial food web of Peard Bay must await better quantification of the importance of these processes in the water column, both spatially and temporally throughout Peard Bay. However, the data presented in the previous section permit the following comments to be made concerning the microbial food web in the few water samples which were available during this study.

1) The phytoplankton standing stock in Peard Bay and environs is moderate (20-40 μg C/L) and most likely limited by availability of nutrients.

2) The productivity of the phytoplankton populations is high (approximately 3 ug C/μg Chl/h). This, coupled with the growth rate measurements (about 1 division per day), suggests that phytoplankton growth rates are close to the maximal rates expected to occur at the prevailing temperatures. Using the same assumptions as Schell (1983), the annual productivity of Peard Bay would be approximately 10 g C/m^2/yr), slightly higher but possibly equivalent to that measured for Simpson Lagoon (6 g C/m^2/yr), and higher than indicated by the few measurements obtained by Schell (1983) in Angun Lagoon in the eastern Beaufort coast.

3) Nutrient flux measurements indicate that there is very active nutrient regeneration occurring within the water column. This is substantiated by our documentation of large heterotrophic populations of microbial organisms which, through the combined effects of grazing and bacterioplankton activities, are largely responsible for the regeneration of ammonia and other nutrients.

4) Approximately 50% of the phytoplankton biomass is contained in the nanoplankton fraction (<10 μm in diameter). Incubation experiments indicated, however, that much of the biomass in these small cells is consumed by heterotrophic microplankton (10-200 μm in diameter).

In contrast to the dynamic microbial food web which emerges from the present study, other investigatiors have described the food chain in Arctic waters to be detrital in character. That concept views the food chain to be essentially the production of organic carbon by microplankton (mostly diatoms), which settles to the bottom, and serves as the food base for organisms living within or close to the sediments. Such a detrital food chain places relatively little importance on heterotrophic microorganisms or macrozooplankton living in the euphotic zone. In light of the mathematical treatment of unstructured food webs by Isaacs (1972, 1973), these two contrasting views of the food web also would present different scenarios in regard to the possible uptake, transfer, and effect of pollutants (metals or hydrocarbons) on marine organisms.

Because the productivity element of the Peard Bay experimental work was so limited, it is difficult to interpret our data as compared to the "detrital food chain" which is often proposed for Arctic waters. In view of the interest and importance of the functioning of the microbial food web, the following suggestions are made for subseqent studies so that the nature of food sources available for higher trophic levels will be better understood.

1) Broader geographic coverage must be obtained for water samples, in addition to sampling at various depths between the surface and bottom sediments. This could be done at two different times (late spring, late summer), and the analyses could be restricted to those measurements which are relatively quick and easy to perform (e.g., chlorophyll, light, nutrients).

2) Those analyses which require more time and funds (carbon and nitrogen uptake studies, ATP, grazing experiments, etc.) could be done once or twice at two or three specific locations.

3) It would be best to get more samples (from just a few locations) throughout the entire growing period. Samples could be restricted to those measurements for which any personnel in the field could obtain the samples (e.g., chlorophyll and preserved sample), which could then be processed at a later time.

4) The biomass of bacterioplankton and autotrophic picoplankton should be ascertained on a few selected samples. This is quite easily done with epifluorescence microscopy. It would also be very useful to determine the capabilities of these bacterioplankton with regard to heterotrophic petroleum substrates, which might be of interest for later impact assessments on the microbial system of Peard Bay.

5) In addition to the carbon isotope samples now being run, effort should be emphasized the second year to determine the ratios of naturally occurring carbon and nitrogen isotopes throughout the food web.

6) In order to appraise the possible merits of the "detrital food chain," it would be very informative to include sediment studies (organic compound concentrations, pigments, faunal descriptions, etc.), as well as some particle-interceptor traps to examine the flux and nature of the organic material which falls to the bottom.

7) The measurements included in 1-3 above should be sufficiently detailed so that the overall rate of primary production in Peard Bay and environs can be better estimated on a daily and on a seasonal basis. Such an estimate, combined with data from other components of the program, would permit some evaluation of the role of autotrophic phytoplankton production in regard to the food sources required to support the observed populations of birds, fishes, and mammals.

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