BEFORE THE COMMISSIONER OF THE ALASKA DEPARTMENT OF FISH AND GAME

PETITION TO LIST THE KITTLITZ'S MURRELET (*BRACHYRAMPHUS BREVIROSTRIS*) AS AN ENDANGERED SPECIES UNDER THE ALASKA ENDANGERED SPECIES ACT, AS §§ 16.20.180 - 210

CENTER FOR BIOLOGICAL DIVERSITY

March 5, 2009

NOTICE OF PETITION

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The Center for Biological Diversity ("Center") formally request that the Commissioner list the Kittlitz's murrelet (*Brachyramphus brevirostris*) as an endangered species under the Alaska Endangered Species Act, AS §§ 16.20.180 - 210. This petition is filed in accordance with AS § 44.62.220. The best available scientific data documents that the Kittlitz's murrelet is a species whose "numbers have decreased to such an extent as to indicate that its continued existence is threatened," and that the Commissioner must therefore determine that it is an endangered species pursuant to AS § 16.20.190. The Center therefore formally request, pursuant to AS § 44.62.220, that the Commissioner publish regulations that declare the Kittlitz's murrelet to be an endangered species and add it to the list of species published at 5 AAC § 93.020. Under AS § 44.62.230, the Commissioner must, within 30 days of the day of this petition, either deny the petition in writing, or schedule a public hearing on the requested action under AS §§ 44.62.190 – 44.62.215. Petitioners look forward to the Commissioner's response.

The Center for Biological Diversity is a non-profit, public interest environmental organization dedicated to the protection of native species and their habitats through science, policy, and environmental law. The Center has over 40,000 members in Alaska and throughout the United States. The Center submits this petition on its own behalf and on behalf of its members and staff in Alaska and elsewhere with an interest in protecting the Kittlitz’s murrelet and its habitat.

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EXECUTIVE SUMMARY

The Kittlitz's murrelet, *Brachyramphus brevirostris*, is a small seabird in the alcid family which nests in the rugged coastal mountains of southern Alaska from the Glacier Bay region westward to the Aleutian Islands, and to a limited extent in western coastal Alaska and the Russian Far East. The Kittlitz's murrelet is the only alcid that nests on open ground near the tops of mountains, particularly near glaciers and in previously glaciated areas, where its cryptic plumage helps it avoid detection. During the summer, the Kittlitz's murrelet primarily forages in nearshore waters of bays and fjords near tidewater glaciers, uplands dominated by ice, and glacier outflows, leading researchers to call it the "glacier murrelet." The Kittlitz's murrelet feeds on fish and macrozooplankton using wing-propelled diving.

The global population size of the Kittlitz's murrelet is estimated to number only ~15,000 individuals in Alaska and perhaps ~20,000 birds worldwide. Kittlitz's murrelets in Alaska occur primarily in four regions with most birds in Southeast Alaska (48%), followed by Southcentral Alaska (22%), the Aleutian Islands (16%), and the Alaska Peninsula (14%). Of foremost concern, Kittlitz's murrelet populations have declined precipitously across its range in southern Alaska in recent years, prompting the World Conservation Union (IUCN) and BirdLife International to classify the Kittlitz's murrelet as Critically Endangered. The Kittlitz's murrelet is a federal candidate for listing at listing priority level 2 due to the high magnitude and imminence of threats to the species (Federal Register 72: 69038).

In the five regions with data on population trends, Kittlitz's murrelets have declined by 83% between 1991 and 1999-2000 in Glacier Bay (Drew and Piatt 2008), 90% between 1992 and 2002-2004 in the Malaspina Forelands (Kissling et al. 2007a), 84% between 1989 to 2000 in Prince William Sound (Kuletz et al. 2003), 83% between 1976 and 2002 in the Kenai Fjords (van Pelt and Piatt 2003), and 43% between 1988-1999 and 2004-2007 in Kachemak Bay (Kuletz et al. 2008). In addition, Kittlitz's murrelets are experiencing extremely low reproductive success in two regions where data are available--Prince William Sound and Agattu Island in the Aleutian Islands.

The Kittlitz's murrelet's small, rapidly declining global population size and highly restricted distribution make it extremely vulnerable to extinction from land and sea-based threats, principally global warming, oil spills, mortality in the gillnet fishery, and disturbance from vessel traffic.

Anthropogenic climate change poses the most significant long-term threat to the survival of the Kittlitz's murrelet. Global warming is causing the rapid melting and retreat of coastal glaciers in Alaska, which is eliminating important glacially-influenced foraging habitat for the Kittlitz's murrelet. More than 98% of Alaska's glaciers are retreating and/or thinning in response to significant regional warming. The loss of coastal glaciers is thought to be altering prey availability for the Kittlitz's murrelet and increasing competition with marbled murrelets for food, and has been linked to the precipitous declines of Kittlitz's murrelets in Alaska. Growing threats from climate change include depletion of prey resources due to changing ocean conditions and ocean acidification; increasing exposure to predators in its alpine nesting habitat; rising pollution as glacier meltwater contributes contaminants to nearshore waters; increasing

competition as temperate species expand their ranges northward; and increasing shipping activity and oil and gas development, with associated risks of oil spills and noise pollution.

The Kittlitz's murrelet is highly vulnerable to mortality from oil spills due to its tendency to cluster in nearshore waters, restricted distribution, diving behavior, and low productivity. An estimated 5-10% of the worldwide population of Kittlitz's murrelet may have been killed as a direct result of the 1989 *Exxon-Valdez* oil spill, representing the largest proportionate loss of any species impacted by the spill. Based on the high level of vessel traffic in the Kittlitz's murrelet range and inadequate vessel safety measures, chronic and acute oiling in the Kittlitz's murrelet marine habitat are certain to occur in the future, posing a significant threat to this species. The Kittlitz's murrelet also faces immediate threats from current and proposed offshore oil and gas development within its at-sea foraging range in the Cook Inlet and the Alaskan and Russian waters of the Bering and Chukchi Seas, which increase the risks from oil and noise pollution.

Commercial gillnet fisheries in Alaska have been documented to cause direct mortality of Kittlitz's murrelet through incidental take as bycatch. Where bycatch data are available, observations indicate that the gillnet fisheries may drown hundreds of Kittlitz's murrelets per year in some regions, and that gillnets have a disproportionately large impact on the Kittlitz's murrelet relative to other seabirds, even the closely related marbled murrelet.

The Kittlitz's murrelet is threatened by the high volumes of recreational and commercial vessel traffic in the bays and fjords that support the largest concentrations of murrelets during the breeding season. Of particular concern, vessel traffic from cruise ships, tour boats, fishing boats, and tankers has increased substantially in many of its breeding areas, especially in Glacier Bay, Prince William Sound, Kenai Fjords, and lower Cook Inlet/Kachemak Bay. Vessel traffic impacts the Kittlitz's murrelet both directly and indirectly by displacing birds from foraging areas, increasing energy expenditure, interrupting normal behaviors, increasing noise pollution, and heightening the risk of oil spills.

Existing regulatory mechanisms have been ineffective at preventing the declines of the Kittlitz's murrelet and mitigating the principal threats to the species. The Kittlitz's murrelet is on a trajectory towards extinction. Based on its small population size, precipitous population declines, and multiple, ongoing threats to its continued existence, the Kittlitz's murrelet merits prompt listing under Alaska's Endangered Species Act, AS §§ 16.20.180 - 210.

I. NATURAL HISTORY AND BIOLOGY OF THE KITTLITZ'S MURRELET

A. Species Description

The Kittlitz's murrelet (*Brachyramphus brevirostris*) is a small, diving seabird in the alcid family. Kittlitz's murrelets have a relatively large, squat head and small, short bill, with long, narrow, pointed wings. Male and female Kittlitz's murrelets are similar in both size and coloration. Adult Kittlitz's murrelets average 25 cm in body length, with a wingspan about two-thirds of their length and wing length 13.6-14.5 cm, and weigh between 190-260 g (about the same as a medium to large apple). In flight, the Kittlitz's murrelet appears as small rapidly flying bird with blurred wing-beats. (Above information from Day et al. 1999).

The Kittlitz's murrelet's breeding plumage is cryptic, making nesting birds and their nests extremely difficult to spot. In breeding plumage, Kittlitz's murrelets are mostly grey with irregular edges of sandy or rufous-gold coloring, with off-white or buff underparts. In winter plumage, they appear black and white from a distance, with a white collar, grey band across the chest, and white on the neck and face that extends to above the eye. Juvenile plumage is poorly known but is believed to be similar to winter plumage with the exception of a faint barring on throat and breast. (Above information from Day et al. 1999).

The Kittlitz's murrelet undergoes two molts per year. The fall molt is complete, overlaps slightly with breeding, and includes a period of flightlessness that begins in late August and continues until an unknown time (possibly late September). The spring molt is partial and does not include flight feathers. It appears to last from mid-April to late May, though birds have been observed as late as mid-June that have not completed the spring molt. (Above information from Day et al. 1999).

B. Taxonomy

The Kittlitz's murrelet (*Brachyramphus brevirostris* Vigors 1829) belongs to the order Charadriiformes, family Alcidae, and genus *Brachyramphus*. It is one of three species in the genus *Brachyramphus,* along with the marbled murrelet (*Brachyramphus marmoratus*) and the long-billed murrelet (*Brachyramphus perdix*). Three recent genetics studies have provided taxonomic clarification for this genus and indicate that the Kittlitz's murrelet, marbled murrelet, and long-billed murrelet are genetically distinct species. A mitochondrial DNA restriction enzyme analysis detected significant genetic differentiation between the Kittlitz's and marbled murrelet, estimating a sequence divergence of 4.4-5% similar to other congeneric species, and a divergence time between species of ~2.2 million years before present ("MYBP") (Pitocchelli et al. 1995). A separate analysis of cytochrome *b* sequences and allozymes also found that Kittlitz's murrelets are genetically distinct from other brachyramphine murrelets, and concluded that Kittlitz's and marbled murrelets form a monophyletic group, with long-billed murrelet as the basal lineage (Friesen et al. 1996 a,b). This study suggested that marbled and Kittlitz's murrelets diverged about 1.6 MYBP (Friesen et al. 1996b). Finally, a genetic analysis of nuclear introns and the mitochondrial cytochrome *b* gene from Kittlitz's and marbled murrelets in areas of sympatry found evidence for little or no hybridization among species and that the species' gene pools have been independent for 1.8 to 5.7 million years (Pacheco et al. 2002).

The Kittlitz's murrelet is also distinguished from the congeneric marbled murrelet by morphological and ecological characteristics, providing additional support that they are reproductively isolated biological species (Pitocchelli et al. 1995, Friesen et al. 1996b, Day et al. 1999). Compared to the marbled murrelet, the Kittlitz's murrelet has a larger head, shorter bill, larger eye diameter, visible white color on its tail feathers when taking off from or landing on water, and differs in basic plumage (e.g. Kittlitz's murrelet has a white face extending above the eye, and the marbled murrelet has a white face extending to below the eye) (Day et al. 1999). Ecologically, Kittlitz's murrelets nest in the open with nests occurring on higher alpine slopes than the ground-based nest sites of marbled murrelets (Day et al. 1983), feed more exclusively near glaciers (Day et al. 1999), and differ in vocalizations (van Pelt et al. 1999).

Intra-specific variation

Kittlitz's murrelet populations in Alaska appear to exhibit significant genetic differentiation. An analysis of cytochrome *b* sequences and allozymes from murrelets sampled from 2 of the 5 Alaskan regions where they occur revealed low rates of population exchange (~0.40 individuals per generation) between murrelets in the western Aleutians (Attu Island) and mainland murrelets in Kachemak Bay in Southcoastal Alaska (Friesen et al. 1996b). Friesen et al. (1996b) highlighted the importance of assessing the extent of population genetic differentiation in Kittlitz's murrelets across the range, especially given this species' declining population status.

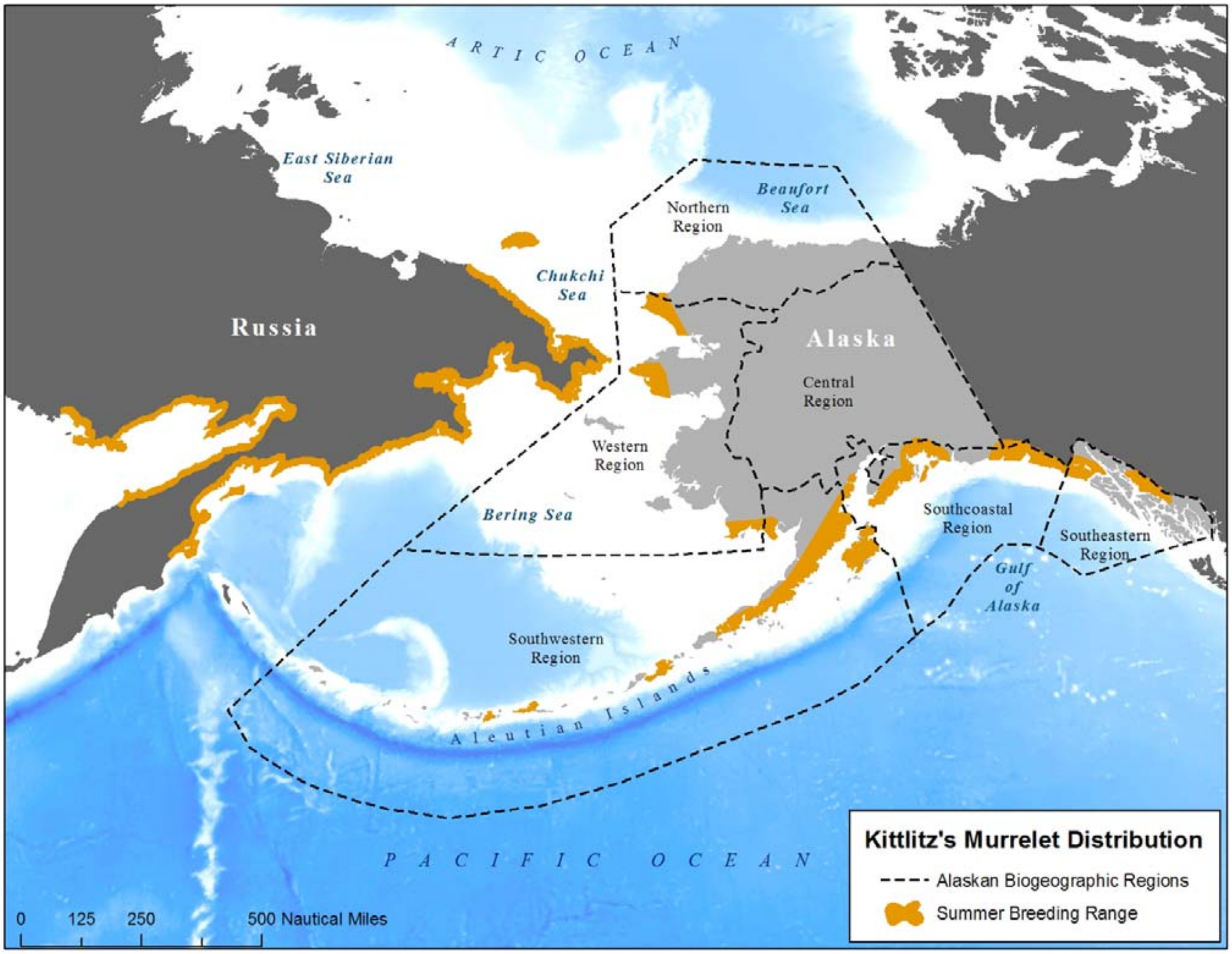
C. Range and Distribution

The Kittlitz's murrelet is restricted to the waters and coastal regions of Alaska and the Russian Far East (Figure 1) (Day et al. 1999). Most of the known world population of Kittlitz's murrelets breed, molt, and winter in Alaska (Day et al. 1999). Kittlitz's murrelets in Alaska primarily occur in four regions--Southeast Alaska, Southcentral Alaska, the Alaska Peninsula, and the Aleutian Islands—with fewer birds occurring in western and northern Alaska (Day et al. 1999). Small populations breed along coastal Russia from the Okhotsk Sea north to the Chukchi Sea (Day et al. 1999).

The present day distribution of Kittlitz's murrelet reflects their association with past and present glaciation (Day et al. 1999, Piatt et al. 1999). Kittlitz's murrelet populations show a disjunct distribution "among mountainous areas with large present-day glacier fields (Glacier Bay National Park, Yakutat Bay, Prince William Sound, Kenai Peninsula, Kachemak Bay), remnant high-elevation glaciers (Kodiak Island, Katmai National Park, Alaska Peninsula, Atka and Attu Islands), and recently deglaciated coastal mountains (Seward Peninsula, Cape Lisburne)" (Piatt et al. 1999: 12). The species is believed to have nested on glacial nunataks during the last ice age and to have spread throughout its current range as the glaciers retreated approximately 10,000 years ago (Day et al. 1999).

The distribution of Kittlitz's murrelets is highly clumped within its geographic range during the summer nesting season (Isleib and Kessel 1973). A detailed summary of the current known distribution of the Kittlitz's murrelet during summer and winter follows.

Figure 1. The summer breeding range of the Kittlitz's murrelet, shown in relation to Alaskan geographic regions. Note that the at-sea range is not depicted, and that the Russian range is approximated.
Map based on Kessel and Gibson (1979), Day et al. (1999), and Kondratyev et al. (2000).



1. Summer Distribution

Southeastern Alaska

The southern boundary of the Kittlitz's murrelet's breeding range is Le Conte Bay on the Southeast Alaska mainland, about 25 miles northwest of the town of Wrangell (Day et al. 1999, Kendall and Agler 1998, Webster 1950). However, based on recent summer surveys by Kissling et al. (2007a), Kittlitz's murrelets were not observed in LeConte Bay or Thomas Bay, making Endicott Arm the location of the southernmost population. Continuing up the coastline, the species is known to breed in Port Houghton, Endicott Arm, and Tracy Arm (Day et al. 1999). Glacier Bay is believed to be the largest Kittlitz's murrelet breeding ground, with birds concentrating near the tidewater glaciers in the northern reaches of the bays (Day et al. 1999, Kendall and Agler 1998).

The Kittlitz's murrelet may also breed in Taylor Bay, a glaciated fjord near Glacier Bay, in Lituya Bay, and in Taku Inlet (just east of the city of Juneau) and Thomas Bay (Day et al. 1999). A scattering of reports around Baranof Island, the only glaciated island in the Archipelago, suggests that these birds may also use some areas on Baranof for breeding, but this is unconfirmed (Day et al. 1999). Kittlitz's murrelets have also been observed in Sea Otter Sound, on the west side of the northern portion of Prince of Wales Island, but it is unknown whether this area is actually used for breeding (Day et al. 1999, Kendall and Agler 1998). Sightings of Kittlitz's murrelets in Southeast Alaska have also been recorded in Icy and N. Chatham Straits near Glacier Bay, at the southern end of Seymour Canal, in Snow Passage near Zarembo Island, and in W. Federick Sound (Day et al. 1999).

Southcoastal Alaska

In Southcoastal Alaska, the Kittlitz's murrelet is known to breed in Yukutat Bay and near the Malaspina and Bering Glaciers (Day et al. 1999). The species is believed to breed near Dry and Icy Bays, both of which have glaciers nearby (Day et al. 1999). In Prince William Sound, the breeding population is concentrated in the glaciated fjords in the northwestern sound: Unakwik Inlet, College Fjord, Harriman Fjord, Balckstone Bay, Port Nellie Juan, and Nassau Fjord (Day et al. 1999, Isleib and Kessel 1973, Kendall and Agler 1998). It breeds elsewhere in Prince William Sound in lower numbers: Hinchinbrook Island, Knight Island and Eaglek Bay, and probably at Galena Bay (Day et al. 1999). The Kittlitz's murrelet also breeds in eastern Cook Inlet as far north as Kachemak Bay and Cape Ninilchik, and on Kodiak Island (Day et al. 1999). In addition to these known breeding locations, the Kittlitz's murrelet likely breeds elsewhere in southcoastal Alaska, most likely along exposed coasts above protected bays (Day et al. 1999).

Southwestern Alaska/Alaska Peninsula

The Kittlitz's murrelet breeds on both sides of the Alaska Peninsula, usually close to glaciers. Breeding is confirmed from western Cook Inlet as far north as Kalgin Island, from Katmai National Park, near Kiukpalik Island, Devils Cove, Kinak Bay, Portage Bay, Agripina Bay, Nakalilok Bay, Amber Bay, Chignick Bay, Castle Bay, Kumlik Island, Kuiukta Bay, Mitrofania Island, Pavlof Bay, and the Cold Bay area. On the northern portion of the Alaska Peninsula, the Kittlitz's murrelet breeds inland from Nelson Lagoon, Herendeen Bay, and Port Heiden. (Above information from Day et al. 1999).

Aleutian Islands

The Kittlitz's murrelet breeds on the larger islands of the Aleutian Chain primarily near remnant glaciers, protected bays, and alpine nesting habitat. There are records from Unalaska, Atka, Adak, Attu, and Agattu, and suspected occurrences on Unimak (Day et al. 1999, Benson 2008). Three birds were seen in Upper Bristol Bay in 1883, suggesting possible breeding in this area. There are records from Shumagin Island and the Koniuji Island Group on the southern side of the Alaska Peninsula which suggest probable breeding. There are two records from the Pribilof Islands, but there us no affirmative evidence of breeding associated with these records.

An author writing in 1886 reported that the species was common on Amchitka Island and occurred throughout the year at Sanak Island. This account has been questioned because no birds were taken, there appears to be no suitable habitat on Sanak Island, and because extensive recent fieldwork on Amchitka has not yielded any evidence of Kittlitz's murrelet occupation. (Above information from Day et al. 1999).

Western Alaska

The Kittlitz's murrelet is known to breed at Goodnews Bay, and is believed to breed on the western half of Nunivak Island, on the Seward Peninsula from Nome to Wales, and possibly on Sledge Island and St. Lawrence Island. Nests have been found inland from Kivalina and Cape Thompson, and the species is believed to breed inland between these two sites and as far northeast as Cape Lisburne. The species is believed to nest as far north as Cape Sabine and Cape Beaufort.

The Kittlitz's murrelet has been observed on Little Diomede Island, but is not believed to breed there. Substantial numbers have been seen along the ice edge in the late summer and fall in the central Chukchi Sea and environs.

The species has not been observed to date in mainland Alaska from north of Goodnews Bay to the mouth of the Yukon River, in Norton sound from the mouth of the Yukon River to Nome, along the northern shore of the Seward Peninsula, or in Kotzebue Sound. (Above information from Day et al. 1999).

Northern Alaska

There are several Kittlitz's murrelet sightings from the 1930s, 40s, and 70s between Wainwright and Barrow. However, since suitable nesting habitat ends north of Cape Beaufort, the species is not believed to breed on the northern coast of Alaska. The Kittlitz's murrelet has never been recorded in the Beaufort Sea or along the coast on the eastern portion of the North Slope. (Above information from Day et al. 1999).

Russia

The breeding range of the Kittlitz's murrelet is still largely unknown in the Russian Far East. Kondratyev et al. (2000) described the range of Kittlitz's murrelet in Russia as distributed along the Bering and Chukchi Sea coasts between 55º N and 67º N. Along the Arctic Chukchi Sea coast, it occurs east of 180º longitude, including the coastal waters of Wrangell Island. Moving southward, it has been observed along the Chukotka coast to Kresta Bay, along the coast of the Koryak Highlands, and along eastern Kamchatka to the Kamchatskiy Gulf in the south. In the Sea of Okhotsk, it occurs in the Shelikhov Gulf to the Koni Peninsula in the south (Kondratyev et al. 2000).

Four nests have been found in Russia: one on the Chukotka peninsula near Provideniya Bay, one in northeastern Kamchatka, and two in the northeastern sea of Okhotsk (one in the Shelikhov Gulf and one in Babushkina Bay) (Konyukhov et al. 1998, Kondratyev et al. 2000). In the Chukokta peninsula, its breeding range is thought to be concentrated on the southeastern tip of the peninsula, from the mouth of Mechigmen Lagoon south to the mouth of Tkachen Bay, close to appropriate alpine nesting habitat (Konyukhov et al. 1998).

2. Winter Distribution

The winter distribution of the Kittlitz's murrelet in Alaska is poorly understood but is thought to be pelagic (Day et al. 1999). Sightings during Alaska Christmas Bird Counts from 1967 to 1997 total only 31 Kittlitz's murrelets--3 in Southeast Alaska, 21 in Southcoastal Alaska, and 7 in Western Alaska--suggesting that most birds leave protected bays and move farther offshore during winter (Day et al. 1999). Kittlitz's murrelets have also been reported during winter in the mid-shelf regions of the northern Gulf of Alaska (Day et al. 1999). The winter range of the Kittlitz's murrelet in Russia is not well known, but murrelets have been sighted near coastal Kamchatka Peninsula and the Kuril Islands (Day et al. 1999). More detailed information on the winter distribution in Alaskan and Russian waters is provided below.

Alaska

Very few winter reports exist from Southeast Alaska, and none of these are from Glacier Bay, the area of greatest concentration in the summer. Early spring records in the vicinity of La Perouse Galcier, Lituya Bay, and Fairweather Grounds suggest some birds may winter nearby. In Southcoastal Alaska, the Kittlitz's murrelet is mostly absent in the winter. Where it has been observed, however, it seems to occur in high densities. Many of the records are from early spring, and it is unclear whether they indicate wintering nearby or early arrival on the breeding grounds. In 1969, Kittlitz's murrelets were observed along the outer coast of the Kenai peninsula off the Nuka, Northwest, and Aialik glaciers. Birds have been spotted very infrequently during Christmas Bird Counts in Cordova, Homer, and at sea between Seward and Kodiak, but never during Christmas Bird Counts on Kodiak Island. The Kittlitz's murrelet is reported to occur in the open waters of Prince William Sound throughout the winter, and is believed to winter over the open continental shelf in the northern Gulf of Alaska. Kittlitz's murrelets are believed to occur only rarely in winter in southwestern and western Alaska. However there are a few records that suggest wintering (presumably of arctic nesting birds) may occur in leads in the pack ice in the Bering Sea. (Above information from Day et al. 1999).

Russia

The winter range of the Russian population is largely unknown, though birds are known to occur near coastal Kamchatka Peninsula and the Kuril Islands (Day et al. 1999). Low numbers also winter in the Sireniki Polynya off the southern Chukotka peninsula (Konyukhov et al. 1998). Kittlitz's murrelets have been seen of the coast of northeast Japan, but this is probably indicative only of casual occurrence here (Day et al. 1999).

D. Habitat Requirements

The Kittlitz's murrelet exhibits a strong association with glacially influenced habitat that has led researchers to call it the "glacier murrelet" (van Vliet 1993). The nesting and at-sea foraging habitat of Kittlitz's murrelet are described in detail below.

1. Nesting Habitat

The Kittlitz's murrelet nests solitarily on bare ground on remote alpine slopes of rugged coastal mountain ranges (Day 1995, Day et al. 1999). The nest itself is simply a scrape or depression, usually in small patch of gravel, although occasionally just on bare rock (Day et al. 1999). Because of its cryptic plumage, secretive behavior, and low nesting densities, very few nests have been observed (Day et al. 1999). Based on the 23 nest records that existed in 1999, nesting habitat has predominantly included unvegetated or sparsely vegetated talus and scree slopes above timberline on coastal mountainsides, and less commonly, small clefts in cliff faces (Day et al. 1999). Nests have generally been located in the vicinity of glaciers, cirques near glaciers, or recently glaciated areas (Day et al. 1983, Day 1995, Day et al. 1999, Piatt et al. 1999). A nest discovered on Kodiak Island in 2006 was located on exposed bedrock (not in scree or talus habitat) on an otherwise sparsely vegetated, south-facing, quartz diorite ridge, near small remnant alpine glaciers and permanent snowfields (Stenhouse et al. 2008). From 2005-2008, 29 Kittlitz's murrelet nests were discovered on Agattu Island in the Aleutian chain on mountainous scree slopes (Kaler et al. 2008). The four nests found in the Russian Far East were located in the alpine zone of mountains at elevations of 230-1070 m in rocky areas (Kondratyev et al. 2000).

At the mesoscale, Kittlitz's murrelet nest-site selection is thought to be influenced by the availability of snow-free habitat early in the breeding season in proximity to foraging areas (Piatt et al. 1999). Kittlitz's murrelet nests have been found at a median elevation of 760 m (range 140-2,000 m, *n* = 11) in the southern portion of the range and at lower elevations averaging 335 m (range 230-430 m, *n* = 6) in the northern portion of the range (Day et al. 1999). Nesting slopes ranged from 15–45° and usually about 15–25° (Day et al. 1999). Day (1995) proposed that nests at higher elevations tend to be located on south facing slopes, presumably because increased solar radiation melts snow earlier, making sites available for nesting earlier in the season. Wind scouring on mountain slopes also appears to be an important mechanism for making nest sites available earlier in the season (Day et al. 1999, Piatt et al. 1999). Piatt et al. (1999) proposed that early snow-free habitat was likely more predictable in wind-scoured areas than in areas influenced only by solar radiation, since snow clearing by solar warming would depend on snow depth. Indeed, several nests have been found in bare spots in snow fields or near glaciers, suggesting that these sites are selected because they are snow-free earlier in spring (Piatt et al. 1999).

Kittlitz's murrelet nest sites appear to be associated with a number of other habitat features. Nests are often found just downhill of a large rock or boulder, which is thought to protect the nest from rocks rolling downhill and to provide a stable microclimate buffered from wind and snow (Day et al. 1999). Nests generally occur within 2,000 meters from the nearest stream and within 200 meters of the top of the mountain or ridge, lending support to the hypothesis that young are assisted in the their fledging voyage to the sea by streams and gravity (Day 1995, Day et al. 1999). Kittlitz's murrelet nests have ranged from 0.25-75 km from the coastline (Day et al. 1999). Day's early analysis found that average nest distance from the coast in the northern portion of the range (23 km) was about twice that in the southern portion of the range (11 km) (Day et al. 1983). These trends are consistent with the rugged coastal mountain topography of the southern portions of the range as compared to the lower elevations and more rolling topography of its northern range.

In relation to the congeneric marbled murrelet, available information suggests that Kittlitz's murrelets generally nest at slightly higher elevations and about twice as far inland as marbled murrelets where their ranges overlap (Day et al. 1983). Kittlitz's murrelets appear to be exclusively ground nesting, while the overwhelming majority (approximately 97%) of marbled murrelets within the range of the Kittlitz's murrelet are tree-nesters, not ground nesters (Pitocchelli et al. 1995). Finally, *Brachyramphus* murrelets are the only alcids that do not nest on predator-free islands (Piatt et al. 1999). Thus, Kittlitz's murrelet nest-site selection and cryptic breeding plumage likely reflect adaptations to avoid predators (Piatt et al. 1999).

2. At-sea Foraging Habitat

Studies of at-sea summer foraging habitat of the Alaska population of Kittlitz's murrelet indicate that it has a restricted set of habitat preferences (Kendall and Agler 1998, Day et al. 2000, Day et al. 2001, Kuletz et al. 2003, van Pelt and Piatt 2003, Kissling et al. 2007a). These studies indicate that during the breeding season the Kittlitz's murrelet is primarily found in nearshore waters (bays and fjords) near tidewater glaciers, uplands dominated by ice, and glacier outflows, particularly where glaciers or glacial-fed streams meet saltwater and produce areas of high turbidity, and to a lesser extent offshore of remnant high-elevation glaciers and deglaciated coastal mountains (Day et al. 1999, Kuletz et al. 2003). The shallow, turbid nearshore waters near tidewater glaciers and glacial outflows provide a productive environment that appears to aggregate high-energy forage fish preferred by Kittlitz's murrelets during the nesting season (Day et al. 2003, Kissling et al. 2007b, Arimitsu et al. 2007). The following section summarizes recent studies on the foraging habitat associations of the Kittlitz's murrelet, focusing on summer habitat.

At-sea surveys of Kittlitz's murrelets conducted in lower Cook Inlet, Prince William Sound, and southeastern Alaska in summer and winter during 1989 to 1996 detected positive associations between Kittlitz's murrelet distribution and glacially influenced habitats (Kendall and Agler 1998). Kendall and Agler (1998) observed the largest concentrations of Kittlitz's murrelets in Prince William Sound and southeastern Alaska where tidewater glaciers occurred. Specifically, in Prince William Sound, Kittlitz's murrelets occurred in high densities near tidewater glaciers or runoff from other glaciers and in low densities away from these habitats. In southeastern Alaska, Kittlitz's murrelets were closely associated with glaciers or recently deglaciated areas with the exception of Sea Otter Sound. In contrast, Kittlitz's murrelets were found in low densities throughout lower Cook Inlet where there are no tidewater glaciers. During winter, Kittlitz's murrelets occurred in low densities in Prince William Sound and were not detected in eastern lower Cook Inlet, suggesting that murrelets may disperse away from fjords and bays in winter to offshore waters (Kendall and Agler 1998).

Day et al. (2000) examined at-sea summer distribution of Kittlitz's murrelet in four bays in Prince William Sound, Alaska, in 1996–1998 in relation to six habitat factors: habitat type, site, ice cover, Secchi depth, sea-surface temperature, and sea-surface salinity. Habitat type showed the greatest effect on the distribution and abundance of Kittlitz's murrelets. Murrelets exhibited an overall preference for glacially-affected and glacial-stream-affected habitats and avoided glacially-unaffected habitats (Day et al. 2000). At the bay scale, they were clumped in distribution, preferring two sites that were more heavily influenced by glaciers--College and Harriman Fjords. Water clarity as indicated by Secchi depth was also important in explaining habitat use and presence/absence, with murrelets preferring highly turbid waters with Secchi depths of 1 m. Day et al. (2000) postulated that sites with large inputs of turbid fresh water from tidewater and hanging glaciers were particularly important to Kittlitz's murrelets. Ice cover was of lesser importance, with birds preferring waters with light ice cover (0.5–15%) and avoiding waters with heavy ice cover (≥50%). Sea-surface salinity was of least importance and indicated attraction to areas of input of fresh water and to areas of high salinity. Day et al. (2000) concluded "The preference of this species for limited areas of heavy glaciation, high turbidity, and partial ice cover associated with glacial affected areas, suggests that these habitats are of greatest importance in conserving this rare species" (p. 105).

In a related analysis, Day et al. (2003) compared habitat use and niche overlap between Kittlitz's murrelet and the sympatric marbled murrelet in the nearshore waters of Prince William Sound during 1996–1998, which provided insight into the ecological specialization of the Kittlitz's murrelet. Kittlitz's murrelets preferred glacially-affected and glacial-stream-affected habitats and avoided marine sills and glacially-unaffected habitats, whereas marbled murrelets preferred glacially-unaffected habitats (Day et al. 2003). Kittlitz's murrelets tended to occur in waters that were more turbid, icier, colder, and fresher than those used by marbled murrelets (Day et al. 2003). Additionally, Kittlitz's murrelets foraged within the glacially-affected fjords throughout the summer until leaving the bays during the winter, while marbled murrelets primarily foraged outside of glaciated fjords in the summer, indicating an even greater habitat separation between the two species (Day et al. 2003). The primary differences between the species for specific habitat types suggests that Kittlitz's murrelets are more closely associated with glacially-derived, turbid water than are marbled murrelets (Day et al. 2003).

Day et al. (2003) also found that Kittlitz's murrelets have proportionately larger-diameter eyes than those of marbled murrelets, and interpreted this as an adaptation of Kittlitz's murrelets for foraging in low light levels in turbid glacial water (Day et al. 2003). The researchers suggested that ability to feed in turbid areas might allow Kittlitz's murrelets to take advantage of food resources that are unavailable to marbled murrelets or that are concentrated in this habitat type (Day et al. 2003). The researchers stated:

> For example, in Glacier Bay, Alaska, known and potential fish prey such as Pacific sand lance (*Ammodytes hexapterus*) and capelin (*Mallotus villosus*) are more common in the more turbid waters of the middle and upper bay than in the clearer waters of the lower bay (Robards et al. 1999), which suggests that specialization for foraging in such waters may provide selective benefits to Kittlitz's murrelets (Day et al. 2003: 695).

Day et al. (2003) cautioned that the Kittlitz's murrelet specialization for foraging in turbid glacial waters makes them more vulnerable to disturbances in these habitats that reduce their foraging ability and to factors that reduce the availability of this foraging habitat, such as glacier loss.

Kuletz et al. (2003) detected positive associations between Kittlitz's murrelet distribution and stable and advancing glaciers in Prince William Sound. Based on extensive surveys in 2001 that targeted 17 fjords and bays, Kuletz et al. (2003) found that 92% of Kittlitz's murrelets were found at the four sites with stable or advancing glaciers and only 8% at sites with retreating or non-tidewater glaciers based on glacial accounts from the late 1980s. In addition, the distribution of Kittlitz's murrelets changed over time during 1989 to 2001. Murrelets increased in abundance in northwest PWS where more glaciers were stable or advancing and largely disappeared in areas with retreating glaciers or which had no direct glacial input, suggesting a strong association with the phase of advancement or recession exhibited by surrounding glaciers (Kuletz et al. 2003). For example, Harriman fjord, with eight stable or advancing glaciers, supported ~ 58% of the estimated PWS population in 2001. Thus Kuletz et al. (2003) concluded that Kittlitz's murrelets appear to prefer regions with stable or advancing glaciers: "Our results support the observation that Kittlitz's Murrelets associate with tidewater glaciers (Isleib & Kessel 1973, Kendall & Agler 1998, Day *et al*. 1999, 2003), and more importantly, the hypothesis that their distribution is affected by glacier status" (Kuletz et al. 2003: 138).

Studies have also reported positive associations between Kittlitz's murrelet distribution and glacially-affected marine habitats along the Kenai peninsula, southeast Alaska, and Kachemak Bay. Van Pelt and Piatt (2003) found that Kittlitz's murrelets occurred almost exclusively near glacier faces or outflows along the southern Kenai Peninsula. In a study of the distribution of Kittlitz's murrelets in southeast Alaska from Icy Bay to LeConte Bay, Kissling et al. (2007a) found that Kittlitz's murrelet abundance was positively correlated with stable, but not advancing or retreating, tidewater glaciers and with adjacent uplands dominated by ice. Kissling et al. (2007a) observed the highest Kittlitz's murrelet densities in Icy Bay where three tidewater glaciers are in a stable-retracted position and one glacier recently underwent rapid retreat but is now considered stable. High numbers of Kittlitz's murrelets were also observed near the stable (or thinning in place) LaPerouse, Malaspina, and Dawes (head of Endicott Arm) Glaciers. Few Kittlitz's were observed north of Dry Bay and in Cross Sound where shrubs and forest dominate the uplands instead of ice and rock (Kissling et al. 2007a).

Kissling et al. (2007b) conducted more detailed at-sea surveys of Kittlitz's murrelets in Icy Bay, Alaska, from 2 July to 5 August 2005. Although Icy Bay has four fjords each headed by an active tidewater glacier, ice conditions permitted surveys in only one fjord, Taan fjord, which has its tidewater glacier classified as recently retreating but currently stabilized. This study detected high abundances of Kittlitz's murrelets in Taan fjord and found that tidal current strength influenced murrelet abundance most consistently, where higher abundances were associated with strong tidal currents. Specifically, the researchers observed the highest densities of Kittlitz's murrelets in mid-Taan fjord and near the mouth of Taan fjord in close proximity to a shallow shoal with an adjacent submarine ridge. The researchers hypothesized that these bathymetric features interacted with strong tidal currents to create local upwelling, tidal rips, and eddies that aggregated prey (Kissling et al. 2007b).

Finally, Kuletz et al. (2008) examined marine habitat use of Kittlitz's murrelets in Kachemak Bay and found that Kittlitz's murrelets were positively associated with glacial outflows and particularly with plumes of glacial silt, where murrelet densities were especially high.

Kittlitz's murrelets are also found in non-glacial waters in Alaska, including the Kodiak Archipelago, the Alaska Peninsula, Bristol Bay, the Aleutian Islands, and the Seward and Lisburne peninsulas, as well as Kamchatka in Russia (Day et al. 1999, Stenhouse et al. 2008), albeit probably in smaller numbers (Day et al. 1999). This distribution outside of current glacial influence may represent remnant populations of previously glaciated habitat (AKNHP 2004). Information on at-sea habitat associations in these regions is sparse. Kittlitz's murrelets have been observed year-round in the major fjords and bays of the Kodiak Archipelago (Stenhouse et al. 2008). In Bristol Bay, Kittlitz's murrelets were observed in summer 1969 at distances of 0.5-65 nautical miles (1-120 km) from shore on the open continental shelf, although most birds occurred <20 nm from shore (Bartonek and Gibson 1972). Off Russia, Kittlitz's murrelets occur in arctic, subarctic, and boreal waters, similar to birds in Alaska (Day et al. 1999).

E. Diet and Foraging Behavior

1. Diet

The summer diet of Kittlitz's murrelet has not been well-described but is thought to consist primarily of neritic forage fishes with a smaller proportion of neritic macrozooplankton (Day et al. 1999). Recorded summer prey species include postlarval capelin (*Mallotus villosus*), Pacific sand lance (*Ammodytes hexapterus*), Pacific herring (*Clupea pallasi*), Pacific sandfish (*Trichodon trichodon*), and juvenile pollock (*Theragra chalcogramma*) as well as euphausiids, gammarid amphipods, and shrimp zoeae (Day et al. 1999). Quantitative diet analysis of 16 Kittlitz's murrelets in the Bering Sea and Kodiak Island found that they were eating approximately 70% fish and 30% euphausiids (Day et al. 1999). The morphology of the Kittlitz's murrelets tongue and palate suggests a preference for fish as well (Day et al. 1999, Day and Nigro 1999).

In Prince William Sound, a visual study of Kittlitz's murrelet feeding found that diet varied temporally (Day and Nigro 1999). Of 29 observations, about 7% of birds were observed with fish in early summer, about 17% of birds in mid-summer, and about 76% of birds in late summer (Day and Nigro 2000). These authors stated that "although some of this seasonal increase in frequency may be caused by the holding of fishes destined for chicks in the nest, the apparent lack of production of young by Kittlitz's murrelets (Day and Nigro, unpubl. data) but increase in fish-holding frequency suggests that other factors, such as availability, were causing this seasonal change" (Day and Nigro 2000). Day and Nigro (1999) have suggested that Kittlitz's murrelets in Prince William Sound likely forage extensively on zooplankton in the early summer, switching to primarily fish by late summer.

The winter diet of the Kittlitz's murrelet is almost completely unknown. One bird collected on April 1, 1977 contained a neritic hyperiid amphipod, *Parathemisto libellula* (Day et al. 1999).

2. Foraging Behavior

As described above, the Kittlitz's murrelet congregates in and prefers to forage in glacially-affected habitats near tidewater glaciers, terminal moraines, or outflows of glacial streams (Day et al. 1999). Beyond this distinctive trait, Kittlitz's murrelet foraging habits are not well known across its range. In general, it has been observed to forage singly or in small groups, occasionally in loose foraging aggregations spread over hundreds of meters, and occasionally in mixed-species foraging flocks (Day et al. 1999). The Kittlitz's murrelet captures its food during wing-propelled underwater "flight," although little is known about its underwater foraging behavior (Day et al. 1999).

Day and Nigro (1999) conducted an extensive study of Kittlitz's murrelet foraging in Prince William Sound from 1996-1998 that provides much detailed information on behavior and microhabitat associations. In Prince William Sound, Kittlitz's murrelets foraged exclusively within bays and primarily within nearshore areas (Day and Nigro 1999). Thus, unlike the marbled murrelet, Kittlitz's murrelets did not leave the bays to feed (Day and Nigro 1999). Kittlitz's murrelets tended to forage singly or in small groups, with a mean feeding group size of 1.3 birds ± 0.8 SD (range 1-12, n = 689 groups) for nearshore water in bays within Prince William Sound, and 1.3 ±0.5 SD (range 1-3, n=77 groups) for offshore waters within these bays (Day and Nigro 1999, Day et al. 1999). Mean diving time while feeding in Prince William Sound was 29.2 sec (SD = 10.4, range = 6-58, n=76), nearly identical to marbled murrelet dive times in the same area (Day and Nigro 1999). Foraging occurred at all times of the day and night, but appeared to be most frequent in the morning (Day and Nigro 1999).

Day and Nigro (1999) examined 15 variables related to feeding frequency, and found eight to be significant. Insignificant variables were time of day, tidal stage, current strength, secchi depth, sea-surface temperature, sea-surface salinity, and distance from nearest fresh water, while significant variables were survey type (distance from shore), season, year, habitat type, percent ice cover, distance from shore in the nearshore zone, depth of the nearshore zone, and shoreline substrate in the nearshore zone (Day and Nigro 1999). Of the significant variables, the most important was survey type (distance from shore). Birds were found to be almost four times more likely to feed in nearshore areas than in offshore areas. Feeding frequency also varied with distance from shore within the nearshore zone: "Feeding frequency declined steadily with increasing distance, suggesting that these birds prefer to feed as close to shore and, thus, in as shallow water as they can" (Day and Nigro 1999). Further, feeding frequency varied with water depth within the nearshore zone, and some areas less than 3 meters deep were regularly used for foraging during this study (Day and Nigro 1999).

Percent ice cover on the water surface was also a significant variable, with feeding frequency declining with increasing ice cover, and then jumping abruptly at the highest percentage of cover (Day and Nigro 1999). Day and Nigro concluded "Hence, it appears that there is a decreasing frequency with increasing cover but that the few birds that are able to penetrate high-cover areas do so because they are good places to feed. Most birds are unable to penetrate such areas, however (only ~4% of all birds were in this cover....)" (Day and Nigro 1999). Within the nearshore zone, feeding frequency also varied significantly by adjacent shoreline substrate. Feeding frequencies were highest offshore of large alluvium, small alluvium, or ice substrates and lowest offshore of bedrock (Day and Nigro 1999).

Overall, Kittlitz's murrelet foraging was associated with highly turbid water in nearshore zones, resulting from proximity to either a tidewater glacier or a glacial stream flowing from a retreated glacier (Day and Nigro 1999).

F. Vocalizations

The vocal array of the Kittlitz's murrelet is not fully understood. This species appears to be relatively reticent, with vocalizations at sea detected primarily when boat motors are turned off and often with the aid of a directional microphone (van Pelt et al. 1999). In contrast, the strident calls of the marbled murrelet are usually detected in surveys by sound rather than by sight (van Pelt et al. 1999). Three calls were described by Day et al. (1999): the groan call, long-groan call, and chew call. The groan call has been observed primarily between members of a presumed pair when one bird is attempting to locate or contact the other. The long-groan call is used for pair maintenance and during courtship displays. The chew call has been heard from one member of a presumed pair when it appeared to be attempting (and failing) to get its mate to fly off (Day et al. 1999). Van Pelt et al. (1999) described the groan call and quack call, but stressed that more information is needed before vocalizations can be used in the design of effective programs to monitor the species.

G. Reproduction

Many aspects of Kittlitz's murrelet reproductive behavior are still poorly understood. Kittlitz's murrelets are presumed to be monogamous like other members of the alcid family, but their mating system has not been confirmed (Day et al. 1999). A courtship and/or pair maintenance display described as the "bill up display" has been observed where a pair swims side by side with the head raised at an angle of ~10° above the horizontal while calling at the same time (Day et al. 1999). The displays observed have been quite short (Day et al. 1999). The display differs from that of the marbled murrelet in that the head is held at a lower angle and the display is shorter (Day et al. 1999). Kittlitz's murrelets are also suspected of carrying out this display underwater, though this has not been confirmed (Day et al. 1999). Copulation may also occur on the water (Day et al. 1999).

Nesting phenology varies considerably across the geographical regions where the Kittlitz's murrelet nests (Day 1996). Nesting begins earlier in the southern portions of the range where birds have a longer window of opportunity in which to breed and hence exhibit more variability in breeding times (Day 1996). In the northern portions of the range, breeding begins later and occupies a smaller window of opportunity and hence variability in breeding times is lower (Day 1996). This pattern is likely due to greater persistence of sea ice and terrestrial ice and snow in the northern regions (Day 1996).

Extrapolating from recorded observations of nests, eggs, and young, and assuming an incubation period identical to the marbled murrelet (~30 days), Day (1996) estimated the phenology of the egg-laying and chick-rearing periods for the northern and southern regions of the breeding range. Day (1996) estimated that egg-laying occurs from May 15-June 14, hatching from June 14-July 14, and fledging from July 8-August 7 in southern regions, while egg-laying occurs from June 16-28, hatching from July 16-28, and fledging from August 9-21 in the northern regions (Day 1996). In total, Kittlitz's murrelets need at least 54 days from the time the egg is laid in order to successfully raise a chick to fledging (Day and Nigro 1999).

Kittlitz's murrelets lay one egg per year in a scrape or depression, usually in small patch of gravel, although occasionally just on bare rock (Day et al. 1999). The single egg is colored olive-green to blue-green with brown mottling (Day et al. 1983, Piatt et al. 1999). Both the male and female have incubation patches on the middle of their abdomens and both sexes incubate (Day et al. 1999). The incubation period is not known but presumed to be about 30 days (Day et al. 1999).

Newly hatched chicks are helpless and covered in down that is buffy to grey in color (Day et al. 1999). Based on observations of one nest, nestlings are fed one fish at a time at rate of 4–6 feedings per day throughout the day and night (Day et al. 1999). Nestlings may fledge at ≤24 d of age at only about 40% of adult weight (Day et al. 1999). At fledging, chicks are still relatively poor fliers, though strong swimmers, leading Day (1996) to hypothesize that chicks reach the water by a series of fluttering flights down the mountains, assisted by glacial streams.

H. Demographic Rates

Demographic data is extremely limited for the Kittlitz's murrelet, although recent data from Alaska provide insights into reproductive success.

Age of first breeding

No data on age at maturity are available for the Kittlitz's murrelet, although the congeneric marbled murrelet begins breeding at two to four years of age (Day et al. 1999).

Reproductive success

Data on reproductive success is limited. However, studies that examined reproductive success of Kittlitz's murrelets in Alaska have reported extremely low chick production.

Day and Nigro (2004) estimated the reproductive success of the Kittlitz's murrelet in four bays in Prince William Sound, Alaska, in 1996–1998, based on counts of young and adult birds sampled during summer at-sea surveys. Following techniques for estimating the reproductive performance of the marbled murrelet in Alaska, Day and Nigro (2004) calculated the ratio of hatch year (HY) to after-hatch-year (AHY) birds detected in each bay as an index of reproductive output. Measured reproductive output in the four study bays was essentially zero in all three years: only one fledgling in 1996, none in 1997, and evidence of breeding but no fledglings seen in 1998. The researchers also observed what appeared to be mixed-species pairs of Kittlitz's and marbled murrelets in early summer 1997 and on all late-summer cruises, which they postulated was a consequence of the low numbers of Kittlitz's murrelets compared with marbled murrelets in the study bays. The authors conclude that "the low reproductive output in all three years and the occurrence of mixed-species pairs are sources of conservation concern and suggest that this species may be experiencing problems reproducing successfully in Prince William Sound" (Day and Nigro 2004: 89).

Further, Day and Nigro (1999) incorporated the findings of low Kittlitz's murrelet recruitment in Prince William Sound in 1996-1998 into a population model developed for the congeneric marbled murrelet to investigate the population-level implications of poor recruitment. Day and Nigro (1999) determined that observed low levels of recruitment combined with average annual adult survival rates of 85-90% would result in annual population declines of 10-15% if maintained over many years:

> Body mass and annual reproductive effort are good predictors of annual survivorship in alcids. Marbled murrelets, which are similar in size to Kittlitz's murrelets and which also lay 1 egg/yr, are estimated to have an annual adult survivorship of ~85%. Further, Kittlitz's murrelets, like marbled murrelets, also exhibit geographic asynchrony in the timing of movements into and out of specific locations that, presumably, reflect asynchrony in the timing of reproduction. Unfortunately, the age at first breeding is unknown for both species, so Beissinger constructed his models for a range of ages. Given these model parameters, a Kittlitz's murrelet population in which the average age at first breeding was 3 yr would need to have an annual (female fecundity of 0.39/pair to remain stable if the average annual survivorship was 85% and 0.23/pair if the annual survivorship was 90%. Such fecundity levels would require HY:AHY ratios of ~0.18-0.28:1 in late summer. After correcting for the higher numbers of AHY birds that occur in the bays in early summer, these ratios would be ~0.13-0.26 for Kittlitz's murrelets or about 6-13 times the ratio that we measured in the only bay that appeared to produce young in 1996.
>
> The implication of Beissinger's modeling (1995) is that, if it occurs regularly in Kittlitz's murrelets, such a low level of productivity will result in substantial annual declines in population size. Although we have not constructed such models, the low levels of fecundity recorded in this study and average annual survival rates of 85-90% would result in annual population declines of 10-15% if maintained over many years (Day and Nigro 1999: 49).

Two additional studies have provided the first data on reproductive success of Kittlitz's murrelet from direct nest observations. A study in Icy Bay that monitored four nest sites throughout the breeding season in 2007 found that one nest fledged successfully, one failed, and two were of unknown fate (USFWS 2007, Kissling et al. 2008). A study of 17 nests on Agattu Island by researchers Robb Kaler and Leah Kenney in 2008 found that 9 of 17 (53%) eggs hatched and only 1 out of 9 (11%) chicks survived to fledge (Kaler et al. 2008), yielding an extremely low productivity of 0.06 chicks fledged per nesting pair. Egg predators and non-hatching eggs led to nest failure during the incubation phase, while chicks were commonly discovered dead in the nest during the chick-rearing phase (Kaler et al. 2008). Hidden cameras trained on the nests indicated that chicks died either from exposure to weather or from starvation (Kaler et al. 2008). While the sample size from the Icy Bay study is too small to draw conclusions, the Agattu Island and Prince William Sound studies indicate that Kittlitz's murrelets are suffering from extremely low reproductive success.

Survival and lifespan

Demographic data on survivorship and lifespan are unknown (Day et al. 1999). However, adult body mass suggests an annual adult survival of about 85–90% (Day et al. 1999).

II. POPULATION STATUS

The Kittlitz's murrelet has been widely recognized as being of high conservation concern. The Kittlitz's murrelet was listed as Critically Endangered by the World Conservation Union (IUCN) in 2004, a category shared only by one other bird species in Alaska, the Eskimo curlew (*Numenius borealis*), which is thought to be extinct (BirdLife International 2008). The IUCN based its listing of Kittlitz's murrelet on rapid population declines that have occurred in important population centers (BirdLife International 2008). While the IUCN listing affords no regulatory protection to the Kittlitz's murrelet, this listing is an unequivocal statement from scientists that the species warrants protection at the national and international level.

The U.S. Fish and Wildlife Service ("USFWS") determined in 2004 that the Kittlitz's murrelet was "warranted but precluded" for protection under the federal Endangered Species Act due to multiple threats including "glacial habitat loss or degradation, increased adult and juvenile mortality, and low recruitment" (Federal Register 69: 24877). The USFWS stated that "we believe that glacial retreat and oceanic regime shifts are the factors that are most likely causing population-level declines in this species" (Federal Register 69: 24877). In 2007, the USFWS elevated the listing priority number of Kittlitz's murrelet from a 5 to a 2 given the high magnitude and imminence of threats to the species:

> Based on the observed population trajectory and the severity of present threats (rapid glacial retreat, acute and chronic oil spills, commercial gillnet fishing, and human disturbance from tour boats), the threats to this species are high in magnitude and imminent. We changed the LPN from a 5 to a 2 to reflect that the threats to this species are ongoing (Federal Register 72: 69038).

NatureServe had categorized the Kittlitz's murrelet as Globally Imperiled (G2, NatureServe 2008), and the National Audubon Society ranked the Kittlitz's murrelet as one of the ten most endangered birds in the United States (National Audubon Society 2006).

A. Historic Abundance Estimates

The first systematic study of Kittlitz's murrelet abundance was conducted in Prince William Sound in July-August 1972 by M.E. "Pete" Isleib and Brina Kessel. Kittlitz's murrelets in Prince William Sound were estimated at 57,000 individuals, and the populations in the North Gulf Coast and Prince William Sound were estimated to number in the hundreds of thousands (Isleib and Kessel 1973). In several fjords and waters near the Malaspina-Bering icefields, Kittlitz's murrelets were reported to "outnumber all other alcids in these waters" (Isleib and Kessel 1973). Specifically, the findings were as follows:

> The Kittlitz's murrelet is a common resident of the North Gulf Coast-Prince William Sound region.
>
> Apparently preferring glacial moraines for nesting, these murrelets are abundant locally in inshore waters during the summer, especially near glaciated coastal areas, they are most abundant in the waters of upper Unakwik Inlet, upper College Fiord, and in waters abutting the Malaspina-Bering icefields, outnumbering all other alcids in these waters. U.S. Fish and Wildlife Service surveys 21 July-4 August 1972 estimated approximately 57,000 Kittlitz's murrelets in Prince William Sound, almost all in the fiords and bays on the northern and western periphery of the sound. On 30 July 1972, there were more than 10,000 Kittlitz's murrelets above the Unakwik Reef in Unakwik Inlet, about 2,500 birds in a single, loose flock, Kittlitz's outnumbered the marbled murrelet in this area, whereas the reverse was true just below Unakwik Reef.
>
> Although there are no specific breeding records for the region, these birds apparently nest above timberline and/or on unvegetated coastal glacial moraines.
>
> During the winter, Kittlitz's murrelets apparently disperse throughout in-shore and offshore waters, becoming rare at the heads of the fiords. Several hundred Kittlitz's murrelets were present in Prince William Sound during U.S. Fish and Wildlife Service surveys 7 March-1 April 1973. Laing (1925) reported six at Yakutat Bay on 12 March 1924.
>
> Estimates of populations utilizing the North Gulf Coast and Prince William Sound: yearly, several 10,000's, probably a few 100,000's. (Isleib and Kessel 1973:100).

Isleib and Kessel's estimate of 57,000 Kittlitz's murrelets in Prince William Sound was later revised to 63,229 ± 80,122 (Day and Nigro 1999).

B. Current Abundance Estimates and Population Trends

1. Global Population Estimates

The Kittlitz's murrelet population in Alaska has been estimated at 15,913 individuals, ranging from 7,769-26,962 birds, based on surveys during 1999-2005 (Table 1) (USFWS 2007). In addition, in Russia as many as 5,000 Kittlitz's murrelets may inhabit the Kamchatka coast (USFWS 2007, Kondratyev et al. 2000) with low numbers in the Okhotsk and Chukchi Seas (van Vliet 1993, Day et al. 1999, Kondratyev et al. 2000). Thus the global Kittlitz's murrelet population may average ~20,000 to ~21,000 individuals.

Table 1. Population estimates of Kittlitz's murrelets in Alaska, by geographic area.
Source: USFWS (2007): Table 2.

Area	**Population estimate N (Range)**	**Year(s) of Survey**	**Source or responsible agency**
Total population of SEAK outside of Glacier Bay	5,049 (2,380-8,097)	2002-2005	Kissling et al. 2005, Kissling, unpub. data
Glacier Bay (SEAK)	2,265 (1,349-3,181)	1999 – 2000	Robards et al. 2003
Kenai Fjords	509 (126-2,050)	2002	Van Pelt and Piatt 2003
Prince William Sound	2,022 (919-3,125)	2001	Kuletz et al. 2003b
Lower Cook Inlet	1,181 (241-2,121)	2004	Speckman et al. 2005
Southern Alaska Peninsula	2,265 (1,165-4,405)	2003	Van Pelt and Piatt 2005
Aleutian Islands	2,622 (1,589-3,983)	2003, 2004, 2005	Piatt et al. 2005, Romano, USGS, Anchorage, unpub. data, Piatt and Romano, USGS, Anchorage unpubl. data
TOTAL	**Mid-point = 15,913 Range = (7,769 – 26,962)**		

Other population estimates for the Kittlitz's murrelet include a global estimate of 18,300 birds by van Vliet (1993) (Table 2), an estimate of 12,130 birds (range = 3,818-20,448) in Alaska by Kendall and Agler (1998), an estimate of 9,500–26,700 birds in Alaska by USFWS in 2005 (Federal Register 71: 53780), and an estimate of 16,700 birds in Alaska by USFWS in 2008 (Federal Register 73: 75194).

Table 2. Kittlitz's murrelet global population estimate, as of 1993.
Source: van Vliet (1993).

Population	**Number of Birds**
Glacier Bay National Park and Preserve region	4,500
Wrangell-St. Elias National Park region including Yakutat Bay	3,000
College Fjord-Unakwik Inlet, Prince William Sound	3,000
Kenai Fjords National Park region	800
Kachemak Bay region	1,500
Katmai National Park and Alaska Peninsula to Unimak Pass	3,200
Kodiak Archipelago	300
Aleutian Islands - Attu to Unimak Pass	1,000
Cape Newenham to Wales - Seward Peninsula region	450
Chukchi Sea coastline, including Wrangell Island	450
Sea of Okhotsk	100
World Total	***18,300***

2. Regional Population Estimates

The USFWS has compiled regional population estimates from summer surveys across the Kittlitz's murrelet range in Alaska during 1993-2005, with most surveys conducted during the 2000s (USFWS 2007). Kittlitz's murrelets in Alaska occur primarily in four regions with most birds in Southeast Alaska (48%), followed by Southcentral Alaska (22%), the Aleutian Islands (16%), and the Alaska Peninsula (14%) (Table 3) (USFWS 2007). The largest populations occur in Glacier Bay and Icy Bay in Southeast Alaska, Prince William Sound in Southcentral Alaska, and the southern Alaska Peninsula (Table 3). However, abundance has not been surveyed off the Lisburne Peninsula, Kodiak Island, and Cold Bay on the Alaska Peninsula since the early 1970s (USFWS 2007). The only winter population estimates available are 410 ± 744 for Prince William Sound and 0 for Cook Inlet (Kendall and Agler 1998).

Table 3. Results from surveys that employed different survey techniques to count birds on transects across large areas. Surveying for an uncommon animal with a clumped distribution, such as the Kittlitz's murrelet, usually results in wide confidence intervals around point estimates.
Source: USFWS (2007): Table 1.

Region	Area	Population estimate N (Range)	Year(s) of Survey	Source or responsible agency
Southeast Alaska	Outer Coast / Cross Sound to Yakutat	1,232 (351-2,432)	2003, 2004	Kissling *et al.* 2005
Southeast Alaska	Malaspina Forelands	906 (300-1,512)	2002	Kissling *et al.* 2005
Southeast Alaska	South of Glacier Bay	612 (0-1,284)	2002	Kissling *et al.* 2005
Southeast Alaska	Icy Bay	2,098 (1,368-2,828) 1317 (1,023-1,611)	2002 2005	Kissling *et al.* 2005 Kissling, unpubl. data
Southeast Alaska	Yakutat Bay	927 (694-1,160)	2000	Stephenson and Andres 2001
Southeast Alaska	Russell/Nunatak Fjords	55 (12-98)	2000	Stephenson and Andres 2001
Southeast Alaska	Glacier Bay	2,265 (1,349-3,181)	1999 – 2000	Robards *et al.* 2003
Southeast Alaska	All of Southeast AK, including Glacier Bay	5,408 (0-12,447)	1994	Kendall and Agler 1998
Southcentral Alaska	Kenai Fjords	509 (126-2,050)	2002	van Pelt and Piatt 2003
Southcentral Alaska	Prince William Sound	2,022 (919-3,125)	2001	Kuletz *et al.* 2003b

Southcentral Alaska	Lower Cook Inlet	3,353 (1,635-5,071) 1,181 (241-2,121)	1993 2004	Kendall and Agler 1998, Speckman *et al.* 2005
Aleutian Islands	Attu Island	279 (103-455)	2003	Piatt, USGS, Anchorage, unpubl. data
Aleutian Islands	Atka Island	749 (471-1,027)	2004	Romano, USGS, Anchorage, unpubl. data
Aleutian Islands	Unalaska Island	1594 (1015-2501)	2005	Romano, USGS, Anchorage, unpubl. data
Alaska Peninsula	Southern Alaska Peninsula	2,265(1,165-4,405)	2003	van Pelt and Piatt 2005

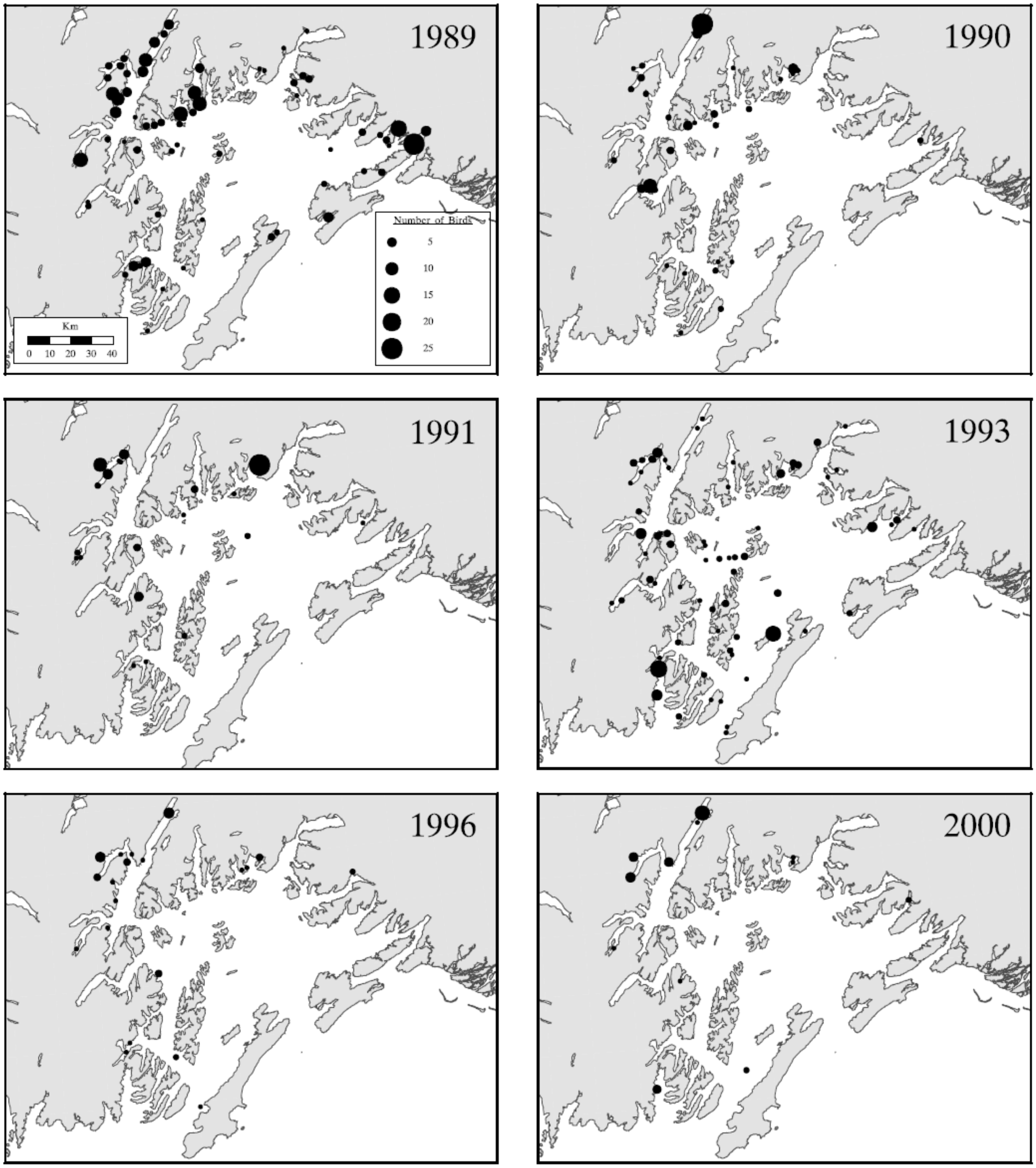
These regional population estimates do not include the Russian population which is not well known. Day et al. (1999) estimated that the Chukchi Sea population may number 1,000-5,000+ birds as estimated by Divoky, and that the breeding population on the Kamchatka and the Bering Sea coastline of Russia may number in the hundreds to low thousands. More recently, Kondratyev et al. (2000) estimated that the number of Kittlitz's murrelets in the Arctic basin is fewer than 1000 birds, that Kittlitz's murrelets are common along northeastern Kamchatka where their density was estimated at 0.8 birds/km^2 within 3 km of shore, that ~5000 birds have appeared at the Kamchatka River delta in the south during the nesting period, and that the number nesting in the Sea of Okhotsk is small (Kondratyev et al. 2000). Thus, more research is needed to confirm the size of populations in the Russian Far East.

3. Population Trends

Population trends for Kittlitz's murrelet have been assessed in five regions along the Gulf of Alaska, and Kittlitz's murrelets have declined dramatically in all of these regions: Prince William Sound (Kuletz et al. 2003), the Kenai Fjords (van Pelt and Piatt 2003), the Malaspina Forelands (Kissling et al. 2007a), Glacier Bay (Drew and Piatt 2008), and Kachemak Bay (Kuletz et al. 2008). These precipitous population declines are particularly worrisome since they have been observed for two of the world's largest concentrations of Kittlitz's murrelets in Glacier Bay and Prince William Sound.

In Prince William Sound, the USFWS conducted sound-wide seabird surveys in July of 1989-1991, 1993, 1996, 1998 and 2000. Kuletz et al. (2003) detected an 84% decline in the Kittlitz's murrelet population of Prince William Sound from approximately 6400 birds in 1989 to 1000 birds in 2000. During this period, Kittlitz's murrelet distribution in PWS changed from being fairly dispersed to being concentrated in the northwest region, and Kittlitz's murrelets have completely disappeared from areas where they were once abundant (Figure 2). If the 18% per year decline between 1989 and 2000 is linear and remains constant, near-extirpation of Kittlitz's murrelets in PWS is predicted to occur within this decade (Kuletz et al. 2005).

Figure 2. Distribution of Kittlitz's murrelets (filled circles) along randomly selected transects during the sound-wide surveys, 1989-2000. Each circle represents the total number of birds sighted on that transect.
Source: Kuletz et al. (2003): Figure 5.

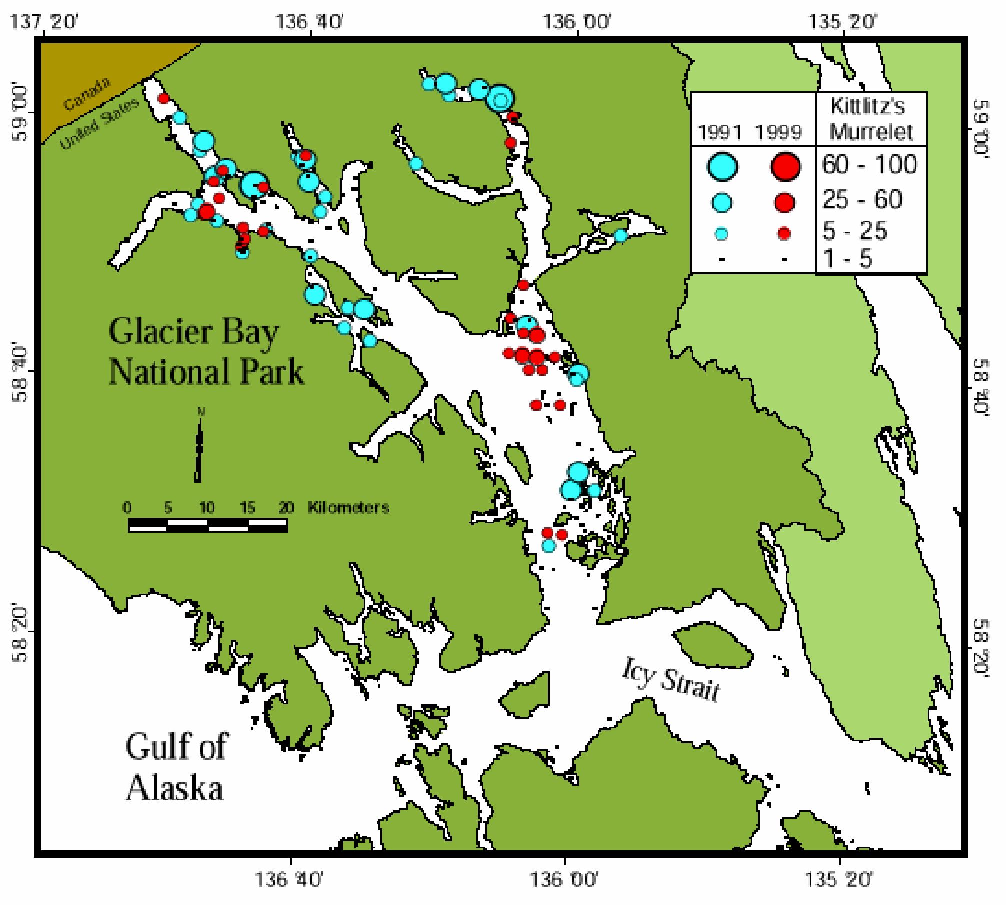


In the Kenai Fjords of Southcentral Alaska, van Pelt and Piatt (2003) reported a 74% decline in Kittlitz's murrelet numbers between 1986 and 2002 based on surveys conducted in 1986, 1989, and 2002 along the shoreline between Gore Point and Cape Resurrection. These researchers also compared the 2002 survey numbers to a 1976 survey and estimated an 83% decline across the 26 years between 1976 and 2002, with an average rate of decline of -6.9 % per year (van Pelt and Piatt 2003) .

In the Malaspina Forelands, Kissling et al. (2007a) reported a 90% decline in Kittlitz's murrelet numbers between 1992 and 2002-2004. Although Kissling et al. (2007a) noted that trends estimated from two time periods must consider the large temporal and spatial variability in murrelet distribution, these researchers concluded that "we believe the steep decline in the Kittlitz's murrelet population that we report here for this area to be legitimate" (Kissling et al. 2007a: 29).

Drew and Piatt (2008) compared survey counts of Kittlitz's murrelets in Glacier Bay, Alaska, between 1991 and 1999-2000, and found that the Kittlitz's murrelet population in Glacier Bay declined by 83% during the study period. The Kittlitz's murrelet had completely disappeared from areas where it was once abundant in Glacier Bay (Figure 3) (Drew and Piatt 2008).

Figure 3. Distribution of the Kittlitz's murrelet in Glacier Bay National Park, 1991-1999. Source: USGS (2001).



Drew and Piatt (2008) concluded that "Given the current small global population estimate for murrelets of 9,500–26,700 birds, population declines of any scale are cause for concern" (Drew and Piatt 2008: 181). Drew and Piatt (2008) also warned that the parallel precipitous declines in Kittlitz's murrelet populations at distant locations suggest a regional-scale mechanism underlying these declines, such as glacier recession:

> Although dramatic, this decline is in line with the estimated 84% murrelet population decline in Prince William Sound from 1989 to 2000 (Kuletz et al. 2003). Concordance between two areas separated by 600 km suggests that a regional–scale phenomenon may be responsible. Researchers have speculated that the decline of murrelet populations may be related to the rapid recession of glaciers in Alaska over the past several decades (van Vliet 1993, Day et al. 2003). (Drew and Piatt 2008: 181).

In Kachemak Bay, Kuletz et al. (2008) reported that Kittlitz's murrelet densities declined significantly in the entire bay by 43% (equivalent to a rate of -18% per year) and by 20% in the inner bay between 1988-1999 and 2004-2007. Kuletz et al. (2008) noted that this estimated rate of decline is conservative, and that declines across the Kittlitz's murrelet range provide strong evidence for listing the Kittlitz's murrelet:

> We conclude that the decline in Kittlitz's murrelets is real, and in fact is likely conservative, because low species identification rates in historic surveys would have reduced density estimates for identified Kittlitz's in early years. The rate of decline in the inner bay, where Kittlitz's murrelets were always present and aggregated, is an indication of a compromised population, and is comparable to declines in other summer breeding areas within its range. Since the 1980s or early 1990s Kittlitz's have declined dramatically in Prince William Sound at -18% per annum (Kuletz et al. 2005), in Kenai Fjords at – 8.7 % per annum (van Pelt and Piatt 2003), and Glacier Bay at – 8.9 % per annum (Robards et al. 2003). Our results lend support to the argument for listing of Kittlitz's murrelets as a threatened species. (Kuletz et al. 2008: 31).

Overall, Kittlitz's murrelets are experiencing precipitous population declines in all regions of Alaska where repeated surveys have been conducted, including Glacier Bay and Prince William Sound which are two of the largest global population centers. If these population trends continue, the Kittlitz's murrelet will decline to extinction in the foreseeable future. Based on its small population size, restricted range, recent drastic population declines, and multiple threats to its continued existence, the Kittlitz's murrelet clearly warrants immediate listing as an endangered species.

III. THE KITTLITZ’S MURRELET MEETS THE CRITERIA FOR LISTING UNDER THE STATE ENDANGERED SPECIES ACT

Under Alaska’s Endangered Species Act, the Commissioner is required to determine whether the continued existence of a species is threatened due to any of the following factors: (1) the destruction, drastic modification, or severe curtailment of its habitat, (2) overutilization for commercial or sporting purposes, (3) disease or predation, (4) other natural or manmade factors affecting its continued existence. AS 16.20.190(a). Here, Petitioners demonstrate that the Kittlitz’s murrelet faces significant threats to its existence from the destruction, drastic modification, and severe curtailment of its habitat due to oil pollution, global warming, and ocean acidification; and from manmade factors including mortality in gillnet fisheries and disturbance from vessel traffic.

A. Destruction, Drastic Modification, or Severe Curtailment of the Kittlitz’s Murrelet’s Habitat

1. Marine Oil Pollution

The Kittlitz’s murrelet is highly vulnerable to mortality from oil pollution. Both chronic and acute oiling in the Kittlitz’s murrelet’s marine habitat are certain to occur in the future (Piatt et al. 2007), and pose a significant threat to this species (USFWS 2007). The vulnerability of the Kittlitz’s murrelet to oil spills was predicted as early as 1979 by King and Sanger (1979) based on its body size, diving behavior, tendency to cluster in nearshore waters, restricted distribution, and low productivity. King and Sanger (1979) analyzed the vulnerability of 176 species of birds in the Northeast Pacific on the basis of 20 factors within the categories of range, population, habits, mortality, and annual exposure. The ratings ranged from 100 (most vulnerable) to 0 (least vulnerable). The Kittlitz’s murrelet received a score of 88 on this scale, four points higher than the marbled murrelet and surpassed only by the short-tailed albatross (endangered throughout its range) and the Eskimo curlew (presumed extinct) (King and Sanger 1979). The existence of a flightless molt from mid-August to approximately late September (Day et al. 1999) makes the Kittlitz’s murrelet particularly vulnerable to oil spills during this time.

Documented mortality of Kittlitz’s murrelets from oil spills highlights its vulnerability to oiling. The *Exxon Valdez* oil spill killed up to 10% of the global population of Kittlitz’s murrelet, which represents the highest proportionate loss of any species impacted by the spill (van Vliet 1994). In addition to causing direct mortality from oiling, oil spills can also result in immediate and long-term impacts to forage fish populations that Kittlitz’s murrelets prey upon. After the *T/V Exxon Valdez* spill, herring, which spawn in nearshore bays, exhibited sublethal damage and larval malformations in oiled bays of Prince William Sound, failed to spawn in historic locations, and suffered a dramatic population decline after the spill (Piatt et al. 2007). Sand lance, which occupy nearshore waters and burrow into sandy substrate, are also vulnerable to oil exposure as contamination sinks to the benthos (Piatt et al. 2007).

The observed impacts to Kittlitz’s murrelets from large oil spills and the threats from continuing chronic and acute spills, including those from oil and gas development in Alaskan and Russian waters, are discussed below.

a. Acute oil spills

Two large oil spills have occurred within the Kittlitz's murrelet range within 15 years: the 1989 *T/V Exxon Valdez* spill of over 11 million gallons, and the 2004 *Selendang Ayu* spill of over 500,000 gallons (USFWS 2007).

i. The 1989 *T/V Exxon Valdez* disaster

On March 24, 1989, the *T/V Exxon Valdez* grounded on Bligh Reef in northeastern Prince William Sound, spilling a reported 11 million gallons of crude oil into the marine environment. Wind and currents subsequently pushed the oil out of Prince William Sound and into the Gulf of Alaska, where it eventually drifted 750 km to the southwest, past Kenai Fjords National Park, up to Kachemak Bay, past Kodiak Island, along Katmai National Park, and most of the way down the Alaska Peninsula coastline and adjacent offshore waters (Piatt et al. 1990, van Vliet 1994). All together the oil covered approximately 30,000 km^2 of coastal and offshore waters occupied by approximately one million marine birds (Lance et al. 1999, Piatt et al. 1990).

Over 30,000 dead and oiled birds were eventually collected along the Southcentral Alaska coastline (Piatt et al. 1990). Seventy-two Kittlitz's murrelets were positively identified, as well as an additional 446 unidentified *Brachyramphus* murrelets. Given that 5-10% of the murrelet population in this area consists of Kittlitz's murrelets, another 22-45 Kittlitz's can assumed to have been recovered, for a total of 94-117. The true number could be as high as 150-200 birds, depending on possible misidentifications and counting errors (van Vliet 1994).

Piatt et al. (1990) estimated that 10-30% of birds killed by the immediate impact of the spill were recovered. This estimate is based on actual drift experiments and observations showing that many oiled birds will drift away from coastlines and never wash ashore, sink before reaching shore, wash up on inaccessible shorelines and not be discovered, or wash up on accessible beaches and be scavenged, buried, or overlooked (Piatt et al. 1990). Therefore, as many as 1000-2000 Kittlitz's murrelets could have been killed as a direct result of the spill, representing 5-10% of the estimated worldwide population (van Vliet 1994). Another estimate of *Brachyramphus* murrelet mortality is provided by Kuletz (1996). This author states "...the estimated mortality for all murrelets was 10,000 - 22,000, with best approximation of 12,800 - 14,800." Multiplying these numbers by the approximately 8% of birds presumed to be Kittlitz's murrelets yields an estimate of 800-1,760 birds killed, with a best approximation of 1,024-1,184. If these numbers are correct, then the Kittlitz's murrelet suffered the largest proportionate loss of its estimated worldwide population of any species impacted by the spill (van Vliet 1994).

Of added concern, the Kittlitz's murrelet population does not appear to be recovering in this area (Lance et al. 1999). Lance et al. (1999) tested for recovery in two ways: (1) if the rate of population increase of a species within the oiled zone was greater than the rate of population increase outside the oiled zone, and (2) if the density of the species within the oiled zone was increasing. Lance et al. (1999) analyzed the data for *Brachyramphus* murrelets as a group, and concluded that there is no evidence of recovery for the summer populations by either measure. The second measure of density showed some signs of recovery for the winter populations (Lance et al. 1999), but given that the winter population is made up primarily of marbled, and not Kittlitz's murrelets, this indicator is much less relevant for the Kittlitz's than the summer measure (Lance et al. 1999).

Finally, in the case of the *T/V Exxon Valdez* disaster, cleaning operations themselves constituted additional harm to the environment by killing surviving marine life and altering shoreline sediment structure which could ultimately affect repopulation of shorelines by sediment-dwelling invertebrates and fish (Lance et al. 1999).

ii. The 2004 *Selendang Ayu* oil spill

In December 2004, the *Selendang Ayu* spilled approximately 504,000 gallons of heavy bunker C and diesel fuel oils into the nearshore waters off Unalaska, Aleutian Islands, oiling approximately 35 km of shoreline (USFWS 2007). Although few *Brachyramphus* murrelet carcasses were recovered immediately after the oil spill, the spill heavily impacted Makushin Bay which is an area known to support high concentrations of Kittlitz's murrelets (one-third of all Kittlitz's murrelet observations around Unalaska were from Makushin Bay), and murrelets were observed in oiled waters (USFWS 2007). Information on the number of species of oiled birds retrieved from affected beaches is not yet available (USFWS 2007).

b. Chronic oil pollution

Smaller spills of oil, fuel, and chemicals, ranging from gallons to tens of thousands of gallons, are frequent in coastal Alaska (Piatt et al. 2007: Table 21 and Table 23) and have the potential to cause significant mortality of Kittlitz's murrelets, especially in preferred foraging locations during the breeding season. Even small amounts of oil can cause metabolic impairment or mortality of seabirds in the cold waters of Alaska (Piatt et al. 20078). Records of vessel spills in coastal Alaska indicate that spills of oil and other contaminants peak in summer in parallel with increases in recreational, tourist, and fishing activities (Piatt et al. 2007) and during the time period when Kittlitz's murrelets occupy nearshore waters in the highest concentrations. Based on records from 1995-2005, vessel-related spills were highest in Southeast Alaska (~877), followed by the Aleutian Islands (~351), Prince William Sound (~231), Cook Inlet (~179), and Kodiak Island (~136) (Piatt et al. 2007: Table 23), which are all important population centers for the Kittlitz's murrelet. USFWS (2007) estimated that ~27,000 gallons of petroleum hydrocarbons are spilled each year in marine habitats within the range of Kittlitz's murrelet, and that spills are expected to increase with rising vessel traffic in Alaskan waters.

Prince William Sound and Cook Inlet have particularly high traffic of oil tankers shipping crude oil and gas from Alaska production and transfer sites, and high levels of cargo and container ship traffic resulting in frequent visits to Alaska's four main industrial ports: Valdez, Anchorage, Nikiski and Homer (Piatt et al. 2007). For example, in 2005, Valdez in Prince William Sound received 312 petroleum or chemical tankers; Anchorage in Cook Inlet received 186 container ships and tankers; Nikiski in Cook Inlet received 72 petroleum or chemical tankers; and Homer in Cook Inlet received 24 petroleum or chemical tankers (U.S. Maritime Administration 2007a). Three of these ports have year-round glacial ice (Valdez) or seasonal pack ice (Anchorage, Nikiski) that increase shipping risks (Piatt et al. 2007).

Highlighting the frequency of spills in these highly trafficked regions, 255 petrochemical and chemical spills occurred in 2005 between Cook Inlet and Dixon Entrance, and 229 spills occurred in 2006 in this region of which 31 were more than 100 gallons (Piatt et al. 2007). Nikiski port has experienced several major spills and accidents that posed high pollution risks (Piatt et al. 2007). These data clearly show that the high frequency of spills from tankers and large vessels moving through Cook Inlet and Prince William Sound pose a significant threat to important Kittlitz's murrelet populations in these regions.

In the Alaska Maritime National Wildlife Refuge which manages much of the Aleutian Island's coastal habitat, approximately 2,900 ships on U.S/Asia routes transit in close proximity to the Aleutian Islands each year (USFWS 2007). Accordingly, the Alaska Maritime National Wildlife Refuge is considered one of the most vulnerable refuges in the country due to the certainty that oil spills will occur based on the large number of ships transiting dangerous waters (USFWS 2007). The high risk of oil spill in this region poses a significant threat to the 16% of Alaska's Kittlitz's murrelet population that inhabits this area.

c. Offshore oil and gas exploration and development

The Kittlitz's murrelet faces immediate threats from growing offshore oil and gas development within its at-sea range that has the potential to destroy or modify large portions of its foraging habitat in Cook Inlet and the Alaskan and Russian waters of the Bering and Chukchi Seas by increasing the risk of oil spills and impacts from noise pollution. Additionally, increased oil and gas production translates into higher greenhouse gas production which furthers global warming's impact on the Kittlitz's murrelet.

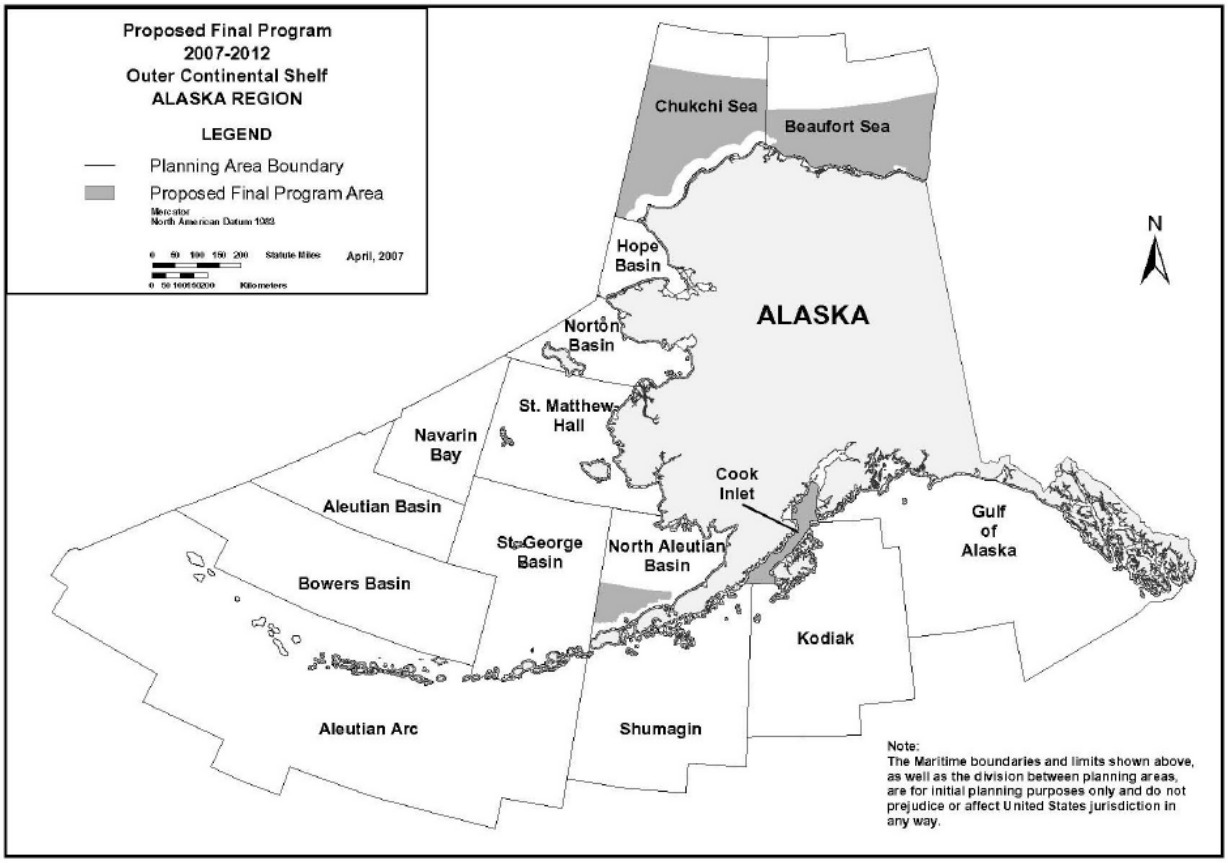
United States (Alaska)

Offshore oil and gas exploration and development activities have been extensive in Alaska. Current and proposed offshore oil and gas development in the Cook Inlet, Bering Sea, and Chukchi Sea will threaten a significant portion of the Kittlitz's murrelet's marine foraging habitat in Alaskan waters. In Cook Inlet, 12 to 15 oil production platforms currently operate, and a high number of oil and chemical spills are related to oil extraction activities including oil rig operations and transport activities (Piatt et al. 2007). In June 2007 Secretary of Interior Kempthorne approved the 2007-2012 Offshore Oil and Gas Leasing Program which planned offshore lease sales in Kittlitz's murrelet habitat in Cook Inlet in 2009 and 2011, Bristol Bay in the southeastern Bering Sea in 2011, and the Chukchi Sea in 2008, 2010, and 2012 (Table 4, Figure 4) (MMS 2007). Chukchi Lease Sale 193 occurred on February 6, 2008, with 2.76 million acres of habitat on the Chukchi continental shelf ultimately being leased to oil companies. Bristol Bay was cleared for development in January 2007 when President Bush reversed the presidential withdrawal of this region from oil and gas development that was instituted from 1998-2012 to protect its rich biological diversity. Thus, risks to Kittlitz's murrelets from offshore oil and gas development in Alaska will increase in coming years.

Table 4. Lease sales for oil and gas development in the range of the Kittlitz's murrelet completed and proposed by the Minerals Management Service for 2007-2012.
Source: Minerals Management Service.

Sale Location and Number	Proposed Sale Year
Chukchi Sea Sale 193	2008
Cook Inlet Sale 211	2009
Chukchi Sea Sale 212	2010
North Aleutian Basin Sale 214	2011
Cook Inlet Sale 219	2011
Chukchi Sea Sale 221	2012

Figure 4. Proposed offshore seismic, leasing, and drilling in Cook Inlet, the Bering Sea, and the Chukchi Sea during 2007-2012.
Source: MMS (2007): Map A.



Russia

Growing oil and gas development in the Okhotsk, Bering, and Chukchi Seas in Russian Federation waters represent a significant threat to the Kittlitz's murrelets populations that inhabit these regions. Kittlitz's murrelets inhabit the Magadan and Kamchatka regions of the Sea of Okhotsk, the Kamchatka and Chukotka regions of the Bering Sea, and the Chukotka region of the Chukchi Sea (Figure 1). Oil and gas companies have already begun or are planning ambitious development projects in these regions (Figure 5) (Lapko and Radchenko 2000, Huettmann and Gerasimov 2006, Huettmann 2008).

In the Magadan Region in the northern Okhotsk Sea, an investment project called "Prospects, investigation and development of oil and gas fields in offshore sectors of the Sea of Okhotsk - Magadan 1 and Magadan 2" is planned for development through initiation by the Ministry of Natural Resources of the Russian Federation and the Administration of the Magadan Region (Figure 5) (Chernenko 2007). Each sector includes three blocks that are subject to licensing. These sectors will enable the annual extraction of 15-20 million tons of oil and 35-50 billion m^3 of gas (Chernenko 2007). The oil company Rosneft is showing interest in Magadan projects, but it can pursue these projects only after the commencement of operations in offshore zones of Sakhalin and Western Kamchatka (Chernenko 2007).

Five prospective petroleum basins in the Chukotka Autonomous District and offshore zones have been identified: Anadirsky, East-Khatirsky, South-Chukotsky, North-Chukotsky and East-Siberian. The total volume of reconnoitered gas stocks equals 11.8 billion m^3 (Chernenko 2007). The company Sibneft-Chukotka has been finishing work on drilling and exploratory wells in the Anadirsky petroleum basin for the purpose of identifying its oil and gas content (Chernenko 2007). According to the newspaper *Kommersant*, the quarterly report "Gazprom of oil" indicates that Sibneft-Chukotka completed geologic exploration of the Bering and Central blocks on April 1, 2007 (Chernenko 2007).

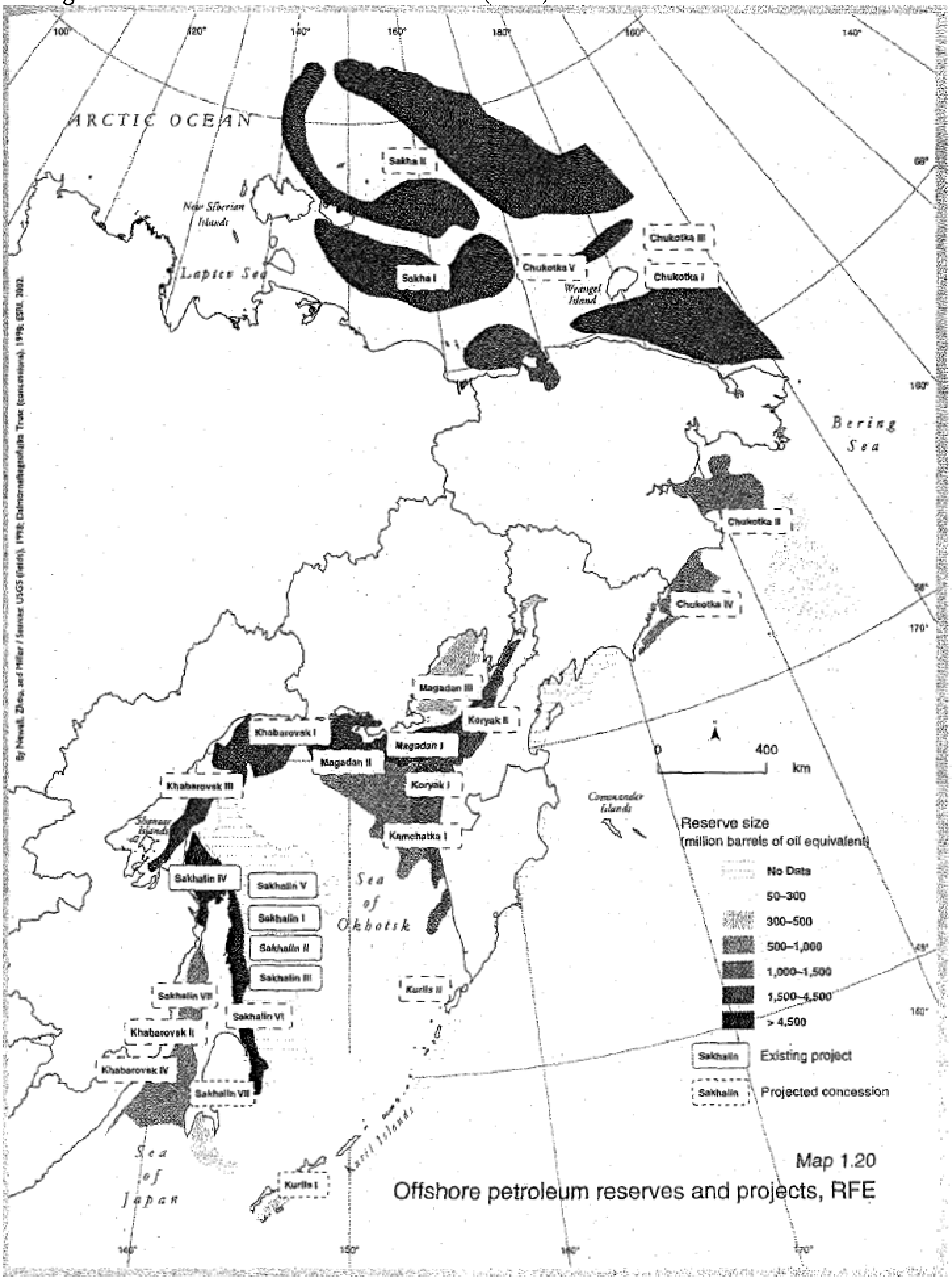
Offshore oil and gas development off Siberia has already resulted in a large oil spill in 1999, and future oil spills are very likely. Lapko and Radchenko (2000) warned against the future impacts from oil spills and dredging in Russian waters on the marine ecosystem:

> Unfortunately, oil exploration and development on the shelf cause dredging, leaking oils and oil pollution. Already by the end of September 1999 an accident on one production complex resulted in a spill of about 3.5 t of oil. No doubt other cases will occur in the future. This kind of industrial activity, as well as the commercial fisher, can seriously degrade the marine ecosystem (Lapko and Radchenko 2000: 186).

d. Other marine pollution

The Kittlitz's murrelet is also vulnerable to other forms of marine pollution such as the dumping of trash and human waste from cruise ships. While such ocean dumping is generally illegal within the breeding range of the Kittlitz's murrelet, the dumping may occur illegally or ocean currents may carry pollution to areas occupied by Kittlitz's murrelets.

Figure 5. Offshore petroleum reserves and projects in Russian Federation waters of the Bering and Chukchi Seas. Source: Chernenko (2007): Exhibit 1.



2. Global Warming

Global warming poses a significant threat to the long-term survival of the Kittlitz's murrelet. Surface temperatures in the Kittlitz's murrelet range in Alaska have increased twice as much as the global average in the past century, and glaciers in coastal regions of southern Alaska are undergoing rapid wastage due to climate change (Dyurgerov and Meier 2000, Arendt et al. 2002, Larsen et al. 2007, Molnia 2007, Muskett et al. 2008). Accelerated retreat of coastal glaciers and rising temperatures are diminishing and degrading important foraging and breeding habitat for the Kittlitz's murrelet, and likely altering prey availability and increasing competition with marbled murrelets for food. Wastage of coastal glaciers has been linked to the precipitous decline of Kittlitz's murrelet populations in Alaska during the past few decades. Growing threats to the Kittlitz's murrelet from climate change include increasing exposure to predators in its alpine nesting habitat; rising pollution as glacier meltwater contributes contaminants to nearshore waters; increasing competition as temperate species expand their ranges northward; and increasing shipping activity with associated risks of oil spills and noise pollution.

The effects of global warming will worsen in this century. Of importance for the Kittlitz's murrelet, rising temperatures and decreased snowfall will lead to increasing wastage of coastal glaciers in Alaska. Greenhouse gas emissions must be cut dramatically in the immediate future to prevent further degradation of the Kittlitz's murrelet's habitat. As discussed under "The Inadequacy of Existing Regulatory Mechanisms," below, such emission cuts are not likely to happen absent significant changes in domestic and global energy policies.

This section reviews the best available scientific information regarding (a) the greenhouse effect and current levels of greenhouse gases, (b) changing climate conditions observed to date in the range of the Kittlitz's murrelet, (c) projected climate change in the range of the Kittlitz's murrelet, and (d) current and predicted impacts to the Kittlitz's murrelet from global warming.

a. The climate system, greenhouse gas concentrations, the greenhouse effect, global warming, and ecological impacts

In its most recent 2007 report, the Intergovernmental Panel on Climate Change (IPCC)[1] expressed in the strongest language possible its finding that global warming is occurring: "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level" (IPCC 2007: 5). The international scientific consensus of the IPCC is that most of the recent warming observed has been caused by human activities and that it is "very likely" due to increased concentrations in anthropogenic greenhouse gases (IPCC 2007).

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[1] The IPCC was established by the World Meteorological Organization and the United Nations Environment Programme in 1988 (IPCC 2001). The IPCC's mission is to assess available scientific and socioeconomic information on climate change and its impacts and the options for mitigating climate change and to provide, on request, scientific and technical advice to the Conference of the Parties to the United Nations Framework Convention on Climate Change (IPCC 2001). Since 1990, the IPCC has produced a series of reports, papers, methodologies, and other products that have become the standard works of reference on climate change (IPCC 2001). The 2007 *Fourth Assessment Report* is the most current comprehensive IPCC reference and has built and expanded upon the IPCC's past products.

One of the most troubling recent findings is that the concentration of atmospheric carbon dioxide, the biggest contributor to global warming, has been rapidly increasing throughout the 2000s and is generating stronger-than-expected and sooner-than-predicted climate forcing (Canadell et al. 2007, Raupach et al. 2007).

The ecological impacts of climate change have been well-documented by numerous peer-reviewed papers, including evidence for changes in distribution, phenology, physiology, demographic rates, and genetics (see Lovejoy and Hannah (2005), Parmesan (2006), Harley et al. (2006) for a small sampling of comprehensive, recent reviews). Studies that have used climate model projections to forecast species extinctions have predicted catastrophic species losses during this century. The IPCC has warned that 20 to 30% of plant and animal species will face an increased risk of extinction if increases in global average temperature exceed 1.5 to 2.5°C (relative to 1980-1999), with predicted extinctions of up to 70% of species worldwide if increases in global average temperature exceed 3.5°C relative to 1980-1999 (IPCC 2007). Thomas et al. (2004) projected that 15-37% of species will be committed to extinction by 2050 under a mid-level emissions scenario. Therefore, immediate reduction of greenhouse gas pollution is critical to slow global warming and ultimately stabilize the climate system before we commit to massive species extinctions.

The IPCC's *Fourth Assessment Report – Climate Change 2007* and the Arctic Climate Impact Assessment's[2] ("ACIA's") *Impacts of a Warming Arctic* (ACIA 2005) have synthesized the best available science on global warming in the Alaska. An ever-growing body of newer climate studies provides continuous updates to the IPCC findings. Based on these synthesis reports and the latest research, this section briefly reviews global warming, the greenhouse effect, and the contributions of greenhouse gases to global warming.

The basic physics underlying global warming are as well established as any phenomena in the planetary sciences. The earth absorbs heat in the form of radiation from the sun, which is then redistributed by atmospheric and oceanic circulations and also radiated back to space (Le Treut et al. 2007). The earth's climate is the result of a state in which the amount of incoming and outgoing radiation is approximately in balance. Changes in the earth's climate can be caused by any factor that alters the amount of radiation that reaches the earth or the amount that is lost back into space, or that alters the redistribution of energy within the atmosphere and between the atmosphere, land, and ocean (Le Treut et al. 2007). A change in the net radiative energy available to the global earth-atmosphere system is called "radiative forcing" (Le Treut et al.

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[2] The Arctic Council is a high-level intergovernmental forum that addresses the common concerns and challenges faced by the Arctic people and governments of the eight Arctic nations – Canada, Denmark/Greenland/Faroe Islands, Finland, Iceland, Norway, Russia, Sweden, and the United States, as well as six Indigenous Peoples organizations – Aleut International Association, Arctic Athabaskan Council, Gwich'in Council International, Inuit Circumpolar Conference, Russian Association of Indigenous Peoples of the North, and Saami Council, as well as official observers (ACIA 2005). The Arctic Council commissioned the ACIA project and charged its working groups – Arctic Monitoring and Assessment Programme ("AMAP"), Conservation of Arctic Flora and Fauna ("CAFF"), and the International Arctic Science Committee ("IASC") - with its implementation. The efforts of hundreds of scientists over four years, as well as the special knowledge of indigenous peoples, contributed to the ACIA report. In sum, the ACIA (2005) is a comprehensively researched, fully referenced, and independently reviewed evaluation of Arctic climate change and its impacts (ACIA 2005).

2007). Positive radiative forcings tend to warm the earth's surface while negative radiative forcings tend to cool it (Albritton et al. 2001).

Radiative forcings are caused by both natural and anthropogenic factors (Albritton et al. 2001, ACIA 2005, Le Treut et al. 2007). The level of scientific understanding of these different forcings varies, and the forcings themselves and interactions between them are complex (Le Treut et al. 2007). The primary cause of global warming, however, is society's production of massive amounts of "greenhouse gases" such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and halocarbons that cause positive radiative forcings (Forster et al. 2007, Le Treut et al. 2007).

The Enhanced Greenhouse Effect is caused by increasing concentrations of these greenhouse gases in the earth's atmosphere. As greenhouse gas concentrations increase, more heat reflected from the earth's surface is absorbed by these greenhouse gases and radiated back into the atmosphere and to the earth's surface. Increases in the concentrations of greenhouse gases slow the rate of heat loss back into space and warm the climate, much like the effect of a common garden greenhouse (Forster et al. 2007, Le Treut et al. 2007). The higher the level of greenhouse gas concentrations, the larger the degree of warming experienced.

By the time of the Fourth Assessment Report of the IPCC in 2007, the atmospheric concentration of carbon dioxide had increased by 36% since 1750 to a level that has not been exceeded during the past 650,000 years and likely not during the past 20 million years (Denman et al. 2007). About three fourths of anthropogenic carbon dioxide emissions come from fossil fuel burning, and most of the remaining emissions are due to land-use changes, primarily deforestation (Denman et al. 2007). Carbon dioxide is considered the most important greenhouse gas overall because the volume emitted is greater that of all the other greenhouse gases combined.

Of great concern, the rate of increase of total atmospheric carbon dioxide concentrations is accelerating, with especially rapid increases observed in the 2000s (Canadell et al. 2007). Carbon dioxide emissions increased from 3.2 ± 0.1 GtC yr^{-1} during the 1990s to 4.1 ± 0.1 GtC yr^{-1} during 2000-2005 (Denman et al. 2007). These increased emissions have been attributed to rises in fossil fuel burning and cement production (average proportional growth increased from 1.3% yr^{-1} to 3.3% yr^{-1}) rather than emissions from land-use change which remained approximately constant (Canadell et al. 2007). During the past 50 years, carbon dioxide sinks on land and oceans have become less efficient in absorbing atmospheric carbon dioxide, which is also contributing to the observed rapid rise (Canadell et al. 2007).

The atmospheric concentration of methane, another important greenhouse gas, has increased by about 150% since 1750, continues to increase, and has not been exceeded during the past 650,000 years (Forster et al. 2007). About 60% of current methane emissions come from human activities, and there is also evidence that current carbon monoxide (CO) emissions are a cause of increasing methane concentrations (Denman et al. 2007). Over a 100-year period, methane will trap about 23 times more heat than an equal amount of carbon dioxide (Albritton et al. 2001).

The atmospheric concentration of nitrous oxide (N_2O) has increased by about 18% since 1750, continues to increase, and has not been exceeded during at least the last 2000 years (Forster et al. 2007). About half of the nitrous oxide emissions to the atmosphere comes from human activities (Denman et al. 2007). Over a 100-year period, nitrous oxide will trap about 296 times more heat than an equal amount of carbon dioxide (Albritton et al. 2001).

Halocarbons are carbon compounds that contain fluorine, chlorine, bromine, or iodine (Forster et al. 2007). Most types of halocarbons are produced exclusively by human activities (Forster et al. 2007). Halocarbons that contain chlorine, like chlorofluorocarbons, ("CFCs") also cause depletion of the stratospheric ozone layer and are regulated under the Montreal Protocol (Forster et al. 2007). The combined tropospheric abundance of ozone-depleting gases peaked in 1994 and is now declining slowly (Forster et al. 2007). However, some compounds which have been promoted as substitutes for now-regulated CFCs are themselves greenhouse gases, and concentrations of these gases, such as hydrochloroflurocarbons ("HCFCs") and hydroflurocarbons ("HFCs") are now increasing (Forster et al. 2007). There are many different types of halocarbons, which have global warming potentials that vary between 12 and 12,000 times that of carbon dioxide (Forster et al. 2007).

Ozone is another important greenhouse gas found in both the troposphere, the portion of the atmosphere that begins at the earth's surface and extends from 8 to 14.5 kilometers (5 to 9 miles) high, and the stratosphere, the portion of the atmosphere that starts just above the troposphere and extends to 50 kilometers (31 miles) high (Albritton et al. 2001). Ozone is not directly emitted, but rather is formed from photochemical processes involving both natural gases and manmade emissions (Albritton et al. 2001). Because ozone persists in the atmosphere for only a short period of time varying from weeks to months, its role in radiative forcing is more complex and less certain than for more persistent greenhouse gases (Albritton et al. 2001).

The loss of ozone from the stratosphere (a phenomenon popularly termed a "hole in the ozone layer") has resulted in negative radiative forcing that has offset some portion of the warming caused by other greenhouse gases (Albritton et al. 2001). However, the ozone layer is expected to rebound as a result of the Montreal Protocol, and the negative forcing caused by the current depressed levels of ozone in the stratosphere is expected to reverse (Albritton et al. 2001). The most recent findings of the Fourth Assessment Report indicate that global stratospheric ozone decreased between the late 1970s to early 1990s but has increased slightly since the early 1990s (Forster et al. 2007).

Increasing concentrations of ozone in the troposphere also cause positive radiative forcing (Albritton et al. 2001). Ozone in the troposphere is in fact the third most important greenhouse gas after carbon dioxide and methane (Albritton et al. 2001). Tropospheric ozone is estimated to have increased by approximately 35% since the Industrial Revolution, though increases have varied by region (Albritton et al. 2001). Ozone concentrations respond relatively quickly to changes in the emissions of ozone precursors such as NO and NO_2 (the sum of which is denoted NOx) and volatile organic compounds ("VOCs") (Albritton et al. 2001).

Black carbon, or soot, consists of particles or aerosols released through the inefficient burning of fossil fuels, biofuels, and biomass (Quinn et al. 2007). Black carbon warms the atmosphere as a solid, not a gas. Unlike greenhouse gases, which warm the atmosphere by absorbing longwave infrared radiation, soot has a warming impact because it absorbs shortwave radiation, or visible light (Chameides and Bergin 2002). Black carbon is an extremely powerful greenhouse pollutant. Scientists have described the average global warming potential of black carbon as about 500 times that of carbon dioxide over a 100 year period (Hansen et al. 2007, *see also* Reddy and Boucher 2007). This powerful warming impact is remarkable given that black carbon remains in the atmosphere for only a few days to a few weeks, with a mean residence time of 5.3 days (Reddy and Boucher 2007).

Black carbon contributes to Arctic warming through the formation of "Arctic haze" and through deposition on snow and ice which increases heat absorption (Quinn et al. 2007, Reddy and Boucher 2007). Arctic haze results from a number of aerosols in addition to black carbon, including sulfate and nitrate (Quinn et al. 2007). The effects of Arctic haze may be to either increase or decrease warming, but when the haze contains high amounts of soot, it absorbs incoming solar radiation and leads to heating (Quinn et al. 2007). Soot also contributes to heating when it is deposited on snow because it reduces reflectivity of the white snow and instead tends to absorb radiation. A recent study indicates that the direct warming effect of black carbon on snow can be three times as strong as that due to carbon dioxide during springtime in the Arctic (Flanner et al. 2007). Black carbon emissions that occur in or near the Arctic contribute the most to the melting of the far north (Quinn et al. 2007, Reddy and Boucher 2007).

Other gases, such as NOx, volatile organic compounds, and carbon monoxide are called indirect greenhouse gases because of their impact on the abundance of tropospheric ozone and other greenhouse gases such as methane (Forster et al. 2007). These compounds interact and contribute to global warming in complex ways. For example, increases in NOx concentrations decrease methane concentrations but increase tropospheric ozone (Forster et al. 2007). Many other natural and human caused factors contribute to positive or negative radiative forcing, including aerosol emissions, land-use changes, and changes in solar and volcanic activity, water vapor, and cloud cover (Le Treut et al. 2007). Nevertheless, scientists now know that greenhouse gases are the most important force driving global warming, and that carbon dioxide is in turn the most important of the greenhouse gases (Forster et al. 2007, Solomon et al. 2007). Carbon dioxide emissions from fossil fuel burning are virtually certain to remain the dominant control over trends in atmospheric carbon dioxide concentrations during this century (Forster et al. 2007).

b. Climate and environmental changes observed to date

This section reviews the best available science on observed climate change relevant to Kittlitz's murrelet across its range in Alaska and Russia, including the Gulf of Alaska, Bering Sea, and Chukchi Sea.

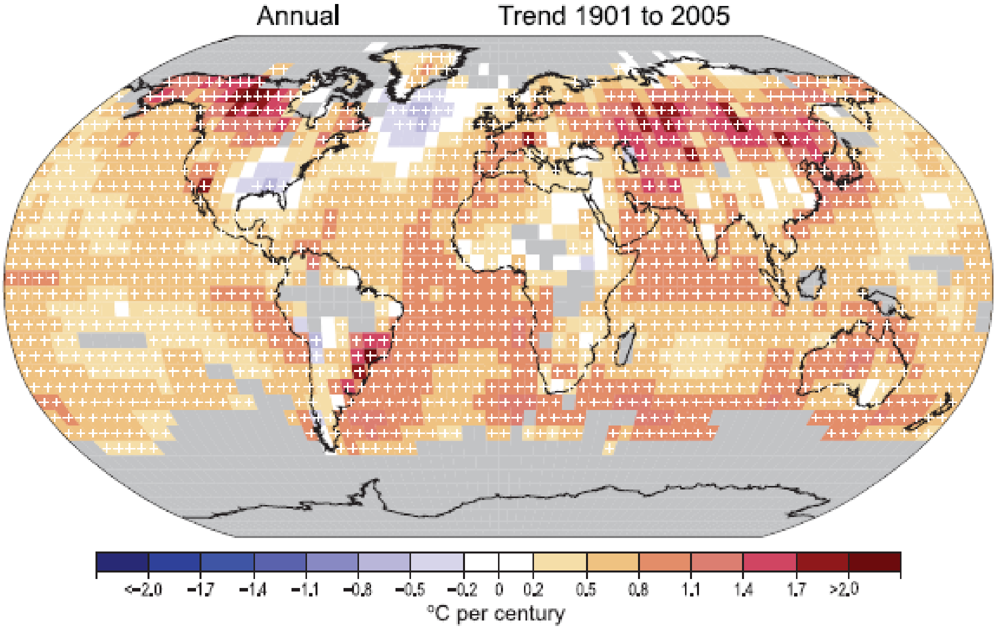
i. Increases in surface temperature

Global average air and ocean surface temperature has risen by approximately 0.74° C ± 0.18° C (1.33° F ± 0.32° F) during the past 100 years (1906-2005), and the rate of temperature rise is accelerating (Trenberth et al. 2007). Over the past 50 years, the rate of warming (0.13°C ±

0.03°C per decade) has doubled compared with the rate over the past century (0.07°C ± 0.02°C per decade) (Trenberth et al. 2007). Eleven of the last 12 years (1995 to 2006 except 1996) were the warmest years on record (Trenberth et al. 2007).

Average surface temperatures in Alaska increased twice as much as the global average during the 20th century (Figure 6), and warming trends have accelerated in recent decades (Trenberth et al. 2007). Alaska warmed by 2.2°C (4°F) on average in the last half of the twentieth century, with the largest warming of 3.9°C (7°F) occurring in the interior in winter (Parson et al. 2001).

Figure 6. Linear trend of annual temperatures for 1901 to 2005 (°C per century). Areas in grey have insufficient data to produce reliable trends. Trends significant at the 5% level are indicated by white + marks.
Source: Trenberth et al. (2007): Figure 3.9.



During 1966-2003, annual air temperature trends in southern and western coastal Alaska in the range of the Kittlitz's murrelet increased by 1 to 1.5ºC per decade (ACIA 2005: Figure 2.7(d)), compared with the much smaller global average temperature rise during this period (~ 0.13°C ± 0.03°C per decade) (Trenberth et al. 2007). Winter and spring (December-May) temperatures in southern and western coastal Alaska increased by as much as 1.5 to 2°C per decade over this period (1966-2003) (Figure 7) (ACIA 2005: Figure 2.8).

Figure 7. Seasonal land-surface air temperature trends for the period 1966-2003.
Source: ACIA 2005: Figure 2.8.

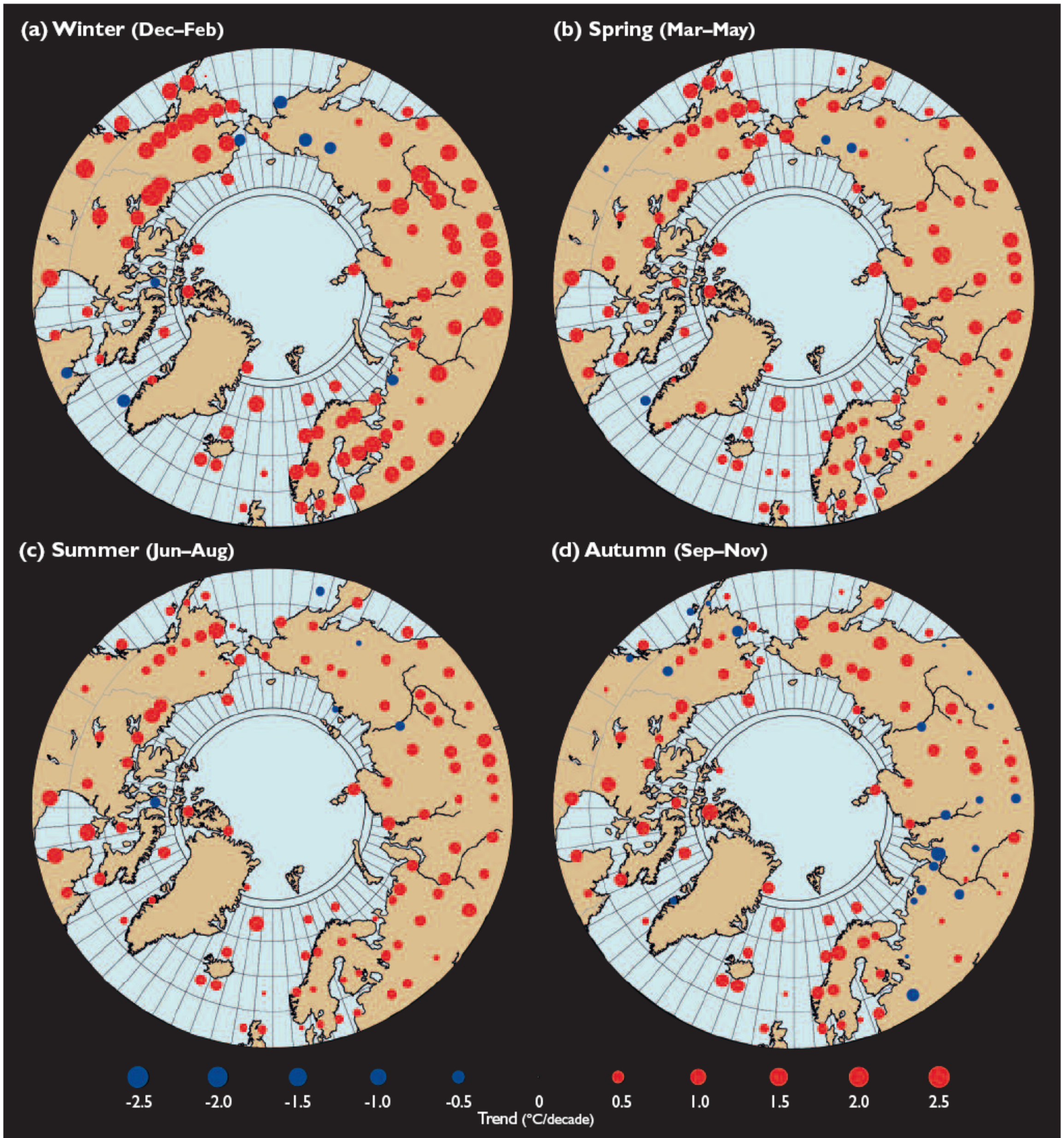


Fig. 2.8. Seasonal land-surface air temperature trends for the period 1966 to 2003 calculated using the GHCN dataset (updated from Peterson and Vose, 1997).

The temperature of the ocean is also rising which has important consequences for altering habitat suitability as well as physiological function, distribution, and abundance of marine organisms throughout the food web. Global ocean temperatures increased by 0.31 °C on average in the upper 300 m during the past 50 years (1948-1998) (Levitus et al. 2000) and changes in ocean heat content have penetrated as deep as 3000 m (Levitus et al. 2005). Notably, the largest increases in global ocean temperature have occurred in the upper ocean where primary production is concentrated and are impacting ocean productivity (Behrenfeld et al. 2006).

Significant global declines in net primary production between 1997-2005 were attributed to reduced nutrient enhancement due to ocean surface warming (Behrenfeld et al. 2006).

In the Gulf of Alaska, ocean surface temperatures have been increasing in recent decades, with a persistent rise in summer and winter surface temperature observed in 2001 to 2005 consistent with anthropogenic warming (Figure 8) (Litzow 2006). A long-term ocean temperature dataset from 1970 to present, measured at the mouth of Resurrection Bay near Seward, Alaska, indicates that ocean temperatures from the surface to the deepwater (250m) have increased over the past several decades (Figure 9) (Weingartner and Royer 2008).

Figure 8. Climate change in the northwestern Gulf of Alaska, 1960-2005. Data are summer (JJA) and winter (DJF) monthly mean surface air and water temperature, expressed as anomaly from the 1961-1990 mean.
Source: Litzow (2006): Figure 2.

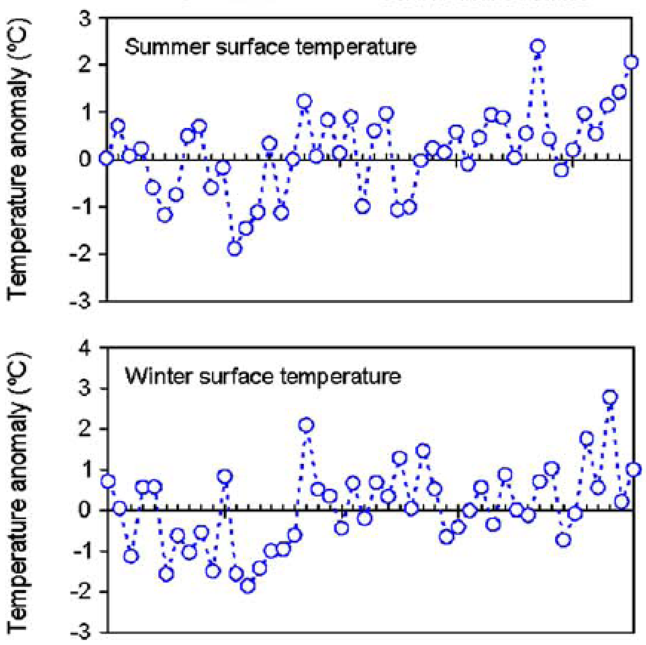
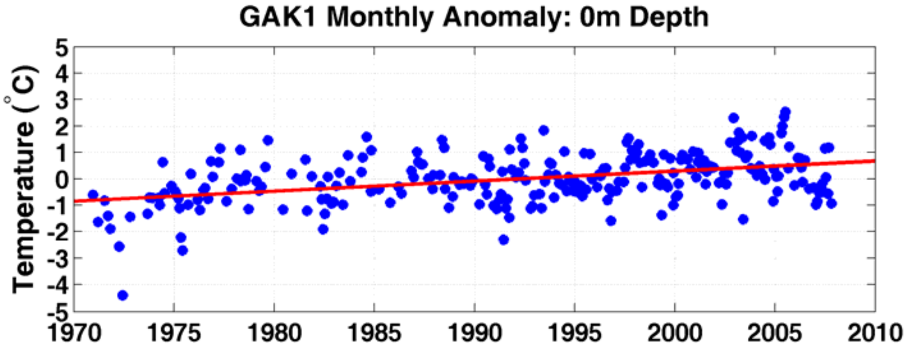
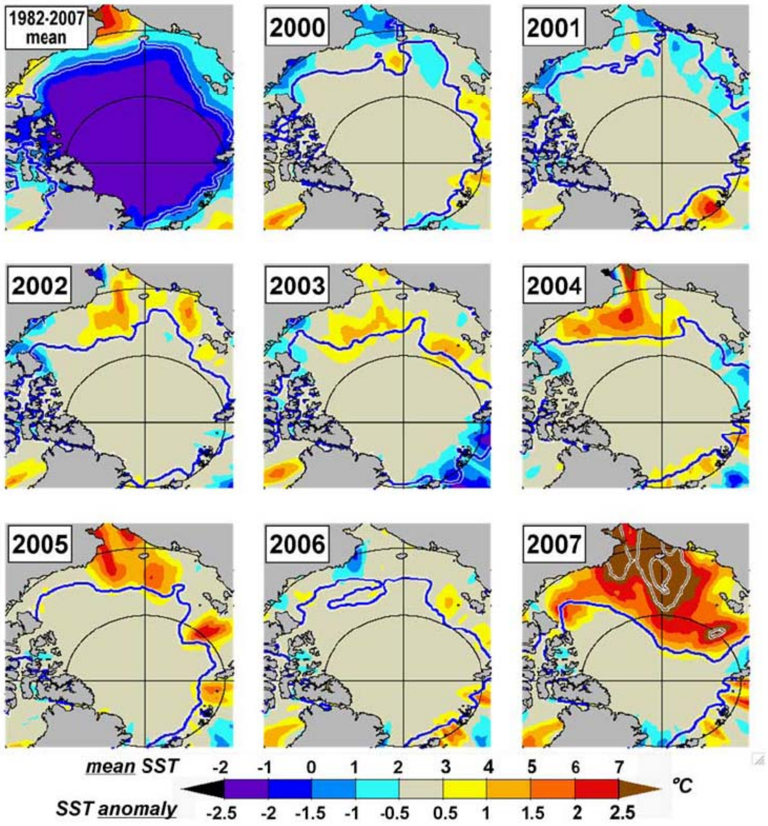


Figure 9. Monthly ocean surface temperature anomaly from 1970-2008 at GAK1 station.
Source: http://www.ims.uaf.edu/gak1/.



Regional analyses have also found that surface air and ocean temperatures are rising significantly in the Bering and Chukchi Seas—regions which support smaller breeding populations of Kittlitz's murrelets and unknown numbers of wintering murrelets. Temperature data from 1950-2002 at St. Paul Island on the southeastern Bering Sea shelf show a transition from cold to warm anomalies in 1976, consistently earlier springs beginning in 1996, and longer warm periods extending from February through November beginning in 2000 (Overland and Stabeno 2004). At St. Lawrence Island in the northern Bering Sea, air temperatures have increased from 1997-2004 (Grebmeier et al. 2006). Depth-averaged summer ocean temperatures measured at a mooring at 70 m depth on the southeastern Bering Sea shelf were 2°C warmer in 2001-2003 compared to the mid-1990s (Overland and Stabeno 2004). In the Northern Bering Sea, bottom water temperatures increased from 1988-2005 (Grebmeier et al. 2006). Finally, in a study of Arctic ocean summertime surface warming trends over the past 100 years, Steele et al. (2008) found that the northern Bering and Chukchi Seas experienced pronounced warming since the mid-to-late 1990s. Surface temperatures in this region during summer of 2007 were 3 to 3.5°C warmer than historical averages and 1.5°C warmer than the historical maximum (Figure 10) (Hines 2007, Stroeve et al. 2008).

Figure 10. Mean satellite-derived summer sea surface temperature from 1982-2007 and anomalies from this mean during 2000-2007. The dark blue contour represents the September mean sea-ice edge.
Source: Steele et al. 2008: Figure 3.



ii. Accelerated melting of glaciers

In response to rising temperatures, glaciers worldwide have been losing mass since the mid-1800s, and the rate of glacier mass loss has accelerated in the past few decades (Dyurgerov and Meier 2000, Lemke et al. 2007). Glaciers in coastal regions of southern Alaska have experienced exceptionally large volume losses and rates of retreat during the past few decades which have been linked to climate change (Dyurgerov and Meier 2000, Arendt et al. 2002, Larsen et al. 2007, Molnia 2007, Muskett et al. 2008). Importantly, rapid glacier loss is already underway in Alaska and worldwide, and rising temperatures and decreasing snowfall will accelerate glacier wastage (Lemke et al. 2007, Meehl et al. 2007). This section (a) briefly discusses glacier dynamics in relation to climate, and (b) reviews scientific studies on trends in Alaskan glacier wastage, focusing on coastal and tidewater glaciers important to Kittlitz's murrelets.

Glacier dynamics in relation to climate

Glaciers provide among the most visible indications of the effects of climate change (Lemke et al. 2007). The mass balance at the surface of a glacier (the gain or loss of snow and ice) in the high and mid-latitudes is largely determined by the seasonal cycle of air temperature and precipitation (Larsen et al. 2007, Lemke et al. 2007). Air temperature in summer largely determines the amount of surface melting (ablation), while snowfall in the winter influences the net surface accumulation of snow and ice on the glacier (Larsen et al. 2007, Lemke et al. 2007). Climate change affects the magnitude and length of the season for glacier accumulation and ablation (Lemke et al. 2007). Overall, increases in temperature and decreases in snowfall can lead to a negative glacier mass balance and glacier wastage.

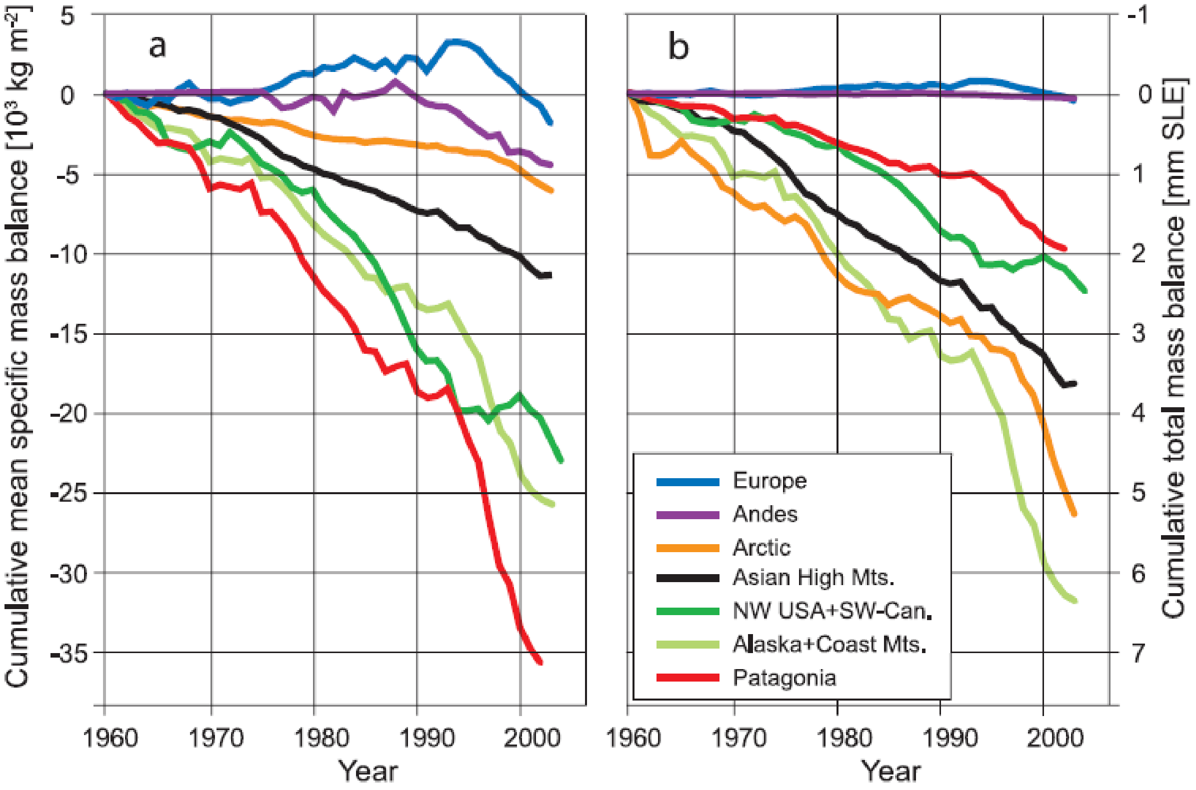
For tidewater glaciers that undergo cycles of advance and retreat, climate conditions are important in determining the rate of glacier advance and the initiation of glacier retreat (Larsen et al. 2007, Molnia 2007). Tidewater glaciers originate in upland accumulation areas, traverse terrestrial areas of varying lengths as they descend towards sea level, and end in the marine environment where they calve icebergs and discharge meltwater directly into the ocean (Larsen et al. 2007). Like other glaciers, the advance of a tidewater glacier is climate dependent and results from a positive mass balance where surface snowfall accumulation dominates over ablation (Molnia 2007). When climate conditions result in a negative mass balance of a tidewater glacier, the glacier terminus retreats and becomes unstable when it leaves its protective shoal on a glacial moraine (Larsen et al. 2007). When the terminus enters deep water, the tidewater glacier enters a rapid retreat phase where the rate of calving of the glacier increases exponentially with water depth (Larsen et al. 2007). Positive feedbacks then further draw down the parent icefield and increase the rate of calving (Larsen et al. 2007, Molnia 2007). As stated by Larsen et al. (2007), "[o]nce climate renders a tidewater calving glacier unstable, ice losses increase dramatically." Tidewater glacier terminus retreat has exceeded 1 km/year in southeast Alaska (Larsen et al. 2007). An additional climate-related feedback that may have accelerated glacier wastage is sea level rise from melting of glaciers and ice caps due to global warming (USFWS 2007). Rising sea levels submerge tidewater glacier termini in deeper water which increases their rate of retreat (USFWS 2007).

Accelerating decline of Alaskan glaciers

Multiple scientific studies have documented the rapid retreat of Alaska's glaciers (Arendt et al. 2002, Lemke et al. 2007, Molnia 2007), including studies that have focused on the coastal glaciers important to Kittlitz's murrelet (Dyurgerov and McCabe 2006, Larsen et al. 2007, Muskett et al. 2008). Overall, glaciers in Alaska cover ~75,000 km^2 in 11 mountain ranges, Kodiak Island, the Alexander Archipelago, and the Aleutian Islands (Molnia 2007). Tidewater glaciers occupy one-third of the glacier-covered area in Alaska, roughly ~27,000 km^2, although they number only ~60 of the more than 100,000 Alaskan glaciers (less than 0.1% by number) (Molnia 2007). Tidewater glaciers occur in the Coast Mountains, St. Elias Mountains, Chugash Mountains, and Kenai Mountains (Molnia 2007).

On a global scale, glaciers in Alaska are experiencing particularly rapid mass losses compared to other regions, with an accelerated rate of loss particularly evident in the 1990s and 2000s (Figure 11) (Lemke et al. 2007).

Figure 11. (a) Cumulative mean specific mass balance and (b) cumulative total mass balances of glaciers and ice caps for each region. Mean specific mass balance shows the strength of climate change in the respective region. Total mass balance is the contribution from each region to sea level rise.
Source: Lemke et al. (2007): Figure 4.15.



Molnia (2007) conducted a comprehensive review of the behavior of glaciers across Alaska over more than a century and found that more than 98% of Alaska's glaciers are retreating and/or thinning. In addition, Molnia (2007) documented that in most areas, every glacier descending below ~1500 m in elevation was currently thinning and/or retreating in response to significant regional warming. Since the late 19th century, more than 50 tidewater glaciers have retreated from tidewater to the terrestrial environment, and some have disappeared completely after transitioning onto land (Molnia et al. 2007). In the late 20th century, 51 active tidewater glaciers and 9 former tidewater glaciers remained (Molnia 2007). Of these 60 glaciers, 10 tidewater or former tidewater glaciers were advancing in 2005 (Anchor, Ogive, Harvard, Meares, Hubbard, Lituya, North Crillon, Lamplugh, Johns Hopkins, and Taku Glaciers) (Molnia 2007), and the majority (50 glaciers) were stable or retreating. Overall, Molnia (2007) concluded:

> Globally, temperate mountain glaciers are excellent indicators of climate change and are shrinking on all continents which host them. Hence, small changes in temperature and precipitation do have a significant impact on the health of these glaciers. Ongoing glacier melting is, and will continue to substantially reduce the length, area, thickness, and volume of Earth's temperate mountain glaciers. As Alaskan glaciers melt, their meltwaters flow into the Gulf of Alaska, and the Bering, Chukchi, and Beaufort Seas, contributing to sea level rise (Molnia 2007: 51).

Dyurgerov and McCabe (2006) analyzed change in glacier mass balance in four coastal regions worldwide, including Alaska, from 1960-2003 and detected a significant acceleration in glacier wastage that “appears to be related primarily to climate warming” (p. 190). These researchers found that glacier wastage has increased for coastal glaciers in Alaska, the Canadian Arctic, ice caps around the Greenland ice sheet, and the Patagonia Ice Fields since the late 1980s or early 1990s. Specifically, volume loss from these glaciers increased from ~45% in the 1960s to 67% in 2003 of the total mass wastage from all glaciers on Earth outside the two largest ice sheets, the Greenland and West Antarctic ice sheets (Dyurgerov and McCabe 2006). Importantly, Dyurgerov and McCabe (2006) found that increasing coastal glacier volume losses were strongly linked with increases in surface summer air temperature at regional and global scales. In addition, coastal glaciers exhibited an increased sensitivity to air temperature, occurring during 1994–2001 for Alaskan coastal glaciers. Dyurgerov and McCabe (2006) warned that the rapid wastage of coastal glaciers will result in continuing sea level rise and represents an early warning of larger changes to come in the Greenland and West Antarctic ice sheets.

In a study focused on Alaskan glacier volume change, Arendt et al. (2002) documented rapid wastage of Alaskan glaciers from the mid-1950s to the mid-1990s, and an increased rate of thinning from the mid-1990s to 2000-2001. This rapid wastage of Alaskan glaciers represented about half the estimated mass lost by glaciers worldwide and the largest glacial contribution to sea-level rise yet deduced from measurements (Arendt et al. 2002). Using airborne laser altimetry to estimate volume changes, Arendt et al. (2002) measured an average rate of thinning of –0.52 m/year between the mid-1950s to mid-1990s and an increased rate of thinning of -1.8 m/year between the mid-1990s to 2000–2001. Arendt et al. (2002) estimated an annual volume loss from Alaska glaciers equal to –96 ± 35 km^3/year, or 0.27 ± 0.10 mm/year SLE, during the past decade alone, which are double the estimated annual losses from the entire Greenland Ice Sheet during the same time period. Arendt et al. (2002) attributed the increased rate of glacier thinning to a combination of factors including climate warming during the past several decades and the rapid retreat of tidewater glaciers initiated by climate warming.

Similarly, Larsen et al. (2007) examined glacier volume changes in southeast Alaska and adjoining Canada during the later half of the 20th century, and found that the majority of glaciers have experienced strong thinning and retreat. The study areas included 14,580 km^2 of temperate alpine and maritime glaciers in four regions (Yakutat, Glacier Bay, Juneau Ice Field, and Stikine Ice Field). Larsen et al. (2007) noted that the generally low elevation and geometry of glaciers and ice fields in southeast Alaska make them particularly susceptible to climate change. Glacier surface elevations decreased in over 95% of the glacier-covered area analyzed, with a net loss of glacial ice in these regions over the study period of 870 ± 140 km^3 equating to a total contribution to sea level rise of 2.4 ± 0.4 mm (Larsen et al. 2007). Over two thirds of the ice losses occurred at tidewater or lake calving glaciers. Larsen et al. (2007) attributed the rapid glacier wastage to a combination of factors, including calving retreats of tidewater glaciers and climate change. As described above, Larsen et al. (2007) noted that climate warming can make tidewater glaciers unstable, initiating glacier dynamics that can lead to dramatic calving losses.

On a regional scale, Muskett et al. (2008) analyzed the area-average changes (volume change divided by glacier area) of the tidewater glaciers of Icy Bay during the past half century. These researchers detected a significant lowering of the accumulation area of the Guyot, Yahtse, and Tyndall glaciers, which has accelerated in recent years. The most striking aspect of this study was that the drawdown of the glaciers' accumulation areas occurred despite increasing high-elevation snow accumulation during 1976 to 2000. The researchers hypothesized that increased low-elevation precipitation in the form of rain and increased melting resulting from higher temperatures are contributing to more basal sliding of glaciers due to higher water drainage to the glacier bed (Muskett et al. 2008). Increasing basal sliding is leading to higher ice velocities and higher-than-normal calving rates. Overall, the study concluded that climate warming is contributing to the drawdown of the tidewater glaciers in Icy Bay and accelerating glacier wastage in Alaska:

> Our observations and measurements of retreat and drawdown of the glaciers of Icy Bay strengthen other results of increased wastage of non-polar glaciers during the decades since the mid-1970s, accelerating during the last decade of the 20th century (Muskett et al. 2008: 357).

Among the numerous additional studies examining accelerating regional glacier loss, VanLooy et al. (2006) documented accelerating thinning of Kenai peninsula glaciers of the Harding icefield, the largest ice field in North America, that included seven tidewater glaciers. Overall, the icefield has decreased in volume by -72.1 ± 15.0 km^3 from 1950 to 1999. In addition, glacier thinning rates increased by 1.5 times from the period spanning the mid-1990s to 1999 (-0.72 ± 0.13 m/year) as compared to the period from 1950 to the mid-1990s (-0.47 ± 0.01 m/year) (VanLooy et al. 2006).

Clearly, the scientific evidence strongly documents that Alaskan glaciers, particularly in the southern coastal regions in the range of Kittlitz's murrelet, have experienced exceptionally large volume losses and retreat during the past few decades that are linked with climate change.

c. Projected climate and environmental changes

All climate models in the IPCC and ACIA assessments project significant warming in this century, with variation only in the rate and magnitude of projected warming (ACIA 2005). For its Fourth Assessment Report ("AR4"), the IPCC performed an unprecedented, internationally coordinated climate change experiment using 23 models by 14 modeling groups from 10 countries to project future climate conditions. This large number of models running the same experiments provides more accurate quantification of future climate conditions, the importance of different model parameters, and the uncertainty in the results.

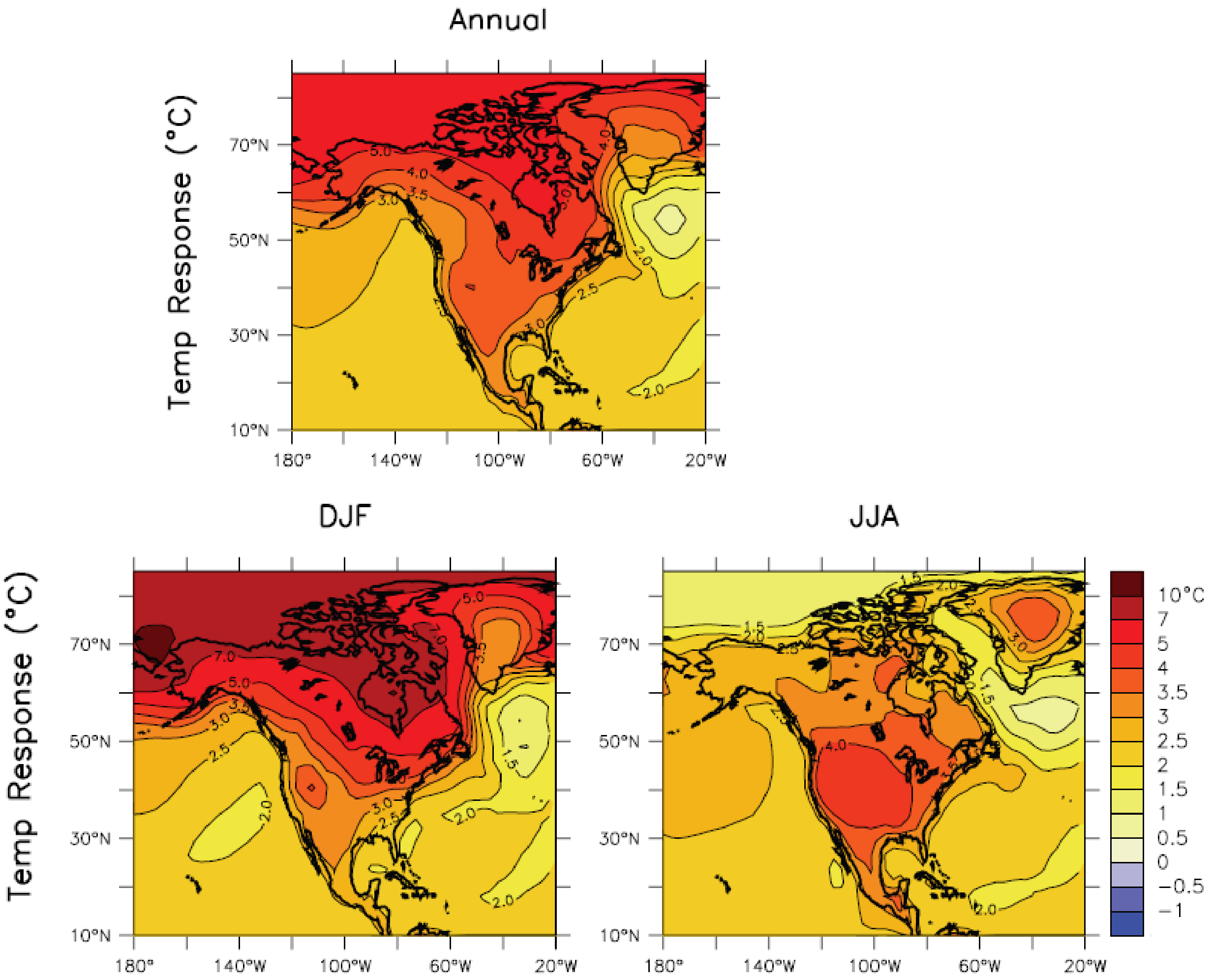
i. Surface temperature, precipitation, and glacier wastage

Climate model projections are unanimous that temperatures will continue to rise throughout the 21st century, with greater warming at the high northern latitudes (Christensen et al. 2007). Annual temperatures in Alaska are projected to rise by an average of 4.5°C by the end of the century under the A1B mid-level emissions scenario, based on the average from 21 models (Christensen et al. 2007: Table 11.1). Temperatures will rise more significantly in winter, by an average of 6.3°C (range: 4.4-11.0°C), than in summer (average 2.4°C; range: 1.3-5.7°C) (A1B scenario) (Christensen et al. 2007). Warming along the southern and western Alaskan coastal regions used by the Kittlitz's murrelet is projected to reach 3-5°C in winter and 2-2.5°C in summer by the end of the century under the A1B scenario (Figure 12) (Christensen et al. 2007).

Precipitation is projected to increase by ~21% (range 6-32%) over Alaska by the year 2100 under the A1B scenario, with most of the increase falling as rain (Christensen et al. 2007). The increase is projected to be largest in the winter and smallest in the summer, consistent with higher projected warming in the winter (Christensen et al. 2007).

Of importance for the Kittlitz's murrelet, rising temperatures and decreased snowfall will lead to increasing wastage of coastal glaciers in Alaska. As the climate warms, glaciers will continue to lose mass as summer melting dominates over winter snowfall accumulation (Meehl et al. 2007). One forecast for northern hemisphere glaciers projected an average glacier volume loss of 60% by the year 2050 under a scenario of doubling CO_2 concentration (Schneeberger et al. 2003). Overall, the disappearance of glaciers is occurring at a rapid pace that may in some areas be irreversible (Meehl et al. 2007).

Figure 12. Temperature change over North America between 1980-1999 and 2080-2099 based on multi-model A1B simulations, including mean DJF (December-January-February) and JJA (June-July-August) temperature change.
Source: Christensen et al. (2007): Figure 11.12



ii. Dangerous anthropogenic climate change and the climate commitment

As scientific understanding of global warming has advanced, so too has the urgency of the warnings from scientists about the consequences of our greenhouse gas emissions. Warming of more than 1.7°C to 2°C above pre-industrial levels (equivalent to 1°C to 1.3°C above year 2000 levels) has been defined as "dangerous climate change" by leading climate scientists and international bodies, with particular reference to species extinction and sea level rise (Hansen et al. 2006, Hansen et al. 2007, Ramanathan and Feng 2008). Beyond this point, climate feedbacks will greatly amplify the warming from anthropogenic emissions, leading to rapid additional temperature increases and catastrophic climate impacts. Hansen et al. (2008) presented evidence that the safe upper limit for atmospheric CO_2 needed to avoid dangerous climate change is 350 ppm.

Using paleoclimatic data, Hansen et al. (2008) measured the sensitivity of the global climate system to increasing CO_2 (where climate sensitivity is defined as the change in global mean surface temperature following a doubling of atmospheric CO_2) when only fast climate feedback processes were considered compared to when both fast and slow feedback processes were considered. Climate sensitivity was ~3°C considering only fast feedback processes such as changes in water vapor, clouds, aerosols, and sea ice, but doubled to ~6°C when slow surface albedo feedbacks were also considered, including ice sheet disintegration, vegetation migration, and greenhouse gas release from soils, tundra, and ocean sediments (Hansen et al. 2008). Current climate models generally do not include important slow climate feedback processes that dramatically increase climate sensitivity (Hansen et al. 2008). However, Hansen et al. (2008) presented evidence that these slow feedbacks may begin to be realized within time scale as short as centuries or less, adding urgency to rapidly reducing our emissions trajectory before the climate system is forced beyond a tipping point (Hansen et al. 2008). At current greenhouse gas emissions levels, our climate commitment is ~2°C warming of which 0.6°C is attributable to fast feedback processes and an additional 1.4°C is attributable to slow feedback processes (Hansen et al. 2008). With the current climate commitment of ~2°C, no additional greenhouse gas forcing is required to raise global temperature to at least the levels of the Pleistocene, 2-3 million years ago, which is a degree of warming that would definitively produce dangerous climate impacts (Hansen et al. 2008).

Hansen et al. (2008) concluded that a 350 ppm CO_2 target is urgently needed, is achievable, and must be pursued on a timescale of decades in order to avoid catastrophic consequences:

> If humanity wishes to preserve a planet similar to that on which civilization developed and to which life on Earth is adapted, paleoclimate evidence and ongoing climate change suggest that CO_2 will need to be reduced from its current 385 ppm to at most 350 ppm, but likely less than that (Hansen et al. 2008:217).

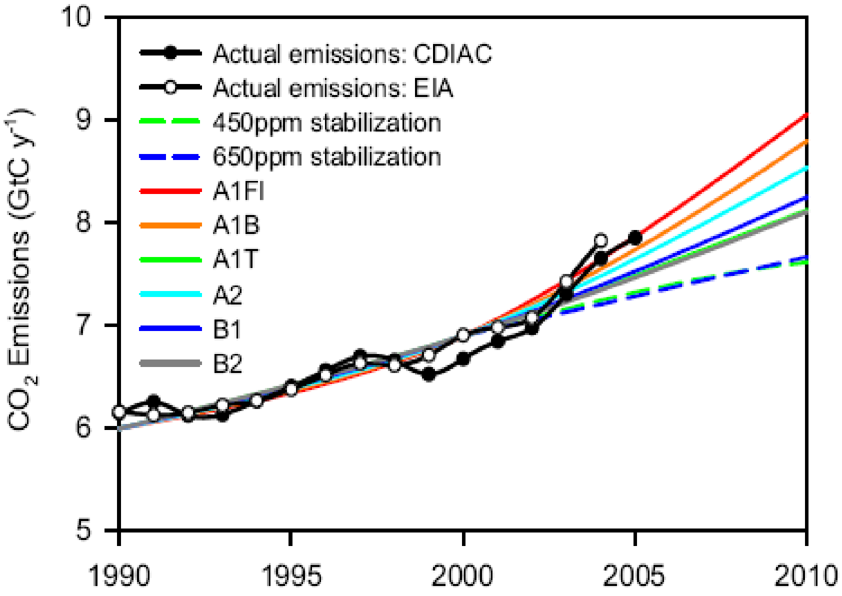
Hansen et al. (2008) provided evidence for a 350 ppm CO_2 target since our current CO_2 level at 385 ppm has committed us to a dangerous warming commitment of ~2°C temperature rise and is already resulting in dangerous changes: the observed 4° poleward latitudinal shift in subtropical regions leading to increased aridity in many regions of the earth, the near-global retreat of alpine glaciers affecting water supply during the summer, accelerating mass loss from the Greenland and west Antarctic ice sheets, rapid loss of Arctic sea ice cover, and increasing stress to coral reefs from rising temperatures and ocean acidification. Hansen et al. (2008) concluded that the overall target of at most 350 ppm CO_2 must be pursued on a timescale of decades since paleoclimatic evidence and ongoing changes suggest that it would be dangerous to allow emissions to overshoot this target for an extended period of time.

Similar to Hansen et al. (2008), Ramanathan and Feng (2008) provide evidence that our current warming commitment has placed us within the realm of dangerous anthropogenic interference with the climate system and that emissions stabilization targets of 450-550 ppm CO_2 are unlikely to prevent dangerous climate change. Ramanathan and Feng (2008) estimated that greenhouse gas emissions since the pre-industrial era have committed the world to a warming of 2.4°C (ranging from 1.4°C to 4.3°C) above pre-industrial surface temperatures. The earth has experienced only ~25% of this warming commitment to date, because the rest of the warming commitment has been masked by the cooling effect of aerosols, compensation by increases in surface albedo due to land-use changes, and delays due to the thermal inertia of the oceans (Ramanathan and Feng 2008). About 90% of the remaining 1.6°C warming commitment will be realized during this century at a rate determined by the rate of unmasking of the cooling effect from aerosols as air pollution is curbed and by the rate of release of greenhouse gas forcing stored in the oceans (Ramanathan and Feng 2008). Importantly, our current warming commitment of 2.4°C above pre-industrial levels exceeds the dangerous anthropogenic interference (DAI) thresholds of 1.7°C to 2°C above pre-industrial levels as defined by leading climate scientists and international bodies (Ramanathan and Feng 2008). In addition, stabilization targets for 450 to 550 ppm will not allow us to avoid this warming commitment and dangerous anthropogenic interference:

> The high probability that the DAI threshold is already in our rearview mirror highlights the urgency issue raised by several studies recently (2–4, 35). But as noted above, CO_2 emission reduction actions and proposals are aimed at containing CO_2 concentrations at ≈ 450 to 550 ppm (9, 12, 35), but this will help neither the 2.4°C (1.4°C to 4.3°C) warming commitment from the accumulated GHGs that are already in the atmosphere, nor the projected commitment of 3.1°C (1.8–5.4°C) as of 2030 (Ramanathan and Feng 2008: 14249).

With atmospheric carbon dioxide at 385 ppm and worldwide emissions continuing to increase by more than 2 ppm each year, rapid and substantial reductions are clearly needed immediately. Since the year 2000, however, society has not followed a path of emissions reductions. Instead, the emissions growth rate has accelerated since 2000, rising from 1.1% per year from 1990-1999 to ~3.25 % per year from 2000-2004 (Raupach et al. 2007). The emissions growth rate since 2000 has even exceeded that of the most fossil-fuel intensive IPCC SRES emissions scenario, A1F1 (Figure 13) (Raupach et al. 2007). As a result, emissions since 2000 were also far above the mean stabilization trajectory needed to reach a 450 ppm stabilization target (Raupach et al. 2007), which is now considered inadequate to prevent dangerous climate change (Hansen et al. 2008). Thus, it is essential that strong greenhouse gas limitations be enacted immediately.

Figure 13. Observed CO_2 emissions from U.S. Department of Energy Energy Information Administration (EIA) data (1980-2004) and U.S. Department of Energy Carbon Dioxide Information and Analysis (CDIAC) data (1751-2005), compared with six IPCC emissions scenarios and with stabilization trajectories describing emissions pathways for stabilization of atmospheric CO_2 at 450 and 650 ppm.
Source: Raupach (2007): Figure 1.



d. Impacts to the Kittlitz's murrelet from global warming

Current and projected anthropogenic climate change pose a significant threat to the survival of the Kittlitz's murrelet. First, the retreat of coastal glaciers throughout Alaska is eliminating important glacially-affected nearshore foraging habitat for the Kittlitz's murrelet and likely altering prey availability and increasing competition with marbled murrelets for food. The loss of coastal glaciers due to global warming is thought to be a significant factor contributing to the precipitous decline of Kittlitz's murrelets in Alaska. In addition, growing threats to Kittlitz's murrelet from rising temperatures and glacier wastage include increasing depredation rates in its alpine nesting habitat, increasing pollution as glacier meltwater contributes contaminants to nearshore waters, increasing competition as temperate species expand their ranges northward, and increasing human disturbance through increased human traffic and development in previously inaccessible areas. All of these mechanisms are described in further detail below.

As documented extensively above, surveys of Kittlitz's murrelets have found that the at-sea abundance of Kittlitz's murrelets during the breeding season is positively associated with stable or advancing tidewater glaciers, uplands dominated by ice, and glacier outflows (Kendall and Agler 1998, Day et al. 1999, Kuletz et al. 2003, van Pelt and Piatt 2003, Kissling et al. 2007a). Based on the parallel trends of recent coastal glacier retreat and recent precipitous declines in Kittlitz's murrelet abundance, multiple researchers have hypothesized that Kittlitz's murrelet population declines are linked to glacier thinning and retreat:

> Over the long term, a potentially significant threat to the Kittlitz's murrelet if the gradual disappearance of coastal glaciers due to global warming over much of the species' range.... [a]s the 21st century approaches, the constant global increase in greenhouse gases in the earth's atmosphere may impact Kittlitz's murrelet directly in unique but detrimental ways than any other species because of its tight

> relationship with the North Pacific's remaining coastal glaciers (vanVliet 1993: 16).
>
> Alaskan glaciers have been thinning and losing mass at a high rate over the past 50 years (Arendt et al. 2002), and we hypothesize that Kittlitz's murrelet population declines are related in some way to glacier thinning and retreat (van Pelt and Piatt 2003:14).
>
> Our results suggest that continued wastage of these glaciers may precipitate future declines in the PWS Kittlitz's murrelet population. Similarly, the decline of Kittlitz's murrelet populations in other regions of the GOA can be expected to continue, particularly if glacial recession lags nearly half a century behind changes in climate (Arendt et al. 2002). (Kuletz et al. 2003: 139).

Glacier thinning and retreat is thought to affect murrelets in several ways which include loss of important foraging habitat, reduced prey availability, and increased competition with marbled murrelets:

(1) Loss of important foraging habitat. The retreat of coastal glaciers is reducing the amount of glacially-affected nearshore habitat that Kittlitz's murrelets use for foraging during the breeding season. Day et al. (2003) cautioned that the specialization of Kittlitz's murrelets for foraging in turbid glacial waters makes them more vulnerable to factors like glacier loss that reduce the availability of this foraging habitat. Of importance for the Kittlitz's murrelet, the loss of coastal glaciers throughout its range (and worldwide) precludes the Kittlitz's murrelet from shifting its range in response to climate change since there will be no glacially-affected foraging areas to move to.

(2) Reduced prey availability. The preference of Kittlitz's murrelet for nearshore glacially-affected areas is thought to be linked to the diversity and abundance of high energy forage fishes such as Pacific capelin and Pacific sand lance in these marine habitats (Day and Nigro 2000, Agness 2006, Arimitsu et al. 2007, USFWS 2007). The distribution and availability of these high energy forage fishes is likely to change as glaciers recede and the physical conditions of these marine habitats are modified. Specifically, the turbid nearshore waters near tidewater glaciers and glacial outflows provide a productive environment that aggregates high energy forage fishes (Day et al. 2003, Kissling et al. 2007b, Arimitsu et al. 2007). At a larger scale, glaciers contribute sediments and associated nutrients to nearshore waters that increase productivity. On a smaller scale, upwelling, tidal rips, and eddies occurring at glacial sills or at glacier faces are important for concentrating prey in bays and fjords with glaciers (Kissling et al. 2007b, Arimitsu et al. 2007).

In contrast, the accelerated melting and calving of retreating tidewater glaciers creates high rates of sedimentation and lower salinity, which is thought to reduce the suitability of marine habitats for zooplankton and forage fish that Kittlitz's murrelets prey upon (Kuletz et al. 2003). The onset of spring phytoplankton bloom in fjords may depend partly on the resuspension of resting spores in the sediment, and increased sedimentation may impair spore resuspension (Kuletz et al. 2003). If the phytoplankton bloom is inhibited by sedimentation, the resulting increased mortality of macrozooplankton would in turn reduce the abundance of invertebrates and forage fish. Kuletz et al. (2003) warned that Kittlitz's murrelets could be affected at multiple trophic levels since they feed on euphausiids, amphipods, small crustacean, and fish (Kuletz et al. 2003). Increased sedimentation may also reduce the water transparency in fjords with retreating glaciers to a threshold where Kittlitz's murrelet foraging success may be impaired (Kuletz et al. 2003).

Overall, the availability of high energy prey in close proximity to the remote nests of Kittlitz's murrelets is thought to be important to allowing parents to provision at rates necessary for fledging young (USFWS 2007). Reduced diversity and abundance of high energy forage fishes resulting from glacier loss could impair the Kittlitz's murrelet's ability to feed young during nesting season, resulting in lower chick production and higher mortality (USFWS 2007).

(3) Increased competition for food with marbled murrelets. Kittlitz's murrelet are thought to be better adapted than other birds to forage in glacial waters with high sediment loads, which allows them to access otherwise under-utilized food resources that are unavailable to marbled murrelets and other seabirds (Day et al. 2003). Loss of the turbid glacial water for which Kittlitz's murrelet is specialized may result in the Kittlitz's murrelet being out-competed by the marbled murrelet and other species for food resources.

Climate change may also affect Kittlitz's murrelet through several other mechanisms that include increases in exposure to predators on its breeding grounds, pollution of nearshore foraging habitats, competition with other species, and disturbance from rising shipping traffic.

(4) Increasing exposure to predators on its breeding grounds. The recession of glaciers may lead to an increase in depredation of Kittlitz's murrelet as its land-based breeding grounds become more accessible to terrestrial predators (Drew and Piatt 2008). In addition, avian predators may increase in number as they expand their ranges northward (Drew and Piatt 2008).

(5) Increasing contamination of nearshore foraging areas. Glaciers act as reservoirs for persistent organic pollutants that are deposited on glacier surfaces from the atmosphere over time (Donald et al. 1999, Blais 2005). As glaciers melt, glacial meltwater can rapidly route pollutants to the nearshore surface waters since meltwater has little opportunity to shed pollutants via evapotranspiration or binding with glacial sediments (Blais 2005). Indeed, several studies have found glacial meltwater has the potential to contribute high concentrations of contaminants to receiving waters for decades or centuries to come (Donald et al. 1999, Blais 2005). Of importance to Kittlitz's murrelets, the wastage of coastal glaciers due to global warming is adding large volumes of meltwater to the nearshore foraging environment that is likely increasing pollutant concentrations in these waters. Exposure of Kittlitz's murrelets to contaminants that have bioaccumulated in zooplankton and forage fish in these nearshore waters could increase mortality and decrease productivity in Kittlitz's murrelets (USFWS 2007).

(6) Increased competition for resources. Kittlitz's murrelets may also face ever-increasing competition for food from temperate species whose ranges are expected to expand northward as temperatures continue to rise (ACIA 2005). As described above, Kittlitz's murrelets are

particularly vulnerable to competition from marbled murrelets and other seabirds as they lose the turbid glacially-affected waters for which they are specialized.

(7) Impacts due to increased shipping traffic. As the sea ice in the Arctic melts, shipping routes will remain open for longer periods of time, the navigation season will be extended, and the Bering and Chukchi Seas inhabited by the Kittlitz's murrelet will experience a substantial increase in shipping traffic. Increased shipping activity in the Bering Sea and Chukchi Seas is almost certain to occur with the opening of two international shipping routes—the Northwest Passage and the trans-polar route—and the expansion of the Northern Sea Route. The Northwest Passage is a potential shipping route that has been historically blocked by perennial sea ice and which connects the Pacific and Atlantic Oceans through the Arctic Ocean along the northern coast of North America. The Northern Sea Route refers to the seasonally ice-covered marine shipping routes from Novaya Zemlya in the west, along the coast of northern Eurasia, to the Bering Sea in the east (ACIA 2005). A trans-polar route across the Arctic Ocean would connect the Atlantic and Pacific Oceans.

The navigation season for the Northern Sea Route is expected to increase from the current 20-30 days per year to 90-100 days per year by 2080, and the Northwest Passage was predicted to open sometime in the 21st century (ACIA 2005). However, expanding access to Arctic shipping routes is occurring much faster than predicted. In September 2007, the most direct route of the Northwest Passage was fully navigable due to the extreme loss of perennial sea ice, while the Northern Sea Route remained only partially blocked (ESA 2007). Opening of shipping routes and extending the navigation season could impact Kittlitz's murrelets in the Bering and Chukchi Seas by heightening disturbance to murrelets from vessel activity and noise, increasing the risk of oil spills, and increasing emissions of greenhouse gases and black carbon that will further accelerate global warming.

3. Ocean Acidification

Ocean acidification poses an ever-increasing risk to the Kittlitz's murrelet because of its deleterious effects on the fish and crustacean species that the murrelet depends on for food. In the past few decades, the oceans have absorbed approximately 30% of carbon dioxide released by human activities (Feely et al. 2004). The world's oceans, in fact, store about 50 times more carbon dioxide than the atmosphere (WBGU 2006), and most carbon dioxide released into the atmosphere from the burning of fossil fuels will eventually be absorbed by the ocean (Caldeira and Wickett 2003). As the ocean absorbs carbon dioxide from the atmosphere it changes the chemistry of the sea water by lowering its pH. The oceans' uptake of these excess anthropogenic carbon dioxide emissions, therefore, is causing ocean acidification (WBGU 2006).

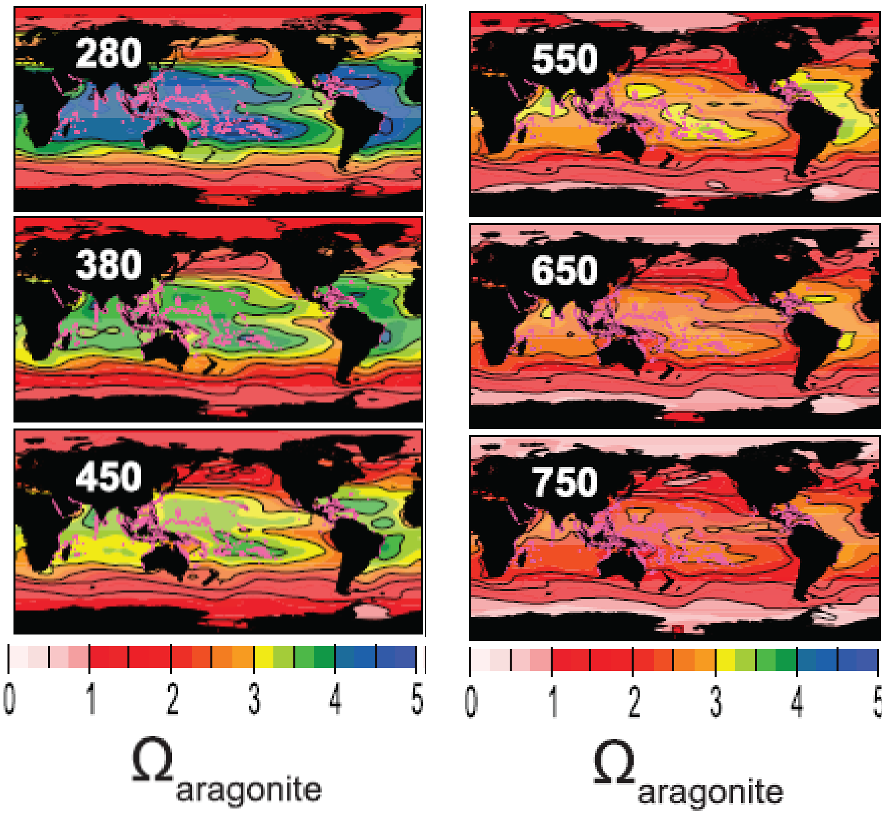
Surface ocean pH has already dropped by about 0.1 units on the pH scale from 1750-1994, equating to a rise in acidity of about 30% (Orr et al. 2005). The pH of the ocean is currently changing rapidly and may drop by another 0.3 or 0.4 units (equating to a 100 to 150% increase in the concentration of H+ ions) by the end of this century (Orr et al. 2005, Meehl et al. 2007). If carbon dioxide emissions continue unabated, resulting changes in ocean acidity could exceed anything experienced in the past 300 million years (Caldeira and Wickett 2003). Even if carbon dioxide emissions stopped immediately, the ocean would continue to absorb the excess carbon dioxide in the atmosphere, resulting in further acidification until the planet's carbon budget returned to equilibrium.

Ocean acidification from unabated anthropogenic carbon dioxide emissions poses a profound threat to marine ecosystems because it affects the physiology of numerous marine organisms, causing detrimental impacts that may ripple up the food chain (Fabry et al. 2008). Changes that have been observed in laboratory experiments include impacts to the photosynthesis of phytoplankton, metabolic rates of zooplankton and fish, oxygen supply of squid, reproduction of clams, nitrification by microorganisms, and the uptake of metals (WBGU 2006). Of particular importance to the Kittlitz's murrelet, studies indicate that larval fish experience higher mortality rates when exposed to higher-than-normal CO_2 concentrations, crustaceans including krill and copepods experience higher mortality rates with increasing CO_2 levels and decreasing pH, and copepod egg hatching success decreases with increasing CO_2 (Fabry et al. 2008: Table 1). Fish and other marine species are also affected when increases in the ocean's CO_2 concentration result in the accumulation of carbon dioxide in tissues and fluids, called hypercapnia, which leads to an increase in internal acidity (Fabry et al. 2008). Hypercapnia can impact acid-base regulation, metabolic activity, respiration, and ion exchange, leading to impairment of growth and higher mortality rates (Fabry et al. 2008).

Importantly, increasing ocean acidity also reduces the availability of carbonate ions that many marine plants and animals rely on to build their shells and skeletons (Feely et al. 2004, Orr et al. 2005, Fabry et al. 2008). Marine organisms including phytoplankton (coccolithophores and foraminifera), coralline algae, corals, echinoderms (sea urchins and starfish), and molluscs (snails, clams, oysters, and squid) are impaired in producing their shells with increasing ocean acidity (Kleypas et al. 2006). Normally, ocean waters are saturated with carbonate ions that marine organisms use to build skeletons (WBGU 2006). However, the acidification of the oceans shifts the water chemistry to favor bicarbonate, thus reducing the availability of carbonate to marine organisms (WBGU 2006). Acidic waters also dissolve existing protective carbonate skeletons and shells (Orr et al. 2005). Because calcifying organisms are at the base of the food web, negative impacts on these organisms will have a cascading effect on other species that rely on these organisms. Crustaceans are thought to be a particularly vulnerable group because of their dependence on the availability of calcium and bicarbonate ions for the mineralization of their exoskeleton after molting (Royal Society 2005).

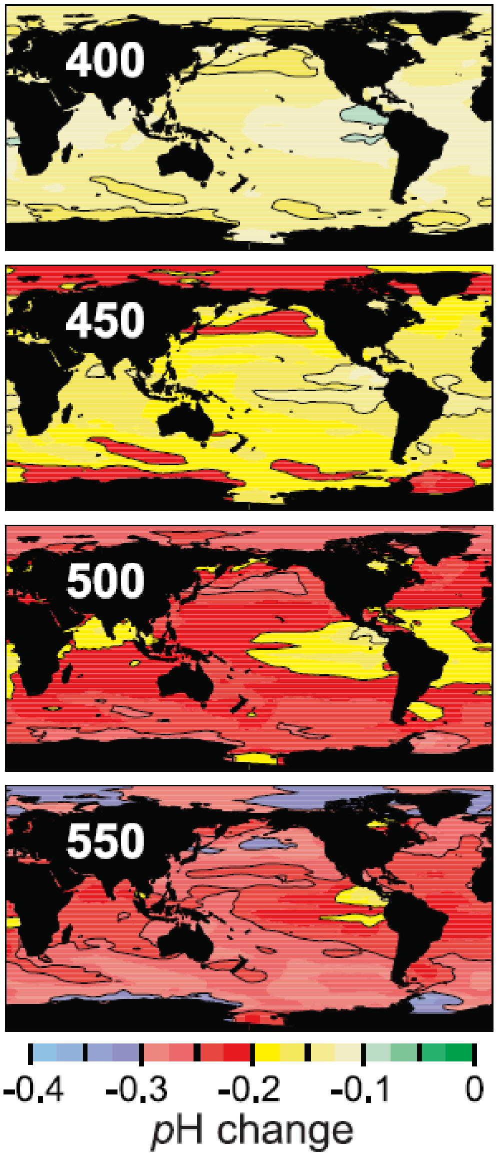
Ocean acidification and its impacts on marine biota will worsen in this century due to the continuing rise in atmospheric carbon dioxide concentrations. The North Pacific Ocean has conditions less favorable for calcification due to the increased solubility of calcium carbonate at lower temperatures and the inflow of CO_2-rich waters from deep ocean basins (Fabry et al. 2008). A large region of the subarctic Pacific bordering the southern edge of the Aleutian Islands in the range of the Kittlitz's murrelet is predicted to experience aragonite undersaturation in surface waters under the IPCC IS92a emissions scenario of 788 ppm CO_2 by 2100 (Orr et al. 2005). Similarly, Cao and Caldeira (2008) found that a large area of the North Pacific Ocean bordering the Alaska peninsula and Aleutian Islands would become under-saturated in the surface ocean with respect to aragonite at a 750 ppm CO_2 stabilization level (Figure 14). Under these scenarios, the aragonite saturation horizon would shoal from depths of ~120 m to the surface, and organisms like pteropods that build their shells from aragonite would no longer be able to survive in this region (Orr et. al 2005). Pteropod marine snails are important food sources for pollock and herring, both of which are major components of Kittlitz's murrelet diet. Thus, reductions in pteropods may lead to declines in the fish species that the Kittlitz's murrelet depends upon.

Figure 14. Maps of model-predicted aragonite saturation states at different atmospheric CO_2 stabilization concentrations (ppm) [plotted over existing shallow-water coral reef locations (shown as magenta dots)].
Source: Adapted from Cao and Caldeira (2008): Figure 1.



In addition, Cao and Caldeira (2008) found that increasing atmospheric CO_2 concentrations over the past two centuries have already caused a 0.1 unit decrease in average pH for the global surface ocean, corresponding to a 30% increase in acidity, consistent with previous studies. When atmospheric CO_2 is stabilized at levels at low as 450 ppm, large regions of the North Pacific within or adjacent to the Kittlitz's murrelet range experience a pH decrease of 0.2 units or more (Figure 15), which violates the criteria set forth by the U.S. Environmental Protection Agency [1976] that ''for open ocean waters. . .the pH should not be changed more than 0.2 units from the naturally occurring variation'' and the ''guard rail'' by the German Advisory Council on Global Change (Cao and Caldeira 2008). When atmospheric CO_2 is stabilized at 550 ppm, most of the surface ocean experiences a pH decrease of more than 0.2 units and large region bordering the Aleutian Islands experiences a pH decrease of more than 0.3 units (Figure 15) (Cao and Caldeira 2008).

Figure 15. Ocean pH change. Changes in surface ocean pH relative to pre-industrial values for different atmospheric CO_2 stabilization levels.
Source: Cao and Caldeira (2008): Figure 3.



Finally, an additional threat posed by ocean acidification is that it will dramatically increase ocean noise pollution levels within the auditory range of 0.01–10 kHz, which could impact Kittlitz's murrelets as described on pages 64-65. Hester et al. (2008) found that the decrease in ocean pH of -0.12 pH units from the pre-industrial era through the 1990s has already resulted in a reduction in sound absorption at 0.44 kHz by 12-20% to depths of ~250 m in the Pacific Ocean at 50°N. In addition, a decrease in ocean pH of 0.3 units (e.g. a change predicted by Cao and Caldeira (2008) for Alaskan waters at a stabilization target of 550 ppm CO_2) would dramatically reduce sound absorption at 0.1 to 1 kHz by almost 40% (Hester et al. 2008: Figure 7(a)). Furthermore, Hester et al. (2008) found that rising ocean temperatures have the effect of decreasing sound absorption in the lower frequency range even more. For example, a temperature increase of 3°C would decreases pH by a further 5-10% (Hester et al. 2008: Figure 7(b)). Sources of underwater anthropogenic noise in the 0.1-1 kHz band come from shipping, explosives, seismic surveying sources, aircraft sonic booms, construction, industrial activities, and naval surveillance sonar, while noise from nearby ships and seismic air-guns can extend up into the 1-10 kHz band. Reduced absorption of low-frequency noise in the 0.01–10 kHz range from shipping and oil and gas development due to ocean increasing ocean acidification will almost certainly increase the negative impacts to the Kittlitz's murrelet from these activities. Overall, Hester et al. (2008) concluded:

> The waters in the upper ocean are now undergoing an extraordinary transition in their fundamental chemical state and at a rate not seen on Earth for millions of years, and the effects are being felt not only in biological impacts but also on basic geophysical properties including ocean acoustics (Hester et al. 2008: 2).

B. Other Natural or Manmade Factors Affecting the Kittlitz's Murrelet

1. Small Population Size

The small population size of the Kittlitz's murrelet makes it more vulnerable to continuing declines and should be considered as a threat factor. There is strong agreement among conservation biologists that small population size per se constitutes an important risk of extinction because of a number of deterministic and stochastic factors of demography and population genetics. Small, declining populations are prone to entering an "extinction vortex" where losses of genetic diversity, environmental and demographic stochasticity, and Allee effects interact to prompt further declines (Gilpin and Soulé 1986). These factors are among the central principles of conservation biology, and the Department of Fish and Game must consider them along with the observed population declines of the Kittlitz's murrelet in its decision whether to list the species.

For the Kittlitz's murrelet, evidence suggests that it may already be experiencing an Allee effect due to its small population size and low densities, in which murrelets are unable to find mates. Researchers have observed mixed-species pairs of Kittlitz's and marbled murrelets during summer in bays with low numbers of Kittlitz's murrelets compared to marbled murrelets (Day and Nigro 2004). If Kittlitz's murrelets densities are so low that they are unable to find mates of their own species, they make unfruitful pairings with marbled murrelets:

> [T]he overall rarity of Kittlitz's murrelets compared with the abundance of marbled murrelets in these bays may be causing these mixed-species pairs, which in turn would be decreasing the overall reproductive output of Kittlitz's murrelets in these bays even further (albeit slightly). Such a waste of reproductive effort (reproductive interference, Levin 2002) can have serious consequences for the rare species, even if offspring are not produced (Rhymer and Simberloff 1996, Simberloff 1996). Hybridization in alcids appears to be rare, with the most common suggested hybrids occurring between the phenotypically similar and often geographically sympatric Common Murre (Uria aalge) and the Thick-billed Murre (U. lomvia, Cairns and DeYoung 1981, Friesen et al. 1993). Such a

> relationship between hybridization and phenotypic and geographic similarity of species raises the possibility of attempted hybridization in Kittlitz's and marbled murrelets, however, no evidence of hybrids between these two species has been found in genetic studies (Pacheco *et al.* 2002), suggesting that such pairings are not producing young" (Day and Nigro 2004: 94).

2. Commercial Fisheries

a. Gillnet bycatch mortality

Commercial gillnet fisheries pose a threat to Kittlitz's murrelet by causing direct mortality of murrelets through incidental take as bycatch. Hundreds of thousands of seabirds are killed annually by commercial gillnet fisheries in the North Pacific (DeGange et al. 1993), and gillnets have been documented to take a significant number of murrelets in Alaska (Carter and Sealy 1984, DeGange et al. 1993, Carter et al. 1995, Piatt et al. 2007). Two types of commercial gillnets are used in Alaskan waters: drift gillnets, which are released from the boat to drift with the current and are then retrieved at a later time, and set gillnets, which remain attached to the boat and can be set at varying depths.

In Alaska, the nearshore salmon gillnet fishery[3] poses a particularly significant threat to Kittlitz's murrelet since it overlaps in space and time with Kittlitz's murrelet foraging areas in fjords and embayments along Alaskan coastal waters and has been documented to cause mortality of Kittlitz's murrelets as incidental take. Ten salmon regional fishing districts in Alaska overlap or potentially overlap Kittlitz's murrelet marine habitat, including districts in the Aleutian Islands, Alaska peninsula, Kuskowim, Bristol Bay, Cook Inlet, Kodiak, Prince William Sound, Yakutat, Juneau, and Sitka (districts shown in Piatt et al. 2007: Figure 18). Of 6,634 salmon fishing permits held during 1998-2002 (including gillnet, seine, and troll fisheries), ~66% of permits were issued in Southeast Alaska, Yakutat, Prince William Sound, Cook Inlet, Kodiak, the Alaska peninsula, and the Aleutians, which are important population centers for Kittlitz's murrelet (Woodby et al. 2005: Table 1). In addition, most salmon gillnet fisheries operate from early June through August which spans the breeding season of the Kittlitz's murrelet in Alaska and the peak period when Kittlitz's murrelets, including newly fledged juveniles, occupy nearshore waters. Fisheries that extend operations into August and September overlap with the fall molt, when adults are flightless (Day et al. 1999) and particularly vulnerable to gillnet mortality since their only possible response to vessel disturbance would be to dive, thereby increasing their chances of being caught by a net and drowned.

Total annual mortality of Kittlitz's murrelets in the salmon gillnet fishery is unknown because there are no regular seabird observer programs for this fishery. However, reported bycatch of Kittlitz's murrelets from regional observations under the Alaskan Marine Mammal Observer Program indicate that Kittlitz's murrelets are particularly vulnerable to incidental take in the salmon gillnet fishery. Wynne et al. (1992) reported the results of an observer program for the salmon gillnet fishery in Prince William Sound in 1991, which documented 7 Kittlitz's

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[3] Sometimes boats participating in the nearshore salmon gillnet fishery are called "drift gillnetters" because the boats drift with the currents while fishing. The nets, however, are technically set gillnets because they stay attached to the boat, and should not be confused with drift gillnets used on the high seas.

murrelets killed as incidental take and estimated that a total of 133 Kittlitz's murrelets were drowned in the fishery in 1991 (Wynne et al. 1992). Although Kittlitz's murrelets represented only 0.5% of all birds seen 10 m from nets, they represented 11.3% of all birds killed by the nets (Day et al. 1999). In addition, Kittlitz's murrelets represented only about 7% of all murrelets in Prince William Sound, but accounted for 30% of all murrelets killed (Day et al. 1999). Based on annual kill of 133 birds in 1991 and a population estimate of 3,368 in the early-to-mid 1990s (Kendall and Agler 1998), this study suggests that nearly 4% of the population in Prince William Sound may be killed by commercial gillnet fishing vessels each year.

Observations of bycatch from the Cook Inlet salmon drift and set gillnet fishery in 1999 and 2000 and for the Kodiak Island salmon set gillnet fishery in 2002 and 2005 also are cause for concern. Although no Kittlitz's murrelets were reported as incidental take in 1999 or 2000 in the Cook Inlet salmon gillnet fishery, murrelets (grouped as Kittlitz's and marbled murrelets) were observed closer than 10 m to the nets on multiple occasions in 1999, and an estimated 37 marbled murrelets were taken by the fishery in 1999 (Manly 2006). Overall, sampling effort was too low to accurately gauge seabird bycatch for this fishery, and the report concluded that "[a]lthough Kittlitz's murrelet (*Branchyramphus brevirostris*) was not observed as fisheries incidental take, it is in the area and incidental take could occur. As this species is a candidate for listing under the Endangered Species Act, any such incidental take would be of major concern" (Manly 2006: 73).

In the Kodiak Island gillnet fishery, in 2005 one juvenile Kittlitz's murrelet was observed killed as incidental take, and an estimated 18.1 (S.E.=16.8) Kittlitz's murrelets were killed in total (Manly 2007). Manley (2007) warned that juvenile murrelets may be particularly susceptible to gillnet mortality because they tend to feed close to shore and are weak divers. In 2002, Kittlitz's murrelets were not encountered on the water during surveys and net watches around Kodiak Island. Although Kittlitz's murrelets were uncommon around Kodiak Island in 2002 and 2005, marbled murrelets, which were much more commonly encountered, suffered high mortality in the salmon gillnet fishery in both years: an estimated 56.4 (S.E.=26.9) murrelets were killed in 2002 and 142.6 (S.E.=67.4) were killed in 2005 (Manly 2007).

Overall, data from observer programs clearly show that the nearshore salmon gillnet fisheries can represent a significant source of mortality for the Kittlitz's murrelet. An additional source of mortality may be salmon gillnets that are set from shore near river mouths. Because Kittlitz's murrelets can forage extremely close to shore and in shallow water, it is possible that these fisheries could drown these birds as well. More research is needed to determine whether these fisheries may pose a risk to the Kittlitz's murrelet.

In addition to direct observation of Kittlitz's murrelet bycatch, detailed information on marbled murrelet bycatch in gillnet fisheries (Carter and Sealy 1984, Carter et al. 1995, DeGange et al. 1993, DeGange 1996) provides important insights into the impacts to Kittlitz's murrelets from these fisheries, given the large overlap in the ecology and range of the Kittlitz's and marbled murrelet. As described above, data from Prince William Sound indicate that Kittlitz's murrelet populations suffer greater proportional losses than marbled murrelets or other seabirds from the nearshore gillnet fishery.

Carter et al. (1995) analyzed available data on bycatch mortality of marbled murrelets in gillnets from the 1950s through the mid-1990s across its range, and concluded that gillnet mortality is one of the major threats to the marbled murrelet. Carter et al. (1995) found that marbled murrelet mortality was occurring in Alaska at least as early as the 1950s and 1960s due to scattered reports throughout that time. According to Pete Isleib (himself a commercial fisherman), "several hundreds" of murrelets were killed per year throughout the 1970s in Prince William Sound along: 100-300 in the Copper and Bering River districts (which front the open Gulf of Alaska) and 500 birds per year in the Coghill-Unakwik and Eshamy districts (Carter et al. 1995). Bycatch mortality in Prince William Sound is thought to have increased throughout the 1980s and 1990s due to the fact that vessels began to fish continuously around the clock, more boats began fishing, and a finer web mesh was introduced for fishing nets (Carter et al. 1995). In Southeast Alaska and the Alaska peninsula, an estimated 1000 murrelets per year were killed in the 1970s and 1980s based on the number of boats on the water and the length of time spent fishing, fishing locations, and the types of gear used (Carter et al. 1995). Based on bycatch mortality data from Prince William Sound in the early 1990s, Piatt and Naslund (1995) estimated that as many as 3,300 marbled murrelets were killed annually in gillnets in Alaska during the 1990-1991 period: 900, 1100, and 300 murrelets in Southeast Alaska, lower Cook Inlet, and along the Alaska Peninsula, respectively (Carter et al. 1995). Finally, Carter et al. (1995) noted that juvenile marbled murrelets may be disproportionately killed by gillnets because young of the year show little fear of vessels, and because juveniles tend to dive from suspected danger while adults tend to fly. This observation is quite likely true of Kittlitz's murrelet young as well, since they are goods swimmers but poor fliers at fledging.

Based on these data, Carter et al. (1995) concluded that likely "several thousand to tens of thousands of murrelets are killed annually in Alaska" (p. 271), and gillnet mortality alone may have been an important factor in the decline in Alaska marbled murrelet populations:

> It is clear that gillnet mortality has the potential to be the greatest conservation problem for marbled murrelets in Alaska since it occurs annually throughout almost all at-sea foraging areas during the breeding season when murrelets are aggregated (Carter et al. 1995: 275).

And further that

> Gillnet mortality may act separately or in concert with the loss of nesting habitat and mortality from oil pollution to threaten survival of several populations (Carter et al. 1995: 271).

These clear and significant impacts to the marbled murrelet from gillnet fisheries raise strong concerns that the Kittlitz's murrelet is being similarly impacted due to its overlap in ecology and range with the marbled murrelet.

There is no known evidence of mortality of Kittlitz's murrelet from the Japanese, Korean, or Taiwanese drift gillnet fisheries for salmon or squid in the North Pacific or Bering Sea (Day et al. 1999). Because little is known about the winter distribution of Kittlitz's murrelets, more research is needed before these fisheries can be eliminated as a source of mortality, especially since mortality from the high seas drift gillnet fishery in the North Pacific was shown to be a significant factor in the decline of endangered Japanese murrelets (*Synthliboramphus wumizusume*) (Piatt and Gould 1994). In the Okhotsk Sea, coastal and offshore salmon fishing is extensive (Huettmann 2008) and creates the potential for bycatch of Kittlitz's murrelets by this fishery in areas of overlap. On a final note, the salmon gillnet fishery is thought to have contributed to the decline of one of the largest colonies of Ancient murrelet (*Snthliboramphus antiquus*) in British Columbia (Bertram 1995), providing further evidence of its potential to threaten the Kittlitz's murrelet.

Overall, mortality due to gillnet fisheries clearly has the potential to be a major threat to the Kittlitz's murrelet. Where data are available, they show both high rates of mortality and a disproportionately large impact on this species relative to other seabirds, even the closely related marbled murrelet. It is absolutely vital for regulatory agencies to increase observer coverage of the nearshore gillnet fisheries as well as seine nets and pound nets which are also known to kill murrelets (Piatt and Naslund 1995). The Alaska Department of Fish and Game ("ADFG"), which manages the salmon fisheries, should immediately institute observer programs to assess the level of bycatch mortality from gillnet fisheries through the Kittlitz's murrelet range. In addition, the ADFG should assess areas of overlap of Kittlitz's murrelet populations and gillnet fisheries in Alaska to better estimate the magnitude of this threat to the species and to inform new regulations for these fisheries to minimize impacts to Kittlitz's murrelets and other seabirds.

b. Other fisheries interactions

Disturbance from commercial fishing vessels may also affect breeding and feeding. Day and Nigro (1999) have suggested that excessive human disturbance has caused the abandonment of certain areas by Kittlitz's murrelets in the summer. (See below section on human disturbance.) Unfortunately, Kittlitz's murrelet habitat is also preferred by commercial fishermen and tourists, due to the presence of fish stocks and the astounding natural beauty of these areas.

3. Ocean Climate Regime Shifts

Ocean climate conditions and climate regime shifts can exert an important influence on seabird populations by altering the availability of their zooplankton and fish prey species. The Gulf of Alaska experienced a significant ocean climate regime shift in 1976/1977 that may have affected the Kittlitz's murrelet (Day et al. 1999). During the 20th century, the Pacific Decadal Oscillation was the dominant source of decadal-scale ocean climate variability in the North Pacific (Litzow 2006), where temperature regimes shifted in 1925 (cold to warm), 1947 (warm to cold), and 1976 (cold to warm) (Anderson and Piatt 1999). During the last reversal in 1976-1977, the Aleutian Low pressure system shifted south and intensified, leading to stronger westerly winds and warmer surface waters in the Gulf of Alaska (Anderson and Piatt 1999). Data compiled by Anderson and Piatt provide compelling evidence that a community reorganization occurred following the 1976-1977 climate regime shift. Populations of shrimp *Pandalidae*, Pacific herring *Clupea pallasii*, capelin *Mallotus villosus*, Pacific sandfish *Trichodon trichodon*, and Pacific tomcod *Microgadus proximus* collapsed, while groundfish (gadids and flatfish including walleye pollock *Theragra chalcogramma*, Pacific cod *Gadus macrocephalus*, arrowtooth flounder *Atheresthes stomias*, and flathead sole *Hippoglossoides elassodon*) and

Pacific salmon (*Oncorhynchus* spp.) increased sharply (Anderson and Piatt 1999, Litzow 2006). While some of the changes observed may have been caused by commercial fishing, species such as capelin which have never been commercially harvested also collapsed almost completely, leading to the conclusion that at least some of the changes were related to the climate shift (Anderson and Piatt 1999).

Agler et al. (1999) have suggested that the 1976/1977 climate regime shift and associated changes in forage fish abundance partially explains the population declines of many piscivorous marine bird populations in Prince William Sound between 1972 to 1989-1993, including *Brachyramphus* murrelets. Specifically, this study found that 14 out of 17 piscivorous marine bird species, including *Brachyramphus* murrelets, declined in Prince William Sound during the study period, and ascribed the declines to mortality from the Exxon-Valdez oil spill and the shift in forage fish species after the ocean regime shift (Agler et al. 1999). Since the Kittlitz's murrelet forages on several species that collapsed after the regime shift--capelin, sand lance, herring, and sandfish--reductions in the availability of these food sources after the regime shift may have impacted Kittlitz's murrelet populations.

More recently, Litzow (2006) analyzed ocean climate and ecological data to detect whether an ocean climate regime shift of similar magnitude to the 1976/1977 event has occurred in the Gulf of Alaska in the past few decades, and found no evidence of a reversion to a colder state of the Pacific Decadal Oscillation. Rather, Litzow (2006) detected a persistent increase in temperature and a decrease in sea level pressure in the Gulf of Alaska from 2001 to 2005 consistent with anthropogenic warming and the emergence of a pattern of decreased winter sea level pressure over subarctic North America.

4. Human Disturbance

The Kittlitz's murrelet faces ever-increasing threats from human disturbance, most notably from high volumes of vessel traffic in its at-sea foraging habitat and increasing human development and recreation in its mountain breeding habitat, as detailed below.

a. Vessel activity

The Kittlitz's murrelet is threatened by high volumes of recreational and commercial vessel traffic in the bays and fjords near tidewater glaciers that support the largest concentrations of murrelets during the breeding season. Of particular concern recreational and commercial tourism and traffic from cruise ships, tour boats, fishing boats, and tankers have increased substantially in many of its breeding areas, especially in Glacier Bay, Prince William Sound, Kenai Fjords, and lower Cook Inlet/Kachemak Bay (USFWS 2007). The number of cruise ships allowed into Glacier Bay has increased 30% since 1985, while smaller charter boats and private boats have increased 8% and 15%, respectively (USFWS 2007). Vessel traffic can impact the Kittlitz's murrelet in a number of ways, both directly and indirectly, by displacing birds from foraging areas, increasing energy expenditure, and interrupting normal behaviors, in addition to increasing noise pollution and heightening the risk of oil spills.

i. Loss of foraging habitat, increase of energy expenditure, and disruption of normal behaviors

Vessel activity can result in a suite of impacts to Kittlitz's murrelets. Vessels can cause loss of suitable foraging habitat for Kittlitz's murrelets if birds displaced by vessel activity do not return to the foraging area after being disturbed (Agness et al. 2008). In addition, vessel activity can negatively affect a bird's daily energy budget if it interrupts or reduces foraging activity, decreases feeding efficiency, or increases energetically costly behavior such as flight, leading to significant energy loss (Agness et al. 2008). Any increases in flight are particularly energetically costly for the Kittlitz's murrelet due to its high wing-loading, especially during the chick-rearing period when birds must make provisioning flights to inland nest sites (Agness et al. 2008). Young chicks may be disproportionately affected if vessel activity decreases their parents' foraging efficiency since chicks are completely dependent on fish brought to them by their parents in order to reach fledging condition. Finally, vessel traffic may scatter the forage fish prey of the Kittlitz's murrelet, which could greatly decrease feeding efficiency, and interrupt courtship and other important behaviors.

Agness et al. (2008) conducted the first focused study of the effects of vessel activity on Kittlitz's murrelets, and detected significant impacts of vessels on nearshore densities and behavior in Glacier Bay. During the study period, 2 cruise ships, 6 large tour boats, and ≤25 private recreational motor-vessels were permitted to enter park waters each day through the summer season. Since tourist vessels overlap in space and time with Kittlitz's murrelets in their preferred foraging areas, vessels have a high potential to adversely affect murrelets. Specifically, Agness et al. (2008) examined the effects of vessel activity on density and behavior of Kittlitz's murrelets in nearshore areas of Glacier Bay to evaluate whether vessel activity caused (1) a decline in the species' near-shore density, (2) a change in group size, and (3) a change in the behavior of individuals at sea.

Agness et al. (2008) found that vessel passage temporarily reduced nearshore densities of Kittlitz's murrelets by an average of 40%. However, Kittlitz's murrelet densities recovered within the day, so vessel activity did not appear to result in persistent loss of foraging habitat for Kittlitz's murrelets. Most importantly, Agness et al. (2008) found that vessel activity increased Kittlitz's murrelet diving effort by a factor of three and increased flying activity more than 30-fold (Agness et al. 2008). Non-breeding (i.e. non-fish holding) Kittlitz's murrelets responded to vessels primarily by flying, especially in response to large vessels (cruise ships and large tour boats), while breeding (i.e. fish-holding) murrelets responded primarily by diving, especially in response to fast to moderate speed vessels (Agness et al. 2008). About 95% of fish-holders dove from vessels transiting at fast to moderate speeds ranging from 17 to 48 km/hr, equivalent to 9.2 to 25.9 knots. Agness et al. (2008) noted that the increased time spend flying likely increased energy expenditure of Kittlitz's murrelets and could constitute a significant energy loss. In addition, marbled murrelet fish-holders have been observed to eat their fish if repeatedly disturbed by approaching vessel, which creates a significant energy expenditure for adults that must catch another fish and an energy deficit for chicks if their meal is not delivered. Kittlitz's murrelets may experience a stress response similar to marbled murrelets in highly trafficked areas in Glacier Bay and elsewhere. Since large and fast-moving vessels caused the greatest disturbance, Agness et al. (2008) recommended regulating large vessels at low numbers in

Glacier Bay National Park, and instituting speed limits of less than 16 km/hr (less than 8.6 knots) to prevent disturbance to Kittlitz's murrelets.

In a second study, Day and Nigro (1999) documented dramatic declines in Kittlitz's murrelet populations in Blackstone Bay in Prince William Sound between 1996-1998, which they linked to disturbance from boating. Population estimates in Blackstone bay fell from 222 ± 306 birds (95% CI) in 1996, to 119 ± 181 birds in 1997, to 48 ± 108 birds in 1998 (Day and Nigro 1999). Blackstone Bay is immediately adjacent to the Whittier Arm, and is heavily impacted by recreation, in particular by motorized boating. Day and Nigro (1999) suggested that excessive human disturbance likely contributed to the abandonment of this area by Kittlitz's murrelets.

Kuletz et al. (2008) also commented that the boat activity in Kachemak Bay is high and has the potential to impact Kittlitz's murrelets in this region, where Kittlitz's murrelets have declined dramatically in recent years:

> Compared to the locations of other populations of Kittlitz's, Kachemak Bay has relatively high boat activity, although most of the traffic during our surveys was from recreational or fishing vessels < 45 ft. However, even small boats can disturb murrelets (Speckman et al. 2004), and boat traffic was high throughout nearshore areas, particularly along the southern shore and including the inner bay area < 2 km from the southern shore, and throughout the Eldredge Passage area (Appendix F). Disturbance in forage areas by large vessels can be energetically expensive for murrelets during the breeding season (Agness 2006). (Kuletz et al. 2008: 33).

Despite these data, regulatory agencies have not been applying the precautionary principle with regard to the possible effects of vessel traffic on the Kittlitz's murrelet and other species. In 2007, Glacier Bay National Park changed its regulations to allow higher seasonal quotas for cruise ships and increase the vessel speed limit from 10 knots to 13 knots (Federal Register 71: 69328-69358). Both of these changes will be detrimental to Kittlitz's murrelets based on the findings of Agness (2006) and Agness et al. (2008) described above, which recommended keeping large vessels at low numbers in Glacier Bay and instituting speed limits of less 8.6 knots to prevent disturbance to Kittlitz's murrelets. Based on this regulations change, the Superintendent of Glacier Bay National Park and Preserve proposed to increase the number of cruise ships allowed to enter Glacier Bay during June, July, and August by ten percent beginning in 2007, increasing the seasonal quota from 139 visits to 153 visits (NPS 2006).

ii. Noise pollution

Vessel noise may also pose a threat to Kittlitz's murrelets, which like all other marine creatures, live in a sound environment influenced by both natural and human-caused factors. The effect of anthropogenic noise on the Kittlitz's murrelet must be assessed relative to the naturally occurring background noise level in the ocean. Sound is measured by the decibel unit, which is the ratio between a measured pressure value and a reference pressure value (NMFS 1999). For

Arctic waters, the ambient sound level in the absence of human activity has been estimated to be 79-119 decibels (NMFS 1999).

Most medium to large ships (like cruise ships) produce source sound levels in the range of 165-175 decibels, though source levels as high as 175-185 decibels may occur. Smaller outboard and inboard motorboats produce source levels generally less than 167 decibels; however several small boats operating near each other may produce sound levels similar to that of a larger ship (Richardson and Malme 1993). Thus, vessel traffic within the range of the Kittlitz's murrelet produces sound levels many hundreds of times greater than what would ever be encountered in the absence of human activity. Cruise ships and Kittlitz's murrelets both tend to congregate in the heads of fjords and bays. This means that the ships approach extremely close to the birds. It may also have important consequences for sound propagation, as the noise from the ship may "bounce" off the walls of the fjords, creating an even greater sonic disturbance. Finally, sounds propagate better at greater depths, and therefore birds would be unable to escape the noise by diving more deeply. Diving, in fact, would make any disturbance from the noise worse.

Assessing the effect of human-caused noise on the Kittlitz's murrelet is extremely complex, and such studies have not yet been attempted. However, it is clear that there are at least three ways that Kittlitz's murrelets could be affected by underwater noise: (1) feeding and/or reproductive behavior could be disrupted because the birds are disturbed by the noise, (2) forage fish prey may be scattered, decreasing feeding efficiency, and (3) individual birds could suffer permanent or temporary hearing impairment from the noise.

b. Human disturbance to nesting areas

While the alpine nesting environment of the Kittlitz's murrelet was previously extremely inaccessible to humans, human development and tourism are also beginning to impact these remote breeding sites. The summer of 2000 marked the opening of the Whittier Road, a tourbus and automobile route that replaced train service from Portage to the town of Whittier, one of the most popular "gateways" to Prince William Sound. The express purpose of this project was to increase commercial tourism to Whittier and to Prince William Sound over the long term (Singer 1998). So important was this goal, in fact, that the Alaska Department of Transportation, Federal Highway Administration, and State of Alaska rejected an improved rail service alternative that would have been safer, cheaper, and less environmentally damaging on the sole basis that demand for access to Whittier via train would simply never be as great as demand for access to Whittier via road (Singer 1998). For the Kittlitz's murrelet, however, vastly increased tourism over the past several decades, coupled with the increase in visitation that the Whittier Road is expected to bring, present a threat.

This problem of increased human disturbance is nesting areas also comes from the rise of "heli-hiking" and "heli-tours" over the past decade. Given the State of Alaska's position that increased tourism must be facilitated, as evidenced by the State's position in the Whittier Road case, there will likely be no meaningful restrictions placed on heli-tours within the range of the Kittlitz's murrelet unless this species receives protection under the state ESA.

C. Disease or Predation

Very little is known about predation on Kittlitz's murrelets and almost nothing is known about diseases and parasites that affect Kittlitz's murrelets. Kittlitz's murrelets are thought to nest at high elevations and on rock or scree cliffs at least in part to avoid mammalian predators, and mammals are not considered to be significant predators of nesting Kittlitz's murrelets (Piatt et al. 1999). However, common ravens may take young from nests (Day et al. 1999), and circumstantial evidence suggests that predation from corvids may be increasing with glacial retreat (USFWS 2007). Corvid populations are known to increase around areas of human inhabitation (e.g. cities, campgrounds, and dumps), and increasing human presence in areas where Kittlitz's murrelets nest could also heighten predation.

Bald eagles and peregrine falcons are known to take marbled murrelets in the Gulf of Alaska (Day et al. 1999), and new information indicates that peregrine falcons and bald eagles depredate Kittlitz's murrelets as well (USFWS 2007). Peregrine falcons have been observed perching on vessel flagpoles and taking murrelets on the water (USFWS 2007). In Icy Bay during summers of 2006 and 2007, peregrine falcons and bald eagles predated 28% and 13% (respectively) of radio-tagged Kittlitz's murrelets in Icy Bay during the summers of 2006 and 2007, although the radio-telemetry research may have increased the predation rates (USFWS 2007). In addition, ~35 Kittlitz's murrelet remains were found in the territories (e.g., eyries and plucking posts) of three peregrine falcon pairs in Icy Bay in 2007 (USFWS 2007). As Kittlitz's murrelet numbers decline, it is possible that natural depredation may become more consequential for murrelet populations.

D. Overutilization for Commercial or Sporting Purposes

The Kittlitz's murrelet does not appear to be currently threatened by overutilization for commercial or sporting purposes. To the extent that the Kittlitz's murrelet itself, as an interesting and beautiful seabird, attracts tourists and tourboats, this issue has been discussed above in the "Human Disturbance" section.

IV. EXISTING REGULATORY MECHANISMS ARE INADEQUATE

The Kittlitz's murrelet faces a formidable list of threats, many of which could be ameliorated or eliminated by regulatory actions. To date, few, if any, of these regulatory actions have been implemented with regard to the Kittlitz's murrelet, despite the existence of regulatory authority by various agencies. The documented decline of the Kittlitz's murrelet is itself *de facto* evidence of the inadequacy of existing regulatory mechanisms.

A. Regulatory Mechanisms Addressing Greenhouse Gas Pollution and Global Warming Are Inadequate

Greenhouse gas emissions and global warming pose a significant threat to the Kittlitz's murrelet and yet are among the least well-regulated threats. The primary international regulatory mechanisms addressing greenhouse gas emissions global warming are the United Nations Framework Convention on Climate Change and the Kyoto Protocol. While the entering into force of the Kyoto Protocol on February 16, 2005 marks a significant partial step towards the regulation of greenhouse gases, it does not and cannot alone adequately address the impacts of global warming that threaten the Kittlitz's murrelet with extinction. There are currently no legal mechanisms regulating greenhouse gases on a national level in the United States. As detailed below, all existing regulatory mechanisms are clearly inadequate to ensure the Kittlitz's murrelet's survival in the wild. The immediate reduction of greenhouse gas pollution is essential to slow global warming and ultimately stabilize the climate system while there is still suitable habitat remaining.

1. The United Nations Framework Convention on Climate Change

The United Nations Framework Convention on Climate Change ("UNFCCC") was adopted in May 1992 at the first Earth Summit held in Rio de Janeiro, Brazil, and entered into force in March 1994 (EIA 2004). The stated objective of the UNFCCC is the stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system (EIA 2004). Due to the complexity of climate issues and the widely divergent political positions of the world's nation states, the UNFCCC itself was unable to set emissions targets or limitations, but instead created a framework that set the stage for a range of subsequent actions (UNFCCC 2004). The UNFCCC covers greenhouse gases not otherwise controlled by the Montreal Protocol on ozone-depleting substances (UNFCCC 2004).

The UNFCCC assigns differing responsibilities to its 189 parties, based on their differing levels of economic development (UNFCCC 2004). Annex I parties include 41 mostly developed countries. Annex I countries set a goal (but not a requirement) of returning their emissions by 2000 to 1990 levels (UNFCCC 2004). They are required to make regular reports on implementation, including reporting on levels of greenhouse gas emissions and policies and measures to reduce them (UNFCCC 2004). Annex II is a subset of Annex I countries which includes the 23 highly developed countries which are required to financially and otherwise support the efforts of the developing countries (UNFCCC 2004). Countries with economies in transition ("EITs") include 14 countries in Eastern and Central Europe and the former Soviet Union which are listed in Annex I but do not have the additional responsibilities of the other Annex I countries. Non-Annex I parties include all parties not included in one of the former categories and are mostly developing countries (UNFCCC 2004). Non-Annex I parties have general commitments to respond to climate change but have fewer obligations and are expected to rely upon external support.

The UNFCCC has not yet effectively controlled greenhouse gas emissions. The year 2000 has come and gone without the UNFCCC's goal of reducing greenhouse gas emissions from Annex I countries to 1990 levels being met. More than thirteen years after the UNFCCC came into force, "dangerous anthropogenic interference with the climate system" remains undefined (International Climate Change Taskforce 2005). There is a growing body of evidence, however, that anthropogenic greenhouse gas emissions are already causing "dangerous" climate change.

2. The Kyoto Protocol

In 1997 the Kyoto Protocol became the first additional agreement added to the UNFCCC to set emissions targets. The Kyoto Protocol set goals for developed countries only to reduce their emissions to at least 5% below their 1990 levels between 2008-2012, the "first commitment period" (UNFCCC 2004). The Kyoto Protocol required ratification by a minimum of 55 countries, encompassing at least 55% of the carbon dioxide emissions of Annex I countries before it would enter into force. Over seven years passed before this occurred. The Kyoto Protocol entered into force on February 16, 2005, 90 days after it was ratified by Russia (UNFCCC 2005).

The targets of the Kyoto Protocol's first commitment period are inadequate to prevent significant climate change, and consequently the decline to extinction of the Kittlitz's murrelet. First, the Protocol's overall emissions reduction targets for the first commitment period are highly unlikely to be met, due in large part to the continuing refusal of the United States to ratify the agreement. Second, even if the Kyoto targets were met, they are far too modest to impact greenhouse gas concentrations and global warming sufficiently to ensure the survival of the Kittlitz's murrelet. Third, negotiations for emissions reductions beyond 2012 are just beginning after being blocked for years by the U.S. Each of these issues is addressed in turn below.

The refusal of the United States to ratify the Kyoto Protocol, announced by the Bush Administration in 2001, is a major reason why Kyoto targets are unlikely to be met. Because the United States is responsible for over 20% of worldwide carbon dioxide emissions (EIA 2004), it is highly unlikely that overall targets can be met without U.S. participation. The Kyoto target for the U.S. was a 7% reduction in greenhouse gas emissions levels from 1990 levels by 2012 (EIA 2004). Between 1990 and 2001, United States emissions have in fact increased by 13%. Total United States emissions are projected to grow a staggering additional 43.5% through the period 2025 (GAO 2003a).

In addition to the outright intransigence of the United States, the overall and many country-specific Kyoto targets are unlikely to be met based on current progress and data. While some Annex I countries have achieved their Kyoto targets or at least some reductions, many other Annex I countries have seen their emissions increase substantially (Figure 16). Emissions also increased in many of the developing nations between 1990 and 2000 (UNFCCC 2004). In addition, although emissions of the EIT countries decreased significantly from 1990-2000 as a result of economic contraction in these countries, they increased from 2000 to 2001 and are projected to continue to do so (EIA 2004). Overall, the EIA estimates that worldwide carbon emissions in 2025 will exceed 1990 levels by 72% (EIA 2004).[4]

Even in the unlikely event that overall Kyoto targets were fully met by the year 2012, the reductions are far too small to substantially reduce global warming and improve the plight of the Kittlitz's murrelet. Implementation of the Kyoto Protocol would only slightly reduce the rate of growth of emissions – it would not stabilize or reduce atmospheric greenhouse gas

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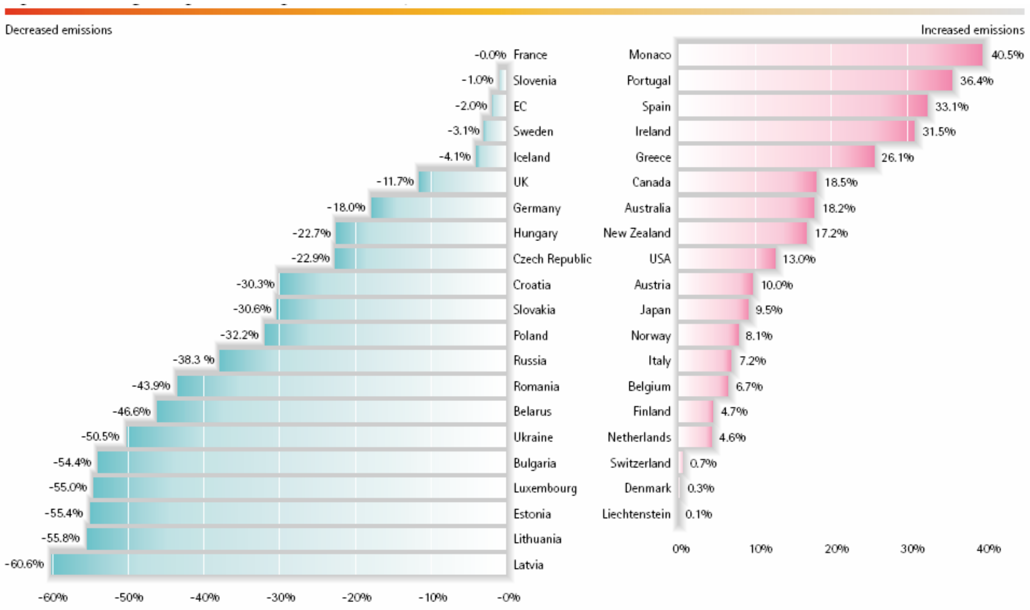
[4] EIA (2004) projections do not reflect the potential impacts of the Kyoto treaty, because it had not yet come into force when the projections were prepared (EIA 2004). Compliance with Kyoto or other measures to reduce greenhouse gases could cause actual emissions to differ from the projections (EIA 2004), however, as discussed above, compliance with overall Kyoto targets is unlikely.

concentrations (Williams 2002). Carbon dioxide levels currently stand at over 385 ppm, from pre-industrial levels of 280 ppm, and are increasing at more than 2 ppm per year (International Climate Change Taskforce 2005). Stabilizing carbon dioxide concentrations at 440 ppm (23% above current levels, and a level likely to lead to a greater than 2° C average global temperature rise) would require global emissions to drop below 1990 levels within a few decades, with emissions eventually declining to a very small fraction of current levels, despite growing populations and an expanding world economy. These cuts will not be achieved simply by compliance with Kyoto (Williams 2002). The IPCC SRES scenarios predict carbon dioxide concentrations of between 490 and 1260 ppm by 2100 (Albritton et 2001), and these scenarios all assume significant reductions in the rate of greenhouse gas emissions (Nakićenović et al. 2000).

Figure 16. Changes in greenhouse gas emissions by Annex I Countries, 1990-2001.
Source: UNFCCC (2004: 25).



Additionally, the Kyoto Protocol's first commitment period only sets targets for action through 2012. There is no current regulatory mechanism governing greenhouse gas emissions in the years beyond 2012. Discussions for targets for the second compliance period from 2012-2016 began at the Bali, Indonesia, UNFCCC conference in 2007. While the European Union delegation attempted to begin discussions at the Conference of the Parties in Milan, Italy in 2003, in Buenos Aires in 2004, in Montreal in 2005, in Nairobi in 2006, not until Bali 2007 did the U.S. agree to a framework for the regulation of post-2012 emissions reductions. No binding or even voluntary agreement yet exists to deal with the cuts needed beyond the Kyoto Protocol.

3. United States Climate Initiatives are Ineffective

Because the United States is responsible for over 20% of global greenhouse gas emissions, regulation of United States emissions is essential to saving the Kittlitz's murrelet from declines to extinction. Unfortunately, despite the nature and magnitude of the risks, and a variety of actions by Congress and the Executive Branch, there is still no regulation of greenhouse gas emissions on the national level in the United States.

Beginning in 1978, Congress established a "national climate program" to improve understanding of global climate change through research, data collection, assessments, information dissemination, and international cooperation. National Climate Program Act of 1978, 15 U.S.C. §§ 2901 *et seq.* Two years later, in the Energy Security Act, Congress directed the Office of Science and Technology Policy to engage the National Academy of Sciences in a study of the "projected impact, on the level of carbon dioxide in the atmosphere, of fossil fuel combustion, coal-conversion and related synthetic fuels activities" authorized by the Energy Security Act. Pub. L. No. 96-294, tit. VII, § 711, 94 Stat. 611, 774-75 (1980). In 1990, Congress enacted the Global Change Research Act, 15 U.S.C. §§ 2931-2938, which established a 10-year research program for global climate issues, directed the President to establish a research program to improve understanding of global change, and provided for scientific assessments every four years that analyze current trends in global change. *Id.* at §§ 2932, 2933, 2936(3). Congress also established a program to research agricultural issues related to global climate change. Pub. L. No. 101-24, tit. XXIV, § 2402, 104 Stat. 4058, 4058-59 (1990). Finally, two years later, in the Energy Policy Act of 1992, Congress directed the Secretary of Energy to conduct several assessments related to greenhouse gases and report to Congress. Pub. L. No. 102-486, § 1604, 106 Stat. 2776, 3002.

The Global Climate Protection Act of 1987 directed the Secretary of State to coordinate U.S. negotiations concerning global climate change. 15 U.S.C. § 2901 note; § 2952(a). Following those negotiations, President George H.W. Bush signed, and the Senate approved, the UNFCCC, which, as discussed above, has yet to effectively control greenhouse gas emissions.

Greenhouse gas emissions have also not yet been effectively regulated under the United States Clean Air Act ("CAA"). Section 103(g) directs the Environmental Protection Agency ("EPA") to establish a "basic engineering research and technology program to develop, evaluate, and demonstrate nonregulatory strategies and technologies for air pollution prevention" that would address substances including carbon dioxide. 42 U.S.C. § 7403(g). The CAA also states that nothing in Section 103(g) "shall be construed to authorize the imposition on any person of air pollution control requirements." *Id.*

In 2003, the EPA rejected a petition urging it to regulate greenhouse gas emissions from automobiles under CAA Section 202. In 2007, the Supreme Court overturned the EPA's refusal to regulate these emissions, and remanded the matter to the agency for further consideration. *Massachusetts v. U.S. EPA*, 127 S. Ct. 1438 (2007). The EPA has yet to act following the remand. Moreover, the EPA has denied California's request for a waiver to implement its Clean Vehicle Law, passed in 2002 (AB 1493, Pavley) which requires greenhouse gas reductions from automobiles sold in California, and is thus actively preventing this law from going into effect.

The George W. Bush Administration's climate initiative, revealed after the Administration renounced the Kyoto Protocol, plainly fails to effectively address global warming. This initiative is based entirely on voluntary measures which are incapable of effectively controlling greenhouse gas emissions. This climate plan, termed the Global Climate

Change Initiative, also focuses only on reducing the amount of greenhouse gas emissions per unit of energy produced ("emissions intensity"), not the overall level of emissions (GAO 2003a).

In the absence of new climate initiatives, United States emissions intensity is expected to decrease by 14% by 2012, while total emissions continue to increase (GAO 2003a). The Bush plan, if fully implemented and successful, would decrease emissions intensity by a mere additional 4%, for an overall reduction of 18%, but total emissions would still continue to increase. Even according to the Bush Administration's own arithmetic, full implementation and success of the plan will result in U.S. greenhouse gas emissions in 2012 that are 30% higher than 1990 emissions, as opposed to the 7% reduction called for by the Kyoto Protocol (Holdren 2003). Cumulative emissions between 2002-2012 will continue to grow and would be only 2% less with the plan than without it (GAO 2003a).

Moreover, the U.S. Government Accounting Office ("GAO") found that the Bush plan does not explain how even the modest 4% claimed reduction in energy intensity will be met. The Bush plan fails to provide any emissions savings estimates at all for 19 of the 30 plan elements (GAO 2003b). Of those 19, at least two seem unlikely to yield any emissions savings at all by 2012 (GAO 2003b). Of 11 initiatives for which savings estimates were provided, at least eight were not clearly attributable to the Bush plan, and there were problems with others as well (GAO 2003b). Overall, the GAO could confirm that emissions savings would be realized from only three of the Bush plan elements (GAO 2003b), an extremely inauspicious finding for the ultimate success of the already modest proposal.

In the absence of federal leadership, state and local governments have taken the lead in measures to reduce greenhouse gas emissions. While certainly a step in the right direction, unfortunately, these measures on their own are insufficient to prevent the extinction of the Kittlitz's murrelet. For example, the strongest law enacted to date is the California Global Warming Solutions Act of 2006. Signed into law in September, 2006, it is the nation's first mandatory cap on a state's overall greenhouse gas emissions. The California Legislature declared:

> Global warming poses a serious threat to the economic well-being, public health, natural resources, and the environment of California. The potential adverse impacts of global warming include the exacerbation of air quality problems, a reduction in the quality and supply of water to the state from the Sierra snowpack, a rise in sea levels resulting in the displacement of thousands of coastal businesses and residences, damage to marine ecosystems and the natural environment, and an increase in the incidences of infectious diseases, asthma, and other human health-related problems. (Cal. Health and Safety Code § 38501(a)).

The Global Warming Solutions Act requires the reduction of greenhouse gas emissions to 1990 levels by the year 2020. *Id.* at § 38550. The law will be implemented through a series of California Air Resources Board (CARB) rulemakings including establishing emission source monitoring and reporting requirements, discrete early action emission reduction measures, and finally greenhouse gas emission limits and measures to achieve the maximum feasible and cost-effective reductions in furtherance of the greenhouse gas emission cap. *Id.* at § 38550. While the

California Global Warming Solutions Act is a promising first step, like the Kyoto Protocol, it is insufficient on its own to slow global warming sufficiently to ensure the survival of the Kittlitz's murrelet.

For all the reasons discussed above, existing regulatory mechanisms relating to global warming are inadequate to ensure the continued survival of the Kittlitz's murrelet. Ensuring the survival of this species requires immediate and dramatic action, particularly in the United States, to reduce greenhouse gas emissions. While ESA listing will alone may not protect the Kittlitz's murrelet and its habitat from human-induced climate change, existing mechanisms are indisputably inadequate.

4. Ocean acidification

Ocean acidification represents a significant threat to the Kittlitz's murrelet and its prey base. Because ocean acidification is driven by anthropogenic carbon dioxide emissions, and, as described above, no adequate mechanisms are in place domestically or internationally to reduce such emissions, regulatory mechanisms to address ocean acidification must also be deemed inadequate.

B. Regulatory Mechanisms Addressing Other Threats to the Kittlitz's Murrelet Are Inadequate

1. Oil pollution

Kittlitz's murrelets are extremely vulnerable to mortality from oil spills. However, chronic and acute oil spills from vessels and oil extraction operations continue to occur at high frequency and volume in the marine range of the Kittlitz's murrelet in coastal Alaska and are certain to occur in the future (Piatt et al. 2007, USFWS 2007). Unfortunately, there is no evidence that the probability of a future large spill has decreased since the 1989 *T/V Exxon Valdez* spill which killed up to 10% of the global Kittlitz's murrelet population.

The Oil Pollution Act of 1990 (33 U.S.C. §§2701-2719), passed in response to the *T/V Exxon Valdez* disaster, requires that single-hulled tankers be phased out of the U.S. fleet and replaced by double-hulled tankers by 2015 in order to reduce the risk of an oil spill. As of December 31, 2007, 17 of the 179 tankers, crude carriers, and tank barges in the U.S. Fleet were still operating with single-hulls (U.S. Maritime Administration 2007b). In addition, although double-hulled vessels can decrease the likelihood of minor spills, there are no data on the probability of spills in the event of a catastrophic accident. Because a double-hull does not prevent navigational errors, it is imperative that tankers are escorted by tugs in order to lessen the likelihood of an accident due to navigational error (Prince William Sound Regional Citizens' Advisory Council 2008). The Prince William Sound Disabled Tanker Towing Study (DTTS), completed in 1994, concluded that double hulls do not prevent groundings, and it can thus be inferred that they also do not prevent collisions, allisions, mechanical failure, human error or organizational failure (Prince William Sound Regional Citizens' Advisory Council 2008). However, the Oil Pollution Act does not require escort vessels for double-hull vessels. Thus, once all of the single-hull vessels have been phased out, there will be no federal requirement for escort vessels to accompany tankers. In summary, even when single-hulled tankers are completely phased out, the threat of a catastrophic oil spill will continue to exist. Clearly the Oil Pollution Act has as yet been inadequate to protect the Kittlitz's murrelet from the threat of oil spills from tankers. Further, as described above, the threat of oil and chemical spills from commercial and recreational vessels and oil extraction operations continues to pose a grave threat to the Kittlitz's murrelet, as oil spills occur at high frequency and volume.

2. Gillnet mortality

Although gillnet fisheries pose a significant threat to the Kittlitz's murrelet, state and federal agencies have failed to establish programs to assess seabird bycatch mortality in gillnet fisheries in Alaska to document the magnitude of this threat. State and federal agencies have also failed to institute regulations to reduce this threat. Mapping areas of overlap between Kittlitz's murrelet populations and gillnet fisheries and establishing gillnet fishery observer programs in these areas will be critical for assessing the level of bycatch mortality of the Kittlitz's murrelet throughout its range in Alaska and informing regulations for gillnet fisheries to minimize impacts to Kittlitz's murrelets and other seabirds. Several researchers have pointed out that gillnet mortality could be substantially reduced by two actions: (1) excluding fishing from areas with high murrelet densities (i.e. area closures), and (2) allowing fishing only during daylight hours, since most murrelets are killed during night-time fishing (Carter and Sealy 1984, Carter et al. 1995, Piatt et al. 2007). No such measures are currently in place with regard to the Kittlitz's murrelet, although the regulatory authority does exist.

3. Human disturbance

Kittlitz's murrelets are threatened by the disturbance caused by human recreation, particularly by motorized vessels in the bays and fjords where they congregate (Agness et al. 2008). Kittlitz's murrelets could be protected by establishing protective zones within which motorized boats could not approach birds, prohibiting motorized access to certain bays during the breeding season, limiting the number and size of motorized boats on the water, and lowering vessel speed limits. Few, if any, such measures are currently in place with regard to vessel disturbance, although most of the world's population of the Kittlitz's murrelet occurs in areas where the regulatory authority exists (e.g., Glacier Bay National Park, Kenai Fjords National Wildlife Refuge, Chugach National Forest).

Moreover, in some cases regulatory agencies are actually involved in promoting increased motorized access to areas inhabited by Kittlitz's murrelets. As described above, Glacier Bay National Park changed its regulations to allow higher seasonal quotas for cruise ships and increase the vessel speed limit from 10 knots to 13 knots (Federal Register 71: 69328-69358). Both of these changes will be detrimental to Kittlitz's murrelets based on the findings of Agness et al. (2008), which recommended keeping large vessels at low numbers in Glacier Bay and instituting speed limits of less 8.6 knots to prevent disturbance to Kittlitz's murrelets.

Current regulatory mechanisms are clearly inadequate to protect the Kittlitz's murrelet. The Commissioner of the Alaska Department of Fish and Game should act promptly to list the Kittlitz's murrelet since it is clearly imperiled by the inadequacy of existing regulatory mechanisms, particularly in regard to global warming, marine oil pollution, fisheries bycatch, and human disturbance.

V. CRITICAL HABITAT SHOULD BE DESIGNATED FOR THE KITTLITZ'S MURRELET

The State Endangered Species Act requires that "the commissioner of fish and game and the commissioner of natural resources shall take measures to preserve the natural habitat of species or subspecies of fish and wildlife that are recognized as threatened with extinction" (AS § 16.20.185). The Center therefore requests the designation of critical habitat for the Kittlitz's murrelet concurrent with its listing. We believe that all current and historic areas utilized by the species for reproduction and foraging meet the criteria for protection under AS § 16.20.185 and must therefore be designated for such protection.

VI. CONCLUSION

Clearly, the best available scientific data documents that the Kittlitz's murrelet is a species whose "numbers have decreased to such an extent as to indicate that its continued existence is threatened," and that the Commissioner must therefore determine that it is an endangered species pursuant to AS § 16.20.190. The Center therefore formally requests, pursuant to AS § 44.62.220, that the Commissioner publish regulations that declare the Kittlitz's murrelet to be an endangered species and add it to the list of species published at 5 AAC § 93.020.

Under AS § 44.62.230, the Commissioner must, within 30 days of the day of this petition, either deny the petition in writing, or schedule a public hearing on the requested action under AS §§ 44.62.190 – 44.62.215. The Center looks forward to the Commissioner's response.

LITERATURE CITED[5]

*ACIA. 2005. Arctic Climate Impact Assessment. Cambridge University Press, Cambridge, UK.

Agler, B.A., S.J. Kendall and D.B. Irons. 1998. Abundance and distribution of marbled and Kittlitz's murrelets in southcentral and southeast Alaska. Condor 100: 254-265.

Agler, B.A, S.J. Kendall, D.B. Irons, and S.P. Klosiewski. 1999. Changes in marine bird populations in Prince William Sound, Alaska coincident with a climactic regime shift. Colonial Waterbirds 22(1): 98-103.

Agness A.M. 2006. Effects and impacts of vessel activity on the Kittlitz's murrelet (*Brachyramphus brevirostris*) in Glacier Bay, Alaska. Master's thesis, University of Washington. 51 pp.

Agness, A.M., J.F. Piatt, J.C. Ha, and G.R. VanBlaricom. 2008. Effects of vessel activity on the near-shore ecology of Kittlitz's murrelets (*Brachyramphus brevirostris*) in Glacier Bay, Alaska. Auk 125(2): 346-353.

AKNHP. Alaska Natural Heritage Program. 2004. Kittlitz's murrelet. <http://aknhp.uaa.alaska.edu/zoology/pdfs/birds/Kittlitz's%20murrelet.pdf>; Downloaded on November 9, 2007

Albritton, D. L., L. G. Meira Filho, U. Cubasch, X. Dai, Y. Ding, D. J. Griggs, B. Hweitson, J. T. Houghton, I. Isaksen, T. Karl, M. McFarland, V. P. Meleshko, J. F. B. Mitchell, M. Noguer, M. Nyenzi, M. Oppenheimer, J. E. Penner, S. Pollnais, T. F. Stocker, and K. E. Trenberth. 2001. Technical Summary. *in* J. T. Houghton, Y. Ding, D. J. Griggs, M. Noguer, P. J. van der Linden, K. Maskell, and C. A. Johnson, editors. Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Anderson, P.J. and J.F. Piatt. 1999. Community reorganization in the Gulf of Alaska following ocean climate regime shift. Mar Ecol Prog Ser 189:117-123.

Anisimov, O. A., D. G. Vaughan, T. V. Callaghan, C. Furgal, H. Marchant, T. D. Prowse, H. Vilhjálmsson, and J. E. Walsh. 2007. 2007: Polar regions (Arctic and Antarctic). Pp. 653-685 *in* M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, and C. E. Hanson, editors. Climate Change 2007: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK.

Arendt, A.A., K.A. Echelmeyer, W.D. Harrison, C.S. Lingle, and V.B. Valentine. 2002. Rapid wastage of Alaska glaciers and their contribution to rising sea level. Science 297:382–386.

Arimitsu, M.L., Piatt, J.F., Romano, M.D., and Douglas, D.C., 2007, Distribution of forage fishes in relation to the oceanography of Glacier Bay. Pp. 102-106 *in* Piatt, J.F., and Gende, S.M., eds., Proceedings of the Fourth Glacier Bay Science Symposium, October 26–28, 2004: U.S. Geological Survey Scientific Investigations Report 2007-5047.

Bartonek, J.C. and D.D. Gibson. 1972. Summer distribution of pelagic birds in Bristol Bay, Alaska. Condor 74: 416-422.

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[5] All references are provided in pdf format on the accompanying compact disk except for those denoted with an asterisk. We are happy to provide ADFG with copies of any references upon request.

Behrenfeld, M. J., R. T. O'Malley, D. A. Siegel, C. R. McClain, J. L. Sarmiento, G. C. Feldman, A. J. Milligan, P. G. Falkowski, R. M. Letelier, and E. S. Boss. 2006. Climate-driven trends in contemporary ocean productivity. Nature 444:752-755.

Bertram, D.F. 1995. The roles of introduced rats and commercial fishing in the decline of ancient murrelets on Langara Island, British Columbia. Conservation Biology 9(4):865-872.

*BirdLife International 2008. *Brachyramphus brevirostris*. 2008 IUCN Red List of Threatened Species. <www.iucnredlist.org>. Downloaded on 13 December 2008.

Blais, J.M. 2005. Biogeochemistry of persistent bioaccumulative toxicants: processes affecting the transport of contaminants to remote areas. Canadian Journal of Fisheries and Aquatic Sciences 62: 236-243.

Caldeira, K., and M. E. Wickett. 2003. Anthropogenic carbon and ocean pH. Nature 425:365.

Canadell, J. G., C. Le Quéré, M. R. Raupach, C. B. Field, E. T. Buitenhuis, P. Ciais, T. J. Conway, N. P. Gillett, J. T. Houghton, and G. Marland. 2007. Contributions to accelerating atmospheric CO_2 growth from economic activity, carbon intensity, and efficiency of natural sinks. Proceedings of the National Academy of Sciences of the United States of America 104:18866-18870.

Cao, L., and K. Caldeira. 2008. Atmospheric CO_2 stabilization and ocean acidification. Geophysical Research Letters 35, L19609, doi:10.1029/2008GL035072.

Carter, H.R., M.L. McAllister, M.E. “Pete” Isleib. 1995. Mortality of marbled murrelets in gill nets in North America. Pp. 271-283 *in* Ralph, C.J., G.H. Hunt, Jr., M.G. Raphael, J.F. Piatt, eds. Ecology and conservation of the marbled murrelet. Gen. Tech. Rep. PSW-GTR0152. Albany, CA: U.S. Dept. of Agriculture, Forest Service.

*Carter, H.R. and S.G. Sealy. 1984. Marbled murrelet *(Brachyramphus marmoratus*) mortality due to gillnet fishing in Barkley Sound, British Columbia. Pp. 212-220 *in* Nettleship, D.N., G.A. Sanger, and P.F. Springer, eds. Marine birds: their feeding ecology and commercial fisheries relationships. Spec. Publ. Ottawa, ON: Canadian Wildlife Service.

Chameides, W. L., and M. Bergin. 2002. Climate change - Soot takes center stage. Science 297:2214-2215.

Chernenko, T. 2007. Appendix 1. The Status of the Yellow-billed Loon in Russia: A Summary of Russian Language Information. *In* Yellow-billed Loon Comments submitted by Center for Biological Diversity, Pacific Environment, and Natural Resources Defense Council on August 6, 2007, to the U.S. Fish and Wildlife Service on the 90-day Finding and Status Review of the Yellow-billed Loon (72 Fed. Reg. 31256).

Christensen, J. H., B. Hewitson, B. A., A. Chen, X. Gao, I. Held, R. Jones, R. K. Kolli, W.-T. Kwon, R. Laprise, V. Magaña Rueda, L. Mearns, C. G. Menéndez, J. Räisänen, A. Rinke, A. Sarr, and P. Whetton. 2007. 2007: Regional Climate Projections. *in* S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, and G. H. Miller, editors. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

Day, R.H. 1995. New information on Kittlitz’s murrelet nests. Condor 97: 271-273.

Day, R.H. 1996. Nesting phenology of Kittlitz’s murrelet. Condor 98: 433-437.

Day, R.H. and D.A. Nigro. 1999. Status and ecology of Kittlitz’s murrelet in Prince William Sound, 1996-1998. Exxon Valdez Oil Spill Restoration Project Final Report 98142. ABR, Inc. Fairbanks, AK.

*Day, R.H. and D.A. Nigro. 2000. Feeding ecology of Kittlitz's and marbled murrelets in Prince William Sound, Alaska. Waterbirds 23(1)1-14.

Day, R.H. and D.A. Nigro. 2004. Is the Kittlitz's murrelet exhibiting reproductive problems in Prince William Sound, Alaska? Waterbirds 27(1): 89-95.

*Day, R.H., K.J. Kuletz, and D.A. Nigro. 1999. Kittlitz's murrelet *Brachyramphus brevirostris*. The Birds of North America, No. 435.

Day, R.H., Nigro, D.A. and Prichard, A.K. 2000. At-sea habitat use by the Kittlitz's murrelet *Brachyramphus brevirostris* in nearshore waters of Prince William Sound, Alaska. Marine Ornithology 28: 105–114.

Day, R., K.L. Oakley, and D.R. Barnard. 1983. Nest sites and eggs of Kittlitz's and Marbled Murrelets. Condor 85: 265-273.

Day, R.H., A.K Prichard, and D.A. Nigro. 2003. Ecological specialization and overlap of *Brachyramphus* Murrelets in Prince William Sound, Alaska. The Auk 120(3): 680-699.

DeGange, A.R. 1996. A conservation assessment for the marbled murrelet in Southeast Alaska. U.S. Forest Service General Technical Report PNW-GTR-388. Pacific Northwest Research Station.

*DeGange, A.R., R.H. Day, J.A. Takekawa, and V.M. Mendenhall. 1993. Losses of seabirds in gill nets in the North Pacific. Pp. 204-211 *in* Vermeer, K., K.T. Briggs, K.H. Morgan, and D. Siegel- Causey, eds. The status, ecology, and conservation of marine birds of the North Pacific. Spec. Publ. Ottawa, ON: Canadian Wildlife Service.

Denman, K. L., G. Brasseur, A. Chidthaisong, P. Ciais, P. M. Cox, R. E. Dickinson, D. Hauglustaine, C. Heinze, E. Holland, D. Jacob, U. Lohmann, S. Ramachandran, P. L. da Silva Dias, S. C. Wofsy, and X. Zhang. 2007. 2007: Couplings Between Changes in the Climate System and Biogeochemistry. *in* S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, and H. L. Miller, editors. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom, and New York, NY, USA.

Donald, D.B., J. Syrgiannis, R.W. Crosley, G. Holdsworth, D.C.G. Muir, B. Rosenberg, A. Sole, and D.W. Schindler. 1999. Delayed deposition of organochlorine pesticides at a temperate glacier. Environmental Science and Technology 33(11): 1794-1798.

Drew, G. S., and J. F. Piatt. 2008. Using geographic information systems to compare non-uniform marine bird surveys: detecting the decline of Kittlitz's murrelet (Brachyramphus brevirostris) in Glacier Bay, Alaska. Auk 125(1):178-182.

Dyurgerov, M. and G.J. McCabe. 2006. Associations between accelerated glacier mass wastage and increased summer temperature in coastal regions. Arctic, Antarctic, and Alpine Research 38(2): 190-197.

Dyurgerov, M.B. and M.F. Meir. 2000. Twentieth century climate change: evidence from small glaciers. Proceedings of the National Academy of Sciences 97(4): 1406-1411.

EIA. 2004. International Energy Outlook: 2004. Energy Information Administration, Washington, D.C. Available at www.eia.doe.gov/oiaf/ieo/index.html.

ESA. 2007. Satellites witness lowest Arctic ice coverage in history. European Space Agency. Available at http://www.esa.int/esaCP/SEMYTC13J6F_index_2.html, Published September 14, 2007.

Fabry, V. J., B. A. Seibel, R. A. Feely, and J. C. Orr. 2008. Impacts of ocean acidification on marine fauna and ecosystem processes. ICES Journal of Marine Sciences 65:414-432.

Feely, R. A., C. L. Sabine, K. Lee, W. Berelson, J. Kleypas, V. J. Fabry, and F. J. Millero. 2004. Impact of anthropogenic CO_2 on the $CaCO_3$ system in the oceans. Science 305:362-366.

Flanner, M. G., C. S. Zender, J. T. Randerson, and P. J. Rasch. 2007. Present-day climate forcing and response from black carbon in snow. Journal of Geophysical Research-Atmospheres 112, D11202, doi:10.1029/2006JD008003.

Forster, P., V. Ramaswamy, P. Artaxo, T. Berntsen, R. Betts, D. W. Fahey, J. Haywood, J. Lean, D. C. Lowe, G. Myhre, J. Nganga, R. Prinn, G. Raga, M. Schulz, and R. Van Dorland. 2007. 2007: Changes in Atmospheric Constituents in Radiative Forcing. *in* S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, and H. L. Miller, editors. Climate Change 2007: The Physical Science Basis: Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom, and New York, NY, USA.

Friesen, V.L., A.J. Baker, and J.F. Piatt. 1996a. Phylogenetic relationships within the Alcidae (Charadriiformes: Aves) inferred from total molecular evidence. Mol. Biol. Evol. 13: 359-367.

Friesen, V.L., J.F. Piatt, and A.J. Baker. 1996b. Evidence from Cytochrome b sequences and allozymes for a "new" species of alcid: the Long-billed Murrelet (*Brachyramphus perdix*). Condor 98: 681-690.

GAO. 2003a. Climate Change: Trends in Greenhouse Gas Emissions and Emissions Intensity in the United States and Other High-Emitting Nations United States General Accounting Office, Washington, D.C. 9 pp. Available at http://www.gao.gov/docsearch/repandtest.html.

GAO. 2003b. Preliminary Observations on the Administration's February 2002 Climate Initiative. GAO-04-131T, October 1, 2003. United States General Accounting Office, Washington, D.C. 9 pp. Available at http://www.gao.gov/docsearch/repandtest.html.

*Gilpen, M.E. and M.E. Soulé. 1986. Minimum viable populations: processes of species extinction, Pp. 19-34 *in* Conservation Biology: The Science of Scarcity and Diversity (M.R. Soulé, ed.) Sinauer, Sunderland, MA.

Grebmeier, J. M., J. E. Overland, S. E. Moore, E. V. Farley, E. C. Carmack, L. W. Cooper, K. E. Frey, J. H. Helle, F. McLaughlin, and S. L. McNutt. 2006. A major ecosystem shift in the Northern Bering Sea. Science 311:1461-1464.

Hansen, J., M. Sato, P. Kharecha, D. Beerling, R. Berner, V. Masson-Delmotte, M. Pagani, M. Raymo, D. Royer, and J.C. Zachos. 2008. Target atmospheric CO_2: Where should humanity aim? The Open Atmospheric Science Journal 2: 217-231.

Hansen, J., M. Sato, R. Ruedy, P. Kharecha, A. Lacis, R. Miller, L. Nazarenko, K. Lo, G. A. Schmidt, G. Russell, I. Aleinov, S. Bauer, E. Baum, B. Cairns, V. Canuto, M. Chandler, Y. Cheng, A. Cohen, A. Del Genio, G. Faluvegi, E. Fleming, A. Friend, T. Hall, C. Jackman, J. Jonas, M. Kelley, N. Y. Kiang, D. Koch, G. Labow, J. Lerner, S. Menon, T. Novakov, V. Oinas, J. Perlwitz, J. Perlwitz, D. Rind, A. Romanou, R. Schmunk, D. Shindell, P. Stone, S. Sun, D. Streets, N. Tausnev, D. Thresher, N. Unger, M. Yao, and S. Zhang. 2007. Dangerous human-made interference with climate: a GISS modelE study. Atmospheric Chemistry and Physics 7:2287-2312.

Hansen, J., M. Sato, R. Ruedy, K. Lo, D. W. Lea, and M. Medina-Elizade. 2006. Global temperature change. Proceedings of the National Academy of Sciences of the United States of America 103:14288-14293.

Harley, C. D. G., A. R. Hughes, K. M. Hultgren, B. G. Miner, C. J. B. Sorte, C. S. Thornber, L. F. Rodriguez, L. Tomanek, and S. L. Williams. 2006. The impacts of climate change in coastal marine systems. Ecology Letters 9:228-241.

Hester, K. C., E. T. Peltzer, W. J. Kirkwood, and P. G. Brewer. 2008. Unanticipated consequences of ocean acidification: a noisier ocean at lower pH. Geophysical Research Letters 35, L19601, doi:10.1029/2008GL034913.

Hines, S. 2007. Without its insulating ice cap, Arctic surface waters warm to as much as 5 degrees C above average. University of Washington, Press Release dated December 12, 2007. Available at http://www.eurekalert.org/pub_releases/2007-12/uowwii121207.php#.

Huettmann. F. 2008. Marine conservation and sustainability of the Sea of Okhotsk in the Russian Far East: an overview of cumulative impacts, compiled public data, and a proposal for a UNESCO world heritage site. Ocean Yearbook 22: 353-374.

Huettmann, F. and Y.N. Gerasimov. 2006. Conservation of migratory shorebirds and their habitats in the Sea of Okhotsk, Russian Far East, in the year 2006: state-of-the-art and an outlook. Stilt 50: 23-33.

International Climate Change Taskforce. 2005. Meeting the Climate Challenge: Recommendations of the International Climate Change Task Force. The Institute for Public Policy Research, London, UK. ix + 26 pp. Available at http://www.americanprogress.org/kf/climatechallenge.pdf.

IPCC. 2001. Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, NY, USA.

IPCC. 2007. 2007: Summary for Policymakers. *in* S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, and H. L. Miller, editors. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom, and New York, NY, USA.

Isleib, M.E. and B. Kessel. 1973. Birds of the North-Gulf Coast - Prince William Sound Region, Alaska. Biological Papers of the University of Alaska 14: 1-149.

Kaler, R.S.A., L.A. Kenney, and J.F. Piatt. 2008. Breeding biology of Kittlitz’s murrelet at Agattu Island, Alaska, in 2008: progress report. U.S. Fish and Wildl. Serv. Rep. AMNWR 08/17.

Kendall, S.J. and B.A. Agler. 1998. Distribution and abundance of Kittlitz’s murrelets in Southcentral and Southeastern Alaska. Colonia Waterbirds 21(1): 53-60.

Kessell, B., and D.D. Gibson. 1978. Status and distribution of Alaska birds. Stud. Avian Biol. no.1. Cooper Ornithological Society.

*King, J.G. and G.A. Sanger. 1979. Oil vulnerability index for marine oriented birds. USFWS, Wildlife Research Report 11: 277-289.

Kissling, M. L, K. J. Kuletz, S. P. Brockmann, and N. R. Hatch. 2007a. Distribution and abundance of *Brachyramphus* murrelets and other marine species from Icy Bay to LeConte Bay, southeast Alaska, 2002-2004. U.S. Fish and Wildlife Service, Juneau Field Office, Alaska.

Kissling, M.L., M. Reid, P.M. Lukacs, S.M. Gende, and S.B. Lewis. 2007b. Understanding abundance patterns of a declining seabird: implications for monitoring. Ecological Applications 17(8): 2164-2174.

Kissling, M.L., S.M. Gender, M. Reid, S.B. Lewis, P.M. Lukacs, and N.R. Hatch. 2008. Discovering nests of a rare non-colonial seabird, the Kittlitz's murrelet. Abstract. Thirty-fifth Annual Meeting of the Pacific Seabird Group. Blaine, Washington. 27 February-1 March 2008.

Kondratyev, A.Y., N.M. Litvinenko, Y.V. Shibaev, P.S. Vyatkin, and L.F. Kondrateyva. 2000. The breeding seabirds of the Russian Far East. Pages 37-81 in Kondratyev, A. Y., N. M. Litvinenko, and G. W. Kaiser, eds. Seabirds of the Russian Far East, Canadian Wildlife Service, Ottawa.

Konyukhov, N. N., L.S. Bogoslovskaya, B.M. Zvonon, and T.I. van Pelt. 1998. Seabirds of the Chukotka Peninsula, Russia. Arctic 51: 4.

*Kuletz, K. 1996. Marbled murrelet abundance and breeding activity at Naked Island, Prince Willilam Sound, and Kachemak Bay, Alaska, before and after the Exxon Valdez oil spill. American Fisheries Society Symposium 18: 770-784.

Kuletz, KJ, Manly B, Nations C, Irons D. 2005. Declines in Kittlitz's and marbled murrelets in Prince William Sound, Alaska: Dealing with uncertainty. Pp. 173-195 *in* Foraging Behavior and Productivity of a Non-Colonial Seabird, the marbled murrelet (*Brachyramphus marmoratus*), Relative to Prey and Habitat. K. Kuletz. Ph.D. Dissertation, University of Victoria, Victoria, British Columbia.

Kuletz, K.J., S.W. Stephensen, D.B. Irons, E.A. Labunski, and K.M. Brenneman. 2003. Changes in distribution and abundance of Kittlitz's murrelets *Brachyramphus brevirostris* relative to glacial recession in Prince William Sound, Alaska. *Marine Ornithology* 31:133-140.

Kuletz, K.J., E.A. Labunski, and S.G. Speckman. 2008. Abundance, distribution, and decadal trends of Kittlitz's and marbled murrelets and other marine species in Kachemak Bay, Alaska. Final Report (Project No. 14) by U.S. Fish and Wildlife Service for Alaska Department of Fish and Game, State Nongame Wildlife Grant, Anchorage, Alaska.

*Lance, B.K. D.B. Irons, S.J. Kendall, and L.L. McDonald. 1999. Marine bird and sea otter population abundance of Prince William Sound, Alaska: trends following the T/V Exxon Valdez oil spill, 1989-98. Exxon Valdez Oil Spill Restoration Final Report, Restoration Project 93045. Exxon Valdez Oil Spill Trustee Council, Anchorage, AK.

Lapko, V.V. and V.I. Radchenko. 2000. Sea of Okhotsk. Marine Pollution Bulletin 41 (1-6): 179-187.

Larsen, C. F., R. J. Motyka, A. A., Arendt, K. A., Echelmeyer, and P. E. Geissler. 2007. Glacier changes in southeast Alaska and northwest British Columbia and contribution to sea level rise. Journal of Geophysical Research, Vol. 112, F01007, doi:10.1029/2006JF000586.

Lemke, P., J. Ren, R. B. Alley, I. Allison, J. Carrasco, G. Flato, Y. Fujii, G. Kaser, P. W. Mote, R. H. Thomas, and T. Zhang. 2007. 2007: Observations: Changes in Snow, Ice, and Frozen Ground. *in* S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, and H. L. Miller, editors. Climate Change 2007: The Physical Science Basis: Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, NY, USA.

Le Treut, H., R. Somerville, U. Cubasch, Y. Ding, C. Mauritzen, A. Mokssit, T. Peterson, and M. Prather. 2007. 2007: Historical Overview of Climate Change. S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, and H. L. Miller, editors. Climate Change 2007: The Physical Science Basis: Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, NY, USA.

Levitus, S., J. Antonov, and T. Boyer. 2005. Warming of the world ocean, 1955-2003. Geophysical Research Letters 32, L02604, doi:10.1029/2004GL021592.

Levitus, S., J. I. Antonov, T. P. Boyer, and C. Stephens. 2000. Warming of the world ocean. Science 287:2225-2229.

Litzow, M.A. 2006. Climate regime shifts and community reorganization in the Gulf of Alaska: how do recent shifts compare with 1976/1977? ICES Journal of Marine Science 63: 1386-1396.

*Lovejoy, T. E., and L. Hannah. 2005. Climate Change and Biodiversity. Yale University Press, New Haven, CT.

Manly, B.F.J. 2006. Incidental catch and interactions of marine mammals and birds in the Cook Inlet salmon driftnet and setnet fisheries, 1999-2000. Cook Inlet Observer Program, 1999-2000.

Manly, B.F.J. 2007. Incidental take and interactions of marine mammals and birds in the Kodiak Island salmon set gillnet fishery, 2002 and 2005. Kodiak Island AMMOP 2002 & 2005.

Meehl, G. A., T. F. Stocker, W. D. Collins, P. Friedlingstein, A. T. Gaye, J. M. Gregory, A. Kitoh, R. Knutti, J. M. Murphy, A. Noda, S. C. B. Raper, I. G. Watterson, A. J. Weaver, and Z.-C. Zhao. 2007. 2007: Global Climate Projections. *in* S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, and G. H. Miller, editors. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge University Press, Cambridge, UK, and New York, NY, USA.

MMS [Minerals Management Service]. 2007. Proposed Final Program. Outer Continental Shelf Oil and Gas Leasing Program 2007-2012. U.S. Department of the Interior.

Molnia, B. F. 2007. Late nineteenth to early twenty-first century behavior of Alaskan glaciers as indicators of changing regional climate. Global and Planetary Change 56: 23–56.

Muskett, R. R., C.S. Lingle, J.M. Sauber, B.T. Rabus, W.V. Tangborn. 2008. Acceleration of surface lowering on the tidewater glaciers of Icy Bay, Alaska, USA from InSAR DEMs and ICESat altimetry. Earth and Planetary Science Letters 265: 345-359.

Nakićenović, N., J. Alcamo, G. Davis, B. de Vries, J. Fenham, D. Gaffin, K. Gregory, A. Grübler, T. Y. Jung, T. Kram, E. L. La Rovere, L. Michaelis, S. Mori, T. Morita, W. Pepper, H. Pitcher, L. Price, K. Raihi, A. Roehrl, H.-H. Rogner, A. Sankovski, M. Schlesigner, P. Shukla, S. Smith, R. Swart, S. van Rooijen, N. Victor, and Z. Dadi. 2000. IPCC Special Report on Emissions Scenarios. Cambridge University Press, Cambridge, UK and New York, NY, USA. 599 pp. Available at http://www.ipcc.ch/.

National Audubon Society. 2006. America's Top 10 Most Endangered Birds. Available at http://www.audubon.org/news/top10/Top10_Endangered_Species.pdf.

*NMFS [National Marine Fisheries Service]. 1999. Biological Opinion for Proposed Construction and Operation of the Northstar Oil and Gas Project. March 4, 1999.

NPS [Glacier Bay National Park and Preserve]. 2006. Cruise Ship Use-Day Quota for the 2007 Operating Seasons, Final Decision. Available at http://parkplanning.nps.gov/document.cfm?parkID=12&projectId=14389&documentID=13677.

Orr, J. C., V. J. Fabry, O. Aumont, L. Bopp, S. C. Doney, R. A. Feely, A. Gnanadesikan, N. Gruber, A. Ishida, F. Joos, R. M. Key, K. Lindsay, E. Maier-Reimer, R. Matear, P. Monfray, A. Mouchet, R. G. Najjar, G. K. Plattner, K. B. Rodgers, C. L. Sabine, J. L. Sarmiento, R. Schlitzer, R. D. Slater, I. J. Totterdell, M. F. Weirig, Y. Yamanaka, and A. Yool. 2005. Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms. Nature 437:681-686.

Overland, J.E. and P.J. Stabeno. 2004. Is the climate of the Bering Sea warming and affecting the ecosystem? Eos 85 (33): 309-312.

Pacheco, N. M., B. C. Congdon and V. L. Friesen. 2002. The utility of nuclear introns for investigating hybridization and genetic introgression: a case study involving *Brachyramphus* murrelets. Conservation Genetics 3: 175-182.

Parmesan, C. 2006. Ecological and evolutionary responses to recent climate change. Annual Review of Ecology Evolution and Systematics 37:637-669.

Parson, E.A. 2001. Potential consequences of climate variability and change for Alaska. In Climate Change Impacts on the United States: the Potential Consequences of Climate Variability and Change. Report for the US Global Change Research Program, Cambridge University Press, Cambridge, UK.

Piatt, J.F., and P.J. Gould. 1994. Postbreeding dispersal and drift-net mortality of endangered Japanese murrelets. The Auk 111(4): 953-961.

Piatt J.F,, and N.L. Naslund. 1995. Abundance, distribution, and population status of Marbled Murrelets in Alaska. Pp. 285-294 *in* Ralph CJ, Hunt GL Jr, Raphael MC, Piatt FJ, editors. Ecology and conservation of the marbled murrelet. US For. Serv. Gen. Tech. Rep. PSW-GTR-152, Albany, CA.

*Piatt, J.F., K.J. Kuletz, A.E. Burger, S.A. Hatch, V.L. Friesen, T.P. Birt, M.L. Arimitsu, G.S. Drew, A.M.A. Harding, and K.S. Bixler. 2007. Status review of the Marbled Murrelet (*Brachyramphus marmoratus*) in Alaska and British Columbia. U.S. Geological Survey Open-File Report 2006-1387. 258 pp.

Piatt, J.F., C.J. Lensink, W. Butler, M. Kendziorek, and D.R. Nysewander. 1990. Immediate impact of the Exxon Valdez oil spill on marine birds. Auk 107: 387-397.

Piatt, J.F., N.L. Naslund, and T.I. van Pelt. 1999. Discovery of a new Kittlitz's murrelet nest: clues to habitat selection and nest-site fidelity. Northwest Nat. 80: 8-13.

Pitocchelli, J., J.F. Piatt, and M. Cronin. 1995. Morphological and genetic divergence among Alaskan populations of Brachyramphus murrelets. Wilson Bulletin 107: 235-250.

*Prince William Sound Regional Citizens' Advisory Council. 2008. Available at: http://www.pwsrcac.org/projects/MaritimeOps/escort.html.

Quinn, P. K., G. Shaw, E. Andrews, E. G. Dutton, T. Ruoho-Airola, and S. L. Gong. 2007. Arctic haze: current trends and knowledge gaps. Tellus Series B-Chemical and Physical Meteorology 59:99-114.

Ramanathan, V., and Y. Feng. 2008. On avoiding dangerous anthropogenic interference with the climate system: formidable challenges ahead. Proceedings of the National Academy of Sciences of the United States of America 105:14245-14250.

Raupach, M. R., G. Marland, P. Ciais, C. Le Quéré, J. G. Canadell, G. Klepper, and C. B. Field. 2007. Global and regional drivers of accelerating CO_2 emissions. Proceedings of the National Academy of Sciences of the United States of America 104:10288-10293.

Reddy, M. S., and O. Boucher. 2007. Climate impact of black carbon emitted from energy consumption in the world's regions. Geophysical Research Letters 34, L11802, doi: 10.1029/2006GL028904.

*Richardson, W. John. and Charles I. Malme. "Man-Made Noise and Behavioral Responses." *In* The Bowhead Whale. Eds. J.J. Burns, J.J. Montague, C.J. Cowles. The Society for Marine Mammology. Special Publication Number 2. Lawrence: Allen Press, Inc., 1993. Pp. 631-700.

Robards M, Drew G, Piatt J, Anson JM, Abookire A, Bodkin J, Hooge P, Speckman S. 2003. Ecology of selected marine communities in Glacier Bay: zooplankton, forage fish, seabirds and marine mammals. Final report to the National Park Service, USGS ASC, Anchorage, Alaska 156p.

Royal Society. 2005. Ocean acidification due to increasing atmospheric carbon dioxide. Policy document 12/05. Available at www.royalsoc.ac.uk. The Royal Society, London, UK.

*Royer, T.C. and T.J. Weingartner. 2008. GAK1 Time Series website. Available at http://www.ims.uaf.edu/gak1/. Accessed December 2008.

Schneeberger, C., H. Blatter, A. Abe-Ouchi, and M. Wild. 2003. Modelling changes in the mass balance of glaciers of the northern hemisphere for a transient 2 x CO_2 scenario. Journal of Hydrology 282: 145-163.

*Singer, M.. 1998. The Whittier Road case: the demise of Section 4(f) since Overton Park and its implications for alternatives analysis in environmental law. 28 Environmental Law 729.

Solomon, S., D. Qin, M. Manning, R. B. Alley, T. Bentsen, N. L. Bindoff, Z. Chen, A. Chidthaisong, J. M. Gregory, G. C. Hegerl, M. Heimann, B. Hewitson, B. J. Hoskins, F. Joos, J. Jouzel, V. Kattsov, U. Lohmann, T. Matsuno, M. Molina, N. Nicholls, J. Overpeck, G. Raga, V. Ramaswamy, J. Ren, M. Rusticucci, R. Somerville, T. F. Stocker, P. Whetton, R. A. Wood, and D. Wratt. 2007. 2007: Technical Summary. *in* S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, and H. L. Miller, editors. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom, and New York, NY, USA.

Steele, M., W. Ermold, and J. Zhang. 2008. Arctic Ocean surface warming trends over the past 100 years. Geophysical Research Letters 35, L02614, doi:10.1029/2007GL031651.

Stenhouse, I.J., Studebaker, S. & Zwiefelhoefer, D. 2008. Kittlitz's murrelet *Brachyramphus brevirostris* in the Kodiak Archipelago, Alaska. Marine Ornithology 36: 59–66.

Stroeve, J., M. Serreze, S. Drobot, S. Gearheard, M. M. Holland, J. Maslanik, W. Meier, and T. Scambos. 2008. Arctic sea ice extent plummets in 2007. EOS Transactions, AGU 89:13-14.

Thomas, C. D., A. Cameron,., R. E. Green, M. Bakkenes, L. J. Beaumont, Y. C. Collingham, B. F. N. Erasmus, M. Ferreira de Siqueira, A. Grainger, L. Hannah, L. Hughes, B. Huntley, A. S. van Jaarsveld, G. F. Midgley, L. Miles, M. A. Ortega-Huerta, A. T. Peterson, O. L. Phillips, and S. E. Williams. 2004. Extinction risk from climate change. Nature 427:145-148.

Trenberth, K. E., P. D. Jones, P. Ambenje, R. Bogariu, D. Easterling, A. Klein Tank, D. Parker, F. Rahimzadeh, J. A. Renwick, M. Rusticucci, B. Soden, and P. Zhai. 2007. 2007: Observations: Surface and Atmospheric Climate Change. *in* S. Solomon, D. Qin, M.

Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, and H. L. Miller, editors. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom, and New York, NY, USA.

UNFCCC. 2004. United Nations Framework Convention on Climate Change the First Ten Years. United Nations Framework Convention on Climate Change, Bonn, Germany. 96 pp. Available at http://unfccc.int/2860.php.

UNFCCC. 2005. Kyoto Protocol: Status of Ratification. Web site at http://unfccc.int/files/ essential_background/kyoto_protocol/application/pdf/kpstats.pdf

USFWS. 2007. Candidate and Listing Priority Assessment Form for Kittlitz's murrelet. U.S. Fish and Wildlife Service, Anchorage, Alaska. 30pp. Available at: http://ecos.fws.gov/docs/candforms_pdf/r7/B0AP_V01.pdf.

*USGS. 2001. Seabirds, marine mammals and forage fish in Glacier Bay National Park. USGS Web site: http://www.absc.usgs.gov/research/seabirdandforagefish/products/presentations/GBay99 web_files/frame.htm.

U.S. Maritime Administration. 2007a. U.S. Port Calls by Vessel Type. Available at Maritime Administration Web site: http://www.marad.dot.gov/library_landing_page/data_and_statistics/Data_and_Statistics.htm.

U.S. Maritime Administration. 2007b. U.S.-Flag OPA-90 Phase-Out Year-End 2007 . U.S. Available at Maritime Administration Web site: http://www.marad.dot.gov/library_landing_page/data_and_statistics/Data_and_Statistics.htm.

van Pelt T.I., Piatt J.F. 2003. Population status of Kittlitz's and marbled murrelets and surveys for other marine bird and mammal species in the Kenai Fjords area, Alaska. Unpublished Report, Alaska Science Center, USGS, Anchorage, Alaska.

van Pelt, T.I., J.F. Piatt, and G.B. van Vliet. 1999. Vocalizations of the Kittlitz's murrelet (*Brachyramphus brevirostris*). Condor 101: 395-398.

VanLooy, J., R. Forster, and A. Ford. 2006. Accelerating thinning of Kenai Peninsula glaciers, Alaska. Geophysical Research Letters 33, L21307, doi:10.1029/2006GL028060.

van Vliet, G.B. 1993. Status concerns for the "global" population of Kittlitz's murrelet: is the "Glacier Murrelet" receding? Pacific Seabird Group 30: 15-16.

van Vliet, G.B. and M. McAllister. 1994. Kittlitz's murrelet: the species most impacted by direct mortality from the Exxon Valdez oil spill? Pacific Seabirds 21: 5-6.

WBGU. 2006. The Future of Oceans -- Warming Up, Rising High, Turning Sour. German Advisory Council on Global Climate Change, Special Report, March 2006, Available at www.wbgu.de.

Webster. J.D. 1950. Notes on the birds of Wrangell and vicinity, southeastern Alaska. Condor 52: 32-38.

Williams, D. 2002. Climate Change Information Kit. United Nations Framework Convention on Climate Change, Bonn, Germany. Available at http://unfccc.int/resource/docs/publications/infokit_2002_en.pdf.

Woodby, D., D. Carlile, S. Siddeek, F. Funk, J. H. Clark, and L. Hulbert. 2005. Commercial Fisheries of Alaska, Special Publication No. 05-09. Alaska Department of Fish and Game, Divisions of Sport Fish and Commercial Fisheries, Anchorage, AK.

Wynne, K.M., D.L. Hicks, and N.R. Munro. 1992. 1991 Marine Mammal Observer Program for the salmon driftnet fishery of Prince William Sound, Alaska. Unpubl. Report prepared for NOAA/NMFS, Alaska Region Office of Marine Mammals, Juneau, by Saltwater, Inc., Anchorage.