

Introduction of Foxes to Alaskan Islands — History, Effects on Avifauna, and Eradication



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Introduction of Foxes to Alaskan Islands — History, Effects on Avifauna, and Eradication

By Edgar P. Bailey

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Foreword

The author, biologist Edgar P. Bailey, joined the U.S. Fish and Wildlife Service in 1966 and spent 3 years working on the Fish Springs National Wildlife Refuge (NWR) in Utah and the Hart Mountain NWR in Oregon. In 1969, he transferred to the Aleutian Islands NWR in Alaska and in 1973, became a member of the planning team for the Alaska Maritime NWR of which the Aleutian Islands NWR is now a unit. He joined the new refuge in 1981. Bailey's tenure with the U.S. Fish and Wildlife Service was preceded by employment with the National Park Service in California, Kentucky, and New Mexico.

During more than 20 years in Alaska, Bailey accumulated a wealth of information about the fauna and flora of Alaskan islands. During his extensive surveys of islands for the planning of the Alaska Maritime NWR, he acquired a comprehensive knowledge about the history of introduced foxes and their effects on fauna of Alaskan islands.

Bailey's paper is invaluable documentation of the history and devastating consequences of the introduction of foxes on Alaskan islands.

Out of deep concern for the consequences of the introduction of exotics, Bailey put his knowledge in writing so it may be useful to future generations. We are glad he did.

Walter O. Stieglitz
Regional Director
Region 7

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Arctic fox with least auklet. *Photo by A. DeGange (1977).*

Introduction of Foxes to Alaskan Islands—History, Effects on Avifauna, and Eradication

by

Edgar P. Bailey

U.S. Fish and Wildlife Service
2355 Kachemak Bay Drive, Suite 101
Homer, Alaska 99603

Abstract. Foxes originally were absent from most Alaskan islands in the North Pacific. Red foxes (*Vulpes vulpes*) were indigenous to the Fox Islands in the eastern Aleutians and to some islands off the Alaska Peninsula and in the Gulf of Alaska. The first recorded introduction of foxes was in 1750 when Russians released arctic foxes (*Alopex lagopus*) from the Commander Islands on Attu, the westernmost island in the Aleutians. Russians released red and arctic foxes on other islands mainly in the early 1800's. By the 1930's, over 450 islands had been stocked mainly with arctic foxes for fur farming. During this period, the first government surveys and concerns about the effects of introduced foxes on insular avifauna arose, although Aleuts had indicated that seabirds were disappearing on some islands with introduced foxes as early as 1811. Besides foxes, Norway rats (*Rattus norvegicus*), ground squirrels (*Spermophilus undulatus*), and other mammals were introduced. Foxes eliminated populations of Aleutian Canada geese (*Branta canadensis leucopareia*) on all except three small islands. Populations of seabirds, particularly burrow-nesters, were also drastically reduced by foxes. Fox trappers regarded seabirds as feed.

Personnel from the Aleutian Islands National Wildlife Refuge began eliminating foxes in 1949, and spectacular recoveries of bird populations have been recorded. Introduced foxes remain on 46 islands, mostly in the Aleutians and off the Alaska Peninsula.

Key words: Alaskan islands, fox introductions, exotics, colonial nesting seabirds, waterfowl, fox eradication.

Most people believe that Alaskan islands are largely undisturbed by modern civilization, especially in comparison with most of the world's temperate and tropical islands, nearly all of which have been seriously affected by introduced plants and animals and various human activities. Although hundreds of Alaskan islands are currently still uninhabited by humans, few islands escaped the drastic ecological changes from the release of exotic animals.

Before the arrival of the first Russian explorers in Alaska in 1741 (Frost and Engel 1988), most of

the Aleutian Islands and many other islands in southern portions of Alaska were free of indigenous terrestrial mammals (Murie 1959; Hopkins 1967). Beginning in 1750 with the Russian introduction of arctic foxes (*Alopex lagopus*) for fur harvesting in the western Aleutians (Black 1984), arctic or red foxes (*Vulpes vulpes*) and sometimes accompanying rodents were eventually released on at least 455 Alaskan islands in the North Pacific Ocean.

The main impetus for American fox farming began in the 1880's on Prince Edward Island off the Atlantic coast of Canada and then spread across the

continent to Alaska (Huston 1956). Introductions of foxes caused the demise of many species of birds breeding on numerous islands. Predation by exotic species worldwide has been a key factor in the depletion or extinction of more seabird populations than any other factor (Moors and Atkinson 1984). Fur farmers regarded seabirds, waterfowl, and other nesting birds on Alaskan islands as food for foxes, and most trappers simply released foxes on islands and trapped their wild progeny. On islands without bird colonies, marine mammal rookeries, or good intertidal food resources for foxes, trappers built pens and provided feeding stations much like mainland fox farms. However, even on most of these islands, some or all foxes eventually freely roamed the islands (personal observation).

Foxes were introduced on islands in only the southern portions of Alaska, which remain free of sea ice. Foxes are indigenous on islands in the

Bering Sea, which are accessible from the mainland across the ice in winter. The adverse effects of exotic foxes on insular birds that Aleut natives used for food and clothing began appearing by the early 1800's (Black 1984). Efforts by the government to save some islands for nesting birds did not begin until after the severe decline of fur markets during the Great Depression. Between southeast Alaska and the Aleutian Islands, large and diverse seabird populations remain on only a few islands where foxes were never introduced (Fig. 1).

On many islands, especially east of Kodiak Island, introduced foxes were removed by trappers when fur prices declined or disappeared naturally after the 1930's when trappers abandoned most islands. Presently exotic foxes persist on only about 10% of the islands on which they were released (personal observation), most of them in the Aleutians. Efforts to eradicate introduced foxes to

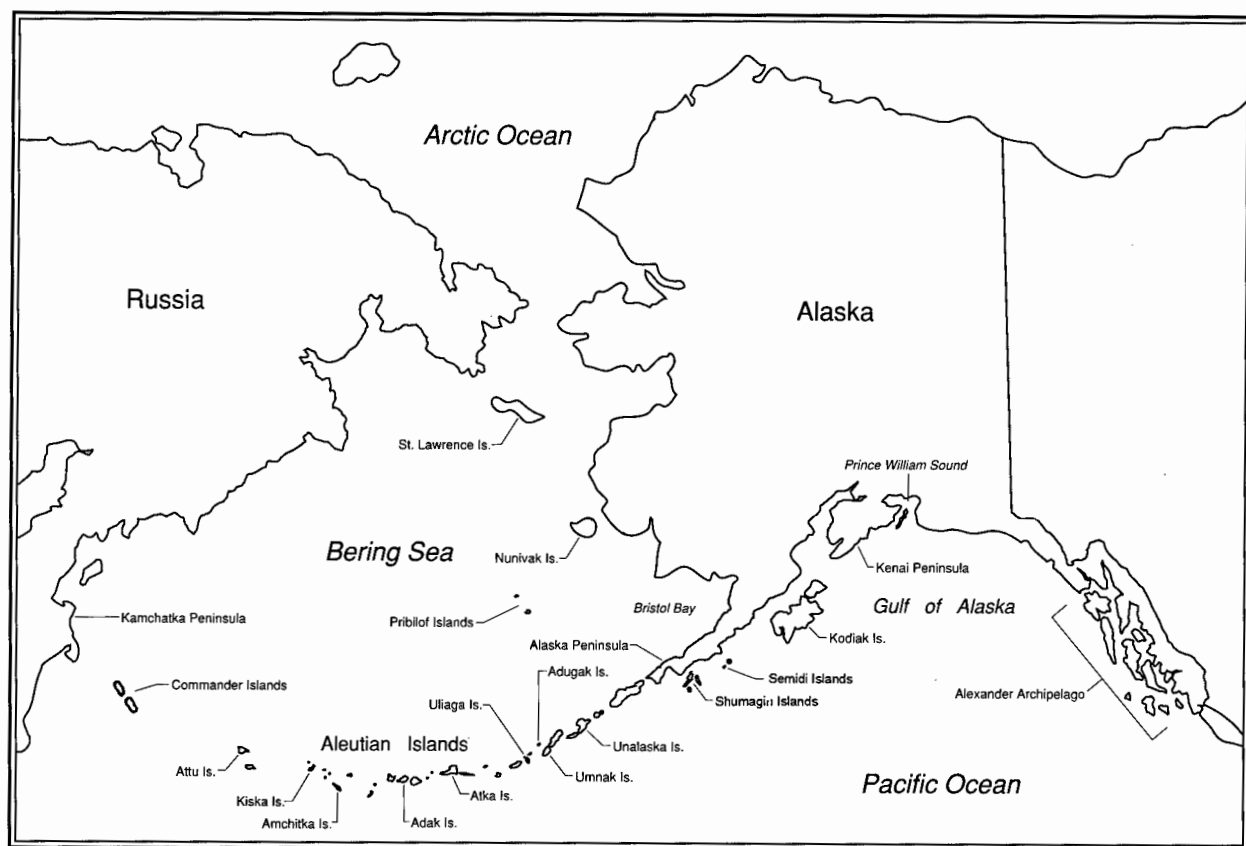


Fig. 1. Kamchatka Peninsula (Russia) to Alexander Archipelago (Alaska).

restore seabirds and waterfowl did not begin until 1949, and to date foxes have been removed from only 21 islands.

Information for this paper has been gathered piecemeal since 1969 when I was conducting marine bird and mammal surveys on numerous islands in southern Alaska and began assisting with the eradication of foxes from islands in the Aleutian Islands National Wildlife Refuge (formerly the Aleutian Islands Reservation and now the Aleutian Islands Unit of the Alaska Maritime National Wildlife Refuge [NWR]). K. Lourie, a graduate student who assisted me in 1979, spent considerable time in the University of Alaska library in Fairbanks seeking historical information on the introduction of foxes and other animals to Alaskan islands. During my work on different Alaskan islands in the past 24 years, the devastating consequences of introduced foxes and rodents became increasingly clear to me. I interviewed many former fox trappers about their operations and knowledge about insular birdlife. Over the years, I read many old files of the U.S. Fish and Wildlife Service and Bureau of Land Management about fox farming. Some information I obtained from files of the U.S. Forest Service. My discussions with retired state and federal land managers and Aleuts in several villages also proved helpful in obtaining information on the history and effects of introduced foxes.

In this paper, I chronicle the introduction of arctic and red foxes to Alaskan islands and describe the past and current effects of these animals on the ecology and especially on the nesting bird populations of the islands.

Natural Occurrence of Foxes and Early History of Introductions on Alaskan Islands

When Vitus Bering discovered Alaska in 1741 (Frost and Engel 1988), most of the Aleutian chain, islands off the south side of the Alaska Peninsula, and islands in the Gulf of Alaska seemingly were free of foxes. Arctic foxes and, on a few near-shore islands, red foxes were indigenous to most islands

in the Bering Sea, having reached them from the mainland across the ice or land bridges when sea levels were lower. Arctic foxes occur naturally only in the Bering Sea and Arctic regions (Chapman and Feldhamer 1982). Murie (1959) and Berkh (1974) believed that arctic foxes were indigenous to Attu Island at the western end of the Aleutian archipelago (Fig. 1). This contention is refuted in early Russian accounts (Nelson 1887; Black 1984) and by analysis of sea ice movement and post-glaciation changes in sea levels (Hopkins 1967), fur records of early Russian voyages, and archaeological evidence (Buskirk and Gipson 1980).

The Aleutian archipelago west of the Islands of Four Mountains (Fig. 2) was seemingly devoid of foxes and all other terrestrial mammals at the end of Pleistocene glaciations, approximately 10,000 years ago, because interisland passes westward remained below sea level and thus prevented mammals of the Alaskan or Siberian mainland from colonizing the central and western Aleutian Islands (Hopkins 1967). Red foxes and some rodents reached the Fox Islands in the eastern Aleutians from the Alaska Peninsula when connecting land and ice bridges existed during the Pleistocene (Hopkins 1967).

Aleutian Islands

Although Russian ship manifests in the mid- and late 1700's revealed transportation of large numbers of arctic fox pelts and pelts of fur seals (*Callorhinus ursinus*), sea otters (*Enhydra lutris*), and other species to the Kamchatka Peninsula (Fig. 1; Berkh 1974), the actual origin of the pelts is unknown. More than likely, the pelts of arctic foxes, formerly called polar or blue foxes, attributed to Attu and other Aleutian islands in early records actually came from the Commander Islands in Russia (Fig. 1), where the species is native (Stejneger 1896; Frost and Engel 1988). Red fox pelts probably came from the Fox Islands in the eastern Aleutians (Fig. 2). Archaeological evidence from Attu, Agattu, and Amchitka islands (Fig. 3) revealed no terrestrial mammal bones in Aleut midden sites (Buskirk and Gipson 1980). Buskirk and Gibson concluded that arctic foxes were not indigenous to any of the Aleutians for the following reasons:

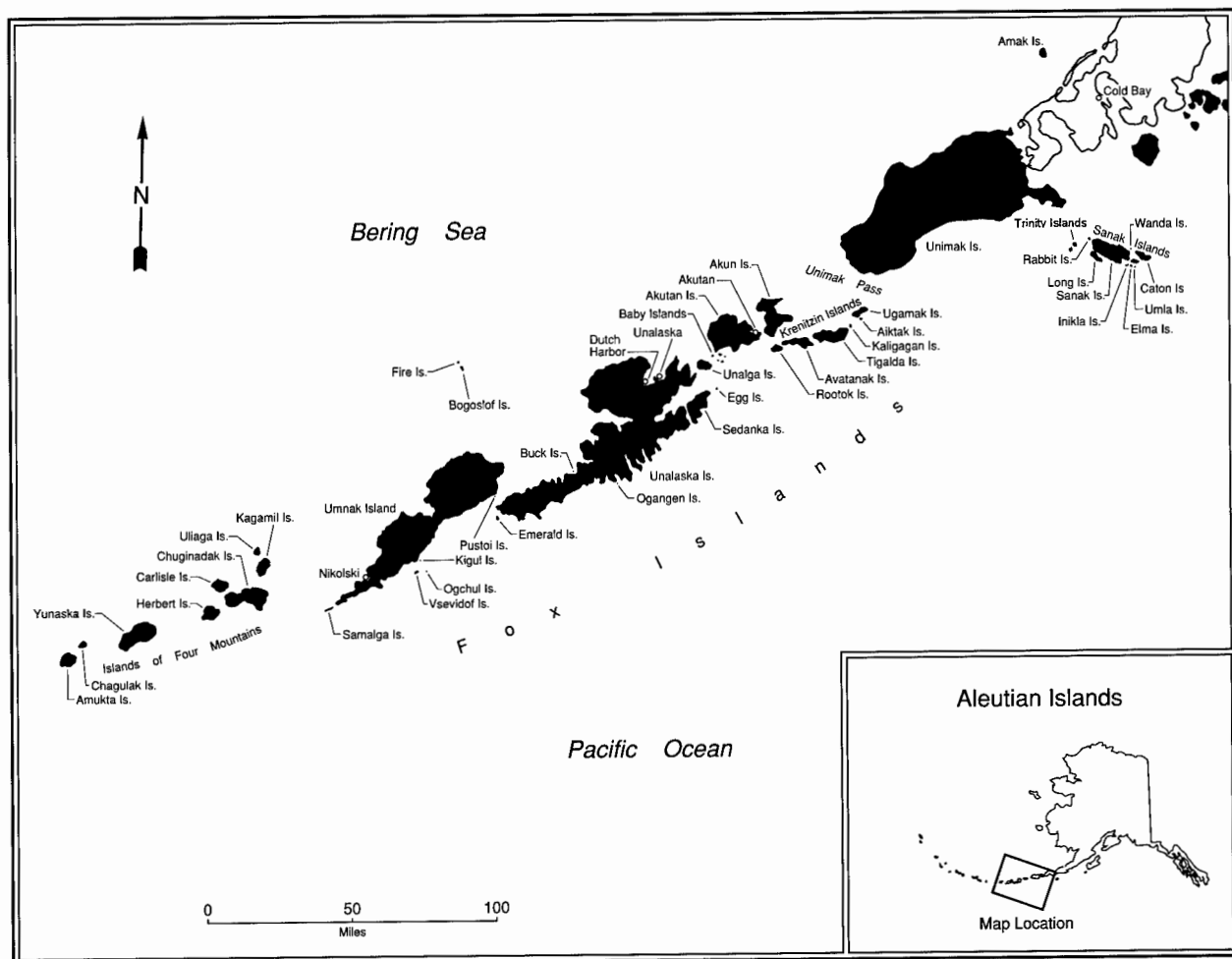


Fig. 2. Eastern Aleutian Islands.

1. the contradictory nature of early historical records, some of which state arctic foxes were on several of the Aleutians;
2. the lack of a plausible mechanism, such as sea ice, for natural colonization by arctic foxes; and
3. the absence of skeletal remains of arctic foxes from islands before the arrival of the Russians.

Evidence seems particularly compelling that the Aleutian Islands west of Amukta Pass (Fig. 4) were devoid of all terrestrial mammals because this pass and those to the west remained submerged at the end of Pleistocene glaciations, even when sea levels may have dropped up to 160 m below current levels (Buskirk and Gipson 1980). Based on the hypothetical maximum advance of sea ice during glacia-

tion, currents, and wind flows, some of the Aleutian Islands east of Attu would more likely have been reached by ice floes carrying foxes than Attu itself. Black (1984) reported that Attu Island was stocked by the Russian government in 1750. During the late 1700's, numerous foxes were harvested on Bering Island (Commander Islands) lying to the west. Elliot (1897 in Murie 1959) also stated that blue foxes had been introduced on Attu Island "many years ago," and Elkins and Nelson (1954) indicated foxes were released there. Dall (1874) and Nelson (1887) also stated that Attu and Atka islands were stocked with foxes from the Commander Islands by the Russians.

The general agreement is that red foxes are indigenous to the eastern Aleutians, at least as far

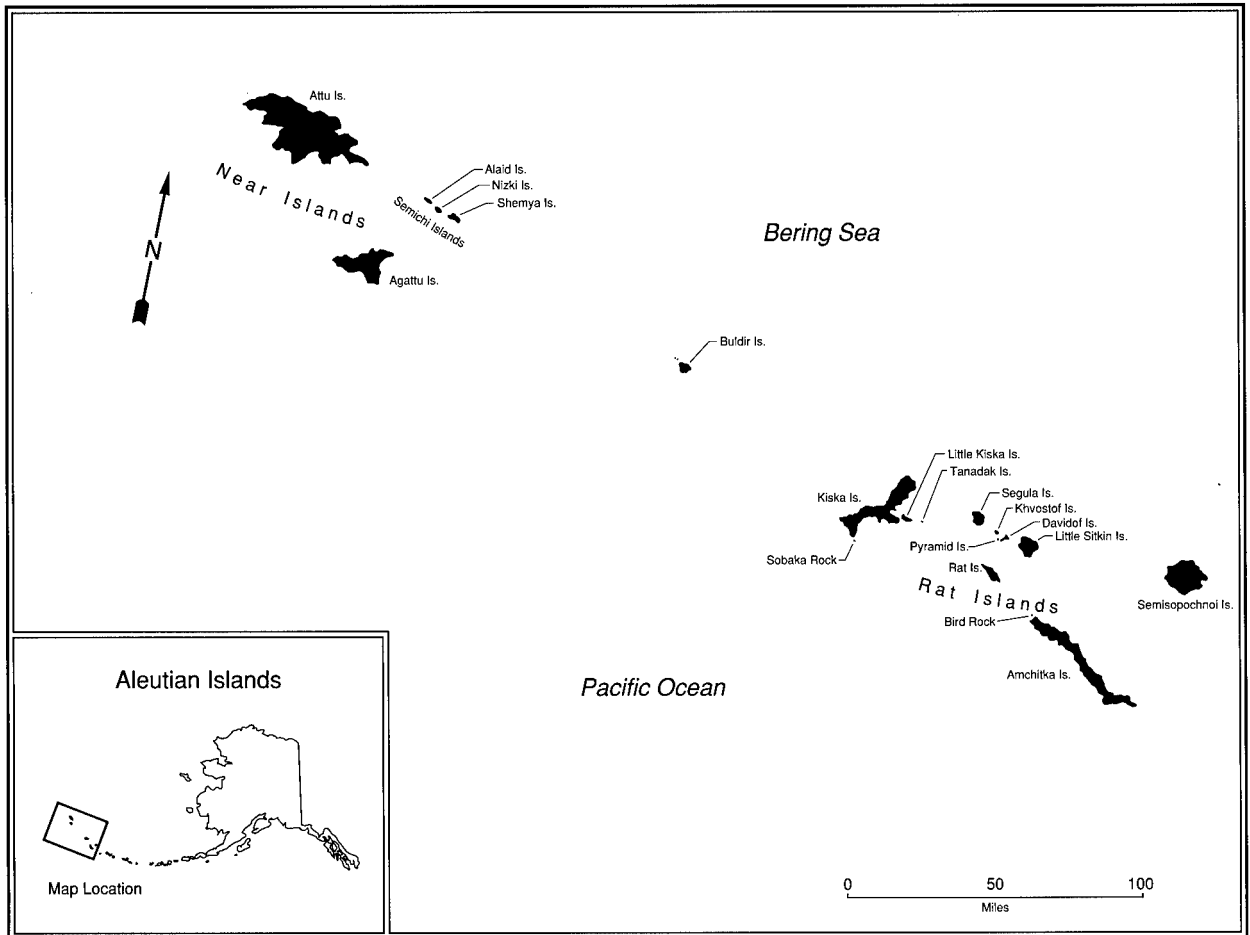


Fig. 3. Western Aleutian Islands.

west as Umnak Island (Murie 1959). The Fox Islands, as they were thus named, were the source of thousands of pelts of red foxes taken by Russians in the early 1800's (Berkh 1974; Veniaminov 1984). Foxes may have naturally ranged as far west as the Islands of Four Mountains. Veniaminov (1984) indicated that in 1840 foxes were on Chuginadak, the largest of these five islands west of Umnak. Records of the former Aleutian Islands NWR (most of the Aleutian Islands) on fox farming indicate that red foxes were on this island in 1926; arctic foxes were released here in 1930. The Islands of Four Mountains were linked to the Fox Islands by glaciers and the Fox Islands were part of the Alaska Peninsula during Pleistocene glaciations and concomitant reduced sea level (Hopkins 1967).

Besides the previously mentioned introduction of blue foxes on Attu Island in the mid-1700's, introductions were made in the Andreanof Islands (Fig. 4) by 1800 (Davydov 1977); foxes released in the central Aleutians originated from Bering Island (Commander Islands). Directives for releases came in 1819 from the main office of the Russian-American Company in St. Petersburg to Governor General Hagemeister in New Archangel (Sitka; Fig. 5), instructing him to transfer 900 pairs of blue foxes from the Pribilof Islands to lesser islands for fox propagation (Russian-American Company records, 1819 in Buskirk and Gipson 1980). A subsequent order in 1820 mandated a transfer of up to 200 pairs of blue foxes from St. George Island (Pribilofs) to each of the Rat Islands

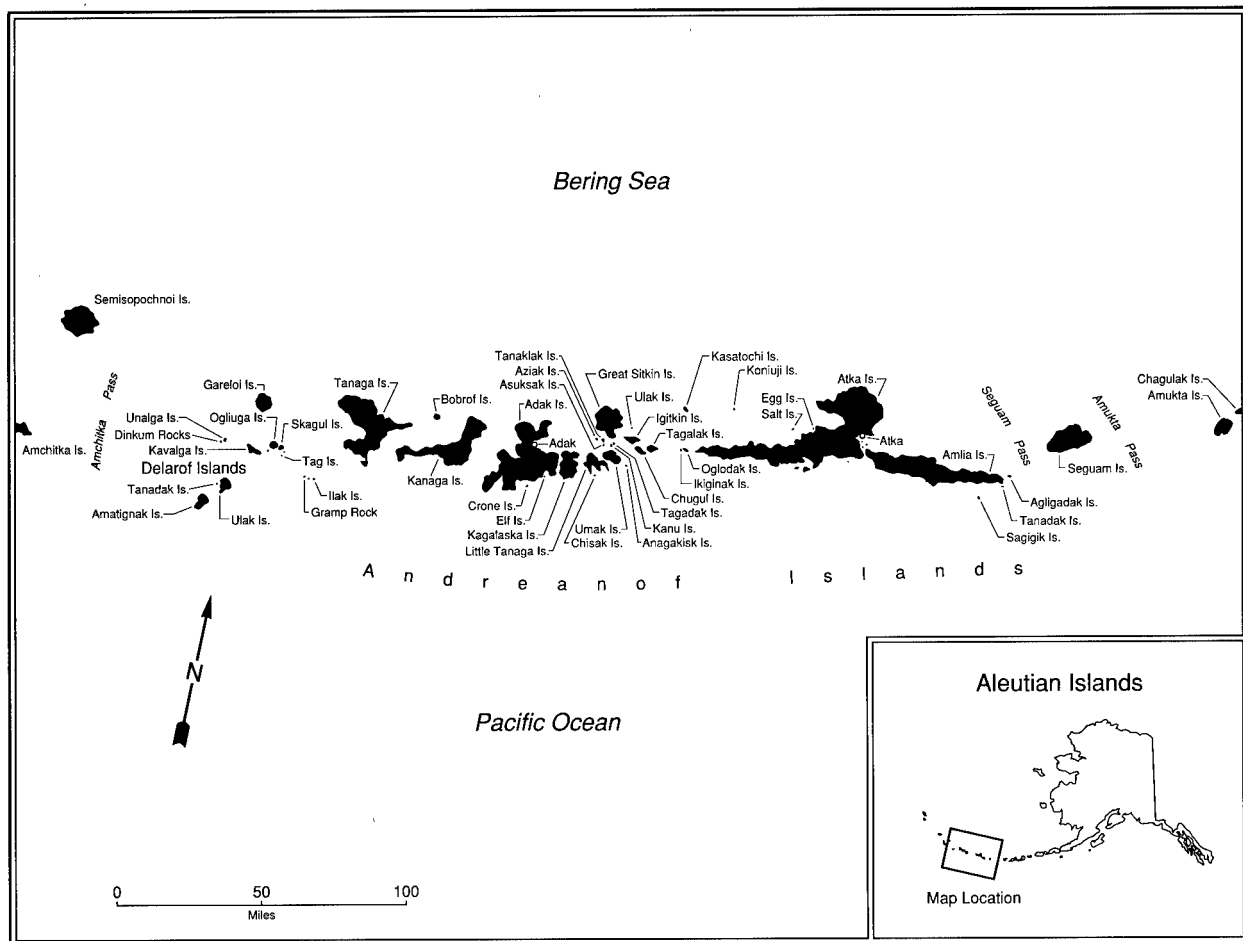


Fig. 4. Central Aleutian Islands.

(Fig. 3). Whether actual introductions were made on various islands and how long stocking continued are not known. Jones and Byrd (1979) indicated that introductions of both species of foxes by the Russian-American Company were made about 1836. Amlia Island (Fig. 4) specifically was mentioned as having been stocked sometime before 1838 (Tikhmenev 1978). In 1835, arctic foxes were liberated on Kiska Island in the western Aleutian Islands (Huston 1956). Directors of the Russian-American Company later ordered "black-brown and other high-grade foxes introduced on the principal islands of Unalaska and Atka district" in 1842 (Spencer et al. 1979). They also outlawed the shooting of foxes because of depletion of local populations and instituted alter-

nating closed seasons to conserve animals (Spencer et al. 1979). Little documentation exists divulging the specific islands to which foxes were translocated by the Russian-American Company, but early American observers found foxes on islands to which they did not seem to be native.

The Aleuts evidently rarely used foxes themselves because marine mammals and birds were more plentiful and of superior quality for clothing and therefore probably did not stock any islands with foxes before the arrival of Russian hunters and trappers (Promyshlenniki) who taught the Aleuts to trap. Furthermore, no evidence of fox traps made by Aleuts was found by Hrdlicka (1945) or other early archaeologists in subsequent investigations (Spencer et al. 1979). The Aleuts

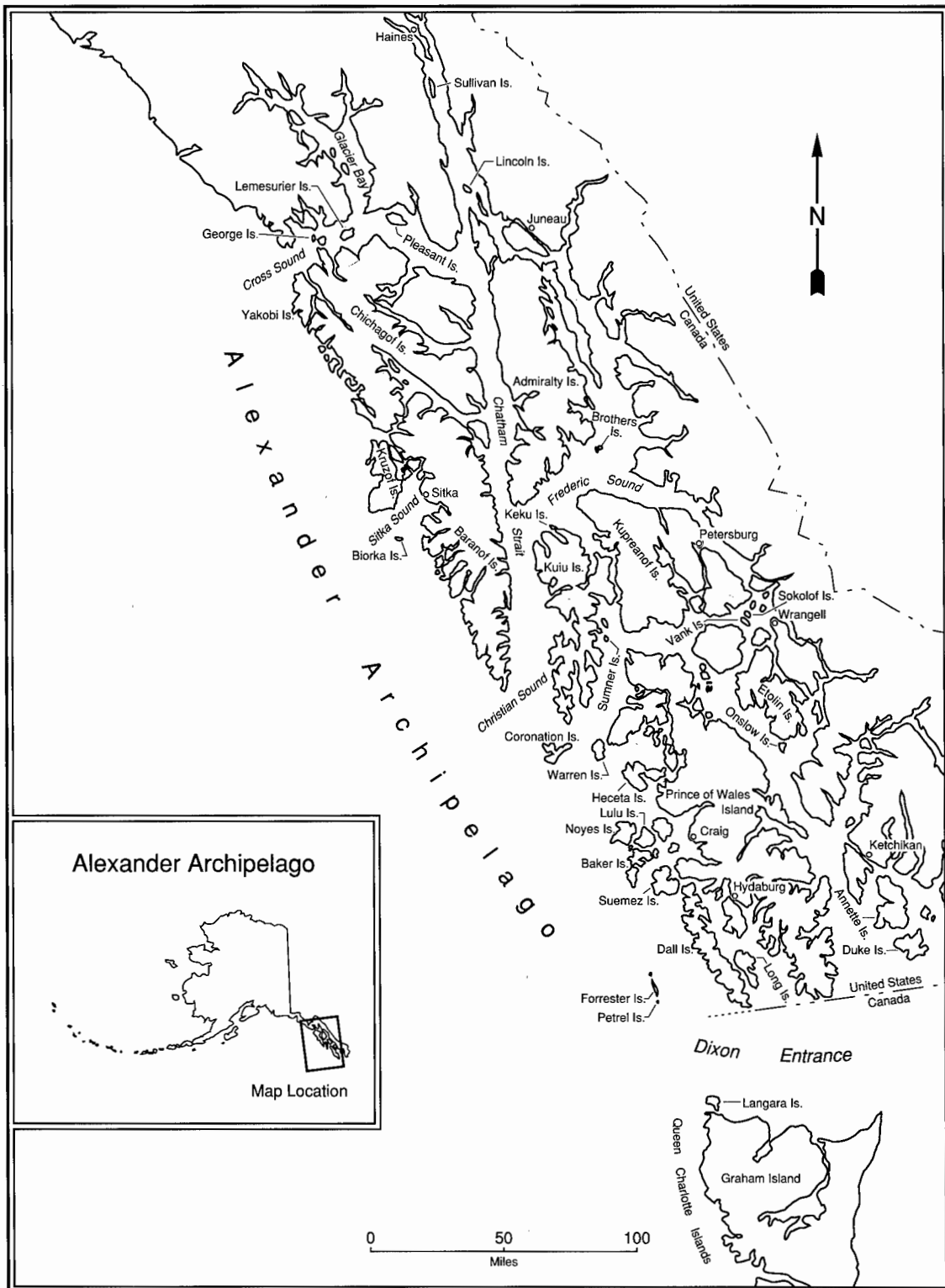


Fig. 5. Alexander Archipelago.

later used traps brought by the Russians who forced the Aleuts to trap for them, according to Veniaminov (1984).

Islands South of the Alaska Peninsula

Red foxes are indigenous to some of the larger islands south of the Alaska Peninsula; Steller noted them on Nagai, the second largest of the Shumagin Islands (Fig. 6), in 1741 (Frost and Engel 1988). The inner Shumagins seemingly were connected to the Alaska Peninsula during the last glacial period (Hopkins 1967). In 1840, Veniaminov (1984) mentioned red foxes were present on the islands of Unga, Korovin, and Popof,

which are closer to the Alaska Peninsula than Nagai Island. Red foxes, however, probably were not indigenous to the outer Shumagin Islands; they were introduced on Big Koniui Island in 1916 (Bower and Aller 1917) and arctic foxes were released on many other outer islands in the Shumagin Islands (Bailey 1978). Veniaminov (1984) also indicated red foxes were present on three of the Pavlof Islands (south of Pavlof Bay) and on Sanak Island (Fig. 6) and some of its surrounding islands. Stocking by Russians or Aleuts, however, cannot be totally discounted.

The first recorded introduction of foxes in Alaska after the region's acquisition by the United States in 1867 was made by a private individual on Popof Island in the Shumagin Islands in about

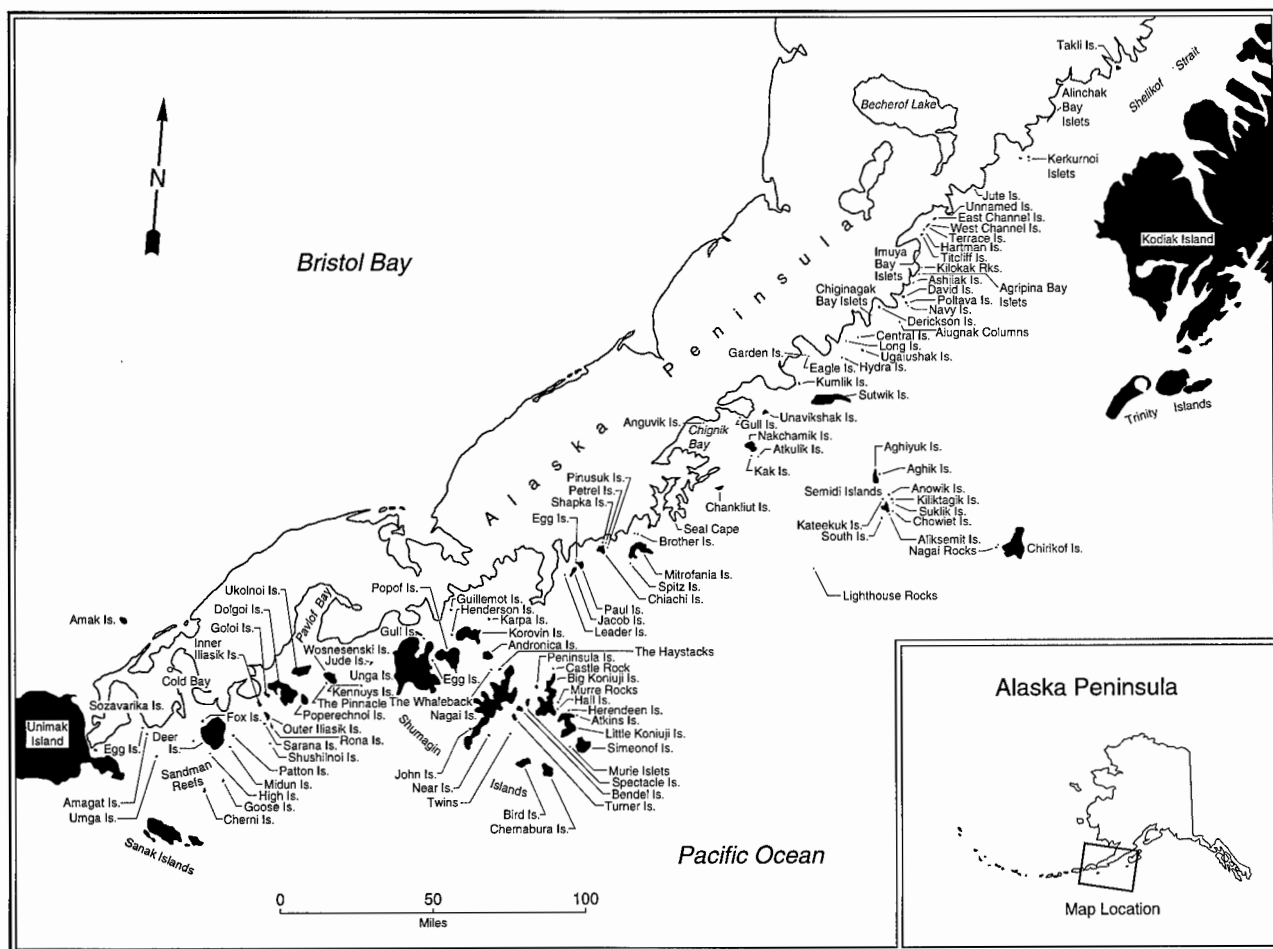


Fig. 6. Islands south of the Alaska Peninsula.

1880 when he attempted to raise silver foxes, a melanistic phase of the red fox (Janson 1985).

Arctic foxes from the Pribilof Islands were released in the Semidi Islands as early as 1881 (Anonymous 1895). In 1885, the Alaska Commercial Company organized the Semidi Propagating Company and released arctic foxes from the Pribilofs on Agihyuk Island (North Semidi) in the Semidi Islands. A year later, nearby Chowiet Island (South Semidi) was stocked (Bower and Aller 1917). Soon afterwards this company stocked nearby Chirikof, Marmot (off Afognak Island), and other islands off the Alaska Peninsula (Huston 1956).

Kodiak Archipelago

The red fox is native to Kodiak, Afognak, and formerly Shuyak islands (Fig. 7); bones of red foxes were found to be one of the most abundant mammal remains in Aleut middens on Kodiak Island (Murie 1959). This is in sharp contrast to the eastern Aleutians, where red fox remains were rarely found in middens predating the arrival of the Russians. Early excavations by Hrdlicka (1945) and others revealed almost no fox bones on Unalaska and surrounding islands in the Fox Island group, indicating that foxes were not used for food or pets as at Kodiak. Before the arrival of Russians in the Aleutians, Aleuts seemingly made little use of foxes (Spencer et al. 1979).

The first documented introduction of foxes in the Kodiak Island region was in the late 1800's, when red foxes were placed on Long Island in about 1880 (Bower and Aller 1917) and blue foxes 5 years later (Evermann 1914). Additional arctic foxes from the Pribilof Islands were placed on Long Island, near the town of Kodiak, in the 1890's, and at least seven other islands in this region were stocked by the Alaska Commercial Company (Janson 1985).

Gulf of Alaska-Alexander Archipelago

Neither species of fox was indigenous to most islands in the Gulf of Alaska and the Alexander Archipelago (Figs. 5, 7, and 8), most of which are heavily forested. Nearly all introductions in this region were arctic foxes; red foxes occur naturally on the mainland and on Kayak and Wingham

islands (Manville and Young 1965; Frost and Engel 1988).

In the Gulf of Alaska, the earliest known introduction of foxes was made in 1890 on isolated Middleton Island (Parker 1923). In 1894, fox farming started in Prince William Sound with the release of arctic foxes from Greenland on Seal Island (Janson 1985). This was unusual because the source of most arctic foxes was the Pribilof or Commander islands. The oldest stocking record for the Alexander Archipelago was the introduction in 1894 of red foxes on Dry Island, northwest of Wrangell (Evermann 1914); arctic foxes were released on the same island 7 years later. The first island to which arctic foxes were introduced in southeast Alaska was Sumdum, south of Juneau, in 1899 (Bower and Aller 1918).

The last part of Alaska where foxes were introduced on islands was the Cook Inlet area (Fig. 7). Here the earliest known introduction was about 1900 on Yukon and Hesketh islands near Homer in Kachemak Bay (Bower 1920). About the same time, Elizabeth Island in the Chugach Islands also was stocked with arctic foxes (Janson 1985).

Peak of Fox Farming

In 1882, the United States Secretary of the Treasury began leasing Alaskan islands for propagation of foxes. By 1900, at least 32 islands scattered from the Alexander Archipelago to the Aleutians were under lease (Spencer et al. 1979). Fox farming grew rapidly in the early 1900's. One of the most successful enterprises, the Semidi Propagating Company, harvested 5,100 arctic foxes between 1890 and 1914 mainly in the Semidi Islands and the Kodiak archipelago (Huston 1956). During this period, the Alaska Commercial Company harvested thousands of arctic foxes in the Pribilofs. In 1911, after promulgation of a convention to protect fur seals and sea otters, followed by creation of the Aleutian Islands Reservation, fox farming escalated as an alternative to hunting sea otters (Janson 1985).

By 1921, 23 of the Aleutian Islands were leased and stocked with mainly arctic foxes (Spencer et al. 1979), and 108 recorded fox farms were on islands in southeastern Alaska (Fig. 5) in 1922 (Huston 1956). Additional islands were stocked illegally

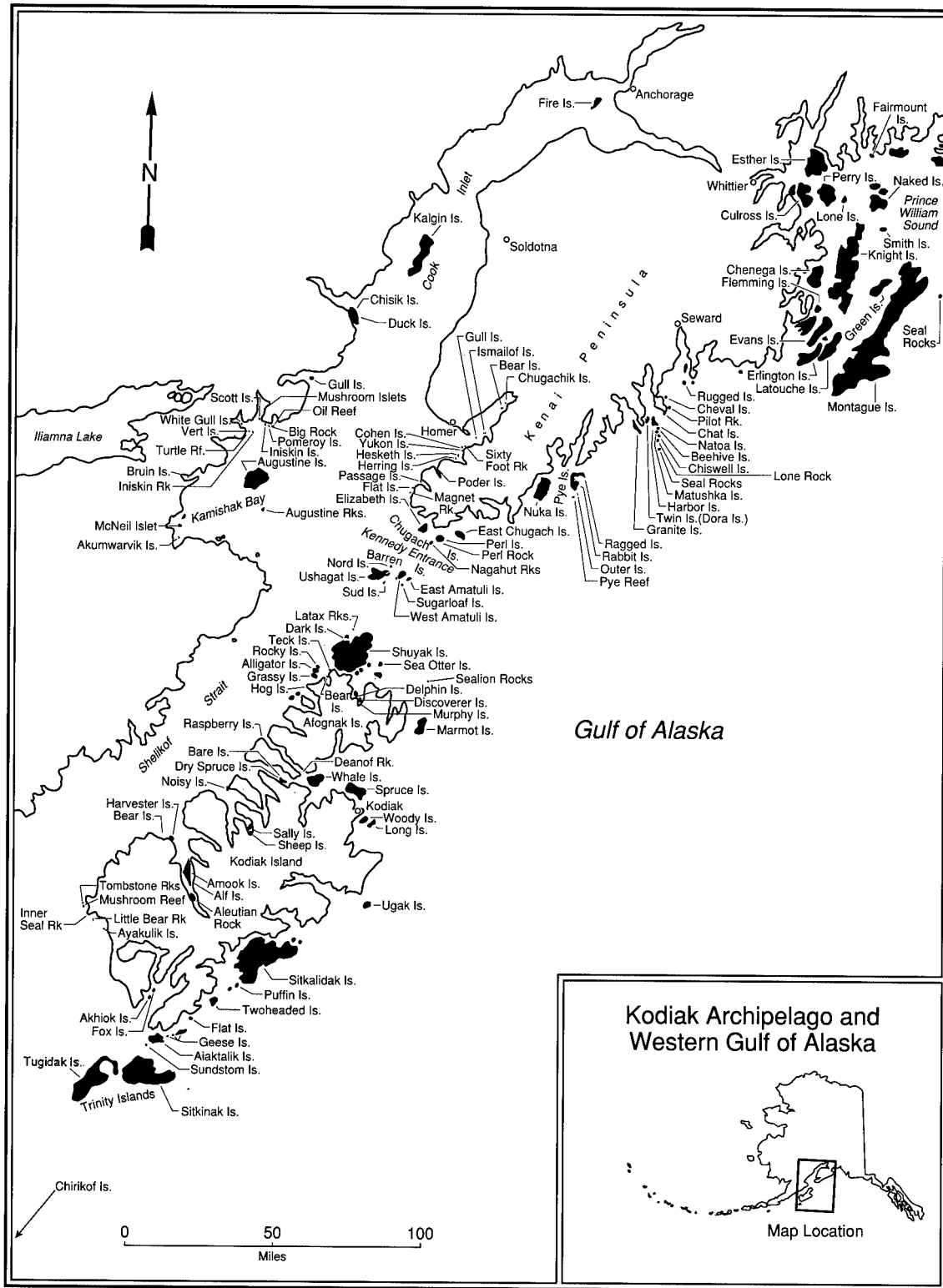


Fig. 7. Kodiak archipelago and western Gulf of Alaska.

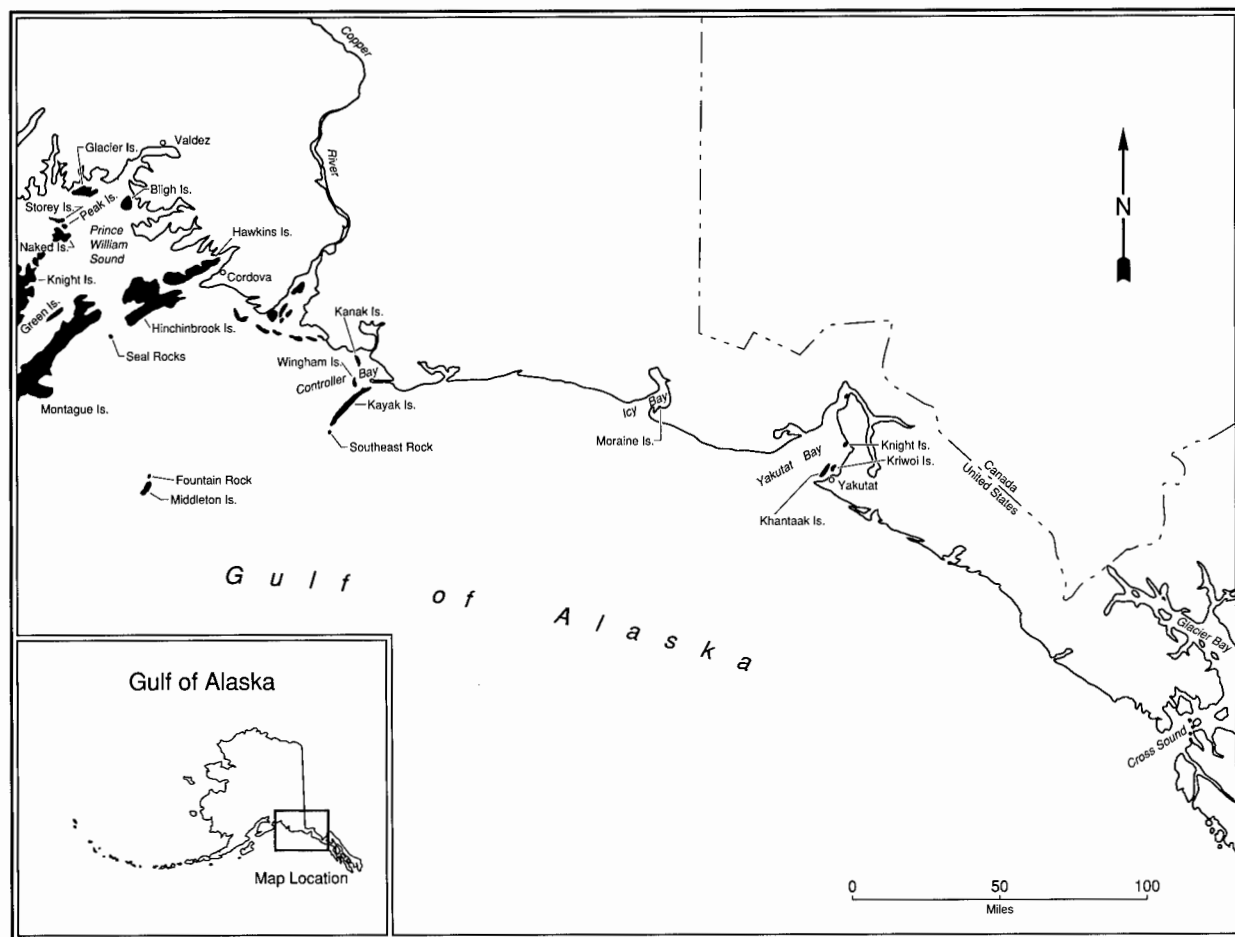


Fig. 8. Islands in the eastern Gulf of Alaska.

without leases. Many island fox farms were operating by this time in the Kodiak and Cook Inlet regions. In 1922, \$100,000 worth of arctic fox pelts were harvested from about 30 islands in Prince William Sound (Janson 1985). Fox furs became fashionable about 1913, and pelt prices rose from approximately \$12.50 in 1903 to as high as \$50 in 1921 (Janson 1985). The number of Alaskan islands leased for fox farming rose from 32 in 1900 to over 150 in 1922 (Huston 1956). Another reason for the sharp increase in pelt prices after 1912 was the continuing decrease in returns from overexploited wild furbearers and the ban on hunting of the few remaining sea otters (Spencer et al. 1979). Consequently, scarcity stimulated higher prices followed by a marked rise in insular fox farming.

During the period from 1867 to 1913, which began with uncontrolled slaughter of furbearers, governmental controls over the fur trade in Alaska slowly came about (Spencer et al. 1979).

The Alaskan fur farming industry grew most rapidly in the 1920's. By 1925, 391 fox farms, mainly on islands, with over 36,000 foxes were valued at about \$6 million (Parks 1925). In 1928, fur production was the third largest industry in Alaska, surpassed only by fishing and mining, and a year later the Alaska Game Commission issued 356 licenses (not all fox farmers obtained licenses) for fur animal propagation (Huston 1956). Most were for foxes. By 1936, nearly 27,000 fox pelts had been taken from the Aleutian Islands NWR since its inception in 1913 (Jones and Byrd 1979). Before

the expansion of fox farming in the mid-1920's, outlandish prices were reported. For example, individual pelts of silver foxes sold for as high as \$2,800 in London and prime breeding pairs for \$34,000 (Anonymous 1909; Ashbrook 1923)! Arctic foxes sometimes sold for over \$150 per pelt in the Aleutian Islands (Murie 1937; Aleutian Islands National Wildlife Refuge files). Elsewhere skins brought up to \$460 each in 1919 (*Fur Trade Review*, November 1919). The average price that year was \$185.

The decade of the 1930's brought a sharp decline in fur prices. Although 431 fur farm licenses were issued in 1931, the value of furs shipped from Alaska declined more than 50% from the previous year. Arctic fox pelts, for instance, dropped from an average of \$108 in 1929 to \$65 in 1930 and only \$32 in 1931 (Parks 1931; Spencer et al. 1979). In 1929, the zenith of fox farming, 9,300 blue fox pelts valued at nearly \$900,000 were exported from Alaska, but by 1931 this value had fallen to less than \$200,000 (Parks 1932). As a result, insular fox farming largely collapsed during the Great Depression and never recovered. Some attempts were made to revive trapping on islands after World War II, but prices of pelts were too low to make efforts on remote islands profitable. For instance, 171 arctic foxes were taken on Seguam Island in the Aleutian Islands in 1945, but the average pelt was worth only \$26. In 1947, 468 arctic fox skins from Kiska Island (western Aleutians) were removed from the market because prices were too low. Virtually no trapping continued after 1948 in the Aleutians (Elkins 1949; R. D. Jones, Jr., former manager of the Aleutian Islands National Wildlife Refuge, personal communication). Between 1953 and 1960, the last years that separate records were kept for shipments of insular arctic fox pelts from Alaska, recorded pelts were only between 10 and 70 (Courtright 1968). Although a few individuals still raise foxes in pens in Alaska, no known fox farm remains on any island.

Insular Fox Farms in Different Regions

I found records of introductions of foxes for 455 islands in the North Pacific Ocean from the British Columbia border across the Gulf of Alaska and the Aleutians to Attu Island. Undoubtedly, more is-

lands for which no records of fox introductions exist also were stocked in Alaska's ice-free waters.

Aleutian Islands

The western Aleutians (Fig. 3) were the first part of this archipelago to be regularly visited and settled by the Russians following Bering's voyage to Alaska, and not surprisingly the first island stocked with foxes was Attu, the island nearest the Kamchatka Peninsula whence early Russian voyages originated. In 1750, Andrean Tolstykh introduced a breeding pair of arctic foxes from Bering Island (Commander Islands) to Attu Island, where trapping began after the foxes had multiplied (Black 1984). Additional releases of foxes were probably also made, but a later introduction of arctic ground squirrels (*Spermophilus undulatus*) to Attu reportedly failed (Tikhmenev 1978).

The next documented introduction of arctic foxes in the Aleutian Islands was around 1790 on Atka (Fig. 4), where, by 1825, the animals were plentiful (Black 1984). The Russian-American Company encouraged introductions of foxes and, as early as 1819, orders were given by the governor to import breeding foxes to the central Aleutian Islands. Subsequently, arctic foxes from St. George Island in the Pribilof Islands were introduced (Fig. 1), and red foxes later were brought from the mainland and Unalaska Island (Fig. 2; Black 1984). By 1835, Kiska Island had been stocked with arctic foxes (Ashbrook and Walker 1925), and in about 1840, foxes were released on Amlia and Unalga islands (Elkins and Nelson 1954). Tikhmenev (1978) indicated that foxes had been imported on Amlia Island before 1838 when Aleuts returned there from nearby Atka Island to propagate previously introduced foxes. Other introductions that were documented before 1900 in the Aleutians included those on Agattu, Samalga, Ogluiga, and Skagul islands (Fig. 9; Table 1). Additional islands probably were stocked without being recorded. All early introductions, species of which were named, were arctic foxes. In two instances when no species was specified, arctic foxes were later found on the islands. By 1931, foxes had been released on at least 86 islands in the Aleutians. Ultimately, arctic foxes were introduced to 79 islands and still survive on 22 of them (Table 1). They were eradicated on 17 islands by personnel of the U.S. Fish and Wildlife Service using poison and traps and disappeared from the

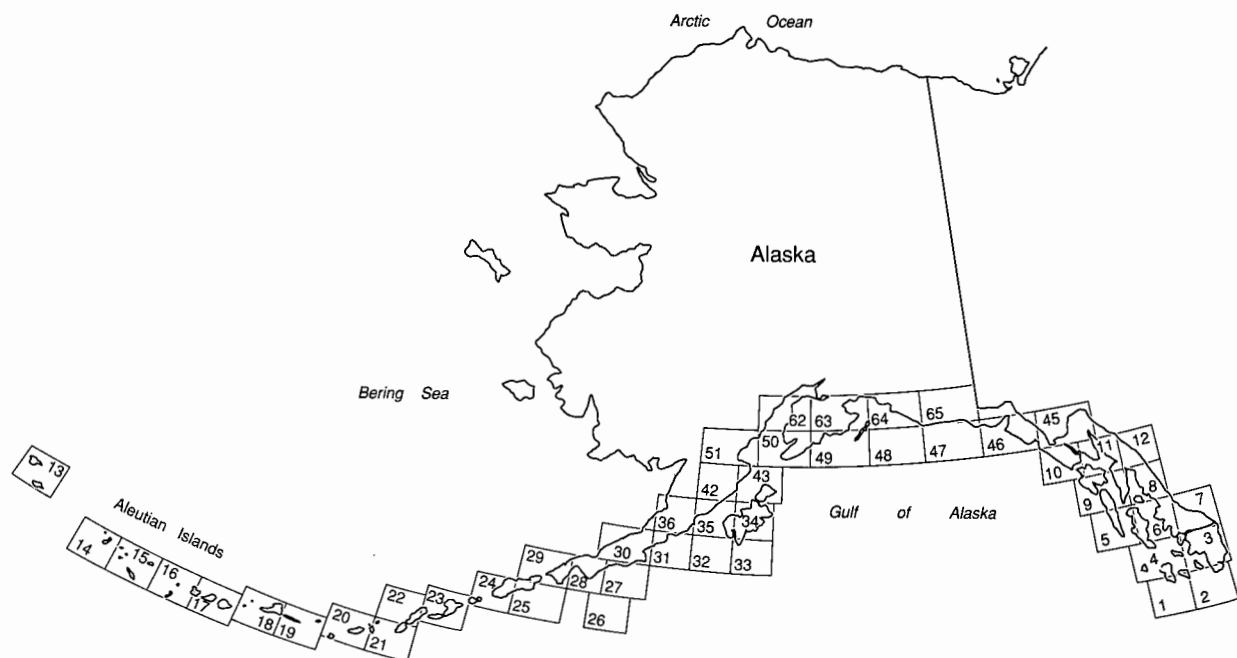


Fig. 9. Seabird colony map numbers showing locations of islands stocked with foxes in Tables 1-5.

Table 1. *Introductions of foxes in the Aleutian Islands.*

Island name ^a	Seabird catalog map (Fig. 9) ^b	Species ^c	Year stocked ^d	Source ^e	Status ^f
Adak	17	arfox	1921	40	p
Adak	17	refox	1929	1	d
Adokt-Koschekt	23	refox	1922	31	d
Adokt-Koschekt	23	arfox	1931	31	d
Adugak	21	arfox	1925	31	e
Agattu ^g	13	arfox	1880	41	e
Aiktak	24	arfox	1921	31	d
Alaid	13	arfox	1911	42	e
Amatignak	16	arfox	1923	31	e
Amchitka	15	arfox	1921	43	e
Amilia	19	fox	1838	44	p
Amilia	19	arfox	1927	31	p
Amukta	20	arfox	1925	31	e
Ananiuliak	22	arfox	1916	31	d
Anocknock		refox	1929	3	d
Atka	18	arfox	1790	45	p
Attu	13	arfox	1750	46	p
Avatanak	24	arfox	1920	31	p
Aziak (Hazuk)	17	arfox	1927	31	d
Bobrof	17	arfox	1930	31	d

Table 1. *Continued.*

Island name ^a	Seabird catalog map (Fig. 9) ^b	Species ^c	Year stocked ^d	Source ^e	Status ^f
Buldir ^g	14	arfox	1924	2	d
Carlisle	20	arfox	1929	1	e
Chiguk		arfox	1929	3	d
Chinkoff	17	arfox	1929	3	d
Chuginadak	21	refox		31	p
Chuginadak	21	arfox	1930	31	d
Chugul	18	arfox	1922	3	d
Davidof	15	arfox	1924	2	d
Excelsior (Baby Islands)	23	arfox	1928	31	d
Excelsior (Baby Islands)	23	refox	1929	3	d
Gareloi	16	arfox	1925	31	p
Great Sitkin	17	refox		40	d
Great Sitkin	17	arfox	1925	31	p
Herbert	21	arfox	1921	31	p
Hog	23	arfox	1914	31	d
Igitkin	18	arfox	1922	31	e
Ilak	16	arfox	1921	31	d
Isoso (Asuksak)	17	arfox	1930	31	d
Kagalaska	17	arfox	1921	31	p
Kagamil	21	arfox	1923	31	p
Kaligagan	24	arfox	1921	31	d
Kanaga	17	arfox	1927	31	p
Kanaga	17	refox	1929	1	d
Kanu (Unak)	17	arfox	1916	3	d
Kasatochi	18	arfox	1927	31	e
Kavalga	16	arfox	1920	31	d
Keegaloo	22	arfox	1918	31	d
Ketnaugh	21	arfox	1922	31	d
Khvostof	15	arfox	1924	2	d
Kiska	14	arfox	1835	28	e
Kositka		refox	1929	3	d
Little Kiska	14	arfox	1924	2	d
Little Sitkin	15	arfox	1923	31	p
Little Tanaga	17	arfox	1922	31	e
Nizki	13	arfox	1911	42	e
Nohatamie		arfox	1919	3	d
Ogangan (Ougingin)	23	arfox	1929	31	d
Ogluiga	16	arfox	1897	3	d
Peter	23	arfox		40	d
Poa	24	arfox	1920	31	d
Pustoi	23	arfox	1932	31	d
Rat	15	arfox	1922	31	e
Rat Islands	15	refox		47	d
Rootok	24	arfox	1913	31	p
Sagchudak	18	arfox	1914	31	d
Salt	18	arfox	1916	31	d

Table 1. *Continued.*

Island name ^a	Seabird catalog map (Fig. 9) ^b	Species ^c	Year stocked ^d	Source ^e	Status ^f
Samalga	21	arfox	1897	8	p
Segarhudik		arfox	1929	3	d
Seguam	19	arfox	1924	31	p
Segula (Chugul)	15	arfox	1920	31	p
Semichi (Shemya)	13	arfox	1911	31	p
Semisopchnoi	15	arfox	1922	31	p
Signals (Ugalga)	23	refox	1916	31	d
Skagul	16	arfox	1897	3	d
Small	23	fox	1922	34	d
Tagadak	18	arfox	1925	31	d
Tagalak	18	arfox	1916	3	d
Tanadak	19	arfox	1929	1	d
Tanaga	17	arfox	1922	31	p
Tanaklak	17	arfox	1918	3	d
Tangaman	23	refox	1929	3	d
Tangik	24	arfox	1920	31	d
Three	23	fox	1921	34	d
Thugskan	23	fox	1929	34	d
Ugamak	24	arfox	1922	31	e
Ulak (west)	16	refox	1915	31	d
Ulak (west)	16	arfox	1924	2	e
Uliaga	22	arfox	1930	31	e
Umak	17	arfox	1921	31	e
Unalaska	23	arfox	1922	48	d
Unalga	23	fox	1842	31	p
Unalga	23	arfox	1914	31	p
Vsevidof	21	arfox	1920	31	d
West Unalga	16	arfox	1915	31	d
Yunacka		arfox	1929	3	d
Yunaska	20	arfox	1930	31	p

^a Islands with the same name are different islands if map numbers are not identical. Names of islands in parenthesis are former or less common names.

^b Location map numbers refer to those in the Catalog of Alaskan Seabird Colonies (Sowls et al. 1978) that uses 1:250,000 scale maps from the U.S. Geological Survey (Fig. 9). Specific island locations that could not be determined are left blank.

^c Introduced species: arfox = arctic fox (*Alopex lagopus*), refox = red fox (*Vulpes vulpes*), and fox = species not specified.

^d Date of indicated introduction is earliest known; often additional introductions were made in later years. A blank space indicates an unknown introduction date.

^e The sources of dates of introductions (numbers) are in Appendix A.

^f Current status of fox population: d = disappeared (disappeared naturally or removed by fur trappers), e = eradicated by U.S. Fish and Wildlife Service personnel, p = foxes still present when island last checked.

^g Records of stocking Agattu and Buldir islands in 1880 and 1924, respectively, are seemingly incorrect or the released foxes failed to survive. Records indicate that Agattu Island was stocked again in 1923, and arctic foxes were not completely removed until the 1970's.

others naturally. In 1928, Russians expanded fox farming in the Commander Islands, ironically the original source of introduced arctic foxes in the Aleutians, to include Toporkov Island, a small outstanding seabird island (Litvinenko 1987).

As many as 20 of the Aleutian Islands were stocked with red foxes, but presumed alien red foxes now survive for certain on only Chuginadak Island in the eastern Aleutians (Bureau of Biological Survey 1940; Spencer et al. 1979; Bailey and Trapp 1986). Silver foxes were present on Amlia Island when arctic foxes were put there in 1927 (Bureau of Biological Survey 1940), and, according to Aleuts, red foxes still existed on nearby Atka Island in 1982, although none has been seen in many years (Bailey and Trapp 1986). Red foxes are indigenous on Unimak Island and on Unalaska, Sedanka, Akutan, Akun, Tigalda, and Umnak islands, all in the Fox Island group (Murie 1959). Red foxes also seemingly were native on Unalga and Ugamak islands, but were eliminated by trappers and replaced with arctic foxes (Shelikhov 1981). In several other instances, red foxes were eliminated from islands by trappers and replaced with more valuable arctic foxes (Swanson 1982). All known introductions of red foxes in the Aleutians were in the central and eastern part of the archipelago (Fig. 9; Table 1). The source of stock usually was from the Fox Islands, but on Kanaga, Adak, and perhaps other islands in the central Aleutians, red foxes reportedly originated from Siberia (Swanson 1982).

Numbers of pelts were incredible from some islands, especially while seabirds and waterfowl still bred in large numbers on given islands (Alaska Maritime National Wildlife Refuge files). Production of foxes was most prolific on Amchitka Island; records indicate that 4,076 arctic fox pelts valued at over \$180,000 were taken between 1921, when the island was stocked, and 1936 when records ceased. Nearly 1,100 arctic foxes were trapped in a single year (1931). About 1,700 arctic fox pelts per island reportedly were harvested on Attu, Kiska, and Atka islands during the same period, and more than 1,100 arctic foxes per island were taken off Adak, Amukta, Agattu, and Kavalga islands. Some small islands, such as Samalga Island (415 ha), produced 771 pelts in 21 years. Besides island size and trapping effort, the number of pelts from a given island was dependent largely on physiographic features like extent of beaches and on breeding bird populations as a source of food (Fig. 10).

Concerns by the U.S. government about the effects of foxes on birds in the Aleutian Islands became evident in 1930, when directives were given not to issue permits for introductions of foxes on notable bird islands, and in 1932, when a government biologist reported a noticeable decline in waterfowl in the Aleutians (Spencer et al. 1979). This new restrictive policy, however, was not fully implemented until 1940, after the collapse of the fur industry in the late 1930's. During the same period, Olaus Murie (1937, 1959) spent two sum-



Fig. 10. Islands like Bogoslof in the eastern Aleutians have ideal food resources for foxes, namely numerous accessible breeding seabirds, a sea lion rookery, and extensive beaches for scavenging and foraging for marine invertebrates. Fortunately, foxes never were released on this small, actively volcanic island. Photo by E. P. Bailey.

mers surveying wildlife in the Aleutians and documented the serious declines of many species of breeding birds caused by introduced foxes. Gradually, government policy changed from facilitation of fox farming as one of the purposes of the Aleutian Islands Reservation to active eradication of foxes to protect and restore breeding bird populations. Eradication began on Amchitka Island in 1949 (R. D. Jones, former manager of the Aleutian Islands National Wildlife Refuge, personal communication). Despite the shift in emphasis by the Aleutian Islands NWR to protecting insular birds and despite the lack of a market for foxes, some natives still trapped on a few islands, such as Amchitka and Tanaga islands, as late as 1949. Since then, permits to trap foxes on refuge islands were no longer required.

Alaska Peninsula

Foxes were introduced to at least 63 islands south of the Alaska Peninsula (Table 2). The first known successful introduction in this region was on the Semidi Islands in 1881 (Anonymous 1895). By 1900, the Semidi Islands reportedly supported about 1,000 arctic foxes (Washburn 1900). A few red foxes also were released here in the 1880's (Bower and Aller 1917). Foxes were put on seven additional islands off the Alaska Peninsula before 1900. Besides the Semidi Islands, early introductions were made in the Shumagin and Chiachi islands. Most introductions before 1900 were arctic foxes originating from the Pribilof Islands (Janson 1985).

Red foxes are native on at least 5 islands and were released on an additional 14 islands off the Alaska Peninsula (Table 2). The progeny of introduced red foxes still exist on Deer, Dolgoi, Inner Iliasiik, and Ukolnoi islands (personal observation). Red foxes probably reached Titcliff Island (Fig. 6) in Wide Bay on the upper Alaska Peninsula naturally by crossing on the ice or by swimming. In 1986, descendants of red foxes introduced to Big Koniui Island in 1916 were exterminated by U.S. Fish and Wildlife Service personnel (Bailey 1986), and red foxes presumably introduced at an unknown date on Poperechnoi Island in the Pavlov Islands were eliminated in 1988 (Bailey 1988). Arctic foxes also allegedly were released on Poperechnoi Island in 1929 (Alaska Game Commission files), but they subsequently disappeared, whereas red foxes persisted. Red foxes disappeared from 13

islands south of the Alaska Peninsula. They were indigenous on Nagai Island, the second largest of the Shumagins, as Steller noted them in 1741 (Frost and Engel 1988). Also, red foxes probably once were native on Korovin, Popof, and other islands in the inner Shumagins and on a few other islands close to the Alaska Peninsula. The population on Nagai Island supposedly was poisoned by early trappers (A. Gronholdt, Sand Point, Alaska, personal communication); this probably is the cause for the demise of natural red fox populations on a few other islands in this region.

Arctic foxes were introduced to at least 54 islands in this region (Table 2), but remain on only 11 islands, all but one of which are in the Sanak and outer Shumagin islands (Bailey 1978; Bailey 1983). Both arctic and red foxes were released at different times on 12 islands. Arctic foxes disappeared from all of these islands, but red foxes survived on Deer, Poperechnoi, and Big Koniui islands. Arctic foxes, which survived on a few islets near Sanak, were introduced to Sanak Island itself in about 1970 by a local cattleman (M. Uttecht, Cold Bay, Alaska, personal communication). At low tides, they then reached Long, Clifford, and other adjoining islands, which originally had red foxes.

All islands south of the Alaska Peninsula are treeless (Fig. 11) and generally receive less precipitation than the Gulf of Alaska region, conditions which favor the survival of arctic foxes. Primarily red foxes inhabit the Alaska Peninsula, although some arctic foxes straggle onto the north side of the Peninsula by way of the Bering Sea ice pack (Murie 1959).

All but 3 of the 11 islands off the Alaska Peninsula where arctic foxes still occur either still have or recently had cattle (personal observation). Dead cattle, particularly in winter, provide additional carrion for foxes and thus enhance their survival. Cattle were put on low relatively flat islands with extensive grasslands and coastal marshes, favorable habitat for waterfowl, but not for most species of nesting seabirds.

Kodiak Archipelago

Records indicate that in the Kodiak archipelago, foxes were released on 51 islands from the Barren Islands to Chirikof Island (Table 3). Red foxes are indigenous to Kodiak, Afognak, Shuyak, Sitkalidak, and Sitkinak islands, the largest in the area

Table 2. *Introductions of foxes on islands off the Alaska Peninsula.*

Island name ^a	Seabird catalog map (Fig. 9) ^b	Species ^c	Year stocked ^d	Source ^e	Status ^f
Aghiyuk (North Semidi)	31	fox	1883	5	d
Aghiyuk (North Semidi)	31	arfox	1885	28	d
Andronica	28	arfox	1900	16	d
Andronica	28	refox	1929	1	d
Bendel	27	arfox	1924	2	d
Big Koniuji	27	refox	1916	25	e
Big Koniuji	27	arfox	1925	29	d
Bird	26	arfox	1916	30	e
Bird	25	arfox	1924	2	d
Bone	25	arfox	1932	31	d
Caton	25	arfox	1916	30	d
Chankliut	30	arfox	1919	11	d
Chercos		arfox	1929	3	d
Chernabura	26	arfox	1900	16	p
Cherni	25	arfox	1916	30	d
Chiachi	27	fox	1900	5	d
Chiachi	27	arfox	1924	2	d
Chowiet (South Semidi)	31	arfox	1886	28	d
Chowiet (South Semidi)	31	refox	1886	28	d
Clifford	25	arfox	1920	32	p
Clifford	25	refox	1923	1	d
David	36	arfox	1930	33	d
Deer	25	refox		8	p
Deer	25	arfox	1929	1	d
Dolgoi	28	refox	1906	8	p
Egg, Eastern	27	arfox	1929	1	d
Elma	25	arfox	1924	2	p
Finneys	25	arfox	1926	34	p
Fox	25	arfox	1929	1	d
Goloi	28	arfox	1930	31	d
Goose (Big Goose)	25	arfox	1916	30	d
Guillemot	28	arfox	1929	1	d
Gunboat (Gumboot)	25	arfox	1925	34	d
Iliasik	28	refox		8	p
Inikla	25	arfox		35	p
Jacob	27	refox	1894	12	d
Jacob	27	arfox	1930	32	d
Kiukpalik	43	arfox	1924	2	d
Korovin	28	refox	1929	1	d
Kumlik	31	arfox	1929	1	d
Lida	25	arfox	1924	31	d
Little Koniuji	27	fox	1895	5	
Little Koniuji	27	arfox	1900	16	p
Mary	25	refox	1924	31	d
Mary	25	arfox	1933	31	d
Midun	25	arfox	1929	1	d

Table 2. *Continued.*

Island name ^a	Seabird catalog map (Fig. 9) ^b	Species ^c	Year stocked ^d	Source ^e	Status ^f
Mitrofanina	27	arfox	1929	3	d
Nagai (Nagay)	28	arfox	1894	12	d
Nagai (native-1741)	28	refox	1840	36	d
Nakchamik	31	arfox	1924	2	d
Paul	27	arfox	1894	12	d
Peterson	25	arfox	1922	37	d
Poperechnoi ^g	28	arfox	1929	1	d
Popof	28	refox	1880	3	d
Popof	28	arfox	1924	2	d
Road	27	fox		38	d
Sakchamak		arfox	1929	3	d
Sanak (including Long) ^g	25	arfox	1970	32	p
Sarana	25	arfox	1918	31	d
Sarana	25	refox	1929	1	d
Semidi Islands	31	fox	1881	39	d
Simeonof	26	arfox	1890	29	p
Sister's	25	arfox	1925	31	d
Spectacle	27	arfox	1924	2	d
Telemitz	25	arfox	1936	34	d
Trithe	25	arfox	1924	31	d
Turner	27	arfox	1898	29	d
Ugaiushak	31	arfox	1915	6	d
Ugashak		arfox	1929	1	
Ukolnoi	28	refox	1913	8	p
Umla (Omla)	25	arfox	1930	34	d
Unavikshak	31	arfox	1924	2	d
Unnamed (N. of Ugaiushak)	31	arfox	1930	33	d
Wanda	25	arfox	1925	31	p
Wosnesenski	28	arfox	1924	2	p

^a Islands with the same name are different islands if map numbers are not identical. Names of islands in parenthesis are former or less common names.

^b Location map numbers refer to those in the Catalog of Alaskan Seabird Colonies (Sowls et al. 1978) that uses 1:250,000 scale maps of the U.S. Geological Survey (Fig. 9). Specific island locations that could not be determined are left blank.

^c Introduced species: arfox = arctic fox (*Alopex lagopus*), refox = red fox (*Vulpes vulpes*), and fox = species not specified.

^d Date of indicated introduction is earliest known; often additional introductions were made in later years. A blank space indicates an unknown introduction date.

^e The sources of dates of introductions (numbers) are in Appendix A.

^f Current status of fox population: d = disappeared (disappeared naturally or removed by fur trappers), e = eradicated by U.S. Fish and Wildlife Service personnel, p = foxes still present when island last checked.

^g Red foxes introduced at undetermined date and eradicated in 1988; red foxes removed from Sanak and arctic foxes released later.



Fig. 11. Seabirds stream from Karpa Island in the Shumagin Islands, located south of the Alaska Peninsula. Foxes were never introduced here. Photo by E. P. Bailey.

Table 3. *Introductions of foxes on islands in the Kodiak archipelago.*

Island name ^a	Seabird catalog map (Fig. 9) ^b	Species ^c	Year stocked ^d	Source ^e	Status ^f
Abram	34	arfox	1903	6	d
Afognak	43	arfox	1929	1	d
Alf	34	arfox	1904	8	d
Amook	34	arfox	1912	7	d
Amook	34	refox	1914	7	d
Bare (Dry)	34	arfox	1897	12	d
Black Point	33	arfox	1924	2	d
Chirikof	32	arfox	1888	22	p
Cook		arfox	1897	12	d
Crooked	34	arfox	1930	3	d
Demidof	34	fox	1898	14	d
Deranof	34	fox	1894	5	d
Deranof	34	arfox	1924	2	d
Fanny	34	arfox	1929	3	d
Flag	34	arfox	1929	3	d
Geese	33	refox		23	p
Geese	33	arfox	1924	2	d
Harvester	34	arfox	1914	7	d
Hog	43	refox	1897	8	d
Hog	43	arfox	1901	8	d
Holiday	34	fox	1900	24	d
Kalsin	34	refox	1915	7	d
Kalsin	34	arfox	1924	2	d
Knoll	33	fox	1900	5	d
Long	34	refox	1880	7	d
Long	34	arfox	1885	8	d

Table 3. *Continued.*

Island name ^a	Seabird catalog map (Fig. 9) ^b	Species ^c	Year stocked ^d	Source ^e	Status ^f
Low	34	fox	1900	24	d
Low	34	refox	1915	7	d
Marmot	43	arfox	1885	8	d
Marmot	43	refox	1897	12	p
Middle	34	refox	1916	25	d
Middle	34	arfox	1929	1	d
Near	34	fox	1900	24	d
Nelson	34	arfox	1924	2	d
Nelson	34	refox	1929	1	d
Noisy	34	refox	1914	25	d
Noisy	34	arfox	1929	1	d
Noonjak	34	arfox	1898	7	d
Queer	34	refox	1916	25	d
Queen	34	arfox	1924	2	d
Raspberry	34	arfox	1911	8	d
Raspberry	34	refox	1912	7	d
Sitkalidak	34	arfox	1926	3	d
Svitlak	34	refox	1916	25	d
Two Headed	33	arfox	1929	1	d
Ugak	34	refox	1891	8	p
Ugak	34	arfox	1894	7	d
Unnamed (2-Blue Fox Bay)	43	arfox	1928	15	d
Unnamed (Ayakulik River)	35	refox	1911	7	d
Unnamed (Kalsin Bay)	34	fox		10	d
Unnamed (Marmot Bay)	43	refox	1914	7	d
Unnamed (Marmot Bay)	43	arfox	1915	7	d
Unnamed (Nelson Island)	34	refox	1915	7	d
Unnamed (Seal Bay)	43	arfox	1924	2	d
Unnamed (Uyak Bay)	34	refox	1911	6	d
Unnamed (Uzinki)	34	refox	1915	7	d
Ushagat	43	arfox	1928	26	e
Whale	34	arfox	1885	8	d
Wooded	34	arfox		27	d

^a Islands with the same name are different islands if map numbers are not identical. Names of islands in parenthesis are former or less common names.

^b Location map numbers refer to those in the Catalog of Alaskan Seabird Colonies (Sowls et al. 1978) that uses 1:250,000 scale maps from the U.S. Geological Survey (Fig. 9). Specific island locations that could not be determined are left blank.

^c Introduced species: arfox = arctic fox (*Alopex lagopus*), refox = red fox (*Vulpes vulpes*), and fox = species not specified.

^d Date of indicated introduction is earliest known; often additional introductions were made in later years. A blank space indicates an unknown introduction date.

^e The sources of dates of introductions (numbers) are in Appendix A.

^f Current status of fox population: d = disappeared (disappeared naturally or removed by fur trappers), e = eradicated by U.S. Fish and Wildlife Service personnel, p = foxes still present when island last checked.

(Rausch 1969; Fig. 7). In addition, red foxes evidently swam to at least three smaller islands near the main islands. Though the islands were not named, in the early 1800's, the Russian-American Company ordered the transplanting of breeding foxes to surrounding small islands where food was available (Tikhmenev 1978). Islands with colonial nesting birds were generally the best islands for foxes. Red foxes were introduced to 18 islands in this archipelago, beginning with Long Island in 1880 (Bower and Aller 1917), but have persisted on only Geese, Ugak, and Marmot islands (R. Smith, Alaska Department of Fish and Game, Kodiak, Alaska, personal communication; J. Bowman, Bureau of Land Management, Anchorage, Alaska, personal communication). Although red foxes were released on Marmot Island (Kutchin 1898), they were reportedly indigenous (Shelikhov 1981). Perhaps the introductions on Marmot Island long after early Russian explorers reported red foxes there represent replacements for overtrapped populations. Indigenous red fox populations on Shuyak and Dark islands seemingly were eliminated with poison by early trappers (Evermann 1914).

Whale, Long, and Marmot islands were the first known islands in the Kodiak region to which arctic foxes were introduced; all were stocked in 1885 (Evermann 1914). Arctic foxes were translocated to Chirikof Island 3 years later (J. McCord, Kodiak, Alaska, personal communication) and had been put on four more islands by 1900 (Table 3). The population on Chirikof grew to 2,000 foxes by 1900 (Washburn 1900). Arctic foxes vanished from all 33 islands to which they were introduced, except Ushagat Island in the Barren Islands (Bailey 1976; L. Matfay, Akhiok, Alaska, personal communication) and Chirikof Island, southwest of Kodiak (personal observation). Ushagat Island is mostly tundra, and Chirikof Island has no native trees. In 1987, U.S. Fish and Wildlife Service personnel eradicated the few remaining arctic foxes on Ushagat Island to restore seabird populations (Bailey 1987). Arctic foxes do not naturally occur in the Kodiak or Gulf of Alaska region, which generally consists of unsuitable rain forest habitat. Arctic foxes normally inhabit arctic tundra (Novak et al. 1987) and are not well suited to rain forests.

Red and arctic foxes were introduced to 10 islands in the Kodiak archipelago; both species dis-

appeared from all except Ugak Island and the Geese Islands, where only red foxes survived.

Gulf of Alaska

Seventy-three islands were stocked with foxes in the Gulf of Alaska (Yakutat to Cook Inlet; Figs. 7 and 8). Arctic foxes were introduced on 67 islands, and red foxes were released on 6. Fox farming in this region was principally in Prince William Sound, where foxes were placed on 44 islands (Table 4). Introductions began in 1890, when arctic foxes were released on Middleton Island, 75 km south of Cordova; by 1900, foxes were introduced to 18 additional islands, all but 1 in Prince William Sound. In 1900, Yukon and Hesketh islands were stocked, marking the beginning of fox farming in Cook Inlet. In 1924, 33 fox farming permits had been issued in the Chugach National Forest, which includes nearly all islands in Prince William Sound. Foxes were fed salmon (*Oncorhynchus* spp.) and harbor seals (*Phoca vitulina*) on some islands (Bower and Aller 1918).

With the possible exception of Glacier Island (M. E. Isleib, Juneau, Alaska, personal communication), foxes have disappeared from all islands in Prince William Sound, according to local residents and Alaska Department of Fish and Game biologists. Also, no foxes remain on any islands in Cook Inlet, but in 1976, arctic fox tracks were found on East Chugach and Elizabeth islands (Chugach Islands) south of the Kenai Peninsula (Bailey 1977). Arctic foxes no longer survive on Pearl Island, which is between East Chugach and Elizabeth islands and was first stocked in 1894 (H. Hess, Anchorage, Alaska, personal communication). The only other island in the Gulf of Alaska region where introduced arctic foxes reportedly persisted by 1985 was Nuka Island (M. Tillion, Homer, Alaska, personal communication). Red foxes still are present on Wingham Island, southeast of Cordova, where apparently they have survived over 70 years since their reintroduction (Bower and Aller 1918). Though never reportedly stocked, Augustine Island still has red foxes, whose ancestors probably came there by crossing sea ice in 1971 (R. Baxter, Homer, Alaska, personal communication).

Alexander Archipelago

One hundred and eighty-two (40%) Alaskan islands that were known to have been stocked with

Table 4. *Introductions of foxes on islands in the Gulf of Alaska region, including Prince William Sound and Cook Inlet.*

Island name ^a	Seabird catalog map (Fig. 9) ^b	Species ^c	Year stocked ^d	Source ^e	Status ^f
Applegate	63	arfox	1923	3	d
Aurora	50	arfox	1929	3	d
Aurora	50	refox	1929	3	d
Axel Lind, Little Axel L.	63	arfox	1916	4	d
Bald-head Chris (Small)	63	arfox	1898	3	d
Bettles (James)	63	refox	1892	5	d
Bettles (James)	63	arfox	1924	2	d
Bligh	64	fox	1897	5	d
Bligh	64	arfox	1924	13	d
Blye	64	arfox	1929	1	d
Busby	64	arfox	1924	2	d
Carlson (Crafton)	63	fox	1898	14	d
Carlson (Crafton)	63	arfox	1924	2	d
Channel	64	arfox	1924	2	d
Chicken	63	fox	1924	15	d
Cohen	50	arfox	1920	6	d
Dangerous (Danger)	63	refox	1891	5	d
Dutch Group	63	refox	1917	4	d
Dutch Group	63	arfox	1924	2	d
Eaglek	63	arfox	1924	2	d
East Chugach	50	arfox	1900	16	p
Eleanor	64	arfox	1924	2	d
Eleanor	46	arfox	1929	1	d
Elizabeth	50	arfox	1900	3	p
Elrington	63	arfox	1924	2	d
Fairmount	63	arfox	1895	4	d
Flemming	63	arfox	1896	3	d
Fool	63	fox	1922	15	d
Gage	63	fox	1896	5	d
Glacier	63	arfox	1900	13	d
Goose	64	fox	1895	5	d
Goose	64	arfox	1897	12	d
Gravina	64	fox	1923	15	d
Green	63	fox	1895	5	d
Green	63	arfox	1897	12	d
Herring	50	arfox	1921	6	d
Hesketh	50	arfox	1900	3	d
Hesketh	50	refox	1929	1	d
Hinchinbrook	64	arfox	1929	1	d
Ingot	63	arfox	1924	2	d
Ismailof	50	arfox	1929	17	d
Kalgin	62	refox	1929	1	d
Kanak	64	arfox	1924	1	d
Kanak	64	refox	1929	3	d
Khantaak	46	arfox	1929	1	d
Knight	46	arfox	1924	2	d
Knight	63	arfox	1929	1	d

Table 4. *Continued.*

Island name ^a	Seabird catalog map (Fig. 9) ^b	Species ^c	Year stocked ^d	Source ^e	Status ^f
Kriwoi	46	arfox	1924	2	d
Latouche	63	arfox	1919	18	d
Lone	63	arfox	1919	3	d
Low	63	fox	1898	5	d
Mackod		arfox	1897	12	d
Martin (Whale and Fox)	64	arfox	1900	19	d
McKeon	50	arfox	1929	2	d
Middleton	48	arfox	1890	20	d
Naked	63	arfox	1898	6	d
North	63	arfox	1924	2	d
Nuka	50	arfox	1924	2	p
Observation	64	arfox	1924	2	d
Olsen	63	arfox	1920	3	d
Otmeloi	46	arfox	1924	2	d
Passage	50	arfox	1916	6	d
Peak (Peek)	63	fox	1895	5	d
Peak (Peek)	63	arfox	1898	6	d
Pearl	50	fox	1894	5	d
Pearl	50	arfox	1897	12	d
Perry	63	fox	1897	5	d
Perry	63	arfox	1915	4	d
Pond	63	fox	1895	5	d
Renard (Fox)	49	arfox	1901	21	d
Seal	64	arfox	1894	3	d
Smith (Big and Little)	63	fox	1898	14	d
Smith (Big and Little)	63	arfox	1924	2	d
Squire (Long)	63	fox	1897	5	d
Squire (Long)	63	arfox	1924	2	d
Squirrel	63	fox	1897	5	d
Squirrel	63	arfox	1924	2	d
Starinkof	50	arfox	1929	3	d
Starinkof	50	refox	1929	3	d
Storey (Little Naked)	63	arfox	1895	3	d
Unnamed (Sheep Bay)	64	arfox	1924	2	d
Wingham	64	refox	1917	4	p
Wingham	64	arfox	1924	2	d
Wooded	49	arfox	1924	2	d
Yukon	50	arfox	1900	3	d

^a Islands with the same name are different islands if map numbers are not identical. Names of islands in parenthesis are former or less common names.

^b Location map numbers refer to those in the Catalog of Alaskan Seabird Colonies (Sowls et al. 1978) that uses 1:250,000 scale maps from the U.S. Geological Survey (Fig. 9). Specific island locations that could not be determined are left blank.

^c Introduced species: arfox = arctic fox (*Alopex lagopus*), refox = red fox (*Vulpes vulpes*), and fox = species not specified.

^d Date of indicated introduction is earliest known; often additional introductions were made in later years. A blank space indicates an unknown introduction date.

^e The sources of dates of introductions (numbers) are in Appendix A.

^f Current status of fox population: d = disappeared (disappeared naturally or removed by fur trappers), e = eradicated by U.S. Fish and Wildlife Service personnel, p = foxes still present when island last checked.

foxes are in southeast Alaska (Fig. 5; Table 5). Red foxes were introduced on only Cleft, Dry, Kupreanof, Passage, and Sokoi islands. Arctic foxes also were released on three of these islands as well as on all the others. By 1924, 140 permits were in force for fox farming in the Tongass National Forest, which covers nearly all of southeast Alaska (Greely

1970). According to discussions with local residents, former fox farmers, Alaska Department of Fish and Game biologists, and J. Leekly, former manager of the state experimental fur farm in Petersburg, no foxes now remain on any islands in the Alexander Archipelago. Foxes put on some of these islands were principally reared in pens, though free-rang-

Table 5. *Introductions of foxes on islands in the Alexander Archipelago.*

Island name ^a	Seabird catalog map (Fig. 9) ^b	Species ^c	Year stocked ^d	Source ^e
Abbess	4	arfox	1929	1
Anguilla	4	arfox	1924	2
Aston	1	arfox	1929	1
Bare	11	arfox	1923	3
Bare	9	arfox	1929	1
Barrier	4	arfox	1924	2
Barrier	6	arfox	1929	1
Beardslee	9	arfox	1924	2
Bellena	4	arfox	1924	2
Benjamin	6	arfox	1924	2
Big Sukoi	6	arfox	1924	2
Biorka	5	arfox	1924	2
Black	3	arfox	1924	2
Blank	3	arfox	1924	2
Blashke	6	arfox	1924	2
Bluff	6	arfox	1924	2
Bold	6	arfox	1924	2
Broad	10	arfox	1924	2
Broad	9	arfox	1929	1
Brothers	8	arfox	1904	4
Bushy	1	arfox	1924	2
Carlton	4	arfox	1924	2
Castle	6	arfox	1924	2
Cat	3	arfox	1924	2
Cedar		fox	1900	5
Channel	4	arfox	1924	2
Channel	6	arfox	1925	6
Chichagof (Hoonah)	9	arfox	1929	1
Cleft	5	refox	1929	1
Coghlan	11	arfox	1924	2
Cohn		arfox	1925	6
Conclusion	6	arfox	1924	2
Cone	3	arfox	1924	2
Coney	6	arfox	1924	2
Converden	11	arfox		3
Crow Islands	9	arfox	1929	1

Table 5. *Continued.*

Island name ^a	Seabird catalog map (Fig. 9) ^b	Species ^c	Year stocked ^d	Source ^e
Dolgoi	1	arfox	1929	1
Dorn	9	arfox	1924	2
Dry	6	refox	1894	7
Dry	6	arfox	1901	8
Eagle	4	arfox	1924	2
Earnest		arfox	1924	2
East		arfox	1929	1
Elovoi	5	arfox	1929	1
Emmons	9	arfox	1924	2
Entrance	8	arfox	1924	2
Entrance	11	arfox	1929	1
Fair	6	arfox	1929	3
Fairway	5	arfox	1924	2
Fairway	9	arfox	1929	1
Fanny	6	arfox	1929	1
Faust	9	arfox	1924	2
Five Finger	8	arfox	1929	1
Florence		arfox	1929	3
Found	6	arfox		3
Gain	8	arfox	1929	1
Galankin	9	arfox	1924	2
Gallagher	11	arfox	1929	3
Gavianski	9	arfox	1924	2
Gedney	3	arfox	1924	2
George	10	arfox	1924	2
Goloi	9	arfox	1929	1
Grand	1	arfox	1924	2
Grant	3	arfox	1924	2
Green	4	arfox	1924	2
Grey's	6	arfox	1924	2
Grief	6	arfox	1924	2
Grindall	4	arfox	1924	2
Halibut	11	arfox	1929	1
Harbor	9	arfox	1924	2
Harmony	4	arfox	1929	1
Harris	3	arfox	1924	2
High	4	fox	1900	5
High		arfox	1922	9
Hill	9	arfox	1919	10
Hogan	9	arfox	1924	2
Hoonah	11	arfox	1924	2
Horseshoe	4	arfox	1924	2
Hotspur	3	arfox	1924	2
Hound	6	arfox	1904	3
Hume	3	arfox	1924	2
Hump	3	arfox		3
Inian	10	arfox	1924	2

Table 5. *Continued.*

Island name ^a	Seabird catalog map (Fig. 9) ^b	Species ^c	Year stocked ^d	Source ^e
Island Point	2	arfox	1924	2
Jack Knife	5	arfox	1924	2
Jackson	1	arfox	1924	2
Kahsheets	6	arfox	1924	2
Kasiana	9	arfox	1924	2
Keene	6	arfox	1929	1
Keku Islets	5	arfox	1924	2
Kochu	45	arfox	1929	1
Kosha	45	arfox	1924	2
Kupreanof	6	refox	1919	11
Legma	5	arfox	1924	2
Legman	5	arfox	1929	1
Lemesurier	10	arfox	1924	2
Lesnoi	6	arfox	1929	1
Level	6	arfox	1924	2
Liesnoi	5	arfox	1924	2
Lincoln	6	arfox	1924	2
Long	5	arfox	1924	2
Long	1	arfox	1924	2
Long	9	arfox	1929	1
Long	11	arfox	1929	3
Lung	6	arfox	1924	2
Maeser	5	arfox	1929	1
Maid	5	arfox	1924	2
Marsh	6	arfox	1924	2
McFarland	4	arfox	1924	2
Meadow	6	arfox	1929	1
Meares	4	arfox	1924	2
Middle	6	arfox	1924	2
Midway	9	arfox	1929	1
Mink	5	arfox	1924	2
Monte Carlo	6	arfox	1924	2
Moss	6	arfox	1924	2
Necker Group (three islands)	5	arfox	1924	2
Niblack	6	arfox	1924	2
Nichols	4	arfox	1924	2
Northerly	6	arfox	1924	2
Onslow	4	arfox	1924	2
Osten	3	arfox	1924	2
Passage	9	refox	1929	1
Patterson	4	fox	1900	5
Patterson	4	arfox	1904	3
Pearl	6	arfox		12
Pearl	9	arfox	1929	1
Peisar	5	arfox	1924	2
Percy	2	arfox	1924	2
Point Madan	4	arfox	1924	2

Table 5. *Continued.*

Island name ^a	Seabird catalog map (Fig. 9) ^b	Species ^c	Year stocked ^d	Source ^e
Porpoise	11	arfox	1924	2
Portland	11	arfox	1924	2
Prince	9	arfox	1929	1
Pybus Bay	8	arfox	1924	2
Ray		arfox	1924	2
Read	8	arfox	1924	2
Robert	8	arfox	1945	3
Romp	8	arfox		3
Ross	5	arfox	1929	3
Round	9	arfox	1924	2
Rudyard	3	arfox	1924	2
Screen	6	arfox	1929	2
Seclusion Harbor	6	arfox	1924	2
Seduction	45	arfox	1924	2
Senatap (Cenopath)	10	arfox	1929	3
Shaw	10	arfox	1924	2
Siginak	9	arfox	1924	2
Siginaka	9	arfox	1929	1
Sisters	11	arfox	1924	2
Skiff	6	arfox	1929	1
Skin	4	arfox	1924	2
Sokoi	6	arfox	1905	4
Sokoi (Sukoi)	6	refox	1916	4
Sokoi, Little	6	arfox	1924	2
Sokolof	6	arfox	1924	2
Southerly	6	arfox	1924	2
Square	3	arfox	1924	2
St. John's	6	arfox	1919	6
Storm	8	arfox	1924	2
Strait	6	arfox	1918	3
Strawberry	10	arfox	1929	3
Strits		arfox	1919	9
Sullivan	11	arfox	1924	2
Sumdum	8	arfox	1899	4
Sumner	6	arfox	1924	2
Sunset	8	arfox	1924	2
Tava	5	arfox	1929	1
Three Hill	10	arfox	1924	2
Torsar	5	arfox	1924	2
Trader	9	arfox	1924	2
Turnabout	8	arfox	1924	2
Ubak		arfox	1929	1
Unnamed (Freshaw Bay)	9	arfox	1924	2
Unnamed (Khaz Head)	9	arfox	1924	2
Unnamed (Moirs Sound)	4	arfox	1924	2
Unnamed (Rough Channel)	9	arfox	1924	2

Table 5. *Continued.*

Island name ^a	Seabird catalog map (Fig. 9) ^b	Species ^c	Year stocked ^d	Source ^e
Unnamed (Tebenkof Bay)	5	arfox	1924	2
Unnamed (near Crow Island)	1	arfox	1924	2
Vank	6	arfox	1924	2
Walter	8	arfox	1924	2
Wehrlick	3	arfox	1924	2
Werlick	2	arfox	1920	3
West	6	arfox	1929	1
Whale	9	arfox	1929	1
Whitney	8	arfox	1924	2
Willoughby	10	arfox	1929	1

^a Islands with the same name are different islands if map numbers are not identical. Names of islands in parenthesis are former or less common names.

^b Location map numbers refer to those in the Catalog of Alaskan Seabird Colonies (Sowls et al. 1978) that uses 1:250,000 scale maps from the U.S. Geological Survey (Fig. 9). Specific island locations that could not be determined are left blank.

^c Introduced species: arfox = arctic fox (*Alopex lagopus*), refox = red fox (*Vulpes vulpes*), and fox = species not specified.

^d Date of indicated introduction is earliest known; often additional introductions were made in later years. A blank space indicates an unknown introduction date.

^e The sources of dates of introductions (numbers) are in Appendix A. No foxes remain on any islands in southeast Alaska (the Alexander Archipelago).

ing animals occurred on most. Also, in the Alexander Archipelago, feeding stations were established on many islands; fish were commonly left on beaches or at feeding houses, where the foxes were captured in winter when pelts were prime (J. Leekly, Juneau, Alaska, personal communication). Compared with islands along the Alaska Peninsula and the Aleutians, few large seabird colonies exist on the forested islands in southeast Alaska (Sowls et al. 1978; S. Hatch, research biologist, U.S. Fish and Wildlife Service, Anchorage, Alaska, personal communication). Thus, few islands in this region provided an ample supply of birds as food for foxes. If not artificially fed, introduced foxes largely had to rely on intertidal organisms and scavenging. On most islands in southeast Alaska, introduced foxes also faced competition and predation from American black bears (*Ursus americanus*), brown bears (*U. arctos*), and gray wolves (*Canis lupus*) (Manville and Young 1965). Undoubtedly, another reason for the disappearance of introduced arctic foxes on all islands in southeast Alaska was unsuitable habitat. Red foxes occur in small numbers on the mainland of southeast Alaska, but are not indigenous to the rain forests of the Alexander Archipelago (Manville and Young 1965).

Causes of Disappearance of Introduced Foxes

Foxes persist on only 46 of the 455 recorded islands to which foxes were introduced (personal observation). Most islands that still have foxes are in the Aleutians and south of the Alaska Peninsula. Foxes disappeared naturally or were removed by trappers other than U.S. Fish and Wildlife personnel on the remaining 388 islands. Because all foxes died out on islands in the Alexander Archipelago and in Prince William Sound, unfavorable habitat seems to have precluded the long-term survival of both red and arctic foxes in these regions. Inadequate food, especially after the foxes eliminated most nesting birds on some islands, probably was the key factor for the disappearance of foxes from many islands. Also, on most islands in these regions, fox farmers supplemented natural foods, whether birds, carrion, or intertidal organisms, with fish and marine mammals (J. Leekly, personal communication). When fox pelt prices plummeted in the 1930's, sale of salmon and other fishes to canneries generally became more profitable, and consequently foxes no longer were fed. Using traps

or poison, fur trappers sometimes removed all foxes before abandoning an island. Earlier indiscriminate use of poison baits by trappers to easily obtain pelts on some large islands, such as Nagai Island in the Shumagin Islands and Shuyak Island north of Afognak Island, inadvertently eliminated all red foxes (Evermann 1914). Arctic foxes survived at low densities on only four islands in the western Gulf of Alaska (Chugach Islands, Barren Islands, and Nuka Island) (Bailey 1977). Red foxes were placed on only eight islands in these regions and survived on only Wingham Island.

In some areas such as Prince William Sound and southeast Alaska, the presence of bears may have adversely affected the survival of introduced foxes. With the exception of Chirikof Island south of Kodiak Island, introduced foxes vanished from the other 17 islands south of the Alaska Peninsula east of the Shumagin Islands, yet still thrive on 17 islands from the Shumagins to the western end of the Alaska Peninsula. Brown bears regularly visit most of the islands south of the upper half of the Peninsula (Fig. 12), but rarely occur on islands south of the lower Peninsula (Bailey and Faust 1984), probably because of the presence of several villages along the lower Peninsula and the fact that people shoot bears. Bears raid seabird colonies on islands east of the Shumagins and seem to have supplanted foxes as a limiting factor on the distribution and abundance of some species of nesting seabirds (Bailey and Faust 1984). Because the cli-

mate and tundra habitat seem similar on all islands south of the Alaska Peninsula, the presence of bears in part of the region seems to be the only significant factor to account for the inverse relation between foxes and bears. Bears probably destroy fox dens on islands.

The presence of river otters (*Lutra canadensis*) may also affect foxes, for foxes, especially arctic foxes, are usually absent or in low numbers on islands inhabited by river otters. Because they sometimes also heavily prey on seabirds, river otters would compete with foxes on some islands (Bailey 1978). Rabies, which has been documented in river otters on the Alaska Peninsula, or other diseases introduced to islands by otters also could be a factor.

Another possible explanation for the extirpation of introduced foxes on some islands may be inbreeding. Depending on the number and the genetic fitness of the original stock, inbreeding may be a survival factor, particularly on small islands. Deleterious recessive genes or mutations could cause isolated populations to die out. Some fox farmers traded breeding stock on different islands to avoid this potential problem (M. Uttecht, Cold Bay, Alaska, and A. Gronholdt, Sand Point, Alaska, personal communication). Nonetheless arctic foxes still survive on islands as small as 32 ha. They are gone from most of the islands less than roughly 500 ha. In the Channel Islands off California, inbreeding seemingly has had little effect on island

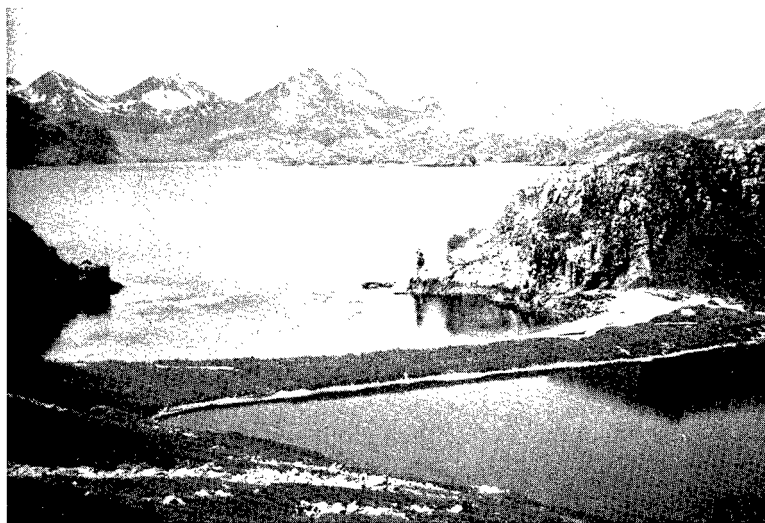


Fig. 12. Arctic foxes were released on David Island, south of the Alaska Peninsula, in 1930. Although foxes appear to no longer be present, large numbers of seabirds have not recolonized this island, probably because brown bears periodically swim to the island in search of nesting seabirds. Photo by N. Faust.

foxes (*Urocyon littoralis*) that have been isolated on six islands for up to possibly 16,000 years (Wayne et al. 1991).

Tsunamis also reportedly annihilated fox populations on some small islands. In 1946, a large tsunami (30 m at Unimak Island) at the eastern end of the Aleutians allegedly killed all foxes on certain small, low islands in the Sandman and Sanak reefs (Fig. 6; M. Uttecht, personal communication).

In summary, although predation, competition, inbreeding, and possibly disease probably accounted for the demise of foxes on some islands, the chief reason for their disappearance from islands lacking suitable beaches and intertidal areas with food seemingly was reproductive failure and starvation after the destruction of accessible bird colonies that provide winter caches.

Effects of Introduced Foxes on Insular Avifauna

Diets of foxes on different islands depend on individual island characteristics such as size, topography, and ocean currents depositing carrion; species and numbers of nesting birds; presence of marine mammal rookeries, introduced rodents, or other animals; availability of creeks with spawning salmon; and good beaches for scavenging dead marine birds and mammals and for procuring intertidal invertebrates. Besides killing birds for immediate needs, foxes store surplus birds and eggs for use in winter when few birds are present. For example, Murie (1959) found single larders with over 100 seabirds of several species.

To some degree, nearly all island birds are harmed by introduced foxes. Colonial breeding seabirds that nest on the surface of the ground or in soil burrows are usually the first species to disappear because of fox predation. Seabirds that nest in rock crevices are somewhat safe from foxes, but only cliff-nesters, such as kittiwakes (*Rissa* spp.), are largely safe. Nesting loons (*Gavia* spp.), waterfowl, and shorebirds also are highly vulnerable to foxes and are often entirely eliminated as breeders on islands. Ptarmigans (*Lagopus* spp.) also nest on the surface of the ground and are on most larger islands. Breeding passerines often also are harmed by foxes on islands west of the Gulf of Alaska, all of

which are treeless. The only other group of birds that inhabits most islands on which foxes were released are raptors, primarily bald eagles (*Haliaeetus leucocephalus*) and peregrine falcons (*Falco peregrinus*). Raptors generally are harmed indirectly by foxes on many islands because of the elimination or sharp reduction in bird populations on which raptors depend for food; however, on a few islands, the introduction of rodents along with foxes provided additional food sources for some species of hawks and owls (personal observation).

Seabirds

Predation by exotic species on islands worldwide has historically been responsible for the decline or extinction of more seabird populations than any other factor (Moors and Atkinson 1984). Most of Alaska's 38 species of breeding seabirds nest on islands to avoid predatory land mammals. The harm by foxes introduced to Alaskan islands became known earliest in the Aleutians, where foxes were first released. As early as 1811, about 20 years after arctic foxes were brought to Atka Island, local Aleuts were complaining about foxes driving away birds that formerly were very numerous and whose feathers and skins were used for clothing (Black 1984). By then the scarcity of birds on Atka Island already was forcing the Aleuts to travel to other islands, and on Attu Island, site of the first known introduction of foxes in the Aleutians, birds were termed rare by 1812 and Aleuts were making clothing from fish skins rather than bird skins (Black 1984). Early Russian accounts on other islands also mention how the "polar foxes have chased off the fowl which nowadays are afraid even to come ashore, not to mention laying eggs and hatching young. Everywhere the polar foxes catch birds, frighten them, and steal eggs..." and in 1812, it was also mentioned that "where there are no polar foxes, there are many birds" (Black 1984). The birds referred to were primarily tufted puffins (*Fratercula cirrhata*), gulls (*Larus* spp.), and ducks, all of which are burrow- or surface-nesters. However, even cliff-nesting seabirds were affected by foxes, as indicated by remarks that foxes crawl everywhere along the cliffs in search of birds (Black 1984). The effects of foxes on cliff-nesting seabirds is illustrated by the restriction of the distribution of nesting birds on St.

Lawrence Island in the Bering Sea (Fig. 1), where foxes are indigenous on islands because of seasonal pack ice (Fay and Cade 1959).

Dall (1874) and Nelson (1887) conducted the first significant biological survey of the Aleutian Islands after the transfer of Alaska from Russian control to the United States in 1867. Dall observed that on islands like Attu and Atka, where foxes had been introduced, the birds primarily nested on offshore rocks and islets or only in inaccessible locations. On fox-free islands, however, the habits of the same species of seabirds were very different because they nested on banks and hillsides of the main islands and avoided the offshore islets altogether. Birds were "bold and fearless" on fox-free isles, which were comparatively devoid of birds after the arrival of foxes (Dall 1874). The deleterious effects of foxes on seabirds also were recognized early on in the Commander Islands. Grebnitzky (1902) indicated that seabirds and their eggs were the chief food source of foxes in summer.

The comprehensive biological survey of islands south of the Alaska Peninsula and the Aleutian Islands by Olaus Murie in 1936 and 1937, began to awaken resource managers to the deleterious effects of foxes on seabirds and waterfowl. His findings were supported by additional surveys (Alaska Maritime National Wildlife Refuge files). Some of the documented harm of introduced foxes on seabirds follows (Murie 1936, 1937, 1959). Large breeding colonies of Cassin's auklets (*Ptychoramphus aleutica*) and ancient murrelets (*Synthliboramphus antiquus*) in the Sanak Islands, off the tip of the Alaska Peninsula, vanished after the introductions of foxes. Cassin's auklets also disappeared from Adugak, Keegaloo, and Ilak islands and from small islands off Amliia Island. Storm-petrels (*Oceanodroma* spp.) seemingly were eliminated by arctic foxes on Salt and Ilak islands. Local Aleuts related to Murie (1936) that foxes finished the auklets previously nesting on Adugak Island and mentioned how numerous birds were on other islands, such as Salt and Bobrof, before foxes were released on them. Northern fulmars (*Fulmarus glacialis*) reportedly nested on Gareloi Island before the arrival of arctic foxes, and this species seemingly disappeared from Segula Island after Murie's visit because he found large numbers of them, but they are no longer present (U.S. Fish and Wildlife Service 1980). Murie noted that whiskered

auklets (*Aethia pygmaea*) were generally becoming scarce in the Aleutian Islands; 50 years earlier, Turner (1886) reported they had vanished from the Near Islands in the western Aleutians. Storm-petrels also nested on Amchitka and Kiska islands before the release of arctic foxes (Nelson 1887; Scheffer 1980).

On many islands, birds were referred to as feed by fox trappers, and declines in numbers of fox pelts on small islands were common within a few years after they were introduced. On some islands, like Uliaga and Kagamil, trappers indicated that after the feed leaves (i.e., the breeding birds migrate), they fed their foxes in winter (Murie 1936). Though Uliaga Island was still regarded an outstanding seabird island in 1936, 6 years after foxes were introduced, virtually no birds nest there now (Bailey and Trapp 1986). On adjacent Kagamil Island, the enormous number of crested auklets (*Aethia cristatella*) noted by Gabrielson (1940) are gone. As Murie (1937) noted over 50 years ago, there was an impression that a fox island was good (for trapping foxes) only so long, and this period usually corresponded with the length of time that the birds lasted. Murie (1936) estimated that foxes were killing 40,000 or more seabirds annually on some islands in the Aleutians. A government report in 1938 clearly depicted the severity of declining bird population on islands from the introduction of foxes. The Bureau of Biological Survey, U.S. Department of Agriculture (1938), indicated that numbers of fox furs had drastically declined compared with when plenty of food (birds) was available. The islands being used for fox farming were almost entirely depleted of birds and thus fox production was much lower. Before they were exterminated on Toporkov Island in the Commander Islands, introduced foxes drastically reduced numbers of tufted puffins (Litvinenko 1987).

Besides testimony from Aleuts and trappers, other evidence that introduced foxes were destroying seabird populations on many islands was apparent. Murie (1959) examined 2,500 arctic fox scats from 22 islands in the Aleutians and found they consisted of 58% birds, mostly seabirds. Between 1975 and 1982, West (1987) noted that seabirds comprised 49% (frequency) of 193 fox scats from three different islands in the Aleutians. Subsequent research revealed that birds are underrepresented in feces because of differential di-

gestibility of food classes and the actual percentage of consumed birds was probably much higher (Smits et al. 1989). On some islands, foxes were almost totally subsisting on seabirds, mainly auklets and storm-petrels (Murie 1959).

A recent natural invasion of a seabird island by foxes that crossed the ice in the Bering Sea illustrated the devastation a few of these animals can cause to nesting seabirds. Two red foxes reached Shaiak Island, site of 156,000 nesting seabirds, before the 1976 nesting season and severely reduced the nesting success of 7 species of seabirds breeding on this small island that year (Petersen 1982). Few birds that nested on slopes accessible to foxes produced young. All of roughly 100 pairs of common eiders (*Somateria mollissima*) lost their eggs, and none of the estimated 2,500 glaucous-winged gulls (*Larus glaucescens*) nesting on the island is known to have produced chicks. Most of the 25,000 pairs of common murres (*Uria aalge*) on Shaiak Island nested on sod-covered slopes and plateaus, and their eggs vanished soon after laying. Double-crested cormorants (*Phalacrocorax auritus*) and tufted puffins also sustained heavy losses. Petersen (1982) found the remains of thousands of eggs in gull territories, indicating that, besides the two foxes, gulls also destroyed many eggs after the foxes presumably flushed incubating birds. She also found eggs cached by foxes all over the island, as well as hundreds of dead adult puffins and gulls

that presumably were killed by foxes. Because their nests were on inaccessible cliffs, black-legged kittiwakes (*Rissa tridactyla*) were unaffected by the two foxes. Fortunately, no foxes were present during the 1977 breeding season on this island.

Arctic foxes, which reached Walrus Island (Figs. 13 and 14) in the Pribilof Islands by crossing on ice, destroyed one of the largest common murre colonies in Alaska (Preble and McAtee 1923; Byrd 1987). Likewise, red foxes, which reached Augustine Island on ice in Cook Inlet in 1971, eliminated all glaucous-winged gull colonies on that island (R. Baxter, Homer, Alaska, personal communication).

In 1976, Moe (1977) estimated 13 red foxes on one part of Big Koniugi Island in the Shumagin Island group killed nearly 800 crested auklets and 100 horned puffins (*Fratercula corniculata*) in less than 3 months (Fig. 15). On Baccaleiu, a 600 ha island off Newfoundland, an estimated 12 red foxes killed about 31,000 Leach's storm-petrels (*Oceanodroma leucorhoa*) in a breeding season (Skepkovich 1986).

Southern et al. (1985) noted surplus killing of nesting ring-billed gulls (*Larus delawarensis*) on a small island in Lake Michigan during 9 years. During this period, the gull population of originally nearly 5,500 pairs declined 84% because of intense fox predation. In 1975, foxes killed an average of over 87 chicks per night, and many additional chicks died of exposure after adults abandoned



Fig. 13. Murres on Walrus Island before foxes reached it presumably in 1971. Photo courtesy of the Fish and Wildlife Service.



Fig. 14. Walrus Island now is devoid of murre because of resident foxes (1989). Photo by A. Sowls.



Fig. 15. Red fox pounces on crested auklet (Big Koniuji Island, Shumagin Islands). Photo by E. P. Bailey.

nests approached by foxes. Herring gulls (*Larus argentatus*) experienced total nesting failure in every year but one because of foxes. Kadlec (1971) made similar observations on the effects of introduced foxes on gull colonies.

Prishvin (1958 in Litvinenko 1987) documented the complete destruction of seabird colonies on Furugelm Island (Russia) after the release of foxes. Fecal analysis of red foxes at a seabird colony in the Baltic Sea revealed that the proportion of birds in their diets rose from 14% volume in winter to 80% in June (Pruter and Vauk 1990). Blokpoel (1971) witnessed almost complete reproductive failure of pelicans (*Pelecanus* spp.), cormorants (*Phalacroco-*

rax spp.), and gulls (*Larus* spp.) on Backes Island in Canada after red foxes gained access to the island. The degree of devastation of nesting colonial seabirds by introduced predators elsewhere in the world is perhaps most graphically illustrated on Kerguelen Island in the southern Indian Ocean where an estimated 1.2 million birds were being killed by feral cats (*Felis catus*) each year (Moors and Atkinson 1984).

Ultimately, the removal of fossorial and surface-nesting seabirds by foxes and concomitant absence of bird excrement resulted in marked changes in island vegetation (personal observation). Islands with huge colonies of fossorial birds have much

lusher vegetation and different species composition than islands devoid of recycled nutrients from thousands of seabirds (Fig. 16). Lusher vegetation enhances the protective cover for nesting seabirds and waterfowl and lessens erosion. Eagles, gulls, and ravens (*Corvus corax*) seem to capture more birds in sparse vegetation (personal observation).

Waterfowl

In addition to the decline or disappearance of seabirds on various islands after introductions of foxes, Murie (1936, 1937) reported marked decreases in breeding waterfowl in the Aleutians. By 1936, the formerly abundant waterfowl population on Agattu Island was scarce, and Aleuts blamed arctic foxes first released in 1880 (Bailey 1880). Dall (1873) found black brants (*Branta bernicla nigricans*) nesting on nearby Attu Island and on Kiska Island. He probably meant Aleutian Canada geese (*Branta candaensis leucopareia*), an endangered subspecies which once bred abundantly between Kodiak Island and the Kurile Islands north of Japan. By 1936, Aleutian Canada geese were absent from both Kiska and Attu islands; the village chief on Attu Island also informed Murie that these geese formerly nested there. Turner (1886) found thousands of geese on the Near Islands, an island group with much good nesting habitat for Aleutian Canada geese. Geese were termed the most abundant bird on Agattu Island in 1910 (Clark 1910), where

they bred by the thousands, but by 1937, Murie (1937) observed fewer than six pairs. Aleutian Canada geese remained on fox-free Buldir Island and until 1979 were thought to be the only surviving breeding population of this subspecies (Jones 1963). In the eastern Aleutian Islands, they originally nested on the Baby Islands, a group of small fox-free islands in the Fox Islands, where red foxes are indigenous on the larger ones (Veniaminov 1984). Veniaminov also mentioned geese nesting on Kagamil in the Islands of Four Mountains. Aleutian Canada geese undoubtedly nested on fox-free islands south of the Alaska Peninsula. For example, in 1790, Merck (Pierce 1980) recorded Canada geese nesting in the Semidi Islands. Foxes were released on Chowiet and Aghiyuk islands, the two largest islands, in the 1880's (Ashbrook and Walker 1925), and a relict Aleutian Canada goose population was discovered in 1979 on 120-ha Kiliktagik Island (Hatch and Hatch 1983). Also, 200 years ago geese were reported in the Shumagin Islands during the breeding season (Pearse 1968), but now geese are present in this area only in winter and during migration, presumably because of introduced foxes (personal observation). Another remnant breeding population of Aleutian Canada geese was located in 1982 on Chagulak, a fox-free island (Fig. 17) in the central Aleutians (Bailey and Trapp 1984).

Common eiders were seriously affected by fox farming in the Aleutians and no doubt elsewhere. Murie (1936) noted that eiders, like geese and some



Fig. 16. Lush grass on Buldir Island. Vegetation on fox-free islands is generally much taller and greener because of the excrement of huge numbers of birds. Photo by E. P. Bailey.

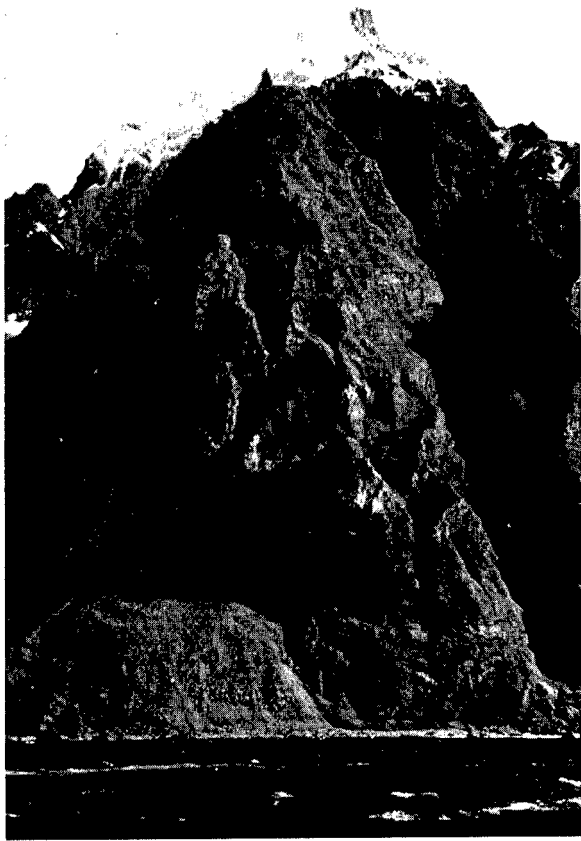


Fig. 17. Since foxes were not released here, rugged Chagulak Island has one of the largest seabird nesting colonies in the Aleutians. Over a million birds, mainly fulmars and murre, swirl about the small island in spring and summer. Aleutian Canada geese survived here and on two other fox-free islands. Photo by E. P. Bailey

species of seabirds, often nested on only islets adjacent to islands with foxes, and he concluded that eiders would have been nesting on practically all islands in the Aleutians, were it not for introduced foxes. In the 1780's, eiders were abundant nesters on Kanaga Island in the central Aleutians (Pearse 1968), but the population was much reduced after foxes were introduced in the 1920's. Schamel (1977) regarded arctic foxes as the principal deterrent to nest location by common eiders on islands off Alaska's Arctic coast. Other nesting ducks, especially green-winged teals (*Anas crecca*), also declined because of foxes (R. D. Jones, Jr., former manager of the Aleutian Islands National Wildlife

Refuge, personal communication). Stickney (1989) found that a single arctic fox on the Yukon River Delta was capable of taking 56 brant eggs per day.

Ptarmigans and Passerines

Rock ptarmigans (*Lagopus mutus*) evidently were heavily preyed on by foxes on some islands because they disappeared on Amukta, Agattu, Alaid, Nizki, Segula, and Shemya islands after foxes were introduced. Aleuts reported that ptarmigans were numerous in the late 1800's on Agattu Island before the release of foxes (Turner 1886), but had been extirpated by the time Murie visited the island in 1937 (Murie 1959). Before fox eradication on Amchitka Island, ptarmigans were very scarce (Kenyon 1961). Ptarmigans seemingly were extirpated from several other islands after foxes were introduced, such as Seguam, Little Sitkin, Semisopochnoi, and the Delarofs (Bailey and Trapp 1986; Day et al. 1978). Whether ptarmigans were on these islands before the introduction of foxes is not definite, but there seems little other reason for their absence. The lack of ptarmigans on fox-free Buldir Island is understandable because of its isolation. Both rock and willow (*Lagopus lagopus*) ptarmigans seemed scarce to me on islands off the Alaska Peninsula inhabited by foxes.

Though winter wrens (*Troglodytes troglodytes*), song sparrows (*Melospiza melodia*), and other breeding passerines generally are much less numerous on islands where foxes were released (personal observation), no certain instance of extirpation of a passerine has been recorded.

Introduced Rodents

Birds also probably were harmed by incidental introductions of rodents. After 1819, when the Russian-American Company encouraged introductions of foxes to islands, ground squirrels from the Kodiak area were released on various islands in the Rat Island group to provide "fodder for foxes" (Black 1984). Some species of ground squirrels are known predators of eggs (Horn 1938; Stanton 1944; SOWLS 1948; Cade 1951; Sargeant et al. 1987), and they may cause significant mortality among nesting puffins (Leschner and Burrell 1977). I have noticed that most species of nocturnal nesting

seabirds are absent on islands off the Alaska Peninsula with arctic ground squirrels, even after the disappearance of foxes.

In the Aleutians, arctic ground squirrels released by the Russians still remain on Unalaska and Amaknak islands. Ground squirrels are also present on Kavalga Island, but whether they originated from early Russian introductions or from a reported 1920 introduction is uncertain (Murie 1959). Ground squirrels are also present on many islands off the Alaska Peninsula where they seem, because of their absence on other nearby islands, to have been introduced (personal observation). I found no records of introductions of ground squirrels in this region.

Norway rats (*Rattus norvegicus*) also became established on Kodiak Island and on 21 islands in the Aleutians accidentally through shipwrecks or from anchored vessels (Appendix B). The earliest known rat infestation occurred on Rat Island before 1780 after a shipwreck (Brecht 1977). Rats, now introduced to at least 82% of the world's islands, have proved very destructive to many species of

nesting birds (Atkinson 1985). In 1992, large numbers of auklets killed by rats were found on Kiska Island in the Aleutians (G. Byrd, U.S. Fish and Wildlife Service, Adak, Alaska, personal communication). The presence of rats probably also exacerbated the effects of foxes on birds because elsewhere in the world, if mammalian predators which feed on rats are also present, the injurious effect on nesting birds is usually greater (Atkinson 1985). Rats probably sustain higher fox populations on islands by providing an additional food source, especially in winter when breeding birds are absent.

Concomitant introductions of other rodents, such as voles (*Microtus* spp.) and house mice (*Mus musculus*; Appendix B), also occurred with the release of foxes on some islands. Early fox farmers filled barrels with ground squirrels and "mice" and released them indiscriminately on islands to encourage newly imported fox populations (Bower 1920; Peterson 1967). Introduced voles overran some islands off the Alaska Peninsula (Fig. 18), damaging habitat for fossorial seabirds (Bailey



Fig. 18. Severe overgrazing by ground squirrels and voles has led to erosion on Chankliut Island south of the Alaska Peninsula. Photo by N. Faust.

and Faust 1981). Voles also prey heavily on the eggs of some species of seabirds (Sealy 1982; Murray et al. 1983).

Comparisons of Bird Populations on Islands With and Without Foxes

One of the most drastic ways to depict the injurious effect of introduced foxes on insular avifauna is the comparison of bird populations and species diversity on similar islands with and without foxes. With the exception of cliff-nesters, such as kittiwakes and murrelets, a marked difference exists between bird populations on islands with and without foxes. It was noted early that islands with large bird populations, except cliff-nesters, were free of foxes. Referring to one of the Kurile Islands south of the Kamchatka Peninsula as a "veritable paradise for birds," Snow (1897) stated that the principal reason for so many birds was the absence of foxes. Murie (1959) repeatedly illustrated this conclusion after surveying the Aleutian Islands. Numerous examples of the abundance of fossorial and surface-nesting seabirds on only fox-free islands are in the *Catalog of Alaskan Seabird Colonies* (Sowls et al. 1978). Fork-tailed storm-petrels (*Oceanodroma furcata*), Leach's storm-petrels, glaucous-winged gulls, Aleutian (*Sterna aleutica*) and arctic (*Sterna paradisaea*) terns, ancient murrelets, Cassin's auklets, rhinoceros auklets (*Cerorhinca monocerata*), and tufted puffins are not present in any significant numbers on islands with foxes. Least (*Aethia pusilla*), crested and parakeet auklets (*Cyclorhynchus psittacula*), and horned puffins generally nest in talus slopes and therefore have been able to coexist with foxes on some islands. However, the general distribution of alcids and other insular avifauna on arctic islands, such as Greenland, is highly influenced by foxes; on some smaller islands off Greenland, visits by arctic foxes often cause seabirds to refrain from breeding (Larson 1960).

Seabird species that are nocturnal at breeding sites, generally burrow-nesters, seem to have suffered most from introduced foxes. Few nocturnal nesting seabirds occur on any islands off the Alaska Peninsula that are or recently were inhabited by foxes, but are abundant on islands with suitable

habitat that never had foxes (Bailey 1978, 1983, 1988; Bailey and Faust 1980, 1981, 1984). This is also generally true for islands in the Aleutian archipelago (Day et al. 1978, 1979; U.S. Fish and Wildlife Service 1980, 1981; Nysewander et al. 1982; Bailey and Trapp 1986). The greatest species diversity and abundance of nocturnal seabirds in Alaska is on fox-free Buldir Island (Byrd and Day 1986). In the Barren Islands, around Kodiak Island, and on other islands in the Gulf of Alaska, large colonies of burrow-nesting seabirds are absent from islands with foxes (Bailey 1976, 1977; Sowls et al. 1978). Although fossorial and surface-nesting seabirds do manage to survive in limited numbers on a few rugged islands in the Aleutians still inhabited by foxes, they do so only on talus slopes, cliff ledges, and in lava flows where their nests are relatively inaccessible (personal observation).

On a few islands, fossorial birds persisted because of their abundance. On Baccaleiu Island (Newfoundland), where over 30,000 storm-petrels a year were killed by red foxes, the overall population exceeded 6 million birds (Skepkovych 1986). The only populations approaching such numbers of nocturnal seabirds in Alaska are on Buldir and Chagulak islands in the Aleutians, some of the Sandman Reefs south of the Alaska Peninsula, and on Forrester Island in the Alexander Archipelago (Sowls et al. 1978; Bailey and Faust 1980; Bailey and Trapp 1986). Foxes have never occupied these islands.

Recovery of Insular Avifauna After the Disappearance of Foxes

On some small Alaskan islands, large increases in numbers of breeding birds occurred after the disappearance or removal of all foxes. In the Aleutians, horned puffins, arctic and Aleutian terns, and red-necked phalaropes (*Phalaropus lobatus*) recolonized Ogliuga and Skagul islands after arctic foxes were eradicated (Day et al. 1979). Vsevidof, Kaligagan, Aiktak, Baby, and several other islands in the eastern Aleutians were once fox farms and were largely devoid of birds during that period. Now all have large populations of storm-petrels, tufted puffins, and other fossorial birds. Murie (1937) recommended that Kaligagan Island continue as a fox farm because of a lack of notable bird colonies, yet

in 1980, after foxes were gone, an estimated 125,000 burrowing birds nested there (Nysewander et al. 1982). During the 1920's, foxes were put on, but later vanished from all the Baby Islands; in 1980, over 170,000 seabirds of 7 burrow- and surface-nesting species were present (Nysewander et al. 1982). Nearby Egg Island, which is similar in size and habitat and which never had foxes, has nearly 500,000 fossorial birds, probably the largest concentration of tufted puffins anywhere in Alaska. When foxes vanished from the aforementioned small islands in this area is not known, but because these islands lack suitable feeding beaches, winter survival of foxes would have become increasingly difficult as cached birds diminished because of heavy summer predation year after year.

On Agattu, Alaid, and Nizki islands, after the recent eradication of foxes, numbers of nesting seabirds and waterfowl increased, and Aleutian Canada geese began to nest for the first time in 50 years (G. Byrd, U.S. Fish and Wildlife Service, Adak, Alaska, personal communication). Specifically, on Alaid and Nizki islands, large increases in breeding bird populations were documented for 24 breeding species, including red-throated loons (*Gavia stellata*), seabirds, waterfowl, shorebirds, and passerines, within 7 years after foxes were removed in 1976. The numbers of 12 seabird species increased at least an average of 500% and of 4 species of waterfowl, rose an average of at least 400% (Zeilemaker and Trapp 1986). By 1990, tremendous increases in populations of some species of seabirds were recorded on Alaid and Nizki islands. For example, breeding pelagic cormorants (*Phalacrocorax pelagicus*) increased from about 20 to 650 birds in 14 years, and glaucous-winged gulls from less than 500 in 1976 to nearly 4,000 in 1990 (Byrd et al. 1992). More than 200 common eider nests were found in 1992 (G. Thomson, U.S. Fish and Wildlife Service, Adak, Alaska, personal communication), but none were found in 1969 when foxes were present (personal observation). Ptarmigan and green-winged teals made a spectacular recovery on Amchitka Island soon after foxes were removed (Williamson and Emison 1969). Aleutian Canada geese were discovered nesting on Amukta Island in 1989, 6 years after foxes were removed (G. Byrd, U.S. Fish and Wildlife Service, Adak, Alaska, personal communication).

Elsewhere in Alaska, observations of changes in insular avifauna after the disappearance of foxes outside the Aleutian Islands are comparatively scarce because until recently most other islands did not receive much scrutiny by biologists. Also, purposeful eradication of foxes outside the Aleutians did not begin until 1984. One notable early observation of burgeoning seabird numbers after foxes had disappeared was in the Semidi Islands, where foxes were introduced to the two largest islands in the group over 100 years ago. By 1940, foxes were gone, and Gabrielson (1940) was surprised by the enormous concentrations of fulmars that appeared since earlier explorations when foxes were present.

Large colonies of mainly fossorial seabirds are again present on Goose, Cherni, Midun, and other islands in the Sandman Reefs (Fig. 6) formerly used by foxes (Bailey and Faust 1980). On some islets in the Sandman Reefs, fox farmers captured seabirds and fed them to foxes on nearby larger islands, or they placed foxes on islands only during the summer to feed on birds and then removed them in the autumn (M. Uttecht, Cold Bay, Alaska, personal communication). Other islands off the Alaska Peninsula, such as Ugaiushak Island, that formerly had foxes, now have large numbers of breeding birds (Bailey and Faust 1984). Similar population recoveries are evident on the Noisy Islands near Kodiak and on Middleton Island in the Gulf of Alaska (Sowls et al. 1978).

Eradication of Introduced Foxes

Previous Removal Efforts

The U.S. Fish and Wildlife Service began eradicating foxes on Amchitka Island in the Aleutian Islands NWR in 1949 to restore habitat for the endangered Aleutian Canada goose, which then was known to survive on only Buldir Island (Jones 1963). By 1992, foxes were believed to have been exterminated from only 21 islands (Table 6). Before most pesticides were banned in 1972 by Executive Order 11643, *Environmental Safeguards on Activities for Animal Damage on Federal Lands*, refuge personnel used strychnine, cyanide projectiles (M-44), Compound 1080 (sodium monofluoroacetate),

Table 6. Islands from which introduced foxes were or are being eliminated by personnel of the Alaska Maritime National Wildlife Refuge.

Island	Method of eradication
Amchitka	Compound 1080 ^a , strychnine
Alaid	Compound 1080, strychnine, M-44 ^b , traps
Nizki	Compound 1080, strychnine, M-44, traps
Agattu	Compound 1080, strychnine, M-44, traps
Kiska ^c	Compound 1080
Rat	traps, M-44
Igitkin	traps
Amukta	traps, M-44, diphacinone
Uliaga ^c	biological control
Adugak	biological control
Bird	traps
Big Koniui	traps, shooting
Ushagat	traps
Poperechnoi	traps
Umak	traps
Little Tanaga ^c	traps
Carlisle	traps, shooting
Kasatochi	traps, shooting
Amatignak ^c	traps, shooting
Ulak (West) ^c	traps, shooting
Ugamak ^c	traps, shooting

^aSodium monofluoroacetate.

^bCyanide projectiles.

^cNot verified that all arctic foxes are gone.

traps, and firearms (Aleutian Islands National Wildlife Refuge files). After 1972, toxicants were employed on five islands in the Aleutians under an emergency provision to protect endangered geese.

The eradication of foxes on Amchitka Island was largely accomplished with aerial and ground dispersal of strychnine. Besides arctic foxes, Amchitka Island also was overrun with feral dogs (*Canis familiaris*) and cats when the military left this large island in 1950 (C. Cottam, U.S. Fish and Wildlife Service, Washington D.C., personal communication). In 1956, 11,000 strychnine pellets imbedded in seal blubber and 130 fish, seal, and bird carcasses injected with Compound 1080 were dropped from the air. By 1957, an additional 85,000 strychnine pellets were dropped on Amchitka Island, and ground crews distributed more

poison in 1960, after which the project was considered successful (Spencer et al. 1979; Aleutian Islands National Wildlife Refuge files). On Amchitka Island, crews also laced rat burrows with Compound 1080, which proved a successful means of killing foxes through secondary poisoning (R. D. Jones, Jr., former manager of the Aleutian Islands National Wildlife Refuge, Cold Bay, Alaska, personal communication).

In 1963 and 1964, poisoning began on Agattu and Kiska islands in the western Aleutians. Roughly 50,000 baits with Compound 1080 were air dropped in the spring of 1964 on rugged 32,400-ha Kiska Island. A follow-up drop of Compound 1080 failed to materialize, and the fox population was not completely destroyed (Spencer et al. 1979; R. D. Jones, Jr., former manager of the Aleutian Islands National Wildlife Refuge, personal communication). Two winter stations with Compound 1080 laced meat on Kasatochi Island (290 ha) also failed to eliminate arctic foxes in 1963 (R. D. Jones Jr., former manager of the Aleutian Islands National Wildlife Refuge, personal communication). Attempts to shoot and trap all foxes on Kasatochi Island in 1984 and 1985 (64 killed) evidently succeeded because none was found in 1991 (Alaska Maritime National Wildlife Refuge files).

In 1964, 50,000 tallow, seal oil, and beeswax baits filled with Compound 1080 were airdropped along the shoreline of Agattu Island. Refuge personnel continued ground follow-up with strychnine and Compound 1080 in 1967 and 1968. In 1970, Agattu Island was erroneously declared fox-free, but when Aleutian Canada geese were translocated to this island in 1974, foxes were still present (Aleutian Islands National Wildlife Refuge, Adak, Alaska, 1974 annual report). Traps, hunting with dogs, and M-44 devices were then employed, and the last known fox was killed in 1979.

Strychnine baits and chicken eggs injected with Compound 1080 were dispersed on nearby Nizki Island in July 1969 until no further fox sign could be found (personal observation). However, during the following winter, a sand spit from adjacent Alaid Island extended to Nizki Island and allowed foxes to repopulate Nizki Island. Not until 1976 were all foxes removed from those two islands with traps and M-44's (Aleutian Islands National Wildlife Refuge, Adak, Alaska, 1976 annual report).

In 1983, arctic foxes were eliminated from 5,000-ha Amukta Island in the central Aleutians with chiefly leg-hold traps and M-44's. A total of 49 foxes was killed in approximately 5 weeks (personal observation); none was taken during 3 subsequent weeks on this island. Trapping continued in 1984, but no fox sign was detected anywhere on the island. Amukta Island was checked again in 1985 and 1989 (G. Byrd, U.S. Fish and Wildlife Service, Adak, Alaska, personal communication).

Arctic foxes on Rat Island (2,780 ha) were eradicated in 1984 with leg-hold traps, snares, M-44's, rifles, and denning smoke cartridges. One hundred seventy-five foxes were taken, and no fox sign was found when this island was briefly revisited in 1985 and 1989 (Alaska Maritime National Wildlife Refuge files).

Eradication of foxes did not begin on islands outside the Aleutians until 1984, when arctic foxes were removed from Bird Island, one of the Shumagin Islands south of the Alaska Peninsula. Three years after this trapping, glaucous-winged gulls began nesting on an accessible part of Bird Island, evidently indicating that foxes were gone (Alaska Maritime National Wildlife Refuge files). I found no fox sign there in 1990.

The first island from which introduced red foxes were removed by U.S. Fish and Wildlife personnel was 9,300-ha Big Koniui Island in the Shumagins. As was the case with nearby Bird Island, only traps, snares, and rifles could legally be used because eradication of foxes was primarily to restore breeding seabirds rather than Aleutian Canada geese, the primary objective for eliminating foxes in the Aleutians. Eighty-four foxes were removed from Big Koniui Island after 3 months of trapping in 1985 and 1986. My subsequent visits in 1987 and 1990 indicated that none remained, especially since a newly accessible gull colony had appeared.

Among the latest eradications of foxes in the Aleutian Islands have been renewed efforts to eliminate arctic foxes on Kiska Island with poison baits and winter trapping (box and leg-hold traps) on Igitkin, Little Tanaga, and Umak islands in the eastern Andreanof Islands near Adak. Approximately 49,000 baits composed of 4 mg of Compound 1080 imbedded in beef tallow were hand-placed or dropped by helicopter on Kiska Island in March 1986. Hundreds of foxes must have been killed because 186 carcasses were observed before leav-

ing the island within 6 days after the dispersal of poison. The use of Compound 1080 in winter is especially effective because it is lethal at lower dosages at colder temperatures. Although one fox was trapped in 1988, no signs of foxes were seen in 1989 or 1992, and it is probable that no viable population survived on Kiska Island (Alaska Maritime National Wildlife Refuge files). Continued surveillance for several years will be necessary to ascertain the absence of foxes on so large an island, particularly because the first attempts with poison in 1963 and 1964 failed. Arctic foxes were believed removed (traps and firearms) from Carlisle, Ulak, and Amatignak islands in the Aleutians in 1990 and 1991 (Bailey 1990, 1991a).

Planned Eradication of Foxes

Ultimately, the U.S. Fish and Wildlife Service plans to remove introduced foxes from 19 more islands in the Alaska Maritime NWR, which are entirely owned by the refuge (Table 7). There are presently no intentions to remove foxes from 27 islands (Table 8) that are inhabited by humans or are now or eventually will be partly owned by Natives, the state of Alaska, or other entities. Completing removal of foxes on so many islands, some of which are very large, will require many years, even if the use of toxicants is allowed. The value of eradicating foxes from islands with introduced rats (Appendix B) is highly questionable.

Comparison of Eradication Techniques

Toxicants

The best means of eliminating foxes from islands, Compound 1080 laced bait, was essentially banned along with most other toxicants for use as a predicide in 1972 (Federal Environmental Pesticide Control Act, 7 U.S.C. 136-136y; 86 STAT.975 as amended). A special exemption by the U.S. Environmental Protection Agency for restoration of Aleutian Canada geese allowed the use of Compound 1080 drop baits on Kiska Island in 1986 (Byrd et al. 1988). Besides 5 mg of Compound 1080, baits contained roughly 90% beef tallow and 10% bees wax; fish meal also was used in some baits. Compound 1080 and strychnine were successfully

Table 7. *Planned eradication of foxes^a on islands in the Alaska Maritime National Wildlife Refuge in order of priority.*

Island	Area (hectares)	Kilometers of shoreline	Fox species
Gareloi	6,868	31.2	arctic
Herbert	5,583	30.6	arctic
Segula	3,317	25.6	arctic
Semisopchnoi	22,677	64.4	arctic
Kagamil	4,187	28.0	arctic
Little Koniui	5,690	66.0	arctic
Inikla	32	3.2	arctic
Elma	290	9.7	arctic
Simeonof	4,050	38.6	arctic
Little Sitkin	6,357	35.0	arctic
Seguam	21,576	66.0	arctic
Yunaska	17,619	62.1	arctic
Great Sitkin	15,878	69.9	arctic
Kagalaska	11,885	100.0	arctic
Chernabura	3,012	29.0	arctic
Chuginadak	17,108	74.4	red
Kanaga	37,132	184.5	arctic
Tanaga	51,822	210.2	arctic
Ukolnoi	4,664	32.2	red

^a Arctic foxes (*Alopex lagopus*) and red foxes (*Vulpes vulpes*).

Table 8. *Islands with introduced foxes for which no eradication is planned because of lack of complete land ownership by a national wildlife refuge.*

Adak	Long
Amlia	Marmot ^a
Atka	Nuka
Attu	Rabbit
Avatanak	Rootok
Chirikof	Samalga
Clifford	Sanak
Deer ^a	Shemya
Dolgoi ^a	Ugak ^a
East Chugach	Unalga
Elizabeth	Wanda
Finneys	Wingham (reintroduced) ^a
Geese ^a	Wosnesenski
Inner Iliasik ^a	

^a Red foxes present; all other islands have arctic foxes.

used on Nizki and Amchitka islands. Registration of Compound 1080 has now been withdrawn, precluding further use for fox eradication.

Strychnine has not been used since 1969 (Nizki Island) and always was employed with Compound 1080 (Aleutian Island National Wildlife Refuge files). Although effective on the large island of Amchitka, further use was banned in 1972 (Executive Order). It is not now registered for use against foxes.

Sodium cyanide ejectors (M-44's) were successfully used with other techniques on three islands. Ejectors were last employed on Rat Island in 1984 (Hanson et al. 1984). The Alaska Maritime NWR has not been able to use these devices since then despite repeated requests. Cyanide ejectors proved an invaluable backup to the elimination of trap-shy foxes on Amukta Island (personal observation).

In 1983, over 9,300 baits with 30 mg of diphacinone were distributed around Amukta Island after 2 months of trapping and use of M-44's. No foxes were known to have been killed with this anticoagulant, and later bait trials with captive arctic foxes revealed that diphacinone was only lethal at very high dosages (Alaska Maritime National Wildlife Refuge files).

A few glaucous-winged gulls and common ravens were inadvertently poisoned on a few islands, but no significant effects on non-target species were documented (Alaska Maritime National Wildlife Refuge files).

Trapping

Since predicides became highly restricted in 1972, personnel of the Alaska Maritime NWR have relied principally on leg-hold traps on most islands (personal observation). Number 1½ or 1¾ coil-spring traps set mainly on beaches and fox trails and different commercial lures and scents were primarily responsible for eliminating foxes from 11 islands (Table 6), but trapping is very time-consuming, labor-intensive, and unsuitable for very large islands. Also, without M-44's or some other backup, eliminating the last few trap-shy foxes is exceedingly difficult, if not impossible. Regularly checking traps is often difficult because of persistent fog and frequent storms in the North Pacific. Some foxes escape traps by twisting a foot off or pulling out trap stakes and thus shun traps and snares. On one island, for example, all foxes simply

could not be trapped despite attempts for 2 months during summer and leaving over 250 traps throughout the winter (Bailey 1986). Trapping is most efficient between May and early July when adult fox populations are lowest, foxes are most territorial, and pups are largely confined to dens and dependent on adults for food. I found that red foxes are more difficult to trap than arctic foxes.

As with poisons, traps pose some danger to non-target species. River otters, common ravens, and ground squirrels are among the most commonly trapped non-target animals on islands off the Alaska Peninsula. Ground squirrels severely hamper trapping because they constantly spring traps.

Shooting foxes, particularly where concentrated around seabird colonies, is locally successful, but nowhere has this technique been successful in eliminating all individuals from an island. Arctic foxes often respond to predator calls, but fewer red foxes seem to respond to calls, even to electronic recordings of foxes and distress calls of birds and small mammals. On most islands, fox hunting, generally with .223 caliber rifles with telescopic sights, should be considered incidental to trapping and poisoning efforts. However, shooting may be vital in removing the last trap-shy animals in some cases.

Biological control

In 1983, I initiated an experiment with male red foxes as biological control agents against previously introduced arctic foxes on Adugak Island in the eastern Aleutians. Native red foxes were obtained from nearby Umnak Island. Five vasectomized male and five female red foxes were released on Uliaga Island in 1984 to see whether they would eliminate arctic foxes that originated from introductions in 1930 (Bailey 1993). Both species have about the same life span in the wild (Chapman and Feldhammer 1982).

I saw arctic foxes on Adugak Island up to 14 months after red foxes were released, but arctic foxes eventually disappeared. No arctic foxes were seen on Uliaga Island after red foxes had been introduced. At least one red fox was still present on both Uliaga and Adugak islands in 1991, but no sign of foxes was found on Adugak in 1992. One of the red foxes released on Uliaga Island in 1984 was recaptured and let out of the trap in 1987 and 1990 (Bailey 1993). Although hybridization between red and arctic foxes has occurred in captivity, no men-

tion of this by island fur farmers was found. Even if the two species did hybridize, the young would be sterile (Makinen and Gustavsson 1982). Though final confirmation of elimination of arctic foxes by sterile red foxes awaits the disappearance of all foxes on these islands, red foxes seem to eradicate arctic foxes on at least small islands through apparent competitive exclusion.

Coyotes (*Canis latrans*), once numerous on Isle Royale in Michigan, vanished within 10 years after the arrival of gray wolves (Mech 1970). Small carnivore populations experienced increases in three western states after coyote control (Robinson 1961), and after coyote poisoning in Saskatchewan, red foxes markedly increased in numbers (Stoudt 1971). Marsh (1938) found no arctic foxes on the west side of Hudson Bay where red foxes had their dens and red foxes often attacked and killed trapped arctic foxes. Chirkova (1968) mentioned that red foxes displace arctic foxes in Russia where their ranges overlap. Red foxes are acknowledged competitors and predators of arctic foxes in Scandinavia and are believed to restrict the distribution and recovery of scarce arctic fox populations in that region (Hersteinsson et al. 1989; Frafjord et al. 1989). In Alaska, fox farmers noted that if red and arctic foxes were put on the same island, the arctic foxes disappeared (Evermann 1914; Bower and Aller 1917; Swanson 1982; M. Shapnikoff, Dutch Harbor, Alaska, personal communication).

Rudzinski et al. (1982) confirmed the dominance of red over arctic foxes in an enclosure. Chesemore (1975) regards red foxes as one of the predators of arctic foxes and a possible factor in arctic fox distribution in Alaska. In the prairie pothole region, Johnson and Sargeant (1977) documented that repeatedly coyotes fared poorly in areas dominated by wolves and red foxes fared poorly in areas dominated by coyotes. Competitive exclusion would be especially acute on islands where the smaller species could not escape. Use of red foxes or coyotes as biological control agents is practical on only smaller islands.

Other possible eradication techniques, such as introduced pathogens and chemical sterilants, have never been tried in Alaska.

In conclusion, selection of the eradication methods depends on size, location, and topography of the island; shoreline distance and character; size of the fox population; prey availability; and the

types and numbers of non-target species. Unequivocally, the removal of introduced foxes from islands is the most beneficial activity that the U.S. Fish and Wildlife Service can undertake for the restoration of island ecosystems in Alaska. However, inability to use toxicants and practically nonexistent funding for continued eradication of foxes seriously hamper efforts to restore biodiversity and former numbers of birds on additional islands.

Summary

Foxes originally were not present on most Alaskan islands. The first recorded introduction of foxes occurred in 1750, when arctic foxes from the Commander Islands were released by Russians on Attu Island at the western extremity of the Aleutian Islands. About 40 years later, foxes were released on Atka Island in the central Aleutians. Archaeological evidence from the western and central Aleutians also confirms that no indigenous terrestrial mammals except Aleut people formerly inhabited this region. In the Pacific Ocean, red foxes are native in the eastern Aleutians and on some islands south of the Alaska Peninsula and in the Gulf of Alaska. In 1819, the Russian government ordered the transfer of arctic foxes from the Pribilof Islands to the Rat Islands and other islands in the Aleutians. Red foxes from Alaska's mainland and Unalaska Island were introduced on several islands.

The first known introduction of foxes after acquisition of Alaska by the United States in 1867 transpired near Kodiak Island and in the Shumagin Islands in 1880. Major fox farming enterprises also soon began in the Semidi Islands, south of the Alaska Peninsula, and on islands in Prince William Sound.

Fox farming increased rapidly in the early 1900's, and by 1925 included 391 known fox farms with over 36,000 animals valued at \$6 million. Fox pelt prices collapsed in the 1930's, and most island operations were abandoned during World War II and never renewed.

Records were found of introductions of foxes on 455 islands between southeast Alaska and Attu Island at the western tip of the Aleutian Islands. Nearly 40% of the known stocked islands were in

southeast Alaska, but foxes failed to survive on these islands. Seventy-three islands were stocked in the Gulf of Alaska, principally in Prince William Sound. In the Kodiak archipelago, foxes were introduced to 51 islands. Foxes were released on at least 63 islands off the south side of the Alaska Peninsula. Except for Chirikof Island, southwest of Kodiak Island, no foxes remain on any islands on which they were introduced off the south side of the Alaska Peninsula east of the Shumagin Islands.

Leasing of islands for fox farming by the U.S. government began in 1882. Production of pelts was large on some islands, especially while large numbers of nesting birds were available as food for foxes. Nearly 27,000 pelts were taken from 86 islands that were part of the Aleutian Islands NWR in the 1920's and 1930's. During the peak of fox farming in Alaska, the first concerns were raised about the injurious effects of introduced foxes on insular birds. Gradually, government policy changed from originally facilitating fox farming to eradicating foxes. The collapse of fur prices during this period also negated further substantial demand and interest in fox farming.

The adverse effects of foxes introduced to Alaskan islands were first noticed in the Aleutians. In 1811, only about 20 years after arctic foxes were brought to Atka Island, local Aleuts complained that foxes were driving away birds that had been numerous, and by 1812 birds on Attu Island became comparatively scarce. Early Russian accounts clearly revealed that ground nesting birds were common only on islands without foxes. Some species of birds also evidently suffered because of accompanying introductions of rats, ground squirrels, and other species. Ground squirrels and voles were introduced to some islands as an additional food supply for foxes.

The first comprehensive documentation of the devastation of some species of nesting birds occurred with Murie's extensive survey of islands off the Alaska Peninsula and in the Aleutian Islands in 1936 and 1937. The disappearance of several former Cassin's auklet, ancient murrelet, and storm-petrel colonies from some smaller islands was apparent after foxes were introduced. In addition to the disappearance or decline of seabirds after introductions of foxes, marked decreases of some waterfowl in the Aleutians were reported. Breeding Aleutian Canada geese survived on only three small

islands, and common eiders no longer nested on most islands inhabited by foxes. Ptarmigans also vanished from some islands after foxes were released. Spectacular recoveries of insular bird populations have been observed after the disappearance of foxes.

Of the 455 islands in Alaska to which foxes were known to have been introduced, foxes currently remain on 46. Except for a few islands where they were eliminated by the U.S. Fish and Wildlife Service, foxes vanished naturally or were removed by trappers on the other islands.

The U.S. Fish and Wildlife Service began eradicating foxes in the Aleutian Islands in 1949 to restore nesting habitat for the Aleutian Canada goose that was then known on only one island. Strychnine, Compound 1080, and cyanide ejectors proved the most effective, but the use of poisons became highly restricted after 1972, necessitating the use of mainly traps on most islands.

Various combinations of eradication techniques are best suited for different islands, depending on size, topography, presence of non-target species, and other factors.

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Appendix A. References for introductions of foxes on Alaskan islands (Tables 1-5)^a

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^a In tables 1-5 space is available for only a single citation for the introduction of each species of fox to an island. Often several accounts were found for stocking a given island in the same year, and other references mention additional releases of foxes at later dates. On some islands, references indicating different initial introduction dates undoubtedly represent variability in historical information in early books, magazines, government reports, and other sources. Multiple introduction dates in different references are common for many of the best fox producing islands. For example, 16 references were found for introductions of red and arctic foxes on Long Island between 1880 and 1929, but in the tables only the earliest record for each species of fox is listed. Fur farmers frequently released additional foxes on a given island in subsequent years to prevent inbreeding or to replace earlier stock that failed to survive or was eliminated accidentally or intentionally.

Appendix B. Introduced small mammals on islands in the Alaska Maritime National Wildlife Refuge

Island	Introduced species	Date of introduction	Source (see References)
Adak	Norway rat (<i>Rattus norvegicus</i>)	ca 1940	U.S. Fish and Wildlife Service 1981 Murie 1959
Akutan	Norway rat	<1937	Murie 1937
Amaknak	Norway rat	early 1800's	Zeilemaker and Trapp 1986
Amchitka (Makarius, Bat, Bird Rock)	Norway rat	ca 1940	Manville and Young 1965
Atka	Norway rat	<1936	Murie 1959
Attu	Norway rat	ca 1940	U.S. Fish and Wildlife Service 1980 Murie 1959
Bolshoi Islets	Norway rat	<1936	Murie 1959
Great Sitkin	Norway rat	?	Murie 1959
Kagalaska	Norway rat	?	West 1987
Kiska	Norway rat	ca 1940	Murie 1959
Kodiak	Norway rat	<1920	Clark 1958
Little Kiska	Norway rat	ca 1990	G. Byrd, Adak, Alaska, personal communication
Ogangeen	Norway rat	?	Nysewander et al. 1982
Rat	Norway rat	<1780	Brechbill 1977
Sanak	Norway rat	<1950	R. Mack, King Cove, Alaska, personal communication
Sedanka, Seal Rocks	Norway rat	?	Nysewander et al. 1982
Shemya	Norway rat	ca 1940	U.S. Fish and Wildlife Service 1980
Unalaska	Norway rat	1828	Elliot 1875
Hog	house mouse (<i>Mus musculus</i>)	1917	Bower and Aller 1918
Kiska	house mouse	<1937	Murie 1959
Kodiak	house mouse ^a	1920's	Clark 1958
Pribilofs	house mouse	1872	Manville and Young 1965
Unalaska	house mouse	<1875	Elliot 1875
Ananiuliak	European hare (<i>Lepus capensis</i>)	ca 1917	S. Ermeloff, Nikolski, Alaska, personal communication
Ananiuliak	European hare	ca 1940	Burris and McKnight 1973
Hog	European hare	<1940	Peterson 1967
Kanaga	European hare	<1936	Murie et al. 1937
Middleton	European hare ^a	1952	Rausch 1958
Poa	European hare	?	Nysewander et al. 1982

Appendix B. *Continued.*

Island	Introduced species	Date of introduction	Source (see References)
Tangik	European hare	?	Nysewander et al. 1982
Umnak	European hare	1930	Burris and McKnight 1973
Chirikof	arctic hare (<i>L. othus</i>)	1891	Janson 1985
Popof	snowshoe hare (<i>L. americanus</i>)	1913, 1955	Murie 1959
Sud	hoary marmot (<i>Marmota caligata</i>)	ca 1930	Elkins and Nelson 1954
Chankliut	vole sp. ^a (<i>Microtus</i> spp.)	1918	Bower 1920
Cherni	vole sp. ^a	?	R. D. Jones, Jr., former manager of the Aleutian Islands National Wildlife Refuge, personal communication
Big Koniuji	ground squirrel ^a (<i>Spermophilus</i> spp.)	ca 1916	R. Rogers, Soldotna, Alaska, personal communication
Kavalga	ground squirrel	1920	Murie 1959
Kodiak and Afognak	ground squirrel	<1934	Burris and McKnight 1973
Unalaska and Amaknak	ground squirrel	ca 1895	Peterson 1967

^aGround squirrels are present on other islands such as Ushagat, Kak, Semidis, Nakchamik, Bird, Chernabura, Near, Simeonof, Little Koniuji, Spectacle, Turner, and Bendel, where they probably were introduced, but no documentation has been found. Mice and voles were also introduced to the Commander Islands before 1880 (Stejneger 1883). Hares disappeared from Chirikof, Kanaga, and Umnak islands, probably, because of foxes. The first introduction of hares on Middleton, which was made before 1918 (Bower and Aller 1918), failed probably because of the presence of introduced foxes. Foxes were absent by the time of the second introduction of hares in 1954. The first liberation of hares on Ananuliak Island around 1917 also failed probably because foxes were released at about the same time.



Chuginadak Island in the eastern Aleutians is one of the few remaining islands with introduced red foxes. They eliminated arctic foxes which also were released on this spectacular island. *Photo by N. Faust.*

A list of current *Resource Publications* follows.

174. Obsolete English Names of North American Birds and Their Modern Equivalents, by Richard C. Banks. 1988. 37 pp.
175. Procedures for the Analysis of Band-recovery Data and User Instructions for Program MULT, by Michael J. Conroy, James E. Hines, and Byron K. Williams. 1989. 61 pp.
176. Sago Pondweed (*Potamogeton pectinatus* L.): A Literature Review, by Harold A. Kantrud. 1990. 90 pp.
177. Field Manual for the Investigation of Fish Kills, by Fred P. Meyer and Lee A. Barclay, editors. 1990. 120 pp.
178. Section 404 and Alterations in the Platte River Basin of Colorado, by Douglas N. Gladwin, Mary E. Jennings, James E. Roelle, and Duane A. Asherin. 1992. 19 pp.
179. Hydrology of the Middle Rio Grande From Velarde to Elephant Butte Reservoir, New Mexico, by Thomas F. Bullard and Stephen G. Wells. 1992. 51 pp.
180. Waterfowl Production on the Woodworth Station in South-central North Dakota, 1965–1981, by Kenneth F. Higgins, Leo M. Kirsch, Albert T. Klett, and Harvey W. Miller. 1992. 79 pp.
181. Trends and Management of Wolf–Livestock Conflicts in Minnesota, by Steven H. Fritts, William J. Paul, L. David Mech, and David P. Scott. 1992. 27 pp.
182. Selection of Prey by Walleyes in the Ohio Waters of the Central Basin of Lake Erie, 1985–1987, by David R. Wolfert and Michael T. Burr. 1992. 14 pp.
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185. Group Decision-making Techniques for Natural Resource Management Applications, by Beth A. K. Coughlan and Carl L. Armour. 1992. 55 pp.
186. DUCKDATA: A Bibliographic Data Base for North American Waterfowl (Anatidae) and Their Wetland Habitats, by Kenneth J. Reinecke and Don Delnicki. 1992. 7 pp.
187. Dusky Canada Goose: An Annotated Bibliography, by Bruce H. Campbell and John E. Cornely. 1992. 30 pp.
188. Human Disturbances of Waterfowl: An Annotated Bibliography, by Robert B. Dahlgren and Carl E. Korschgen. 1992. 62 pp.
189. Opportunities to Protect Instream Flows and Wetland Uses of Water in Nevada, by James L. Bingham and George A. Gould. 1992. 33 pp.
190. Assessment of Habitat of Wildlife Communities on the Snake River, Jackson, Wyoming, by Richard L. Schroeder and Arthur W. Allen. 1992. 21 pp.
191. Evaluating Temperature Regimes for Protection of Smallmouth Bass, by Carl L. Armour. 1993. 26 pp.
192. Sensitivity of Juvenile Striped Bass to Chemicals Used in Aquaculture, by Terry D. Bills, Leif L. Marking, and George E. Howe. 1993. 11 pp.

NOTE: Use of trade names does not imply U.S. Government endorsement of commercial products.

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