Appendix I
Network Maps

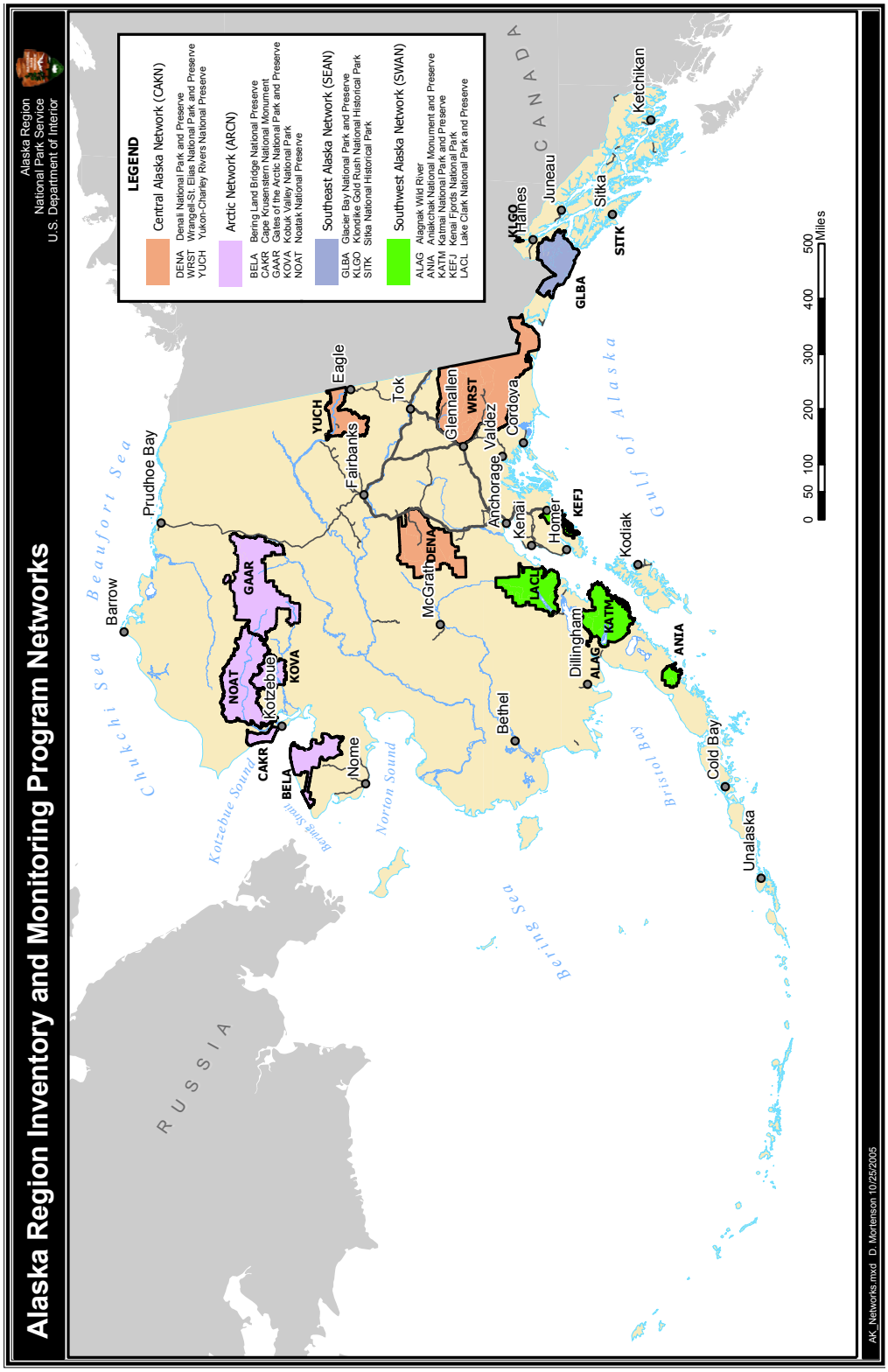

Figure I-1 *I&M networks within the Alaska Region of NPS.*

Figure I-2 *Physiography of SWAN parks and nearby areas.*

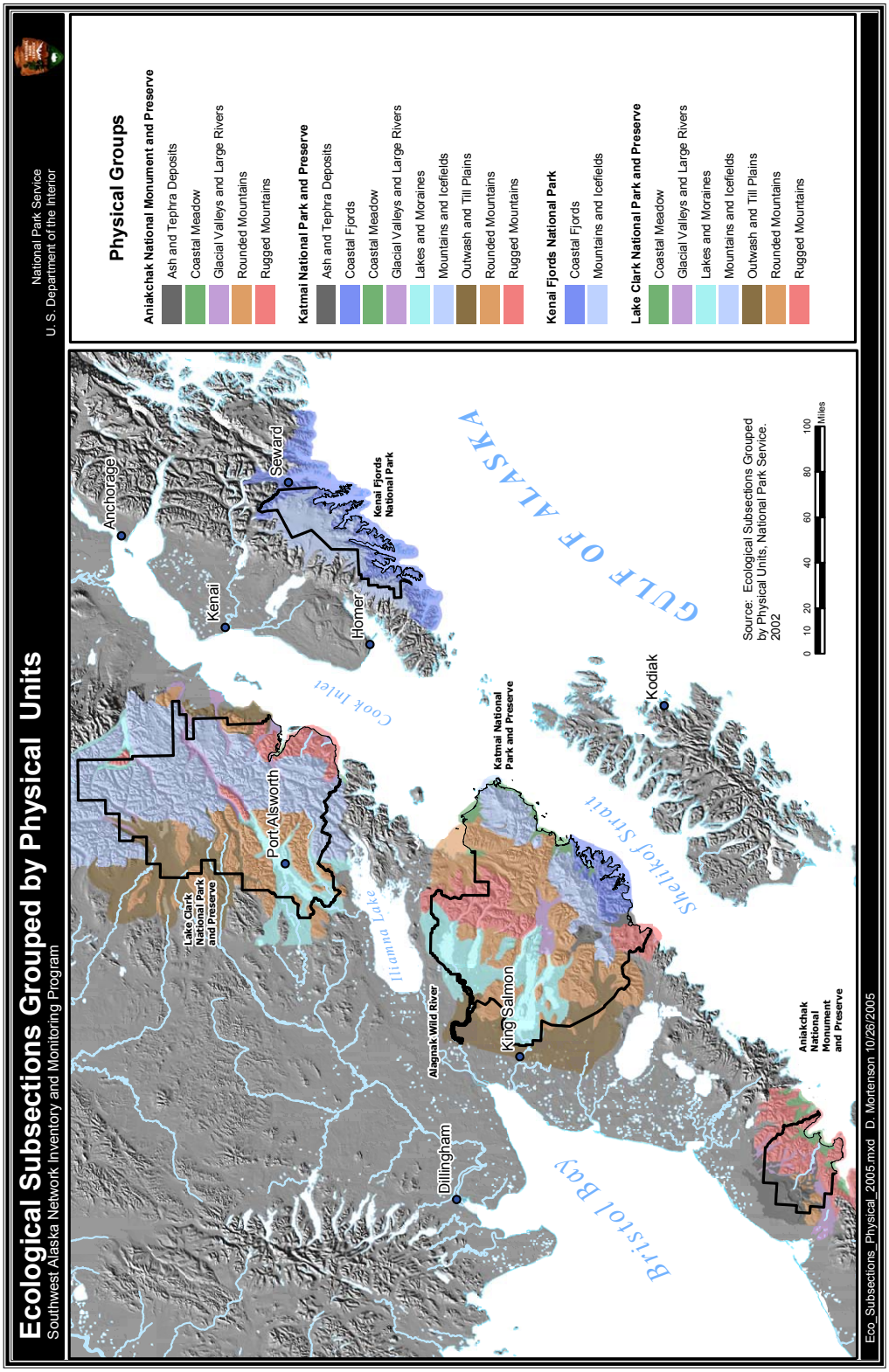

Figure I-3 *Ecological subsections grouped by physical units in SWAN parks.*

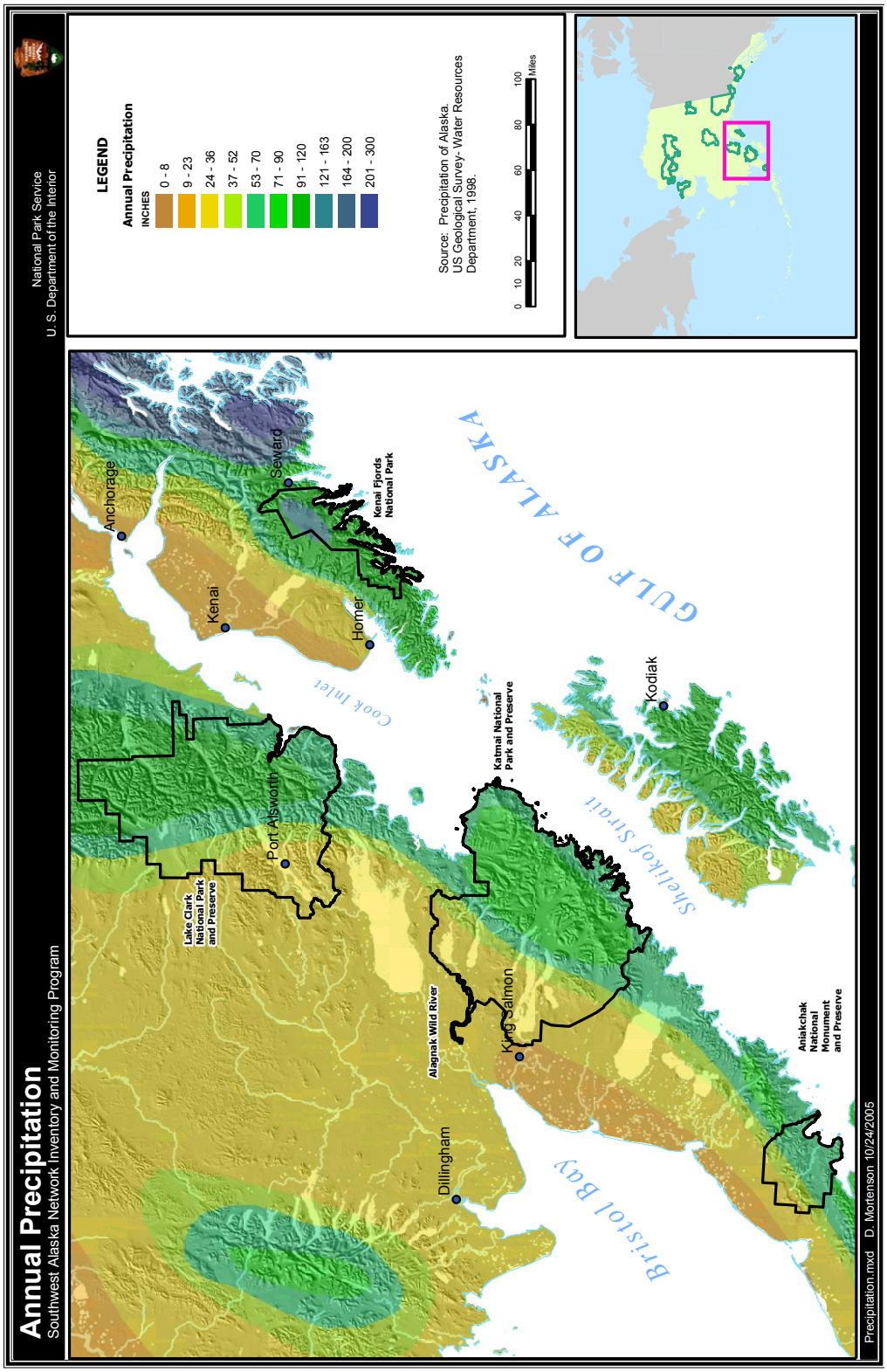

Figure I-4 *Annual precipitation in SWAN parks and nearby areas.*

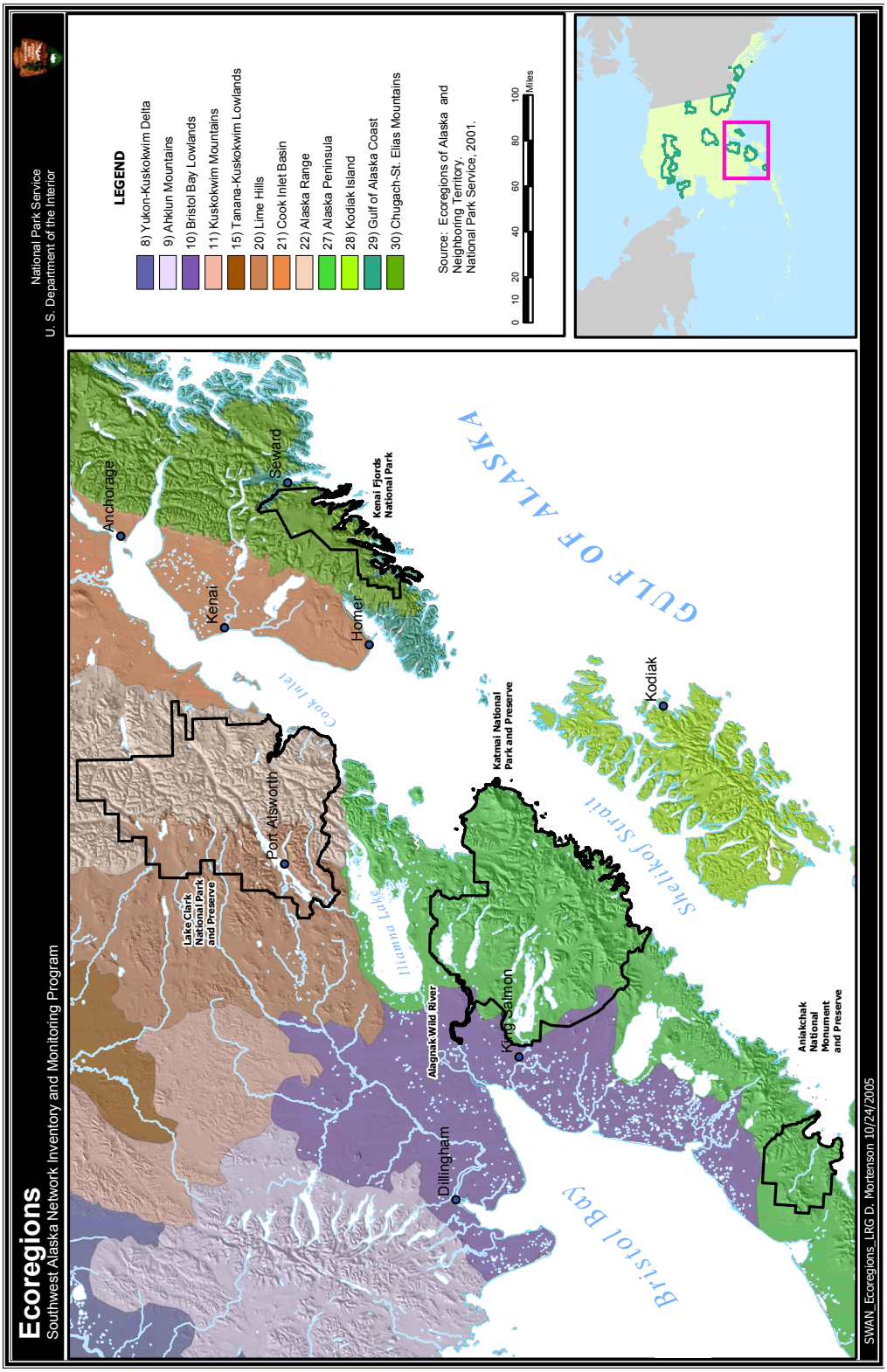

Figure I-5 *Ecoregions of SWAN parks and nearby areas.*

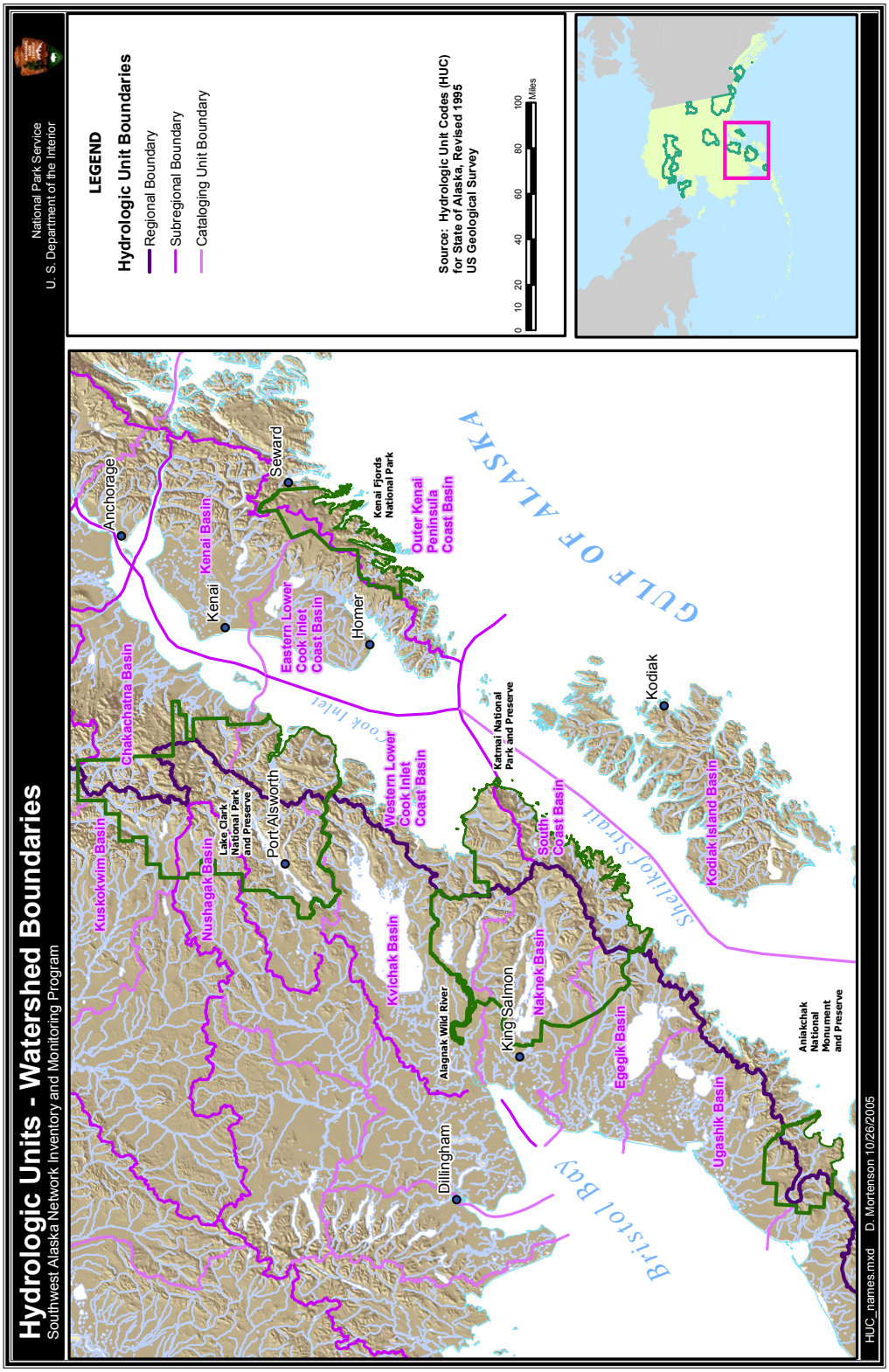

Figure I-6 *Hydrologic unit and watershed boundaries in SWAN parks and in southwest Alaska.*

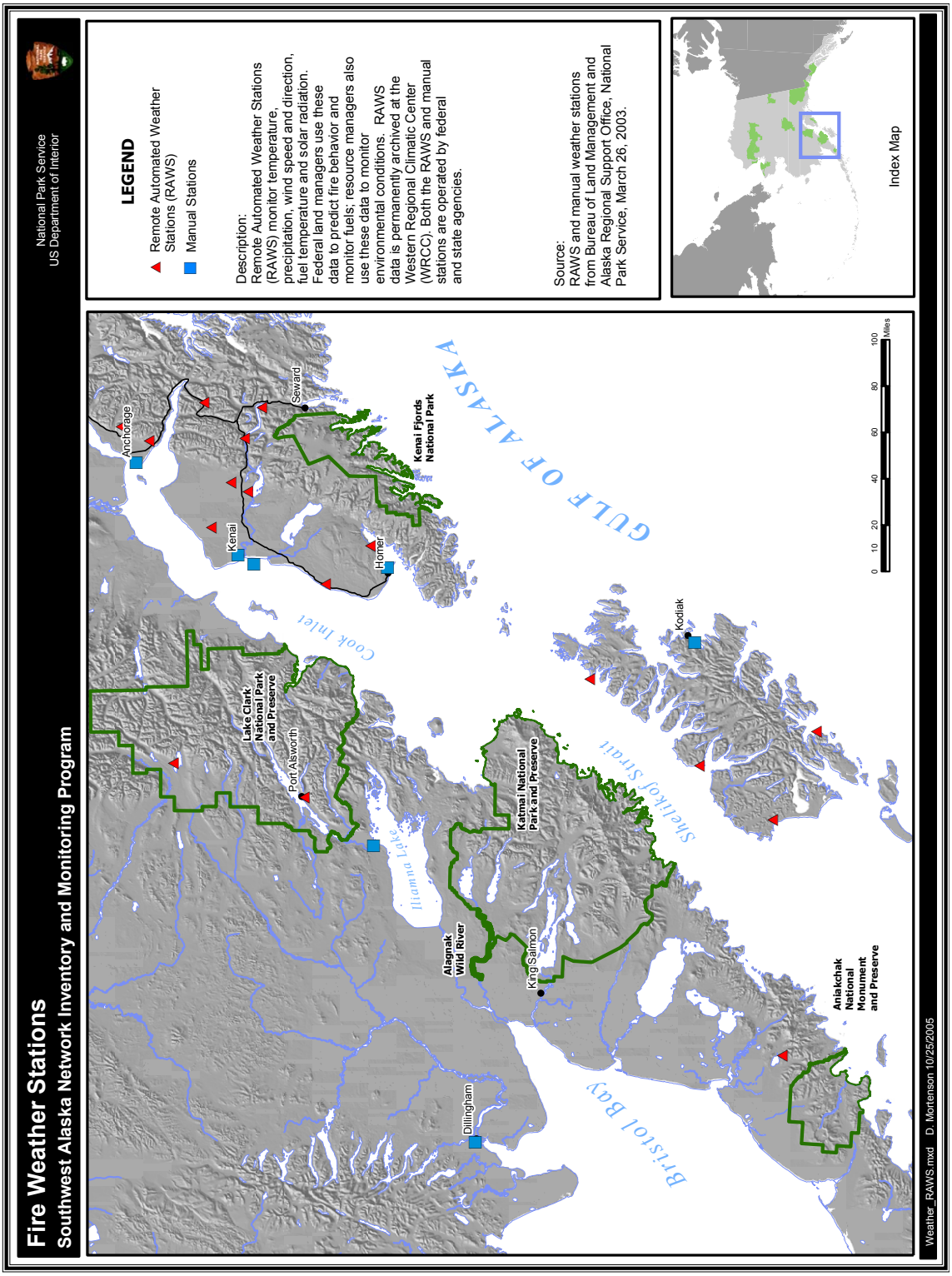

Figure I-7 *Current deployment of remote automated weather stations (RAWS) in southwest Alaska.*

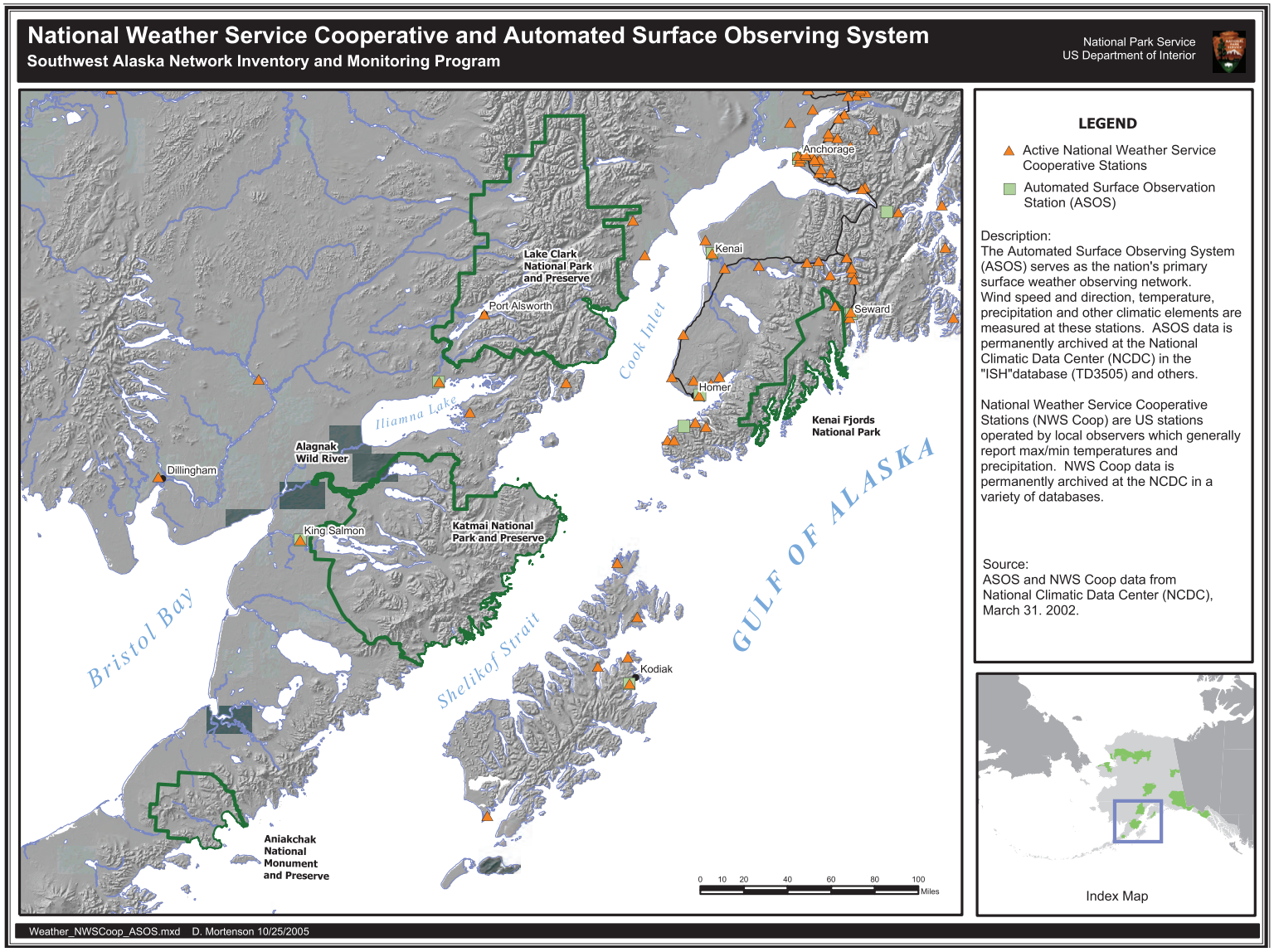

Figure I-8 *Active National Weather Service and automated surface observation stations (ASOS) in southwest Alaska.*

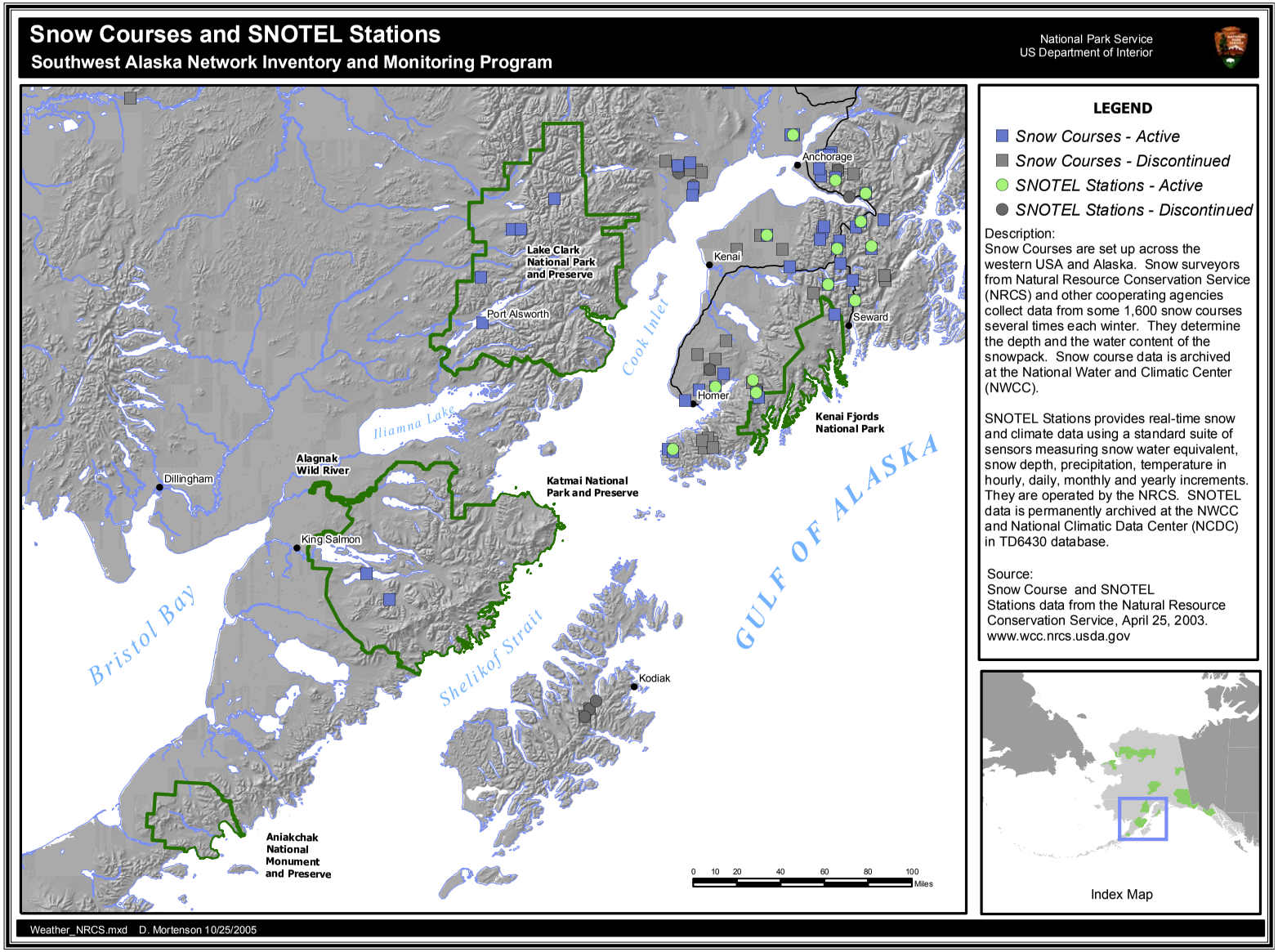

Figure I-9 *Snow courses and snowpack telemetry (SNOTEL) stations in southwest Alaska.*

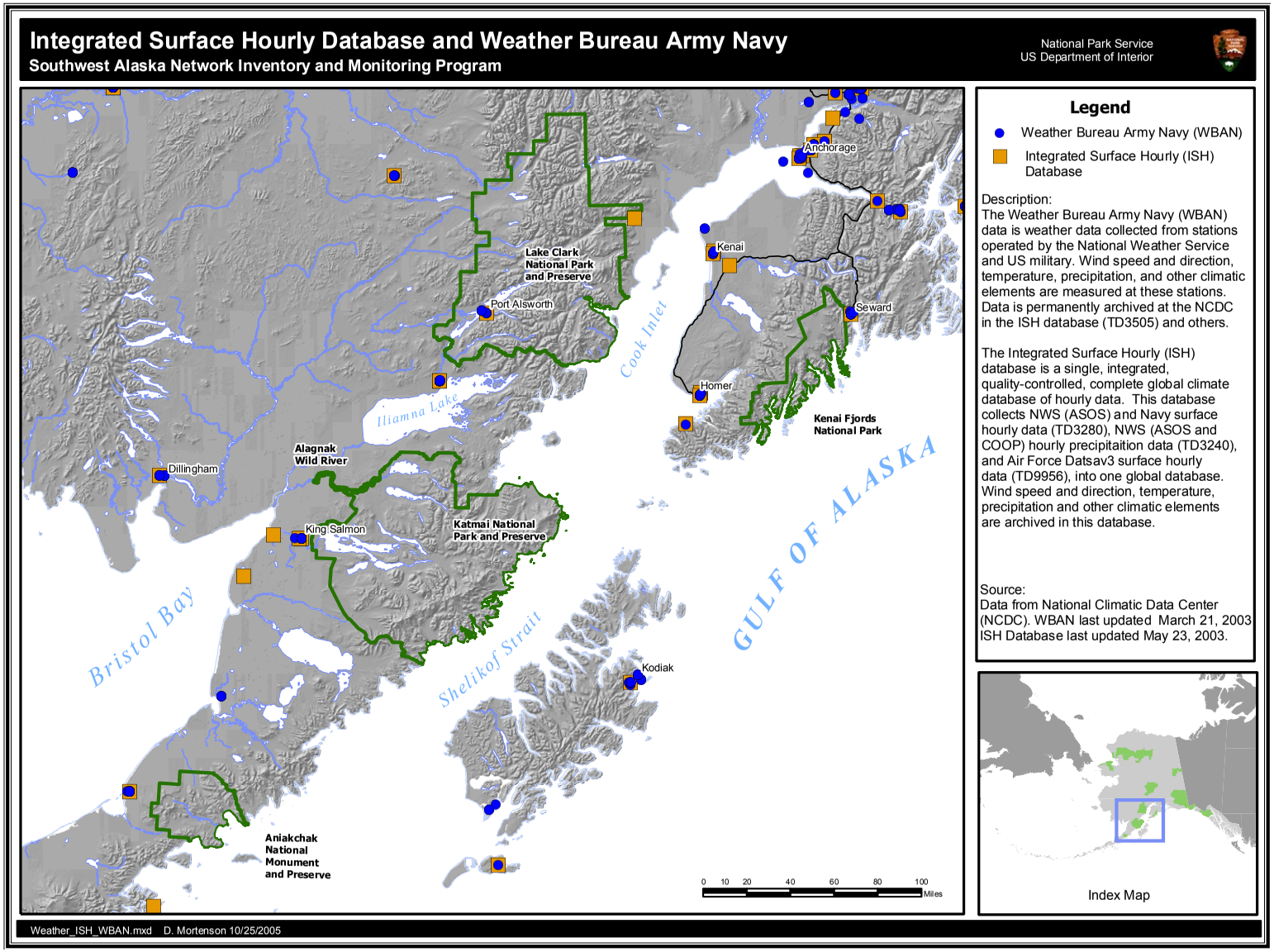

Figure I-10 *Weather Bureau Army Navy (WBAN) stations and integrated surface hourly (ISH) database locations in southwest Alaska.*

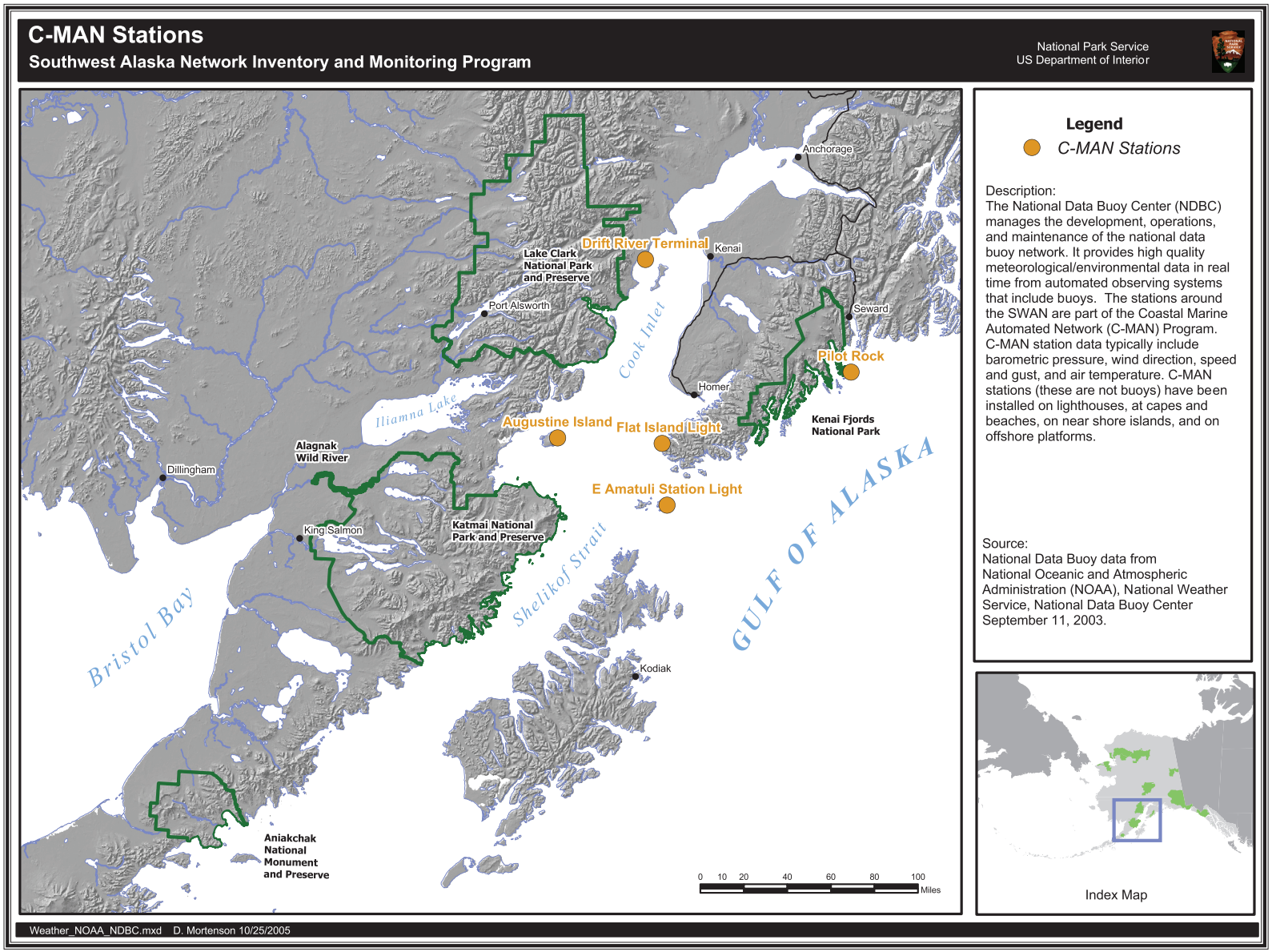

Figure I-11 *Coastal-marine automated network (C-MAN) stations in southwest Alaska.*

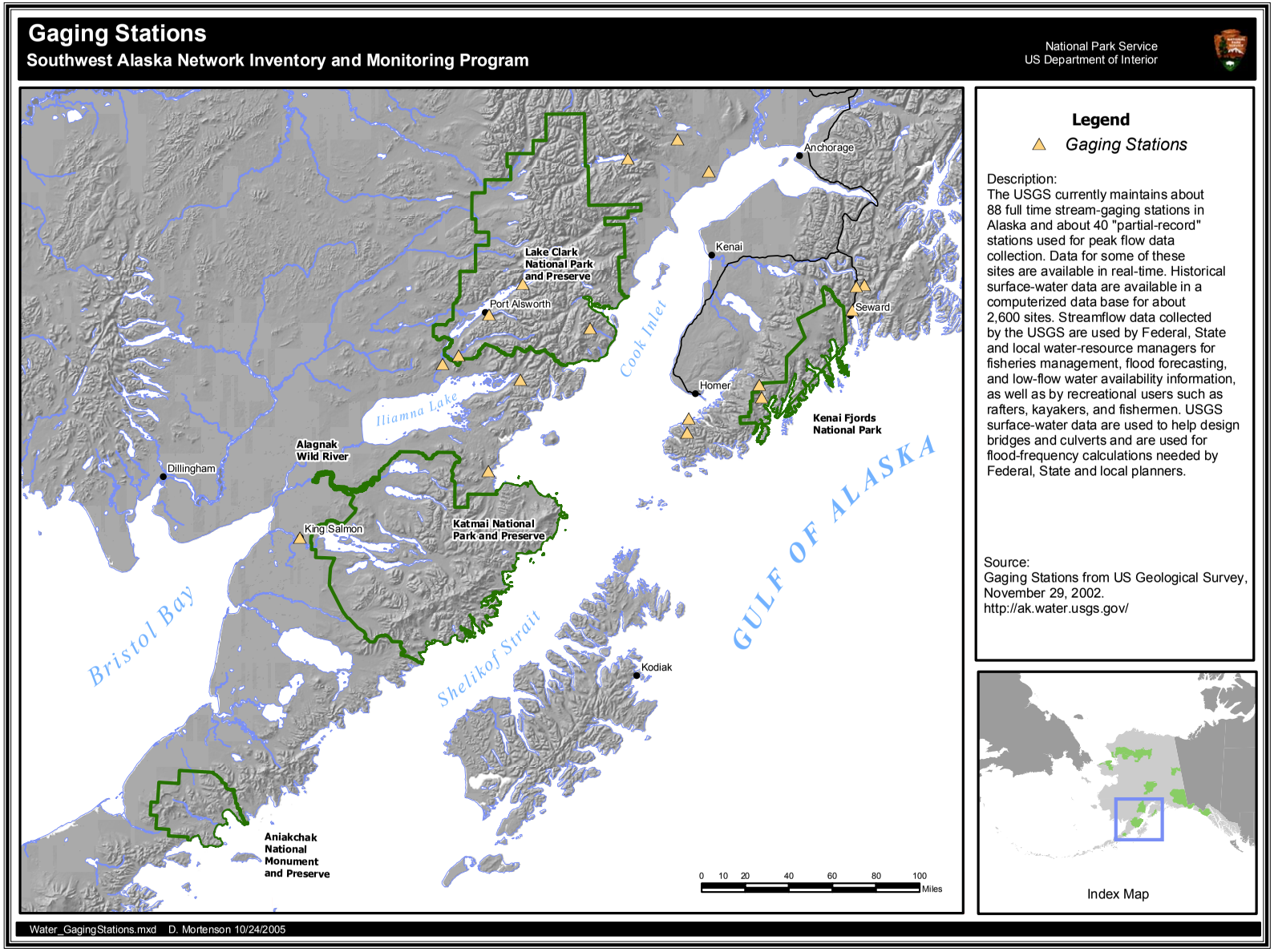

Figure I-12 *U.S. Geological Survey stream-gaging stations in southwest Alaska.*

Appendix II

Network Park Ecological Profiles

Ecological Profile: Aniakchak National Monument and Preserve

Physical Environment

Climate

Aniakchak National Monument and Preserve's (ANIA) climate is cool, windy, and wet. The Pacific Coast has a maritime climate characterized by high precipitation and moderate temperatures, while the Bristol Bay side has a more continental climate with lower precipitation, foggy summer days, and wider temperature ranges.

Weather inside the caldera is affected by shifting air currents that carry weather from the two climate zones, as well as by its own topography. Low cloud ceilings, rain, and high winds are common, even when the weather is relatively calm outside the caldera.

Geology

ANIA is located 400 mi (644 km) southwest of King Salmon on the Alaska Peninsula. Although dominated by volcanism, scattered Pleistocene glacial deposits occur within the monument, and Jurassic and Cretaceous sedimentary formations of sandstone, shale, conglomerate and limestone are also present (National Park Service 1985). In 2002, fossilized hadrosaur tracks were found.

Aniakchak has erupted at least 40 times in the past 10,000 yr, with the most recent eruption occurring in 1931 (Neal et al. 2001). Ancestral Aniakchak Volcano underwent a catastrophic explosive eruption about 3,400 yr BP, forming Aniakchak Caldera and blanketing much of the surrounding landscape with thick, fast-moving pyroclastic flows. Postformation volcanic activity within the caldera has resulted in the emplacement of numerous lava domes, maars, eruptions pits, and lava flows (Miller 1990).

A series of glacial advances concurrent with the volcanic activity carved the landscape and deposited thick sequences of till and other glacial debris. During times of glacial maximums, ice sheets extended from the Aleutian Range well into coastal waters. Changes in sea level during this period produced nearshore marine deposits in the lowlands.

Hydrology

Aniakchak River Watershed

Surprise Lake, a large (660 ac [267 ha]) lake located along the northeast edge of the caldera floor, drains 80% of the caldera and is fed by 11 surface inlets and numerous warm and cold springs (Cameron and Larson 1992). The Aniakchak River heads eastward from Surprise Lake, drops steeply out of the caldera, and then flows through a broad valley to Aniakchak Bay. Despite its small volume and relatively short length, the Aniakchak River is the largest stream on the Alaska Peninsula draining into the Pacific Ocean.

Meshik River Watershed

Meshik Lake, at 66 ac (26 ha), lies southeast of the caldera, and is fed by wetlands and small, steep drainages from Pinnacle Mountain. The Meshik River flows out of the southwest side of the park, including Meshik Lake, and discharges into Bristol Bay near Port Heiden. Many of its tributaries drain the south side of the caldera.

Cinder River Watershed
The upper reaches of the Cinder River drain the northeast portion of the park and discharge into Bristol Bay.

Cameron and Larson (1992) conducted a 2-yr study of physical, chemical, and biological attributes of Surprise Lake and the inlet streams. Additional studies in ANIA have all been associated with fisheries work and are considerably less comprehensive (Wagner and Lanigan 1988, Mahoney and Sonnevil 1991, Bennett 2004).

Coastal/Marine
The Anaikchak coastline extends 80 mi (129 km) from Cape Kunmik to Kujulik Bay on the peninsula's southern mountainous spine. The coast is rugged with precipitous cliffs, offshore reefs, and islands. Bays are exposed, with wide, cinder-covered beaches. Tidal forces are generally moderate.

Biological Resources

Flora
Large expanses of cinder and tephra plains surround the crater itself. This area is largely barren, with scattered willow and forb patches around the edges and in lower drainages. Inside the caldera, wet herb and sedge meadows are concentrated near the outlet, and the northwest end of Surprise Lake. Patches of willow, bluejoint grass, and crowberry heath are found on the gentler, lower elevations of old lava flows, while more exposed areas remain unvegetated.

The Cinder River drainage has a few isolated cottonwood trees, relatively lush willow stands, and grass/forb meadows with patches of crowberry heath or wetlands. Alder patches grow in the valleys above the cinder plains. The upper Meshik River valley is dominated by wetlands. Willow and alder thickets occur near Meshik Lake and along the Meshik River. Coastlands are likely dominated by bluejoint grass and forb meadows, alder patches, and crowberry heath.

Fauna
Fishery Resources
Documented freshwater fish diversity in ANIA is low, but a substantial intertidal zone in the Aniakchak River suggests that there is probably significant transient marine diversity. All five species of Pacific salmon are present, and Dolly Varden or arctic char occur in most streams.

Terrestrial Mammals
Thirty terrestrial mammal species are documented or are expected to occur within ANIA. Some of the more commonly observed species include brown bear, moose, caribou, red fox, Arctic ground squirrel, and tundra vole. Species less frequently observed include wolf, river otter, wolverine, porcupine, and beaver. Information on the distribution, abundance, and breeding status of most terrestrial mammal species is limited.

Birds
About 129 bird species are documented or expected to occur within ANIA, including 47 landbird species, 47 inland waterbird species, and 35 seabird species. Information on bird species largely consists of anecdotal sighting records noted by NPS ranger and resource management staff.

Some of the more regularly noted landbird and inland waterbird species include red-throated loon, greater scaup, harlequin duck, Barrow's goldeneye, common merganser, bald eagle, rough-legged hawk, sandhill crane, semipalmated plover, lesser yellowlegs, wandering tattler, whimbrel, western sandpiper, least sandpiper, rock sandpiper, common snipe, red-necked phalarope, belted kingfisher, tree swallow, bank swallow, common raven, hermit thrush, American dipper, American pipit, savannah sparrow, golden-crowned sparrow, Lapland longspur, snow bunting, rosy finch, and common redpoll. Some of the

more common seabird species in anecdotal records include cormorants, black oystercatcher, mew gull, glaucous-winged gull, black-legged kittiwake, Arctic tern, common murre, pigeon guillemot, marbled murrelet, Kittlitz's murrelet, ancient murrelet, and horned puffin (Stroud and Fuller 1983, Manski et al. 1987, Meyer 1987, Sowl 1988, Starr and Starr 1988, Savage 1993b).

Terrestrial Threatened and Endangered Species

Currently no federally listed species are known to occur in terrestrial areas of ANIA (USFWS 2005). Harlequin duck, which occur in freshwater areas of ANIA, is a USFWS species of concern, a designation that indicates that further research is needed to assess biological vulnerability, taxonomy, and/or threats. Lynx, also a species of concern, is at the southern boundary of its range in ANIA, and sightings are rare.

The Boreal Partners in Flight Working Group identified six landbird species as "priority species" for western/southwestern Alaska—gyrfalcon, gray-cheeked thrush, varied thrush, golden-crowned sparrow, McKay's bunting, and hoary redpoll (Andres and Gill 2000). Gyrfalcons are uncommon in anecdotal sighting records, but, similar to peregrine falcon, they are noted on occasion in NPS patrol and survey reports. Meyer (1987), Sowl (1988), and Savage (1993b) described golden-crowned sparrow as a common species in Aniakchak Caldera, and Sowl (1988) described evidence of nesting there. Golden-crowned sparrows were also described as abundant on the ANIA coast by Manski et al. (1987).

Steller's eider, golden eagle, peregrine falcon, and gray-cheeked thrush are species known to occur in ANIA that are listed as State of Alaska Species of Special Concern (http://www.wildlife.alaska.gov/index.cfm?adfg=concern.main [Accessed 25 August 2005]).

Natural Resources Management Issues

- **Commercial fishing.** Harvesting of salmon, especially in the commercial fishery, may be one of the greatest threats to the Surprise Lake/Aniakchak River system. Overharvest may adversely effect salmon endemic to this system and alter the volume and distribution of nutrients in the aquatic-terrestrial food web.
- **Petroleum development, storage, and transportation.** The marine coastline of ANIA is at constant risk from environmental threats associated with petroleum development, storage, and/or transportation. ANIA beaches were oiled by the 1989 *Exxon Valdez* oil spill and residual pockets of unweathered oil persist (Irvine, In press).
- **Subsistence and recreational activities.** Nonconsumptive recreational visitation is limited and typically focuses on the same small areas in the most accessible locations. More than 90% of ANIA's visitation is by guided hunters and anglers (National Park Service 1986). Off-road vehicle use associated with subsistence activities occurs in wetlands and along stream channels on the coastal drainages. Erosion and compaction associated with these recreational and subsistence activities may have localized adverse effects on stream morphology and spawning habitat.
- **Global warming.** ANIA's environment is thought to be very susceptible to climate change. Changes in the thermal regime can extend ice-free seasons, usually leading to increases in the ratio of evaporation + evapotranspiration to precipitation, and result in less water in the landscape (Schindler 1997).
- **Air quality.** Little air quality data have been collected in the park, but it is assumed that ANIA's air is pristine due to its remote location. However, the global dispersion and deposition of pollutants has subjected many remote areas to pollutants.

Ecological Profile: Alagnak Wild River and Katmai National Park and Preserve

Physical Environment

Climate

The climate of the Alaska Peninsula and Katmai National Park and Preserve (KATM) is heavily influenced by storms originating in the North Pacific and moving along a storm track that parallels the Aleutian chain. Storm frequency for the KATM area is greatest during the late summer and early fall from August through October (Klein 1957). Additionally, local geographic conditions produce a variety of microclimates.

KATM's eastern and southern coasts bordering Shelikof Strait have a maritime climate characterized by small temperature variations, high humidity, heavy precipitation, high occurrence of clouds and fog, temperatures generally above freezing, cool summers, and warm winters (Selkregg 1976). The North Pacific high pressure system dominates the area during the summer, bringing south to southwest winds, while in winter the weather is controlled by the Aleutian low atmospheric pressure system. Winds associated with this system are generally north to northwesterly. High winds are common along the Shelikof Strait due to the funneling of air between Kodiak Island and the Aleutian Range. The Aleutian Range also forms a cloud barrier, creating orographic rainfall along the Shelikof coast and on the eastern flank of the Aleutian Range.

West of the coastal range, KATM can be classified as transitional with climate conditions intermediate between maritime and continental. Mean annual temperature at King Salmon ranges between 15.4 °F (-9.2 °C) in January to 55.7 °F (13.2 °C) in July (National Oceanic and Atmospheric Administration 2005). Southeasterly and easterly winter winds predominate in the King Salmon area from October through March (Waythomas 1994). These winter winds are associated with high pressure over northern Alaska and low pressure over the southern Bering Sea and Gulf of Alaska. Summer winds, present between June and September, are generally from the south or southeasterly direction. The strongest winds for King Salmon come from the east, but average wind speeds for King Salmon display little monthly variability with a high of 11.3 mph (18.5 km/hr) in March and a low of 9.8 mph (15.9 km/hr) in July (National Oceanic and Atmospheric Administration 2005).

Geology

KATM rests above a convergent plate margin, part of the circum-Pacific Ring of Fire, and one of the most active volcanic belts in the world. The 1912 eruption of Novarupta, and subsequent caldera-forming collapse of Mt. Katmai, are the most notable volcanic events occurring in KATM in historic times. Ash from Novarupta covered the adjacent valley to great depth, creating numerous fumaroles and thus the name, the Valley of Ten Thousand Smokes. Mt. Trident erupted in 1952, and minor ash eruptions and outbursts have also occurred on Mount Mageik, Mount Martin, Novarupta, and Mt. Katmai since the 1912 eruption (Wilcox 1959:419).

Hydrology

KATM stretches over five river basins. The Naknek, Kvichak, and Egegik River basins are on the western side of the Aleutian Range and drain into Bristol Bay. The North and South Coastal basins are on the eastern side of the Aleutian Range and drain into Cook Inlet and the Shelikof Strait, respectively.

KATM contains the largest freshwater lake in the National Park System (Naknek Lake) and some of the largest lakes in Alaska. These lakes make up approximately 8% of the park's surface area. Glaciers make up 216,000 ac (87,412 hectare) (6%) of KATM (National Park Service 1994). The hydrologic cycle in the park is influenced in part by extensive glaciers and snowfields that supply vast quantities of silty meltwater to the drainage basin headwaters during the summer months.

Streams draining the eastern side of the Aleutian Range are typically short, high gradient on bedrock. In contrast, on the western side of the range rivers flowing toward Bristol Bay consist of large, low gradient river and lake systems, and small, low gradient stream complexes.

Gunther (1992) examined basic water quality parameters of 12 lakes in the Naknek and Alagnak drainages in 1984–86. During the summers from 1990–92, LaPerriere (1996, 1997) assessed conditions in 11 large lakes and some of the important inlet, outlet, and connecting streams along the Naknek and Alagnak drainages within KATM. Data needs and long-term monitoring recommendations for KATM were presented in LaPerriere (1996).

In 1996 and 1997, the USFWS sampled six sites (three per year) for hydrocarbons in KATM waters that receive heavy public use (Kulik Lodge, Grosvenor Lake Lodge, Alagnak Wild River, Naknek Lake, Brooks Lake, and Lake Camp). Elevated hydrocarbon concentrations and visual observations were reported at several sites during this project (Johnson and Berg 1999).

Coastal/Marine

The KATM coastline extends from the mouth of the Kamishak River in Kamishak Bay to Cape Kubugakli in Shelikof Strait, with 497 linear mi (800 km) of coast, including islands. The entire coastline has been shaped by glaciation, with long, narrow fjords and U-shaped valleys. Exposed bedrock and shallow soils prevail on headlands and islands. Typically rivers enter at the heads of the fjords and are characterized by shorter, wider estuarine embayments. This complex ecosystem includes salt marshes, sandy beaches, island and sea stack bays, and rocky headlands.

Biological Resources

Flora

KATM is still a young landscape, with succession yet occurring from past glaciation, as well as the 1912 Katmai eruption. In the interior, lower elevation glacial moraines support spruce and birch/balsam poplar forests with low and dwarf shrub communities in the understory and openings. The southernmost extent of white spruce on the Alaska Peninsula is just south of King Salmon. Lacustrine deposits and old lake terraces west of Brooks and Naknek lakes are vegetated with sedge/low shrub tundra and open alder stands, while portions of the large west-flowing river valleys (Naknek, Nonvianuk) are forested with white spruce, with balsam poplar along the floodplains. Several valleys around Novarupta and Katmai, and slopes on the eastern side of the range, are still covered with deep ash deposits that remain unvegetated.

The Kejulik and Cape Douglas mountains are permanently glaciated, with valley glaciers nearly reaching the Shelikof coast. Below barren, exposed ridgetops and outcrops, patches of alpine tundra and low shrubs find footholds in sheltered niches and shallower patches of ash from the 1912 Katmai eruption. Lower slopes support dense alder stands, with a few Sitka spruce on the coastal headlands. To the north, the Walatka Mountains and Kamishak highlands support dwarf shrub and alpine tundras at higher elevations, with dense alder on lower slopes and cottonwood stands along the streams in the lowest valleys.

Fauna

Fishery Resources

During 1972–91, the annual run of sockeye salmon bound for the Naknek and Kvichak drainages averaged 15.3 million fish, 53% of the total Bristol Bay run—one of the largest in the world. For a variety of reasons, returns to the Kvichak have declined in recent years, while Alagnak drainage sockeye runs have been above average.

Species of anadromous Pacific salmon in KATM include sockeye (red), chinook (king), coho (silver), chum (dog), and pink (humpy). Rainbow trout is the only species of trout known to occur in the park. Species of char include lake trout, arctic char, and dolly varden. Whitefish are well represented, with

round, pygmy, broad, and humpback whitefish, as well as least cisco. Arctic grayling are also present in the park.

Terrestrial Mammals
Thirty-five terrestrial mammal species are documented or are expected to occur within KATM. Commonly observed species include brown bear, moose, caribou, red fox, ermine, mink, porcupine, beaver, Alaskan hare, snowshoe hare, red squirrel, Arctic ground squirrel, northern red-backed vole, and little brown bat. Species less frequently observed include wolf, coyote, lynx, river otter, wolverine, and marten.

Marine Mammals
Sea otters, harbor seals, and Steller's sea lions, a federally listed threatened species, occur along most of the KATM coastline. Although the park's coastal waters are relatively shallow, beluga whales, fin whales, and humpback whales regularly occur offshore and in bays (Goatcher, pers. comm.).

Birds
About 180 bird species are documented or expected to occur within KATM, including 81 landbird species, 64 inland waterbird species, and 35 seabird species.

Some of the inland waterbird species more commonly recorded in anecdotal sighting records in recent years at Brooks River (late spring through fall) include common loon, red-necked grebe, tundra swan, green-winged teal, mallard, American widgeon, greater scaup, harlequin duck, common goldeneye, Barrow's goldeneye, common merganser, and red-breasted merganser. Landbirds noted during the Valley of Ten Thousand Smokes Breeding Bird Survey include osprey, bald eagle, northern harrier, northern goshawk, spruce grouse, rock ptarmigan, willow ptarmigan, semipalmated plover, greater yellowlegs, spotted sandpiper, black turnstone, surfbird, common snipe, great horned owl, belted kingfisher, downy woodpecker, three-toed woodpecker, tree swallow, violet-green swallow, bank swallow, gray jay, black-billed magpie, common raven, black-capped chickadee, boreal chickadee, hermit thrush, American robin, varied thrush, American pipit, orange-crowned warbler, yellow-rumped warbler, blackpoll warbler, northern waterthrush, Wilson's warbler, American tree sparrow, savannah sparrow, golden-crowned sparrow, white-crowned sparrow, dark-eyed junco, snow bunting, white-winged crossbill, and common redpoll.

Landbird and inland waterbird species commonly noted in NPS staff reports for the KATM coast include black scoter, white-winged scoter, surf scoter, northwestern crow, yellow warbler, and fox sparrow (LaFrance and Peterson 1991, Litch and Blackie 1988, Starr and Starr 1992) Black-legged kittiwakes, tufted puffins, horned puffins, glaucous-winged gulls, and pigeon guillemots are the dominant breeding seabirds. Nesting bald eagles are relatively common in KATM, primarily along the coast and along inland lakes and rivers. Golden eagles are occasionally observed in mountainous areas of KATM.

Terrestrial Threatened and Endangered Species
Currently no federally listed species are known to occur in terrestrial areas of KATM. Federal bird species of concern that occur in terrestrial areas of KATM include the harlequin duck and olive sided flycatcher. American peregrine falcon, olive-sided flycatcher, gray-cheeked thrush, and blackpoll warbler are State of Alaska Species of Special Concern that have been documented or are thought to occur in KATM (http://www.wildlife.alaska.gov/index.cfm?adfg=concern.main [Accessed August 25, 2005]).

Natural Resource Management Issues

- **Discharge of water pollutants.** At Brooks Camp, soils and groundwater have been contaminated by a leaking NPS fuel distribution system. Remediation of groundwater at Brooks Camp began in September 1998. In 1996, low levels of polycyclic aromatic hydrocarbons (PAHs) were found at Grosvenor Lodge, and sediment and water samples collected at a former U.S. Air Force recreation area within the park contained elevated concentrations of hydrocarbons (Johnson and Berg 1999).

- **Petroleum development, storage, and transportation.** Fieldwork by the U.S. Geological Survey in 1979 and 1980 revealed promising petroleum exploration targets in the Shelikof Strait (Smith and Petering 1981). A 2004 federal lease sale for the lower Cook Inlet was cancelled, and a sale scheduled for 2006 has been postponed due to lack of industry interest. However, state lease sales for upland and marine tracts held in 2004 and 2005 were moderately to highly successful, and an additional sale is scheduled for 2006.

  The strong currents and high tidal ranges along the Alaskan coast can transport oil spills great distances from their source. During the *Exxon Valdez* oil spill of March 24, 1989, KATM's coast received the greatest impact of the NPS units (National Park Service 1990). Numerous petroleum facilities occur along the north gulf coast, including the Valdez oil terminal in Prince William, terminus for the TransAlaska Pipeline. Cook Inlet supports 15 production platforms, the Drift River Marine Terminal (a privately owned offshore oil loading platform with an onshore storage facility), and the Nikiski oil terminal and refinery.
- **Erosion and streambed alteration from boats.** Increased rate of erosion and alteration of streambed morphology have been found in American Creek and on the Alagnak River as a result of jet boat use (National Park Service 1994, Dorava 1998a, b). Jet boat operation can also lead to significant embryo mortality in salmonids (Horton 1994).
- **Commercial developments.** Seven backcountry lodges exist within KATM, and at least four more are being developed or planned on private inholdings, including the Alagnak Wild River, Naknek River, and along the coast (Johnson and Berg 1999). National Park Service (1994) identified several ongoing activities that could affect natural resources in KATM's backcountry, including camping in high use areas, and boat, aircraft and all-terrain vehicle use.
- **Commercial, sport, and subsistence fish harvest.** Humans intercept and harvest many returning salmon and other fish in commercial, subsistence, and recreational fisheries. Harvesting of salmon, especially in the commercial fishery, represents the greatest threat to their populations, populations of other wildlife, and their natal ecosystems, which depend on them for food and the cycling of nutrients. Crab pot, salmon seine, long-line, scallop, bottom-dragger, and open-ocean trawl commercial fishing, as well as commercial urchin diving, all occur along the Shelikof Strait. Pollock stocks in the Shelikof Straits area were decimated by overfishing in the 1980s.
- **Recreational use.** Although visitation occurs throughout KATM, it is typically focused in small areas such as the most accessible sections of fishing streams. The result is a pattern of intensive use of numerous widely dispersed areas. Bear viewing has become an increasingly popular activity along some salmon streams and especially along the KATM coast.
- **Air pollutants.** The Resource Management Plan for KATM identified several threats to air quality in the park (National Park Service 1994:150). These included automobile and air traffic from King Salmon and Naknek, smoke from incinerators, dumps, fireplaces, wood-burning stoves, and furnaces in the local area, power generation from King Salmon, Naknek, and local communities, regional pollution from Dillingham and Kodiak, campfires at Brooks Camp and backcountry sites, and long-distance transport from industrial areas.
- **Global warming.** KATM's environment is thought to be very susceptible to climate change. Changes in the thermal regime can extend ice-free seasons, usually leading to increases in the ratio of evaporation + evapotranspiration to precipitation, and result in less water in the landscape (Schindler 1997). Climate also has a great influence on peatlands, which are found in KATM's lowlands (Belland and Vitt 1995).

Ecological Profile: Kenai Fjords National Park

Physical Environment

Climate

Warm ocean currents flowing through the Gulf of Alaska result in a climate characterized by cool summers and winters mild for the latitude. The park, divided by the Kenai Mountains, lies in both the maritime and transitional Cook Inlet zone.

The coast has a typical maritime climate, with cool rainy summers and snowy, storm-driven winters. The occasional calm sunny day is a treat to be savored. Steep mountains rising straight from sea level to over 5,000 ft (1,500 m) force moisture-laden storms to rise, where cooling temperatures cause the clouds to drop massive loads of snow onto the Harding Icefield. It receives 400 in (1,016 cm) of snowfall annually and is snow-covered year-round (National Park Service 1999a). In contrast, mean annual snowfall for the area is approximately 50 in (127 cm). Snow cover occurs at sea level from November to late May and may linger on upper slopes until late August.

Annual precipitation in the maritime zone is about 60 in (152 cm) with 100 wet days per yr and 32 in (81 cm) of precipitation occurring from mid-July to late December (National Park Service 1999a). Rainfall is heaviest in Aialik Bay, ranging from 45 to 80 in (114 to 203 cm) during summer months in the 1990s, and decreasing somewhat along the coast to the west. Aialik Bay frequently gets 3–4 in (8-10 cm) of rainfall in one day, and August 20, 1993 recorded a memorable 10.55 in (26.8 cm) (National Park Service 1999b).

Geology

The outer coast of KEFJ rides the exposed edge of the North American Plate, where the Pacific Plate is "diving" beneath the North American plate. As a result, it is subject to earthquakes of moderate frequency and intensity, with resulting ocean floor landslides and terrestrial uplift and subsidence. The beautiful circular bays of the Aialik, Harris, and McCarty peninsulas are drowned cirques of the Chugach Mountains, which were partially submerged by tectonic subsidence during the Holocene (Hamilton and Nelson 1989).

The bedrock of the Resurrection Peninsula and the KEFJ coast is a mixture of faulted metamorphics and intruded volcanics. An arc of cretaceous upper Jurassic rocks stretches from KEFJ near Gore Point around through the Chugach Mountains, as far east as Glacier Bay. These rocks are primarily "grawyacke, slate, argillite, minor conglomerates, volcanic detritus and interbedded mafic volcanic rocks" (Beikman 1980). Several granite and granodiorite intrusions are scattered along the coast.

Pleistocene and Holocene glaciations are among the major forces in shaping the land and ecological processes of the KEFJ coastline. Warming and cooling cycles over the past (at least) 100,000 yr have resulted in multiple glacial advances and retreats. Karlstrom (1964) showed ice sheets of Naptown age (7,000–1,100 yrs BP) extending 50–100 mi into the Gulf of Alaska beyond the current KEFJ coastline. These glaciations carved off all soft and loose material, leaving steep polished bedrock walls and deep submarine valleys all along the Kenai coast. More recent glaciations, apparently reached their maximal extent in the 19th century, and are currently undergoing a fairly dramatic retreat.

Hydrology

There are more than 150 lakes and ponds in KEFJ with a combined surface area exceeding 4,200 ac (1,700 ha) (National Park Service 1999a). Recent deglaciations have opened up new streams and lakes, which are rapidly colonized by salmon. Delight, Desire, and Delusion (Delectable) lakes, on the east side of McCarty Fjord, are three of the larger lakes in KEFJ, and all are currently utilized by salmon. Ice-free dates for these systems range from about 1920 for Delight to 1978 for Delusion (York and Milner 1999). Glaciers, such as Bear, Dinglestadt, and Pederson, have silty lakes or estuarine lagoons at their faces.

Freshwater streams on the KEFJ coast tend to be short, steep, and generally "flashy," in that the flows respond rapidly to rain events, which can be extreme along this coast. Glacial streams, formed of meltwater from grounded and hanging glaciers, also tend to be short, but lower gradient than most of the clear water streams. Primary glacial streams flow into Nuka Bay, Northwestern Lagoon, and Aialik Bay.

A brief report on water resources and hydrologic hazards in the Exit Glacier area was produced in 1985 (Sloan) and additional water chemistry analysis was completed in 2001 (Wright 2001b). Streams adjacent to unpatented mining claims in Nuka Bay were examined on several occasions (National Park Service n.d., Griffith 1999, Shannon and Wilson, Inc. 1996, L. Stromquist, pers. comm. 2005). The Alaska Department of Fish and Game has conducted extensive limnological work on Delight and Desire lakes in McCarty Fjord while assessing the potential to enhance existing salmon runs through lake fertilization (Edmundson et al. 1998, 2001). In 2004, water chemistry information was collected throughout KEFJ in association with a fish inventory (Bennett 2005).

Coastal/Marine

The KEFJ coast is a series of deep narrow fjords cutting into the Kenai Mountains, spaced by even steeper rock cliffs along the exposed outer coast. More than a third of the park's coast is affected by high energy waves, primarily driven by offshore winds and Gulf storms. An additional quarter of the coast has low and very low energy protected coves and lagoons, several of which support salt marshes.

Tidal ranges for the coast are moderate, in the range of -3.2 to +14 ft (-.98 to 4.3 m). Sea surface temperatures off the KEFJ coast range from 40–55 ºF (4.4–12.8 °C) throughout the year (Robinson 1957).

Biological Resources

Flora

Vegetation communities of the coast lands reflect the harsh environment and Holocene glacial and tectonic events. Beginning at the intertidal and moving upward: sheltered waters contain stands of *Laminaria*, grading into *Fucus* in shallow mudflats exposed at low tides. An eelgrass bed grows in Pilot Bay of the North Arm of Nuka Bay. Gravel beaches grade into a supratidal community of beach ryegrass, beachpea and *Hockenyna* with scattered flowering forbs such as iris and Jacob's ladder. Protected lagoons, like the backs of James and Beauty bays, have rich beds of goose tongue, a favorite spring food for bears. Exposed rocky cliffs have tufts of grasses and perennial forbs, some richly fertilized and aerated by puffin nests.

Alder stands and Sitka spruce/hemlock forests begin immediately above the storm tide zone. Alder is a rapid invader in disturbed zones, following avalanche tracks from the alpine down to tide line. Scattered grasses and forbs find a foothold under the shrubs. Alder provides nitrogen for recently deglaciated soils, enriching the environment for spruce invasion. Sitka spruce appears to move into deglaciated terrain within 20 yr of ice retreat (Rice and Spencer 1990). Recently developed Sitka spruce stands have uniform-aged trees with a thin moss ground cover, scattered grasses, and shrubs such as salmon berry and *Menziesia*. Older stands, growing through the last glacial maximum, have spruce of varying ages and a thick moss cover over the ground as well as on tree limbs, with alder, salmonberry, and devil's club in openings.

Alder thickets and open stands extend above the forested zone along the coast up to a narrow band of alpine tundra, which quickly grades into bare rock and ice. Glacial retreats have formed several wide valleys, with broad braided floodplains and stands of alder and willows on the coast, and the addition of cottonwood in the Exit Creek floodplain.

Fauna

Fish

Although some fisheries surveys have been conducted in nearshore waters, there have been no systematic surveys for freshwater fish. King, chum, coho, pink, and sockeye salmon are known to spawn in numerous

park streams. Three-spine stickleback and Dolly Varden char were commonly found in park streams and lakes (Miller et al. 2005).

The nearshore pelagic realm supports many species of fish, including rock fish, halibut, ling cod, and pollock. Forage fish, such as caplin and herring, and several species of shrimp abound. Commercial fishing for salmon and halibut occurs in the fjords and in lagoons such as James and McCarty in McCarty Fjord.

Delight and Desire lakes, and to a lesser extent, Delusion Lake, in McCarty Fjord have been the subject of several studies and publications (York and Milner 1999, Milner 1997) due to their large runs of anadromous fish (ADF&G 1992) and recent (20th century) emergence from glaciation.

Terrestrial Mammals
Twenty-nine species of terrestrial mammals are documented or are expected to occur within KEFJ. Among these, mountain goat, moose, black bear, brown bear, hoary marmot, snowshoe hare, porcupine, ermine, red squirrel, and red-backed vole are the species most frequently encountered (KEFJ 1999). Also present, but less frequently observed, are wolf, coyote, lynx, wolverine, marten, flying squirrel, beaver, river otter, little brown myotis bat, and mink (KEFJ 1999). The distribution, abundance, and breeding status of terrestrial mammal species in KEFJ is, for the most part, unknown. Most information regarding terrestrial species in the park has come from anecdotal reports by park staff and visitors.

Marine Mammals
The Gulf current provides a migratory path for humpback, grey, minke, and fin whales in spring and fall, and a quasi resident pod of killer whales frequents outer Resurrection Bay. Sea otters, northern fur seals, Steller's sea lions (a federally listed threatened species), harbor seals, harbor porpoises, and Dall's porpoises also use the KEFJ coast.

Birds
Two hundred eighteen species of birds are documented or expected to occur within KEFJ. The species most commonly observed by Wright (2001) were Wilson's warbler, varied thrush, hermit thrush, fox sparrow, ruby-crowned kinglet, and orange-crowned warbler. Other passerine (songbird) species commonly encountered include Steller's jay, black-billed magpie, northwestern crow, common raven, chestnut-backed and black-capped chickadee, common redpoll, snow bunting, white-winged cross bill, and dark-eyed junco. Raptor species include bald eagle, golden eagle, northern goshawk, sharp-shinned hawk, and great horned owl. Additionally, willow ptarmigan, rock ptarmigan, white tailed ptarmigan, and spruce grouse are present in upland areas of the park.

The Chiswell and Pye islands are nesting grounds for thousands of pelagic seabirds, including tufted and horned puffins, black-legged kittiwakes, murres, pigeon guillemots, and three species of cormorants (Miller 1984). Marbled murrelets nest under glacial rocks and in old Sitka spruce along the coast. Black oystercatchers scratch shallow nests into gravel beaches just above the tide lines and protect them viciously from beach walkers. Glaucous-winged gulls are aggressively colonizing recently deglaciated islands in the fjords. Bald eagles nest along the coast, averaging 50 active nests per year.

Terrestrial Threatened and Endangered Species
No federally listed species are known to occur in terrestrial portions of the park (USFWS 2005). However, several State of Alaska Species of Special Concern (http://www.wildlife.alaska.gov/index.cfm?adfg=concern.main [Accessed 25 August 2005]) are present, including the Kenai Peninsula population of brown bear, Townsend's warbler, gray-cheeked thrush, blackpoll warbler, and olive-sided flycatcher.

- **Access.** Corridors of impact exist in KEFJ along the Exit Glacier Road and Harding Icefield Trail. Gravel extraction activities and the physical access routes themselves have the potential to alter hydrologic regimes.
- **Mineral extraction.** Park lands are fairly secure from new mineral extraction, but significant problems exist at the site of past activities, particularly in Nuka Bay. Hydrology and vegetation have still not recovered in riparian areas. Reclamation may be required to regain more natural streambed alignment and grade as well as to encourage revegetation or erosion control.
- **Air quality.** Although only limited air quality data have been collected, KEFJ is probably affected by long-range transport of contaminants from the Far East. In addition, local and regional sources of contaminants may be of concern, particularly from oil refineries on the Kenai Peninsula and cruise ship emissions.
- **Oil and gas exploration, transport, and production activities.** Oil transport accidents from tankers traveling from the Port of Valdez have resulted in damage to the KEFJ coast in the past, and the potential for a reoccurrence of a large spill is great. Smaller spills resulting from onboard fuel of commercial boats that run aground or sink and chronic, small spills from boats are yet another form of waterborne contamination.
- **Hazardous materials and waste management.** Hazardous waste on disturbed lands, especially mining claims, could be affecting water resources in the Nuka Bay area of the park. In 1997, high concentrations of arsenic at the Beauty Bay mine were stabilized. Staff are identifying hazards on abandoned mine lands in the park, and contaminated soil remediation will continue in the future.

  Underground storage tanks are continually a threat to ground- and surface waters. The park is working to get all underground storage tanks into federal and state compliance, but the threat of undetected spills from old tanks is a concern.
- **Water diversion for Bradley Lake hydroelectric power.** In June 1986 an agreement was signed with the Alaska Power Authority allowing diversion of meltwater off the Nuka Glacier (outside NPS lands) into Bradley Lake for a hydroelectric power project. The agreement stipulates that 5 cfs will flow into the park's Nuka River. A diversion structure regulates the flow from the Nuka Glacier pool.
- **Recreational use.** Visitor use has increased dramatically within the past 15 yr, with three companies and approximately 15 vessels offering daily tours into the park. Many smaller charters run fishing trips to Resurrection and Ailalik bays. Kayaking has become increasingly popular, frequently basing out of the four NPS public use cabins. Human waste, littering, bank erosion, and fuel spills are all areas of concern. Additionally, impacts of beach campers on the nearshore meadows, oystercatchers, and black bears are currently being studied.

Ecological Profile: Lake Clark National Park and Preserve

Physical Environment

Climate

The Chigmit Mountains divide the subpolar marine climate of Cook Inlet from the continental climate of Interior Alaska. Local climatic conditions within these two regimes vary with elevation and the distance from mountains and large bodies of water (National Park Service 1999c).

The coastal east side of the mountains is typically warmer and wetter than the west side, with an annual average precipitation between 15 and 20 in (38 to 51 cm). Precipitation increases dramatically, ranging between 40 to 80 in (102 to 203 cm) per yr, where the mountains immediately rise from Cook Inlet (LACL southeast coast). Mean coastal air temperature ranges from 10 to 32 °F (-12.2 to 0 °C) during January, typically the coldest month. Mean temperature for the warmest month, July, ranges from 48 to 60 °F (8.9 to 15.6 °C) (National Park Service 1983).

Port Alsworth, located west of the Chigmit Mountains, represents inland climatic conditions. Annual precipitation at Port Alsworth is approximately 17 in (43 cm). Mean air temperature ranges from 12 °F (11 °C) in January to 56 °F (13.3 °C) in July. From 1960–81, extreme air temperatures recorded at Port Alsworth were –55 °F (-48.3 °C) and 86 °F (30 °C) (National Park Service 1983).

Geology

The Chigmit Mountains are composed of a complex of multiple granitic stocks and batholiths that intruded after Triassic time into Paleozoic and Cenozoic rocks. The main batholith is elongated to the northeast, parallel to the structural trends of the region. The intruded rocks, which dip away from the Chigmits, are moderately to highly deformed volcanic and sedimentary rocks. Three volcanic piles of Tertiary to Recent age are still active: Mount Spurr, Redoubt Volcano, and Iliamna Volcano (National Park Service 1988).

The park has been extensively glaciated, with three known advances. All glacial deposits appear to be of Wisconsin age or younger (National Park Service 1988).

Hydrology

LACL encompasses approximately 4 million ac of public and private lands in southwestern Alaska and contains more than 6,000 mi of rivers and streams—some of the most diverse water resources in the National Park system. The Alaska and Aleutian mountain ranges form a continuous watershed divide separating the coast from the interior.

Glacial ice, much of it associated with Redoubt and Iliamna volcanoes, covers approximately 30% of the park. Most of the glaciers in the park have retreated dramatically in the last four decades (National Park Service 1999c). Silty meltwater from these glaciers and associated snowfields strongly influences the hydrologic cycle in the park.

The headwaters for five major drainage basins are located within LACL's boundaries: the Kvichak River, Nushagak River, Kuskokwim River, Chakachatna River, and Coastal basins. LACL also includes the sixth largest lake in Alaska, Lake Clark, and three river segments designated as "Wild Rivers": Chilikadrotna (11 mi), Mulchatna (24 mi), and Tlikakila (51 mi) (National Park Service 1999c).

Early limnological studies of the aquatic systems that include LACL were of a broad or general nature (Burgner et al. 1969, Mathisen and Poe 1969, ADF&G and National Park Service 1980). A 3-yr study of chemical, physical, and biological characteristics of surface waters in the park (Dale and Stottlemyer 1986, Stottlemyer and Chamberlain 1987, Chamberlain 1989) provided more specific water chemistry data on selected surface waters in LACL.

USGS-WRD monitored water quality and runoff characteristics for the Tlikakila River and other major Lake Clark tributaries over three runoff seasons, 1999–2001 (Brabets 2002). In 2001, USGS-WRD collected data on runoff components in the Tlikakila River basin to determine the relative contributions of springs, glaciers, rainfall, and snowmelt. Several airborne profiles of glaciers were flown to help construct a history of glacier change in the basin. Preliminary results indicate that from 1957 to 1996, the glaciers have been thinning at an average rate of between 1.5 ft/yr (0.46 m/yr) and 3.2 ft/yr (0.96 m/yr). However, the glaciers may have thickened from 1996 to 2001 (Brabets 2001a).

The University of Alaska at Fairbanks initiated a limnology study of Lake Clark in 1999 (Wilkens 2002). This study looked at the physical and chemical characteristics of Lake Clark to its full depth of 860 ft (262 m) and examined the zooplankton species and biomass in cooperation with contemporaneous studies on the tributaries and the sockeye salmon in the lake.

While most studies have focused on Lake Clark, water quality data have also been collected at the Johnson River, a coastal watershed explored in the 1980s and early 1990s for potential mineral extraction. During 1998–2001, the Johnson River was included in the Cook Inlet National Water Quality Assessment Program. Results indicate good water quality and a "low acid-generating potential/high neutralizing potential" of the ore deposit (Brabets 2001b).

Coastal/Marine

LACL contains 130 mi (209 km) of coastline in western lower Cook Inlet, an extremely dynamic, high-energy estuarine environment. The normal tidal cycle has an average height ranging from about 18 ft (5.5 m) in Kachemak Bay to 29 ft (8.8) m at Anchorage. Extreme high tides can be in excess of 36 ft (11 m), making the tidal ranges in Cook Inlet among the largest in the world (Britch 1976, Brower et al. 1977).

The rivers emptying into Cook Inlet carry very high loads of suspended sediments, mainly fine glacial flour. Average concentrations of suspended sediments in Cook Inlet are about 200 mg/l with maximum concentrations in excess of 2,000 mg/l (Sharma and Burrell 1970, Feely and Massoth 1982).

Winter ice formation can be extensive in Tuxedni Bay and Channel. Estuary ice that forms in Tuxedni Bay consists of freshwater and is much harder than sea ice. Due to a combination of ice structure, lower air temperatures, and shelter from wind, this bay can remain ice covered for 3-4 mo during winter (Bennett, pers. obs.). When the bay ice breaks up in late winter, ice flows that are moved by tides and winds gouge shorelines, cause shoreline erosion, and exert significant forces on offshore structures (B. Woods, pers. comm.).

Forty-three percent of the LACL coastline is either very protected or protected from high energy waves (Schoch 1996). Salt marsh accounts for 22% of the total shoreline length and 42% of the total intertidal area. The combined soft substrates (salt marsh, sand, and mud flats) account for 90% of the total coastline length and 98% of the total area (Schoch 1996). Combinations of rocky shores (ramps, platforms, cliffs) are a very small percentage of the total habitat type on the LACL coastline.

Biological Resources

Flora

There are no threatened or endangered species of plants listed by the USFWS (2005) in LACL. The Alaska Natural Heritage Program Rare Vascular Plant Tracking List for April 2000 identifies 25 plant species that are classified by the State as critically imperiled (S1), imperiled (S2), or rare or uncommon (S3). Several rare species are exclusively associated with wetland, riparian, or lakeshore habitats.

Coastal side: The Cook Inlet coast has a narrow fringe with coastal salt marshes in Tuxedni and Chitintna Bays and scattered marshes and lagoons along the Inlet coast. Coastal zones without marshes have long gravel beaches or bedrock cliffs rising abruptly out of Cook Inlet. The salt marshes are a rich zone of sedges

and some grasses with varying tolerance to saltwater flooding, and form an early spring food source for bears grazing along the beaches. Much of the LACL coast appears to be rising from tectonic movements, and narrow bands of young spruce are establishing themselves into the *Elymus* grass community in back of the beaches. The depositional flats and lower mountainsides behind the beaches are covered with spruce forests and alder thickets. Both white and Sitka spruce grow along the coast, with Sitka generally south of the Johnson River, and white spruce to the north. Conifer forests have multiaged trees with thick moss understory, devil's club, salmonberry, and scattered alder. Scattered stands of spruce rise out of a sea of alder, especially around the Tuxedni coast and above the dense spruce forest. Alder thickets grow above the spruce zone, thinning out into *Calamagrostis* meadows at the upper limits. The alpine tundra zone is very narrow on the coastal side of the mountains, dominated by *Luetka*, *Empetrum*, and forbs. Tundra yields to bedrock and ice.

Mountainous spine: The center of the park is primarily glacial ice and bedrock or till. Most valley glaciers are in retreat, leaving large expanses of moraines and ground till, which are slowly revegetating with mosses and lichens, fireweed and Dryas, willow and alder. An ecosystem of note is the expansive shallow wetlands along the Neacola River, which runs into Chakachamna Lake. The valley provides rich habitat for beaver, moose, nesting waterfowl, and bear. The wetlands appear to be dominated by sedges and willows, and are maintained by flooding and beaver activity.

Lake side: The western side of the park is dominated by a series of large long lakes with their eastern extents in the Alaska Range and their western edge bounded by terminal moraines from the most recent advances of large valley glaciers. Low ridges and subdued mountains lie between the lake systems. The northern part of the park, by the Stony River, is boreal in character, with black spruce, muskeg, aspen and birch, and subject to wildfire. Further south, vegetation is a mosaic of spruce and mixed spruce/birch or cottonwood forests, paper birch, low shrubs dominated by dwarf birch, dwarf shrub tundra with ericaceous shrubs, scattered wetlands, and alpine tundra. Vegetation patterns are arrayed in response to soil texture and drainage patterns from a complex glacial and alluvial history.

Fauna

Marine Invertebrates

Intertidal sand flats in some locations within LACL support dense populations of mollusk bivalves, including razor, littleneck, and soft-shell clams. Intertidal mud flats in Chinitna and Tuxedni bays support large to moderate standing crops of suspension- and deposit- feeding invertebrates (Lees 1977). Eighteen species of Polychaeta, 7 species of Mollusca and 12 species of Crustacea have been identified in Chinitna Bay (Bennett 1996). Infauna in both bays are dominated by the pink clam (*Macoma balthica*).

The trophic relationship between shorebirds, sea ducks, diving ducks, and Macoma may be the most significant near-coastal predator-prey linkage along the LACL-Cook Inlet coastline (Bennett 1996).

Fish

Forty-six species of fish are listed as present or probably present in LACL. In marine waters, small pelagic schooling fish, including capelin, sand lance, eulachon, and Pacific herring, occur in nearshore and estuarine waters, while halibut and gray cod are found offshore (Bennett, pers. obs.). Dominant species during summer in Tuxedni Bay include juvenile pollock, sand lance, osmerids, and herring (Piatt et al. 1999). No information exists on seasonal abundance or distribution.

Sockeye salmon are a keystone species in the LACL aquatic and terrestrial ecosystem. Nutrients from spawned-out salmon carcasses play a crucial role in sustaining the productivity of riparian and lacustrine ecosystems, including the perpetuation of future salmon runs (Kline et al. 1990, 1993). Sculpin, least cisco, lake trout, rainbow trout, and burbot all derive nutrients from sockeye salmon in one form or another. Salmon influence the seasonal distribution and abundance of birds and mammals that prey on them. In the interior of the park and preserve, bald eagles are exclusively associated with river-lake systems that support salmon. Bears depend on abundant salmon to bolster fat reserves vital to survival

during hibernation. Because much of Lake Clark remains ice-free until February, salmon carcasses support overwintering bald eagles and are an important food resource for an array of vertebrate predators and scavengers, including wolves, coyotes, red fox, wolverine, and lynx.

Terrestrial Mammals

Thirty-six species of terrestrial mammals are documented or expected to occur within LACL. Moose occur throughout LACL, but due to deep snow, are less common on the coast. Dall sheep reach the southern extent of their range in LACL and occur along the western slopes of the Chigmit Mountains on the common boundary of the park and preserve. The Mulchatna caribou herd calves adjacent to the western boundary of the preserve and ranges through the foothill lakes and tundra plains of the western preserve. This herd is one of the most important for local subsistence and nonlocal Alaska hunters and heavily supports Alaska's guide and transporter industry. Brown/grizzly bears, common in all habitats, are most numerous along the coast, where an estimated 180–230 bears graze in salt marshes during the summer (Bennett 1996).

Black bears use all areas of the park and preserve except the higher elevations. Other terrestrial mammals—wolves, lynx, coyotes, and wolverines—range widely throughout the forests and low alpine areas, also populated with porcupines and snowshoe hares. Hoary marmots, arctic ground squirrels, and pikas occur in alpine meadows and boulder fields. Twelve species of vole, lemming, and shrew probably occur, of which the redback vole is most abundant. Mink, beaver, and river otter inhabit ponds, lakes, and rivers. River otters are particularly common along the coast. Red squirrel, American marten, shorttail weasel, and least weasel are also found throughout the park and preserve.

Marine Mammals

Harbor seals (200–250 animals) haul out at three sites (Tuxedni Bay, Chinitna Bay, and Johnson River) and pup near the mouth of the Tuxedni River (Bennett 1996). Beluga whales seasonally occur off the mouths of glacial rivers in both bays and are most numerous (160–200 animals) during August and September (Bennett 1996, Speckman and Piatt 2000). Sea otter occasionally stray into park waters, but are more common in the clearer waters south of the park (Bennett 1996).

Birds

One hundred eighty-nine species of birds are documented or expected to occur in the park and preserve. Of these, 70 are landbirds, and many are neotropical migrants. Raptors, including bald eagle, golden eagle, northern goshawk, sharp-shinned hawk, northern harrier, and merlin, breed in the area. About 50 pairs of bald eagles and 5–10 pairs of golden eagles are known to nest in the park and preserve. Two pairs of osprey also nest in the preserve. Peregrine falcons occupy eyries on cliffs along interior lakes and rivers, and at Tuxedni Bay (Haugh and Potter 1975, Bennett 1996).

Waterfowl nest and molt in wetlands throughout the area. Large migratory flocks of ducks, swans, and geese rest and feed in the park and preserve before flying from Nikabuna Lakes to Lake Clark through low mountain passes in the Chulitna River drainage.

Sea ducks, primarily white-winged scoters and surf scoters, are the most abundant waterfowl on the coast, numbering more than 18,000 in mid-August. The coast also provides important breeding habitat for mallards, American widgeon, Barrow's golden-eye, and red-throated loons. Diving ducks, primarily greater and lesser scaup, stage along the coast in spring. Other ducks include green-winged teal, northern pintail, harlequin, common golden-eye, black scoter, common eider, bufflehead, and long-tailed duck. About 30 pairs of trumpeter swans nest in the park and preserve, the farthest west breeding population. Canada geese occur in Tuxedni Bay and can number about 4,400 during fall migration.

Seabird breeding colonies occur along Cook Inlet and concentrate at Tuxedni and Chinitna Bays (Bennett 1996). Of the seven seabird colonies surveyed from 1994 to 1996, the largest contained 2,700 black-

legged kittiwakes. Less numerous seabirds include horned puffins, double-crested cormorants, pelagic cormorants, glaucous-winged gulls, tufted puffins, common murres, and pigeon guillemots.

During spring migration, 86,000 to 122,000 shorebirds, primarily western sandpipers and dunlin, use intertidal mud flats in Tuxedni and Chinitna bays (Bennett 1996). Rock sandpipers, designated as a "Species of Moderate Concern," (National Audubon Society 2002) winter in Tuxedni Bay. Tuxedni Bay qualifies as an International Reserve in the Western Hemisphere Shorebird Reserve Network (Andres and Gill 2000).

Threatened and Endangered Species
Currently no federally listed species are known to occur in terrestrial areas of LACL (USFWS 2005). Federal species of concern (formerly category 2 candidate species) that occur in terrestrial areas of LACL include the harlequin duck, olive-sided flycatcher, and lynx.

American peregrine falcon, olive-sided flycatcher, gray-cheeked thrush, Townsend's warbler, and blackpoll warbler are State of Alaska Species of Special Concern that have been documented or are expected to occur in LACL (http://www.wildlife.alaska.gov/index.cfm?adfg=concern.main [Accessed 25 August 2005]).

Natural Resources Management Issues

- **Air quality.** Quantitative air quality data are limited throughout Alaska, and currently no baseline air quality data exist for LACL (National Park Service 1999c). The park includes environments extremely susceptible to contaminants because of poor buffering geology. Numerous sources for airborne contamination exist in the Lake Clark region, including emissions from offshore oil/gas development in Cook Inlet and coal extraction at the Beluga coal fields northeast of the park.
- **Climate change.** LACL's environment is thought to be very susceptible to climate change. In 1938, a glacial toe 5 mi wide filled Lake Clark Pass (Alaska Geographic Society 1986). Today the glaciers in Lark Clark Pass have receded into the higher mountain valleys, suggesting that the climate has warmed.
- **Mining.** Under the Alaska Native Claims Settlement Act of 1976, the Cook Inlet Region Corporation (CIRI) received title to approximately 21,000 ac of land known as the "Johnson River Tract" located on the west side of Cook Inlet in LACL. Based on the current size estimate of the ore body, approximately 270,000 tons of ore would be mined and transported annually over a 3-yr mine life (National Park Service 1999c; CIRI and WestMin 1994). Due to the proximity of the planned mine and support network of roads and ore stockpiles to the Johnson River, there is a high potential for contaminants to reach the Johnson River estuary and be transported along the coastline by prevailing tidal currents (Bennett 1996).
- **Petroleum development, storage, and transportation.** State oil and gas lease sales for upland and marine tracts in Cook Inlet, held in 2004 and 2005, were moderately to highly successful, and another sale is scheduled for 2006. A 2004 federal lease sale for lower Cook Inlet was cancelled, and a sale scheduled for 2006 has been postponed due to lack of interest by the oil industry. The strong currents and high tidal ranges along the Alaskan coast can transport oil spills great distances from their source, as evidenced by the *Exxon Valdez* oil spill of March 24, 1989. Numerous petroleum facilities occur along the north gulf coast, including the Valdez oil terminal in Prince William Sound, terminus for the TransAlaska Pipeline. Cook Inlet supports 15 production platforms, the Drift River Marine Terminal (a privately owned offshore oil loading platform in Cook Inlet with an onshore storage facility), and the Nikiski oil terminal and refinery.
- **Residential development.** Residential subdivision and economic development on private lands within LACL's boundary can conflict with the park's enabling legislation and NPS management objectives. About 617,000 ac (250,000 ha) are in private or state ownership, or are being adjudicated. This includes approximately 75% of Lake Clark's shoreline (National Park Service 1999c).

- **Commercial fishing.** The number of adult salmon returning to this watershed has declined in recent years and in 1996 was 75% below the previous 10-yr average. Commercial fishing of mixed stocks of sockeye salmon, such as occurs in the Bristol Bay Naknek-Kvichak Commercial Fishing District, has the potential to overharvest or eliminate small populations (Willson and Halupka 1995). Due to the mix of glacial and clear-water aquatic habitats within this vast system, genetic differentiation is likely (Wood 1995).
- **Sport and subsistence fishing.** The NPS estimates that about 1,600 sport hunting days, 3,500 angler days, and 30 to 35 river trips occur in LACL annually (National Park Service 1999d), and this number is increasing. In addition, the number of subsistence fishing permits issued for this system has tripled during the past 10 yr. This increase in visitor and subsistence use has also increased resource impacts.

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Appendix III

Protocol Development Summaries

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Weather and Climate

Protocol: Weather and Climate

Parks Where Protocol Will Be Implemented: KATM, KEFJ, LACL, ANIA

Justification/Issues Being Addressed: Climate is a basic driver of all ecological systems. Global climate models predict that climate change and variability will be most severe at high latitudes, and there are many indications that environmental conditions are already changing in these regions.

Accurate, long-term data sets are important for understanding the relationship between climate and other components of biotic and abiotic systems. Without climate data, it is impossible to appreciate the causes of a variety of ecosystem changes—from vegetative cover changes to shifts in aquatic and terrestrial plant and animal communities. Climate is also a fundamental driver for physical processes (fluvial and glacial) on the landscape.

Existing weather stations in southwest Alaska are focused primarily on the safety and needs of the aviation community, the primary form of transportation in this area, and are thus collocated with the sparse human development. Commonly, these stations are sited at lower elevations in broad valleys, or in coastal areas. SWAN parks exhibit extreme topographic and geographic gradients and consequently, climate variability (maritime to continental), most of which is not represented in the current network of weather stations. Deployment of weather stations and the accurate collection of weather observations in remote coastal and mountainous locations will help to fill data gaps that currently exist in SWAN.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

Question:

- What is the natural variability in weather (temperature, relative humidity, precipitation, wind) and the long-term climate trends in SWAN parks?

Objectives:

- Record and archive hourly weather observations, including temperature, relative humidity, precipitation, wind speed/direction, solar radiation, relative humidity, and snow depth at weather stations located in representative areas within SWAN parks.
- Produce monthly and annual summaries of weather observations and identify extremes of climatic conditions for common parameters (precipitation and air temperature), and other parameters for which sufficient data are available (e.g., wind speed and direction, solar radiation).

Basic Approach: Strategically deploy a network of remote automated weather stations (RAWS) in SWAN. There are currently > 100 RAWS stations in Alaska, including three in SWAN. Air temperature, relative humidity, soil moisture, wind direction and speed, snow depth, solar radiation, and precipitation are transmitted via NOAA's Geostationary Operational Environmental Satellite (GOES) telemetry. These data are received via a direct-readout ground site in Boise, Idaho, in cooperation with the Bureau of Land Management. RAWS protocols have been developed by numerous parks and will be used, with minor modification, at SWAN. Initial steps will focus on selecting instrumentation and station locations.

Determine the best method for measuring all-season precipitation at sites within SWAN without access to a power grid.

- Evaluate USGS method (propylene glycol/ethanol mix with tipping bucket) on the Harding Icefield weather station.
- Evaluate Central Alaska Network/Natural Resource Conservation Service partnership for SNOTEL storage precipitation gages.

Identify, evaluate, and select potential weather station deployment locations based on their ability to:

- Fill in gaps of the existing network of weather stations.
- Capture average climate and climate variability across the SWAN region.
- Contribute to larger scale climate monitoring and modeling efforts.

Weather station site identification will utilize a combination of tools:

- Site recommendation report prepared by the Western Regional Climate Center (Redmond et al. 2005).
- Knowledge and expertise of park employees (land status, sensitive areas, park needs, access logistics, potential collocation sites such as radio repeater locations and Federal Aviation Administration weathercams).
- PRISM (Program for Integrated Earth System Modeling) data set (temperature and precipitation).
- North Gulf of Alaska coastal wind event modeling (Olsson et al. n.d).

Potential sites will be evaluated through over-flights and on-site evaluation of ground conditions, using photo documentation and a site characteristic evaluation form adapted from the NOAA Climate Reference Network Program. Following field visits, a report evaluating and ranking potential deployment sites will be prepared and submitted to park and Network staff, then peer reviewed by climate experts (National Weather Service, State Climatologist, and others) with Alaskan knowledge and experience in climate monitoring.

Principal Investigators and NPS Lead:

- Bruce Giffen, NPS-ARO (NPS Lead)
- Kelly Redmond, Western Regional Climate Center

Development Schedule, Budget, and Expected Interim Products:

FY 2006 Site identification and evaluation. Preparation of site evaluation report and peer review. Final site selection, National Environmental Policy Act ($20,000).

FY 2007 Draft protocol completed.

FY 2008 Protocol peer review.

Deployment of weather stations for testing ($10,000).

FY 2009 Full implementation (recurring annual costs) ($25,000).

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Protocol: Glacier Extent

Parks Where Protocol Will Be Implemented: KATM, KEFJ, LACL

Justification/Issues Being Addressed: Glaciers are highly sensitive, natural, large-scale, representative indicators of the energy balance of both mountains and lowlands within SWAN. Glaciers are often referred to as natural "water towers" because of their capacity to store water for extended periods and to exert control on the surface water cycle through timing of discharge, volume and variability, and delivery of sediments. Glaciers are a significant landscape feature in SWAN parks, especially KEFJ, KATM, and LACL, but they have been in widespread retreat and thinning since the Little Ice Age (1900). Although this ice loss has occurred at varying rates over time, it is generally understood to have significantly increased in the last few decades. This variation in glacial coverage is responsible for significant landscape change within these parks.

Glacier systems are primarily regulated by climate fluctuations and thus provide a record of long-term climate change. Glaciers act as huge ice reservoirs for freshwater storage in SWAN parks, and much of the freshwater flow systems in the network are currently of glacial origin. Glacial meltwater recharges valley lakes and regulates seasonal stream flows. Freshwater productivity is strongly influenced by glacially forced colder temperatures and limited light penetration due to light scattering from fine, suspended, glacial sediments. Key issues that need to be addressed in monitoring are changes to the extent of glacial ice and the direct effect of these changes on freshwater flow systems in KEFJ, KATM, and LACL.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

Question:

- What are the changes and trends in glacier extent in KATM, KEFJ, and LACL?

Objectives:

- Document whether the surface area of glacier ice cover is growing or shrinking, the rate of any change, and where the greatest change is occurring.

Basic Approach: Photography, including the use of satellite imagery, is recognized as a simple and effective means for documenting change in glacier extent. Recently, this approach was used to examine change in glacial extent at KEFJ (Hall et al. 2005). Landsat satellite imagery is available from the 1970s to the present, and each scene encompasses large areas. This imagery will be used to monitor glacier extent on a decadal scale in SWAN parks, using a combination of supervised classification and manual methods. Icefields and outlying glaciers will be outlined using vector segments to produce shape files for geographic information system analysis. Changes in all the glaciers can be determined from analysis of the shape files and measurements for terminus-position change for selected glaciers. In areas where glacier boundaries cannot be clearly differentiated, such as moraine-covered ice, Landsat will be supplemented with higher resolution imagery (ASTER and air photos).

Although Landsat imagery can be used for retrospective studies, Landsat-program continuity is currently uncertain. In the future, the glacier extent protocol will be updated with changes in satellite technologies or with the advancements in classification methodologies. Protocol development will also be coordinated with the GLIMS (Global Land Ice Measurements from Space) working group, as they develop their protocols.

Repeat photography of the glacier terminus can provide a more long-term perspective on expansion or shrinkage of specific glaciers (Molnia and Sfraga 1999). The repeat photography makes use of photos taken during scientific expeditions into SWAN parks early in the last century. Repeat photography is conducted to duplicate to the greatest extent possible the location and orientation of historical photography,

using methods described by Hall (2002). In cases where the vantage point used in original photography no longer exists (e.g., a river cutbank), an alternative vantage point is selected to approximate the original as closely as possible. During field visits, the geographical coordinates for each photo-monitoring site are recorded using the GPS to facilitate repeated monitoring.

Principal Investigators and NPS Lead:

- Dorothy K. Hall, NASA/Goddard Space Flight Center
- Torre Jorgenson, ABR, Inc., Fairbanks
- Bruce Giffen, NPS-ARO (NPS Lead)
- Alan Bennett, NPS-SWAN

Development Schedule, Budget, and Expected Interim Products:

2005 Draft protocol with SOPs, acquire imagery, and determine decadal glacial extent for KATM ($32,000).

2006 Test and finalize protocol, acquire imagery, and determine decadal glacial extent for LACL ($45,000).

2007 Implement ($ to be determined).

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Landscape Dynamics and Terrestrial Vegetation

Protocol: Landscape Processes

Parks Where Protocol Will Be Implemented: LACL, KATM, ANIA, ALAG, KEFJ

Justification/Issues Being Addressed: SWAN parks are in an extremely dynamic region. The major landscape drivers are climate and terrain and the interactions between them. The climate is driven by the interplay of cold arctic and warm maritime systems that meet across the SWAN area. The parks are arrayed along the edge of the subduction zone where the North Pacific plate is diving beneath the North American plate. This tectonically active area has multiple arcs of mountains rising abruptly from sea level, frequent earthquakes and uplift, and numerous active volcanoes. The coastal mountains are distinguished as some of the snowiest places on the planet, resulting in the greatest density of tidewater and valley glaciers outside Antarctica. The annual storm pattern in the region is a critical feature of the climate-hydrologic cycle in the network parks (Bennett et al. 2004).

SWAN has identified several physical and biological processes to monitor across all the parks in the Network. These processes have been combined into the vital sign Landscape Processes. These processes include freeze-up and break-up of large freshwater and marine water bodies, pattern and timing of snow cover, pattern and timing of surface sediment in large lakes, timing of vegetation green-up and senescence, and relative biomass. Some of these are affected by large-scale patterns that extend beyond the immediate park boundaries into the surrounding region of southwest Alaska and marine waters. A common theme of these Landscape Processes is the need for a temporal window of days to weeks, a large spatial scale across the region, and the potential to use remotely sensed data to interpret and integrate these processes. Remotely sensed data also provide an opportunity to build an archive of historic images that may be used to evaluate episodic events such as ash deposition from volcanoes or large-scale human development, including logging and mines.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

Questions:

- How are onset, duration, and extent of ice cover changing on large lakes in SWAN parks?
- How are timing, location, and duration of snow cover changing in SWAN parks?
- How are timing and relative extent of sediment plumes changing in large lakes and river mouths in SWAN parks?
- How are onset, duration, and relative biomass of vegetation productivity changing in SWAN parks?

Objectives:

- Track long-term trends in lake freeze-up and ice break-up dates in large lakes in SWAN parks.
- Estimate long-term trends in duration of snow cover in SWAN parks.
- Estimate long-term trends in spatial extent of August sediment plumes for Lake Clark, Naknek Lake, and Resurrection Bay offshore of Bear Glacier.
- Estimate long-term trends in growing season normalized difference vegetation index in SWAN parks.

Basic Approach: The primary tool to monitor landscape processes will be multispectral satellite data similar to that currently acquired by the MODIS satellites. MODIS satellites fly a polar orbit and acquire data for the entire earth daily. Data are acquired in visible, near infrared, and thermal bands that can be composited and enhanced to provide images and time-integrated products. Initial investigations reveal complex spatial and temporal patterns of lake and sea ice, snow cover, and green-up/senescence timing and patterns across North America and the SWAN region (Reed 2005). Images derived from MODIS data can be analyzed manually or with algorithms to provide information about the landscape processes discussed above. Rectified images and derivative products will be archived in the SWAN databases or

served through the Alaska Geographic Data Clearinghouse through USGS. Interpretations will be stored as geographic information system or flatfile data as appropriate. Initial protocol development is being accomplished through an interagency agreement (IA) with USGS at the Earth Resources Observation & Science (EROS) Data Center (Reed and Budde 2004).

Principal Investigators and NPS Lead:

- Brad Reed, USGS EROS Data Center
- Michael Budde, USGS EROS Data Center
- Page Spencer, NPS-ARO (NPS Lead)
- Amy Miller, NPS-SWAN

Development Schedule, Budget, and Expected Interim Products:

The IA with USGS EROS began March 1, 2005. A draft protocol will be presented to SWAN by October 1, 2005, with the final protocol available by December 15, 2005. NPS personnel will test the protocols in FY06, with implementation in FY07. The IA is funded for $40,376. An additional $10,000 will be used to purchase software and training for NPS use to test and implement the protocols. MODIS data are free.

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Landscape Dynamics and Terrestrial Vegetation

Protocol: Vegetation Complexes Integrated Protocol

Parks Where Protocol Will Be Implemented: ALAG, ANIA, KATM, KEFJ, LACL

Vital Signs Addressed: Vegetation Composition and Structure, Land Cover/Land Use, Sensitive Vegetation Communities

Justification/Issues Being Addressed: Vegetation is integral to ecosystem function, energy transfer, and element cycling, and has the potential to both affect and respond to environmental drivers (Bennett et al. 2004). Enabling legislation for SWAN parks includes provisions for the preservation of arctic tundra, boreal forest, and coastal rainforest, among other vegetation types. Global and regional drivers expected to affect these ecosystems include increasing climatic variability, changing atmospheric chemistry and pollutant loads, and increasing variability in pathogens and pests in the forested sites.

Human-induced changes in biological diversity and modification of ecosystem processes, including primary productivity and element cycling, are two of the most pronounced ecological trends of the last century (Vitousek et al. 1997). Human activities, including motorized and nonmotorized access, resource development, subsistence activities, and activities associated with private in-holdings and/or adjacent lands, have the potential to cause rapid and long-lasting changes to ecosystems of SWAN (Bennett et al. 2004). Model simulations and empirical data indicate that a combination of land use change and climatic variation could have profound impacts on subarctic vegetation (e.g., Rupp et al. 2000, Jorgenson et al. 2001), both through vegetation loss and changes in species composition.

Changes in species composition and structure, particularly age- and size-class structure, may have important intrinsic effects at the ecosystem level (Nichols et al. 1998), and may affect habitat connectivity (Lindborg and Eriksson 2004) and landscape-scale patterns of species richness or endemism (e.g., Sabo et al. 2005). High-latitude plant communities are expected to be particularly sensitive to increased climatic variation (e.g., Spicer and Chapman 1990, Epstein et al. 2004) and physical disturbance (e.g., Auerbach et al. 1997). As such, they may serve as early indicators of environmental change on the landscape (Bennett et al. 2004). Vegetation Composition and Structure focuses on changes in vegetation in response to environmental drivers, whereas Land Cover/Land Use focuses on responses associated with human activity, e.g., vegetation loss. Sensitive Vegetation Communities highlights changes in ecosystems that are strongly controlled by physical factors (e.g., hydrology, thermal regime) or that may be at the edge of their environmental tolerance (Spicer and Chapman 1990, Lesica and McCune 2004, Epstein et al. 2004).

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

<u>Vegetation Composition and Structure</u>

Questions:

- Are the distribution and abundance of major land cover classes (incorporating vegetation composition and structure) changing through time in the SWAN landscape?
- Are species composition, vegetation structure (physiognomy), and woody species regeneration changing through time in focal ecosystems in SWAN parks?

Objectives:

- Map long-term, landscape-scale changes in the distribution and extent of major land cover classes in SWAN using satellite imagery and/or aerial photographs.
- Quantify long-term changes in the extent of land cover classes in SWAN.
- Quantify long-term changes in the distribution of land cover classes in SWAN.

- Estimate long-term changes in species richness, cover, and diversity in focal ecosystems in KATM, KEFJ, and LACL.
- Where applicable, estimate long-term changes in the density of seedlings, saplings, and mature trees and/or shrubs at these sites.

Land Cover/Land Use

Questions:

- Is vegetation loss occurring in SWAN parks?
- Are patterns of land use changing in and adjacent to SWAN parks?

Objectives:

- Map long-term, landscape-scale changes in vegetation to identify areas where vegetation loss is occurring due to human activities in and adjacent to SWAN.
- Document changes in land-use patterns in and adjacent to SWAN parks.

Sensitive Vegetation Communities

Question:

- Is species composition changing through time in focal ecosystems in SWAN parks?

Objectives:

- Estimate long-term changes in species richness, cover and diversity in focal ecosystems in KATM, KEFJ, and LACL.
- Where applicable, estimate long-term changes in the density of seedlings, saplings, and mature trees and/or shrubs at these sites.

Basic Approach:

Vegetation Composition and Structure

We will monitor vegetation composition and structure both at the landscape scale, using aerial photographs and/or remotely sensed data (e.g., Sturm et al. 2001, Zhou et al. 2001, Stow et al. 2004), and at the ecosystem scale, using targeted, ground-based sampling. Monitoring will employ the following tools:

(i) Landscape scale: Multispectral satellite imagery

Satellite imagery and aerial photos will be acquired at 10-year intervals for retrospective and future analyses of landscape-scale vegetation change (ANIA, KATM, KEFJ, LACL). Landsat MSS, TM, and ETM+ imagery are available for southwest Alaska between 1972-1977 (262 ft [80 m]) and 1990-2004 (98 ft [30 m]), and satellite coverage is expected to resume in the state by 2009. We will explore the use of widely applied change detection algorithms (e.g., univariate image differencing, change vector analysis) to identify areas of change in paired sets of images. These techniques involve the subtraction of one set of georectified spectral data from another and avoid the issue of consistency inherent in post-classification comparisons (Coppin et al. 2004). Field validation and high-resolution imagery (e.g., IKONOS) and aerial photos will be critical to interpretation of summer scenes, as will ongoing land cover classifications supported by the NPS-USGS Interagency Vegetation Mapping/Multi-Resolution Land Characteristics Program. Rectified satellite image data and derivative products will be archived in the SWAN databases or served through the USGS in the Alaska Geographic Data Clearinghouse. Interpretations will be stored as geographic information system (.shp) or flat file data, as appropriate.

(ii) Ecosystem scale: Ground-based sampling

Ground-based sampling required for the detection of more subtle, ecosystem-level change will be initiated at two to three index sites in each of three parks (KEFJ, KATM, LACL). These sites will target the dominant ecosystems in the parks, including open spruce woodland and low shrub tundra (3 and 15% of land cover in KATM and LACL, respectively), and spruce-hemlock forest (8% of cover in KEFJ). Where possible,

index sites will be collocated with instrumented weather stations and/or hydrological monitoring stations. Species cover and frequency will be measured at index sites every year for 5 yr to develop estimates of interannual variability (cf. Lesica and Steele 1996), and at 3-yr intervals thereafter using a rotating panel design. A series of parallel transects with a random start will be used to locate sampling points at each site, following a modification of the design used by the Bonanza Creek Long Term Ecological Research site (http://www.lter.uaf.edu/bcef/exp_design.cfm) and the Heartland Network (DeBacker et al. 2004).

In addition to the intensively sampled index sites, an extensive array of sites will be selected using a spatially balanced probabilistic sampling framework (e.g., GRTS design), weighted by site accessibility and landscape attributes (e.g., elevation, aspect classes). Extensive sites will be visited in the order that they are assigned and will be sampled if they meet criteria for the target environments. The extensive sites will be visited less frequently (e.g., every 7-10 yr), but will expand the area of inference from index sites. Extensive sites may or may not be instrumented, and the number of sites per park will depend on sample heterogeneity and available funding. To expand our sampling frame in the short-term, we will develop a Memorandum of Understanding with the USFS for the acquisition of Forest Inventory and Analysis (FIA) data.

Land Cover/Land Use

Methods used to detect change in Land Cover/Land Use will be the same as those used for Vegetation Composition and Structure ((i) Multispectral satellite imagery), but will focus on vegetation loss due to human activities rather than more subtle, environmentally induced vegetation change.

Sensitive Vegetation Communities

The monitoring approach for Sensitive Vegetation Communities will be similar to that for Vegetation Composition and Structure ((ii) Ground-based sampling). In sensitive communities characterized by tree or shrub cover (e.g., white spruce/tundra ecotones; ericaceous wetlands), permanent subplots consisting of nested 10.7, 43, and 108 ft^2 (1, 4, and 10 m^2) plots will be established at fixed intervals along transects for determination of cover in herbaceous, shrub, and tree layers, respectively. In herbaceous communities (e.g., alpine tundra/nunataks), nested 2.8 and 10.7 ft^2 (0.25 and 1 m^2) plots will be used to estimate species cover and frequency. The sample size required for an estimate of a single population mean (90% confidence interval) will be calculated from randomly placed quadrats in the field (cf. Elzinga et al. 1998). Plots will be sampled every 3-5 yr for the first 10 yr to determine short-term species-level variation (cf. Lesica and Steele 1996), and every 7-10 yr thereafter.

Principal Investigators and NPS Leads:

Vegetation Composition and Structure

(i) Multispectral satellite imagery

- Warren Cohen, USFS-PNW, Corvallis, OR (PI)
- Robert Kennedy, USFS-PNW, Corvallis, OR (Co-PI)
- Amy Miller, NPS-SWAN (NPS Lead)
- Page Spencer, NPS-ARO

(ii) Ground-based sampling

- Amy Miller, NPS-SWAN (NPS Lead)

Land Cover/Land Use Change

Multispectral satellite imagery

- Warren Cohen, USFS-PNW, Corvallis, OR (PI)
- Robert Kennedy, USFS-PNW, Corvallis, OR (Co-PI)
- Amy Miller, NPS-SWAN (NPS Lead)
- Page Spencer, NPS-ARO

Sensitive Vegetation Communities

Ground-based sampling
- Amy Miller, NPS-SWAN (NPS Lead)
- Page Spencer, NPS-ARO

Development Schedule, Budget, and Expected Interim Products:

Vegetation Composition and Structure

(i) Multispectral satellite imagery
2006 Develop draft protocol for change detection ($85,000).
2007 Protocol review and testing ($76,000).
2008 Implementation ($30,000).

(ii) Ground-based sampling
2007 Develop draft protocol for ground-based monitoring ($15,000).
2008 Protocol review and testing ($53,000).
2009 Implementation ($10,000-$45,000).

Land Cover/Land Use

Same as for (i) Multispectral satellite imagery, above. Costs are included in those for Vegetation Composition and Structure.
2006 Develop draft protocol for change detection.
2007 Protocol review and testing.
2008 Implementation.

Sensitive Vegetation Communities

Same as for (ii) Ground-based sampling, above. Costs for protocol development and testing are included in those for Vegetation Composition and Structure. Costs for implementation will vary with number and location of sites visited.
2007 Develop draft protocol for ground-based monitoring.
2008 Protocol review and testing.
2009 Implementation ($35,000-$60,000).

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Landscape Dynamics and Terrestrial Vegetation

Protocol: Insect Outbreaks

Parks Where Protocol Will Be Implemented: KATM, KEFJ, LACL

Justification/Issues Being Addressed: Disturbance is an important force regulating landscape pattern and process in SWAN (Bennett et al. 2004). High-latitude forests have experienced widespread mortality and/or loss of canopy cover due to insect and disease outbreaks in the past. Resultant changes in stand structure and composition have the potential to substantially impact primary productivity (Mattson and Addy 1975), fuel loads and fire regimes (Schulz 2003, McCullough et al. 1998), wildlife habitat and foraging patterns, biogeochemical cycling, and water quality (Swank et al. 1981). Spruce bark beetles (*Dendroctonus rufipennis* Kirby) and a variety of native and nonnative defoliators (e.g., birch leaf roller, *Epinotia solandriana*; amber-marked birch leaf miner, *Profensa thomsoni*; and willow-defoliating noctuid, *Sunira verberata*) occur at various levels within SWAN parks. An unidentified alder canker (*Cytospora* group) has recently caused widespread mortality of thin-leaf alder in south-central Alaska, and recent defoliation of birch, alder, and willow by a noctuid moth has occurred on approximately 6,920 ac (2,800 ha) in KATM (Wittwer 2005). Changing land use patterns and climatic variation may affect future population dynamics of insects and forest pathogens in the region (Dale et al. 2001), potentially altering forest structure and successional pathways. The current spruce bark beetle outbreak has killed 1.98-2.97 million ac (0.8-1.2 million ha) of forest on the western Kenai Peninsula (Berg 1998) and approximately 86,500 ac (35,000 ha) on the west side of Cook Inlet (Wittwer 2005). Tree-ring reconstructions indicate that most areas of the Kenai experienced regional episodes of thinning during the last two centuries, and work completed in LACL in 2005 is expected to provide a context for the current bark beetle infestation in southwest Alaska.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

Questions:

- What species of forest insects and/or pathogens are present in SWAN, and which forest communities are they affecting?
- Are outbreaks of forest insects and/or pathogens localized or widespread in SWAN parks?
- Is tree mortality due to insect or disease outbreaks increasing (i.e., is the rate of mortality increasing)?

Objectives:

- Detect the establishment of new native and nonnative insects and pathogens in SWAN parks, as identified by U.S. Forest Service (USFS) and Alaska Department of Natural Resources (ADNR) inventories.
- Use ADNR/USFS inventory data to monitor extent and rate of expansion of insect and disease outbreaks in SWAN parks over 1-, 5-, and 10-yr intervals.
- Identify areas in SWAN that have experienced the greatest insect-related mortality (e.g., post-stratify by elevation class and/or landform).

Basic Approach: Broad-scale mapping of insect and disease outbreaks can be used to monitor biotic disturbance in SWAN parks. The USFS, Alaska Region, and ADNR, Division of Forestry, conduct aerial detection mapping annually to document the extent of forest insect damage throughout large areas of the state. Aerial sketch maps (1:250,000) are converted to polygon-based geographic information system map products (http://agdc.usgs.gov/data/projects/fhm/) that are distributed with the Forest Health Condition Report. The ADNR/USFS data are available from 1989 to present and may be used in conjunction with multispectral satellite imagery (e.g., Landsat TM or equivalent) to quantify changes in the distribution and extent of forest mortality (see Land Cover and Land Use Change protocol). Areas of specific interest in SWAN parks may be mapped and/or visited by ADNR/USFS, upon request.

Principal Investigators and NPS Lead:

- Amy Miller, NPS-SWAN (NPS Lead)
- Dorothy Mortenson, NPS-SWAN
- Michael Shephard, USDA Forest Service, State and Private Forestry, Anchorage
- Roger Burnside, ADNR, Anchorage

Development Schedule, Budget, and Expected Interim Products:

This is an existing monitoring program through ADNR and USFS with no cost to NPS for development or implementation of the sampling protocol. A protocol to acquire annual ADNR/USFS forest survey data will be developed in FY 2006.

2006 Develop protocol for data acquisition.

2007 Test protocol.

2008 Implement protocol.

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Landscape Dynamics and Terrestrial Vegetation

Protocol: Volcanic and Earthquake Activity

Parks Where Protocol Will Be Implemented: ALAG, ANIA, KATM, KEFJ, LACL

Justification/Issues Being Addressed: Earthquake occurrence is common in the SWAN parks and region. This is a result of the Pacific plate moving in a northwest direction and subducting beneath the North American plate in southern Alaska, the Alaska Peninsula, and the Aleutian Islands. This plate boundary is responsible for most of the earthquakes occurring in this region. The location and magnitude of seismic events could be significant in terms of human health and safety and landscape change (mass movement).

There are 17 active volcanoes within the SWAN parks and region. Explosive volcanic eruptions, such as Katmai's Novarupta in 1912, can catastrophically disturb hundreds to thousands of square miles of landscape, profoundly affecting fluxes of water and sediment. Vegetation can be defoliated, buried, or removed, and the landscape can be mantled with tephra (airborne volcanic ejecta ranging from ash to small blocks of rock). Rivers, lakes, and valleys can be partly or completely filled with pyroclastic debris, or massive deposits from debris avalanches and pyroclastic flows.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

Questions:

- Where are the epicenters and hypocenters of earthquakes occurring in the SWAN parks and region?
- What are the magnitudes of earthquakes occurring in the SWAN parks and region?
- How many earthquakes occur in the SWAN parks and region on an annual basis?
- Where are the eruptive volcanic events occurring in the SWAN parks and region?
- What is the frequency and magnitude of volcanic events occurring in the SWAN parks and region?
- Where are the origins of ash clouds affecting the SWAN parks and region?

Objectives:

- Record the occurrence and magnitude of seismic events (earthquakes) in the SWAN parks and region.
- Record the occurrence and magnitude of volcanic events (eruptions and/or ash deposition events) in the SWAN parks and region.

Basic Approach:

- On an annual basis SWAN will acquire seismic data from the Alaska Earthquake Information Center, Geophysical Institute, University of Alaska Fairbanks (http://giseis.alaska.edu/Seis/html_docs/db2catalog.html).
- On an annual basis SWAN will acquire volcanic event data from the Alaska Volcano Observatory (AVO) (http://www.avo.alaska.edu/). AVO is a joint program of the United States Geological Survey, the Geophysical Institute of the University of Alaska Fairbanks, and the State of Alaska Division of Geological and Geophysical Surveys.
- If available, acquire remotely sensed data (i.e., Moderate Resolution Imaging Spectrometer (MODIS)) for ash events occurring in the SWAN parks and region.

Principal Investigators and NPS Lead:

- Bruce Giffen, NPS-ARO (NPS Lead)
- Page Spencer, NPS-ARO
- Dorothy Mortenson, NPS-SWAN

Development Schedule, Budget, and Expected Interim Products:

2006 Draft SOPs ($ to be determined).

2007 Test protocol.

2008 Implement protocol ($ to be determined).

Marine Nearshore

Protocol: Geomorphic Coastal Change

Parks Where Protocol Will Be Implemented: KATM, LACL, KEFJ

Justification/Issues Being Addressed: The problem of land loss/gain and landscape alteration at the marine edge is fundamental to the many issues facing coastal park resource managers. Shoreline change is a prime geo-indicator of coastal environmental resource threats within parks. The physical configuration of the SWAN coastal shoreline is dynamic and constantly changing due to coastal erosion and accretion from natural events, such as storm-driven waves, high tides, nearshore currents, rainfall and runoff, landslides, and earthquakes. Changes in the position of the shoreline affect the composition, relative abundance, and distribution of coastal habitats. Shoreline position also has jurisdictional implications for park management and affects cabins and other structures along the coast. Shape and sedimentary character of a beach (e.g., beach slope, cusp dimensions, bar position and morphology, barrier crest and berm elevation, sediment size and shape) are highly sensitive to oceanographic forcing, including deep-water wave energy, nearshore wave transformation, wave setup, storm surge, tides, and nearshore circulation. Qualitative assessments of shoreline morphology can be used as a proxy for shore-zone processes (Boak and Turner 2005).

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

Question:

- How are the position, shape, slope, and sediment character of the shoreline changing?

Objectives:

- Document changes in the width of the dry beach, position of the mean water line, the high water line, and the base of the beach.
- Document how the position of the top and toe of the bluffs is changing.
- Document how the position of foreshore and backshore vegetation is changing.
- Document how the sediment type and grain size is changing between the high water line and the base of the beach.

Basic Approach: The options for monitoring this vital sign range from simple rod and transit ground surveys to aerial LIDAR imaging. Using traditional beach across-shore survey methods, data are collected along a transect seaward from a benchmark. Conversely, remotely sensed LIDAR data are collected from an aircraft and provide topographic information over broader areas of coastline. Shoreline change metrics that can be determined from ground and LIDAR surveys are mean-high-water contour, bluff toe/top, vegetation boundary, subaerial beach volume changes, and dune crest height. Each approach requires ground truthing using traditional surveying and new GPS technology.

Protocols for the use of LIDAR are under development and testing elsewhere (Northeast Coastal and Barrier Island Network) and may be applied to SWAN if partnerships materialize that make this technique affordable. In lieu of this, we anticipate using a ground-based approach that can be integrated with other nearshore monitoring tasks. Beach profiles are relatively simple and inexpensive to collect and are extremely accurate (Morton et al. 1993, Ruggiero et al. 2000). Cross-shore profiles will be measured by differential GPS at mixed sand/gravel beaches by walking from the landward side of the primary dune (bluff), over the dune crest, across the beach, and out to wading depth at low tide. Survey-grade GPS equipment is accurate to approximately 0.75 in (2.0 cm) in both the horizontal and vertical position. GPS is not as accurate as standard terrestrial surveying using a rod and level; however, its use is justified by both the reduction in survey time and the magnitude of change observed on the high-energy beaches of SWAN.

Variables such as slope, dune toe and crest elevation, beach width, and substrate volume above a specified datum can be extracted from the beach profiles. These variables will be used as inputs to models that predict coastal shoreline change. Cross-shore beach profiles can also provide an assessment of the current shoreline position at one alongshore location. Biannual or quarterly surveys make it possible to calculate the seasonal variability of shoreline position. Twelve beach profile transects were established along the LACL-Cook Inlet coastline in 1992. Eight of these sites were resurveyed in 2004 and will be incorporated into the long-term data set for the network.

Principal Investigators and NPS Lead:

- Joel Cusick, NPS-ARO
- Alan Bennett, NPS-SWAN (NPS Lead)

Development Schedule, Budget, and Expected Interim Products:

2005 Evaluate decadal change at LACL cross-shore beach profiles and draft final report.

2006 Draft monitoring protocol and select KATM sites.

2007 Implement and test protocol.

2008 Peer review and finalize.

There will be no staff salaries, and equipment costs will be $10,000.

Literature Cited:

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Marine Nearshore

Protocol: Harbor Seal

Parks Where Protocol Will Be Implemented: ANIA, KATM, KEFJ, LACL

Justification/Issues Being Addressed: Harbor seals (*Phoca vitulina*) perform a dynamic role in the marine nearshore environment by transferring nutrients and energy though their predatory activities and by influencing the physical complexity of their environment. Thus, they may serve as indicators of status and change of the marine nearshore environment. Harbor seals also are an important resource for Alaska Natives and for the tourism industry. However, this species has suffered serious declines in abundance at several coastal areas in Alaska over the past several decades; populations in the Gulf of Alaska are of particular concern to management agencies (Boveng et al. 2003, Ver Hoef and Frost 2003).

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

Questions:

- Are numbers of harbor seals decreasing along marine coastlines of SWAN parks?
- Are numbers of occupied haul-outs of harbor seals changing over time along marine coastlines of SWAN parks?
- Is distribution of harbors seals changing along marine coastlines of SWAN parks?

Objectives:

- Devise and implement a protocol for obtaining past, present, and future survey data of harbor seals for marine coastlines of ANIA, KATM, KEFJ, and LACL from the Polar Ecosystems Program (PEP) at NMFS-National Marine Mammal Laboratory (NMML).
- Estimate long-term trends in abundance and occupancy of harbor seals at haul-outs sampled via aerial photosurvey along marine coastlines of ANIA, KATM, KEFJ, and LACL.

Basic Approach: The PEP at NMFS-NMML conducts aerial surveys of harbor seal haul-outs on a 5-year rotational basis to monitor trends in seal abundance on Alaska's marine coastlines (Boveng et al. 2003). PEP has divided Alaska's entire marine coastline into five regions (Southern southeast, Northern southeast, Gulf of Alaska, Alaska Peninsula and Bristol Bay, and Aleutian Archipelago); one region is surveyed each year. Regions are further subdivided into routes, and one observer is assigned to each route. Surveys are conducted during the time of day and time of season when maximum number of seals are known to haul out.

The survey is divided into reconnaissance and site-to-site phases. The reconnaissance flight searches every possible seal haul-out along the route, with a list of previous haul-out locations to aid in the search. One reconnaissance flight is conducted on the first day of the survey and a second one at the midway point of the survey. The first reconnaissance generates a reduced list of currently occupied new and former haul-outs that is used to devise the site-to-site route. Digital photographs of each occupied haul-out are taken to obtain counts of seals during both phases of the survey. Counts will be corrected for seals present but undetected (underwater) based on haul-out behavior of radiotagged individuals (Huber et al. 2001) from previous research at seal haul-outs in Alaska (Simpkins et al. 2003).

In addition to the statewide surveys discussed above, the Alaska Sea Life Center conducts aerial surveys of harbor seals on a seasonal basis within KEFJ. These efforts are partially funded by KEFJ.

Principal Investigators and NPS Lead:

- Dave Withrow, NMFS-NMML
- Bill Thompson, NPS-SWAN (NPS Lead)
- Dorothy Mortenson, NPS-SWAN

Development Schedule, Budget, and Expected Interim Products: Because this is an existing monitoring program within PEP at NMFS, there will be no costs to NPS for developing or implementing the sampling protocol. PEP has tentatively indicated that previous survey data for SWAN parks should be available for transfer to SWAN by the end of FY 2006.

2006 Draft SOPs ($ to be determined).

2007 Implement data acquisition protocol ($ to be determined).

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Marine Nearshore

Protocol: Marine Nearshore Integrated Protocol

Parks Where Protocol Will Be Implemented: KATM, KEFJ, LACL

Vital Signs Addressed: This protocol will address seven vital signs [Kelp and Eelgrass, Marine Intertidal Invertebrates, Seabirds, Black Oystercatcher (*Haematopus bachmani*), Sea Otter (*Enhydra lutris*), River Otter (*Lutra canadensis*), and Marine Water Quality]. The protocol will contain approximately 30 standard operating procedures (SOPs).

Justification/Issues Being Addressed: The marine coastline of SWAN spans 1,900 kilometers in the Northern Gulf of Alaska and contains almost one-third of the marine coastline in the national park system. The marine nearshore zone is defined as that portion of the park's marine coastline that stretches from the high tide line to approximately 65-ft (20-m) depth. The intertidal and subtidal areas of the nearshore habitat are brackish and saltwater coastal habitats that are some of the most productive in the Gulf of Alaska and are highly susceptible to anthropogenic perturbations. Nearshore habitats provide important feeding grounds for larger animals such as sea otter and brown bears (*Ursus arctos*) and provide nurseries for marine organisms. Contaminants such as persistent organic pollutants may be found in high concentrations in invertebrate species of the nearshore, providing pathways and potential threats to wildlife and human health.

In partnership with the USGS-BRD Alaska Science Center, USFWS, NMFS, and State of Alaska, SWAN will develop protocols and monitoring strategies for implementation of the Gulf Ecosystem Monitoring (GEM) initiative being developed by the *Exxon Valdez* Oil Spill Trustee Council (EVOS). The flagship of the GEM program will be a core monitoring program, which, when combined with the monitoring efforts of other resource agencies and research entities, will help detect environmental change over time and greatly expand understanding of the Gulf of Alaska ecosystems. The GEM conceptual framework for marine nearshore monitoring has the following elements:

1) **synoptic**—monitor a few variables everywhere, i.e., remotely and quickly sample large areas; most balanced sampling;

2) **extensive**—monitor many variables in few places, i.e., broad range of measurements at few sites across large area; detects large scale changes; and

3) **intensive**—monitor mid range of variables over moderate range of sites, i.e., fewer measurements, more areas, smaller spatial coverage; detects small-scale changes.

The vital signs and metrics to be sampled include both biological and physical elements. Plant and invertebrate species were selected that are numerically dominant, structurally important, or critical prey of specified nearshore vertebrate predators. These species were also selected because they provide a sound statistical basis for detecting change in a cost-efficient manner (Houghton et al. 1993, Highsmith et al. 1994). Physical variables to be measured will include shoreline geomorphology, water temperature, air temperature, and salinity.

Kelp and Eelgrass, along with other seagrasses, are "living habitats" that serve as a nutrient filter, provide understory and ground cover for planktivorous fish, clams, and urchins, and a physical substrate for invertebrates and algae. Kelp plants are the major primary producers in the marine nearshore, and because they are located in shallow water they could be significantly affected should there be an oil spill. Other stresses include activities that disturb the beds directly, such as dredging and anchor scars, and events that reduce the ability of light to penetrate into the water column, such as runoff (increased turbidity) or nutrient addition.

Marine Intertidal Invertebrates provide a critical prey resource for shorebirds, ducks, fish, bears, sea otters, and other marine invertebrate predators, as well as a spawning and a nursery food source for forage fish and juvenile crustaceans. Benthic invertebrates are ecologically diverse in terms of habitat and trophic requirements, have a wide range of physiological tolerances and feeding modes, are relatively sedentary, and have short generation times. They are therefore good biological indicators and generally respond much more rapidly than fishes to changes in environmental conditions.

Seabirds and sea ducks are predators near the top of marine nearshore food webs. Marine birds are long-lived, conspicuous, abundant, widespread members of the marine ecosystem and are sensitive to change. Because of these characteristics, marine birds are good indicators of change in the marine ecosystem. Many studies have documented that their behavior, diets, productivity, and survival change when conditions change. Public concern exists for the welfare of seabirds because are affected by human activities such as oil pollution and commercial fishing.

Black Oystercatchers are well suited for inclusion into a long-term monitoring program of nearshore habitats because they are long-lived; reside and rely on intertidal habitats; consume a diet dominated by mussels, limpets, and chitons; and provision chicks near nest sites for extended periods. Additionally, as a conspicuous species sensitive to disturbance, the black oystercatcher would likely serve as a sentinel species in detecting change in the nearshore community resulting from human or other disturbances.

Sea Otters (western Alaska stock) were federally listed on September 2005 as threatened. Sea otters dramatically change the structure and complexity of their nearshore ecological community and are a prime example of the top-down cascade type of food chain in which the highest trophic level can determine the populations of the lower trophic levels. Sea otters tend to be relatively sedentary in comparison to other marine mammals, eat large amounts of food, have an incidence of disease that is correlated with contaminants, and have broad appeal to the public.

River Otters live in coastal environments and select habitats close to the shore, where their chief food items are marine bottom-dwelling fishes. In the aftermath of EVOS, studies of coastal river otters in Prince William Sound indicated that they are a keystone species for the land-margin ecosystem and a "sentinel species" for monitoring levels of environmental contamination.

Marine Water Chemistry, including temperature and salinity, are critical to intertidal fauna and flora and are likely to be important determinants of both long-term and short-term fluctuations in the intertidal biotic community. Basic water quality parameters provide a record of environmental conditions at the time of sampling and are used in assessing the condition of biological assemblages.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

Kelp and Eelgrass

Question:

- What are annual trends in the abundance, distribution, and composition of kelp, eelgrass, and surfgrass?

Objective:

- Estimate long-term trends in abundance and distribution of kelp and seagrass.

Marine Intertidal Invertebrates

Questions:

- How is the annual composition and relative abundance of sessile and motile invertebrates changing in the intertidal zone?
- How is the concentration of contaminants changing in mussel tissue?

Objectives:

- Monitor long-term trends in invertebrate species richness.
- Document how the size distribution of limpets (*Tectura persona*) and mussels (*Mytilus trossulus*) is changing annually.
- Estimate long-term trends in abundance of littleneck clam (*Protothaca staminea*).
- Document how the size distributions and growth rates of littleneck clams are changing annually.
- Monitor status and trends in the concentration of metals, organochlorides, PCBs, and mercury in mussel tissue.

Seabirds

Question:

- How is the abundance of birds closely linked to the nearshore, especially harlequin ducks (*Histrionicus histrionicus*) and Barrow's goldeneye (*Bucephala islandica*), changing annually during summer and winter?

Objective:

- Estimate long-term trends in the seasonal abundance of seabirds and sea ducks.

Black Oystercatcher

Question:

- How is the relative density (pairs/linear mile [km] of shoreline) of black oystercatcher nests (breeding territories) changing annually?

Objective:

- Estimate long-term trends in relative density of black oystercatchers.

Sea Otter

Questions:

- How is abundance of sea otters changing annually? Where? Which park coastlines/nearshore areas?
- How is age-specific survival of sea otters changing annually? Where? Which park coastlines/nearshore areas?

Objectives:

- Estimate long-term trends in sea otter abundance.
- Estimate and compare age-specific survival rates of sea otters among regions within the Gulf of Alaska.

River Otter

Question:

- How is the distribution and relative abundance of coastal river otters changing annually?

Objective:

- Estimate long-term trends in river otter abundance.

Marine Water Chemistry

Questions:

- How are seasonal and annual patterns of sea surface temperature, chlorophyll a standing stock, sediment levels, and flow patterns changing in nearshore waters of Shelikof Strait, Lower Cook Inlet, and the Outer Kenai Peninsula?
- What is the daily, seasonal, and annual variation in intertidal and subtidal water temperature and salinity and how are they changing over time?

Objectives:

- Acquire regional synoptic nearshore oceanographic data collected by the Alaska Ocean Observing System (AOOS) and incorporate into regional (SWAN) data sets.
- Document daily, seasonal, and annual variability and gradients in temperature and salinity at randomly selected shallow water (< 65 ft [< 20 m]) nearshore sampling sites.

Basic Approach: In January 2004, a report was submitted to the *Exxon Valdez* Oil Spill Trustee Council that outlined several alternative sampling designs for monitoring in the nearshore (Bodkin and Dean 2003). The next phase in the effort to implement a nearshore monitoring plan requires that specific sampling sites be selected and specific SOPs be developed for each Vital Sign.

Kelp and Eelgrass Seagrasses are monitored in many regions as an indicator of nearshore habitat quality by comparing maps of resource abundance and distribution over time. An existing protocol using low-tide, oblique aerial video imagery (Harper and Morris 2004) will be used to document annual and decadal changes in occurrence and distribution of seagrasses along the entire intertidal length of the coastline. Each video frame is georeferenced with GPS coordinates. Biological mappers provide an inflight, synchronous narration of shore-zone features to supplement the imagery (e.g., identification of eelgrass or kelp in the shallow, subtidal zone).

Marine Intertidal Invertebrates Protocols for transect and quadrat-based sampling of intertidal invertebrates exist. The overall approach will be to select subsampling unit sizes such that the mean abundance per subsampling unit (for dominant species) would be large enough to afford reasonable power to detect change, but not so large as to be excessively time-consuming and inefficient. The smallest subsampling unit (2.7 ft^2 [0.25 m^2]) is larger than those used by Highsmith et al. (1994), which were found to have reasonable power to detect changes for these numerically dominant species following the *Exxon Valdez* oil spill (Peterson et al. 2001). Sampling sites are defined as 328 ft (100 m) stretches of coastline with contiguous sheltered rocky or mixed sand/gravel habitat. The approximate location of each site will be predetermined using existing shoreline maps and habitat data.

Mussels (*Mytilus trossulus*) will be collected from sheltered rocky intertidal sites (10 systematic sites within each block plus 18 selected sites). The meat of the mussels will be removed, the samples from each site combined, and the composite sample analyzed to determine the concentration of contaminants. The chemical analyses will consist of a metals screen, an organic carbon screen, a fluorescent aromatic hydrocarbon screen, and mercury analyses.

Seabirds Survey methodology will conform to established procedures used in the Gulf of Alaska to estimate the abundance of nearshore seabirds from small skiffs (Irons et al. 1988, 2000, Lance et al. 2001). The marine waters within 656 ft (200 m) of land will be divided into discrete transects and identified by geographic features, such as points of land, to facilitate orientation in the field and to separate the shoreline by habitat (Irons et al. 1988). Shoreline transects will vary in size, ranging from small islands with < 0.62 mi (< 1 km) of coastline to sections of the mainland with more than 18.6 mi (30 km) of coastline. All transects will be sampled in March and July, and the same transects will be sampled each year.

Black Oystercatcher Andres (1998) has developed boat-based survey techniques for black oystercatchers. A survey of all shoreline habitats will be conducted in mid-May, the location of all black oystercatchers will be mapped on aerial photographs, and GPS locations will be recorded. Locations with territorial pairs will be searched extensively by foot for nests. This intensive survey will be repeated once both in June and in July in an effort to locate all oystercatcher nests throughout the nesting season.

Sea Otters An SOP for sea otter surveys has been developed by Bodkin and Monson (1999) and involves: (i) aerial strip transect counts and (ii) aerial intensive search units. Sea otter habitat is sampled in two strata, high density and low density, distinguished by distance from shore and depth contour. Intensive

search units are flown at intervals dependent on sampling intensity throughout the survey period to obtain a sightability correction factor.

River Otters Relative abundance of river otters can be generated by surveying and documenting the distribution and use of latrine sites (Bowyer et al. 2003). Ben-David et al. (2005) are currently testing scat deposition rates (i.e., scats deposited/day) at latrines for estimating river otter population levels and trends among different areas of coastline in SWAN.

Marine Water Chemistry Satellites will be used for synoptic measurements of surface temperature and turbidity. Visible remote sensing (i.e., ocean color) will be used to infer the chlorophyll a standing stock, sediment levels, and flow patterns. Water temperature will be measured continuously (spring-fall) with Hobo data loggers at middle intertidal stations near long-term sheltered rocky and mixed sand/gravel sampling sites. Offshore water quality information will be provided by other programs, including AOOS, Alaska Department of Fish and Game, National Oceanic and Atmospheric Administration, Coastal Management Institute, and the Cook Inlet Regional Citizen Advisory Council.

Principal Investigators and NPS Lead:

- James Bodkin, USGS-Alaska Science Center (Project Coordinator, Sea Otter)
- Tom Dean, Coastal Resources Associates, Inc. (Project Coordinator)
- Alan Bennett, NPS-SWAN (NPS Lead)
- John Harper, Coastal and Oceans, Inc. (Kelp and Eelgrass)
- Brenda Konar, University of Alaska-Fairbanks (Marine Intertidal Invertebrates)
- Ray Highsmith, University of Alaska-Fairbanks (Marine Intertidal Invertebrates)
- David Irons, USFWS (Seabirds)
- Brad Andres, USFWS (Black Oystercatcher)
- Merav Ben-David, Univ. of Wyoming (River Otter)
- Mandy Lindeberg, NMFS-Auke Bay Lab (Water Quality/Contaminants)
- Laurel Bennett, NPS-SWAN (Water Quality/Contaminants)

Development Schedule, Budget, and Expected Interim Products:

2006 Draft SOPs and protocols, revise, and finalize GEM/SWAN Nearshore Monitoring Plan ($35,000).

2007 Test protocols and make final selection of monitoring sites ($70,000).

2008 Implement Nearshore Monitoring Plan ($ to be determined).

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Lakes, Rivers, and Fish

Protocol: Freshwater Flow Systems Integrated Protocol

Parks Where Protocol Will Be Implemented: ALAG, ANIA, KATM, KEFJ, LACL

Vital Signs Addressed: Surface Hydrology, Freshwater Chemistry, Resident Lake Fish

Justification/Issues Being Addressed: Network parks contain some of the largest and most "pristine" freshwater resources in the national park system. These include the two large lakes, Naknek Lake and Lake Clark, numerous multilake systems, and thousands of miles of rivers, including five designated "Wild Rivers"—and largely unexploited resident lake fish populations. Aquatic systems in the interior of KATM and LACL are so extensive that they form the physical template upon which nearly all biological systems are organized.

In establishing these park units, Congress recognized the importance of clean water, with a specific reference to protecting and maintaining rivers and/or lakes in their natural state in the enabling legislation for ALAG, ANIA, KATM, and LACL. Legislation for KEFJ mentions the Harding Icefield—a major source of freshwater for this park and the adjacent coastal zone.

Surface Hydrology

Groundwater, lakes, and streams comprise an interconnected flow system within the broader landscape (Riera et al. 2000). As collectors of water, energy, nutrients, solutes, and pollutants from the landscape and atmosphere, lakes and streams are interactive with their adjacent environments, integrative of the biophysical processes occurring there, and thereby sensitive to local climate and to land-use changes in and adjacent to parks.

Climate warming is decreasing glacial coverage in SWAN, shortening the length of ice cover on lakes, and increasing evaporation from water and land surfaces. This appears to be changing surface hydrology which, in turn, will also influence water chemistry, availability of aquatic habitats to fish and wildlife populations, and recreational opportunities.

Measurements of discharge and lake levels are fundamental to understanding the biophysical characteristics of the SWAN park system. Water quality and fish community parameters are also directly influenced by seasonal and annual flow patterns.

Freshwater Chemistry

Water quality—especially temperature, specific conductance, pH, dissolved oxygen, turbidity and nutrients—is important for the survival, growth, and reproduction of aquatic organisms. Temperature plays an important role in physiological processes, affecting the makeup of biological communities. Changes in water temperature may indicate climate change. Specific conductance typically reflects the ionic strength or mineralization of the water. It may signal the water source, with a high specific conductance representative of a strong groundwater influence (Brabets 2002). Alterations in pH can affect major ions and cations, total organic carbon, trace metal concentrations, and biogeochemical processes, including sulfate reduction, N_2 fixation, and organic matter decomposition (Brezonik et al. 1993). In SWAN, low pH may reflect volcanic influence. Adequate dissolved oxygen is essential for the survival of most aquatic organisms, and it can also control chemical cycling. Turbidity affects visual acuity and, through algal photosynthesis, primary productivity. Nitrogen, phosphorus, silicon fluxes, and chlorophyll concentrations are measures of nutrient loading or aquatic productivity, and may be influenced by geologic (disturbance) events such as volcanic eruptions, or reflect local lithologies and biological interactions such as anadromous fish returns or increased alder (*Alnus*; a nitrogen fixer) expansion within watersheds. Dissolved organic carbon integrates watershed and water body productivity, because much of the carbon

is derived from the watershed (Schindler et al. 1997). Dissolved organic carbon is generally proportional to the amount of wetlands in a watershed (Gergel et al. 1999) and is affected by climate change (Schindler et al. 1997).

Major ions, which provide important geochemical data, include the dissolved cations of calcium, magnesium, sodium, and potassium and the major anions of sulfate, chloride, and bicarbonate. Trace elements (including arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc) occur naturally only in minor amounts and have important influences on primary productivity, but become toxic to biota with increased concentrations. Atmospheric deposition from anthropogenic activities is a frequent cause of increased concentrations. Alkalinity measures the susceptibility of a water body to acidification.

Because water quality in SWAN parks is relatively pristine, has very little in the way of buffering capacity, and no known anthropogenicly related variance from Alaska water quality standards, our focus will be on documenting natural variability, future changes from existing conditions, and changes due to far-field effects such as climate change and atmospheric transport of pollutants.

Resident Lake Fish

Resident lake fish serve an important ecological role in SWAN parks. They represent a variety of trophic levels (omnivores, insectivores, planktivores, and piscivores) and hence reflect changes that occur in the food chain. Resident fish also provide a measure of environmental contaminants in aquatic systems, such as PCBs carried into the system by spawning salmon (Krummel et al. 2003), airborne toxic trace metals deposited directly or indirectly via melting snowpack (Wania 1997), and toxic contaminants potentially produced by mining activities (e.g., proposed Pebble Mine near LACL; see [http://www.ndmpebblemine.com/]). In addition to these characteristics, resident fish are relatively easy to sample and use a wide variety of habitats, so they are well suited to serve as environmental indicators. Resident fish play important recreational, economic, and subsistence roles as well. Several species, such as rainbow trout (*Oncorhynchus mykiss*), lake trout (*Salvelinus namaycush*), northern pike (*Esox lucius*), and Arctic grayling (*Thymallus arcticus*), provide excellent recreational opportunities to local, in-state, and out-of-state anglers, which may inject significant sources of income to local and state economies. Whitefish (*Coregonus* spp., *Prosopium* spp.) and northern pike are important subsistence species for local native Alaskans.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

Surface Hydrology

Question:

- How are the timing and magnitude of peak river discharge and lake level changing in key SWAN glacial and nonglacial systems?

Objectives:

- Monitor maximum and minimum annual daily flow, maximum and minimum annual 3-d or 7-d duration flow, and total annual water yield in selected SWAN river systems.
- Monitor annual trends in the timing and magnitude (average, maximum, minimum) of lake levels in selected SWAN flow systems.

Freshwater Chemistry

Questions:

- How are the annual maximum, minimum, and average measurements for core parameters (pH, dissolved oxygen, specific conductance, and temperature) and turbidity changing?
- How are the annual degree days changing in lakes? How are summer lake stratification patterns changing?

- How are nutrient levels (nitrogen, phosphorus, silicon), chlorophyll a, and dissolved organic carbon changing as measured in midsummer?
- How are dissolved major ions, trace elements, and alkalinity changing as measured in midsummer?

Objectives:

- Observe annual and interannual variability in maximum, minimum, and average temperature, pH, dissolved oxygen, specific conductance and turbidity in selected SWAN flow systems.
- Quantify midsummer lake profiles of temperature, specific conductance, pH, dissolved oxygen, and turbidity on an annual basis for high-priority lake systems and less frequently for other SWAN lakes.
- Estimate nutrient and chlorophyll concentrations on an annual basis in high-priority lake systems and less frequently for other SWAN lakes.
- Monitor dissolved major ions, trace elements, and alkalinity on an annual basis for high-priority lake systems and less frequently for other SWAN lakes.

Resident Lake Fish

Questions:

- Are important recreational, subsistence, and other endemic species of resident fish persisting in SWAN lakes?
- What are the trends in relative composition of resident fish communities among key lake systems within SWAN parks?
- Do nonendemic fish species occur in key lake systems in SWAN parks, and are they increasing in distribution?
- Are bioaccumulated contaminants increasing in fish communities in SWAN lakes?

Objectives:

- Estimate occupancy of important recreational, subsistence, and other endemic species of resident fish annually within high-priority lakes and every 2-10 yr within lower priority lakes in KATM and LACL.
- Estimate long-term trends in relative species richness of resident fish communities in high-priority lake systems within SWAN parks.
- Annually monitor influx of nonendemic fish species within high-priority lakes and every 2-10 yr within lower priority lakes in KATM and LACL.
- Collect and archive tissue samples of resident fish for later biocontaminant analysis every 5 yr from within high-priority lakes and every 10-15 yr within lower priority lakes in KATM and LACL.

Basic Approach: Invited experts and SWAN park staff employed a 3-tier categorization to prioritize sampling of major lakes or streams within SWAN parks to ensure that key flow systems will be monitored annually even if I&M funding is greatly reduced. Categorization criteria included access, level of use/management issues, and ecological and spatial coverage. Tier 1 (high priority) lakes and streams offer easy access and hence receive the heaviest use and management concern. Naknek and Brooks Lakes, both containing anadromous fishes, are Tier 1 lakes representative of the Naknek flow system in KATM. Tier 1 lakes in the Lake Clark flow system in LACL include Lake Clark (anadromous) and Kontrashibuna Lake (nonanadromous). Resurrection River/Exit Creek is the Tier 1 river system in KEFJ.

Tier 2 (medium priority) lakes and rivers are less accessible than their Tier 1 counterparts, and a randomly chosen subset will be sampled less frequently (e.g., 2-5 yr). These lakes and rivers are important for expanding the spatial inference beyond Tier 1 lakes and rivers, e.g., to ensure that trends observed at Tier 1 sites are present in other flow systems in the parks. Tier 3 (low priority) lakes and rivers further expand the scale of inference, but will be sampled less frequently (e.g., 10 years), if at all, because of funding constraints. However, data for certain vital sign metrics may be collected annually at Tier 2 and 3

locations where volunteer and/or park staff are seasonally present. Tier 2 and 3 lakes and rivers, by SWAN park, are:

Tier 2
ANIA: Aniakchak River drainage, including Surprise Lake
KATM: JoJo Lake, Grosvenor Lake, Murray Lake, Hallo Lake system
LACL: Kijik Lake, Lachbuna Lake, Crescent River system
KEFJ: Delusion Lake, Nuka River

Tier 3
KATM (includes ALAG): Kukaklek Lake, Battle Lake, Dakavak Lake
LACL: Twin Lakes, Telaquana Lake

Sampling within lakes and streams will be based on a combination of targeted and random selection procedures. Surface hydrology and freshwater chemistry data, in part, will be collected at the main outlet streams for the Tier 1 lakes and at bridge crossings for the Tier 1 river systems in KEFJ, whereas related data will be gathered at the deepest point of each lake. A generalized random-tessellation stratified design (GRTS; Stevens and Olsen 2004) will be used to select feeder streams in sampled lakes for collecting discharge and water chemistry data. This design also will be used to select net locations for sampling resident lake fish. Tier 2 and/or Tier 3 lakes or rivers will be stratified by lake size, water type (clear, glacial, brown), and accessibility prior to selecting a GRTS sample from the Tier 2 or 3 list. Sampling within Tier 2 or 3 locations will follow the same sampling protocols as those used in Tier 1 lakes and rivers.

Background information on spatial and temporal variability of the freshwater vital signs within these parks is limited. To determine the appropriate sampling interval, intensive sampling will occur during the initial implementation of this protocol, particularly in Tier 1 systems. Following the third year of sampling, data analysis will determine the sampling frequency for long-term monitoring.

During development of this protocol, the potential for integration with monitoring for other vital signs will be considered. In particular, co-location of tributary streams monitoring and core vegetation plots is likely.

Surface Hydrology

Stream flow will be estimated for targeted streams using acoustic Doppler current profile (ADCP) technology (Simpson 2001) and lake level measurements. ADCP is well suited for large, fast flowing rivers, such as the outlet streams for Tier 1 lakes (Tim Brabets, USGS, personal communication). Unfortunately, equipment and training for this method is expensive. USGS charges for stream gaging are also quite high (> $32,000/yr per stream), reflecting the logistical challenges in access. Brabets (2002) found a good relationship ($r^2 = 0.98$) between lake levels in Lake Clark and discharge in the Newhalen River. We are currently developing a cooperative agreement with USGS to assess this methodology for estimating stream flow in other Tier 1 outlet streams. If proven feasible, SWAN or park staff would record lake levels, whereas USGS would provide stream profiles and ADCP discharge measurements on a 2-5 yr basis.

Stage level is continuously recorded at Exit Creek and the Resurrection River by the National Weather Service River Forecast Office, with data available at (http://aprfc.arh.noaa.gov/cgi-bin/ahps.cgi?pafc&resa2).

Freshwater Chemistry

Continuous recorders (YSI 6600 or 6920) for temperature, pH, dissolved oxygen, conductivity, and turbidity will be placed in the Naknek River (KATM), in Exit Creek (KEFJ), and in the Newhalen River (LACL) following USGS protocols (Wagner et al. 2000). Temperature data logger (Onset HOBO and TidBit) strings will be anchored in midlake at ice out, and retrieved in late fall. In midsummer, lake profiles for the same parameters plus Secchi depth will be measured at the deepest part of the Tier 1 lakes (Gorransson et al. 2004). During implementation, measurements will be taken every 3 wk during the open-

water season and at more than one location in the lakes (e.g., Chamberlain 1989, Wilkens 2002) to ensure that sampling is representative. Previous studies have shown SWAN lakes to be only weakly (Wilkens 2002, Chamberlain 1989) or discontinuously (LaPerriere 1997) stratified, and Wilkens (2002) found that in some years, stratification only lasted through July. Surface water samples, collected concurrently, will be analyzed for total phosphorus, total nitrogen, chlorophyll a, dissolved organic carbon, alkalinity, and a suite of selected major ion and trace elements. Temperature data, core parameters, and water chemistry samples will also be collected in selected inlet streams. Protocol will be guided by USGS methods and include a quality assurance plan and SOP for data entry into STORET.

Resident Lake Fish

Species Occupancy and Relative Species Richness. We will use beach seines and multimesh gill nets (Appelberg 2000) to sample resident fish species in selected lakes every 3–5 yr, where lake selection will additionally be restricted to those with a boat available for sampling. Netting effort will be standardized and recorded for each net location. Each lake first will be stratified by shoreline slope, and then these strata will be stratified further by distance to nearest tributary. A GRTS sample will be chosen from each stratum to identify net locations. We will use catch data in robust design, mark-recapture models (Pollock 1982) to estimate both occupancy (MacKenzie et al. 2003) of key species and relative species richness (Cam et al. 2000) of resident fish communities within selected SWAN lakes across time. Relative species richness is the ratio of resident fish species present in a given lake to the maximum number present in the relevant flow system. Year will be the primary occasion and net location will be the secondary occasion in the robust design framework. These mark-recapture approaches adjust for incomplete detectability at individual (occupancy) and species (relative richness) levels during sampling periods.

Biocontaminants. Alaska Department of Environmental Conservation (ADEC) has been collecting and analyzing fish in Alaska for baseline information on contaminant levels since 2001. During protocol development activities in LACL in 2005, SWAN collected and prepared a sample of resident fish species as per ADEC protocol and submitted them to ADEC for analyses. ADEC had agreed to pay for laboratory analyses. SWAN will pursue establishment of a similar agreement with ADEC or other relevant agency to analyze subsets from future samples of resident fish.

Principal Investigators and NPS Leads:

Surface Hydrology

- Laurel Bennett, NPS-SWAN (NPS Lead)
- Ron Rickman, USGS-WRD

Freshwater Chemistry

- Laurel Bennett, NPS-SWAN (NPS Lead)

Resident Fish

- Dan Young, NPS-LACL
- Troy Hamon, NPS-KATM
- Laurel Bennett, NPS-SWAN (NPS Lead)

Development Schedule, Budget, and Expected Interim Products:

Surface Hydrology

2006 Initiate cooperative agreement with USGS ($60,000).

2007 Develop draft protocol ($25,000).

2008 Implement and test ($25,000).

2009 Peer review and finalize ($25,000).

Freshwater Chemistry

2006 Develop and test draft protocol ($100,000).

2007 Implement protocol ($100,000).

Resident Lake Fish

2005 Draft SOPs ($15,000).

2006 Test protocols ($20,000).

2007 Implement protocol ($25,000).

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Protocol: Salmon

Parks Where Protocol Will Be Implemented: ALAG, ANIA, KATM, KEFJ, LACL

Justification/Issues Being Addressed: Pacific salmon (*Oncorhynchus spp.*) play a critical role in maintaining productivity of many freshwater and adjacent terrestrial systems in SWAN parks by transporting marine-derived energy and nutrients upstream, by consumption of returning spawners by terrestrial predators, and by processes related to the decomposition and redistribution of post-spawning carcasses and their nutrients (Naiman et al. 2002, Schindler et al. 2003). Adult spawners provide a crucial food resource to brown bears (*Ursus arctos*), an excellent recreational opportunity to anglers, and an important subsistence and cultural resource to Native Alaskans. Sockeye (*Oncorhynchus nerka*) is an especially important species in this regard within SWAN parks and is specifically named in the enabling legislation of LACL. Therefore, monitoring abundance and condition of sockeye salmon returning to spawn (escapement) is of paramount importance to sustain this critical species. In addition, tracking spawner distribution and number of recruits per spawner within streams and lakes across time provides a measure of habitat quality and change (Hilborn et al. 2003). Changes in timing of spawning runs may indicate climatic shifts. Freshwater residence time and condition of out-migrating juvenile salmon are used to indirectly measure productivity of natal habitats.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

Questions:

- Are sockeye salmon abundance and productivity changing in SWAN parks?
- Is the timing of upstream sockeye salmon migration and spawning changing in SWAN parks?
- Are the number of recruits per spawner, freshwater residence time, or body condition of sockeye salmon changing in SWAN parks?

Objectives:

- Devise and implement a protocol for obtaining past, present, and future data from ADF&G on spawner abundance and distribution, timing of spawning runs, and freshwater residence time of sockeye salmon from sampled systems in SWAN parks.
- Estimate long-term trends in spawner abundance, growth rates and distribution, timing of spawning runs, and freshwater residence time and body condition of sockeye salmon in SWAN parks.

Basic Approach: *Spawner Abundance, Distribution, and Run Timing*. ADF&G currently uses a combination of counting towers, a sonar station, a weir, and aerial surveys to monitor abundance and/or distribution of spawning sockeye salmon in selected streams and lakes within SWAN parks. Returning sockeye are counted from towers from both sides of a stream for 10 min each hour during the spawning runs; estimates are multiplied by 6 to generate an estimate of total daily and seasonal escapement (Fair 2003). ADF&G operates counting towers adjacent to KATM on the Naknek River and on the Alagnak River. In addition, USGS-BRD Alaska Science Center operates a counting tower for spawning sockeye salmon on the Newhalen River, which drains Lake Clark (Woody 2004), although funding for this operation is secured only through 2007. ADF&G uses a weir to monitor sockeye salmon returning to spawn in Delight Lake in KEFJ (Edmundson et al. 2001), operates a sonar station on Crescent River in LACL to record spawning sockeye salmon passing through its sensors (King et al. 1993), and conducts aerial surveys for spawner abundance and distribution of all five Pacific salmon in selected streams and lakes in ANIA, ALAG, KATM, and LACL.

Spawner Productivity and Body Condition. We will calculate number of recruits per spawner (Hilborn et al. 2003). Scales taken from returning spawners and from archived samples can be used to measure

growth rates in freshwater and in the ocean. Additionally, body condition (e.g., weight/length^3) of juvenile and adults fish measured in the field provides an index of vitality.

Freshwater Residence Time. ADF&G collects scales from a subsample of sockeye salmon captured by beach seine as they pass counting towers in the Naknek and Alagnak Rivers and from a subsample of fish passing through the weir at Delight Lake. USGS-BRD also collects scales from fish passing its counting tower on the Newhalen River. In addition to the measurements for growth and condition, these scales are analyzed to estimate length of freshwater residence for each annual run of sockeye salmon.

Principal Investigators and NPS Lead:

- Troy Hamon, NPS-KATM
- Dan Young, NPS-LACL
- Laurel Bennett, NPS-SWAN (NPS Lead)

Development Schedule, Budget, and Expected Interim Products: Because this is an existing monitoring program, costs to SWAN will be limited to those incurred for analyzing body condition and growth data from scales.

2006 Draft SOPs ($ to be determined).

2007 Implement and test data acquisition protocol ($ to be determined).

2008 Peer review and finalize ($ to be determined).

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Protocol: Brown Bear

Parks Where Protocol Will Be Implemented: ALAG, ANIA, KATM, LACL

Justification/Issues Being Addressed: Brown bears (*Ursus arctos*) are an integral part of SWAN parks and are specifically mentioned in the enabling legislation of ANIA, KATM, and LACL. These animals play important ecological roles as top predators influencing population dynamics of other species and as means of nutrient transfer from spawning salmon (*Oncorhynchus* spp.) to the terrestrial system (Gende et al. 2002). Moreover, ALAG, ANIA, KATM, and LACL support high densities of brown bears; in fact, estimated densities of brown bears along the KATM coastline are the highest reported in North America (Sellers et al. 1999). Brown bears are drawn to these areas because of the abundant salmon runs (Hilderbrand et al. 1999), which also draw sport fishing enthusiasts from around the world. The presence of the bears has begun to draw larger numbers of bear viewers during the past two decades (National Park Service 2004). In addition, the Alaska Board of Game is interested in opening more bear hunting opportunities on state and federal land adjacent to these parks. The impacts of high numbers of backcountry anglers, hunters, and recreationalists on bear foraging behavior, habitat use, and survival are largely unknown, particularly at coastal sites, where bears feed heavily on salt marsh vegetation in addition to fish. Further, brown bears in ALAG, ANIA, KATM, and LACL are subject to subsistence hunting and are available for sport hunting in the preserves.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

Question:

- Are numbers and distribution of brown bears remaining stable in ALAG, ANIA, KATM, and LACL?

Objective:

- Estimate long-term trends in abundance and area of occupancy of brown bears from a random sample of relevant elevations and terrains in ALAG, ANIA, KATM and LACL.

Basic Approach: An aerial double-count, line transect method (Quang and Becker 1996, 1997, 1999) will be used to estimate abundance and distribution of brown bears in ALAG, ANIA, KATM, and LACL. The double-count feature is used to relax the assumption of complete detectability of bears along the sampled transects. Using program AdfgBearTrans (see Becker 2001), random transects are selected from relevant habitats within each park across a variety of elevations and terrains (see Quang and Becker 1999 and Becker 2001 for details). A pilot and observer in a fixed-wing aircraft survey each selected transect and record perpendicular distances to each detected bear. Independence between observers is ensured through use of a curtain between the pilot and rear passenger. Distances to detected bears are estimated via flyover and recording the bear's location on a GPS unit. Other covariate information is collected at each detection, including bear species (in case black bears are detected), group size, group type (sex and age), activity at time of detection, percent vegetational cover and snow cover at detection point, and which observer (pilot, passenger, or both) detected the bear. Surveys are conducted in May after bears emerge from winter dens but prior to leaf-out.

Principal Investigators and NPS Lead:

- Tammy Olson, NPS-KATM
- Judy Putera, NPS-LACL
- Jim Woolington, ADF&G
- Bill Thompson, NPS-SWAN (NPS Lead)

Development Schedule, Budget, and Expected Interim Products: NPS and ADF&G have tested the double-count, line transect method in KATM and LACL.

2008 Draft SOPs ($ to be determined).

2009 Test protocols ($ to be determined).

2010 Implement protocol ($ to be determined).

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Protocol: Wolf

Parks Where Protocol Will Be Implemented: ALAG, ANIA, KATM, LACL

Justification/Issues Being Addressed: Wolves (*Canis lupus*) are top predators in terrestrial systems within SWAN parks and hence can significantly influence population dynamics of their ungulate prey species (Miller et al. 2001). They also can indirectly affect structure, composition, and parkwide patterns of vegetation communities through their influence on ungulate abundance and distribution. Further, because of its cascading effects through various trophic levels, wolf predation is a key component of biodiversity (Ripple and Beschta 2004). Recent declines and shifts in spatial distribution of the Mulchatna Caribou Herd (Woolington and McDonald 2003) could potentially have a detrimental effect on wolf abundance and distribution in LACL and KATM, especially if this herd shifts to outside park boundaries, where wolves are subject to aerial hunting and other forms of harvest.

Wolves are found over most of SWAN at densities that are correlated with variations in ungulate biomass, and they are known to readily colonize new habitats as prey become available. In Alaska, conflicts among people with different interests in wolves are intense. Wolves can be a major predator of moose and caribou in national parks and preserves. Subsistence and sport hunters desire fewer wolves because they compete for game resources, whereas nonconsumptive park users desire wolves for viewing and photography. Because of these challenges, park managers need long-term data on wolf numbers, wolf prey, and natural processes such as vegetation succession that influence their populations.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

Question:

- What are the trends in wolf populations within SWAN parks?

Objective:

- Estimate long-term trends in abundance and distribution of wolves from randomly sampled areas in SWAN parks.

Basic Approach: The sample unit probability estimator (SUPE; Becker et al. 1998) design will be used to estimate abundance of wolves in SWAN parks. SUPE is a stratified network (or snowball) sampling design based on aerially detecting and following fresh animal tracks in the snow from beginning to end. The length of a track is used to calculate its encounter probability during the survey, which then is used in a Horvitz-Thompson estimator (Horvitz and Thompson 1952) to estimate abundance. The assumptions of this design are: (i) all wolves move during the period of interest; (ii) wolf tracks are easily identifiable from a slow, low-flying aircraft; (iii) tracks are continuous; (iv) track lengths (movements) are not influenced by the survey aircraft; (v) fresh wolf tracks can be distinguished from old tracks; (vi) all fresh wolf tracks are detected within searched units; (vii) fresh tracks can be followed from beginning to end; and (viii) pack size of detected wolves is correctly recorded (Becker et al. 1998).

Each park is divided into 3.9-15.8 mi^2 (10-41 km^2) rectangular or square quadrats (sampling units) that are assigned to one of three strata. Strata represent areas of low, medium, and high perceived probability of detecting wolf tracks based on previous experience. Sampling units are randomly chosen to be surveyed within each stratum based on the approximate percentages of 65, 40, and 20 for high, medium, and low strata, respectively, which will focus survey effort in those strata where tracks have the highest probability of detection. Each selected unit is aerially surveyed for wolf tracks by a pilot and experienced observer in a Super Cub within 24–48 hr after snowfall (2–3.9 in [5–10 cm]) or after strong winds have subsided after a snowfall. Detected tracks are followed until wolves or their dens are located (Becker et al. 1998, Becker et al. 2004). Results of abundance surveys also will provide an estimate of spatial distribution.

Principal Investigators and NPS Lead:

- Howard Golden, ADF&G
- Lem Butler, ADF&G
- Jim Woolington, ADF&G
- Judy Putera, NPS-LACL
- Bill Thompson, NPS-SWAN (NPS Lead)

Development Schedule, Budget, and Expected Interim Products: ADF&G has a well-established protocol for surveying wolves that has been successfully implemented in 11 locations across Alaska (Becker et al. 2004).

2008 Draft SOPs ($ to be determined).

2009 Test protocols ($ to be determined).

2010 Implement protocol ($ to be determined).

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Protocol: Wolverine

Parks Where Protocol Will Be Implemented: ALAG, ANIA, KATM, KEFJ, LACL

Justification/Issues Being Addressed: Wolverines (*Gulo gulo*) serve an important ecological role as scavengers and predators in SWAN parks and are a significant economic resource to fur trappers. Moreover, they are effective indicators of the cumulative effects of changes in human harvest and other activities, habitat, and prey populations. Wolverines typically occur at low population densities and are sparsely distributed across the landscape. Their reproductive potential is low relative to other furbearers; hence they take much longer to rebound from population declines. Overharvesting is the greatest potential threat to wolverine populations (Banci 1994), but they also are susceptible to displacement from prime habitats due to human disturbances such as snowmobiling, climate-induced reductions in habitat, and declines in prey populations, such as caribou. For instance, recent declines and shifts in spatial distribution of the Mulchatna Caribou Herd (Woolington and McDonald 2003) could have a detrimental effect on wolverine abundance and distribution in LACL and KATM.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

Question:

- What are the trends in wolverine populations within SWAN parks?

Objective:

- Estimate long-term trends in abundance and distribution of wolverines from randomly sampled areas in SWAN parks.

Basic Approach: The sample unit probability estimator (SUPE; Becker et al. 1998) design will be used to estimate abundance of wolverines in SWAN parks. SUPE is a stratified network (or snowball) sampling design based on aerially detecting and following fresh animal tracks in the snow from beginning to end. The length of a track is used to calculate its encounter probability during the survey, which then is used in a Horvitz-Thompson estimator (Horvitz and Thompson 1952) to estimate abundance. The assumptions of this design are: (i) all wolverines move during the period of interest; (ii) wolverine tracks are easily identifiable from a slow, low-flying aircraft; (iii) tracks are continuous; (iv) track lengths (movements) are not influenced by the survey aircraft; (v) fresh tracks can be distinguished from old tracks; (vi) all fresh tracks are detected within searched units; (vii) fresh tracks can be followed from beginning to end; and (viii) group size of detected wolverines is correctly recorded (Becker et al. 1998).

Each park is divided into 9.7 mi^2 (25 km^2) rectangular or square quadrats (sampling units) that are assigned to one of three strata. Strata represent areas of low, medium, and high perceived probability of detecting wolverine tracks based on previous experience. Sampling units are randomly chosen to be surveyed within each stratum based on the approximate percentages of 65, 40, and 20 for high, medium, and low strata, respectively, which will focus survey effort in those strata where tracks have the highest probability of detection. Each selected unit is aerially surveyed for wolverine tracks by a pilot and experienced observer in a Super Cub within 24–36 hr after snowfall (2–3.9 in [5–10 cm]) or after strong winds have subsided after a snowfall. Detected tracks are followed until wolverines or their dens are located (Becker et al. 1998, Becker et al. 2004). ADF&G used the SUPE design to estimate wolverine abundance in the Kenai Mountains during 1995 (Golden 1996) and in the upper Turnagain Arm and the Kenai Mountains during 2004 (ADF&G and NPS, unpublished data). Results of abundance surveys also will provide an estimate of spatial distribution.

Principal Investigators and NPS Lead:

- Howard Golden, ADF&G
- Judy Putera, NPS-LACL
- Bill Thompson, NPS-SWAN (NPS Lead)

Development Schedule, Budget, and Expected Interim Products: SWAN provided $23,000 to ADF&G and LACL personnel to test the SUPE design for estimating wolverine abundance in LACL during FY 2005, but weather conditions did not allow the survey to be performed, so field testing has been rescheduled for FY 2006.

2008 Draft SOPs ($ to be determined).

2009 Test protocols ($ to be determined).

2010 Implement protocol ($ to be determined).

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Woolington, J. D., and M. G. McDonald. 2003. Caribou management report: Mulchatna herd. Pages 34-52 *in* C. Healy, editor. Caribou management report of survey-inventory activities, 1 July 2000-30 June 2002. Alaska Department of Fish and Game, Juneau. Online. (http://www.wildlife.alaska.gov/pubs/techpubs/mgt_rpts/ca03mt-sc-int.pdf). Accessed 26 July 2005.

Protocol: Moose

Parks Where Protocol Will Be Implemented: ALAG, ANIA, KATM, LACL

Justification/Issues Being Addressed: Moose (*Alces alces*) are an integral component of terrestrial systems in ALAG, ANIA, KATM, and LACL. During cycles of high abundance, this species has the potential to influence structure and function of terrestrial systems both through its browsing effects on vegetational communities (Naiman 1988) and through its role as a prey species. Thus, tracking abundance and distribution of moose provides important information on dynamics of terrestrial systems. Further, the bull:cow ratio is useful for monitoring their reproductive potential. Moose also are an important subsistence and cultural resource to local Native Alaskans and provide significant recreational opportunities for resident hunters. Changes in numbers and distribution of moose are anticipated in response to climate-induced changes in their habitats.

NPS staff have worked in cooperation with ADF&G to conduct annual fall surveys of moose in established trend count areas (TCAs) since the 1970s. However, aerial surveys of moose TCAs sometimes lacked consistent application of methods and did not account for sightability. More rigorous surveys are needed to minimize sampling error and enhance comparability of long-term data for the purpose of managing moose harvest and understanding plant-herbivore-predator interactions.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

Questions:

- Are abundance, sex-age composition, and distribution of moose changing in ALAG, ANIA, KATM, and LACL?
- Are shifts in moose distribution occurring in ALAG, ANIA, KATM, and LACL and, if so, are they occurring evenly across ecoregions and/or state Game Management Units?

Objective:

- Estimate long-term trends in abundance, sex composition (bulls:100 cows), age composition (calves:100 cows), and distribution of moose from a random sample of areas in ALAG, ANIA, KATM, and LACL.

Basic Approach: A modified version of the aerial survey method of Gasaway et al. (1986) within stratified random samples will be used to estimate abundance, distribution, and sex-age composition of moose in ALAG, ANIA, KATM, and LACL. A sightability model (Drummer and Aho 1998) will be used to estimate the sightability of moose within surveyed units. A sightability study composed of 160 trials recently conducted in LACL concluded that habitat type, percent snow cover, and group size were the major factors affecting moose sightability. In addition to numbers, age, and sex of detected moose, data for the three sightability factors will be collected during aerial surveys of randomly sampled units within each of four strata in LACL each November. Strata were defined based on perceived densities of moose (high, medium, and low), which were linked to habitat. However, strata could be created based on nonchanging factors (e.g., elevation, slope, and aspect) that could be linked to moose densities. Survey data will be analyzed using a computer program provided by Dr. Thomas Drummer of Michigan Tech University. This model will have to be field-tested in ALAG, ANIA, and KATM to assess its applicability in those locations.

Principal Investigators and NPS Lead:

- Judy Putera, NPS-LACL
- Tammy Olson, NPS-KATM
- Lem Butler, ADF&G
- Bill Thompson, NPS-SWAN (NPS Lead)

Development Schedule, Budget, and Expected Interim Products: LACL completed a project in 2005 that produced a moose sightability model for the park. The applicability of this model and method, or an alternative method (e.g., double-count, line transect sampling [Manly et al. 1996]), to ALAG, ANIA, and KATM will have to be evaluated.

2008 Draft SOPs ($ to be determined).

2009 Test protocols ($ to be determined).

2010 Implement protocol ($ to be determined).

Literature Cited:

Drummer, T. D., and R. W. Aho. 1998. A sightability model for moose in upper Michigan. Alces **34**:15-19.

Gasaway, W. C., S. D. DuBois, D. J. Reed, and S. J. Harbo. 1986. Estimating moose population parameters from aerial surveys. Biological Papers of the University of Alaska No. 22, Fairbanks.

Manly, B. F. J., L. L. McDonald, and G. W. Garner. 1996. Maximum likelihood estimation for the double-count method with independent observers. Journal of Agricultural, Biological, and Environmental Statistics **1**:170-189.

Naiman, R. J. 1988. Animal influences on ecosystem dynamics. BioScience **38**:750-752.

Protocol: Caribou

Parks Where Protocol Will Be Implemented: ALAG, ANIA, KATM, LACL

Justification/Issues Being Addressed: Caribou are an integral component of terrestrial systems in ALAG, ANIA, KATM, and LACL. During cycles of high abundance, this species has the potential to influence structure and function of terrestrial systems both through its grazing effects on vegetational communities (Naiman 1988) and through its role as a prey species. Caribou also are an important subsistence and cultural resource to local native Alaskans and provide significant recreational opportunities for resident hunters. Caribou are specifically mentioned as a species of interest in the enabling legislation of LACL. The Northern Alaska Peninsula Caribou Herd (NAPCH) and Mulchatna Caribou Herd (MCH) occur in KATM, NAPCH is present in ANIA, and MCH also occurs in LACL. KATM and LACL have resident animals as well. The MCH was estimated at 18,600 animals in 1981, increased to a peak of over 200,000 animals in 1996, and has declined to an estimated 85,000 animals in 2004. Changes in numbers and distribution of caribou are anticipated in response to climate-induced changes in their habitats.
Caribou herds annually move over extensive areas, sometimes migrating hundreds of kilometers between wintering areas and calving-summering grounds. Movement patterns of caribou can be complicated and unpredictable, subherds periodically intermingle with the main herd, and the location of calving and wintering areas can change annually. National Park Service staff have worked in cooperation with ADF&G to conduct annual caribou surveys (1986-2004). Ongoing caribou monitoring will increase understanding of natural and human-related fluctuations of the herd and provide information that park managers need to respond to management of subsistence and sport hunting.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

Question:

- Are abundance, sex-age composition, and distribution of caribou herds changing in ALAG, ANIA, KATM, and LACL?

Objectives:

- Devise and implement a protocol for obtaining past, present, and future survey data of NAPCH and/or MCH in ALAG, ANIA, KATM, and LACL from the multiagency team performing aerial photosurveys and radiotelemetry flights.
- Estimate long-term trends in abundance, calf:cow ratios, extent of occurrence, and area of occupancy of NAPCH and/or MCH in ALAG, ANIA, KATM, and LACL.

Basic Approach: ADF&G, ADNR, BLM, USFWS, and NPS are cooperating to monitor caribou in the NAPCH and/or MCH. Surveys are based on the protocol described in Valkenburg et al. (1985), and the following is summarized from the "Mulchatna Caribou Herd Monitoring Plan" (J. Woolington, ADF&G, unpublished draft). A large number of caribou in these herds have active radio and satellite transmitters; additional animals will be captured and radiocollared as needed, depending on mortality rates and funding availability. Two types of aerial surveys are employed to gather distribution and demographic data: (i) radiotelemetry flights and (ii) reconnaissance flights. Radiotelemetry flights are performed during calving surveys in late May to estimate productivity, are done in conjunction with photosurveys in late June/early July to estimate herd size, and are conducted in early October to record distribution prior to fall composition counts. Directed reconnaissance uses relocations of collared individuals and visual searches for noncollared animals to estimate numbers. These data are supplemented by incidental observations of caribou during the course of other work or surveys. Aerial photos are taken of large postcalving aggregations of caribou during radiotelemetry/photosurvey flights in late June/early July, and these photos are used to enumerate individuals. These various sources of seasonal data are combined to estimate annual patterns of movements and spatial distribution.

Principal Investigators and NPS Lead:

- Judy Putera, NPS-LACL
- Jim Woolington, ADF&G
- Lem Butler, ADF&G
- Bill Thompson, NPS-SWAN (NPS Lead)
- Dorothy Mortenson, NPS-SWAN

Development Schedule, Budget, and Expected Interim Products: Because this is an existing monitoring program, there will be no costs to SWAN for developing or implementing the sampling protocol.

2006 Draft SOPs ($ to be determined).

2007 Implement and test protocol for harvesting data ($ to be determined).

Literature Cited:

Naiman, R. J. 1988. Animal influences on ecosystem dynamics. BioScience **38:**750-752.

Valkenburg, P., D. A. Anderson, J. L. Davis, and D. J. Reed. 1985. Evaluation of an aerial photocensus technique for caribou based on radiotelemetry. Pages 287-299 *in* T. C. Meredith and A. M. Martell, editors. Proceedings of the Second North American Caribou Workshop, McGill Subarctic Research Paper No. 40, McGill University, Montreal, Quebec, Canada.

Woolington, J. D., and M. G. McDonald. 2003. Caribou management report: Mulchatna herd. Pages 34-52 *in* C. Healy, editor. Caribou management report of survey-inventory activities, 1 July 2000-30 June 2002. Alaska Department of Fish and Game, Juneau, Alaska, USA. Online. (http://www.wildlife.alaska.gov/pubs/techpubs/mgt_rpts/ca03mt-sc-int.pdf). Accessed 26 July 2005.

Protocol: Bald Eagle

Parks Where Protocol Will Be Implemented: ALAG, ANIA, KATM, KEFJ, LACL

Justification/Issues Being Addressed: Bald eagles (*Haliaeetus leucocephalus*) are keystone predators on avian (e.g., seabirds) and fish (e.g., salmon) populations and hence serve an important ecological role in freshwater and marine coastal systems in SWAN parks. Their occurrence and reproductive performance may be influenced by weather conditions, toxic contaminants, food availability, human-related impacts, and climate (Grim and Kallemeyn 1995). Bald eagles may not attempt to nest or their attempt may fail if breeding conditions are unsuitable during a given year. Thus, their nest occupancy and reproductive rates may be useful indicators of both current condition and long-term change (variability) of freshwater and marine coastal systems. KATM, KEFJ, and LACL all contain large breeding populations of bald eagles, and this species is specifically mentioned in enabling legislation for LACL. Bald eagle populations are under continuing threat from human-related impacts such as ecotourism, sport and commercial fishing, timber harvest, potential mining activities adjacent to the parks, and potential oil spills or other accidents along marine coastlines. Further, global climate change will have an unknown effect on their forage base and nesting habitat.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

Questions:

- Are bald eagles successfully reproducing in SWAN parks?
- Are nest occupancy rates of bald eagles changing over time in SWAN parks?
- Does nest success differ between bald eagles nesting along interior rivers/lakes and those nesting along marine coastlines in SWAN parks?

Objective:

- Estimate long-term trends in nest occupancy and productivity from a random sample of bald eagles nesting along interior rivers/lakes and marine coastlines of SWAN parks.

Basic Approach: The USFWS currently performs periodic surveys of nesting bald eagles along the Pacific coast of the Alaska Peninsula. Frequency of surveys is dependent on funding. They employ a stratified random sampling design in which the coastline is partitioned into approximately 20.7 km^2 quadrats, which are stratified into low, medium, and high perceived densities of nesting eagles based on kilometers of shoreline with certain physical characteristics (e.g., exposed shoreline with strong tidal influences; Grier 1977, Grier et al. 1981, Hodges et al. 1984). Three surveyed quadrats occur along the coastline of KATM and 1.5 quadrats fall within ANIA coastline boundaries. An aerial survey using fixed-wing aircraft is performed during maximum nest occupancy in late April-early May. A pilot/observer and second observer search for active nests and record locations and nest contents of detected nests. Steps should be taken to ensure these observations are independent with observers conferring shortly after each nest detection to determine whether either or both detected the nest. When funding is available, a second flight is conducted in July to revisit detected nests to estimate nest productivity. KATM has previously conducted aerial surveys for nesting bald eagles in the Naknek drainage when personnel and funding were available.

LACL conducts a minimum of two aerial surveys every year of bald eagle nests known to be active during the previous 2-3 yr in each of three subareas: (i) marine coastline and shorelines of associated lakes and rivers ("Coast"); (ii) shorelines of Lake Clark and associated rivers ("Lake Clark"); and (iii) shorelines of major lakes and rivers north of Lake Clark ("Interior"). In addition, all potential nesting habitats are intensively searched for new nests in the Coast and Lake Clark subareas in alternate years, with the Interior

subarea intensively searched with one of the other subareas during the third year. Nests are surveyed for initial occupancy during May, and active nests are revisited to estimate productivity during July.

KEFJ has previously conducted boat- and ground-based surveys of nesting bald eagles during spring and summer to estimate occupancy and productivity. Frequency of surveys is dependent on funding.

SWAN will adopt the USFWS protocol to annually survey interior lakes and rivers via fixed-wing aircraft in KATM. Existing surveyed quadrats along ANIA and KATM coastlines will be supplemented with additional randomly chosen quadrats. The USFWS protocol will be implemented in KEFJ except surveys will be helicopter-based to increase nest detections and observer safety. Depending on availability of a trained observer, pilot/observer, and plane, SWAN could supplement existing LACL surveys by conducting intensive nest searches in subareas not intensively searched by LACL staff during a given year.

Principal Investigators and NPS Lead:

- Susan Savage, USFWS-Alaska Peninsula/Becharof NWR
- Judy Putera, NPS-LACL
- Mike Tetreau, NPS-KEFJ
- Bill Thompson, NPS-SWAN (NPS Lead)

Development Schedule, Budget, and Expected Interim Products: USFWS has a well-established protocol for surveying nesting bald eagles. However, availability bias is not addressed under the current protocol. Because of the large effort and expense associated with radiomarking and tracking bald eagles, an evaluation of availability bias of nests in forested habitats would most likely be addressed in partnership with any future research projects studying radiomarked eagles in SWAN parks.

2008 Draft SOPs ($ to be determined).

2009 Test protocols and augment existing monitoring sites ($ to be determined).

2010 Implement protocol ($ to be determined).

Literature Cited:

Grier, J. W. 1977. Quadrat sampling of a nesting population of bald eagles. Journal of Wildlife Management **41**:438-443.

Grier, J. W., J. M. Gerrard, G. D. Hamilton, and P. A. Gray. 1981. Aerial-visibility bias and survey techniques for nesting bald eagles in northwestern Ontario. Journal of Wildlife Management **45**:83-92.

Grim, L. H., and L. W. Kallemeyn. 1995. Reproduction and distribution of bald eagles in Voyageurs National Park, Minnesota, 1973-1993. U.S. Department of Interior, National Biological Service, Biological Science Report 1, Washington, D.C.

Hodges, J. I., J. G. King, and R. Davies. 1984. Bald eagle breeding population survey of coastal British Columbia. Journal of Wildlife Management **48**:993-998.

Human Activities

Protocol: Resource Harvest for Subsistence and Sport

Parks Where Protocol Will Be Implemented:

Sport Fish: ALAG, KATM, LACL
Sport and Subsistence Wildlife Harvest: ALAG, ANIA, KATM (Preserve), LACL

Justification/Issues Being Addressed: The Alaska National Interest Lands Claim Settlement Act of 1980 (ANILCA Public Law 96-487) established by statute that subsistence hunting, fishing, and gathering would be legitimate activities on some 41,458,000 ac (16,777,457 ha) of new park lands, including lands within ALAG, ANIA, KATM (Preserve), and LACL. Because they existed before ANILCA, subsistence harvest of fish and wildlife is not authorized in Katmai National Park and KEFJ. ANILCA also allowed sport harvest within preserves; sport fishing has always been allowed in national park units unless specifically prohibited. Subsistence harvest regulations and bag limits are often more liberal than sport harvest, and have the potential to depress wildlife populations in local areas, such as around human population centers or access routes.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

Questions:

- How are sport and subsistence fish harvests of resident and anadromous fish changing in major drainages within or including SWAN parks?
- How are sport and subsistence wildlife harvest levels changing for brown bear, black bear, caribou, Dall sheep, and moose in Game Management Units and Uniform Coding Units that include SWAN parks?
- How are harvests of beaver, lynx, river otter, wolf, and wolverine changing within and around SWAN park units?

Objectives:

- Track annual harvest of resident and anadromous fish species within ALAG, KATM, and LACL.
- Track number and locations of brown bear, black bear, caribou, Dall sheep, and moose harvested annually within Game Management Units and Uniform Coding Units that include portions of ALAG, ANIA, KATM, and LACL.
- Track annual harvest levels within and adjacent to ALAG, ANIA, KATM, and LACL for beaver, lynx, river otter, wolf, and wolverine.

Basic Approach: This protocol will define a process to extract and use data from existing fish and wildlife harvest data sources and make them readily available to park managers.

Sport Fish Harvest-Since 1970, the ADF&G Sport Fish Division has conducted an annual mail survey to estimate total sport fish harvest levels by major watershed. Harvest estimate is broken down by these species: king salmon (*Oncorhynchus tshawytscha*), silver salmon (*Oncorhynchus kisutch)*, red (sockeye) salmon, pink salmon (*Oncorhynchus gorbuscha*), chum salmon (*Oncorhynchus keta*), kokanee (*Oncorhynchus nerka*), lake trout (*Salvelinus namaycush)*, Dolly Varden/arctic char, rainbow trout (*Oncorhynchus mykiss*), Arctic grayling (*Thymallus arcticus)*, whitefish, northern pike (*Esox lucius*), burbot (*Lota lota*), smelt, and razor clams (*Siliqua patula*). Watersheds for which harvest data are collected have varied over time, and do not always conform to park boundaries. ADF&G currently does not estimate harvest for ANIA or KEFJ, but collects information for the two major rivers in ALAG and KATM, Naknek and Alagnak. For LACL, harvest data are available for Lake Clark, Silver Salmon Creek, and Polly Creek Beach/Crescent River Bar (razor clams), although not all sites meet ADF&G standards for useable harvest estimates (> 30 respondents) (Walker et al. 2003).

Wildlife Harvest-Since 1983, wildlife harvest statistics for brown bear, black bear, caribou, and moose have been collected by ADF&G and the Federal Subsistence Board, and are currently provided to the Alaska Regional Office Subsistence Division on an annual basis. Sandy Rabinowitch, NPS Subsistence, is currently breaking out harvest by Game Management Units and park areas. Under state hunting regulations, license holders are required to report all harvests. However, ADF&G sends follow-up letters for permit hunts, and response levels for all hunts are higher in urban areas.

Furbearer Harvest-The ADF&G Division of Wildlife Conservation collects trapping harvest figures through sealing records on river otter, wolf, and wolverine. Sandy Rabinowitch will also be compiling trapping harvest statistics. Survey units are large, and trapping in and around SWAN parks is not intensive.

Other Data Sources-The ADF&G Subsistence Division carries out periodic intensive, comprehensive surveys through interviews of subsistence users within subsistence communities. Data from these community surveys are included in the Community Profile Database (CPD) at (http://www.subsistence.adfg.state.ak.us/geninfo/publctns/cpdb.cfm). Although not directly comparable, the CPD can provide context and complementary data for comparison with the harvest database.

SWAN Contacts and NPS Lead:

- Bill Thompson, NPS-SWAN (NPS Lead)
- Dorothy Mortenson, NPS-SWAN

Development Schedule, Budget, and Expected Interim Products:

2005–2007	Develop agreements for data sharing, complete data gathering.
2008	Draft data management protocol.
2009	Protocol testing/statistical analysis.
2010	Implement.

Development of this protocol will be done in house, and no major costs are anticipated.

Literature Cited:

Walker, R. J., C. Olnes, K. Sundet, A. L. Howe, and A. E. Bingham. 2003. Participation, catch, and harvest in Alaska sport fisheries during 2000. Alaska Department of Fish and Game, Division of Sport Fish. Fishery Data Series No. 03-05.

Human Activities

Protocol: Visitor Use

Parks Where Protocol Will Be Implemented: ALAG, ANIA, KATM, KEFJ, LACL

Justification/Issues Being Addressed: Human presence can have unexpected and significant effects on ecosystems and ecosystem processes. Humans can serve as a vector for exotic species and, through habitat change, decreased competitive ability of resident species. Heavy use can fragment the landscape for sensitive wildlife, modify wildlife behavior through conditioning, and lead to overfishing, or overharvest in focal areas.

To effectively manage and protect national parks, information is needed concerning visitor use parameters. For example, information about the spatio-temporal distribution of visitor use can help managers identify potential recreation-related threats to the natural resources of an area and the quality of visitors' experiences. While in some cases it may be possible to monitor visitor flows through on-the-ground observation, this becomes increasingly difficult in large remote Alaskan parks that receive dispersed use.

Methods to determine park visitation vary between and within park units, and no rigorous written protocols exist.

Specific Monitoring Questions and Objectives to be Addressed by the Protocols:

Questions:

- How is the number of visitors (nature-oriented tourists) changing in SWAN parks?
- How is the type of visitor use, timing of visits, and areas of use changing in SWAN parks?
- How are visitors accessing SWAN parks and where are modes of access changing?

Objectives:

- Track annual numbers of recreational visitors in SWAN parks.
- Document how timing of visits, activities, and destinations of visitors change over 5-year periods.
- Monitor 5-year trends in points of visitor origin and entry into SWAN parks.

Basic Approach: Of the five park units within SWAN, only KEFJ is road-accessible from major population centers. Visitor access is primarily by small aircraft, frequently via direct flights to back-country areas from towns 10 to 160 miles (16 to 257 km) distant. Parks currently do not require visitor registration or permits, and are unlikely to do so in the near future. With few well-defined gateways, large management areas, and small staffs, a combination of direct and indirect methods is the only practical means to estimate park visitation.

Utilizing the recommendations of the Visitor Use Estimation Working Group Draft Report (2002), as well as input from the LACL and KATM Concessions Chief and the LACL Chief of Resources, the following techniques will be assessed and refined into a visitor use protocol:

1) Direct visual observations by NPS personnel at specific, focal locations such as bear viewing areas, staging locations for wilderness float trips, high-use fishing spots, or popular back-country hiking areas.
2) Indirect estimation through minor revision of the incidental business permits (IBPs) process.
3) Aerial surveys.
4) Compliance checks on IBPs.

Principal Investigators and NPS Lead:

- Becky Brock, NPS-KATM
- Colleen Matt, NPS-LACL
- Dorothy Mortenson, NPS-SWAN (NPS Lead)

Development Schedule, Budget, and Expected Interim Products:

FY 2006 Select principal investigator.

Develop contract/cooperative agreement ($70,000).

FY 2007 Draft protocol ($28,812).

FY 2008 Test.

FY 2009 Implement.

Literature Cited:

Visitor Use Estimation Working Group. 2002. Working Group Draft Report, National Parks Service, Alaska Region.

Human Activities

Protocol: Invasive/Exotic Species

Parks Where Protocol Will Be Implemented: LACL, KATM, ANIA, ALAG, KEFJ

Justification/Issues Being Addressed: Invasive exotic species are plants and animals that are introduced into an ecosystem through human activities, as opposed to native species that are part of an ecosystem through natural migration, succession, or evolution. Invasive exotic species can often thrive in natural systems, outcompeting native species and disrupting successional patterns. SWAN has identified invasive exotic plants as a vital sign based on the need for early detection and effective management response, as well the prediction of potential impacts to natural ecosystems (Bennett et al. 2004).

Currently, the level of invasive exotic species infestation is very low in SWAN parks, especially when compared with parks and lands in the lower 48 states. Until recently, it was thought that Alaska environments were too remote and harsh to allow invasions of exotic plants (Densmore et al. 2001). However, the combined effects of environmental warming and human activities in previously remote areas will increase the rate of exotics introduction and facilitate their establishment in park ecosystems. Surveys conducted in Alaska parks by the Alaska Exotic Plant Management Team (EPMT) and U.S. Geological Survey-Biological Resources Division show that exotic plants in most SWAN parks are associated with areas of human disturbance. However, in interior and south-central Alaska, white sweet clover (*Melilotus alba*) is spreading rapidly along undisturbed glacial river systems, affecting the stability of sand bars and hydrologic flow paths, and replacing native vetches and willows, prime browse species for moose and hares.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

Question:

- Are nonnative species of vascular plants invading areas in or near SWAN parks and, if so, at what rate?

Objectives:

- Monitor number of nonnative, vascular plant species in or near SWAN parks.
- Monitor amount of acreage colonized by nonnative vascular plant species in or near SWAN parks.
- Estimate long-term rate of change in acreage colonized by nonnative vascular plant species in or near SWAN parks.

Basic Approach: Data collection for monitoring invasive exotic species will primarily be conducted by the NPS-EPMT. Alaska EPMT survey data (species distribution and control monitoring) are stored in the Alien Plant Control and Management (APCAM) Database and will be acquired by SWAN staff. Procedures for data collection and management are documented in the APCAM procedures manual (APCAM 2005). Additionally, many other agencies also conduct exotic plant surveys and control actions in Alaska. These data, including the NPS-EPMT data, are captured in the Alaska Exotic Plants Information Clearinghouse (AKEPIC) and database (AKEPIC 2004).

The AKEPIC database will be reviewed annually. If invasive exotic plants are reported in or near SWAN parks, tabular and geographic information system data will be downloaded from AKEPIC into the SWAN centralized database. If appropriate, SWAN may develop a monitoring plan for specific species that may pose a serious threat.

Principal Investigators and NPS Lead:

- Jeff Heys, NPS-Alaska EPMT Liaison
- Brad Welch, NPS-WASO I&M-EPMT Liaison
- Page Spencer, NPS-ARO (NPS Lead)
- Dorothy Mortenson, NPS-SWAN

Development Schedule, Budget, and Expected Interim Products:

Surveys and monitoring of nonnative vascular plant species are ongoing, following established NPS-EPMT survey methods (Heys and Bauder 2005). Data collection and management are documented in a variety of locations, including the APCAM and AKEPIC databases for vascular plants.

2007 Review ongoing data collection by EPMT and draft data management protocol and SOPs.

2008 Test protocol.

2009 Implement protocol.

No anticipated costs other than Network staff salaries.

Literature Cited:

AKEPIC. 2004. The Alaska Exotic Plant Information Clearinghouse (AKEPIC) mapping project Collaborator's manual. Online. (http://akweeds.uaa.alaska.edu/pdfs/akepic_manual_05_final.pdf). Accessed 25 October 2005.

APCAM 2005. APCAM data entry and management protocols (draft). APCAM database protocols. NPS in-house document. Denver Service Center.

Bennett, A. J., K. L. Oakley, and D. C. Mortenson. 2004. Phase II vital signs monitoring report, Southwest Alaska Network. National Park Service, Anchorage.

Densmore, R. V., P. C. McKee, and C. Roland. 2001. Exotic plants in Alaskan national park units. USGS in-house report to NPS. Anchorage.

Heys, J., and P. Bauder. 2005. Alaska EPMT data collection protocol. In-house report. Alaska Regional Office, Anchorage.

Human Activities

Protocol: Visibility and Particulate Matter

Parks Where Protocol Will Be Implemented: ANIA, LACL, KATM

Justification/Issues Being Addressed: Federal land managers must protect air quality and related values (including visibility) of Class I lands, including all wilderness > 500 acres (202 ha), and consider, in consultation with the U.S Environmental Protection Agency, whether proposed facilities will have an adverse impact on these values (42 U.S.C. 7475(c)). Air quality in SWAN parks is considered pristine by national standards, but airborne pollutants associated with increasing global and regional industrialization, and increased particulate loads associated with wildfire and volcanic activity, have the potential to affect climatic conditions and ecological processes in the Network (Bennett et al. 2004). Effects of anthropogenic nitrogen deposition alone may include soil acidification, changes in plant community composition, increased emissions of greenhouse gases, and diminished water quality (Fenn et al. 1998). Aerosol sampling conducted in King Salmon (1987-1992) indicated that elements associated with anthropogenic sources were proportionately greater at that site than in other parks surveyed in Alaska (Polissar et al. 1998), and with continued industrial development in the region, atmospheric inputs are expected to increase.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

Questions:

- Are particulate loads and chemical composition of aerosols changing through time in or near SWAN parks?

Objectives:

- Develop a protocol to acquire aerosol data and summary reports from the Interagency Monitoring of Protected Visual Environments (IMPROVE) Network sites in southwest Alaska.

Basic Approach: The IMPROVE Network consists of optical and aerosol samplers that measure a range of particulates, including nitrate, sulfate, and organic and elemental carbon. Although SWAN does not currently support an air quality monitoring program, IMPROVE sites administered by the USFWS in the Tuxedni and Simeonof Wilderness Areas (Sand Point) provide data relevant to LACL and ANIA, respectively. Summary data (2002) are currently available online (http://vista.cira.colostate.edu/improve/Data/data.htm). Integration of these data into SWAN reports will be done in consultation with the IMPROVE program manager and SWAN data manager.

Principal Investigators and NPS Lead:

- Amy Miller, NPS-SWAN (NPS Lead)
- Dorothy Mortenson, NPS-SWAN
- Ellen Porter, NPS-WASO

Development Schedule, Budget, and Expected Interim Products:

Aerosol sampling sites are administered through the IMPROVE Network and are maintained by USFWS, with no cost to NPS for development or implementation of the sampling protocol.

2006 Develop a protocol to acquire annual IMPROVE summary data.

2007 Test and implement IMPROVE data acquisition protocol.

Literature Cited:

Bennett, A. J., K. L. Oakley, and D. C. Mortenson. 2004. Phase II vital signs monitoring report, Southwest Alaska Network. National Park Service, Anchorage.

Fenn, M. E., M. A. Poth, J. D. Aber, J. S. Baron, B. T. Bormann, D. W. Johnson, A. D. Lemly, S. G. McNulty, D. F. Ryan, and R. Stottlemyer. 1998. Nitrogen excess in North American ecosystems: Predisposing factors, ecosystem responses, and management strategies. Ecological Applications **8**:706-733.

Polissar, V., P. K. Hopke, P. Paatero, W. C. Malm, and J. F. Sisler. 1998. Atmospheric aerosol over Alaska. 2. Elemental composition and sources. Journal of Geographic Research **103**:19045-19057.

Appendix IV

Introduction to Bayesian Belief Networks

This appendix provides a brief introduction to Bayesian belief networks (BBNs; Olson et al. 1990). Within the context of the SWAN I&M program, BBNs can serve as the quantitative link between monitoring results and characterizing the "state of a park." However, they have much broader uses as integral components of a decisionmaking process, i.e., when decision and utility nodes (see node definition below) are added to the network to create an influence diagram (Clemen 1996; also referred to as a decision graph, Jensen 2001). General guidelines for constructing BBNs for ecological applications can be viewed at: (http://www.spiritone.com/~brucem/bbns.htm).

IV.1 Terminology

A BBN sometimes is referred to as a **causal tree** (causal polytree for more complex networks), which is reflected in its terminology. For instance, circles are referred to as **nodes**. A node with no arrows leading into it is a **root node**, whereas one with no arrows leading out of it is a **leaf node**. In Figure IV-1, Node A is a root node and Node C is a leaf node. Node-to-node relationships are characterized in more familial terms. For example, Node A is a **parent** to Nodes B and C, Nodes B and C are **children** of Node A, Node B is a parent to Node C, and Node C is a child of Node B. In tree terminology, a node with no parents is a root node and one with no children is a leaf node.

IV.2 Quantitative Basis of a BBN

The quantitative framework of a BBN is based on conditional relationships among nodes and probabilistic assignments within nodes. Nodes that are not connected by arrows are considered conditionally independent. For example, *if* there was *not* an arrow connecting Node B to C in Figure IV-1, they would be conditionally independent so that learning the outcome of B would add no new information about C if A was already known.

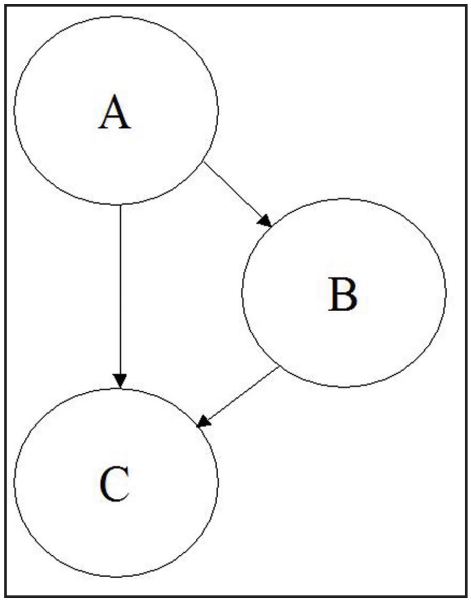

Figure IV-1 *A three-node network with one root node (A), one leaf node (C), and one intermediate node (B). In this network, there is a causal influence between B and A, C and A, and B and C.*

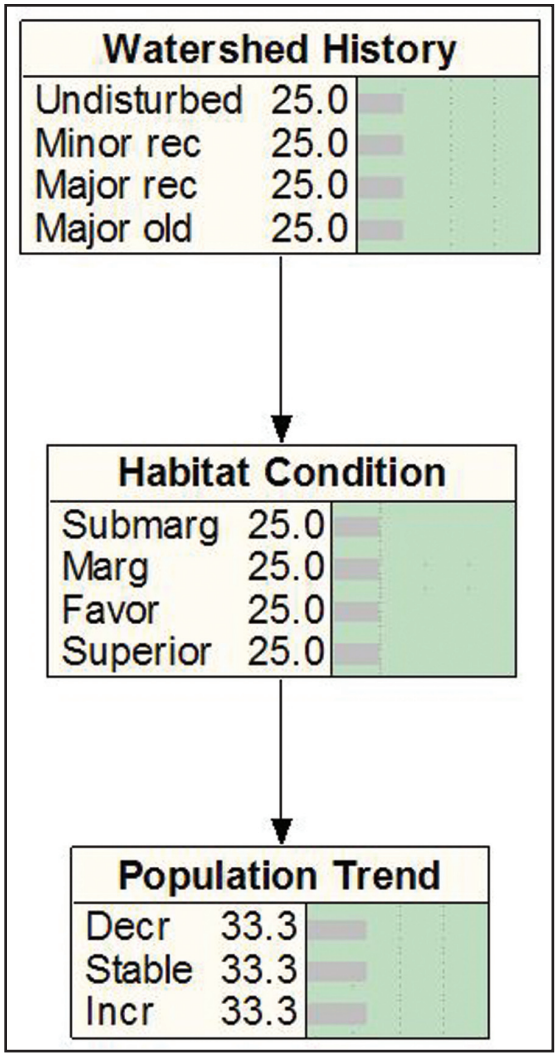

Figure IV-2 *A simple Bayesian belief network showing the causal influences among watershed history, aquatic habitat condition, and fish population trend (for illustrative purposes only; taken from Lee 2000). Belief vectors within each node have been assigned uniform probabilities, which are expressed as percentages.*

Each node is defined by levels or **states**, which are discrete and mutually exclusive categories describing the node. Figure IV-2 shows a simple network composed of watershed history, habitat condition, and fish population trend. The root node, watershed history, is defined in terms of four states that represent historical magnitude and timing of disturbance for a given watershed: undisturbed; recent minor disturbance; recent major disturbance; and old major disturbance.

The first step to incorporating a probabilistic structure into a BBN is to quantify the relationship between a child node and its parent(s). This is done via the **conditional probability table** or **link matrix**. In Table IV-1, each row contains the probabilistic relationship between each state level of the root node, watershed history, and those of its child node, habitat condition (Figure IV-2). Note that values within each row should sum to 1. Each row-column intersection in Table IV-1 is interpreted as the probability of a state level of habitat condition *given* a state level of watershed history. For example, according to this table, the probability of the habitat condition being submarginal given that there was a recent minor disturbance in the watershed is 0.08.

Table IV-1 The conditional probability table (link matrix) quantifying the probabilistic relationships between watershed history and its child node, habitat condition (Figure IV-2; taken from Lee 2000).

Watershed History	Habitat Condition			
	Submarginal	Marginal	Favorable	Superior
Undisturbed	0.05	0.15	0.60	0.20
Minor recent	0.08	0.22	0.55	0.15
Major recent	0.20	0.50	0.28	0.02
Major old	0.10	0.41	0.42	0.07

There are three ways to assign probabilities to a link matrix: (i) empirical data; (ii) expert or professional opinion; and (iii) simulation model outputs. Although the preferred option is to parameterize the matrix with empirical data or models (see Clemen 1996: Chapter 10), such information often is lacking, especially at larger spatial scales. A more typical option is to assign subjective probabilities to the matrix based on expert opinions from professionals. A third approach is to generate matrices from many simulation runs of the network (e.g., Lee and Rieman 1997). Regardless of the method of assignment, conditional probability tables are an extremely important component to a BBN. Poorly constructed tables will undoubtedly lead to misleading results.

The second step to incorporating a probabilistic structure into a BBN is to assign probabilities to each state level of each node. For instance, in the sample network in Figure IV-2, we have to assign the probability that the disturbance history for a given watershed is best characterized by that disturbance. As stated before, the preferred option is to use empirical data to assign these probabilities. These marginal probabilities are referred to as **belief vectors**. If data are unavailable, then we may resort to expert opinion to generate them. If we have no basis for an expert opinion, or our opinion is that each state level is initially as probable as another, we would assign equal probabilities to each state level (Figure IV-2). State levels usually represent a range of values because of the uncertainty involved in knowing the true value.

IV.3 How Does a BBN Work?

The previous section described how a network is initialized via the assignment of probabilities to node levels and link matrices. After this initialization, these probabilities are used to mathematically solve or compile the network. This calculation is based on matrix algebra of conditional probability relationships between a parent node and its child or children and vice versa (when applicable). Thus, the mathematics are bidirectional so that information can flow either down or up a network. These calculations "update" the belief vectors, which in turn represent the probability of a given state for a specific node. For instance, the compiled network in Figure IV-3 shows that, with equally probable levels of disturbance history, the probability of a decreasing population trend in the watershed is about 0.392. The most likely state is a stable trend, but the uncertainty in this conclusion is evident. Those interested in mathematical details for solving a BBN should see Olson et al. (1990) and Haas (1991) for example calculations.

IV.4 Advantages of Using a BBN

BBNs represent a statistically rigorous way to explicitly incorporate both quantitative and qualitative information in a formal framework for evaluating a variety of ecological and management questions. There are a few key points here. First, empirical data often are lacking to assess, for example, potential effects of some management action on future status of a fish population. However, there may be biologists familiar with a system who could offer professional judgments based on their knowledge and experience. BBNs incorporate these judgments as subjective probabilities, which is an expression of uncertainty about each node level. Further, this uncertainty also is expressed in the definitions of the node levels as parameter ranges rather than assigning an exact number. Second, going through the process of assigning probabilities to parameterize the network forces one to think about the system and processes in an explicit manner. This can be even more instructive when conducted with a team of experts. Third, a BBN makes transparent the thought and evaluation processes through its general structure and, especially, its parameterization.

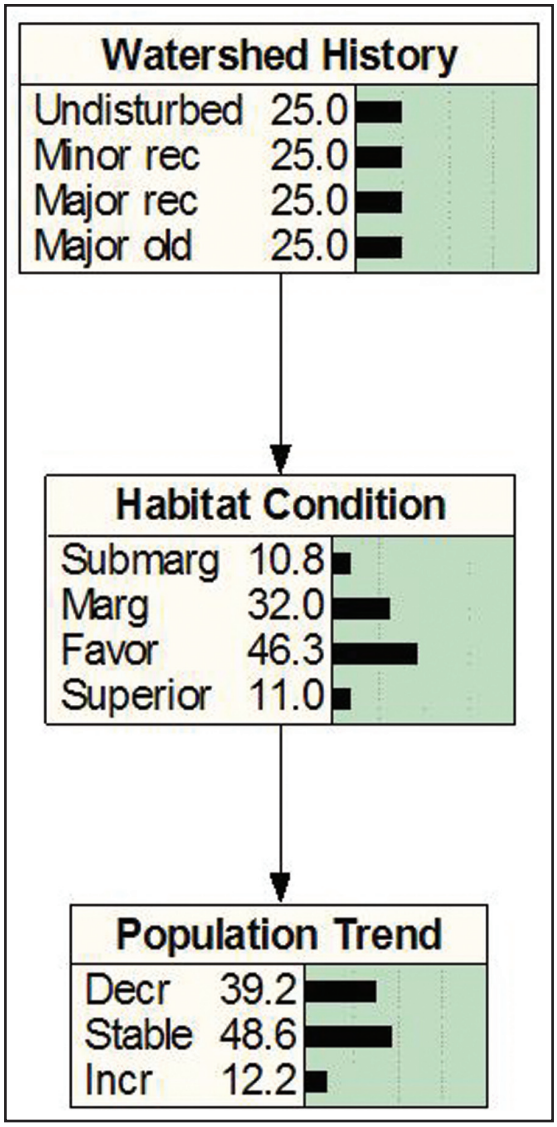

Figure IV-3 *The initial compiled version of the network in Figure IV-2.*

Assignment of probabilities should be accompanied by supporting references, documentation, or other description for why a particular probability was assigned to a link matrix or belief vector. This allows for an honest evaluation of why one arrived at a particular decision or finding. Fourth, a BBN can be used to help identify data gathering needs, such as which nodes seem to have the most influence due to uncertainty associated with them (i.e., sensitivity analysis; Peterson 1999).

IV.5 Cautionary Remarks

"All models are wrong but some are useful." --- G. E. P. Box (1979:202)

As with any model, a BBN is only a rough approximation of reality. The quality of its outputs depends upon the quality of the inputs as well as how closely the model approximates reality with respect to its structure and conditional relationships. Poorly parameterized link matrices will undoubtedly lead to misleading results, particularly if the link matrix includes an output (leaf) node.

". . . [BBNs] . . . will be referred to as advisory systems to avoid the implication of proven competence associated with the word "expert." --- Haas (1991:627)

Subjective probabilities are just that, subjective. Thus, this approach can be easily misused if not conducted using a rigorous protocol, such as citing supporting documentation, and persons with proper knowledge and experience. Even applying appropriate rigor to the process will not ensure useful parameterization of the network. Certain links may not be well understood, such as the link between habitat and population status of species A. As with any other model, BBNs can be a useful tool when employed and interpreted within the proper context.

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