



Kenai Fjords National Park

Natural Resource Condition Assessment

Natural Resource Report NPS/KEFJ/NRR—2015/900



ON THE COVER

A sea otter in Kenai Fjords National Park.
Photograph by National Park Service.

Kenai Fjords National Park

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Executive Summary

The Natural Resource Condition Assessment (NRCA) Program provides documentation about the current conditions of important natural resources within National Park Service (NPS) units. This NRCA provides managers of Kenai Fjords National Park (KEFJ) with an assessment of a subset of important natural resources within the park, as well as supporting data products that will assist in future designations of condition. Overall, this document should help managers develop near-term management priorities, engage in partnership and education efforts, conduct park planning, and report program performance.

To complete this assessment, Saint Mary's University of Minnesota, GeoSpatial Services (SMUMN GSS) and the NPS engaged in a cooperative agreement. Working in partnership, SMUMN GSS and NPS defined key resource components, relevant GIS analyses, and key project outcomes. The KEFJ NRCA is unique in that multiple, detailed spatial analyses relevant to key park resource condition are included in this assessment. During project development, NPS staff identified the need and relevancy for completion of the spatial analyses presented.

For non-spatial analysis of resources, SMUMN GSS worked with NPS to define existing literature and data sources to use to describe the condition of particular resource components. In addition, SMUMN GSS searched for and acquired literature not identified by NPS staff when supplemental information was needed. The condition of biological resource components assessed in this report was generally good, except for those components that condition could not be determined due to lack of data available.

This assessment also includes spatial analysis of key resources within KEFJ. Specifically, datasets focusing on coastal geomorphology, Exit Creek fluvial dynamics, and coastal landing areas were developed to inform change during the recent history of the park. Coastal geomorphology in KEFJ has changed markedly during the last 50 years, as glaciers have receded and landscape-changing events, such as the 1964 earthquake, have occurred. These datasets will provide baseline data for future analysis of condition and change in KEFJ.

Overall, the condition of the resources in this park is good. However, threats and stressors of high concern may cause resource impact in the near future. Specifically, climate change and oil spills could have a substantial influence on all park resources. Already, the effects of a warming climate are reflected in the recession of glaciers and exposure of new shorelines in KEFJ. Similarly, some of the effects from the Exxon Valdez oil spill still persist today.

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Acronyms and Abbreviations

AAR- Accumulation Area Ratio

ADF&G- Alaska Department of Fish and Game

AHAP- Alaska High Altitude Photography

ANILCA- Alaska National Interest Lands Conservation Act

BHIMS- Bear Human Information Management System

CL- Condition Level

DLP- Defense of Life or Property

ELA- Equilibrium Line Altitude

EPA- Environmental Protection Agency

EPMT- Exotic Plant Management Team

GLEI- Great Lakes Environmental Indicators Project

GLOF- Glacial Lake Outburst Floods

I&M- Inventory & Monitoring

IRMA- Integrated Resource Management Application

KEFJ- Kenai Fjords National Park

MODIS – Moderate Resolution Imaging Spectroradiometer

NPS- National Park Service

NRCA- Natural Resource Condition Assessment

NABCI- North American Bird Conservation Initiative

PDS- Permanent Dataset

RSS- Resource Stewardship Strategy

SAGA- Southeast Alaska Guidance Association

SL- Significance Level

SOP- Standard Operating Procedure

Acronyms and Abbreviations (continued)

SMUMN GSS- Saint Mary's University of Minnesota Geospatial Services

SWAN- Southwest Alaska Network

USFWS- United States Fish and Wildlife Service

USGS- United States Geological Survey

WCS- Weighted Condition Score

Chapter 1 NRCA Background Information

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national park units, hereafter “parks.” NRCAs also report on trends in resource condition (when possible), identify critical data gaps, and characterize a general level of confidence for study findings. The resources and indicators emphasized in a given project depend on the park’s resource setting, status of resource stewardship planning and science in identifying high-priority indicators, and availability of data and expertise *to assess current* conditions for a variety of potential study resources and indicators.

NRCAs represent a relatively new approach to assessing and reporting on park resource conditions. They are meant to complement—not replace—traditional issue- and threat-based resource assessments. As distinguishing characteristics, all NRCAs:

- are multi-disciplinary in scope;¹
- employ hierarchical indicator frameworks;²
- identify or develop reference conditions/values for comparison against current conditions;³
- emphasize spatial evaluation of conditions and GIS (map) products;⁴
- summarize key findings by park areas; and⁵

NRCAs Strive to Provide...

Credible condition reporting for a subset of important park natural resources and indicators

Useful condition summaries by broader resource categories or topics, and by park areas

¹ The breadth of natural resources and number/type of indicators evaluated will vary by park.

² Frameworks help guide a multi-disciplinary selection of indicators and subsequent “roll up” and reporting of data for measures ⇒ conditions for indicators ⇒ condition summaries by broader topics and park areas

³ NRCAs must consider ecologically-based reference conditions, must also consider applicable legal and regulatory standards, and can consider other management-specified condition objectives or targets; each study indicator can be evaluated against one or more types of logical reference conditions. Reference values can be expressed in qualitative to quantitative terms, as a single value or range of values; they represent desirable resource conditions or, alternatively, condition states that we wish to avoid or that require a follow-on response (e.g., ecological thresholds or management “triggers”).

⁴ As possible and appropriate, NRCAs describe condition gradients or differences across a park for important natural resources and study indicators through a set of GIS coverages and map products.

- follow national NRCA guidelines and standards for study design and reporting products.

Although the primary objective of NRCAs is to report on current conditions relative to logical forms of reference conditions and values, NRCAs also report on trends, when appropriate (i.e., when the underlying data and methods support such reporting), as well as influences on resource conditions. These influences may include past activities or conditions that provide a helpful context for understanding current conditions, and/or present-day threats and stressors that are best interpreted at park, watershed, or landscape scales (though NRCAs do not report on condition status for land areas and natural resources beyond park boundaries). Intensive cause-and-effect analyses of threats and stressors, and development of detailed treatment options, are outside the scope of NRCAs.

Due to their modest funding, relatively quick timeframe for completion, and reliance on existing data and information, NRCAs are not intended to be exhaustive. Their methodology typically involves an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or indicator, reflecting differences in existing data and knowledge bases across the varied study components.

The credibility of NRCA results is derived from the data, methods, and reference values used in the project work, which are designed to be appropriate for the stated purpose of the project, as well as adequately documented. For each study indicator for which current condition or trend is reported, we will identify critical data gaps and describe the level of confidence in at least qualitative terms. Involvement of park staff and National Park Service (NPS) subject-matter experts at critical points during the project timeline is also important. These staff will be asked to assist with the selection of study indicators; recommend data sets, methods, and reference conditions and values; and help provide a multi-disciplinary review of draft study findings and products.

Important NRCA Success Factors

Obtaining good input from park staff and other NPS subject-matter experts at critical points in the project timeline

Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures ⇨ indicators ⇨ broader resource topics and park areas)

Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for indicator-level condition findings

NRCAs can yield new insights

⁵ In addition to reporting on indicator-level conditions, investigators are asked to take a bigger picture (more holistic) view and summarize overall findings and provide suggestions to managers on an area-by-area basis: 1) by park ecosystem/habitat types or watersheds, and 2) for other park areas as requested.

NRCA Reporting Products...

Provide a credible, snapshot-in-time evaluation for a subset of important park natural resources and indicators, to help park managers:

Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations

(near-term operational planning and management)

Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values

(longer-term strategic planning)

Communicate succinct messages regarding current resource conditions to government program managers, to Congress, and to the general public

("resource condition status" reporting)

about current park resource conditions but, in many cases, their greatest value may be the development of useful documentation regarding known or suspected resource conditions within parks. Reporting products can help park managers as they think about near-term workload priorities, frame data and study needs for important park resources, and communicate messages about current park resource conditions to various audiences. A successful NRCA delivers science-based information that is both credible and has practical uses for a variety of park decisionmaking, planning, and partnership activities.

However, it is important to note that NRCAs do not establish management targets for study indicators. That process must occur through park planning and management activities. What an NRCA can do is deliver science-based information that will assist park managers in their ongoing, long-term efforts to describe and quantify a park's desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning⁶ and help parks to report on government accountability measures.⁷ In addition, although in-depth analysis of the effects of climate change on park natural resources is outside the scope of NRCAs, the condition analyses

⁶ An NRCA can be useful during the development of a park's Resource Stewardship Strategy (RSS) and can also be tailored to act as a post-RSS project.

⁷ While accountability reporting measures are subject to change, the spatial and reference-based condition data provided by NRCAs will be useful for most forms of "resource condition status" reporting as may be required by the NPS, the Department of the Interior, or the Office of Management and Budget.

and data sets developed for NRCAs will be useful for park-level climate-change studies and planning efforts.

NRCAs also provide a useful complement to rigorous NPS science support programs, such as the NPS Natural Resources Inventory & Monitoring (I&M) Program.⁸ For example, NRCAs can provide current condition estimates and help establish reference conditions, or baseline values, for some of a park's vital signs monitoring indicators. They can also draw upon non-NPS data to help evaluate current conditions for those same vital signs. In some cases, I&M data sets are incorporated into NRCA analyses and reporting products.

Over the next several years, the NPS plans to fund a NRCA project for each of the approximately 270 parks served by the NPS I&M Program. For more information on the NRCA program, visit <http://nature.nps.gov/water/nrca/index.cfm>

⁸ The I&M program consists of 32 networks nationwide that are implementing “vital signs” monitoring in order to assess the condition of park ecosystems and develop a stronger scientific basis for stewardship and management of natural resources across the National Park System. “Vital signs” are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values.

Chapter 2 Introduction and Resource Setting

2.1 Introduction

2.1.1 *Enabling Legislation*

On 2 December 1980, President Jimmy Carter signed the Alaska National Interest Lands Conservation Act (ANILCA), establishing Kenai Fjords National Park (KEFJ). Section 101 of ANILCA describes the purpose of the act:

In order to preserve for the benefit, use, education, and inspiration of present and future generations certain lands and waters in the State of Alaska that contain nationally significant, natural, scenic, historic, archeological, geological, scientific, wilderness, cultural, recreational, and wildlife values, and units described in the following titles are hereby established.

Kenai Fjords National Park was established specifically for the following purposes:

...to maintain unimpaired the scenic and environmental integrity of the Harding Icefield, its outflowing glaciers, and coastal fjords and islands in their natural state; and to protect seals, sea lions, other marine mammals, and marine and other birds and to maintain their hauling and breeding areas in their natural state, free of human activity which is disruptive to their natural processes (ANILCA sec.201(5)).

ANILCA is one of the most significant land conservation measures in the history of the United States. It protects over 100 million acres of federal lands in Alaska. By passing this act, the size of the national park and refuge system was doubled, and the amount of land designated as wilderness tripled.

2.1.2 *Geographic and Climatic Setting*

KEFJ is located on the east coast of the Kenai Peninsula in south central Alaska. The park headquarters are in Seward, located outside the northeastern corner of the park. Kenai Peninsula Borough has a human population density of 1.19 persons per square kilometer, which is above the average for Alaska (0.42 persons per square kilometer) (USCB 2010). KEFJ covers approximately 271,140 hectares (670,000 acres), of which the National Park Service (NPS) manages approximately 245,645 hectares (607,000 acres). The remaining area is owned and managed by the State of Alaska, Port Graham Native Corporation, and private landholders. The Kenai Mountains are located to the north and west of the park. KEFJ is situated on the shelf of the subducting Pacific Ocean Plate (Cook and Norris 1998).

KEFJ encompasses nearly 65% of the Harding Icefield, including the fjords, islands, and peninsulas (Plate 1). The Harding Icefield provides originates over 30 different glaciers that terminate at the ocean, inland lakes, or on land (Hall et al. 2005). The landscape is shaped by the downhill flow and massive weight of the ice pushing down on the bedrock. The fjords represent the most common erosional feature in the park. They are characterized by steep-sides and a flat-bottomed U-shaped valley (Pendleton et al. 2006).

KEFJ has a maritime climate, which is known for precipitation, cloudiness, reasonably mild temperatures, and strong winds. Low pressure systems produced in the Aleutians move into the Gulf of Alaska, where they stay and strengthen, producing a southeasterly circulation of maritime air, which moves into the coastal mountains of KEFJ (Bailey 1977, as cited by Nagorski et al. 2010). Toward the interior of KEFJ, annual precipitation increases and can exceed 380 cm (150 in) over the Harding Icefield (Chuck Lindsay, NPS Physical Scientist, written communication, 2009, as cited in Nagorski et al. 2010). Temperature and precipitation normals (1949-2005) for a National Weather Service station in Seward located on the eastern border of KEFJ are presented in Table 1.

Table 1. Monthly temperature and precipitation normals (1949-2005) for Seward, Alaska (Western Region Climatic Data Center 2011).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Temperature (°C)													
Max	-0.94	0.44	2.83	6.88	11.16	14.72	16.78	16.67	12.94	7.00	2.17	-0.28	7.56
Min	-6.50	-5.44	-3.72	-0.11	3.83	7.44	10.00	9.72	6.50	1.39	-3.00	-5.72	1.22
Average Precipitation (cm)													
Total	15.49	14.66	9.60	10.21	10.21	5.84	6.68	13.05	25.55	24.82	17.70	19.18	173.02

2.1.3 Park Visitation

Several activities attract visitors to KEFJ including hiking, camping, boat tours, viewing Exit Glacier, kayaking, and fishing. In 2010 alone, over 297,500 people visited KEFJ. A total of 242,812 hectares (600,000 acres) of KEFJ are considered remote backcountry with no trails. The majority of backcountry users kayak to landing beaches and camp along the coast. However, backcountry overnight visits made up a small portion of the overall visitation in 2010, totaling 485 individuals (NPS 2011).

In the summer months, boat tours are a popular choice to experience the park. In 2010, 61,728 visitors went on boat tours, which depart from Seward (NPS 2011). There are many tour options, schedules, and amenities provided by various tour boat companies. Park rangers provide a narrative on all Major Marine Tours, and give daily presentations on Fox Island and at the Kenai Fjords Tours day lodge during peak visitation times (NPS 2009).

Exit Glacier is open year round to visitors and is the only area of the park accessible via road in the summer. Nearly 200,000 people visited Exit Glacier in 2010 (NPS 2011). Visitors learn how glaciers shape the landscape at the Exit Glacier Nature Center (also only open in the summer months). In 2010, the nature center had 84,034 visitors (NPS 2011).

In 2010, 16,410 visitors utilized the Harding Icefield Trail (NPS 2011). The Harding Icefield Trail is 13.2 km (8.2 mi) round trip.

2.1.4 Land Ownership

Because Kenai Fjords National Park was created through ANILCA, coastal land ownership within the park's boundaries is complicated. Two native corporations, English Bay Corporation and Port

Graham Corporation, were able to withdraw lands from within the park's boundaries to be conveyed through the earlier 1971 Alaska Native Claims Settlement Act (ANCSA). The regional corporation, Chugach Alaska Corporation, acquired the subsurface rights to those conveyed land withdrawals. The English Bay Corporation surface lands were purchased by NPS but the subsurface is still owned by Chugach Alaska Corporation, and cultural resources from these lands are still owned by English Bay Corporation. Port Graham Corporation continues to own their conveyed lands, with the subsurface owned by Chugach Alaska Corporation.

To further complicate coastal land ownership, other state and federal agencies also own parts of the coast within the park's designated boundaries. On coastal lands owned by NPS within KEFJ, NPS owns lands above the mean-high tide line while the State of Alaska owns below the mean-high tide line and submerged lands out to 3 miles. Islands located off park shores are also not owned by NPS; instead, offshore islands are owned by the U.S. Fish and Wildlife Service through the Alaska Maritime National Wildlife Refuge, or by State of Alaska through Kachemak Bay State Park (**Figure 1**).

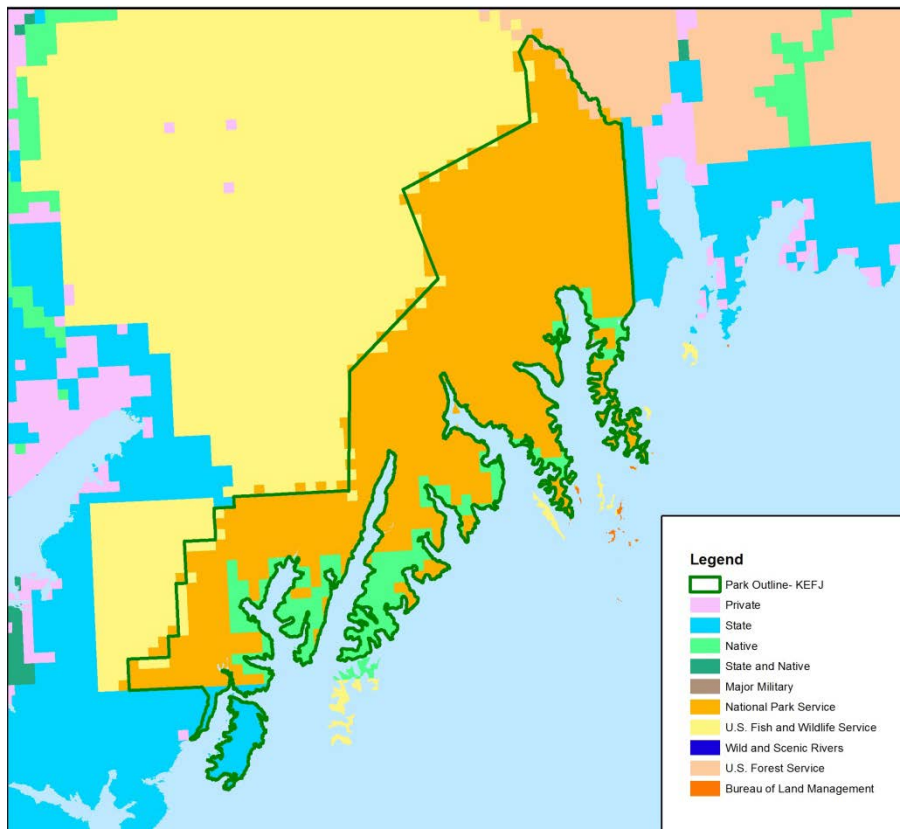


Figure 1. Generalized Land Ownership for KEFJ area. Boundaries are not exact.

2.2 Natural Resources

2.2.1 Ecological Units and Watersheds

KEFJ is part of both the Environmental Protection Agency's (EPA) Gulf of Alaska Coast and Chugach-St Elias Mountain Level III Ecoregions. The following are descriptions of these ecoregions respectively:

The steep and rugged mountains along the southeastern and south central coast of Alaska receive more precipitation annually than either the Alaska Range (116) or Wrangell Mountains (118) Ecoregions. Glaciated during the Pleistocene, most of the ecoregion is still covered by glaciers and ice fields. Most of the area is barren of vegetation, but where plants do occur, dwarf and low scrub communities dominate (EPA 2010).

Located along the southeastern and south central shores of Alaska, the terrain of this ecoregion is a result of intense glaciation during late advances of the Pleistocene. The deep, narrow bays, steep valley walls that expose much bedrock, thin moraine deposits on hills and in valleys, very irregular coastline, high sea cliffs, and deeply dissected glacial moraine deposits covering the lower slopes of valley walls are all evidence of the effects of glaciation. The region has the mildest winter temperatures in Alaska, accompanied by large amounts of precipitation. Forests of western hemlock and Sitka spruce are widespread (EPA 2010).

Figure 2 indicates the extent of both the Gulf of Alaska Coast and Chugach-St Elias Mountain Level III Ecoregions within KEFJ.

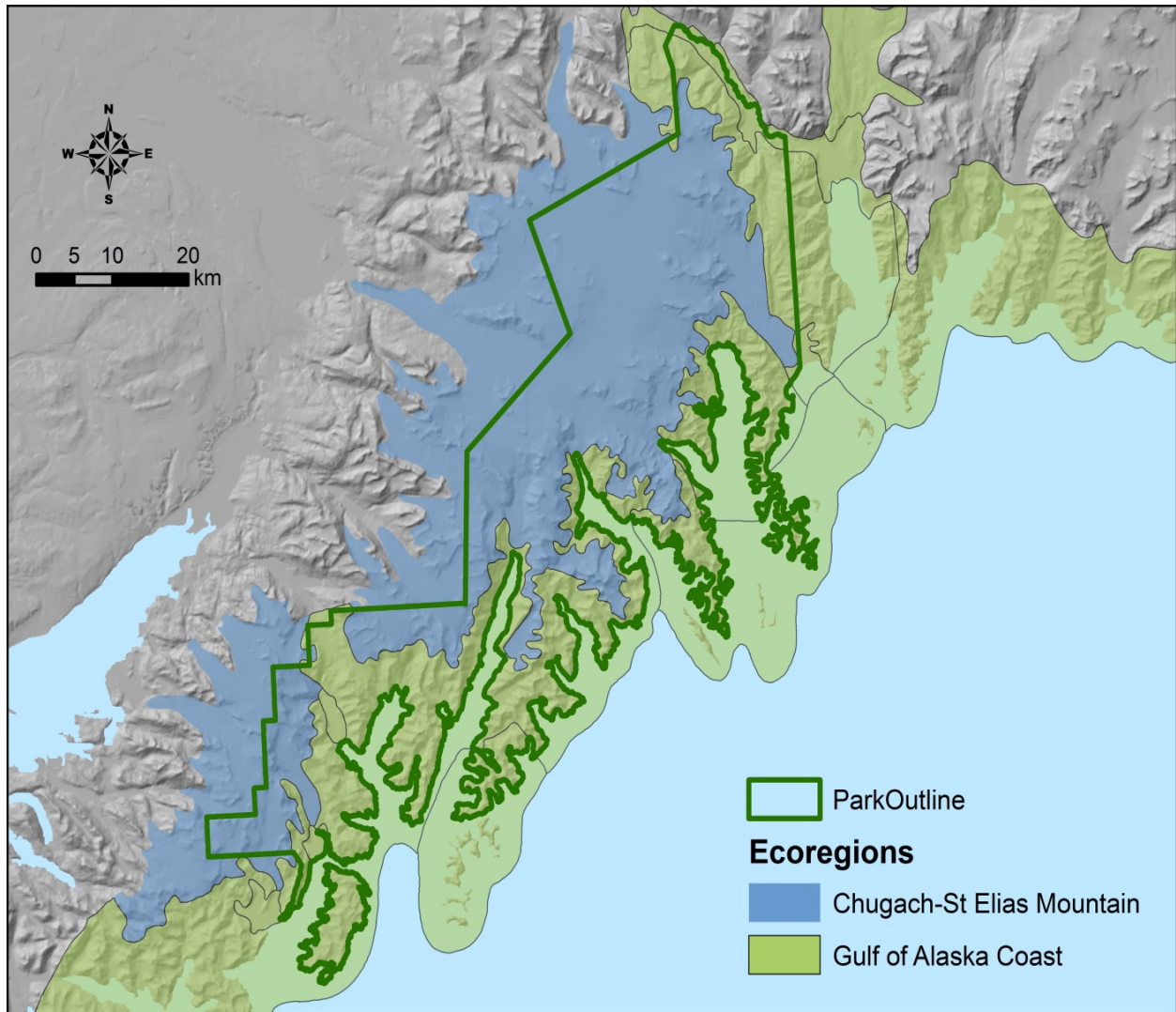


Figure 2. Level III ecoregions within KEFJ (NPS 2005).

KEFJ is located on the boundary of three Hydrologic Unit Code (HUC) 8 sub-basin watersheds (Figure 3). The northwestern section of the park is located in the Upper Kenai Peninsula watershed. The total park area in the watershed is approximately 254 km² (98 mi²). The central northwestern section of the park is located in the Lower Kenai Peninsula watershed, which is roughly 186 km² (72 mi²). Lastly, along the coast the majority of the park is located in the Western Prince William Sound watershed. This watershed consists of 2,260 km² (873 mi²) within KEFJ.

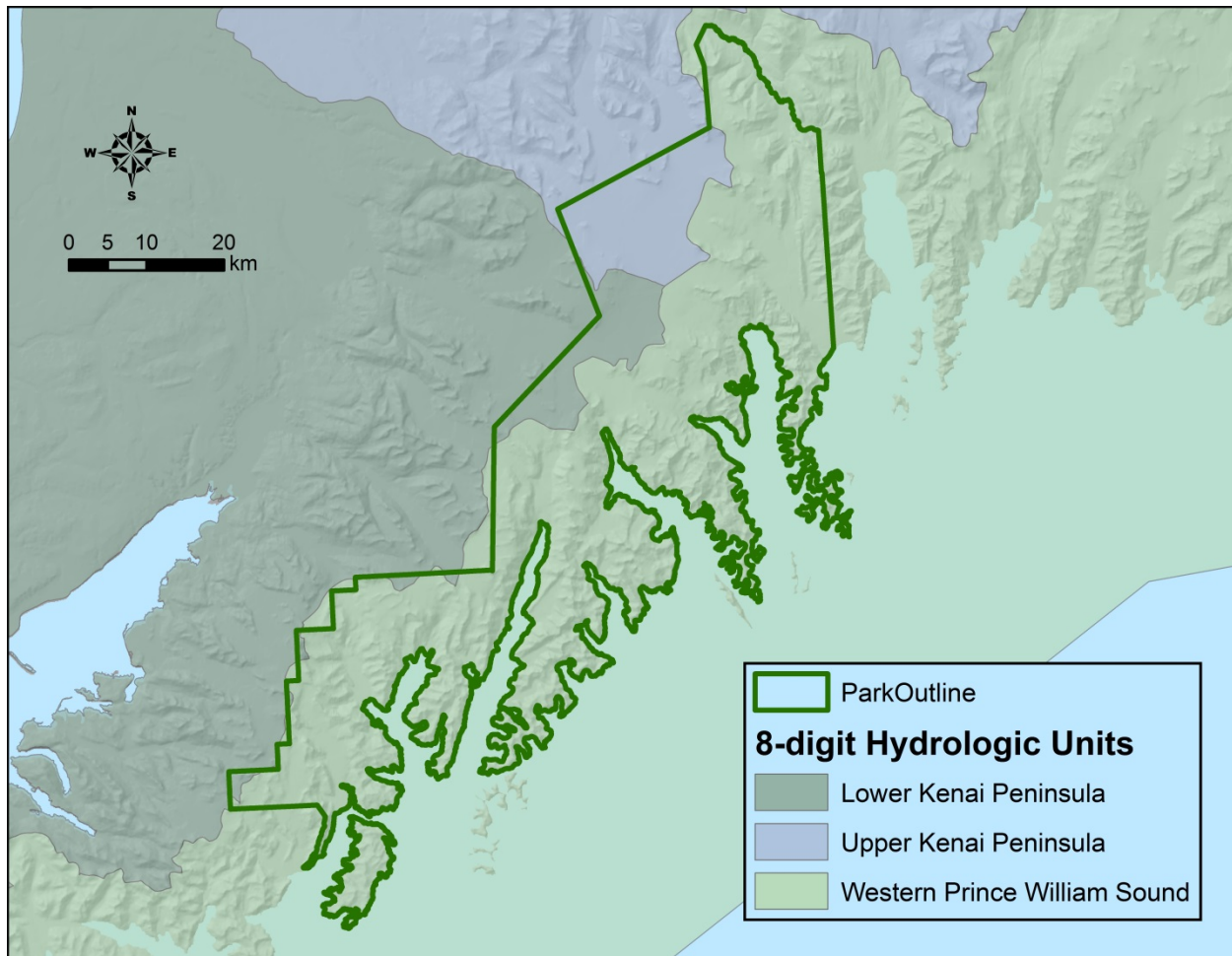


Figure 3. National Hydrography Dataset 8-digit Hydrologic Units or watersheds (USGS 2009).

2.2.2 Land Cover and Landscape Processes

Description

Land cover is the physical surface of the earth, often described using classes of vegetation and land use (e.g., vegetation: alpine herbaceous, closed alder shrub-lands, etc.; land use: developed, transportation, etc.). Land cover is portrayed in maps created through field surveys and/or analyses of remotely sensed imagery (Comber 2005). Land cover and landscape processes are vital signs in the Southwest Alaska Network Inventory and Monitoring (SWAN) monitoring plan and both fall within the broader project of Landscape Dynamics and Terrestrial Vegetation (Bennett et al. 2006). SWAN is working with partners to develop monitoring protocols for both of these Vital Signs for network parks including KEFJ. Land cover is important, in part, because climate models and empirical data indicate that climatic variation could result in significant changes to subarctic vegetation, both in distribution and species composition (Bennett et al. 2006). If examined over multiple time steps, land cover and related remote sensing analyses can provide indications of landscape processes. Land cover in KEFJ is affected by recent and current deglaciation, infrequent large-scale disturbances (volcanic eruptions, earthquakes, tsunamis), and by more frequent, small-scale disturbances (insect

outbreaks, floods, landslides, coastal erosion and accretion). Each of these contributes to a shifting mosaic of landscape patterns.

Available Land Cover Datasets

Two land cover GIS datasets exist for the park, one representing ground conditions captured in 1999 Landsat satellite imagery and the other developed from early 2000s color-infrared aerial photography.

The 1999 dataset provides a land cover classification for nearly the entire park, excluding approximately 955 hectares (2,360 acres) at the tip of Aialik Cape (Figure 4, NPS 1999). These data were created from Landsat satellite imagery and refined utilizing field observations, aerial photography and other GIS data (NPS 1999). A total of 21 land cover classes were defined within KEFJ representing a total of 268,683 hectares (663,928 acres) (Table 2). The most prevalent land cover class was snow/ice, covering 158,191 hectares (390,897 acres) or 58.7% of the total park area identified by the 1999 land cover dataset. Sparsely vegetated and barren lands cover 8.1% and 6.9% of the mapped area respectively. Lastly, much of the vegetated areas are shrubs and herbaceous cover (NPS 1999, Plate 2).

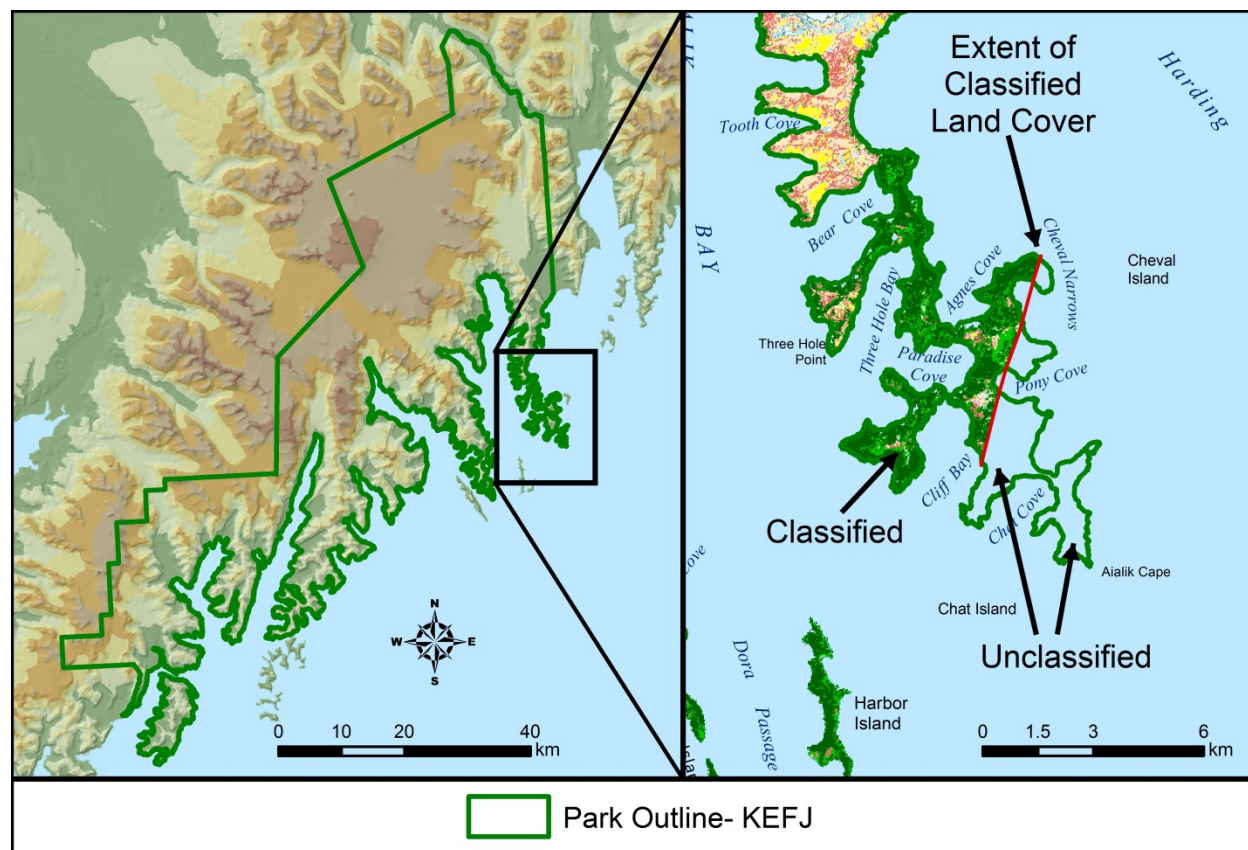


Figure 4. Unclassified area of Aialik Cape in the 1999 satellite image-derived land cover dataset created by Ducks Unlimited (NPS 1999).

Table 2. 1999 land cover classes in KEFJ by area and percent of total area. All land cover classes representing less than 0.3% of total area are listed in a table note (NPS 1999).

Land cover Class	Hectares	% of total area
Snow/Ice	158,191	58.7
Sparsely Vegetated	218,778	8.1
Barren	18,497	6.9
Closed Alder	14,832	5.5
Closed Conifer	11,223	4.2
Open Alder	10,977	4.1
Alpine Herbaceous	9,465	3.5
Open Conifer	6,590	2.4
Other Shrub	5,086	1.9
Dwarf Shrub	3,557	1.3
Herbaceous	2,800	1.0
Clear Water	1,502	0.6
Unclassified	955	0.4
Turbid Water	851	0.3
Alder/Willow Riparian	838	0.3
Woodland Conifer	765	0.3
Totals:	268,007 ^a	99.4 ^b

^a Total park area is approximately 270,030 ha.

^b Additional land cover classes each representing less than 0.25% of the total park area are: Willow, Closed Deciduous, Elymus, Open Conifer/Deciduous Mix, Closed Conifer/Deciduous Mix, Open Deciduous. Together, these additional land cover classes cover 1,631 hectares (4030 acres) or 0.6% of the park area.

A second land cover geospatial dataset was later created for the park. This geospatial dataset was developed using photo interpretation of 2003 and 2004 color infrared photography at a scale of 1:40,000 and 1:36,000, respectively. Land cover class boundaries were originally delineated on hard-copy mylar overlays (IRMA 2009). The delineated mylars were then scanned, orthorectified and converted to digital geospatial data in vector format (i.e., polygons). The resulting dataset, hereafter referred to as land cover 2003-4, identifies ecosystem and land cover classifications for the entire extent of the park as of the 2008 NPS boundary (IRMA 2009). The classification follows a hierarchical structure which includes ecological systems and land cover classes. A total of 30 ecological systems (aka ecosystems), the highest level of the hierarchy, were defined within KEFJ, representing a total of 270,030 hectares (667,256 acres). The most prevalent ecological system was snow/ice, covering 150,195 hectares (371,138 acres) or 55.6% of total area. Other prevalent ecological systems include tall shrub (9.2%), alpine herbaceous (5.6%), recently deglaciated tall shrub (5.0%), Sitka spruce (5.0%), and sparse vegetation ridge & cliff (3.3%) (Table 3, NPS 2009).

Table 3. 2003-04 ecological systems and coverage areas for KEFJ (IRMA 2009). All ecological systems representing less than 0.3 % of total area are listed in a table note.

Ecological System	Hectares	% of Total Area
Snow/Ice	150,195	55.6
Tall Shrub	24,819	9.2
Alpine Herbaceous	15,208	5.6
Recently Deglaciaded Tall Shrub	13,584	5.0
Sitka Spruce	13,579	5.0
Sparse Vegetation Ridge and Cliff	8,906	3.3
Floodplain	7,014	2.6
Unvegetated Talus	6,395	2.4
Unvegetated Bedrock	5,948	2.2
High Alpine Herbaceous	4,130	1.5
Sitka Spruce - Mountain Hemlock	3,872	1.4
Mountain Hemlock	3,432	1.3
Lake	2,508	0.9
Alpine Dwarf Shrub	1,888	0.7
Tree Line Forest Sitka Spruce - Mountain Hemlock	1,669	0.6
Sloping Peatland	1,088	0.4
Talus Slopes and Colluvial Fans	987	0.4
Ocean	973	0.4
Sea Cliff	879	0.3
Road	700	0.3
Total:	267,770	99.2

^a Total park area is approximately 270,030 ha.

^b Additional land cover classes each representing less than 0.25% of the total park area are: Active Colluvial Slope, Tidal Marsh and Mudflat, Alpine Active Colluvial Slope, Freshwater Marsh and Wet Meadow, Sandy Beach and Beach Meadow, Alpine Floodplain, Depressional Peatland, Pond, Cobble Beach and Beach Meadow, Freshwater Aquatic Bed. Together these additional land cover classes cover 2,260 hectares or 0.8% of the park area.

The dataset also contains land cover classes, a more finite classification. Therefore, in many cases, several land cover classes can be found within a given ecological system. Similar to the ecological system, the most prevalent land cover class by area in the park is snow and ice (55.0%). Other prevalent land cover classes include unvegetated (7.1%), closed alder – mesic herbaceous mosaic (5.0%), closed tall alder (4.4%), mesic herbaceous (4.0%), dwarf shrub-mesic herbaceous mosaic (3.1%), closed alder – salmonberry (2.8%), closed Sitka spruce (2.1%), sparse vegetation (2.0%), and open Sitka spruce (1.9%) (Table 4) (NPS 2009, Plate 3).

Table 4. Land cover classes in KEFJ by area and percent of total area. All land cover classes representing less than 0.3 % of total area are listed in a table note.

Land cover Class	Hectares	% of Total Area
Snow and Ice	148,615	55.0
Unvegetated	19,103	7.1
Closed Alder - Mesic Herbaceous Mosaic	13,547	5.0
Closed Tall Alder	11,844	4.4
Mesic Herbaceous	10,715	4.0
Dwarf Shrub - Mesic Herbaceous Mosaic	8,431	3.1
Closed Alder - Salmonberry	7,435	2.8
Closed Sitka Spruce	5,652	2.1
Sparse Vegetation	5,318	2.0
Open Sitka Spruce	5,246	1.9
Woodland Sitka Spruce - Alder	3,188	1.2
Closed Tall Alder – Willow	3,124	1.2
Lake	2,507	0.9
Closed Sitka Spruce - Mountain Hemlock	2,477	0.9
Open Low Alder	2,016	0.7
Dwarf Shrub	1,790	0.7
Woodland Mountain Hemlock	1,709	0.6
Closed Mountain Hemlock	1,483	0.5
Open Mountain Hemlock	1,178	0.4
Moss – Lichen	1,087	0.4
Woodland Sitka Spruce - Alder-Willow	1,054	0.4
Open Low Alder - Willow	1,049	0.4
Open Sitka Spruce - Mountain Hemlock	1,041	0.4
Ocean	973	0.4
Closed Low Alder - Willow	876	0.3
Mountain Hemlock - Sitka Spruce Peatland	749	0.3
River	694	0.3
Open Tall Alder	690	0.3
Totals:	263,591	97.7 ^b

^a Total park area is approximately 270,030 ha.

^b Additional land cover classes each representing less than 0.25% of the total park area are: Open Low Willow - Mesic Herbaceous, Open Tall Alder – Willow, Woodland Sitka Spruce - Mountain Hemlock, Woodland Sitka Spruce – Herbaceous, Herbaceous Marsh and Wet Meadow, Closed Low Alder, Woodland Sitka Spruce, Closed Tall Willow, Open Low Shrub Peatland, Open Black Cottonwood, Woodland Black Cottonwood, Closed Black Cottonwood, Herbaceous Peatland, Open Low Shrub, Open Sitka Spruce / Black Cottonwood, Krumholz, Woodland Sitka Spruce / Black Cottonwood, Pond, Open Tall Willow, Intertidal Sparse Vegetation, Open Low Willow, Closed Low Willow, Dead Forest, Closed Low Salmonberry, Closed Sitka Spruce - Black Cottonwood, Freshwater Aquatic Bed, Closed Tall Salmonberry, Road. Together, these additional land cover classes comprise 6,440 hectares or 2.38% of the park area.

Land Cover Changes

Changes in the abundance, distribution, or classification of land cover over time can be directly related to regional climatic or geomorphologic influences affecting ecological processes (Bennett et al. 2006). Coastal mountain ranges like those found in KEFJ produce snowfalls rivaled by few other places on earth. However, greater snowfall totals are found on the windward (coastal) sides of these mountains and are furthermore unevenly distributed across these landscapes through the effects of topography and wind. Variable snow distribution defines or changes ecological communities by affecting an area's growing season length and the availability of water (Bennett et al. 2006).

KEFJ is unique compared to other SWAN parks as over half of the park area is classified as snow/ice comprising large ice fields and numerous valley and mountain glaciers (NPS 2009). Large expanses of snow and ice make the KEFJ landscape susceptible to change over both long (post-Pleistocene warming) and short time scales (Pacific Decadal Oscillation) (Bennett et al. 2006). Glacial retreat and diminishing ice fields provide newly deglaciated terrain where vegetation establishes itself and succeeds over time. These changes in vegetation distribution and composition represent land cover changes. NPS (2009) classified 13,584 hectares (33,566 acres) or 5% of the classified land cover area within KEFJ as recently deglaciated land vegetated by tall shrubs; recently deglaciated land is defined as land exposed since the end of the Little Ice Age (Boggs et al. 2008). Figure 5 represents the successional changes that are likely to occur on lands deglaciated from 0 to 150 years ago.

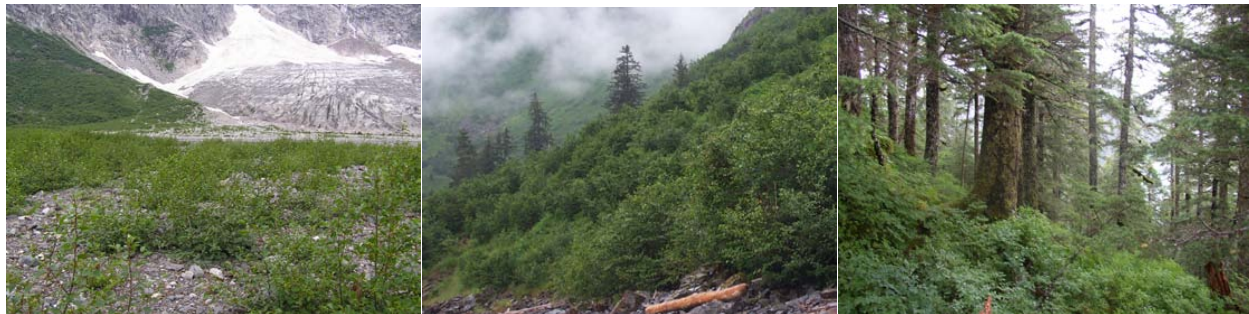


Figure 5. Recently deglaciated tall shrublands 0-50 years since deglaciation (left photo), Sitka spruce invading alder and willows 56-64 years since deglaciation (middle photo), and mature Sitka spruce 97-147 years since deglaciation (right photo) (Boggs et al. 2008).

Tectonic activity has caused subsidence along KEFJ's coastline, in some instances of more than 1.8m (6 ft) (Bennett et al. 2006). Given the active tectonic history of the park, landscape changes driven by these forces are likely to occur in the future. Some of the recent changes to the park's coast are evident in comparisons of 1950s aerial photography with 2005 IKONOS satellite imagery. However, much of what is observed in these comparisons was likely the result of subsidence that was an immediate response to the 1964 earthquake, whereas, current tectonic activity actively resulting in uplift along the park's coast (Freymueller et al. 2008). A comparison of the 1950s to 2005 imagery is examined in the "Coastal Geomorphology – Visual Changes (1950s to 2005)", a later chapter of this report.

Human use within KEFJ also has the potential to drive land cover change through the transportation of invasive terrestrial species into the park (Bennett et al. 2006). The Exit Creek Area has the greatest potential to be negatively impacted by invasive terrestrial species. Since the vast majority of park coastal visitation is by boat tours where visitors do not set foot on land, the coastal backcountry of the park is at a lower risk of invasive plant infestations compared with the Exit Glacier area which receives many visitors. Still, Kurtz (2010) warns that with backcountry visitors accessing coastal areas via water taxi, private boat, or kayaks and often frequenting many beaches along the park's coast, there remains some potential for invasive plants to become established at camping beaches, public use cabins and a commercial development site at Pedersen Lagoon. To date, most invasive plant species have established themselves in the Exit Glacier area; hence, during the first seven field seasons, invasive plant management efforts have been focused in the Exit Glacier area. The park also intensively surveys coastal locations for early detection of invasive plant species (Kurtz 2010). Some of the coastal public use cabins and remote beaches have had invasive plants.

Outbreaks of various insects including beetles, sawflies, bud worms, and defoliators have caused major landscape changes to some regions in Alaska (Wittwer 2005). Spruce beetles (*Dendroctonus rufipennis*) have been a significant natural disturbance on the Kenai Peninsula and elsewhere in Alaska in recent years. Wittwer (2005) reported the spruce beetle infested 1,993 hectares (4,924 acres) of forest land on the Kenai Peninsula in 2004. Although this survey showed a 72% decrease in spruce beetle activity, the threat to KEFJ's Sitka spruce forests remains, as nearly 50% of the infested acres on the peninsula are within the Kenai National Wildlife Refuge, approximately 48 km (30 mi) from KEFJ. Berg et al. (2006) suggests that while spruce beetles have long presented a natural disturbance regime in the Kenai Peninsula, if summer temperatures continue to warm, it is possible that endemic spruce beetle populations would be large enough to thin forest areas each year as soon as trees reach the susceptible size. To date, the beetle has not been a major issue in KEFJ. However, according to a KEFJ land cover dataset (NPS 1999), closed and open Sitka spruce cover types, account for approximately 4% of the park's total area or approximately 11% of the vegetated area of the park (excluding snow & ice and unvegetated areas).

2.2.3 Resource Descriptions

According to the Pendleton et al. 2006, "Kenai Fjords National Park contains several coastal landform types, including low to very low change-potential rock cliffs, moderate change-potential alluvial and glacial deposits, high change-potential gravel beaches, and very high change-potential mudflats, sand beaches, and tidewater-glacier termini."

KEFJ supports a wide variety of wildlife, including one marine mammal species, harbor seals (*Phoca vitulina richardsi*). SWAN has chosen harbor seals as a Vital Sign for their monitoring program. In 1972, Congress passed the Marine Mammal Protection Act, which prohibits the "taking" and importation of marine mammals as well as products taken from them; native Indians, Aleut, and Eskimo people being the only exemptions from this act (USFWS 2011). Through their predatory activities they transfer nutrients and energy through the near-shore ecosystem. Harbor seals haul out (i.e., leave the water) on glacial ice, boulders, or land (Hoover 1983). Maximum numbers can be observed during June, when pupping occurs, and in August when molting occurs (Hoover 1983).

KEFJ has many different species of marine birds. Murres (*Uria* spp.), murrelets (Alcidae), puffins (*Fratercula* spp.), guillemots (*Cepphus* spp.), cormorants (*Phalacrocorax* spp.), and gulls (Laridae) are fish eating species. Glaucous-winged gulls (*Larus glaucescens*) and kittiwakes (*Rissa* spp.) are surface feeders (Speckman 2002). Trends in populations of marine birds often reflect the integrity of their environment (Bennett et al. 2006). The marine environment in KEFJ is nutrient rich due to the combination of coastal streams, glacial melt, and the Alaska Coastal Current. Marine ecosystems provide essential wintering, staging, feeding, and nesting grounds for migratory and resident birds (Vequist 1990). Marine bird distribution largely depends on the availability of prey, water temperature, and salinity (Speckman 2002).

2.2.4. Resource Issues Overview

There are a number of concerns regarding wildlife in KEFJ. Climate change could alter habitat, phenology, and marine water chemistry, having implications on wildlife. In addition, visitor disturbance related to marine mammals, catastrophic disasters, contaminants, and marine debris are all concerns to park management (L. Phillips, pers. comm. 2014).

Spruce beetles (*Dendroctonus rufipennis*) are a growing concern for the Kenai Peninsula, although they have not affected the park to date. “Recent outbreaks have caused extensive mortality of spruce across approximately 1.2 million hectares of forest in south-central Alaska from 1989 to 2004” (USFS 2005, cited by Berg et al. 2006). A build-up of mature trees and global warming may be contributing to a bark beetle population outbreak. Warming climates may speed up the reproductive cycles and reduce mortality rates (Berg et al. 2006).

Climate is one of the most important factors influencing ecosystems. Global climate models indicate high latitudes are more vulnerable to climate change and variability (SWAN 2009). Alaska experienced both warming and precipitation increase over the 20th century (Weller et al. 1999). Within the SWAN region of AK, mean annual and winter temperatures increased from 1949-2013 (Alaska Climate Research Center 2014).

The 1989 Exxon Valdez oil spill was one of the largest oil spills in American history. This disaster affected 2,090 km (1,300 mi) of coastline and the wildlife that inhabit it. About 11 million gallons of crude oil spilled into Prince William Sound, and some of the affected areas have not been restored to their original condition. Currently, monitoring related to the spill still occurs at the park (S. Kim, pers. comm. 2014). It cost \$2 billion to clean up the oil spill, and even more in environmental damages (State of Alaska 2007). Park staff noted the significance of this event during project scoping; many of the current research and monitoring priorities for the park are an outcome from that disaster (L. Phillips, pers. comm. 2014).

Monz and Twardock (2004) assessed the extent of visitor-created impacts in Prince William Sound; the mouth of Prince William Sound is located approximately 85 nautical miles by sea from the shores of KEFJ. Their study focused on assessing beaches accessible by sea kayak and motorboat, where camping was possible. They state that:

The loss of vegetation, soil erosion and associated aesthetic degradation of sites is a significant management concern, particularly when visitation is increasing. Moreover, impacted sites not only tend to increase in size with increasing use, but impacted areas can also proliferate, as campers move from degraded sites to unused areas. Since an overwhelming proportion of soil and plant impact tends to occur with the first few nights of visitation, this trend can cause a rapid increase in the total amount of impacted area (Hammit and Cole 1998).

Laura Phillips (pers. comm. 2014) noted that while physical impacts are monitored, the park is most concerned with the visitor impacts to wildlife species through disturbance.

2010 marked the eighth consecutive year that KEFJ conducted inventory, monitoring, and control of invasive plant species in compliance with Alaska's regional Exotic Plant Management Team (EPMT) protocol. "During the 2010 field season, park staff, volunteers, and Southeast Alaska Guidance Association (SAGA) hired with American Recovery and Reinvestment Act funding pulled 2,617 pounds of weeds in the park" (Kurtz 2010). A weed pull conducted in 2010 removed over 856 pounds of invasive species including sweet clover (*Melilotus officinalis*), oxeye daisy (*Leucanthemum vulgare*), and dandelions (*Taraxacum officinale*), and a new infestation of birdvetch (*Vicia cracca*) from areas within and adjacent to KEFJ (Kurtz 2010). Invasive species are a persistent concern in many areas including the Exit Glacier area, along roads and trails, and in areas where visitors access the backcountry or beaches of the outer coastal areas (Kurtz 2010).

2.3 Resource Stewardship

2.3.1 Management Directives and Planning Guidance

KEFJ's general management plan (NPS 1984) lists the following management objectives, based on the park's statement for management:

- Maintain the natural abundance, diversity, behavior, and ecological integrity of native animal populations.
- Protect the wildlife population within the fjords, coastal waters, and offshore islands near Kenai Fjords National Park.
- Educate visitors about the negative impacts and consequences of specific boater or visitor behavior in the fjords.
- Make the park available for people but leave the area generally undeveloped and its resources free of man-made influences.

KEFJ's Resource Management Plan (NPS 1999) outlines specific resource themes including:

- Preserve unique, naturally functioning fjords ecosystem for the benefit, appropriate use, education and inspiration of visitors.
- Preserve scenic and geological values.
- Provide maintenance for the population and habitat of marine and terrestrial wildlife.

- Preserve the natural state of the rainforest ecosystem.
- Protect and preserve historical and archaeological sites portraying the unique aboriginal people of the Alaskan coast.
- Preserve wilderness resources of the coast and recreational opportunities.
- Maintain opportunities for scientific research and undisturbed ecosystems.

The Exit Glacier Area Plan (NPS 2004) is an amendment to the General Management Plan (NPS 1984). It focuses on the enhancement of the Exit Glacier viewing experience, and to provide for additional non-motorized recreational opportunities. To achieve this, Exit Glacier is divided into different zones:

- Visitor Facilities Zone (all season)
 - The Visitor Facilities Zone provides basic infrastructure necessary to accommodate visitors arriving to the Exit Glacier area.
- Pedestrian Zone (all season)
 - The Pedestrian Zone accommodates numerous visitors, many of who wish to experience the glacial ice of Exit Glacier up close.
- Hiker Zone (summer only)
 - The Hiker Zone allows visitors to access more remote locations along well maintained trails.
- Backcountry Semi-Primitive Zone (summer only)
 - The Backcountry Semi-Primitive zone provides better opportunities for visitors to experience wildlands and solitude than the other zones described above.
- Backcountry Primitive Zone (summer only)
 - The Backcountry Primitive Zone provides the opportunity for visitors to experience the Exit Glacier area in its most undisturbed state.

The Interim Bear Management Plan (NPS 2009) is still awaiting final research results to fill information gaps regarding population and habitat parameters, and the impacts of human activities. This preliminary document was designed to provide guidance for park operations. Specific interim goals are:

- Provide safety for visitors and staff by minimizing bear-human conflicts.
- Minimize the effects of human activities on the distribution, abundance and behavior of black (*Ursus americanus*) and brown (*U. arctos*) bear populations.
- Ensure opportunities for visitors to observe, understand, and appreciate black and brown bears, as a part of an intact ecosystem.

- Achieve these goals with minimum intrusive management actions.

2.3.2 Status of Supporting Science

SWAN identifies key resources network-wide and for each of its parks that can be used to determine the overall health of the parks. These key resources are called Vital Signs. In 2006, SWAN completed and released a Vital Signs monitoring plan (Bennett et al. 2006). Table 5 shows the network Vital Signs selected for monitoring in KEFJ.

Table 5. SWAN vital signs selected for monitoring in KEFJ (Bennett et al. 2006).

Category	SWAN Vital Signs
Air and Climate	Weather and climate
Geology & Soils	Glacier extent, geomorphic coastal change, volcanic and earthquake activity
Water	Surface hydrology, marine water chemistry, freshwater chemistry
Biological integrity	Invasive/exotic species, insect outbreaks, kelp and eelgrass, marine intertidal invertebrates, resident lake fish, salmon, black oystercatcher, bald eagle, seabirds, river otter (coastal), wolf, wolverine, sea otter, harbor seal, vegetation composition and structure, sensitive vegetation communities
Human use	Visitor use
Landscapes (ecosystem pattern and process)	Land cover/land use, landscape processes (snow cover, lake and coastal ice and suspended sediments)

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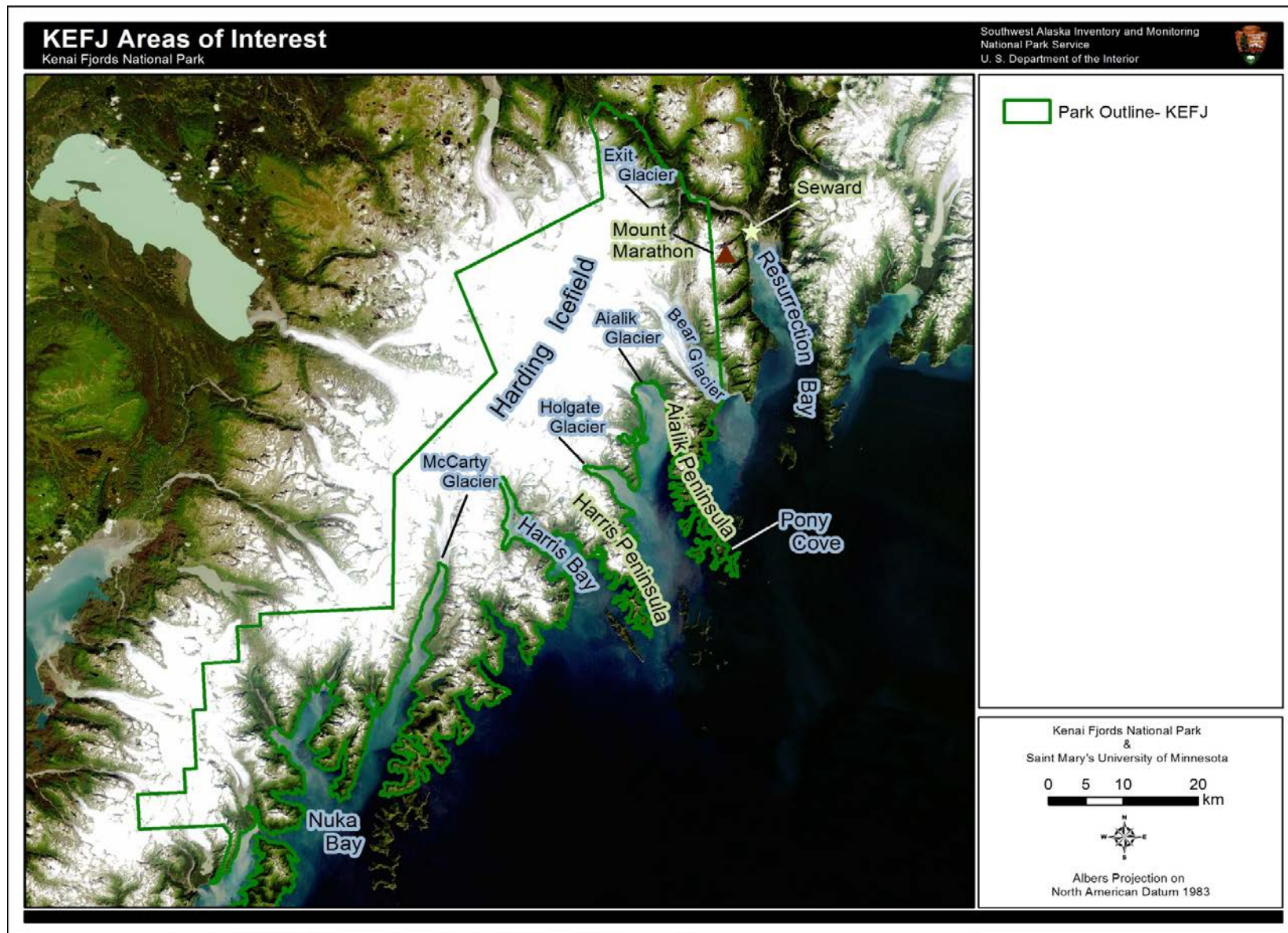


Plate 1. Areas of interest in KEFJ (commonly referred-to place names).

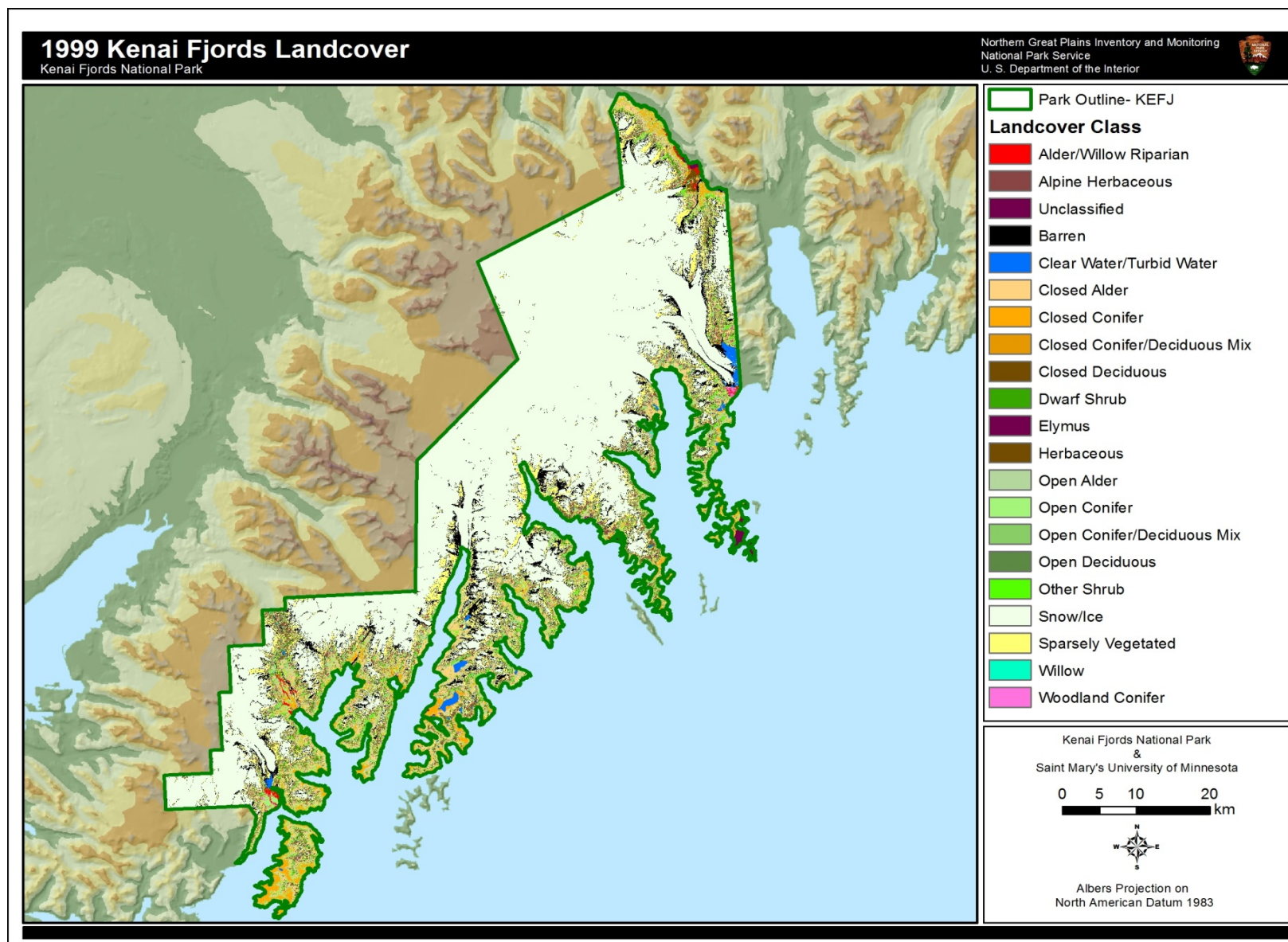


Plate 2. 1999 land cover map of KEFJ. Land cover classes combined from original data for display purposes (NPS 1999).

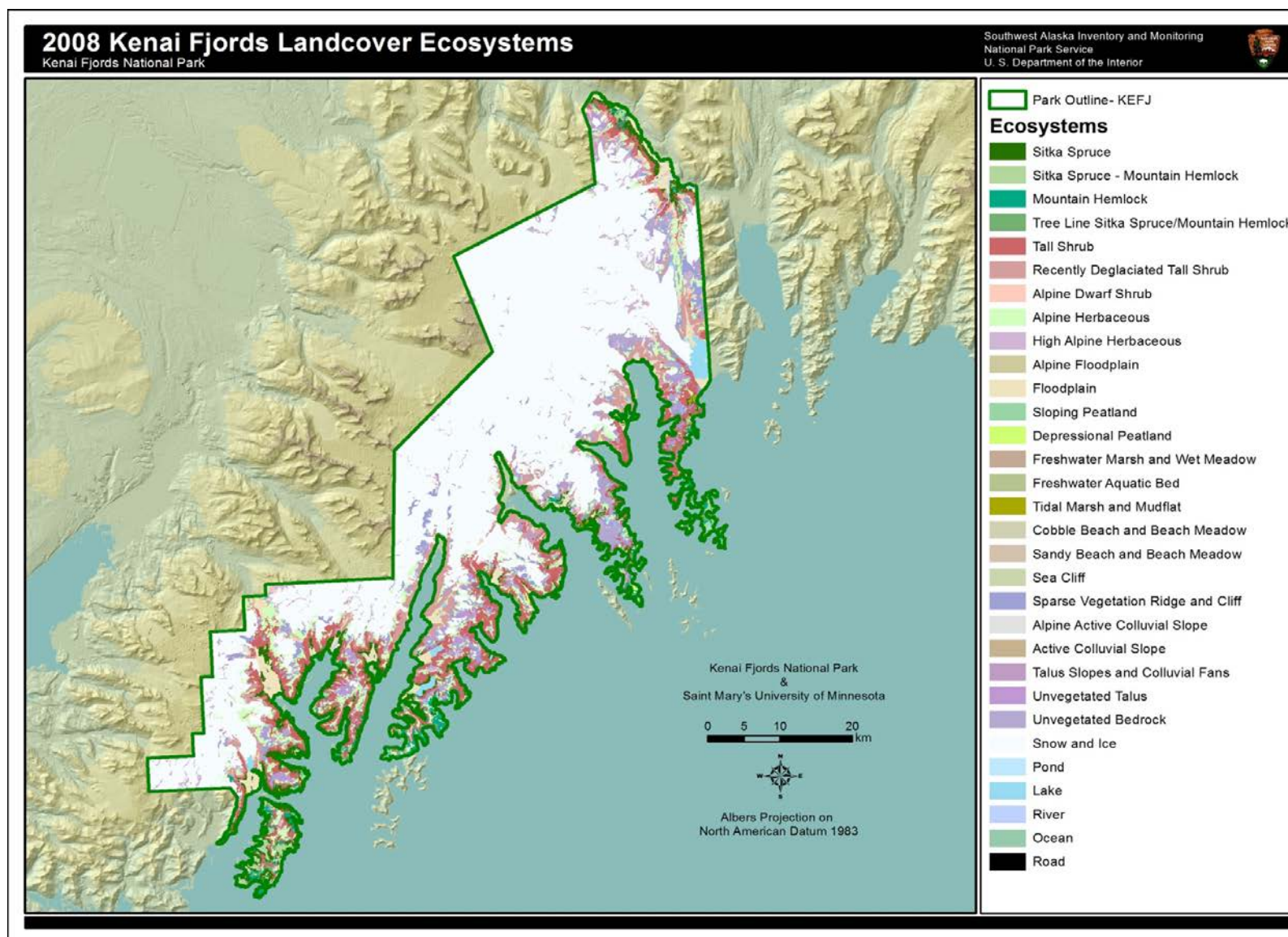


Plate 3. Ecological Systems (i.e., ecosystems) for KEFJ 2008. Land cover classes combined from original data for display purposes (IRMA 2009).

Chapter 3 Study Scoping and Design

This NRCA is a collaborative project between the NPS and Saint Mary's University of Minnesota Geospatial Services (SMUMN GSS). Project stakeholders include the KEFJ resource management team and SWAN Inventory and Monitoring Program staff. Before embarking on the project, it was necessary to identify the specific roles of the NPS and SMUMN GSS. Preliminary scoping meetings were held, and a task agreement and a scope of work document were created cooperatively between the NPS and SMUMN GSS.

3.1 Project Scoping

3.1.1 Initial Project Scoping and Expectations

A preliminary scoping meeting was held soon after project initiation. At this meeting, SMUMN GSS and NPS staff confirmed that the purpose of the KEFJ NRCA was to evaluate and report on current conditions, critical data and knowledge gaps, and selected existing and emerging resource condition influences of concern to KEFJ managers. Certain constraints were placed on this NRCA:

- Condition assessments are conducted using existing data and information;
- Identification of data needs and gaps is driven by the project framework categories;
- The analysis of natural resource conditions includes a strong geospatial component;
- Resource focus is primarily driven by KEFJ resource management priorities.

This condition assessment provides a “snapshot-in-time” evaluation of the condition of a select set of park natural resources that were identified and agreed upon by the project team. Project findings will aid KEFJ resource managers in the following objectives:

- Develop near-term management priorities (how to allocate limited staff and funding resources);
- Engage in watershed or landscape scale partnership and education efforts;
- Consider new park planning goals and take steps to further these;
- Report program performance (e.g., Department of Interior Strategic Plan “land health” goals, Government Performance and Results Act [GPRA]).

Specific project expectations and outcomes included the following:

- For key natural resource components, consolidate available data, reports, and spatial information from appropriate sources including: KEFJ resource staff, the NPS Integrated Resource Management Application (IRMA) website, Inventory and Monitoring Vital Signs program, and available third-party sources. The NRCA report will provide a resource assessment and summary of pertinent data evaluated through this project.

- When appropriate, define a reference condition so that statements of current condition may be developed. The statements will describe the current state of a particular resource with respect to an agreed upon reference point.
- Clearly identify “management critical” data (i.e., those data relevant to the key resources). This will drive the data mining and gap definition process.
- Where applicable, develop GIS products that provide spatial representation of resource data, ecological processes, resource stressors, trends, or other valuable information that can be better interpreted visually.
- Utilize “gray literature” and reports from third party research to the extent practicable.

3.2 Rescoping

After NPS review of some initial resource assessment draft sections and discussions regarding the difficulty in defining reference conditions for many of the resources, KEFJ decided to reprioritize and refocus efforts on a suite of analytical products from a select set of detailed component analyses. These components we already identified as important natural resource aspects of the park, but were rescoped to incorporate specific photo interpretation products and GIS analyses to provide additional information to the park. This refocusing of project resources also reduced the number of components analyzed for the project because of the increased level of effort required to complete these more detailed examinations. The following components were considered “analysis” components for this natural resource condition assessment: salmon, black bear, landform (landing beaches), coastal geomorphology – shoreline changes, and Exit Glacier and Creek Area hydrology (channel migration and flooding). Several components were not assessed, although some initial data and literature mining efforts were completed by NPS personnel and by GSS SMUMN. Deborah Kurtz of KEFJ completed a data mining effort in which digital files and physical holding were searched according to the original NRCA.

Additional proposed analyses or mapping approaches and primary data sources are presented in Table 6. These analyses were not addressed, due to project time constraints after prioritization. For nunataks, which are exposed mountain peaks or ridges rising above surrounding glacial ice (Miller et al. 2006); it was proposed to map their aerial extents using select time series aerial photography and satellite imagery. These base imagery data include orthophotography from the 1950s and 1980s and IKONOS satellite imagery from the 2000s. An example nunatak visible in these images is shown in Figure 6. For glaciers, it was proposed to develop a methodology for repeat mapping of Late Summer Snowlines (LSSL) using available MODIS data downloadable from the Geographic Information Network of Alaska (GINA). Lastly, for land cover it was proposed to delineate and describe major physiognomic vegetation classes associated with succession and colonization post-glaciation using time series photography (orthophotos from the 1950s and 1980s and IKONOS satellite imagery from the 2000s).

Table 6. Proposed analyses as part of the rescoping of the KEFJ natural resource condition assessment not addressed in this assessment.

Topic (component)	Description
Sensitive Vegetation Communities - Nunataks	Mapping the aerial extents of nunataks and examining changes using existing time-series orthophotography (1950s and 1980s) and 2005 IKONOS satellite imagery
Glaciers ^a	Developing a methodology for repeat mapping of Late Summer Snowlines (LSSLs) using available MODIS satellite data
Land Cover ^b	Delineating and describing major physiognomic vegetation classes associated with succession and colonization post-glaciation using time series photography/imagery (1950s & 1980s orthophotography and 2005 IKONOS satellite imagery).

^a Late Summer Snowline mapping methodology is discussed as a data gap in the Glaciers component beginning on page 222.

^b A brief description of an existing pilot project is provided in the land cover section of chapter 4.

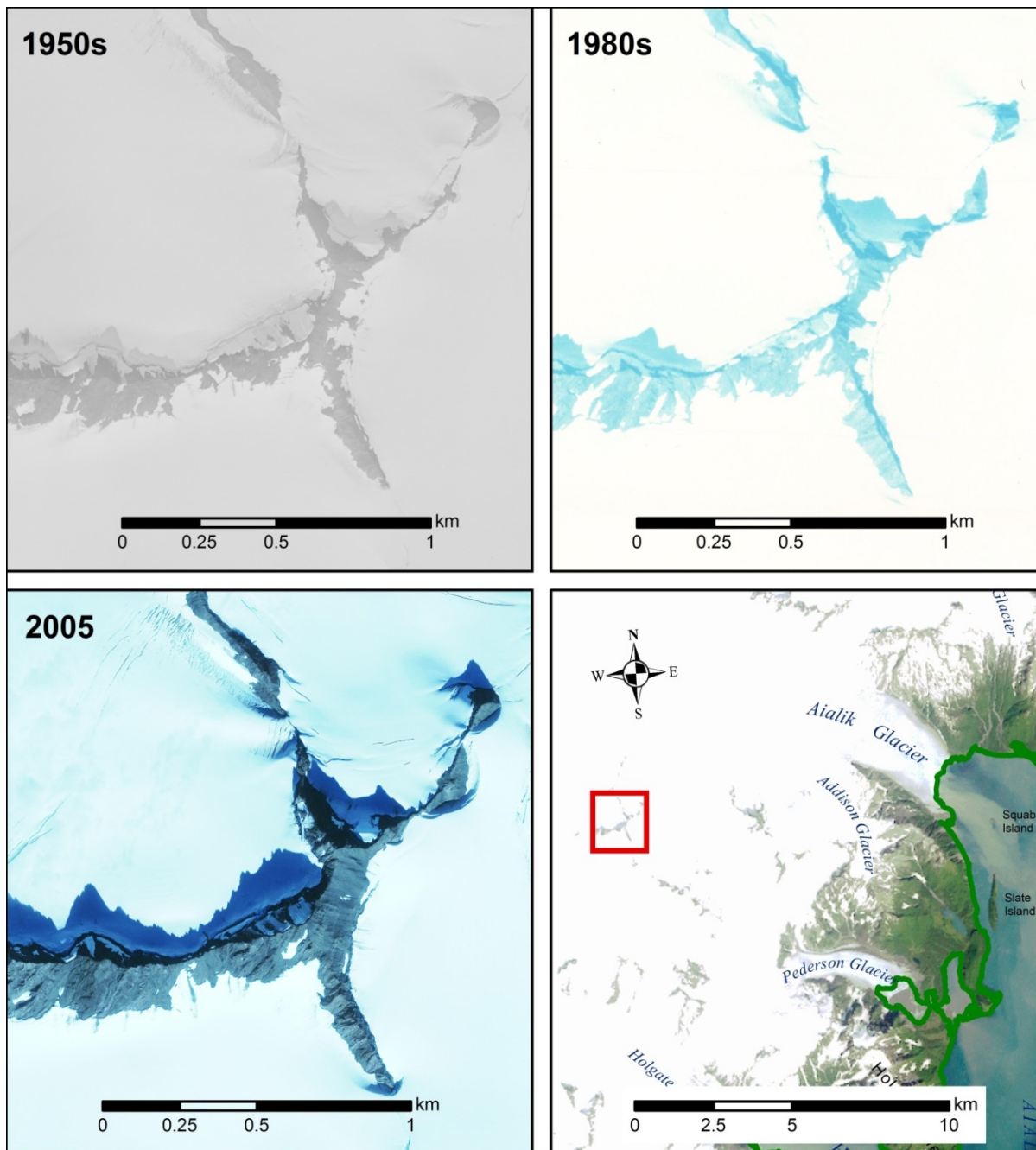


Figure 6. Example nunatak area within the Harding Icefield of KEFJ displayed in 1950s (upper left) and 1980s (upper right) aerial orthophotography and in 2005 IKONOS satellite imagery (lower left). Lower right image displays this nunatak in relation to known areas of the park such as Aialik and Pederson Glaciers.

3.3 Project Framework

The initial scoping meeting yielded a framework with 21 candidate natural resource components to consider for analysis in the NRCA. After rescoping, the final project framework included 10 resource components (Table 7). The final project framework includes resources that were assessed according to a standard methodology presented in section 3.4. The different resources in the project framework correlate to the sections in Chapter 4 of this report. Certain components in the project framework were deemed not-assessable, but still valuable to represent and discuss in the NRCA; these were Landing Areas, Hydrology, and Coastal Geomorphology.

Table 7. Kenai Fjords National Park natural resource condition assessment framework.

Component	NPS Collaborator	Description and Measures	Primary Data Sources	Notes and Stressors
Landform (landing beaches)	Fritz Klasner	Measures: Landing area/beach locations, Marine debris collection sites, General resource conditions (extent, substrate, slope, plant wildlife communities, cultural resources at the locations)	Campsite Inventory data, I&M nest site locations (BLOY & BAEA), also incorporate marine debris	KEFJ has more Campsite Inventory Data than what Joel has at the network, the data is not super well organized, needs some work. Sites are measured more intensively in the more heavily used areas and other areas are captured with a rapid site assessment. NOAA has some info on Marine Debris. Also contact MCAF (Marine Conservation Aliances Foundation).
Black Bear	Laura Phillips	Measures: Distribution, Abundance, and Number and Seasonality of bear-human incidents.	Existing KEFJ BHIMS database	Also use annual KEFJ reports. KEFJ uses the BHIMS database to create these reports.
Bald Eagles	Laura Phillips	Measures: Nest occupancy, Productivity, and Nest distribution	KEFJ eagle nesting survey data. KEFJ eagle survey GIS data.	Stressors include visitor use, predator abundance and distribution, oil spills, and contaminants.
Marine Birds	Laura Phillips, Heather Coletti	Measures: Seabird colony composition, Abundance of breeders in seabird colonies, Distributino of seabird colonies, Density and distribution of target taxa, Productivity	Historic survey data (Bailey 1976, Nishimoto and Rice 1987), KEFJ and USFWS surveys for SWAN near shore monitoring.	Stressors include visitor use, prey availability, predator abundance and distribution, oil spills, and contaminants.
Black Oystercatcher	Laura Phillips, Heather Coletti	Measures: Active nest territory density, Productivity, Prey species composition	Morse et al. (2006) chick survival data, SWAN near shore monitoring.	Stressors include visitor use, prey availability, climate change (storm severity, beach erosion, sea level rise), tour boat wakes, contamination, and predator populations.
Salmon	Laura Phillips	Measures: Inidividual stock escapement, Anadromous Waters Catalog (AWC) additions	Existing ADF&G data	Use AWC and Fish Weir Data (active counts) from Delight and Desire Lakes. Contact Dan Bosch from the Soldotona or Anchorage office.
Hydrology	Deb Kurtz	Measure: Changes in horizontal channel position	Ortho photos: 1950, 1980s, 2000 and IKONOS Imagery	Delineate and describe channel migration of Exit Creek using time series photograpy.
Glaciers	Bruce Giffen, Deb Kurtz	Measures: Area, Rate of terminus retreat, Mass balance (surface elevation), Late summer season snow line, Glacial lake outburst floods	MODIS data downloadable from GINA	Other contacts to describe a potential method may include Dayne Broderon from GINA (UAF) and possibly Parker Martin.
Coastal Geomorphology	Deb Kurtz	Analyze/characterize areas of coastal change (e.g., beaches, gravel bars, river deltas) using historic and recent imagery. Measures: Position of mean high water line (MHWL), Top and toe of bluff, Position of foreshore and backshore vegetation.	Ortho photos: 1950, 1980s, 2000 and IKONOS Imagery	Identifiy areas with significant change: (e.g., lower-Bear glacier near terminus, larger covers bulldog/porcupine etc. (ghost forests) beaches outside of the marine in Northwestern Bay/fjiord

3.4 Standard Resource Component Methods

This study involved gathering and reviewing existing literature and data relevant to each of the key resource components included in the framework. No new data were collected for this study; however, where appropriate, existing data were further analyzed to provide summaries of resource condition or to create new spatial representations. After all data and literature relevant to the measures of each component were reviewed and considered, a qualitative statement of overall current condition was created and compared to the reference condition when possible.

3.4.1 Data Mining

The data mining process (acquiring as much relevant data about key resources as possible) began at the initial scoping meeting, at which time KEFJ staff provided data and literature in multiple forms, including: NPS reports and monitoring plans, reports from various state and federal agencies, published and unpublished research documents, databases, tabular data, and charts.

GIS data were also provided by NPS staff. Additional data and literature were acquired through online bibliographic literature searches and inquiries on various state and federal government websites. Data and literature acquired throughout the data mining process were inventoried and analyzed for thoroughness, relevancy, and quality regarding the resource components identified at the scoping meeting.

3.4.2 Data Development and Analysis

Data development and analysis was highly specific to each component in the framework and depended largely on the amount of information and data available for the component, as well as recommendations from NPS reviewers and sources of expertise including NPS staff from KEFJ and the SWAN. Specific approaches to data development and analysis can be found within the respective component assessment sections located in Chapter 4 of this report.

3.4.3 Scoring Methods and Assigning Condition

Significance Level

A set of measures are useful in describing the condition of a particular component, but all measures may not be equally important. A “Significance Level” represents a numeric categorization (integer scale from 1-3) of the importance of each measure in assessing the component’s condition; each Significance Level is defined in Table 8. This categorization allows measures that are more important for determining condition of a component (higher Significance Level) to be more heavily weighted in calculating an overall condition. Significance Levels were determined for each component measure in this assessment through discussions with park staff and/or outside resource experts.

Table 8. Scale for a measure's Significance Level in determining a component's overall condition.

Significance Level (SL)	Description
1	Measure is of low importance in defining the condition of this component.
2	Measure is of moderate importance in defining the condition of this component.
3	Measure is of high importance in defining the condition of this component.

Condition Level

After each component assessment is completed (including any possible data analysis), SMUMN GSS analysts assign a Condition Level for each measure on a 0-3 integer scale (Table 9). This is based on all the available literature and data reviewed for the component, as well as communications with park and outside experts.

Table 9. Scale for Condition Level of individual measures.

Condition Level (CL)	Description
0	Of NO concern. No net loss, degradation, negative change, or alteration.
1	Of LOW concern. Signs of limited and isolated degradation of the component.
2	Of MODERATE concern. Pronounced signs of widespread and uncontrolled degradation.
3	Of HIGH concern. Nearing catastrophic, complete, and irreparable degradation of the component.

Weighted Condition Score

After the Significance Levels (SL) and Condition Levels (CL) are assigned, a Weighted Condition Score (WCS) is calculated via the following equation:

$$WCS = \frac{\sum_{i=1}^{\# \text{ of measures}} SL_i * CL_i}{3 * \sum_{i=1}^{\# \text{ of measures}} SL_i}$$

The resulting WCS value is placed into one of three possible categories: good condition (WCS = 0.0 – 0.33); condition of moderate concern (WCS = 0.34 - 0.66); and condition of significant concern (WCS = 0.67 to 1.00). Figure 7 displays all of the potential graphics used to represent a component's condition in this assessment. The colored circles represent the categorized WCS; red circles signify a significant concern, yellow circles a moderate concern and green circles a good condition. Gray circles are used to represent situations in which SMUMN GSS analysts and park staff felt there were currently insufficient data to make a statement about the condition of a component. For example, condition is not assessed when no recent data or information are available, as the purpose of an NRCA is to provide a “snapshot-in-time” of current resource conditions. The arrows inside the circles indicate the trend of the condition of a resource component, based on data and literature from the past 5-10 years, as well as expert opinion. An upward pointing arrow indicates the condition of

the component has been improving in recent times. A two-sided arrow indicates condition is unchanging, and an arrow pointing down indicates a decline in the condition of a component in recent times. These are only used when it is appropriate to comment on the trend of condition of a component. If the trend of the component's condition is currently unknown, no arrow is given.






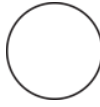




Condition Status		Trend in Condition		Confidence in Assessment	
	Warrants Significant Concern		Condition is Improving		High
	Warrants Moderate Concern		Condition is Unchanging		Medium
	Resource is in Good Condition		Condition is Deteriorating		Low
	<p>An open (uncolored) circle indicates that current condition is unknown or indeterminate; this condition status is typically associated with unknown trend and low confidence</p> <p><i>(explanation is required if a trend symbol or a medium/high confidence band is shown)</i></p>				

Figure 7. Symbol descriptions in the component condition graphics.

3.4.4 Preparation and Review of Component Draft Assessments

The preparation of draft assessments for each component was a highly cooperative process among SMUMN GSS analysts and KEFJ and SWAN staff. Though SMUMN GSS analysts rely heavily on peer-reviewed literature and existing data in conducting the assessment, the expertise of NPS resource staff also plays a significant and invaluable role in providing insights into the appropriate direction for analysis and assessment of each component. This step is especially important when data or literature are limited for a resource component.

The process of developing draft documents for each component began with a detailed phone or e-mail conversation with an individual or multiple individuals considered local experts on the resource components under examination. These conversations were a way for analysts to verify the most relevant data and literature sources that should be used and also to formulate ideas about current condition with respect to the NPS staff opinions. Upon completion, draft assessments were forwarded to component experts for initial review and comments.

3.4.5 Development and Review of Final Component Assessments

Following review of the component draft assessments, analysts used the review feedback from resource experts to compile the final component assessments. As a result of this process, and based on the recommendations and insights provided by KEFJ resource staff and other experts, the final component assessments represent the most relevant and current data available for each component and the sentiments of park resource staff and, in some cases, outside resource experts.

3.4.6 Format of Component Assessment Documents

All resource component assessments are presented in a standard format. The format and structure of these assessments is described below.

Description

This section describes the relevance of the resource component to the park and the context within which it occurs in the park setting. For example, a component may represent a unique feature of the park, it may be a key process or resource in park ecology, or it may be a resource that is of high management priority. Also emphasized are interrelationships that occur among the featured component and other resource components included in the NRCA.

Measures

Resource component measures were defined in the scoping process and refined through dialogue with resource experts. Those measures deemed most appropriate for assessing the current condition of a component are listed in this section, typically as bulleted items.

Reference Conditions/Values

This section explains the reference condition determined for each resource component as it is defined in the framework. Explanation is provided as to why specific reference conditions are appropriate or logical to use. Also included in this section is a discussion of any available data and literature that explain and elaborate on the designated reference conditions. If these conditions or values originated with the NPS experts or SMUMN GSS analysts, an explanation of how they were developed is provided.

Data and Methods

This section includes a discussion of the data sets used to evaluate the component and if or how these data sets were adjusted or processed as a lead-up to analysis. If adjustment or processing of data involved an extensive or highly technical process, these descriptions are included in an appendix for the reader or a GIS metadata file. Also discussed is how the data were evaluated and analyzed to determine current condition (and trend when appropriate).

Current Condition and Trend

This section presents and discusses in-depth key findings regarding the current condition of the resource component and trends (when available). The information is presented primarily with text but is often accompanied by detailed maps or plates that display different analyses, as well as graphs, charts, and/or tables that summarize relevant data or show interesting relationships. All relevant data and information for a component is presented and interpreted in this section.

Threats and Stressor Factors

This section provides a summary of the threats and stressors that may impact the resource and influence to varying degrees the current condition of a resource component. Relevant stressors were described in the scoping process and are outlined in the NRCA framework. However, these are elaborated on in this section to create a summary of threats and stressors based on a combination of available data and literature, and discussions with resource experts and NPS natural resources staff.

Data Needs/Gaps

This section outlines critical data needs or gaps for the resource component. Specifically, what is discussed is how these data needs/gaps, if addressed, would provide further insight in determining the current condition or trend of a given component in future assessments. In some cases, the data needs/gaps are significant enough to make it inappropriate or impossible to determine condition of the resource component. In these cases, stating the data needs/gaps is useful to natural resources staff seeking to prioritize monitoring or data gathering efforts.

Overall Condition

This section provides a qualitative summary statement of the current condition that was determined for the resource component using the WCS method. Condition is determined after thoughtful review of available literature, data, and any insights from NPS staff and experts, which are presented in the Current Condition and Trend section. The Overall Condition section summarizes the key findings and highlights the key elements used in determining and justifying the level of concern, if any, that analysts attribute to the condition of the resource component. Also included in this section are the graphics used to represent the component condition.

Sources of Expertise

This is a listing of the individuals (including their title and affiliation with offices or programs) who had a primary role in providing expertise, insight, and interpretation to determine current condition (and trend when appropriate) for each resource component.

Literature Cited

This is a list of formal citations for literature or datasets used in the analysis and assessment of condition for the resource component. Note, citations used in appendices and plates referenced in each section (component) of Chapter 4 are listed in that component's "Literature Cited" section.

3.5 Literature Cited

Miller A., M. Carlson, R. Lipkin, and P. Spencer. 2006. Vascular plant inventory and baseline monitoring of nonatak communities (2004). Lake Clark National Park and Preserve and Kenai Fjords National Park. Southwest Alaska Network, National Park Service. Anchorage, AK. 43 pp.

Chapter 4 Component Condition Summaries

4.1 Landform – Coastal Landing Areas

4.1.1 Description

Landing areas along the park's coast are important for visitor access to the coastal backcountry and for activities such as sea kayaking, boating, and camping. Coastal landing areas provide stop-over locations for daytrips out of Seward and access to many undeveloped campsite areas, some developed or established campsites, and two public use cabins in the park (Holgate and Aialik cabins). However, much of the coastline in KEFJ is steep with rocky headlands, cliffs, and large boulder beaches, which limit accessible landing areas for boaters and campers (Klasner et al. 2011).

The park does not require permits for camping or for most other visitor use activities; therefore, it is important for managers to understand the spatial distribution and condition of campsites over time (Klasner et al. 2011). Likewise, it is important to understand the spatial distribution and condition of the landing areas used to access these campsites and to identify potential additional landing areas, even if only used as temporary stop-over locations. In addition to being relatively scarce along the coastline, landing areas tend to be dynamic in nature with shifting coastal sediments, marine debris, and changing river discharge and sediments. These factors increase the importance of knowing where landing areas are located and how they might be changing over time.



Photo 1. Marine debris collection site (collector beach) and potential landing area in KEFJ (Photo by Erin Mckittrick).

Based upon known locations of campsites contained within a park campsite database, shoreline segments where marine debris collections have taken place (GIS data from the Resurrection Bay Conservation Alliance - RBCA), and shoreline GIS data available from the NPS (Crowell and Mann 1995, Mann 1997), landing areas appear to typically associate with narrow gravel and/or sand beaches; flat, wide gravel areas associated with stream deltas; and sand and/or gravel fans. However, they are also associated with protected lagoon shorelines where beaches are not visible in 2005 IKONOS satellite imagery. Landing areas are important to park management because, like the campsites established near these landing areas, they are destinations and focal points for park visitors where use tends to concentrate (Monz and Twardock 2004). Increasing resource impacts at campsites and the associated landing areas in KEFJ has raised concerns about altered ecological conditions, impacts to visitors' wilderness experiences, and visitor safety (Klasner et al. 2011). KEFJ has finalized a campsite monitoring protocol, however, to date, the associated database for recording campsite locations and many parameters related to campsite condition is not yet finalized.

As landing areas become increasingly popular and are subject to visitor-use impacts, concerns for landing areas expressed by park personnel during project scoping is the potential for human-caused disturbance of nesting bald eagles and black oystercatchers along the coast as well as introduction of invasive non-native plant species. Another concern regarding landing areas, specifically landing beaches, are that they can act as marine debris collection sites (i.e., collector beaches). Marine debris presents a source of potential environmental degradation and can negatively affect visitors' wilderness experience.

4.1.2 Measures

- Landing area/beach locations
- Marine debris collection sites
- General resource conditions (extent, substrate, slope, plant wildlife communities, invasive non-native plants, cultural resources at the locations)

4.1.3 Reference Conditions/Values

Reference conditions are not currently established for coastal landing areas. More information needs to be collected to establish baseline data that would allow park management to develop a set of desired conditions that can be used in balancing visitor use while protecting natural resources. A reference condition for these areas may be established in the future with further management consideration and deliberation.

The park is interested in understanding where landing areas exist along the coast and the general resource conditions at these landing areas, along with nearby established campsites. Regarding backcountry campsite conditions, the park has been collecting spatial, photographic, and tabular data for multiple years and has completed a campsite monitoring protocol designed to consistently capture campsite conditions (Monz et al. 2011). From this protocol a campsite inventory database, once finalized is intended to thoroughly and consistently document campsite locations and a variety of conditions related to these campsites. To date, no reports have been published reporting the condition of these campsites according to this protocol. However, Monz et al. (2011) states that the information could be used in the development of a Limits of Acceptable Change (LAC) or Visitor Experience and Resource Protection (VERP) planning process. This information could be combined with potential landing area data (e.g., linear shoreline GIS data) developed for this assessment, to further inform the topic of backcountry visitor use.

4.1.4 Data and Methods

As a part of this NRCA, the park's shoreline was delineated (photo-interpreted) by SMUMN GSS at a scale of 1:3,500. The 2005 IKONOS orthoimage mosaic of the park was used as a base layer, providing a more contemporary and higher resolution (i.e., larger map scale) representation of the shoreline compared to that of existing shoreline GIS data for the park (most of which has been developed from 1:63,360 USGS map information). This interpreted shoreline dataset extends along all of the park's shoreline except for Nuka Island, where the 2005 IKONOS mosaic coverage is lacking. In this effort, the shoreline was interpreted as the visible waterline (i.e., the instantaneous waterline) in the satellite imagery. Because this line was created from an image mosaic made of

several individual IKONOS images which were not tidally coordinated, tidal positions are unknown and are likely to vary slightly throughout the mosaic. Therefore, the resulting digital shoreline does not consistently represent a particular tidal position, such as the mean high water line (MHWL) or the mean low waterline (MLWL); it is not intended to represent a specific waterline nor jurisdictional boundary along the KEFJ coast. However, this dataset is useful for representing the shoreline regarding potential landing areas or beaches and for representing potential collector beaches.

This linear GIS dataset was geographically split and subset, based on photo-interpretation and consultation of existing GIS datasets, into shoreline segments intended to represent potential landing areas (PLAs). Although commonly referred to as landing beaches, these interpreted PLAs were not strictly limited to beaches; shorelines associated with stream deltas, sand or mudflats, and alluvial fans were also identified as PLAs. Shoreline segments considered PLAs were also not only restricted to sites that appear to provide access to a potential camping area, but include possible stop-over beaches at which water craft could land, at least temporarily, depending on tide and weather conditions. To aid in identification of these PLAs and to provide an interpretation of general shoreline types, a GIS line data set called 'Shore-Zone Classifications of Kenai Fjords National Park' (Mann 1997), was consulted. This dataset used an existing shoreline GIS dataset developed at a map scale of 1:63,360 from 1980s Alaska High Altitude Photography (AHAP). From this dataset the author used black and white 1992-1994 1:12,000 scale aerial photographs to characterize the coast in the Gulf of Alaska, and specifically in KEFJ (Mann 1997). In addition, the Crowell and Mann (1995) GIS dataset (aka SAIP - Stream Deltas and SAIP-Wave Energy layers within Alaska NPS permanent GIS dataset or ThemeManager), were also consulted in the interpretation of PLAs. Patterns regarding how the Crowell and Mann (1995) and Man (1997) datasets are associated with the identified PLAs are summarized in the current condition section of this document.

An unpublished KEFJ campsite geodatabase (GIS data type) called 'KEFJ Campsite Inventory V.13', was also consulted as a collateral GIS data source during the photo-interpretation process. It provided the general locations of known campsite areas, food storage locations, and specific locations of campsites captured using GPS units, many of which have been monitored for multiple years by the NPS. The following layers within this database were consulted and combined into one point GIS dataset: 1) 'camp areas' layer from Theme Manager (i.e., known, undeveloped campsites); 2) 'generalized campsites' (not an inventory, but general areas and what type of food storage is available, if any); and 3) 'other data sources' (a compilation of multiple campsite-related location information). Shorelines associated with these locations were delineated as PLAs. The photo-interpreter captured whether or not the shoreline segment (digital, tabular record) was associated with a known campsite and the type of available nearby food storage, if any, in the PLA dataset. Most of the shoreline segments associated with a known campsite or indicated as having available food storage were associated with a relatively prominent, visible landform (e.g., beach or stream delta) in the 2005 IKONOS satellite imagery. Similar features and photographic signatures (beaches, deltas, alluvial fans, etc.) were found elsewhere along the park's shoreline using the 2005 IKONOS satellite imagery and identified as PLAs.

Marine debris collection site information along the park's shoreline was from two sources, the Resurrection Bay Conservation Alliance (RBCA) and from select data contained within NOAA's Alaska ShoreZone database (a copy of the database was received from Steve Lewis, NOAA Fisheries Analytical Team). RBCA observers/volunteers cleaned and surveyed nineteen beaches along the KEFJ shoreline during the summers of 2009-2012. RBCA organizers used Marine Conservation Alliance Foundation (MCAF) data summary sheets to record the length of beach surveyed/cleaned, number of bags filled with debris, debris type, weight of debris, and percent fishing and non-fishing debris at each beach. A summary of these data (2009-2012) are available in Table 10. The RBCA also created a GIS line dataset using heads-up digitizing (photo interpretation) on aerial imagery, identifying these beaches. This dataset was made available to KEFJ and used in this assessment to provide example signatures of known marine debris collection sites during the photo interpretive process. In order to find additional, potential marine debris collection sites, the NOAA's ShoreZone GIS dataset was queried based on particular attributes contained within the database. Details of this query and information from RBCA are discussed further and related to the PLAs in the threats and stressors section of this assessment.

Table 10. Marine debris collection statistics for Resurrection Bay Conservation Alliance (RBCA) marine debris monitoring beaches in KEFJ (2009-2012).

Beach Name	Length (miles)				No. of Filled Bags				Pieces (unbagged)				Weight (lbs)				% fishing	No. of Yrs.
	'09	'10	'11	'12	'09	'10	'11	'12	'09	'10	'11	'12	'09	'10	'11	'12		
North Bulldog*	--	--	--	--	--	8	--	--	n/a	8	--	--	--	165	--	--	50	1
South Bulldog*	1	1	1	--	6	6	6	--	5	3	1	--	210	115	210	--	30	2
Porcupine Cove*	1	1	--	--	46	19	--	--	14	5	--	--	1310	320	--	--	35	2
Pinnacle	--	0	--	--	--	9	--	--	--	8	--	--	--	125	--	--	35	1
Verdant island Beach	--	--	--	1	--	--	--	11	--	--	--	7	--	--	--	255	35	1
Verdant Cove Beach	--	--	--	1	--	--	--	1	--	--	--	0	--	--	--	10	10	1
Taroka 1*	0	--	0	0	6	--	8	10	7	--	2	4	400	--	145	275	43	3
Taroka 2	0	--	0	--	3	--	3	--	1	--	0	--	80	--	35	--	60	2
Taroka 3	0	--	0	--	16	--	24	--	3	--	2	--	600	--	570	--	60	2
Taroka 4*	1	--	1	--	46	--	6	--	50	--	3	--	2350	--	170	--	67	2
Taroka 5	0	--	--	0	6	--	--	19	10	--	--	14	650	--		495	55	2
Taroka 6*	1	--	1	--	32	--	5	--	20	--	1	--	1100	--	90	--	63	2
Thunder 1	0	0	0	--	147	30	16	--	60	53	3	--	5660	1225	203	--	51	3
Thunder 2	0	0	0	--	40	26	7	--	20	9	1	--	1750	525	115	--	44	3
Thunder 3*	0	0	0	--	6	2	2	--	3	1	1	--	700	50	40	--	60	3
Thunder 4	0	0	0	--	8	5	2	--	20	2	1	--	450	140	75	--	61	3
Paguna 1*	--	--	1	--	--	--	3	--	--	--	2	--	--	--	110	--	50	1
Paguna 2*	--	--	1	--	--	--	1	--	--	--	0	--	--	--	5	--	50	1
Paguna 3*	--	--	1	--	--	--	2	--	--	--	1	--	--	--	70	--	50	1
Totals:	5.419	2.758	7.418	2.208	362	105	85	41	213	89	18	25	15260	2665	1838	1035	48 (ave)	

* Indicates beaches associated with known campsite areas (i.e., landing areas or beaches).

-- Indicates no data collected.

4.1.5 Current Condition and Trend

Potential Landing Area Locations

PLAs were generally found to be widely distributed across the park. However, PLAs were usually limited along rocky-cliff shorelines, such as along the outer reaches of Aialik and Harris Peninsulas. Here, only occasional, narrow beaches and small pocket beaches, sand or gravel beaches within small indentation in the shoreline bound on both sides by rocky scarps or headlands (Hayes 1980), were identified.

Potential landing areas (PLAs), both shoreline segments near known campsites and additional shoreline segments not nearby known campsites, were identified along a total of 226.4 km (140.7 mi) of the park's shoreline. This represents approximately 27% of the total length of the KEFJ coast (842 km or 523 mi) as defined through delineation/photo interpretation on 2005 IKONOS satellite orthoimagery. This excludes Nuka Island's shoreline as IKONOS imagery is lacking here. A total of 324 contiguous shoreline segments were identified as PLAs, many of which were sheltered beaches. However, this also included small pocket beaches along steep shorelines, entire extents of large and small stream deltas, sand and mud flats near lagoons and estuary areas, and alluvial fans along steep recently deglaciated areas (e.g., McCarty Fjord). Many of the PLAs identified in this assessment may not provide access to a suitable camping area, but may represent potential shoreline segments where small watercraft could safely land, at least temporarily.

A total of 88 contiguous shoreline segments were associated with known campsite locations, with a total length of 92.2 km (57.5 mi). Klasner (2011) presents a similar estimate of 80 sheltered beaches that offer camping opportunities along the park's shore. The PLAs associated with known campsites were identified in cases where the shoreline segments were in close proximity to a known campsite, cabin, or food storage location (e.g., typically within less than 0.5 km, within the same cove). These shoreline segments were used as a guide to locate additional PLAs based on similar image signatures and apparent land forms. In addition to the PLAs near known campsites, a total of 134.2 km (83.4 mi) of shoreline was also identified. Plate 4 and Plate 5 display locations of both PLA line segments near campsites and those not associated with known campsite locations across the park's coast.

The additional PLAs (not associated with known campsites) include shorelines along the lagoon/estuary just east of the Aialik Glacier terminus, within Pedersen Lagoon, Crescent Beach Pond, and McArthur Lagoon. These examples account for approximately 35 km (22 mi) of the additional PLA shoreline length. Each of these shorelines is relatively complex and, therefore, long compared to many of the beaches along the coast associated with known campsites. In addition, approximately 17 km (11 mi) of shoreline was delineated on both shores of McCarty Fjord, northeast of James Lagoon (farther into the fjord). Many of these shoreline segments were associated with alluvial fans occurring along otherwise steep and relatively recently deglaciated shorelines or long narrow gravel beaches along steep shorelines. It is unclear if these PLAs constitute suitable landing areas or if many of these even provide any camping opportunities, only possible stop-over sites, but should be verified in the field or through local knowledge of these shorelines.

General Resource Condition (extent, substrate, slope, plant wildlife communities, cultural resources)

The park is interested in understanding general resource conditions of landing areas, such as the extent of the landing area, substrate, slope, plant and wildlife communities, and cultural resources that may be nearby. To date there is no documentation that captures this type of information. However, using the PLA dataset as a guide, this type of information could be collected in the field, possibly in conjunction with ongoing backcountry campsite inventory efforts.

The park has found a general increasing trend in resource impacts at backcountry campsites (Klasner 2011). With this increase, the park is concerned that ecological conditions may be altered, visitors' wilderness experiences may be impacted, and visitor safety could be threatened (Klasner 2011). The park has periodically surveyed campsites in the past, with the earliest survey occurring in 1988 by Tetreau (2004), where the author found evidence of resource impacts including fire rings, trash, human waste, soil erosion, trampled vegetation, and social trails. However, Tetreau (2004) and Monz et al. (2011) suggested that improvements be made to earlier efforts which would improve consistency, accuracy, and efficiency of field assessment and subsequent data analyses.

In response to these recommendations, the NPS has since completed a campsite monitoring protocol for coastal backcountry campsites in the park (Monz et al. 2011). This was done with four overall goals that address some items lacking in earlier park campsite inventory efforts: 1) protocols need to be more clear in definition of terms and descriptions of ratings-based procedure; 2) campsites needed established reference points that could easily be relocated 3) efficiently planning field work needed to be addressed in terms of staff time during an assessment trip and integrating program work into park operations; and 4) protocols must withstand a changing field staff without sacrificing accuracy and repeatability (Klasner 2011). A 2007 rapid campsite assessment reported that visitor campsite impacts were concentrated in the Northwestern Fjord and Aialik Bay areas of the park (Klasner 2011). However, how these impacts relate to overall conditions of the landing area used to access the campsites is not clear.

A summary of how PLAs relate to other GIS datasets is presented below in an effort to provide descriptive information regarding the shoreline segments represented by the PLAs. For example, collateral GIS datasets provide further detail regarding shoreline descriptions (land form types), wave energy categories and exposure types, and stream delta types. PLAs associated with known campsites and those considered additional PLAs not associated with a known campsite are summarized separately.

PLAs and Shoreline Descriptions

Mann (1997) provided a GIS dataset that defined the shoreline within KEFJ and general characteristics of that shoreline at a relatively coarse scale. Because some co-registration issues exist between the Mann (1997) data and the IKONOS and PLA data, shoreline descriptions contained within Mann (1997) were populated in a column of the PLA tabular dataset through image interpretation and not through an automated GIS process. This allowed for a summary of primary shoreline types (shoreline descriptions) according to the Mann (1997) dataset. Figure 8 provides an example of an area at the entrance to Pedersen Lagoon with known campsite locations, nearby shorelines considered PLAs (2005 IKONOS delineation), and Mann (1997) data with some of the

shoreline descriptions. Notice the geographic registration of the Mann (1997) digital shoreline data overlain on the 2005 IKONOS imagery in this figure.

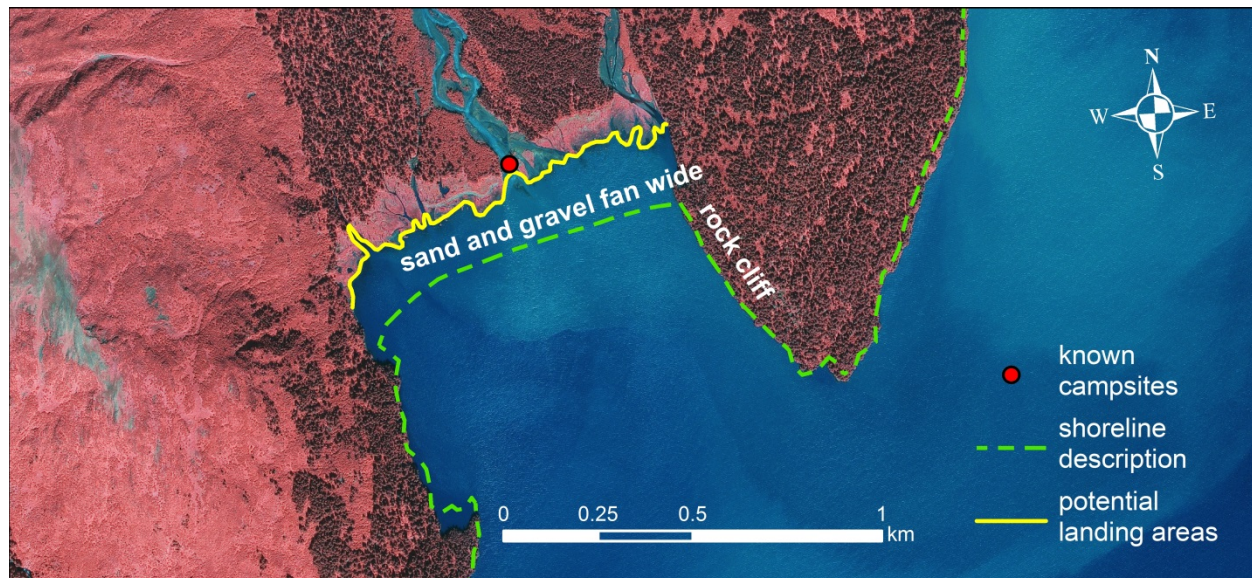


Figure 8. Example of digital shorelines near a known campsite location in the North Arm of Nuka Bay in KEFJ. The solid yellow line represents the shoreline considered to be a potential landing area (PLA) and the green dashed line is the digital shoreline from Mann (1997) with some of the shoreline descriptions labeled in white. Shown here on near-infrared 2005 IKONOS satellite imagery.

Most of the PLAs near known campsites were associated with narrow beaches composed of sand and/or gravel, sand and/or gravel flats, or sand and/or gravel fans. The most common shoreline descriptions coinciding with these PLAs were “gravel beach narrow,” “sand and gravel flat,” “gravel flat wide,” “sand and gravel fan wide,” and “gravel fan.” For PLAs not associated with a known campsite, a similar pattern of common shoreline descriptions was revealed where most PLAs were also narrow beaches composed of sand and/or gravel. However, these PLAs were also associated with several other shoreline descriptions. For example “cliffs with gravel beaches” were much more common for PLAs with no known campsite nearby. They were also more commonly associated with sand and mud flats and pocket beaches, for example (Table 11).

Table 11. Shoreline descriptions in Mann (1997) associated with potential landing areas (PLAs) near known campsite locations and their total length and percentage of total length.

Shoreline Descriptions (Mann 1997) ^a	Total PLA length (km) ^b	% by total PLA length
Campsite nearby		
gravel beach narrow	21.8	23.9
sand and gravel flat	11.6	12.7
gravel flat wide	10.6	11.6
sand and gravel fan wide	9.1	10.0
gravel fan	6.5	7.2
sand and gravel beach narrow	6.0	6.6
999 ^c	5.9	6.5
sand flat	4.9	5.4
cliff with gravel beach	3.6	3.9
sand and gravel flat wide	2.9	3.1
mudflat	2.4	2.7
gravel beach	2.1	2.3
ramp with gravel beach narrow	1.4	1.5
sand beach	1.2	1.3
gravel flat	1.1	1.2
Subtotal:	91.0	100

^a only shoreline descriptions with a total PLA length ≥ 0.5 km are reported here.

^b total length of PLAs near known campsites or with no known campsite nearby.

^c no description listed in original dataset (Mann 1997).

Table 11. Shoreline descriptions in Mann (1997) associated with potential landing areas (PLAs) near known campsite locations and their total length and percentage of total length. (continued)

Shoreline Descriptions (Mann 1997) ^a	Total PLA length (km) ^b	% by total PLA length
No known campsite		
gravel beach narrow	31.8	24.0
cliff with gravel beach	18.4	13.9
999 ^c	11.5	8.7
sand and gravel beach narrow	10.5	7.9
lagoon shoreline, sand and gravel beach narrow	8.5	6.4
gravel flat wide	7.9	5.9
gravel fan	7.1	5.4
sand flat	6.1	4.6
mud flat	4.0	3.1
channel	3.9	3.0
lagoon shoreline, 999	3.9	2.9
sand and gravel fan	3.6	2.7
rock ramp narrow	2.3	1.7
pocket beach, rock cliff	1.9	1.4
estuary	1.6	1.2
gravel fan, calving glacier terminus	1.4	1.1
gravel fan, cliff with gravel beach	1.4	1.0
beach narrow, rock cliff	1.2	0.9
beach, rock cliff	0.9	0.6
sand and gravel flat	0.8	0.6
gravel beach, rock cliff	0.7	0.6
gravel beach narrow, rock cliff	0.7	0.5
cliff with gravel sand beach	0.7	0.5
rock cliff	0.6	0.5
cliff with gravel beach narrow	0.6	0.4
ramp with gravel beach	0.6	0.4
Subtotal:	132.5	100

^a only shoreline descriptions with a total PLA length ≥ 0.5 km are reported here.

^b total length of PLAs near known campsites or with no known campsite nearby.

^c no description listed in original dataset (Mann 1997).

PLAs and Wave Energies & Exposure Categories

An example aerial view of each of the wave energy categories associated with PLAs is presented in Figure 9. Related to wave energy, are shoreline exposure categories within a different dataset (Mann 1997). These are also labeled in the examples shown in Figure 9. According to the photo-interpreted wave energies (GIS line data) in Crowell and Mann (1995), most PLAs were associated with either moderate or high wave energy shoreline segments. Approximately 51% by total PLA length were moderate wave energy shoreline segments, 23% low, 18% high, and 8% associated with non-rated wave energy shoreline segments (e.g., shorelines within protected lagoons like Bear Glacier Lake) (Table 12).

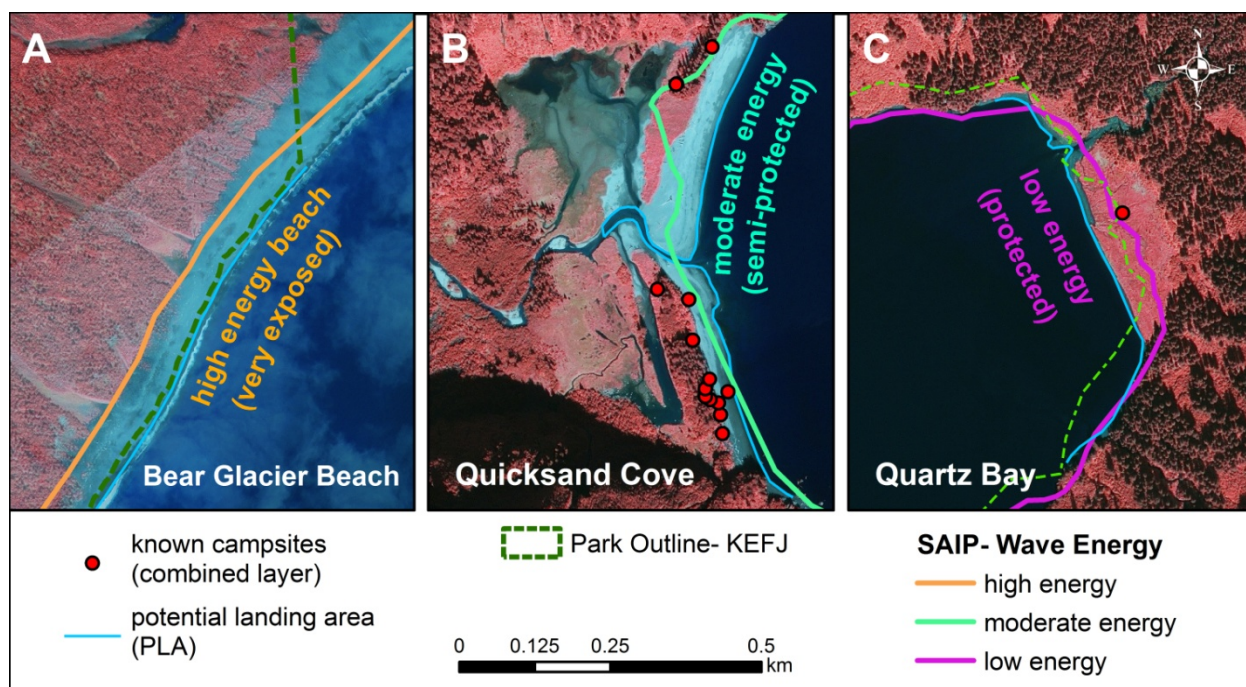


Figure 9. Aerial views of three shoreline wave energy categories according to Crowell and Mann (1995) (i.e., SAIP-Stream Deltas) and exposure categories (listed in parenthesis) from Mann (1997) associated with potential landing areas (PLAs) in KEFJ. Shown here on near-infrared 2005 IKONOS satellite imagery. (A) high energy, wave-dominated beach along a very exposed shoreline (Bear Glacier Beach). (B) moderate energy, wave-dominated stream delta/beach along a semi-protected shoreline in Quicksand Cove. (C) low energy, wave-dominated stream delta/beach along a protected shoreline in Quartz Bay.

Table 12. Wave energy categories associated with potential landing areas (PLAs) and their percentage by total PLA length in KEFJ. Wave energies were according to Crowell and Mann (1995) GIS data, referred to as SAIP-Wave Energies in the Alaska NPS permanent dataset.

Wave Energy (Crowell and Mann 1995)	PLA length (km)	% by length ^a
Campsite nearby		
Low	31.2	34
Moderate	47.4	51
High	13.6	15
Subtotal:	91.2	100
No known campsite		
none ^b	13.8	10
Low	30.5	23
Moderate	63.8	47
High	26.5	20
Total:		100

^a rounded to the nearest whole percentage.

^b no wave energy category assigned as these were typically shorelines within protected lagoons.

A similar attribute to the wave energy category (Crowell and Mann 1995) is wave exposure category contained within Mann (1997). Six exposure categories were subjectively assigned by the author to

represent each shore zone unit's (linear GIS shoreline segment) exposure to waves. The author based these category assignments on field observations for beaches in question or ones similar in setting. Three of these exposure categories are illustrated in Figure 9 and the proportion by length for each of the exposure categories for both PLAs associated with known campsites and PLAs with no known campsite nearby are displayed in Table 13.

Table 13. Shoreline exposure categories associated with potential landing areas (PLAs) and their percentage by total PLA length in KEFJ. Exposure categories are according to Mann (1997) GIS data.

Exposure Category (Mann 1997)	PLA length (km)	% by length ^a
PLA (campsite nearby)		
very protected	14.0	15
protected	15.3	17
semi-protected	19.6	21
semi-exposed	29.2	32
exposed	11.0	12
very exposed	0.9	1
undefined ^b	2.2	2
Subtotal:	92.2	100
PLA (no known campsite)		
very protected	12.3	9
protected	16.2	12
semi protected	9.9	7
semi-exposed	67.1	50
exposed, 999 ^c	0.6	0
exposed	8.1	6
very exposed	8.4	6
undefined ^b	12.1	9
Subtotal:	134.7	99
Grand Total:	226.8	

^a rounded to the nearest whole percentage

^b attribute not populated in the original dataset.

^c attribute not populated in the original dataset, but appears based on photo-interpretation to be "exposed" like nearby exposed shorelines.

PLAs and Stream Delta Types

Major stream delta types are also indicated in the Crowell and Mann (1995) shoreline GIS dataset. By manually populating the PLA dataset with the stream delta type indicated in the Crowell and Mann (1995) data (i.e., the SAIP – Stream Deltas in the Alaska NPS permanent dataset), a summary of stream delta types by PLA length was created. Aerial view examples of PLAs for each of the stream delta types identified by Crowell and Mann (1995) are presented in Figure 10. The majority of PLAs were not stream deltas. However, of the PLAs that were considered stream deltas, wave-dominated stream deltas comprised the most PLA length (22% of all PLAs by length).

Approximately 5% of the PLAs by length were alluvial fans and only 1% were considered tidally-dominated stream deltas (Table 14).

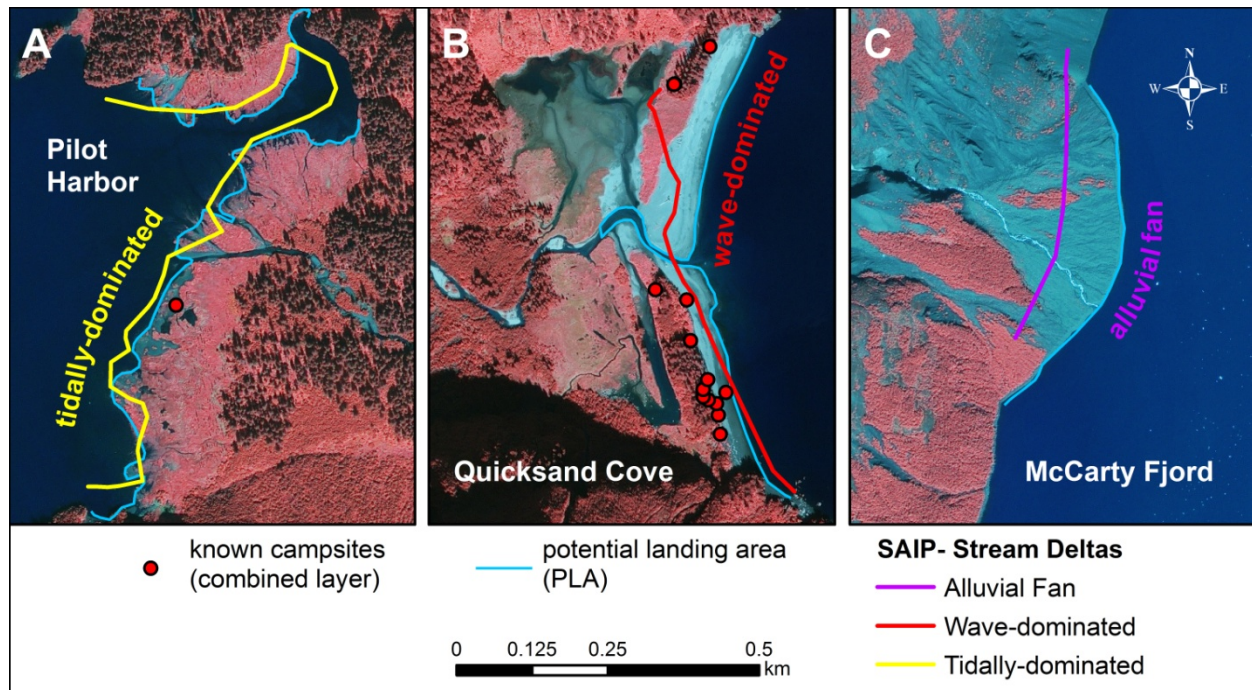


Figure 10. Aerial views of three stream delta types according to Crowell and Mann (1995) (i.e., SAIP-Stream Deltas) associated with potential landing areas (PLAs) in KEFJ. Shown here on near-infrared 2005 IKONOS satellite imagery. (A) Tidally-dominated stream delta associated with a known campsite location in Pilot Harbor. (B) Wave-dominated stream delta associated with several known campsites in Quicksand Cove. (C) Alluvial fan along the western shoreline of McCarty Fjord, north of the Dinglestadt Glacier terminus with no known campsites.

Table 14. Stream delta types associated with potential landing areas (PLAs) and their percentage by total PLA length in KEFJ. Stream delta types were according to Crowell and Mann (1995) GIS data, referred to as SAIP-Stream Delta Types in the NPS Alaska permanent dataset.

PLA/Stream Delta Type (Crowell and Mann 1995)	Total length (km)	% of total length ^a
Campsite nearby		
Wave-dominated		
Alluvial Fan	0.8	1
Tidally-dominated	3.1	4
N/A (not identified as a stream delta)	66.3	
subtotal:	70.2	
No known campsite		
Wave-dominated	28.4	21
Alluvial Fan	9.8	7
Tidally-dominated	--	--
N/A (not identified as a stream delta)	96.4	72
subtotal:	134.6	100
Grand total:	204.8	

^a rounded to the nearest whole percentage.

Marine Debris Collection Sites

Marine debris is considered a threat or stressor factor in this assessment; see the following section.

Threats and Stressor Factors

Marine debris and trash

Marine debris and trash can cause environmental degradation and can negatively affect aesthetic values in the coastal backcountry of KEFJ. In surveys regarding the acceptability of campsite and recreational impacts in wilderness areas, trash is often considered by visitors as unacceptable in terms of amenity value of campsites (Farrell et al. 2001). Trash that can be found near campsites is considered, in KEFJ campsite monitoring, separately from marine debris. The campsite monitoring protocol defines trash as all recreational litter left behind by visitors that is seen when standing at the center point of the campsite, but it does not include flotsam (i.e., marine debris) (Monz et al. 2011). The ongoing efforts of the coastal campsite inventory will capture an ocular estimate of this trash in campsites. Marine debris, on the other hand, is defined as any manufactured solid-material product that is disposed of or discharged, either intentionally or unintentionally, into the marine environment (NOAA 2008). Marine debris is known to wash ashore along various stretches of the park's shorelines, but only a portion of the park's coast have been recently monitored for this debris. NOAA (2008) regards marine debris as manufactured materials; however, saw logs that wash ashore could also be considered marine debris as they are derived from anthropogenic sources. Both saw logs (anthropogenic) and other logs (biogenic) are noted in the ShoreZone habitat mapping database, where saw logs are those that have clearly sawn ends.

Marine debris poses a threat to marine near-shore and terrestrial habitats, to some biota through entanglement or ingestion, and to aesthetic values associated with coastal shorelines. Derraik (2002) asserts that marine debris, specifically plastic debris, which now makes-up most of the worldwide marine debris, poses a major threat to marine life. For example, marine birds can ingest plastics or

become entangled in plastic debris (Derraik 2002). Through studying plastic ingestion's effects on chickens, researchers found that storage volume of the birds' stomachs was reduced, reducing overall food consumption, limiting birds' abilities to store fat ultimately, and thereby reducing overall bird fitness (Ryan 1988). Similar effects are expected in marine birds as they can ingest plastic particles, mistaking them for food in their environment. Aesthetic values of the park's shoreline are also compromised as debris continues to wash ashore. Another possible threat presented by drifting marine debris that washes ashore in KEFJ is the introduction of non-native species. Marine debris, namely plastics, floating at sea can pick up a variety of organisms such as bacteria, diatoms, algae, barnacles, hydroids, and tunicates (Clark 1997).

Beginning in the summer of 2009, the Resurrection Bay Conservation Alliance (RBCA), a grass-roots conservation organization based in Seward, began marine debris collection efforts at high tides and at vegetation lines along several coastal locations in KEFJ and near Seward. RBCA works with NPS staff to coordinate these cleanup efforts with local community members. Goals of their data collection efforts are to document specific beaches cleaned, the weight of debris removed, and the estimated composition of the debris at each beach. RBCA marine debris cleanup efforts in 2009 encompassed approximately 391 km (243 mi) of beach along the KEFJ coast. In the same year, 478 garbage bags were filled with a total of 8,600 kg (18,960 lbs) from the 14 beaches within and nearby KEFJ surveyed that year (RBCA 2011). Photo 2 shows an example of clean-up efforts on a KEFJ beach.



Photo 2. Cleanup efforts at one of the collector beaches in KEFJ by the Resurrection Bay Conservation Alliance. Photo courtesy of Ocean Alaska Science and Learning Center.

RBCA marine debris monitoring and clean-up efforts have continued each summer from 2009 through 2012 on eight beaches (a total of 4.1 miles) outside KEFJ and 19 beaches (a total of 17 kilometers [10.6 miles]) within KEFJ. Each year from 2009 to 2012, the weight of debris collected has decreased both in total weight and weight by the annual beach length surveyed. It is unclear if this represents a reduction in the amount of debris washing ashore. According to GIS data from the RBCA and the KEFJ campsite geodatabase, ten of the eighteen beaches regularly monitored for marine debris in KEFJ are associated with known campsite locations. Marine-debris monitored beaches

associated with known campsites are indicated in Appendix 2, along with summary statistics regarding the amount and type of debris collected at each of the beaches within KEFJ monitored and cleaned by RBCA observers/participants.

Beaches within KEFJ containing the most debris during 2009 to 2012 efforts are Thunder Bay sites 1 and 2 (187 full bags, 7,410 lbs combined), and Porcupine Cove (46 full bags, 1,310 lbs) (Johnson et

al. 2011, RBCA 2011) (Plate 6 and Plate 7). Collections generally consisted of commercial fishing debris (e.g., gill nets, Hawser lines, buoys, etc.), which accounted for approximately 75% of all the debris collected across all of the beaches of the park and several outside of the park boundaries (Pfeiffenberger 2011). Recreational fishing (e.g., fishing line) and household items (e.g., general plastics such as bottles and jugs) accounted for the remaining 25% of marine debris collections. Pfeiffenberger (2011) noted that these percentages were roughly reversed as operations continued to move northeast, closer to Seward. Other notable non-fishing items found included general (unidentified) pieces of plastic, plastic bottles, caps/lids, food containers, and 55-gallon drums. Observers conclude that some KEFJ beaches appear to be naturally heavy collection sites. These locations include: North Bulldog, Thunder Bay sites 1 and 2, Pinnacle Beach, and Taroka site 5. Of these five beaches, participants in cleanup efforts found hazardous waste (e.g., oil containers and lead-acid batteries) at three of the beaches (Pinnacle Beach, Thunder Bay sites 1 and 2, and Bulldog Cove) (Johnson et al. 2011, RBCA 2011). Marine debris data collected by RBCA from 2009-2012 for KEFJ beaches is provided in Appendix 2.

KEFJ staff are also interested in understanding where additional marine debris might collect along the park's shoreline in order to develop a better understanding of park-wide marine debris trends, to plan debris collection efforts, and potentially to monitor possible natural resource impacts in these areas in the future. In combining an image-interpretative approach and a query of an existing coastal habitat mapping and classification system database (ShoreZone), additional shoreline segments that have a potential to collect marine debris can be found. These shoreline segments would be in addition to beaches that have already been visited by RBCA participants. While additional shorelines represented by the resulting GIS data set could prove useful for planning future marine debris monitoring and clean-up efforts, these data should be field-checked for accuracy and refined accordingly.

One method for identifying where marine-derived debris might tend to concentrate along the shoreline is by querying the Alaska ShoreZone database, a standardized geomorphic and biological database hosted by NOAA. Coastal and Ocean Resource Inc. (CORI) developed a marine debris query of the ShoreZone database, using criteria for supratidal zone width, material, substrate or sediment type in the supratidal zone (e.g., anthropogenic logs) (CORI 2010). Altering the query of the "Xshr" (cross-shore) table in ShoreZone is intended to represent a more inclusive representation of potential marine debris shoreline segments (collection sites) along the shoreline of KEFJ. The following query identifies shoreline segments that have the following materials as the primary material in the supratidal zone: ("A"), anthropogenic materials (A = Anthropogenic) such as human-derived debris, logs ("t" = cut trees); biogenic ("B") such as trees ("I" = trees, fallen not cut, dead). The assumption is if the ShoreZone unit collects logs such that they are the primary material in the supratidal zone, it may not matter if these are anthropogenic or natural source logs; the ShoreZone unit may have the potential to collect other marine debris. The "WIDTH" in this case refers to the average width of the component in meters. This query allows for all supratidal zone widths of five meters or greater (attributes definitions are available in CORI [2003]).

[ZON] = 'A' AND [WIDTH] >= 5 AND ([Mat1] LIKE 'A*t*' OR [Mat1] LIKE 'A*d*' OR [Mat1] LIKE 'B*1*').

According to this query, potential marine debris collection sites have anthropogenic (cut) logs or biogenic (natural source) logs as the primary material in their supratidal zones and they have sufficient width for this type of material to collect above the high tide line. Therefore, shorelines that may only have some logs (not the primary material) in the supratidal zones or beaches that have narrow supratidal zones would not be identified by this query. Therefore, it is likely that the query identifies areas that may be more likely to collect large amounts of marine debris, but exclude some areas that could collect debris to a lesser extent.

The marine debris query of the ShoreZone database results in a total of 83 unique shoreline segments (digital line segments) along the KEFJ coast, for a total length of approximately 102.3 km (63.6 mi). Fifteen of the segments, totaling approximately 12.9 km (8.0 mi), occur along Nuka Island, for which the 2005 IKONOS imagery is lacking; PLAs were not mapped along Nuka Island. While the results of this query represent an initial cut of potential marine debris collection sites (digital shoreline segments as represented by the ShoreZone GIS data), additional shoreline segments may also have the potential to collect marine debris. For example, sun-bleached logs are visible on some KEFJ beaches in the 2005 IKONOS imagery, and many of these areas are not represented in the ShoreZone marine debris query or in GIS data of known debris collection beaches identified by the RBCA monitoring and clean-up efforts.

GIS data from the RBCA, representing known collector beaches or collection sites and the resulting GIS data from the aforementioned ShoreZone database query were captured in the PLA dataset. Potential marine debris collection sites were also identified strictly through photo-interpretation of the 2005 IKONOS satellite imagery of the park. In some of the PLAs, white or light-colored linear objects were visible along the shoreline (on the beach or along the backshore vegetation). These were interpreted as possible sun-bleached logs or other debris. The PLA was then considered a potential marine debris collection site and was recorded as such in the dataset. If one or more of the following situations were met, the PLA shoreline segment (digital record) was considered a potential marine debris collection site: 1) the PLA segment was associated (spatial coincidence) with the results of the ShoreZone query; 2) the PLA segment was associated (spatial coincidence) with known RBCA collector beaches; or 3) the PLA segment had some logs and/or debris visible in the 2005 IKONOS imagery. Figure 11 displays an example of potential marine debris collection sites identified by the ShoreZone marine debris query, known debris collection beaches from the RBCA, and a small beach not identified by the ShoreZone query or by RBCA, but considered a potential marine debris collection beach (or site) based on apparent logs/debris washed ashore.

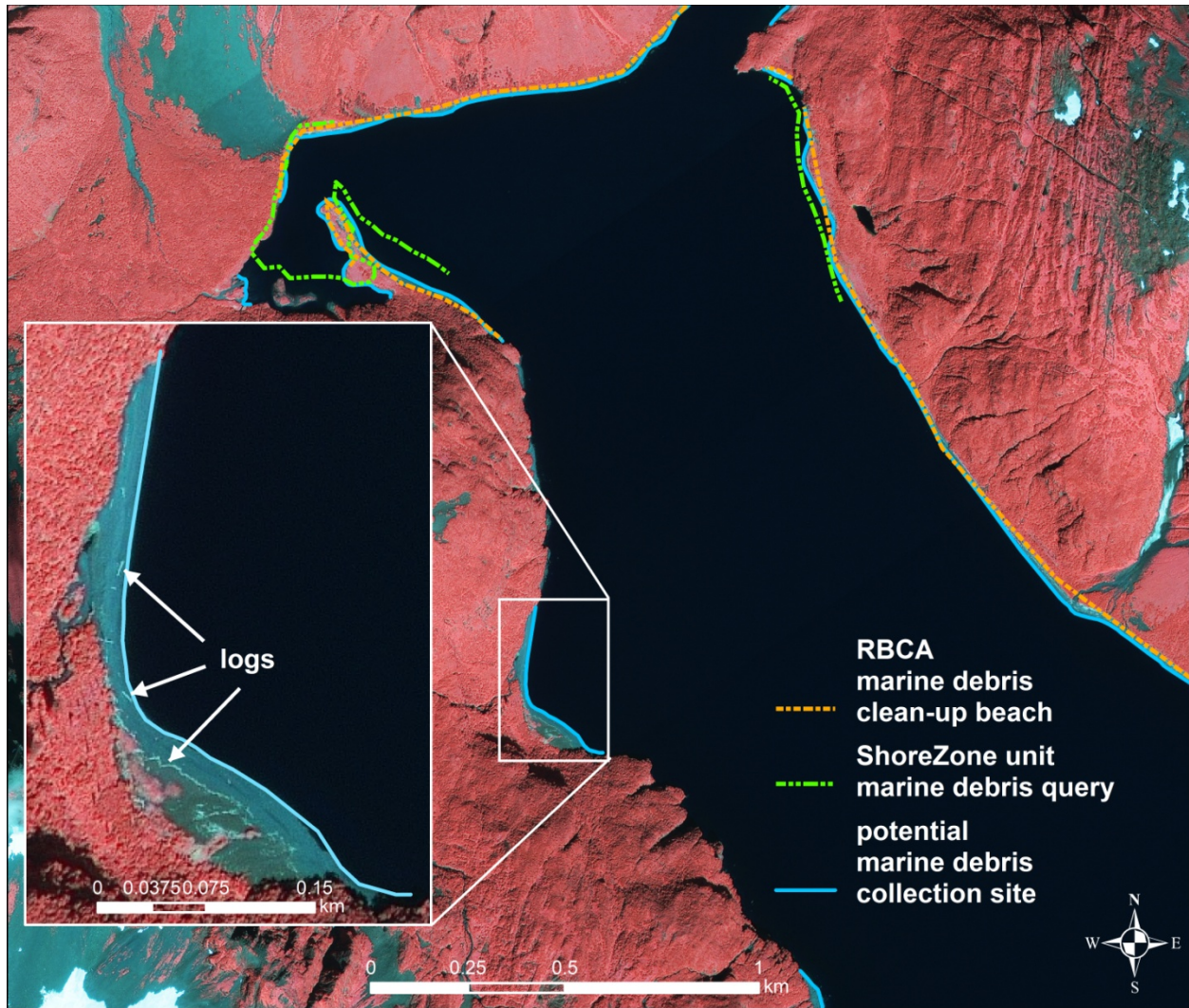


Figure 11. Example of shoreline segments resulting from the ShoreZone marine debris query (dashed green line), potential marine debris collection sites created through interpretation/delineation (solid blue line) (also considered a potential landing area), and known marine debris collection sites from Resurrection Bay Conservation Alliance (RBCA) beach segments (dashed orange line) in Taroka Arm, Two Arm Bay of KEFJ. Shown here on near-infrared IKONOS satellite orthoimagery. The beach shown in the inset of the figure was not identified by the ShoreZone query as a potential marine debris collection site; however, logs are visible here.

Based on this photo-interpretation and selection process, 129 individual segments (digital records in the GIS dataset) covering approximately 72.2 km (45.5 mi) of shoreline were considered to be potential marine debris collection sites. These shoreline segments are intended to represent a more inclusive estimation of potential marine debris sites. However, given that each of the indications used (i.e., RBCA site, ShoreZone query, or logs visible in IKONOS) were recorded separately in the PLA dataset, they can be queried and field-verified separately. The locations of PLAs considered potential marine debris collection sites, both those associated with a known campsite and those without a known campsite nearby, along with the general locations of RBCA sites are displayed in Plate 6 and Plate 7.

The ShoreZone database also contains video and photographic still images of shoreline segments. This information could be used to aid in the identification of landing areas and potential marine debris collector beaches along the KEFJ coast. Figure 12 and Figure 13 provide examples of oblique ShoreZone photos and associated aerial views in IKONOS satellite imagery along two beaches known to be heavy marine debris collection sites in KEFJ.

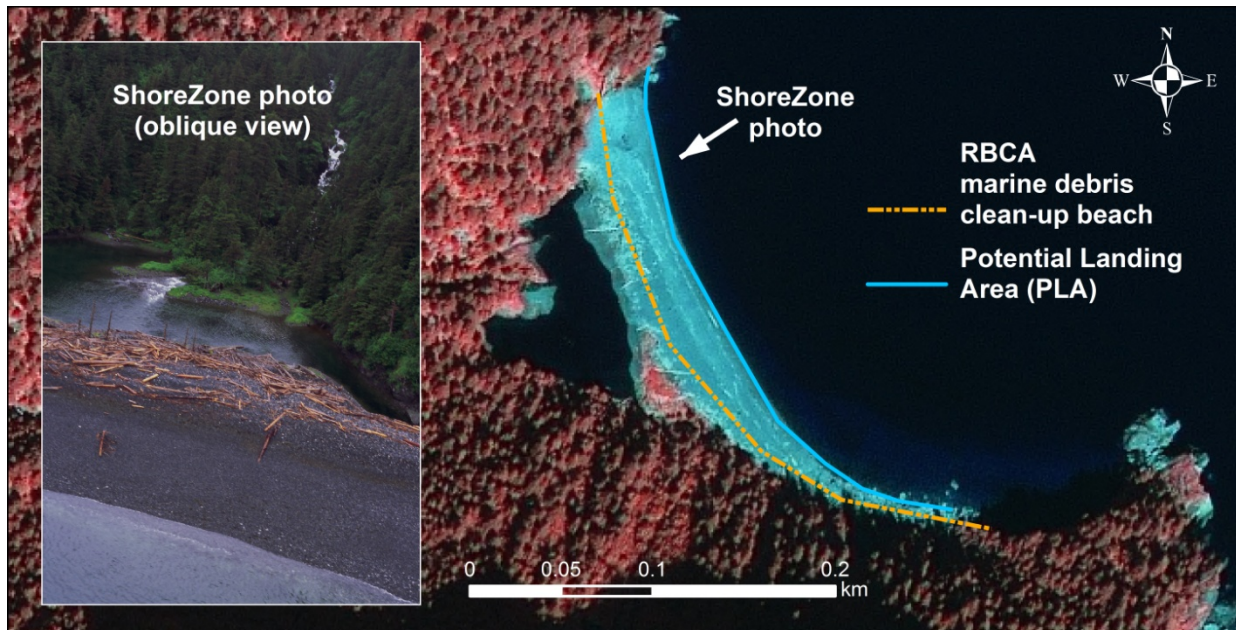


Figure 12. Aerial and oblique views of a collector beach in the Thunder Bay area of KEFJ associated with the Thunder Bay #1 2009 Resurrection Bay Conservation Alliance (RBCA) marine debris clean-up site, shown with an RBCA marine debris shoreline segment (dashed orange line) and an interpreted/delineated potential landing area (PLA) also noted to be a marine debris collection site in KEFJ (solid blue line) on near-infrared IKONOS orthoimagery.

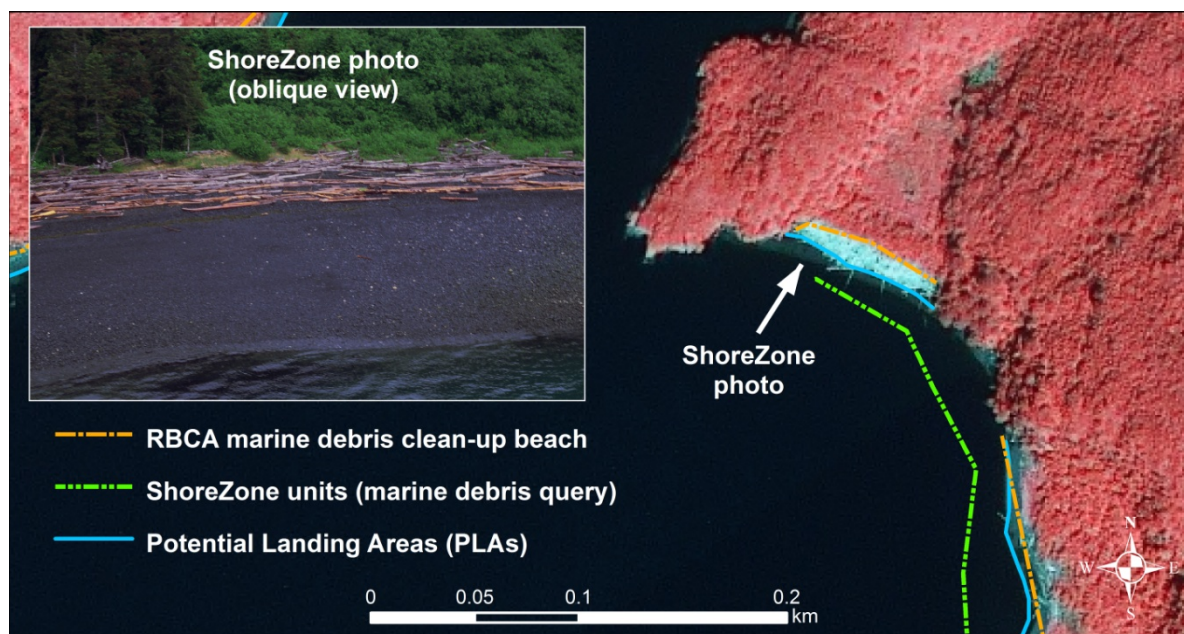


Figure 13. Aerial and oblique views of a marine debris collection site or collector beach (RBCA: Taroka Arm #5), shown with RBCA marine debris shoreline segments (dashed orange lines), results of the ShoreZone marine debris query (dashed green line), and the interpreted/delineated potential landing areas (PLAs) (solid blue line) on near-infrared IKONOS othoimagery. Inset photo is an oblique view from ShoreZone.

Oil spills

Landing areas may be affected by persistent oil from the Exxon Valdez oil spill (EVOS) and could be threatened by potential future oil spills. Oil has remained persistent in the Kenai Peninsula region since 1989 (Irvine et al. 2006). Future oil spills in the region continue to be a potential threat from source areas such as the Valdez Marine Terminal (Prince William Sound); Drift River Marine Terminal (Cook Inlet); Nikiski Oil Terminal and Refinery (Cook Inlet), and 17 gas and seven oil producing fields within the Cook Inlet (Nagorski et al. 2010).

Visitor Use – Bald Eagle Nest Proximity

Although the vast majority of visitors do not overnight in landing areas along the coast, the popularity of back-country cabin use and kayaking/camping has increased since the park was created. With this increase, there is a potential for bald eagles to be disturbed during breeding season by nearby human activity at landing areas and campsites. According to national bald eagle management recommendations in the conterminous U.S. published by the USFWS, a 100-meter (330-foot) buffer is recommended during the breeding season around nests, particularly where eagles are unaccustomed to activities such as hiking, camping, fishing, hunting, bird-watching, and kayaking (USFWS 2007). While, according to the USFWS (2012), eagles are most sensitive to human disturbance during their courtship and nest building phase which occurs in late winter to early spring, very little visitor use likely occurs in the park during this time (USFWS 2012). However, eagle nestling through fledgling phases are still considered sensitive time periods for human disturbance and this may overlap with higher seasonal visitor use in KEFJ.

To understand the proximity of known (documented) eagle nests to the potential landing areas (PLAs), eagle nest points were selected in a GIS within a few predetermined buffer distances of the PLAs and combined campsite locations, starting with USFWS's recommended 100 m buffer. The GIS data used for this selection included eagle nest site locations (GIS point data received from KEFJ from a 2009 park survey), an older USFWS bald eagle nest GIS dataset, the combined campsite points (a combination of the following feature datasets in the KEFJ Campsite Inventory geodatabase [V13]: Camp_areas_layer_from_TM, Generalized_Campsites_KEFJ; Rapid_Assessment_Campsite), and the PLA shoreline dataset. Table 15 displays the results of the nest selections using the two bald eagle nest location datasets and multiple buffer distances for PLA line segments associated with known campsite(s), PLAs not associated with a known campsite, and campsite locations (points) from the park's campsite database. Additional buffer distances were chosen in order to understand how many nests might be just outside of the recommended distance and to capture nests that may not otherwise be selected due to horizontal spatial inaccuracies of any of the datasets used in the selection process. For example, campsite locations used in this selection include both those collected with high spatial accuracy by mapping grade GPS units and points interpreted on satellite imagery to represent a general camping area.

Table 15. Number of bald eagle nest locations within buffered distances of PLAs (GIS lines) and known campsite locations (point GIS data) for two eagle nest location datasets (point GIS data), USFWS nest locations published in 1996 and 2009 NPS bald eagle nest locations.

Item and Buffer Distance:	Number of Bald Eagle Nests by data source	
PLA (campsite nearby)	USFWS (1996)	NPS (2009)
330 ft. (100 m)	6	10
660 ft (201 m)	14	21
990 ft (302 m)	18	32
1320 ft (402 m)	26	39
PLA (no known campsite nearby)		
330 ft (100 m)	12	23
660 ft (201 m)	27	41
990 ft (302 m)	38	52
1320 ft (402 m)	47	60
Combined campsite (points)		
330 ft (100 m)	1	2
660 ft (201 m)	4	11
990 ft (302 m)	7	15
1320 ft (402 m)	11	18

From a total of 168 known bald eagle nests within 152 m (500 ft) of the park boundary in NPS (2009), ten nests were within 100 m (330 ft) of a PLA associated with a campsite. By this GIS buffer, the vast majority of bald eagle nests appear to be outside of the recommended minimum USFWS buffer distance. However, with additional buffer distance, (double, triple, and quadruple the recommended minimum distance), many more eagle nests may be in relatively close proximity to PLAs, both those associated with known campsite locations and those not near a documented campsite location. The same is true when the combined campsite points are buffered to select eagle

nests, with a maximum total of eighteen nests occurring within 402 m (1,320 ft) of a campsite. If the additional PLAs (those not associated with a known campsite location) are considered, the number of bald eagle nests potentially near visitors may double. This could be important if these PLAs provide access to overnight camping.

Actual distances of visitor proximity to eagle nests are difficult to ascertain because of variance in the horizontal accuracy of the available point and line GIS data (eagle nests and campsite locations, and PLA line segments). Elevation may also play an important role in the actual distance of eagle nests from campsites or PLAs. However, the available digital elevation model (DEM) for the area is not accurate enough to confidently estimate actual distances. In reviewing the eagle nest locations in the GIS and on the 2005 IKONOS imagery, many nests appear to occur along steep cliffs and shorelines or in forested areas further inland and up slope of many of the PLAs associated with known campsites. The apparent differences in elevation may actually provide some additional effective buffer between visitors and the eagle nests. That is, a nest may appear to be within a close proximity to a campsite, by horizontal distance, but the nest could be much higher on the cliff and farther away than the horizontal distance might indicate.

Some notable general camping areas which may be within relatively close proximity to known eagle nests include Pederson Lagoon, James Lagoon, Bulldog Cove, Quicksand Cove, Bear Cove, Bear Glacier Point, near the Aialik Bay ranger station, near the cabin along the east shore of North Arm, in Beauty Bay, and in Pilot Harbor.

Climate Change

Climate warming may lead to changes to the coastal shorelines of KEFJ. For example, from 1986 to 2000, glacial ice extent in the park was reduced by 1.6%, with larger decreases in the greater Harding Icefield, Grewingk-Yalik Glacier Complex, and surrounding glaciers (Giffen et al. 2007). This will continue to alter physical characteristics of shorelines associated with tidewater glaciers in the park, but may also have a variety of effects on surface hydrology and sediment budgets of the streams entering the ocean along the park's coast. While sea levels are predicted to rise along Alaska's western coast, the relative sea level is likely to decrease slightly due to post glacial isostatic rebound (Smith and Williams 2010). Increasing storm activity, another potential result of climate change, although not likely as pronounced of an affect as in western Alaska, could cause coastal erosion which may directly alter landing areas in the park. With expected increases in precipitation and storm-event frequencies, coastal landslides may also alter shorelines and present a potential hazard.

Mass wasting

Mass wasting, which includes landslides, rockfall, and snow avalanches, could present a hazard to visitors in some landing areas. Much of the park's shoreline is steep and this is the primary factor that contributes to mass wasting events. Given the seismic history of the area, some areas of KEFJ could be under a threat of earthquake-caused mass wasting events. However, the events can also be triggered by rainstorm, or other high moisture events. Potential landing areas most at risk for these events would be along steep shorelines with loose rock.

Underwater and above water landslides occurred as the result of the 1964 Great Alaska Earthquake (Spencer and Irvine 2004). Spencer and Irvine (2004) suggest that landslides may have occurred specifically in Beauty Bay and in the North Arm of the McCarty Fjord in KEFJ. Additional landslides could occur from earthquakes or, in some places, cliffs may be undercut and eroded by wave-action over time and eventually result in large chunks of rock falling into the water. Much of the KEFJ shoreline is steep and mass wasting events could occur in many areas.

Stream channel movement

Stream channel movement is a natural process and is especially dynamic in glacial-fed streams where glacial sediment is constantly shifting and air temperature and precipitation tend to create highly variable and quickly changing stream discharges. Landing areas near river and stream channels and the deltas formed where they reach the ocean are subject to a variety of changes associated with stream flow and sediment regimes.

Data Needs/Gaps

Additional criteria may be needed to further identify suitable landing areas along the park's shoreline. The PLA dataset created for this assessment is intended to provide an initial base layer that is based upon physical appearance in satellite imagery and some inferences made from existing GIS data. However, the data might be further refined with local knowledge of the park's shoreline and with field verification. This would ensure that the PLAs identified in this dataset truly represent known landing areas or potentially viable landing areas along the park's shoreline.

According to Klasner (2011), only about 80 sheltered beaches along the park's shoreline provide potential camping opportunities to backcountry visitors. Klasner (2011) also states that remotes sites such as in the southern part of the park, along the outer coast, or in Nuka Bay experience limited overnight use, but backcountry camping occurs yearly at about 40 beaches in Aialik Bay and Northwestern Fjord. This suggests that whether or not a particular shoreline segment is actually used by visitors as a landing area and how much use it experiences might be driven by two primary considerations: 1) whether the landing area provides access to suitable camping opportunities; and 2) the travel distances required to reach a particular landing area. However, many other considerations are likely to be important in determining if a shoreline might be used as a landing area. For example, a given shoreline segment might be used as a temporary stop-over location for kayakers traveling along the coast, as a single or multi-night camping locations, or as a water taxi drop off site with no overnight stay. Other possible considerations for determining whether a potential site might be viable landing area could be its proximity to natural features (e.g., salmon streams, ponds, lagoons) or the difficulty of hiking in the nearby terrain. If visitor considerations are further examined and coupled

with data analyses from the campsite monitoring, the park might develop further information and insight useful in managing coastal backcountry visitor use and potential natural resource impacts associated with this use.

During project scoping for this assessment, it was suggested that if logs/debris were visible in 1950s orthophotography available for the park, an assessment of how debris amounts and locations might have changed could be completed by comparing the 1950s images to the 2005 IKONOS imagery of the park. However, it was found that these photo signatures were not readily visible in the 1950s orthophotos, and therefore, change in debris could not be detected with these two aerial image sources. The 1993 coastal orthophotos for the park were also briefly examined for their usefulness in identifying possible marine debris, and while the photo-interpreter determined that it wasn't possible to confidently conclude anything regarding the amount of debris in 1993 compared with 2005, additional review of the 1993 imagery in the future might help to further refine marine debris collection site identification along the park's shoreline.

Overall Condition

Landing beach location

For the purpose of this assessment, it is assumed that PLAs (shoreline segments) within a reasonably close proximity (< 0.5 km) to known campsites, food storage locations, or cabins act as landing areas for those sites. However, additional shoreline segments identified in the PLA dataset need to be verified through local knowledge and possibly field-checked. This effort would be conducted to, first, determine if the PLA is sufficient for landing watercraft. Secondly, in terms of managing potential impacts of backcountry visitor use, it might also be important to determine which of these additional PLAs might provide camping opportunities. It is likely that many of the PLAs identified by this process might be suitable for landing small watercraft, but may not contain suitable areas for overnight camping. For example, small beaches along the outer coast or narrow beaches along the steep shores of McCarty Fjord may not provide camping opportunities because of the steep shorelines behind relatively narrow landing areas. One of the key questions that the campsite monitoring protocol intends to answer through ongoing monitoring is the locations of the existing campsites in coastal areas of Kenai Fjords (Monz et al. 2011). The PLA dataset could be used as a guide in finding established campsites not yet discovered or to find additional places where visitors could possibly be directed for camping opportunities in the future. This may allow for an option to lessen visitor use concentration if park management finds it necessary to reduce campsite and/or landing area impacts.

Marine debris collection sites

According to RBCA marine debris monitoring, seventeen debris collection sites coincide with PLAs identified in this assessment. Together, the PLAs associated with the RBCA collection sites cover approximately 16.9 km (10.5 mi) of the park's shoreline. Sites in Thunder Bay and the beach at Porcupine Cove represent particularly heavy debris collections sites. Many additional PLAs may also be potential marine debris collection sites. In addition to PLAs associated with known collection sites identified by the RBCA, PLAs were considered potential collection sites if logs or debris were

visible in the 2005 IKONOS satellite imagery or PLAs were coincident with the results of the aforementioned ShoreZone marine debris query. From this, approximately 105 PLAs were considered to be potential marine debris collection sites. These PLAs were represented by 144 individual line segments (i.e., digital records), covering approximately 73.5 km (45.7 mi) of shoreline. Ground verification is needed to confirm if these areas truly represent debris collection sites and to what extent they might collect debris over time.

General resource condition (extent, substrate, slope, plant wildlife communities, cultural resources)
No information has been published regarding general resource conditions such as extent, substrate, slope, plant and wildlife communities, and cultural resources at landing areas. However, to provide some descriptions of the PLAs in KEFJ without an on-the-ground survey of these areas, shoreline descriptions, wave energy categories, exposure categories, and stream delta types were reported for each of the PLAs by using existing shoreline GIS datasets.

PLAs, both those near known campsites and those with no known campsite nearby, were associated with a total of 45 different shoreline descriptions in GIS data from Mann (1997). However, PLAs near known campsites were generally associated with narrow beaches composed of sand and/or gravel, sand and/or gravel alluvial fans, or sand and/or gravel flats. Additional PLAs not near known campsites were generally associated with similar shoreline descriptions, but included more cliffs with narrow beaches, sand and mud flats, and small pocket beaches. Wave energies (low, moderate, high from Crowell and Mann [1995]) associated with PLAs near known campsites were mostly (51% by length) in the moderate category and 35% by length in the low wave energy category. Similar proportions of wave energy categories by PLA length were found for PLAs with no known campsites. Shoreline exposure categories from Mann (1997) for PLAs near known campsites appear to be more common in lower exposure categories with protected, semi-protected, or semi-exposed categories. Together these accounted for 70% by length of PLAs near a known campsite. Approximately 50% (by length) of the PLAs not near known campsites coincided with the semi-exposed exposure category. However, these no known campsite PLAs were also more commonly found on exposed and very exposed shorelines.

Approximately 20% by length of all PLA shorelines (those near campsites and those with no known campsite) were considered stream deltas according to GIS data from Crowell and Mann (1995). Only 5% (by length) of the PLAs near known campsites were considered stream deltas, most of which were tidally-dominated stream deltas (e.g., shoreline of Pilot Harbor in North Arm). Approximately 28% (by length) of PLAs with no known campsite were considered stream deltas. Most of these were wave-dominated stream deltas and some were alluvial fans. For example, the shoreline associated with several glacial streams just east of the Aialik Glacier terminus was considered a wave-dominated stream delta by Crowell and Mann (1995) and identified as a PLA in this assessment. Several examples of PLAs that were considered alluvial fans exist along the western shore of McCarty Fjord.

Weighted Condition Score

An overall weighted condition score (WCS) was not determined for the KEFJ landform – landing beaches component as the park is still in the early stages of the campsite monitoring protocol and many of the park’s landing areas/beach locations are not yet confirmed based on this preliminary photo interpretation effort.

4.1.6 Sources of Expertise

Deborah Kurtz, KEFJ

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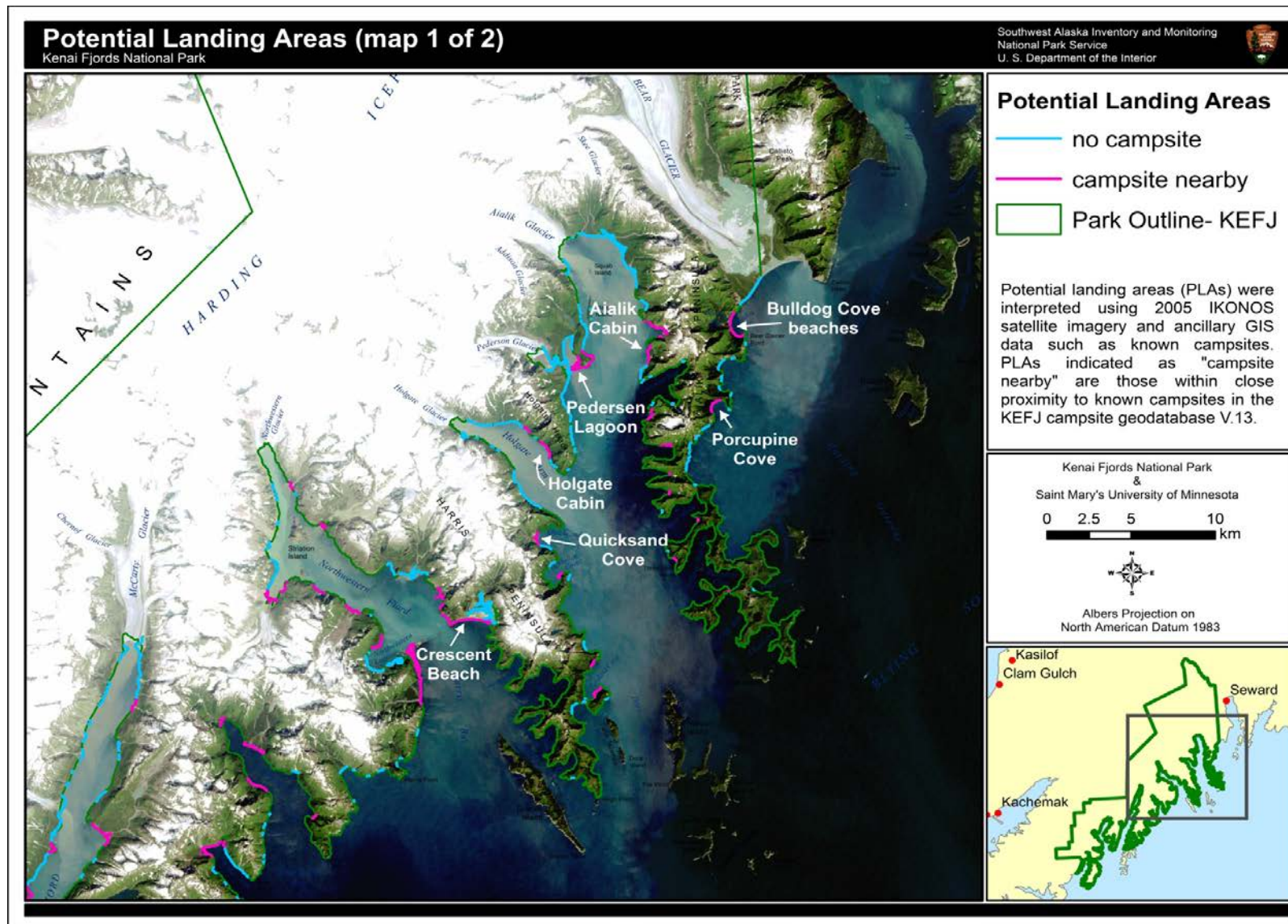


Plate 4. Potential landing areas (PLAs) near known campsites and those with no known campsite nearby. PLAs were interpreted from the 2005 IKONOS satellite orthomosaic of the park. The white labels identify some notable coastal locations. (Map 1 of 2).

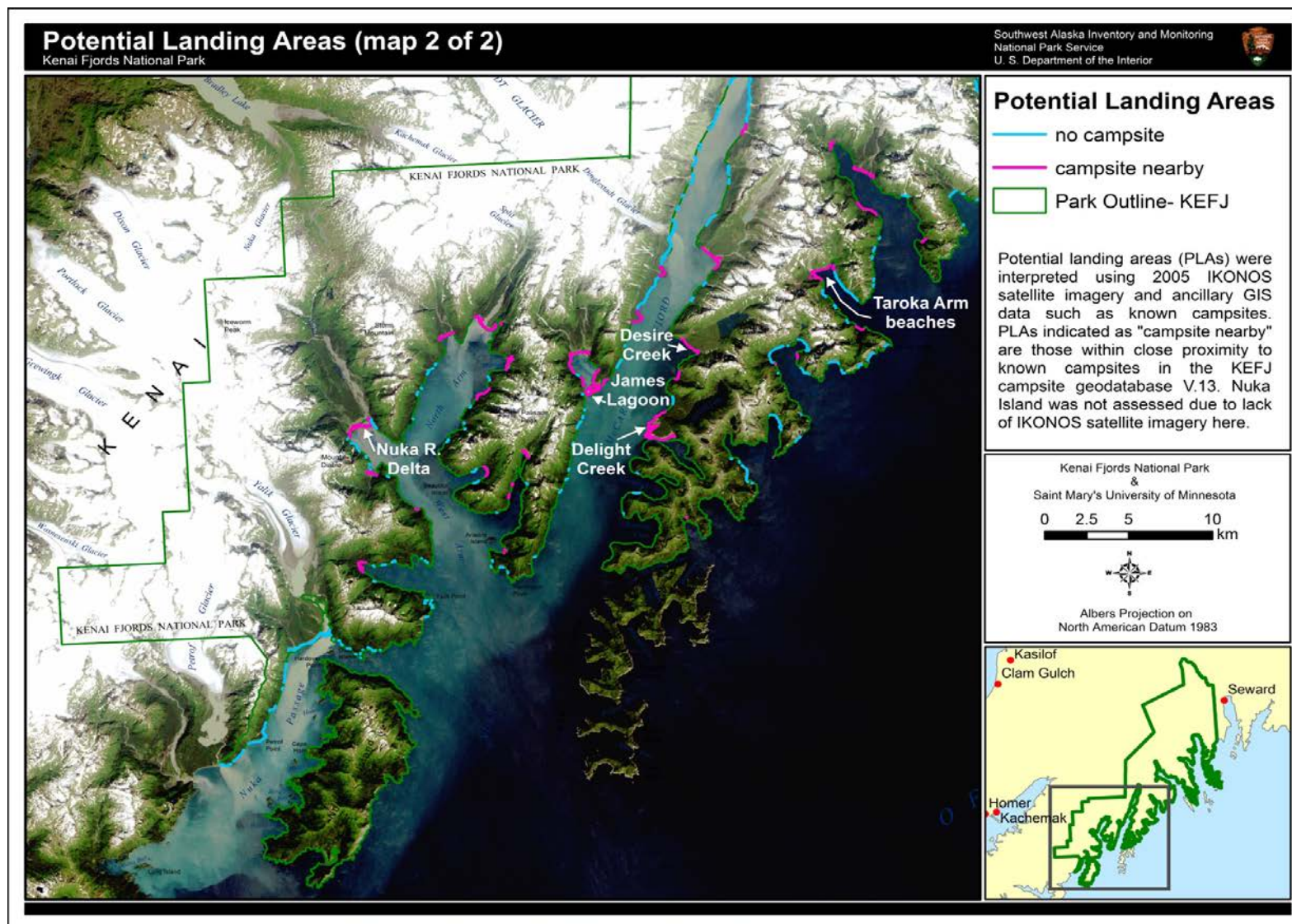


Plate 5. Potential landing areas (PLAs) near known campsites and those with no known campsites nearby. PLAs were interpreted from the 2005 IKONOS satellite orthomosaic of the park. Nuka island lacks 2005 IKONOS and therefore is not assessed for PLAs. The white labels identify some notable coastal locations. (Map 2 of 2).

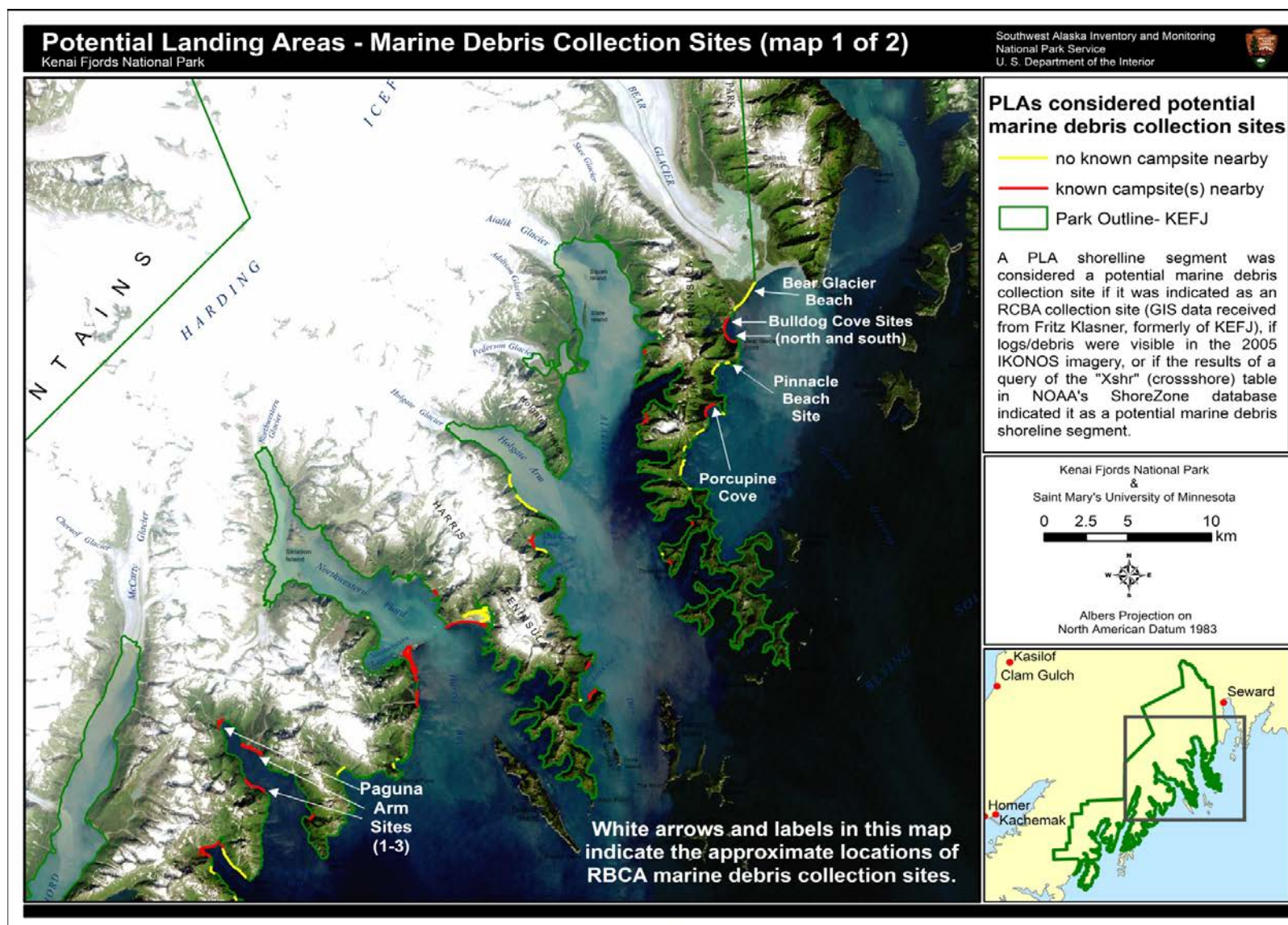


Plate 6. Potential landing areas (PLAs) considered to be potential marine debris collection sites, near known campsites and those with no known campsites nearby (map 1 of 2, northeast KEFJ).

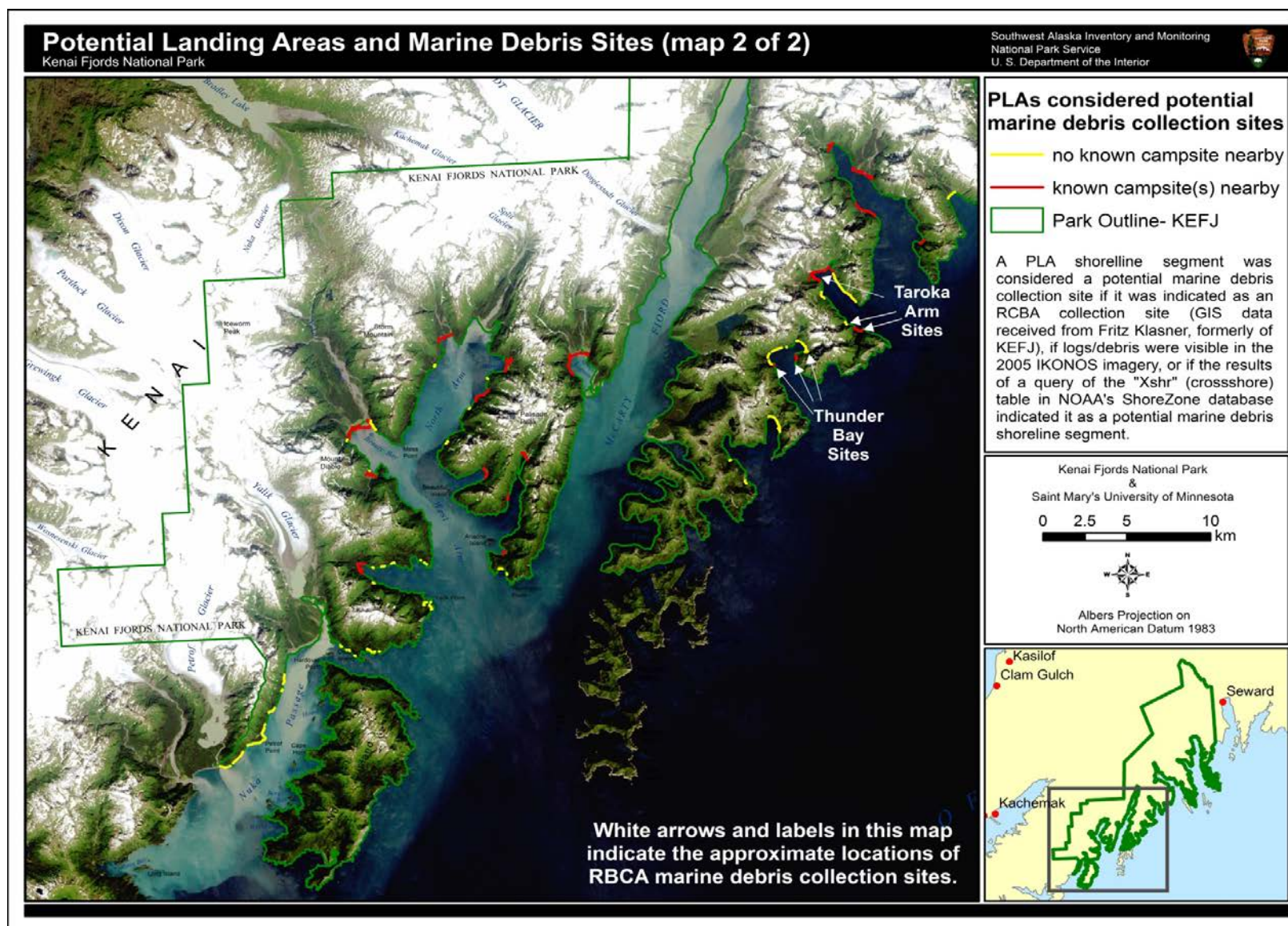


Plate 7. Potential landing areas (PLAs) considered to be potential marine debris collection sites, near known campsites and those with no known campsites nearby (map 2 of 2, southwest KEFJ).

4.2 Black Bear

4.2.1 Description

The American black bear (*Ursus americanus*) (Photo 3) is the smallest and most common bear species native to North America (Pelton 2003). They are often associated with habitat types such as coniferous forests, alpine meadows, coastal rainforests, wetlands, boreal forests, and lower-elevation tundra areas. During the summer months, bears frequently are found at higher mountainous



Photo 3. American black bear (NPS photo by Kent Miller).

elevations. They are typically solitary year-round, except during mating seasons (Ward and Kynaston 1999). Black bears grow to between 1 to 2 m (3.3 – 6.6 ft) in length; adult females average between 40 to 70 kg (88 to 154 lbs) and adult males between 60 to 140 kg (132 to 309 lbs) (Pelton 2003).

For visitors to KEFJ, seeing a black bear in its natural habitat is often a highlight. Many of the recorded black bear sightings in KEFJ occur at Exit Glacier and usually consist of solitary individuals or females with offspring (Hahr 2007). Black bears are also seen on the park's coast as they are pervasive throughout the fjord system.

Black bears are opportunistic omnivores that feed primarily on grasses and forbs during spring, soft fruits of shrubs and trees in summer, and a mix of hard and soft mast in fall (Pelton 2003). Crews (2002) examined the composition of black bear scat samples in Aialik Bay of KEFJ from late May through late August during 2000 and 2001 to determine diet habits of coastal black bears in KEFJ; salmonberry seeds (*Rubus spectabilis*) were the most common plant species in scat samples, along with graminoids and herbaceous vegetation (e.g., salmonberry, *Pedicularis* spp.) (Crews 2002). Black bears also consumed blueberries (*Vaccinium ovalifolium*, *V. alaskensis*), willow (*Salix* spp.), insects, devil's club (*Oplopanax horridus*), and red elderberry (*Sambucus racemosa*) (Crews 2002). Crews (2002) hypothesized that salmonberry is of relatively high importance to KEFJ black bears and that, counter intuitively, salmon were generally absent from black bear scat examined in the study. However, Robinson et al. (2009) noted salmon as an important food source for bears.

A black bear's home range, which can range from 2.6 km² (1 mi²) up to 259 km² (100 mi²), is primarily determined by food type, abundance, and availability (Powell et al. 1997). In Aialik Bay of KEFJ, a study found that females' home ranges varied from 0.8 km² to 59.5 km² (0.3 to 23.0 mi²) and for males varied from 1.2 km² to 57.4 km² (0.5 to 22.2 mi²) (French 2003); however, this study was relatively limited in sample size and duration. In fall, intense foraging precedes a transition into the den for hibernation. Depending on factors such as latitude, available food, sex and age, and local weather conditions, black bears begin to enter dens for hibernation between October and January and emerge from mid-March to early May (Pelton 2003). Black bear dens in the Kenai Peninsula were

almost exclusively found to be excavated by the bears themselves in contrast to natural cavities such as caves, rock piles, or in trees (Schwartz et al. 1987).

Black bears mature between four and five years old and breeding occurs every 2-3 years (Ward and Kynaston 1999). Usually two cubs per female are born in the spring, but there are sometimes as many as four (Erickson and Nellor 1964). Cubs remain with their mother throughout their first year (Pelton 2003).

4.2.2 Measures

- Distribution
- Abundance
- Number and seasonality of bear-human incidents

4.2.3 Reference Conditions/Values

There is insufficient information to determine reference conditions for black bear distribution and abundance in KEFJ at this time. While population abundance and distribution estimates are available for the harvestable Kenai Peninsula black bear population for ADF&G management units 7 and 15 (Selinger 2011), which encompass KEFJ, precise estimates do not exist for a park-wide, baseline reference condition. The reference condition for the number of bear-human incidents and the number of bear incidents in which bears obtain food is no occurrences.

4.2.4 Data and Methods

From 2003-2005, researchers used non-invasive genetic sampling and DNA-based capture-mark-recapture analysis to estimate the abundance of black bears in four coastal study sites in KEFJ including Aialik Bay, Harris Bay, Two Arm Bay, and Nuka Bay (Robinson et al. 2009).

The Bear Human Information Management System (BHIMS) is a region-wide database that stores information related to bear activity in Alaska National Parks. The database tracks bear-human conflicts, bear observations, certain bear harvests (e.g., bears harvested for management purposes or removal of nuisance bears), and bear natural history data from 1983 to present. Information such as aggressive bear behavior, area closures, reported bear mortalities, and bear spray discharge events are also recorded. This database facilitates informed bear management decisions and public education efforts. These data are used in this assessment to indicate primary locations and timing of bear-human encounters. Independent of the BHIMS, bear observations and voucher locations are also recorded with an NPS service-wide database for tracking biological inventories.

Bear activity including observations, encounters, incidents, and management actions are summarized in annual reports including Hahr (2007), Hahr and Jezierski (2008), Jezierski (2009), and McFarland (2010).

4.2.5 Current Condition and Trend

Distribution

Black bears occur across much of Alaska and North America, including south central Alaska and KEFJ (Pelton 2003). They are typically common in heavily forested areas without dense human settlements (Pelton 2003). Distribution of black bears in KEFJ is not well characterized. In KEFJ, black bears tend to be concentrated in low elevation coastal areas that occur between the marine ecosystem and Harding Icefield (French 2003). Del Frate (2002) noted that distributions of devil's club were one of the primary positive factors influencing black bear distributions on the Kenai Peninsula.

Abundance

Black bears are abundant throughout most of the Kenai Peninsula (Del Frate 2002). In KEFJ, Robinson et al. (2009) generated statistical estimates of black bear abundance using DNA-based capture-mark-recapture models based on non-invasive genetic sampling. The authors used CAPWIRE estimation model in four different study sites within KEFJ (Table 16). Results indicated that black bears are relatively common along the coastal areas of the park. The ADF&G establishes management goals for abundance and harvest within each Alaska game management unit (GMU). GMUs 7 and 15 encompass KEFJ and much of the Kenai Peninsula (Plate 11). There is no absolute desired abundance established for either GMU 7 or 15; the management direction is “not to exceed an average of 40% female in the harvest during the most recent 3-yr period”. Data suggest the ADF&G is within this goal and that estimates are “well over 4,000 black bears throughout Units 7 and 15” (Selinger 2011).

Table 16. Point estimates and 95% confidence intervals for estimates of black bear abundance for four bay areas in Kenai Fjords National Park during July and August, 2003-2005, using CAPWIRE (Robinson et al. 2007).

Aialik Bay	Two Arm Bay	Nuka Bay	Harris Bay
107 (95% CI 63-131)	101 (95% CI 60-154)	69 (95% CI 31-132)	301 (95% CI 122-750)

Number and Seasonality of Bear-Human Interactions

Bear interactions with humans are classified as encounters or incidents. KEFJ follows the definitions established by Smith et al. (2005) where: 1) A sighting is when a person sees a bear, but the bear is apparently unaware of the person; 2) An encounter occurs when a person and bear are mutually aware of each other. Bears may react with seeming indifference, avoidance, or by approaching the person; 3) An incident is an interaction between a person and bear in which the bear acts aggressively or in which a bear damages property or obtains food. Bear incidents are a subset of bear-human interactions and have outcomes ranging from benign to injury. All bear-human incidents and an unknown portion of bear-human encounters within the park are reported by the NPS using the BHIMS. In addition, KEFJ records management actions including all aversive conditioning or hazing operations, closures (e.g., trail or area), and bear removals either by re-location or by defense of life or property (DLP) database (Phillips et al. 2012).

According to the BHIMS database, 185 black bear-human interactions (incidents, encounters, sightings, or management actions) were reported between 18 June 1983 and 15 September 2009 (NPS 2009). This translates to an average of 9.4 interactions per year from 1983 to 2009. While bear-human incidents have been reportedly lower in recent years (Hahr and Jezierski 2008, Jezierski 2009), reports of interactions as a whole have significantly increased (2003-2009) (Figure 14) (NPS 2009). Plate 8 shows bear-human interactions by species, Plate 9 shows locations of bear-human interactions by month, and Plate 10 shows locations of bear-human interactions by interaction type.

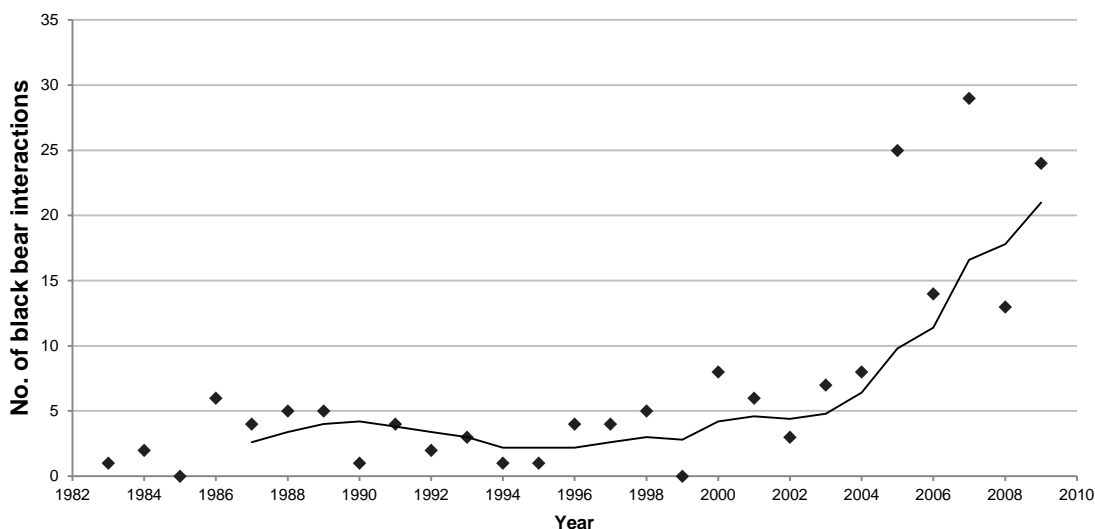


Figure 14. Number of black bear-human interactions from 1983 to 2009 in KEFJ (BHIMS database - NPS 2009). Shown with a five period (year) moving average line. There is no statistical significance associated with these data due to inconsistent reporting.

A high number of bear interactions are reported in the Exit Glacier area when compared to coastal areas of the park. This is likely primarily a function of the higher staffing level and park visitation rate at Exit Glacier compared to other park areas, most of which are considered backcountry areas. Backcountry areas with reported human-bear interactions include Delight Spit, Aialik Bay Ranger Station, Holgate Public Use Cabin, Pedersen Lagoon, and Quicksand Cove (Table 17). When examining only human-bear incidents, a smaller portion of the total interactions occurring in the Exit Glacier area were classified as incidents (only 19 of 81 were incidents); most interactions in areas including the Aialik Bay Ranger Station (9 of 11) and Cabin (4 of 4), the Delight Spit Area (10 of 10), the Holgate Public Use Cabin (12 of 13), Pedersen Lagoon (10 of 12) and Quicksand Cove (6 of 6) were categorized as black bear-human incidents. Adams (pers. comm., 2012) suggests this may be a function of reporting. That is, it is possible that visitors to the backcountry (locations other than Exit Glacier Area) are less likely to report minor-incidents and encounters (e.g., bear huffed, approached curiously) but more likely to report major incidents (e.g., bear got food, destroyed property, or bear charged). Visitors at Exit Glacier also have greater access to park staff and facilities and are more likely to report any and all bear-human interactions than in coastal/backcountry locations.

Table 17. Place name and number of black bear interactions (total incidents, encounters, observations, and natural history/management) and incidents in KEFJ from 1983-2009 (BHIMS database - NPS 2009). These counts do not take into account the number of bears in each encounter.

Place Name	# of Interactions	% of Total Interactions	# of Incidents	% of Total Incidents
Exit Glacier Area	81	43.8	19	18.1
<i>Unreported Location</i>	15	8.1	14	13.3
Holgate Public Use Cabin	13	7.0	12	11.4
Pederson Lagoon	12	6.5	10	9.5
Aialik Bay Ranger Station	11	5.9	9	8.6
Harding Icefield Trail	10	5.4	5	4.8
Delight Spit Area	10	5.4	10	9.5
Aialik Bay	6	3.2	2	1.9
Quicksand Cove	6	3.2	6	5.7
Aialik Bay Public Use Cabin	4	2.2	4	3.8
Nuka Bay	4	2.2	3	2.9
Paguna Arm	3	1.6	3	2.9
Harris Bay	2	1.1	2	1.9
James Lagoon	2	1.1	2	1.9
Taroka Arm	1	0.5	1	1.0
Willow Cabin	1	0.5	1	1.0
Thunder Bay	1	0.5	1	1.0
Surprise Bay	1	0.5	1	1.0
Exit Glacier Campground	1	0.5	--	
Northwestern Lagoon	1	0.5	--	
Total:	185	100.0	105	100.0

Over the BHIMS period of record (1983-2009), human-black bear interactions have been reported on nearly every day-of-year from about 16 May (day-of-year 136) to 15 September (258) (Figure 15). However, reports as early in the year as 5 May (125) and as late as 8 October (282) occur in the data. From 1983-2009, the yearly mean day-of-year human-black bear interaction ranged from 142 to 238 while the mean day-of-year interaction across all years was 188.6 (~7-8 July) (Table 18).

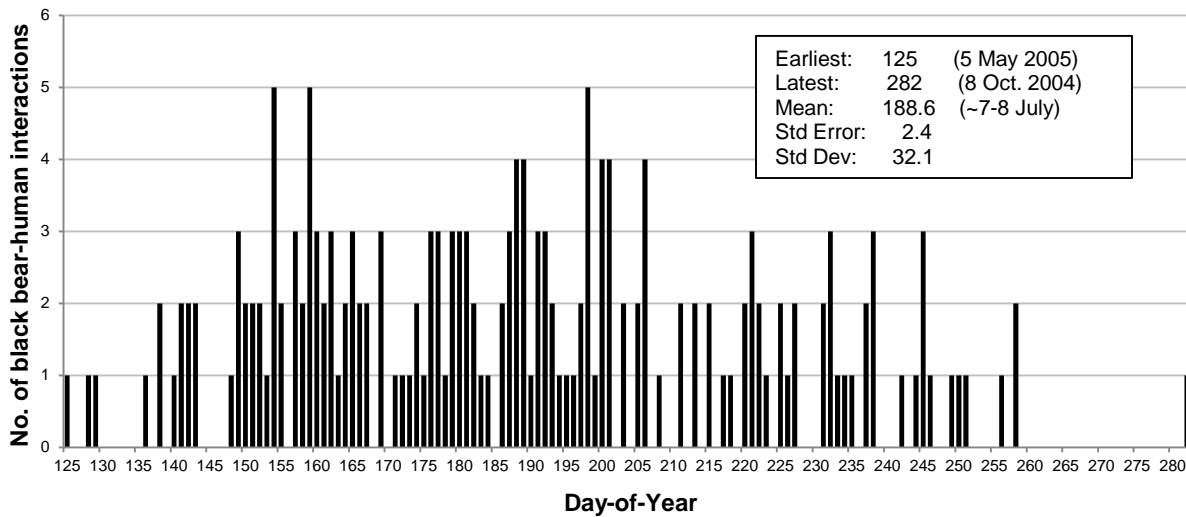


Figure 15. Total number of black bear interactions (incidents and encounters) by day of year from 1983 to 2009 in KEFJ (BHIMS database - NPS 2009). Bear-human interactions reported here do not take into account the number of bears in each encounter.

Table 18. Total number of black bear interactions (incidents and encounters) by year and mean day of year occurrence by year in KEFJ (BHIMS database – NPS 2009). Mean day-of-year across all years (n = 25) = 188.6 (std. dev = 32.1). min day-of-year = 125, max day-of-year = 282

Year	Total number of interactions	Day of year (mean)	Year	Total number of interactions	Day of year (mean)
1983	1	169	1997	4	222
1984	2	171	1998	5	198
1986	6	199	2000	8	177
1987	4	225	2001	6	157
1988	5	189	2002	3	153
1989	5	164	2003	7	187
1990	1	238	2004	8	217
1991	4	178	2005	25	187
1992	2	184	2006	14	180
1993	3	182	2007	29	189
1994	1	179	2008	13	194
1995	1	142	2009	24	188
1996	4	213			

Threats and Stressor Factors

Stressors identified by NPS staff include harvest near the park, regional population trends, nutritional health, disease, climate change, and park visitor use. Hunting mortalities and near-park harvests could potentially affect black bear populations and abundance. Habitat quality, sub-adult dispersal, and infanticide also play an important role in bear densities (Everitt 2001).

While hunting is not permitted on NPS lands within KEFJ, GMUs 7 and 15 surrounding the park permit black bear harvest, with exceptions such as the Portage Glacier Area and several controlled use/wildlife management areas (Plate 11). Black bear hunting has become increasingly popular

around the outer coast in the southern part of the Kenai Peninsula, which has led to an increase in the number of bears harvested annually in GMUs 7 and 15 (Del Frate 2002, Selinger 2011). According to two recent ADF&G black bear management reports (Del Frate 2002, Selinger 2011), bear populations appear stable across the Kenai Peninsula. The recent five-year average harvest for the Kenai Peninsula GMUs was 573 bears/year (Selinger 2011). Selinger (2011) stated that annual black bear harvest rates were acceptable and within ADF&G management objectives in Units 7 and 15. In a prior report, Del Frate (2002) warned that elevated black bear harvest rates could lead to decreased populations. This population decrease could be compounded by continued loss of habitat through human encroachment and in the 1969 burn area because of fewer moose.

Although the black bear is not likely to become extinct with significant climate changes, warming temperatures and anthropogenic modifications to the landscape could potentially contribute to habitat fragmentation (Kerr and Packer 1998). Diseases may also pose an increased risk to black bears, especially cubs, assuming further changes in climate (Bradley et al. 2005). Bradley et al. (2005) stated that incidents of Leptospirosis (*Leptospira serovars*) could increase due to warming Arctic weather regimes. Although much is unknown with regard to climate change and the impact of infectious diseases on Arctic fauna, continual changes are expected (Bradley et al. 2005). Climate change may also affect black bear food source distribution and availability. Hilderbrand et al. (1997) noted that limited nutrition during spring and summer months can delay molt in bears and that bone growth can be continually affected by current nutritional status. Crews (2002) found that fruit and vegetative masses of salmonberries, blueberries, and huckleberries were integral to seasonal black bear diets in KEFJ. Reduction or elimination of these berry sources could degrade black bear health and affect reproductive or hibernation success (Rogers 1976, Claar et al. 1999).

Increased visitor use of KEFJ, especially in areas of high bear density, could result in increased numbers of bear-human interactions and potentially in the number of conflicts. In a study examining bear responses to humans in the coastal backcountry of KEFJ, Smith et al. (2012) found that bears responded differently to human presence in two different bays. In Aialik Bay, black bears avoided campsites while in the lesser visited Nuka Bay, bears were attracted to campsites. Likewise, bears were noted to forage closer to cover in Aialik Bay than in Nuka Bay, suggesting wariness and risk averse behavior in areas with a defined human presence. In addition, the study found that when some bears were approached by humans, the bears climbed nearby mountainsides, then sat and waited for the humans to leave. This example of displacement may represent a negative energetic cost to bears. The study recommends KEFJ discourages camping in productive estuarine areas. This management action could minimize the displacement of bears from productive foraging areas, reduce the interruption of bear travel, and decrease the probability of potentially harmful bear-human interactions.

Injuries, property damage, and habituation can all result from increased bear-human encounters. Goodrich and Berger (1994) found that den abandonment was common in response to human activities around denning sites. Crews (2002) noted that increased park visitation could also result in adverse effects on remote vegetative plant communities, those often frequented by black bears. During berry season, males have shown patterns of reduced activity in response to human presence

(French 2003). Often, resource managers must balance public safety with public enjoyment of the park's natural resources. Smith et al. (2012) identified potential conflicts between bears and visitors in coastal areas, due to the bears seasonal use of low elevation coastal areas coinciding with visitors landing boats and kayaks along the coast and camping in the supratidal zone.

A total of 141 bear incidents (an interaction between a person and bear in which the bear acts aggressively or in which a bear damages property or obtains food) occurred from 1983 to 2009 in KEFJ. A large percentage of these were reported in the early to mid-2000s (Table 19).

Table 19. Bear-human incidents by year (1983-2009) in KEFJ (Black n=105, Brown n=6, Unidentified n=30) (BHIMS database - NPS 2009).

Interaction Year	Count	% of total	Interaction Year	Count	% of total
1983	3	2.1	1997	5	3.6
1984	3	2.1	1998	1	0.7
1985	2	1.4	1999	1	0.7
1986	6	4.3	2000	2	1.4
1987	4	2.8	2001	4	2.8
1988	6	4.3	2002	3	2.1
1989	6	4.3	2003	11	7.8
1990	1	0.7	2004	9	6.4
1991	4	2.8	2005	17	12.1
1992	3	2.1	2006	17	12.1
1993	5	3.6	2007	13	9.2
1994	1	0.7	2008	6	4.3
1995	3	2.1	2009	4	2.8
1996	4	2.8	Total:	141	100.0

Data Needs/Gaps

Distribution and abundance data for KEFJ are lacking. The most recent reports containing distribution or abundance data are nearly 5 years old. Furthermore, investigations by Robinson et al. (2007) focused only on four major bay areas of the park and excluded inland areas. Nevertheless, Robinson et al. (2007) provided baseline data which future studies could use to determine newer estimates of relative abundance and identify trends. The study compared four different estimation methods in four survey sites, but even the best estimates had wide confidence intervals. The authors recommend a larger sampling effort to achieve a more precise abundance estimator.

In recent years, more brown bear-human interactions have been documented in the BHIMS database for KEFJ. A total of six brown bear-human interactions occurred in 2006 and 26 in 2009 (Table 20). Adams (pers. comm., 2012) suggests that the recent increase in brown bear reports may be a function of increased reporting efforts rather than evidence of change in bear abundance or behavior in KEFJ, but there are not enough data to determine the true cause.

Table 20. Number of brown bear-human interactions by year, month and place name in KEFJ (BHIMS database - NPS 2009).

Year, Month	Place Name	Count of Brown Bear-Human Interactions
1999		1
July	Northwestern Lagoon	1
2004		1
June	Exit Glacier Campground	1
2006		6
May	Exit Glacier Area	4
June	Harding Icefield Trail	2
2007		1
September	Exit Glacier Area	1
2009		26
May	Exit Glacier Area, Nuka bay	4, 1
June	Exit Glacier Area	15
July	Exit Glacier Area	3
August	Exit Glacier Area	3
Grand Total:		35

Overall Condition

Distribution

A *Significance Level* of 2 was assigned to the measure of distribution. This measure was assigned a *Condition Level* of 0, indicating that it is not currently a concern to resource managers. Black bears are common throughout the fjords system and frequently seen within the park; bears inhabit much of the 644-km (400-mile) coastline of KEFJ (Hahr 2007, Hahr and Jezierski 2008, Jezierski 2009). Black bears have a very large distribution throughout KEFJ, and are generally found in higher densities along the coast.

Abundance


A *Significance Level* of 3 was assigned to the measure of abundance. Despite only one study providing abundance estimates in KEFJ, black bear abundance was assigned a *Condition Level* of 0, indicating that it is currently of low concern. Genetic sampling by Robinson et al. (2009) provides the most park-specific and statistically sound black bear abundance estimates to date. The abundance estimates apply to four major bays in the park (Aialik, Harris, Two Arm, and Nuka Bays) where black bears use coastal food resources. This information may act as baseline information to which future estimates can be compared (Robinson et al. 2009).

Number and seasonality of bear-human interactions

A *Significance Level* of 2 was assigned to the measure of number of bear-human encounters. This measure was assigned a *Condition Level* of 1, indicating that it is of relatively low concern to resource managers. Bear-human incidents were lower in recent years although interactions and observations were reportedly higher, namely in the Exit Glacier area of KEFJ.

Weighted condition score

The overall weighted condition score for the KEFJ black bear component is 0.095, indicating that this resource is currently of low concern. Overall, the trend of this resource is considered stable.

Black Bear			
Measures	Significance Level	Condition Level	Weighted Condition Score = 0.1
Distribution	3	0	
Abundance	3	0	
Number and Seasonality of Bear-Human Interactions	2	1	

4.2.6 Sources of Expertise

Laura Phillips, KEFJ Ecologist

Leslie Adams, KEFJ Wildlife Technician

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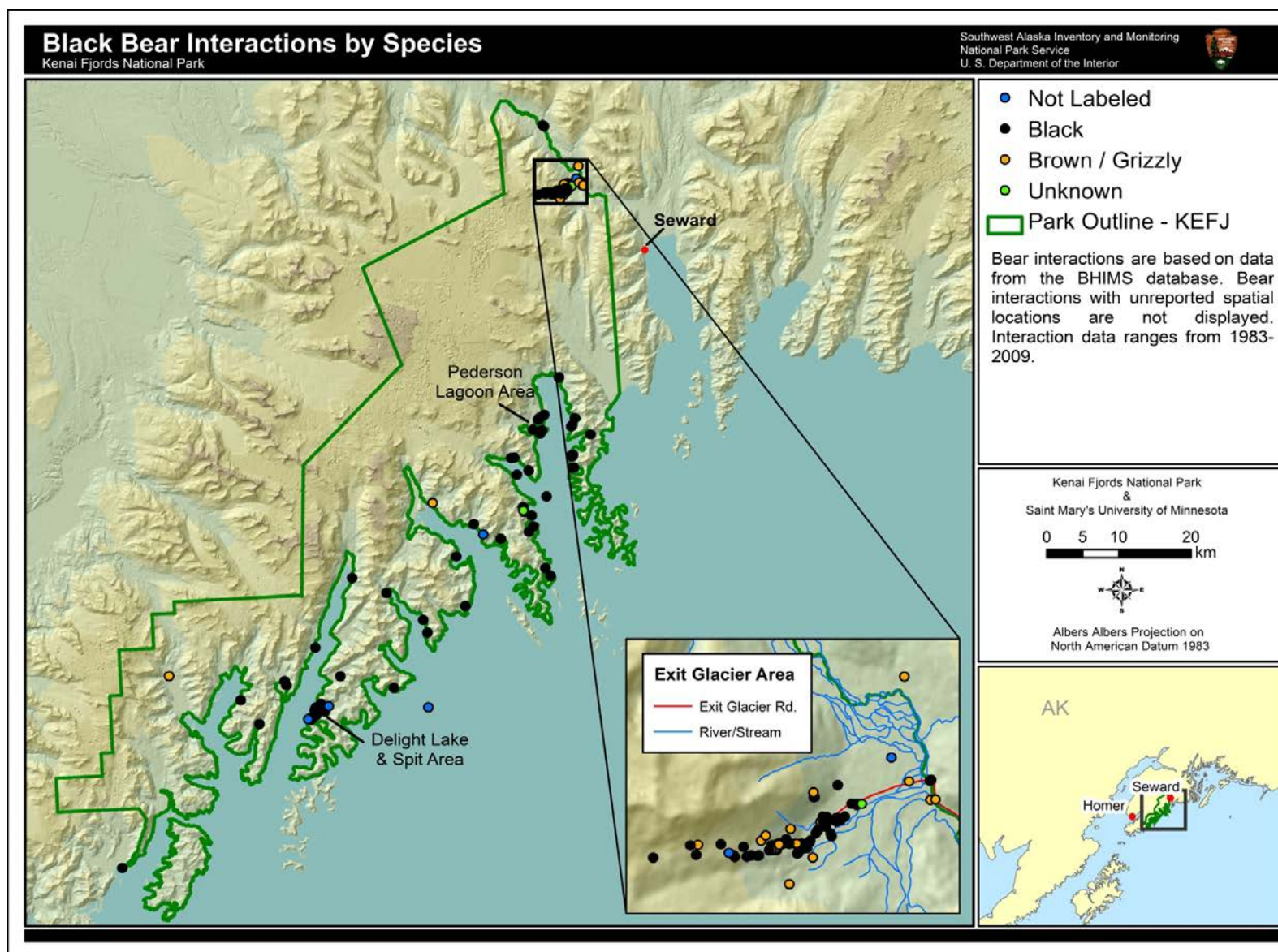


Plate 8. Bear interactions by species within KEFJ (1983-2009) (NPS 2009).

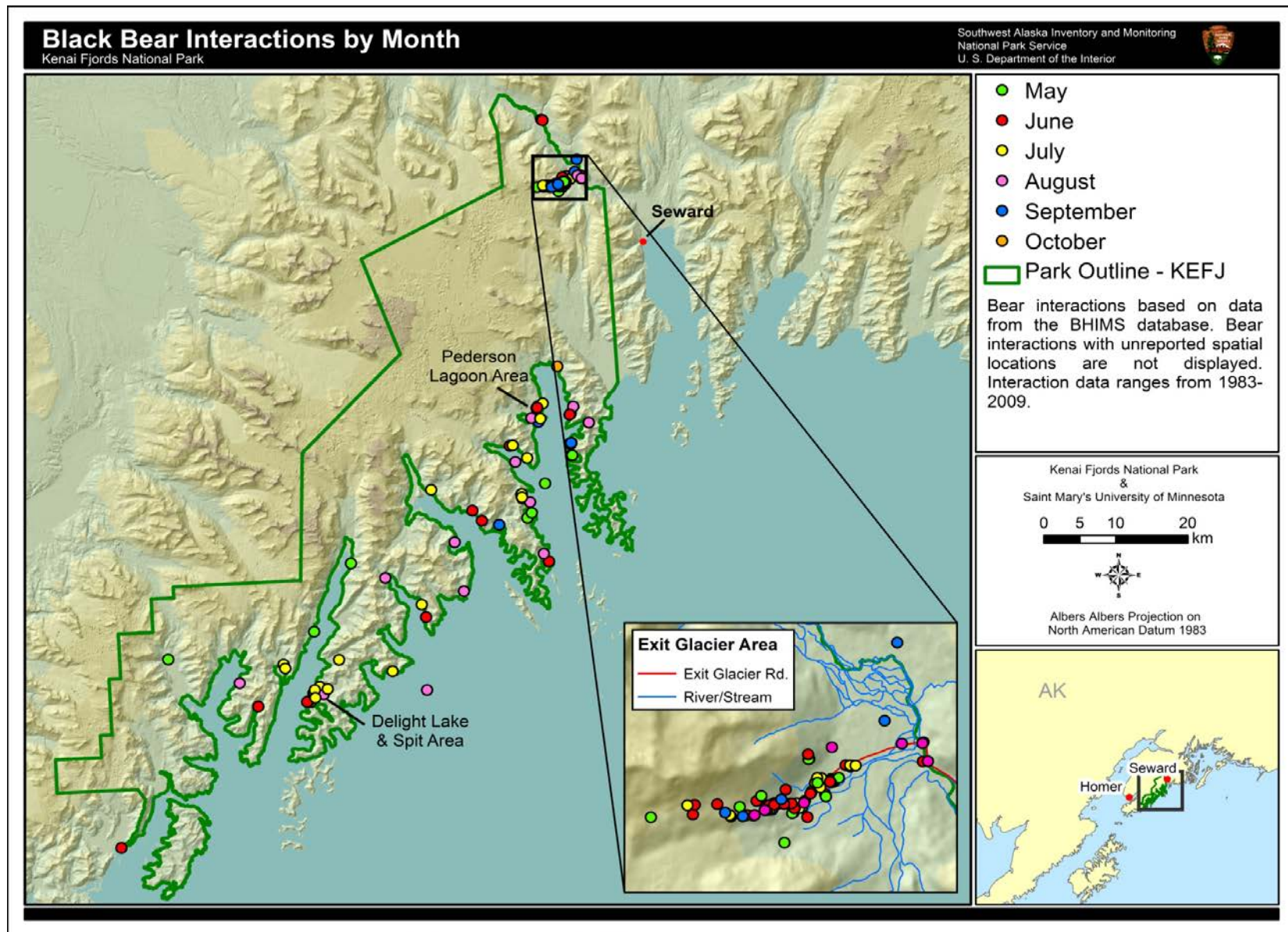


Plate 9. Black bear interactions by month within KEFJ (1983-2009) (NPS 2009).

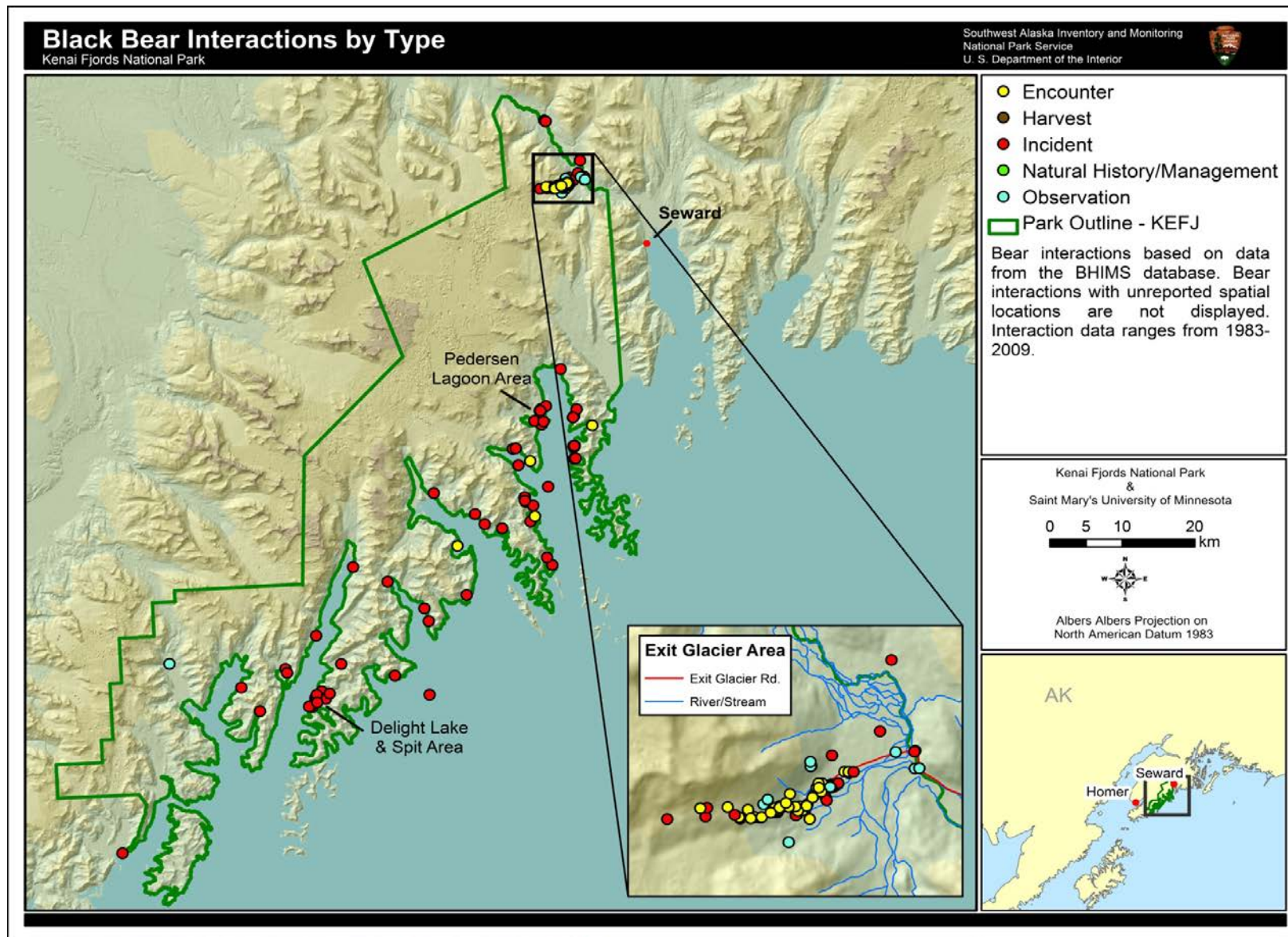


Plate 10. Black bear interactions by interaction type within KEFJ (1983-2009) (NPS 2009).

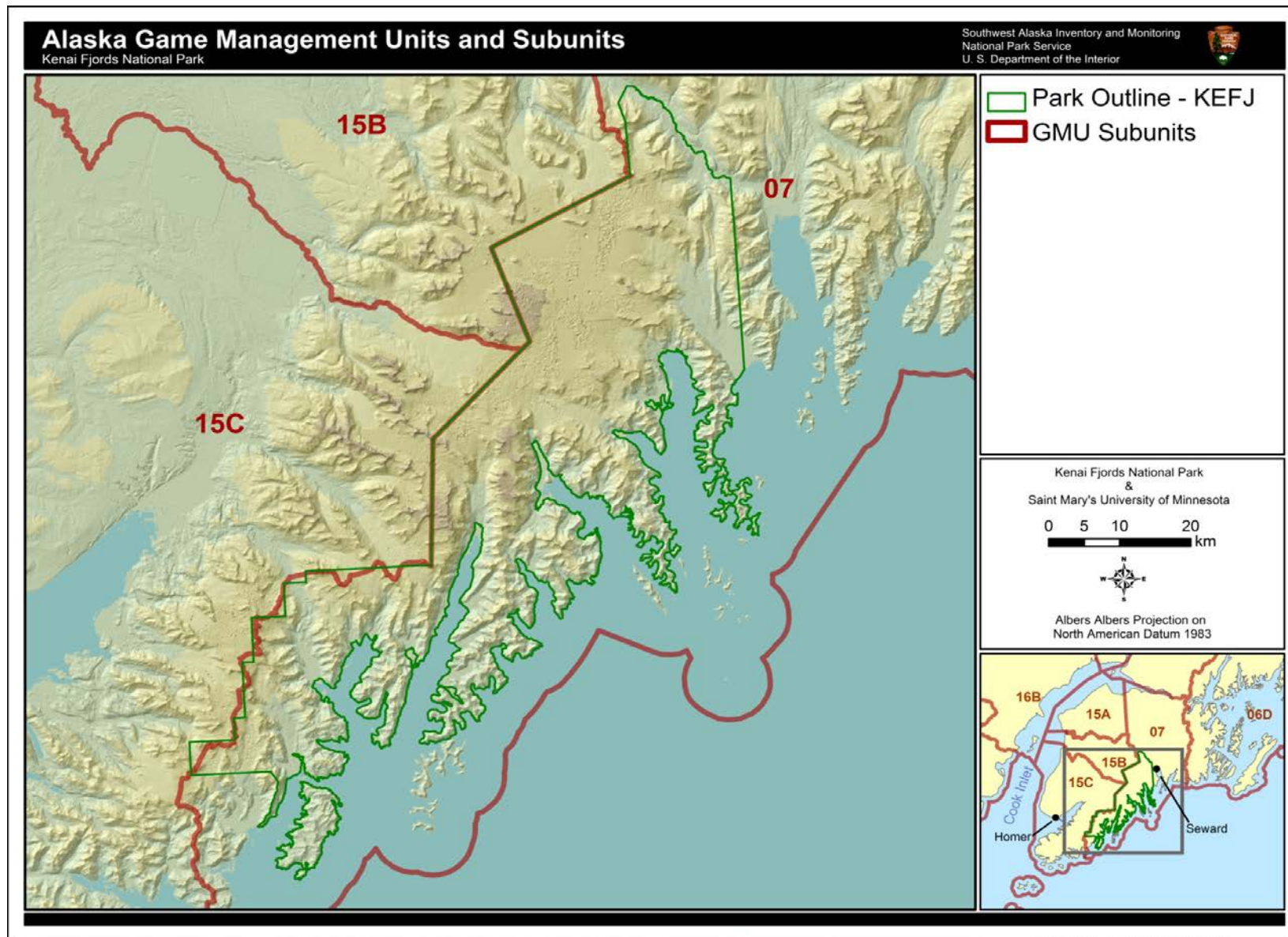


Plate 11. Alaska game management units and subunits. KEFJ falls within GMU 7 (AKDF&G 2008).

4.3 Bald Eagles

4.3.1 Description

KEFJ is home to the northern subspecies of bald eagle (*Haliaeetus leucocephalus alascanus*) (Stalmaster 1987, Tetreau 2000). This subspecies is slightly larger than the southern subspecies (*H. l. leucocephalus*), and is the only subspecies that has a breeding range in Alaska (Stalmaster 1987). Bald eagles are present throughout KEFJ, except for the Harding Icefield; however, the population is concentrated near the coast where breeding occurs during the spring and summer months (Tetreau 2000). In KEFJ, bald eagles most commonly nest in Sitka spruce (*Picea sitchensis*) stands along the coastlines, although there are also ground nests in recently deglaciated areas (Tetreau 2000). Bald eagles exhibit high nest-site fidelity and will return to the same nest/territory each year (Stalmaster 1987, Buehler 2000).

Bald eagles are top-level predators and are excellent indicators of an ecosystem's overall health (Hutto 1998, Morrison 1986, Stalmaster 1987, Tetreau 1991). Bald eagles also possess two characteristics that make them easy to observe and monitor: a large body size, and large, easily visible nests.

On average, male bald eagles were approximately 84.3 cm (2.8 ft) from head to tail, weighed 4.3 kg (9.5 lbs), and had a wingspan of about 207.3 cm (6.8 ft) (Imler and Kalmbach 1955, Stalmaster 1987). Typical of raptor species, bald eagles exhibit reverse sexual size dimorphism; females are larger than the males, weighing approximately 5.3 kg (11.7 lbs) and with a wingspan of 221.1 cm (8 ft) (Imler and Kalmbach 1955, Stalmaster 1987). Juveniles exhibit an entirely brown/mottled brown plumage until they reach sexual maturity at around 5 years of age, at which time the characteristic white head and white tail appear on the bird (Stalmaster 1987).

Bald eagles construct very large nests, the largest nest of any North American bird species (Stalmaster 1987). Both the male and female eagles construct the nest, and they will often construct a second or third “alternate” nest in the territory to use if the other nest is damaged (Bowman et al. 1992). Sticks and other materials are added to the nest at the beginning of each breeding season, and eventually nests can be as large as 4 m (13 ft) deep, 2.5 m (8.2 ft) across, and weigh one metric ton (del Hoyo 1994).

As top-level predators, bald eagles are exposed to several threats and variables that can affect their reproductive success and occupancy rates (Tetreau 1991). These environmental variables and threats can be natural in occurrence, or they can have human-caused origins. Figure 16 is an adaptation from Stalmaster (1987), and represents the various factors that influence bald eagle populations. A change



Photo 4. Adult bald eagle (Photo from Dave Menke USFWS).

in bald eagle reproductive success can be indicative of a change in one or more of these variables (Stalmaster 1987, Tetreau 1991).

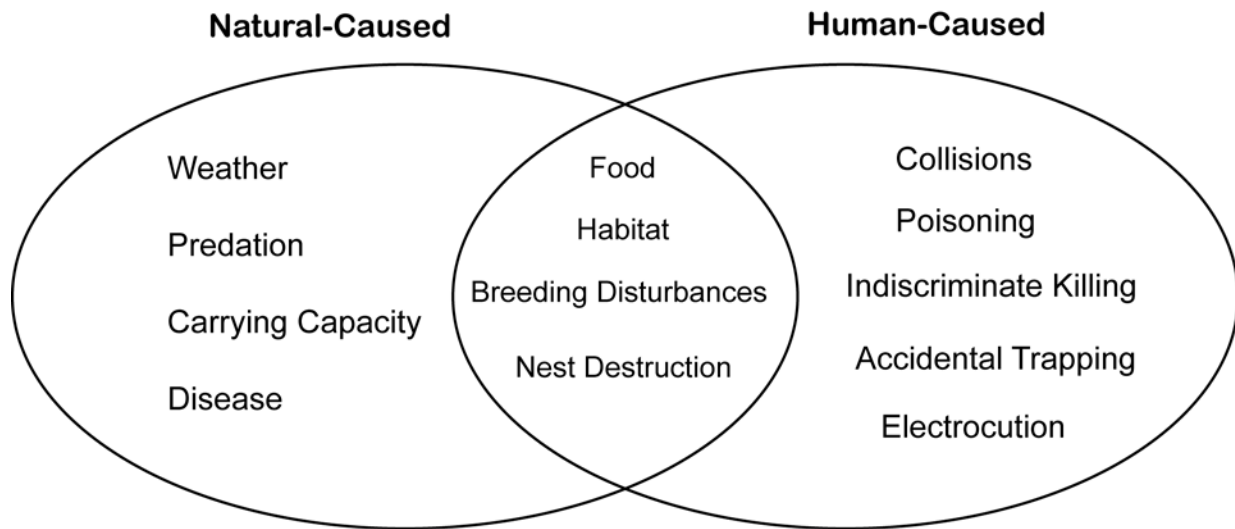


Figure 16. Various natural and human-caused factors that influence bald eagle populations. Reproduced from Tetreau (1991), Stalmaster (1987).

The bald eagle's prey items include fish, birds, and mammals (Stalmaster 1987, Anthony et al. 1999, Armstrong 2008). Despite the broad spectrum of potential prey species, fish appear to be the primary prey item for bald eagles; Stalmaster (1987) summarized several bald eagle data sources and determined that fish made up approximately 56% of the species' diet. This conclusion holds true in Alaska, as Imler and Kalmbach (1955) reported fish constituting 66% of bald eagle's diet in southeast Alaska, and Grubb and Hensel (1978) reported 62% of the bald eagle's diet consisted of fish on Kodiak Island, Alaska. Bald eagles are opportunistic feeders and will scavenge and steal food from other animals given the opportunity (Bowman et al. 1992). Winter limits the eagle's ability to hunt, and scavenging is often the primary tactic that an eagle will use to feed in the winter.

The egg-laying period begins in late March in KEFJ, and lasts approximately 44 days (late-March to early-May) (Tetreau 2000). Bald eagles lay one to three eggs and the incubation period lasts approximately 35 days (Tetreau 2000). Both the male and female eagles take turns incubating the eggs, but the female will perform most of the incubating duties. Once hatched, the chicks take about 10-12 weeks to fledge (USFWS 2010).

Bald eagle populations across the United States began declining in the early 1900s due to habitat fragmentation and direct human persecution (Sprunt and Ligas 1966, Buehler 2000). The use of toxic chemicals and pesticides, such as dichlorodiphenyltrichloroethane (DDT) and other organochlorides, exacerbated the decline (Brown et al. 2006).

The use of DDT as an insecticide became widespread worldwide during the 1940s and 50s because it is effective at preventing the transmission of insect-borne diseases to humans (Carson 1962). DDT

and its derivatives are persistent organic pollutants that accumulate in the environment, and DDT concentrations are highest in high trophic-level predators due to the process of bioaccumulation (EPA 1975).

Bald eagle populations in Alaska remained stable during the same time period that the continental U.S. populations of eagles declined. However, from the 1800s to 1953, Alaska offered a bounty on bald eagles because they were believed to prey on livestock (Laycock 1973), and between 1917 and 1952, a bounty was paid on 128,273 eagles (Laycock 1973). Despite the effects of the bounties, bald eagles in Alaska were never federally listed as endangered. However, all bald eagle populations (both continental and Alaskan) are protected under the Bald Eagle Protection Act of 1940. This Act provides for the protection of the bald eagle by prohibiting the taking, possession, and commerce of the species (USFWS 2011).

Bald eagles are a “highly desirable” Vital Sign for all NPS units in the SWAN (Thompson et al. 2009). SWAN will summarize data on nest occupancy and distribution annually in KEFJ; they will also estimate trends every 5 years (Bennett et al. 2006). Bald eagles serve an important ecological role in freshwater and marine coastal ecosystems within the SWAN, and monitoring of their populations across the region, including KEFJ, is important to understanding the overall ecological health of the area.

4.3.2 Measures

- Nest occupancy
- Productivity
- Nest distribution

4.3.3 Reference Conditions/Values

Reference conditions for KEFJ bald eagles are yet to be defined.

4.3.4 Data and Methods

Bald eagle nesting surveys were conducted in KEFJ from 1986-2002 (Tetreau 2000). Surveys conducted from 1986-1989 did not follow a standard protocol (a protocol was developed in 1990 and administered for the duration of the surveys) (Thompson and Phillips 2011). Surveys included both aerial (helicopter) and ground (including inflatable zodiac boats) efforts; productivity and occupancy data were reported from 1989-1998, and in 2002 (Tetreau 2000, NPS 2012).

Three GIS data sources related to bald eagles are available in the Alaska Regional GIS Permanent Dataset (PDS). One representing efforts of Michael Tetreau and other KEFJ employees (1986-2002), a USFWS bald eagle nest point dataset (1991-1996), and a recent, nearly entire KEFJ coast survey effort by NPS (2010). Associated nest occupancy and productivity data are not available for the USFWS nest data.

After 2002, eagle monitoring was not performed until 2009 when the SWAN and KEFJ began to develop a long-term monitoring plan for bald eagles in the park as part of the SWAN Vital Sign

Monitoring Program (Laura Phillips, KEFJ Ecologist, written communication, 8 September 2011). A dual-frame sampling design (Haines and Pollock 1998) was proposed by the USFWS. This sampling design incorporates a double-observer component (Nichols et al. 2000) as an adjustment for nests that may be missed during surveys (USFWS 2007). This survey method has been performed in KEFJ in 2009 and 2010 (Thompson et al. 2009, Thompson and Phillips 2010). Occupancy data was reported for both years, while productivity data was reported only for 2010.

4.3.5 Current Condition and Trend

Nest Occupancy

Bald eagles may not attempt to nest, or their attempts to nest may fail if breeding conditions are not suitable in a given year. Unsuitable conditions include the presence of toxic contaminants, limited food availability, human-related impacts, and climatic variation (Buehler 2000). In species that exhibit high nest-site fidelity and re-use the same nest/territory year after year, an estimate of the proportion of nests occupied by pairs in any given year is a useful index to the size and status of the population (Steenhof and Newton 2007). Occupancy has been defined differently in KEFJ depending upon the survey method. From 1986-1997, occupancy was defined as a nest with fresh nesting materials, or a nest that had two adults actively defending near, or at, the nest (Tetreau 1991). In 2009 and 2010, occupancy was defined as an adult on the nest in an incubating posture (Thompson and Phillips 2011).

In KEFJ, various researchers monitored bald eagle nest occupancy from 1989-2002 (Tetreau 2000, NPS 2012) (Table 21). Data from 2000-2001 are not reported here; data from 2000 have not been entered into the NPS database, and data from 2001 have not been summarized (Leslie Adams, KEFJ Wildlife Biological Science Technician, email comm., 30 March 2012). The Nuka Bay region of KEFJ did not have an occupancy survey conducted in 1993 (Tetreau 2000). Because of this, occupancy data for 1993 are most likely underestimated.

Table 21. Number of occupied bald eagle nests observed in KEFJ from 1989-1998, 2002. Data from Tetreau (2000) and NPS (2012).

Year	# of Occupied Nests	Year	# of Occupied Nests
1989	31	1995	32
1990	27	1996	36
1992	50	1997	31
1993	34	1998	24
1994	19	2002	61

* In 1991, the bald eagle surveys in KEFJ were conducted too slowly and the number of occupied nests was most likely underestimated. The results of that survey are not included in this table.

Because of varying survey methods (see Tetreau 1991 and Thompson et al. 2009), surveys from 2009 and 2010 are not compared to earlier survey results in KEFJ. In 2009, Thompson et al. (2009) recorded 44 occupied nests during aerial surveys of the KEFJ coastlines (Table 22). Using a computer-generated model (see Thompson et al. 2009), Thompson et al. (2009) estimated the total number of occupied nests in the park at 65 (95% confidence intervals 50-101) (Table 22). During a

sample of 25 segments in KEFJ in 2010, Thompson and Phillips (2011) detected 29 occupied nests (14 of these nests were newly identified nests) (Table 22). Similar to Thompson et al. (2009), a computer-generated model was used to estimate the number of occupied nests in KEFJ for 2010. The estimate suggested that KEFJ had 153 occupied nests in 2010, with a 95% confidence interval of 88-218 nests (Thompson and Phillips 2011) (Table 22).

Table 22. Observed and estimated bald eagle occupancy in KEFJ from 2009-2010. Data from Thompson et al. (2009), and Thompson and Phillips (2011).

Year	Observed # of Occupied Nests	Estimated # of Occupied Nests	95% Confidence Interval
2009	44	65	50-101
2010	29	153	88-218

Productivity

Productivity is the number of fledglings or large young per occupied nest (Postupalski 1974, Tetreau 2000), while nesting success is defined as a nest that produces at least one young to an advanced stage of reproductive development (Postupalsky 1974, Tetreau 2000). A nesting success rate of 50% and 0.7 young per occupied nest are needed for bald eagle populations to maintain themselves (Kozie, personal communication from 1991 cited in Tetreau 1998). However, a bald eagle population with a nesting success rate of 70% and productivity levels of one fledgling per occupied nest is more indicative of a healthy population (Kozie, personal communication from 1991 cited in Tetreau 1998).

Surveys (both aerial and ground) conducted from 1989-1998, and 2000-2002 provide productivity data for the KEFJ population of bald eagles (Tetreau 2000, NPS 2012). Although surveys were also conducted from 1986-1988, no productivity data exists for these years due to only one survey being conducted during the nesting season. According to Tetreau (2000), the data sets from 1992, 1995, and 1996 are considered the most reliable for the park; the 1991 and 1994 data sets are less reliable. As was mentioned previously, the 1991 bald eagle survey was conducted late in the season and the reported productivity values were likely underestimated (Tetreau 2000). The 1994 survey did not report any productivity data, and the 2000 and 2001 survey data have not been updated/summarized in the NPS database.

Bald eagle productivity in KEFJ from 1989-1997 is shown in Table 23. The average percentage of successful occupied nests from 1989-1997 was 63.38% (Table 23). The average number of young produced per occupied nest was 0.81, while the average number of young per successful nest was 1.28 (Table 23). Compared to other bald eagle populations in southeast Alaska, average productivity values for KEFJ (1989-90, 1992-93, 1995-97, 2002) were similar, although the average number of young per occupied territory was noticeably lower in KEFJ (Table 24).

Table 23. Bald eagle productivity and reproductive success in KEFJ from 1989-1997 (Tetreau 2000).

Year	% of Occupied Nests Successful	Number of Young per Occupied Nest	Number of Young per Successful Nest
1989	58%	0.65	1.11
1990	59%	0.89	1.50
1992	74%	1.14	1.54
1993	65%	0.74	1.14
1994	No Data	No Data	No Data
1995	31%	0.41	1.30
1996	75%	0.94	1.26
1997	65%	0.77	1.20
2002	80%	0.93	1.16
Average	63.38%	0.81	1.28

Table 24. Productivity and nest success of bald eagle populations in southern Alaska.

Region	Avg. # of Young/Occupied Territory	Avg. % Active Territories Successful	Period	Source
Kodiak Is., AK	1.00	63	1963-1970	Sprunt et al. (1973)
Prince Wm. Sound, AK	0.87	57	1990	Bowman et al. (1995)
KEFJ	0.81	63.38	1989, 1990, 1992-93, 1995-97, 2002	Tetreau (2000), NPS (2012)

Thompson and Phillips (2011) revisited nests that were occupied during the first survey of the 2010 season and recorded productivity. Nineteen of the 29 (66%) occupied nests produced fledglings; 14 of these nests each produced one fledgling, while five nests each produced two fledglings (Thompson and Phillips 2011).

Using the same computer-generated model from Thompson et al. (2009), the total number of fledglings for 2010 in KEFJ was estimated. According to Thompson and Phillips (2011, p. 8),

We [Thompson and Phillips 2011] employed Bayesian modeling to estimate the number of young fledged in the sampling frame based on nests detected with incubating bald eagles in a GRTS [generalized random-tessellation stratified] sample of 25 segments. This estimate was calculated by multiplying the number of segments in the sampling frame by the estimated proportion of occupied segments, the average number of nests detected with incubating adults, and the average number of young per successful nest.

This process resulted in an estimate of 53 fledglings (95% confidence interval of 28-96) in KEFJ during the 2010 breeding season (Thompson and Phillips 2011).

Nest distribution

Three bald eagle GIS datasets are available from the Alaska NPS permanent dataset. These data sets represent varying survey efforts (both ground and aerial) and provide eagle nest locations along the KEFJ coast. It is unclear, based upon available GIS data, how nest locations relate to each other between datasets. For example, between a USFWS dataset and the Tetreau 1986 to 2002 dataset, it is unclear if there are redundant nest locations that do not necessarily coincide spatially. These three GIS point datasets are displayed in two subset maps of KEFJ (Plate 12 Plate 13).

Several inputs were combined to create one point dataset of known eagle nests locations in a 1996 USFWS GIS point dataset. These data represent survey efforts from 1991 to 1996 from researchers (both NPS and USFWS) responding to the Exxon Valdez oil spill. According to the metadata of this GIS point data, the intent was to consolidate the known information on bald eagle nests across Alaska to form a single point reference (i.e., a centralized repository aimed at reducing redundancy for land managers and others with an interest in these data). The metadata indicate that approximately 60 percent of the study area was surveyed; however, the exact study area is not listed. The data extend along much of the Pacific coast of the Alaska Peninsula, and includes the coast of Kodiak Island, most of the Kenai Peninsula coast, most of the Prince William Sound coast, and along much of the Alaska road system and interior Alaska National Park Units. Approximately 80 to 90 percent of nests were located in the surveyed areas. The spatial accuracy of nest locations is estimated to be accurate within 100 m.

Another data source was a point dataset of nest locations more specific to KEFJ. The point dataset titled “Bald Eagle Nests on KEFJ Coast” was originally created through years of surveys led by Michael Tetreau. These include both ground and aerial surveys starting in 1986 through 2002. Most locations were identified from 1989 to 1996, following the Exxon Valdez oil spill. An additional 34 nests were added to the dataset in 2002 via interpretation of aerial imagery. From 1990 through 2002, these data followed a standard protocol.

SWAN created the last GIS point dataset of eagle nest locations during more recent aerial (helicopter) survey efforts. These surveys occurred from 13-19 May 2009. Collected using GPS units inside an aircraft, the spatial accuracy of the points are estimated to be +/- 50 m after comparing locations to IKONOS satellite imagery. Along with this dataset, geotagged digital photos of each nest from the air are available for hyperlinking to the nest GIS points.

Given the different survey methods, varying horizontal location accuracies, the multiple agencies involved, the variability in survey extents (i.e., survey effort each year), and the potential for nests to be missed, trends or patterns of nest distribution along the KEFJ coast over time or between datasets are not conclusive. Despite this, it appears that eagle nests have been widely distributed across the KEFJ coast. With new scientific protocol development for nest surveys (see Thompson and Phillips 2011), GIS data will become more comparable as protocol methods are repeated in the future.

Threats and Stressor Factors

Bald eagle populations face many continuing threats from human-related activities: ecotourism, fishing (sport and commercial), timber harvest, potential mining activities adjacent to the parks, and

potential oil spills or other accidents along marine coastlines (Buehler 2000). In KEFJ, nesting bald eagles may experience stress from visitor use of the park; visitor activities that occur along the coastline (e.g., boating, cruises, and fishing) could negatively impact the nesting population, as the vast majority of nests are located along KEFJ's coasts.

Bald eagles are heavily dependent upon fish for their diet (Stalmaster 1987). In Alaska, salmon (Salmonidae family) often comprise a large portion of an eagle's diet (Grub and Hensel 1978, Stalmaster 1987), and a change in the abundance of these prey items could affect the mortality rates of the eagles in the park. Poor hunting conditions and scarcity of food forces adults to leave the vulnerable nestlings exposed for longer periods, thus increasing their chances of becoming hypothermic (Stalmaster 1987).

The introduction of contaminants into the food web (e.g., heavy metals, organochlorides, and other pesticides) could result in nesting failure, as observed in the continental U.S. population of bald eagles from the 1940s-1970s (Sprunt and Ligas 1966, Anthony et al. 1999, Buehler 2000). While Alaska was thought to have been less affected by the use of organochlorides, Anthony et al. (1999) found elevated levels of DDE (a metabolite of DDT), other organochlorides, and mercury in bald eagles of the Aleutian Islands. The bald eagles that had the highest concentration of these toxins had diets that were dominated by avian species, and lived in areas that were occupied by the military during World War II.

DDT is still widely used in Japan and Russia as a pesticide (Anthony et al. 1999), and may be present in Alaskan ecosystems. Anthony et al. (1999)'s suggestion that an avian diet may increase the risk of DDE in bald eagles further supports the need for a prey base analysis in KEFJ. An analysis of the contaminant levels in KEFJ's bald eagle population may help to better understand the distribution of these chemicals across Alaska. Such a study would also help managers better gauge the health of the KEFJ bald eagle population.

Climate change is a threat poorly documented in the literature, but nonetheless appears to be affecting animal species worldwide. In KEFJ, changes in precipitation, temperature, related changes in prey base abundance, and storm intensity appear to be the primary threats stemming from climate change.

In KEFJ, precipitation data from Exit Glacier are used as an index of spring rainfall, since no spring data are available for the coast. Tetreau (2000) compared precipitation to nesting success of bald eagles in KEFJ for 1989-1997. While the data are not optimal (heavy rains in 1991 limited sampling efforts, and no data were collected in 1994), high precipitation levels in April and May seem to lower the reproductive success of bald eagles in KEFJ (Figure 17).

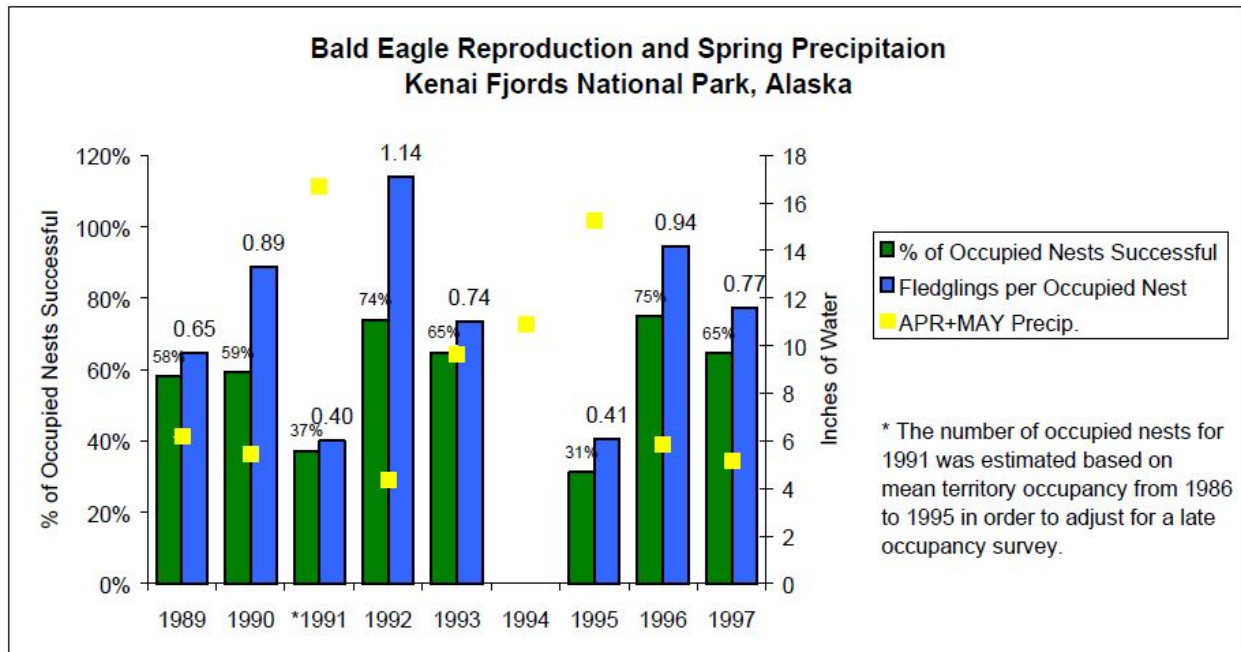


Figure 17. Bald eagle reproductive success along the coast of KEFJ, displayed with combined April and May precipitation data from Exit Glacier (Reproduced from Tetreau 2000).

According to Stalmaster (1987, p. 64), “cold, wet weather could directly influence the nesting pair by delaying the production of eggs until the weather improves.” Continued monitoring of this relationship to examine the overall effect that precipitation levels have on bald eagle nesting success is necessary.

Other climate related threats, such as temperature changes and the frequency of strong storms, may also alter the productivity and occupancy of bald eagles in KEFJ. Temperature changes can cause dramatic changes in bird populations; timing of courtship, egg laying, and foraging are all closely tied to specific temperature ranges (Crick 2004). Temperature changes can also impact breeding success through, for example, chilling or starvation of young (Newton 1998, Crick 2004). Extreme weather shifts in the area (e.g., prolonged frozen spells, droughts) could have catastrophic effects on bald eagle nesting success (Crick 2004). With an increase in strong storms, the likelihood of nest destruction and reproductive failure will likely increase. Heavy rainfall events (like those that hindered the 1991 survey efforts) appear to have a negative correlation to nesting success (Figure 17), and could be a significant threat to bald eagles in KEFJ.

Data Needs/Gaps

Continued monitoring of bald eagle nest occupancy and success is needed at KEFJ. The current dual frame sampling design (Haines and Pollock 1998) with dual-observers (Nichols et al. 2000) appears to be an effective sampling procedure. Continuation of this survey, along with optimization of the number of sample routes and estimates of total occupancy, will allow researchers and managers in KEFJ to have an accurate estimate of the total bald eagle population in the park. Repetition of these surveys for 10-15 years would allow the population estimates from 2009-2010 to serve as a baseline to compare condition.

Data related to bald eagle diet are needed for KEFJ. No studies have been completed in KEFJ specifically related to bald eagle diet. While literature suggests that fish comprise a large portion of the eagle's diet in Alaska (Imler and Kalmbach 1955, Grubb and Hensel 1978, Stalmaster 1987), an investigation into the prey base in KEFJ would allow managers to better understand population fluctuations and nest tree selection. Furthermore, contaminant analysis (similar to Anthony et al. 1999) would provide managers at KEFJ with necessary information related to contaminant levels not only in bald eagles, but also in the ecosystem and potential prey species.

Data relating to bald eagle wintering and nonbreeding ecology is needed. Typically, avian species nesting at northern latitudes exhibit a southward migration from their nesting territories (Dunstan 1973, Reese 1973, Dunstan et al. 1975, Postupalsky 1976, Gerrard et al. 1978, Griffin 1980). No studies exist regarding bald eagle wintering ecology in KEFJ, and the wintering locations of the breeding birds in KEFJ is unknown. Large aggregations of wintering eagles (>1,000 individuals) are reported on the Chilkat River in southeastern Alaska. Furthermore, the behavior of nonbreeding birds (eagles do not reach sexual maturity until around 5 years of age) is also unknown in the park.

Overall Condition

Nest Occupancy

KEFJ staff assigned this measure a *Significance Level* of 3. Occupancy levels from 1989-2002 did not appear to exhibit any increasing or decreasing trends, and occupancy as reported by Thompson et al. (2009) and Thompson and Phillips (2011) indicates an increasing number of occupied nests (although this is only speculation, as two years of data is not enough to ascertain such trends). Occupancy levels appear to be relatively stable, and observed fluctuations are likely due to temporal and regional variations (Laura Phillips, KEFJ Ecologist, phone conversation, 27 March 2012). For these reasons, SMUMN GSS assigned the measure nest occupancy a *Condition Level* of 0.

Productivity

The measure productivity was assigned a *Significance Level* of 3 during KEFJ scoping meetings. Productivity levels from 1989-1997, and 2002 were largely above levels needed for bald eagle populations to maintain themselves (as suggested by Kozie, pers. comm. from 1991 cited in Tetreau 1998). Nesting success rates only fell below the 50% threshold one time during these surveys (in 1995, no data for 1994) (Table 23). The number of young per occupied nest during this time period fell below the 0.70 threshold twice (1989, 0.65 young/nest; 1995, 0.41 young/nest) (Table 23). Compared to other Alaskan bald eagle populations, the average number of young per occupied nest in KEFJ from 1989-2002 was low (Table 24), while the average percentage of successful territories was on par with other areas (Table 24).

Productivity estimates were not calculated during the 2009 aerial survey of the park. However, Thompson and Phillips (2011) did estimate productivity in KEFJ for 2010. Productivity was estimated at 53 fledglings in 2010; the estimated percent of active nests that were successful was 0.35, which is low compared to other populations in Alaska (Table 24). Comparable populations presented in Table 24 are not estimates, and represent annual intensive surveys in Alaska.


Limited contemporary data make it difficult to determine current condition and trends for bald eagle productivity in KEFJ (Laura Phillips, phone conversation, 27 March 2012). While historic data suggest that the population has a stable, sustaining level of productivity, more recent data is needed to support such a claim. Because of this, a *Condition Level* was not assigned to this measure.

Nest Distribution

KEFJ staff assigned the distribution of nests measure a *Significance Level* of 1. Surveys along the KEFJ coast appear to indicate a wide distribution of nests. Data do not appear to suggest any obvious shifts in coast-wide distribution of nests; however, a quantitative analysis of nest distribution that compares data over time and between available GIS datasets in a common survey extent is problematic. Some of the factors that may affect such an analysis include the variability in methods, lack of individual nest identification dates, potential nest location redundancy between datasets, and variations in horizontal position accuracy because of varying survey methods. Because of these difficulties, a *Condition Level* was not assigned to this measure.

Weighted Condition Score (WCS)

Because >50% of the measures were not assigned a *Condition Level*, a WCS was not assigned for this component.

Bald Eagle			
Measures	Significance Level	Condition Level	Weighted Condition Score = N/A
Nest Occupancy	3	0	
Productivity	3	n/a	
Distribution of Nests	1	n/a	

4.3.6 Sources of Expertise

Laura Phillips, KEFJ Ecologist

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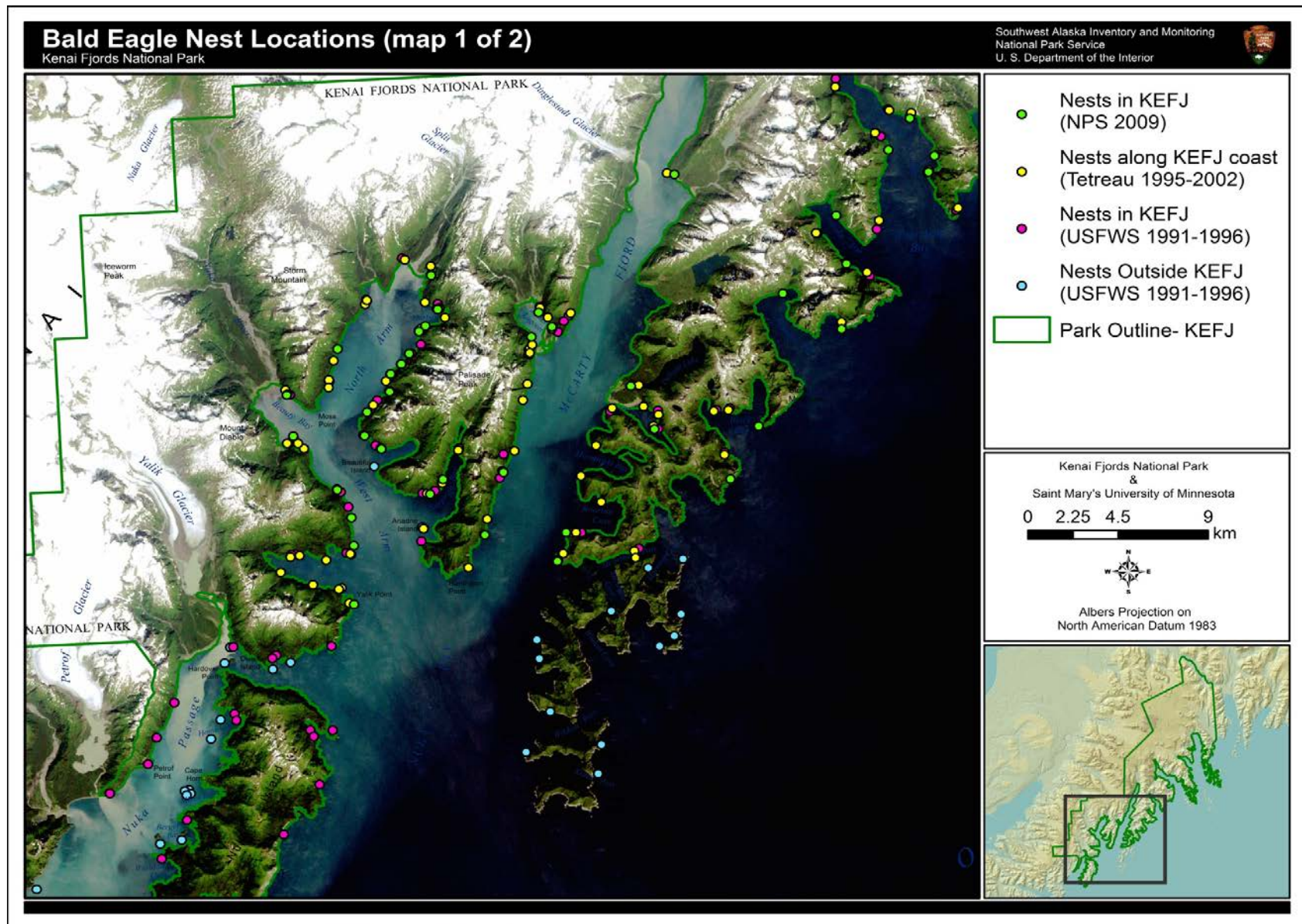


Plate 12. Bald eagle nest locations along the KEFJ coast identified through various survey efforts (map 1 of 2).

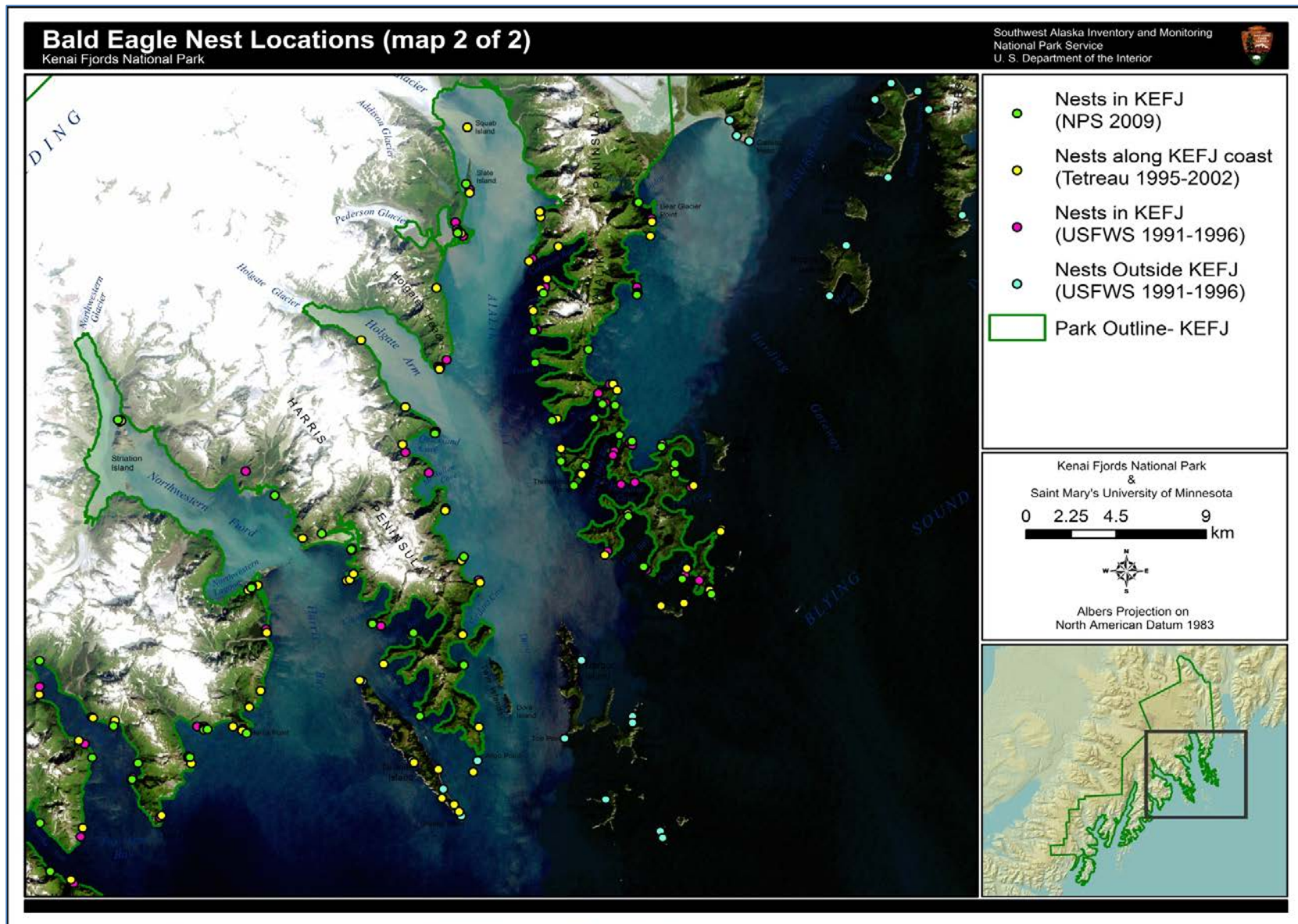


Plate 13. Bald eagle nest locations along the KEFJ coast identified through various survey efforts (map 2 of 2).

4.4 Marine Birds

4.4.1 Description

Marine birds are classified as species from the Family Anatidae (Order Anseriformes) and the Families Alcidae, Ardeidae, Charadriidae, Laridae, Phalacrocoracidae, Scolopacidae, and Stercorariidae (Order Ciconiiformes). They are top predators in the nearshore marine ecosystem of KEFJ and are inextricably linked to the coastal marine food web (Coletti et al. 2011b, Coletti et al. 2013). Trends in marine bird populations tend to reflect the integrity of the environment; therefore, coastal marine birds are often used as bioindicators of overall ecosystem health, serving as early indicators of stressed or changing marine ecosystems (Bennett et al. 2006, NABCI 2009). The marine environment in KEFJ is abundant in nutrients due to the combination of coastal streams, glacial melt, and the Alaska Coastal Current. This unique ecosystem provides essential wintering, staging, feeding, and nesting grounds for migratory and resident birds (Vequist 1990). Benthic-feeding and forage fish-feeding bird species utilize the near shore environment in KEFJ, although in general marine bird distribution largely depends on the availability of prey, water temperature, and salinity (Speckman 2002).



Photo 5. Harlequin duck (NPS photo).



Photo 6. Black-legged kittiwakes (NPS photo by Max Kauffman).

In this assessment, two separate monitoring efforts are summarized that include work on marine bird species along the coast of KEFJ; marine birds are examined as part of the SWAN Nearshore Monitoring Program and in park-driven seabird colony surveys.

Marine birds were selected as a Vital Sign by the SWAN Nearshore Monitoring Program. Several marine bird species were selected and are considered indicators of environmental change due to their life history characteristics and foraging ecology (Dean and Bodkin 2011). The species chosen for long-term monitoring are relatively abundant and trophically linked to the nearshore through foraging, and in some cases, breeding (Bodkin 2011). These target or focal species include harlequin duck (*Histrionicus histrionicus*) (Photo 5), black-legged kittiwakes (*Rissa tridactyla*) (Photo 6), glaucous-winged gulls (*Larus glaucescens*), cormorants (*Phalacrocorax* spp.), Barrow's goldeneye (*Bucephala islandica*), mergansers (*Mergus* spp.), scoters (*Melanitta* spp.), and black oystercatcher (*Haematopus bachmani*) (addressed as a separate component in this document). Marine bird or

seabird colonies are also monitored by the NPS within the park and islands adjacent to the park in the Alaska Maritime National Wildlife Refuge (AMNWR). This monitoring program includes surveys of colonies containing glaucous-winged gulls, black-legged kittiwakes, common murre (*Uria aalge*), cormorants, horned puffins (*Fratercula corniculata*), and tufted puffins (*Fratercula cirrhata*).

Black-legged kittiwakes are common nesting marine birds found throughout the Gulf of Alaska (Irons 1996, Sowls et al. 1978) and are found primarily near island nesting sites during the breeding season (Vequist 1990). They breed colonially, and build nests on cliffs located near the ocean. They feed on small fish at the surface of the water (Shultz 2002).

Glaucous-winged gulls are abundant in bays, harbors, estuaries, rivers, intertidal coastal zones, and even urban environments. They nest on sandbar islands, flat tops of rugged islands, along beaches and on cliffs. They are opportunistic feeders on fish, marine invertebrates, birds, fish waste, and occasionally garbage (Denlinger 2006).



Photo 7. Pigeon guillemot (NPS photo).

Pigeon guillemots (*Cepphus columba*) (Photo 7) are widely dispersed in shallow and deepwater locations (Vequist 1990), although they tend to forage near shore, focusing on invertebrates, demersal fish, and pelagic fish (Ewins 1993, Litzow 2002). Guillemots breed on rocky shores and steep cliffs.

Cormorant species in KEFJ include pelagic (*Phalacrocorax pelagicus*), red-faced (*P. urile*), and double-crested (*P. auritus*) (Coletti et al. 2010).

Pelagic and red-faced cormorants nest on steep nearshore cliffs, and prefer to stay in nearshore areas

year-round, although large wintering populations immigrate to the area from other locales (Vequist 1990). Cormorants tend to feed within 3.2 km (2 mi) of land, with double-crested feeding in protected bays and estuaries and pelagic and red-faced feeding along rocky coasts (AMNWR 2008). Fish are the primary food source for cormorants.

Harlequin ducks spend most of the year (fall, winter, and spring) in the ocean and only travel inland to breed. They nest near fast-moving streams and rivers, which makes them unique among ducks (Rosenberg and Rothe 2007). During non-breeding season they live nearshore in rocky intertidal and shallow subtidal waters where they dive for invertebrates.

Three *Bucephala* species inhabit KEFJ: common goldeneye (*B. clangula*), Barrow's goldeneye, and buffleheads (*B. albeola*). Goldeneyes nest in tree cavities and forage nearshore in the summer months. In the winter months, the population of goldeneyes increases as birds move into the area to overwinter along the park's coastline. Their diet typically consists of fish and invertebrates. Barrow's goldeneyes are much more frequently observed in KEFJ than the common goldeneye or bufflehead (Vequist 1990, Coletti et al. 2011b).

Scoters (*Melanitta* spp.) are common year-round residents of KEFJ and are found in shallow bay areas. The three species present in KEFJ are the surf scoter (*M. perspicillata*), black scoter (*M. americana*), and white-winged scoter (*M. deglandi*). They nest near coastal habitats where they feed on crustaceans and mollusks.

Mergansers (*Mergus* spp.) are piscivorous ducks that dive underwater for their prey. The red-breasted merganser (*Mergus serrator*) is a common migratory bird found in nearshore marine habitats. The common merganser (*M. merganser*) usually nests in trees or rock crevices and frequently inhabits freshwater streams or lakes.

There are a total of 77 documented marine bird species in KEFJ (NPS 2012a). This assessment focuses on five species from the park's seabird colony work and seven target taxa identified by the SWAN Vital Signs Nearshore Monitoring Program. Appendix 3 presents the list of all marine bird species certified as being present in the park and separates SWAN target taxa and species counted in park seabird colony surveys (NPS 2012a).

4.4.2 Measures

- Seabird colony composition
(*park-driven colony survey efforts*)
- Abundance of breeders in seabird colonies (blagged-legged kittiwake, glaucous-winged gulls, red-faced cormarant, pelagic cormarant, and double-crested cormarant)
(*park-driven colony survey efforts*)
- Distribution of seabird colonies (blagged-legged kittiwake, glaucous-winged gulls, red-faced cormarant, pelagic cormarant, and double-crested cormarant)
(*park-driven colony survey efforts*)
- Density and distribution of target taxa (blagged-legged kittiwake, glaucous-winged gulls, cormorants, harlequin duck, Barrow's goldeneye, and scoters)
(*SWAN Nearshore Monitoring – marine bird counts on established transects*)
- Productivity

4.4.3 Reference Conditions/Values

A set of reference conditions for each of the aforementioned measures is not established for this assessment. Ideal reference conditions might be the natural variation in these measures over an acceptable time period. Developing an understanding of this natural variability is part of the long-term goals of monitoring efforts such as park seabird colony surveys (variation in colony composition, abundance of breeders, and colony distributions over time) and SWAN nearshore monitoring, marine bird surveys (variation in densities and distributions of target taxa over time). Changes occurring in these measures, beyond that of the natural variability in the measures, might indicate an environmental problem. A clearer understanding of natural variation might allow researchers to create inferences of the causes for changes, or at minimum, allow researchers to

develop a set of research questions to determine causes for changes. Presently, both the seabird colony surveys and SWAN nearshore transect surveys efforts are relatively young and data are yet too limited to establish a set of explicit reference conditions or, for most species, to determine statistically significant trends.

The oldest colonial marine bird survey prior to the Exxon-Valdez Oil Spill that provides colony locations and bird counts occurred in 1976 (Bailey 1976). Then, during the summer of 1986, the first comprehensive re-survey was completed (Nishimoto and Rice 1987). Recent seabird colony survey efforts in KEFJ began in 2007 with Hahr (2008). Since 2007, KEFJ and USFWS have continued colony surveys at various levels of intensity along the park's coast and along nearby AMNWR islands. These data are reported under the current condition and trends section. In 2011, KEFJ, USFWS, and UAF staff began a more focused study on colonial seabirds with the goal of developing a long-term monitoring plan for ledge-nesting seabirds in the park and adjacent AMNWR lands (Phillips and McFarland 2012). Phillips and McFarland (2012) compared recent seabird colony data to data from surveys conducted in 1976 and 1986. The authors note that the comparisons help KEFJ staff to develop research questions and objectives for future work. Because colony surveys have been sporadic, replicate counts were often not made in past surveys, and differing survey and record keeping techniques exist across survey years, data are often not immediately comparable for each species.

Likewise, there are no historic reference data to compare with recent marine bird target taxa density and distribution data collected as part of the SWAN Nearshore Monitoring Program efforts. Lastly, no information on marine bird productivity is available, except for in recent black oystercatcher work by SWAN researchers.

4.4.3 Data and Methods

Historic survey efforts of seabird colonies included periodic studies by the park and other researchers (Bailey 1976 and Nishimoto and Rice 1987). Contemporary, adult seabird counts at known seabird colonies began in 2007 (14 colonies along the park's coast), and continued in 2009 (17 colonies), 2010 (10 colonies), and 2011 (16 colonies - beginning of 3-yr survey with systematic survey of the entire KEFJ coast and AMNWR). Survey efforts also occurred in 2008 (2 colonies in KEFJ) but focused only on common murre colonies (Phillips and McFarland 2012). The results of surveys such as Phillips and McFarland (2012) and Parsons et al. (2012) estimate the abundance of marine bird species at colonies of nesting marine birds. While several marine bird species are observed in colony counts, for this assessment, focus is on five ledge-nesting species, blaggen-legged kittiwake, glaucous-winged gulls, red-faced cormorant, pelagic cormorant, and double-crested cormorant. Spatial data for displaying species distribution in map form (plates and figures) come from an NPS shapefile containing information from 1976, 1986, and 2007-2010 surveys. According to this seabird colony shapefile a total of 49 seabird colonies were documented in 1976 (Bailey 1976) and resurveyed in 1986 (Nishimoto and Rice 1987). Twenty of these are considered along the KEFJ coast and 29 along AMNWR. Recently (2007-2010) surveyed colony locations are displayed in Plate 14.

The seabird colony survey efforts, which are conducted by KEFJ and USFWS staff, and recently by some UAF researchers are separate from and differ in objective from monitoring efforts of SWAN.

Marine birds are one of the SWAN's Nearshore Monitoring Vital Signs and marine bird surveys conducted by SWAN researchers in KEFJ and in nearby AMNWR have occurred from 2007 to 2011. They are associated with the following reports: Bodkin et al. (2008) and Coletti et al. (2009, 2010, 2011b, 2013). SWAN survey efforts are intended to determine trends in abundance and distribution of marine birds and mammals during the summer and winter months. Marine bird counts have been conducted at 45 transects (38 nearshore, seven offshore) in winter and summer surveys, accounting for approximately 20% of the 770 km (478.46 miles) of the KEFJ shoreline (Coletti et al. 2011a). The transect locations are shown in Plate 15. Observers record species counts while traveling in a small vessel along selected shoreline sections (predetermined 200 meter-wide transects). On each side of the vessel, observers count all species within 100m ahead of, behind, and over the vessel. They record date, region, segment numbers (transect), latitudes and longitudes (or waypoints), taxon, number of animals, and photo numbers. The waypoints provide scientists with geographic locations of birds or groups of birds by taxon so distributions can be examined. Using the survey data, researchers estimate the density of marine birds in the nearshore environment using transect surveys.

All species observed during the SWAN bird and mammal surveys are counted; however, post-survey data analyses target seven specific taxa (target species) due to their diverse roles in the nearshore food web and as indicators of environmental change in the marine ecosystem (H. Coletti, pers. comm., 2012). The target taxa in this assessment include the same ledge-nesting bird species counted in park-driven colony surveys plus pigeon guillemot, harlequin duck, Barrow's goldeneye, and scoters. Black oystercatchers are dealt with as a separate component in this document.

Surveys are conducted along these transects during summer and winter seasons. Summer surveys (late June to early July) for marine birds in KEFJ (2007 to 2011) have been a part of an ongoing protocol development for the SWAN-wide Nearshore Vital Signs monitoring protocol. Winter (March) surveys are intended to characterize species composition, distribution and density of overwintering marine ducks before they leave for their breeding grounds, but during winter surveys, observers collect data that inform seasonal differences in species composition, distribution, and density of other marine birds and mammals (Coletti et al. 2011). That is, they still collect counts on target taxa if present in the area in winter (black-legged kittiwake, glaucous-winged gulls, cormorants, mergansers, and black oystercatcher), but focus on goldeneyes, harlequin ducks, and scoters (Coletti et al. 2011). Cormorant, goldeneye, scoter, and merganser species were grouped into higher taxa in studies by Coletti et al. (2009, 2011b) due to high potential for misidentification. For this assessment, references to these species are to the genus level.

4.4.4 Current Condition and Trend

Seabird Colony Composition (glaucous-winged gulls, black-legged kittiwake, red-faced cormorant, pelagic cormorant, and double-crested cormorant) (park seabird colony surveys)

Since the colony surveys in 1976 by Bailey (1976), seabird colony survey data are varied and minimal along the Kenai coast (Phillips and McFarland 2012). Phillips and McFarland (2012, p. 24) describe colonial nesting seabird data as, "less than ideal for monitoring seabird populations." According to the NPS seabird colony GIS dataset, glaucous-winged gulls are also considered the

primary species in 20 of 24 colonies to contain glaucous-winged gulls from 2007-2010 surveyed colonies.

Abundance of Breeders in Seabird Colonies (glaucous-winged gulls, blaggen-legged kittiwake, red-faced cormorant, pelagic cormorant, and double-crested cormorant) (park seabird colony surveys)

Again, given differences in methods and relatively limited data (e.g., single counts), identifying statistically significant trends regarding the abundance of seabird colonies is not possible. However, researchers present contemporary data for comparison with older surveys and caution that they are “apparent” breeding populations. According to colony data in KEFJ with six years of data, like the overall relative abundance of glaucous-winged gulls, apparent breeding populations of glaucous-winged gulls have appeared to increase from 1976 to 2007, then stabilize since (Figure 18) (Dewberry et al. 2012). Breeding black-legged kittiwakes were only found in one location with four years of data (Cloudy Cape colony) during a 1986 survey (Phillips and McFarland 2012), and counts exhibit little variation between years (Parson et al. 2012). Parsons et al. (2012) suggests that this is evidence that the Chiswell Islands black-legged kittiwake population, within AMNWR, is likely stable. The apparent breeding populations of cormorant species at KEFJ colonies appear to be highly variable (Figure 19) (Parsons et al. 2011). One exception might be at the Black Bay colony, where the apparent breeding population of cormorants increased (Phillips and McFarland 2012).

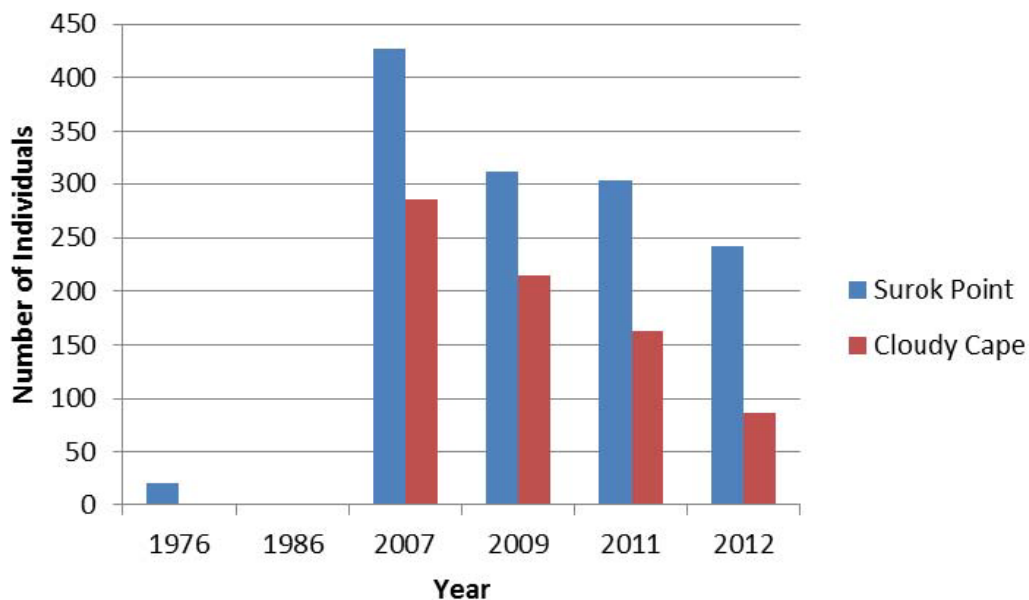


Figure 18. Observed breeding population of glaucous-winged gulls at two colonies in KEFJ for four years of count data. Counts for 1976-2009, 2012 are from single visits. In 2011 counts are an average from multiple visits, Cloudy Cap nine times and Sorok Point four times. Reproduced from Dewberry et al. (2012).

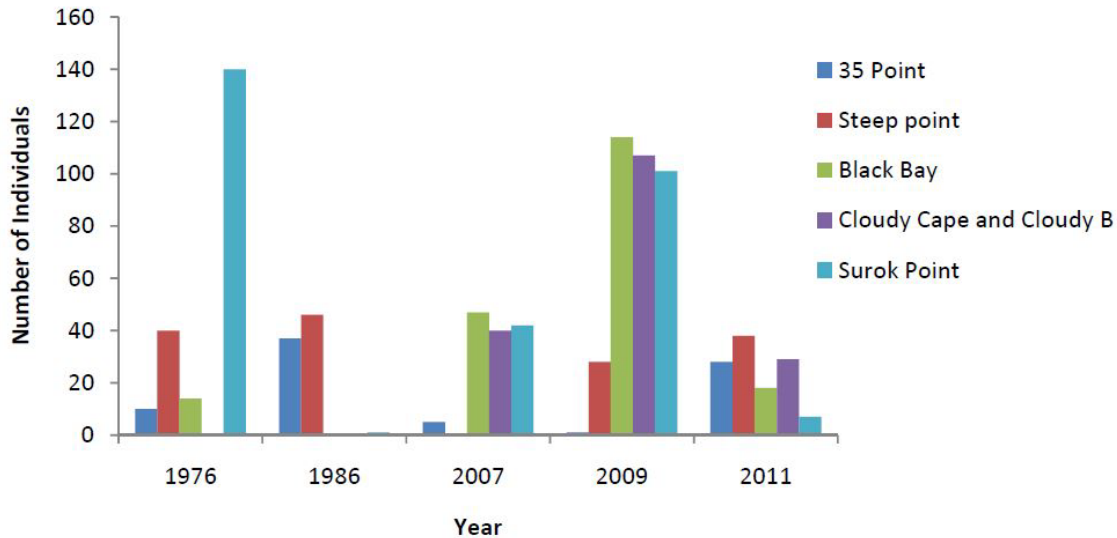


Figure 19. Apparent breeding population of three species of cormorant (red-faced cormorant, double-crested cormorant, and pelagic cormorant) at five colonies in KEFJ for five years of count data. Counts for 1976-2009 are from single visits. With the exception of 35 Point, 2011 counts are an average from multiple visits: Steep Point was visited two times, Black Bay three times, Cloudy Cape and Cloudy B nine times and Surok Point four times. Reproduced from Parsons et al. (2011)

Distribution of seabird colonies (glaucous-winged gulls, blagged-legged kittiwake, red-faced cormorant, pelagic cormorant, and double-crested cormorant) (park seabird colony surveys)

According to the NPS-KEFJ seabird colony GIS dataset (shapefile), as of 2010, five of the original forty-nine colonies surveyed in 1976 and re-surveyed in 1986 have not been revisited since. Most of these occur on AMNWR lands (29 in AMWR and 20 along KEFJ coast). Figure 20, Figure 21, Figure 22, Figure 23, and Figure 24 show the most recent distributions available from 2007-2010 surveys for glaucous-winged gulls, blagged-legged kittiwake, red-faced cormorant, pelagic cormorant, and double-crested cormorant, respectively. During recent (2007-2010) surveys in KEFJ or AMNWR., a total of 28 colonies were observed to have at least one of the following taxa glaucous-winged gulls, blagged-legged kittiwake, red-faced cormorant, pelagic cormorant, and double-crested cormorant.

Glaucous-winged gulls have the widest distribution across known colonies of the park and AMNWR during this time period. Glaucous-winged gulls are also the most prevalent in terms of the number of colonies in the park where they've been observed during 2007-2010 surveys. Their most recent distribution across colonies from 2007-2010 is displayed in Figure 20 (NPS 2012b). In this available spatial data, black-legged kittiwakes were only found in two colonies near the park in 2009, both of which were located on ANMWR lands, one near Hoof Point and a large colony on Outer Island (Figure 21, NPS 2012b). The cormorant species occupy many of the same colonies as glaucous-winged gulls, with highest concentrations from Two Arm Bay south to the Pye Islands and with pelagic and double-crested being more common and widely distributed across colonies compared with red-faced (Figure 22) (NPS 2012b). In terms of changes in the location (i.e., distribution) of

seabird colonies, locations for many colonial seabirds can be fairly stable, but comormants are known to move colonies frequently (Delinger 2006).

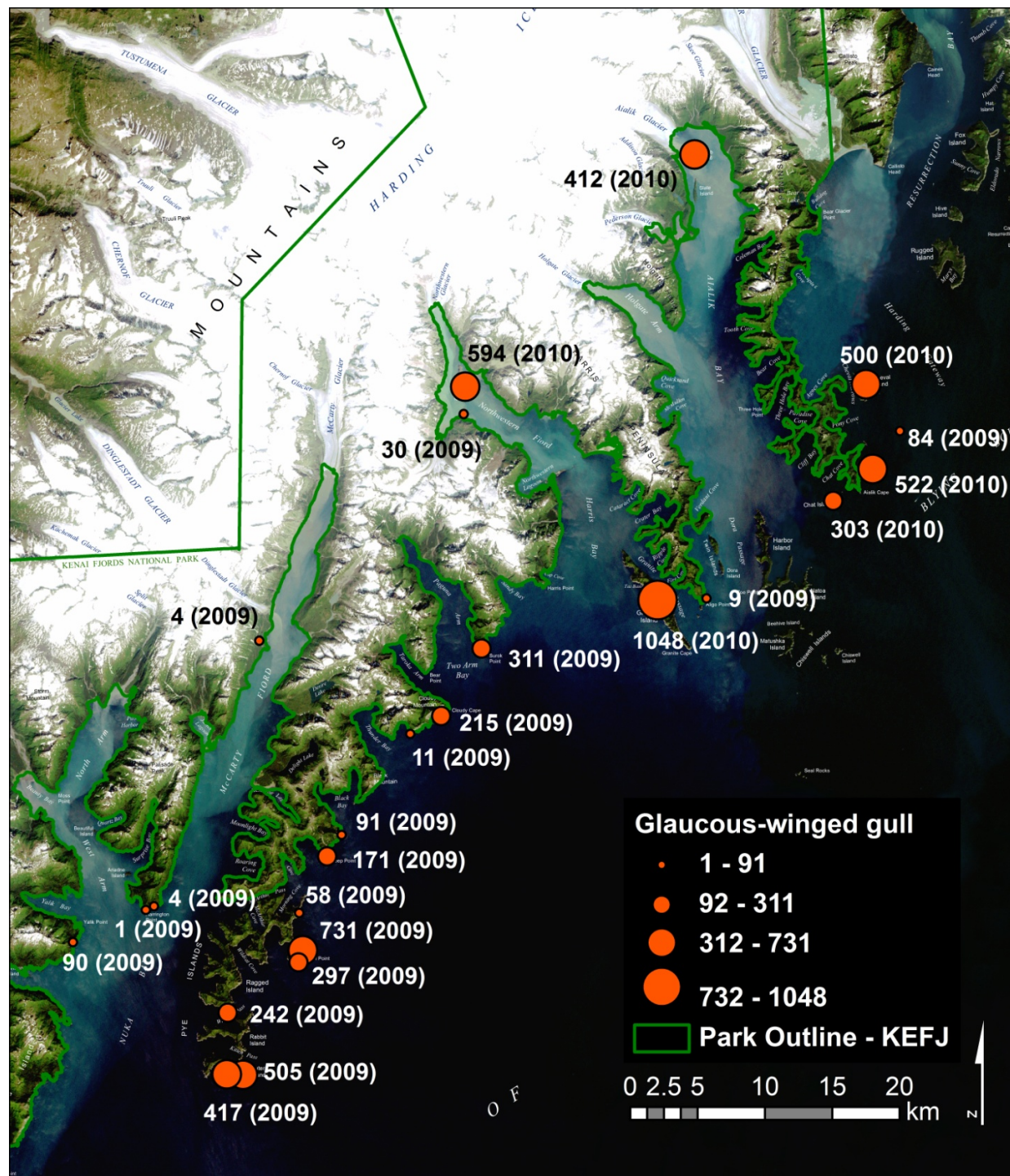


Figure 20. Relative abundance and distribution of glaucous-winged gull in colonies along the coast of KEFJ and AMNWR from the most recently available survey data, 2007-2010 (NPS 2012b). Labels in the map list the number of gulls observed at each colony (point) and the most recent survey year represented.

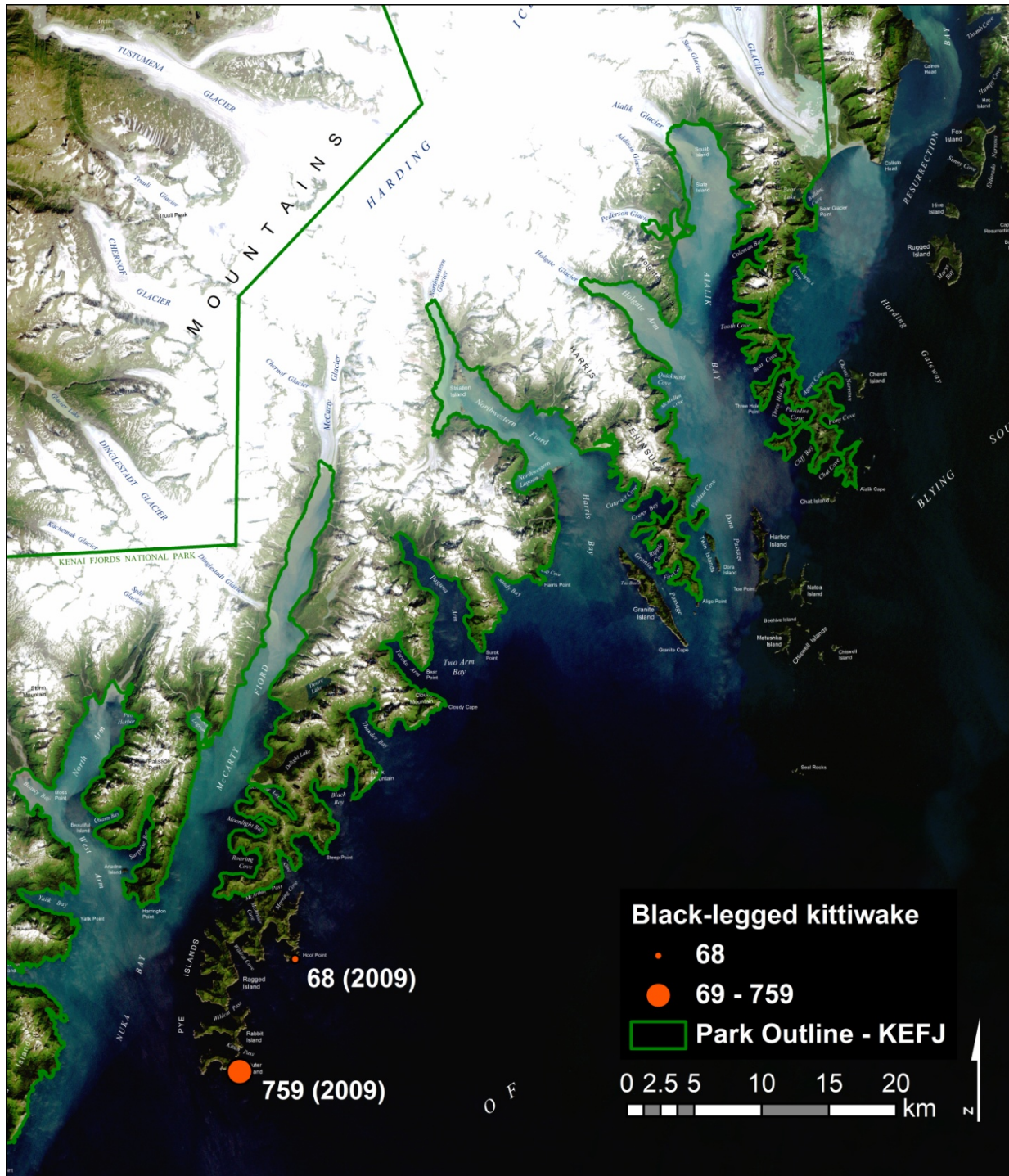


Figure 21. Relative abundance and distribution of black-legged kittiwake in colonies along the coast of KEFJ and the AMNWR from the most recently available survey data, 2007-2010 (NPS 2012b). Labels in the map list the number of kittiwakes observed at each colony (point), and in parentheses, the most recent survey year represented.

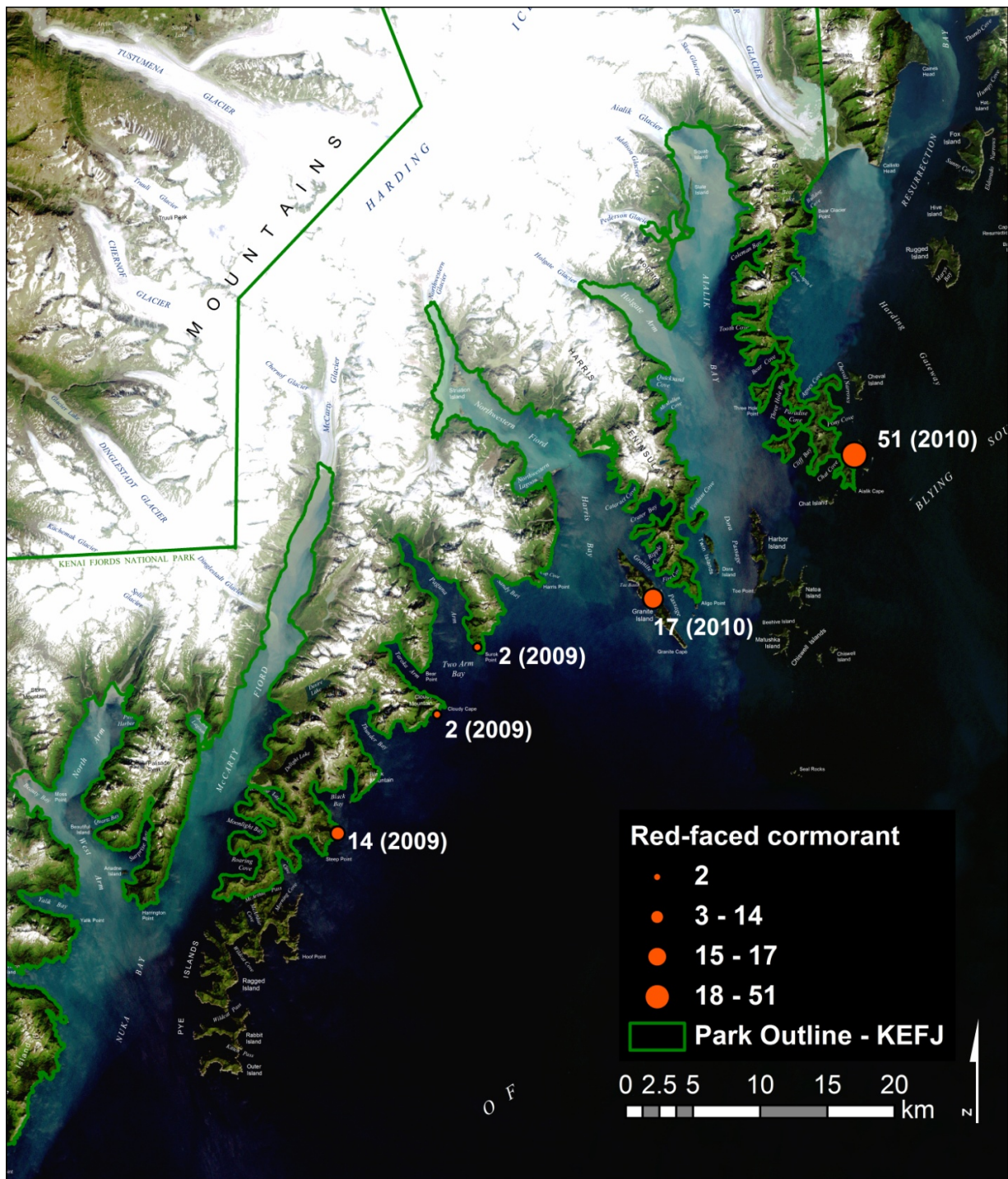


Figure 22. Relative abundance and distribution of red-faced cormorant in colonies along the coast of KEFJ and the AMNWR from the most recently available survey data, 2007-2010 (NPS 2012b). Labels in the map list the number of red-faced cormorants observed at each colony (point), and in parentheses, the most recent survey year represented.

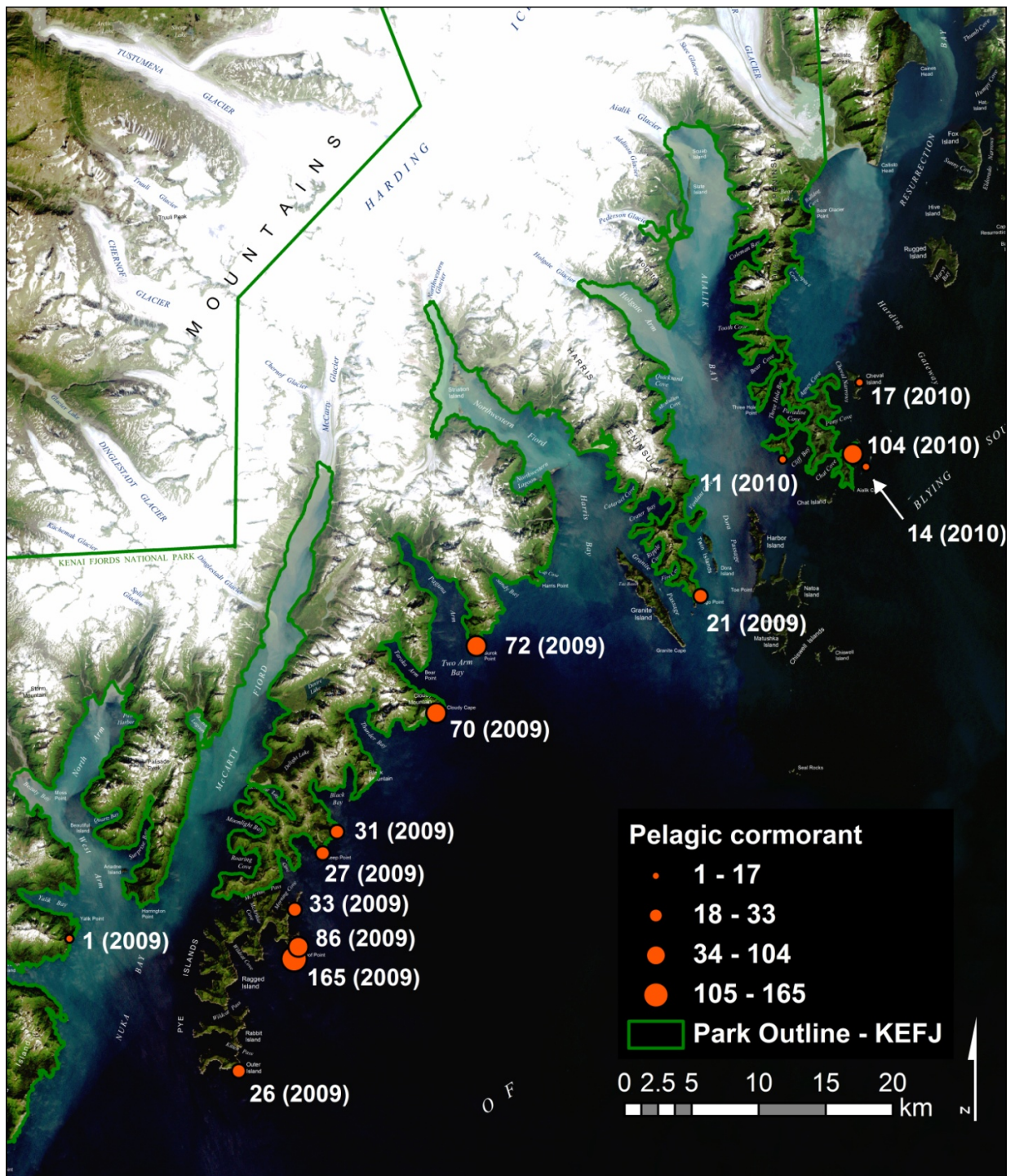


Figure 23. Relative abundance and distribution of pelagic cormorant in colonies along the coast of KEFJ and the AMNWR from the most recently available survey data, 2007-2010 (NPS 2012b). Labels in the map list the number of pelagic cormorants observed at each colony (point), and in parentheses, the most recent survey year represented.

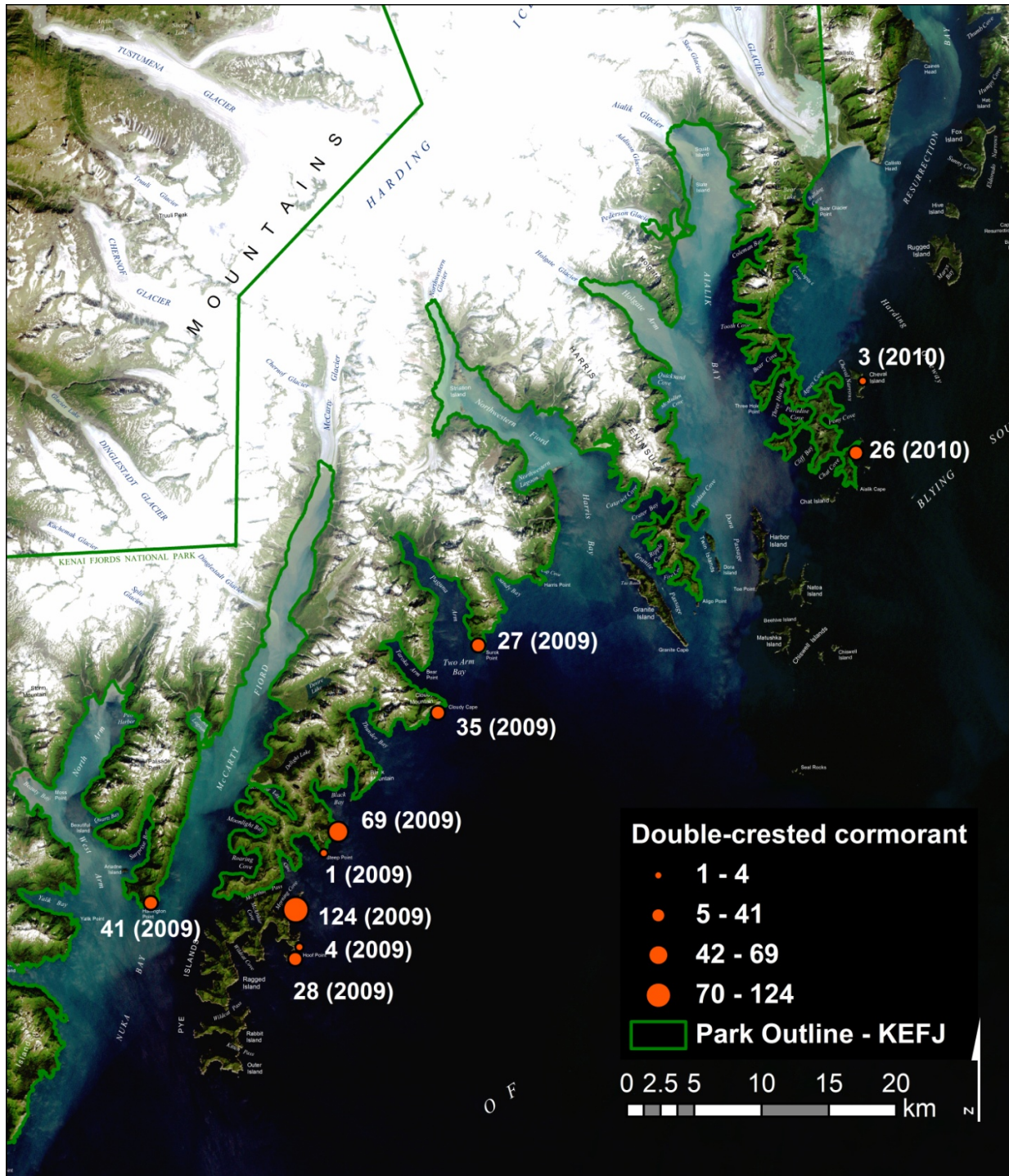


Figure 24. Relative abundance and distribution of double-crested cormorant in colonies along the coast of KEFJ and the AMNWR from the most recently available survey data, 2007-2010 (NPS 2012b). Labels in the map list the number of double-crested cormorants observed at each colony (point), and in parentheses, the most recent survey year represented.

Density and Distribution of Target Species (SWAN nearshore monitoring efforts)

Summer surveys are completed annually and winter surveys biennially. For KEFJ, summer surveys reported here include 2007-2011 and winter surveys, 2008 and 2010. Both summer and winter surveys count the seven target taxa, as scientists expect to observe different species compositions depending on the season. The following sections present marine bird density information for each season, followed by some marine bird distribution information for each season.

Winter Densities

In the 2010 SWAN winter survey, densities of two species, Barrow's goldeneye and Harlequin duck, approximately doubled from those observed during the 2008 survey (Table 25) (Coletti et al. 2011a). Large increases in observed densities between 2008 and 2010 also occurred for glaucous-winged gulls and surf scoters. However, Coletti (2011a) notes that these surveys do not account for interannual variation or imperfect detection by observers and that the differences in densities between the two years of surveys may not represent actual changes in population. In addition, statistical power is not yet sufficient to detect trends. The current survey design, given additional years of data collection in the future, should, be adequate for detecting trends for some of the observed species, while for other species power to detect trends may be low (Coletti 2011a).

Table 25. Densities of KEFJ target species from the 2008 and 2010 winter marine bird surveys. Table modified from Coletti et al. (2009, 2011b). Blank cells indicate unreported species densities.

Species	2008 average density (#/km ²)	SE	2010 average density (#/km ²)	Standard Error
Barrow's goldeneye (<i>Bucephala islandica</i>)	15.33	5.43	29.35	9.24
Black-legged kittiwake (<i>Rissa tridactyla</i>)	0.05	0.03	0.45	0.35
Black oystercatcher (<i>Haematopus bachmani</i>)	0.06	0.05	0.12	0.07
Black scoter (<i>Melanitta nigra</i>)	0.88	0.52	2.24	1.58
Common merganser (<i>Mergus merganser</i>)	1.42	0.49	2.97	1.06
Double-crested cormorant (<i>Phalacrocorax auritus</i>)	1.59	0.79	1.01	0.6
Glaucous-winged gull (<i>Larus glaucescens</i>)	2.49	0.74	20.4	6.91
Harlequin duck (<i>Histrionicus histrionicus</i>)	17.70	1.74	29.3	4.72
Pelagic cormorant (<i>Phalacrocorax pelagicus</i>)	11.77	1.91	10.1	2.5
Pigeon guillemot (<i>Cephus columba</i>)	0.39	0.18	0.34	0.11
Red-breasted merganser (<i>Mergus serrator</i>)	0.05	0.04		
Red-faced cormorant (<i>Phalacrocorax urile</i>)	8.75	4.89	3.01	2.24
Surf scoter (<i>Melanitta perspicillata</i>)	5.87	2.20	10.01	3.74
Unidentified cormorant (<i>Phalacrocoracidae</i> sp.)	5.13	2.33	0.34	0.2
Unidentified duck (<i>Anatidae</i> sp.)	0.05	0.03		
Unidentified goldeneye (<i>Bucephala</i> sp.)	2.81	1.26		
Unidentified merganser (<i>Mergus</i> sp.)	0.57	0.29		
Unidentified scoter (<i>Melanitta</i> spp.)	0.27	0.20	0.06	0.04
White-winged scoter (<i>Melanitta fusca</i>)	0.03	0.03	0.34	0.22
Overall scoter			12.64	4.01
Overall cormorant			14.45	4.03

Species densities in gray shading are noted as over-wintering sea ducks species expected to be more abundant in winter surveys.

Summer Densities

Annual trends in bird densities from 2007-2011 surveys are reported for KEFJ (Figures 8-14) (Coletti et al. 2013). The 95% confidence intervals are very wide for these data, such that most densities are not significantly different from each other and lack power to detect statistically significant trends. However, in visually interpreting these data, some variation appears to occur in the observed densities of black-legged kittiwakes over the five survey years in KEFJ, with densities between approximately 30-80 individuals/km² (Figure 25). Observed glaucous-winged gull densities appear to have decreased in KEFJ (Figure 26). Harlequin duck densities have varied, but remained approximately 10-30/km² (Figure 27). Pigeon guillemots have remained at low densities, <7/km² (Figure 28). Cormorant densities have remained between approximately 20 -38/km² (Figure 29), and merganser densities have remained low, <6/km² (Figure 30). Scoter densities have remained below 15/km² (Figure 31).

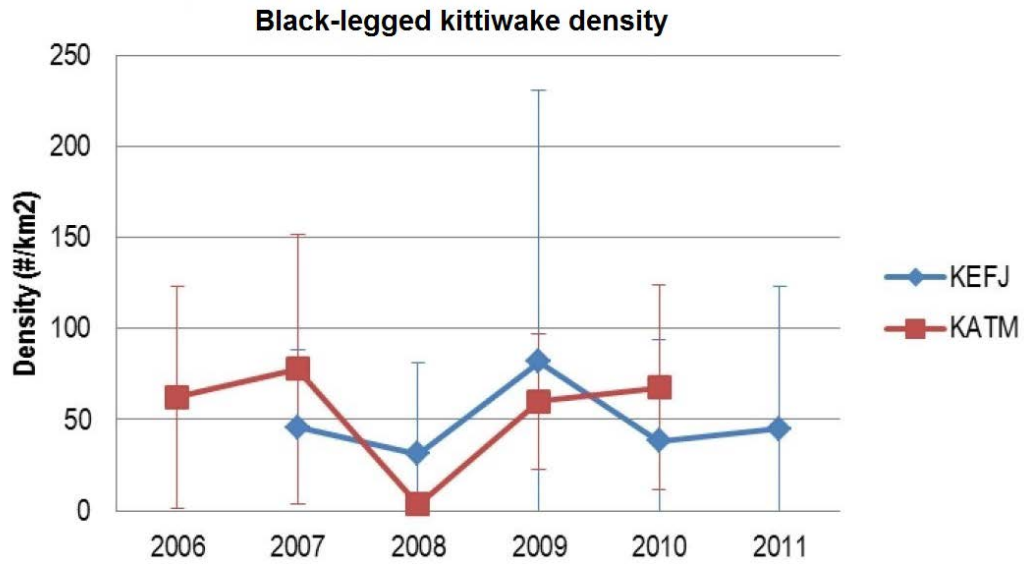


Figure 25. Density of black-legged kittiwake in KATM and KEFJ, 2006-2011. Error bars indicate 95% CI. Reproduced from Coletti et al. (2013).

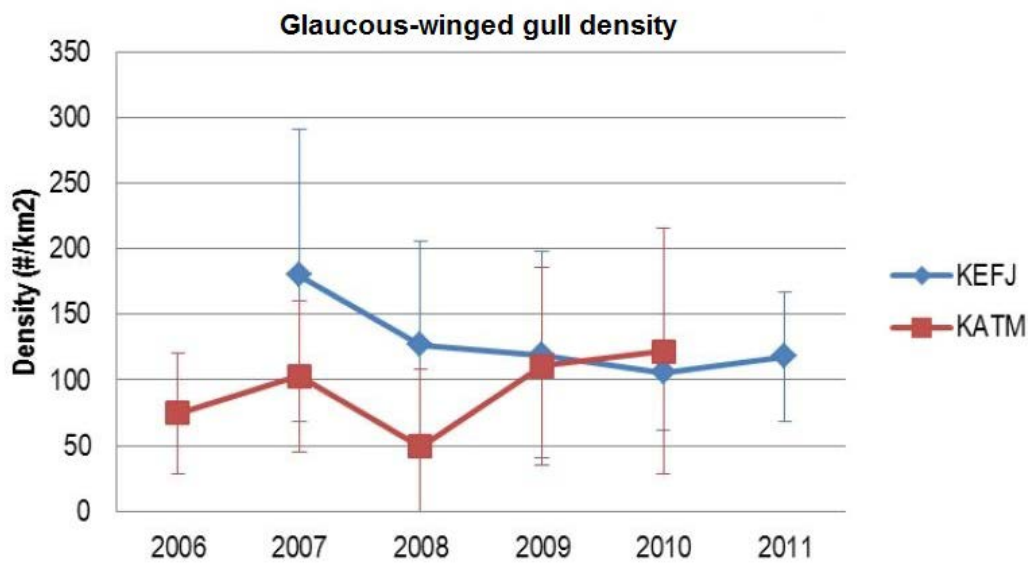


Figure 26. Density of glaucous-winged gulls in KATM and KEFJ, 2006-2011. Error bars indicate 95% CI. Reproduced from Coletti et al. (2013).

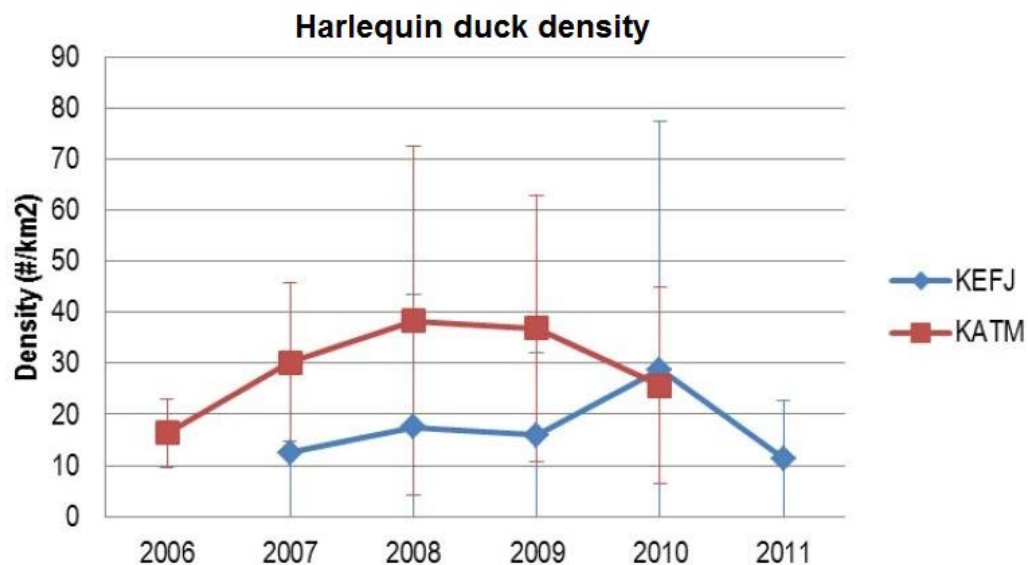


Figure 27. Density of harlequin ducks in KATM and KEFJ, 2006-2011. Error bars indicate 95% CI. Reproduced from Coletti et al. (2013).

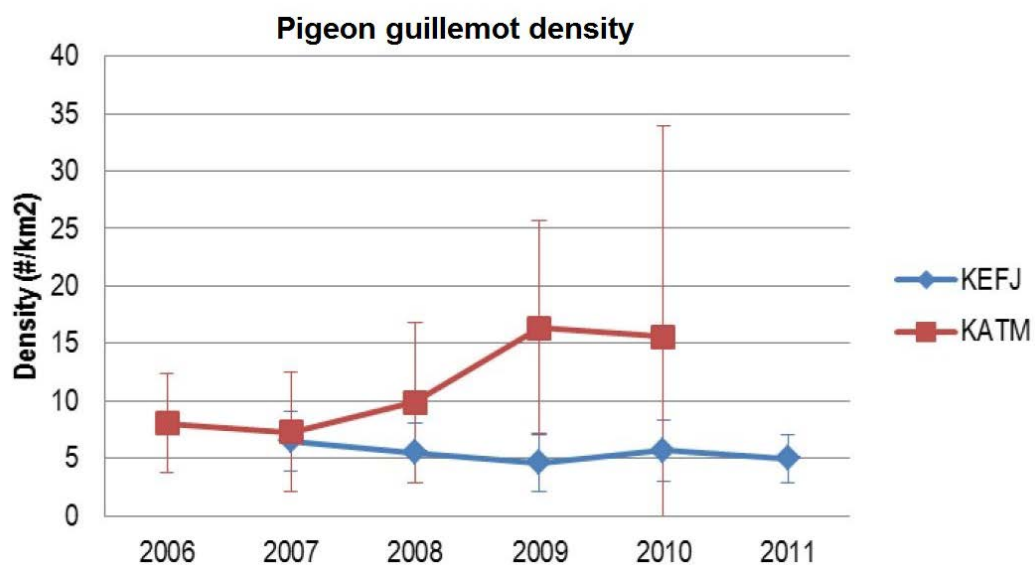


Figure 28. Density of pigeon guillemots in KATM and KEFJ, 2006-2011. Error bars indicate 95% CI. Reproduced from Coletti et al. (2013).

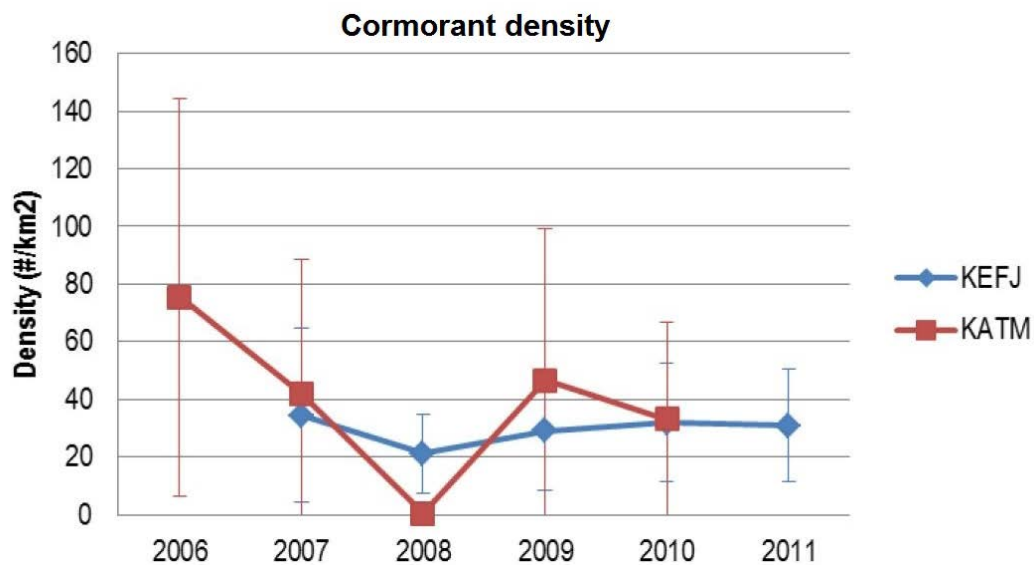


Figure 29. Density of cormorants in KATM and KEFJ, 2006-2011. Error bars indicate 95% CI. Reproduced from Coletti et al. (2013).

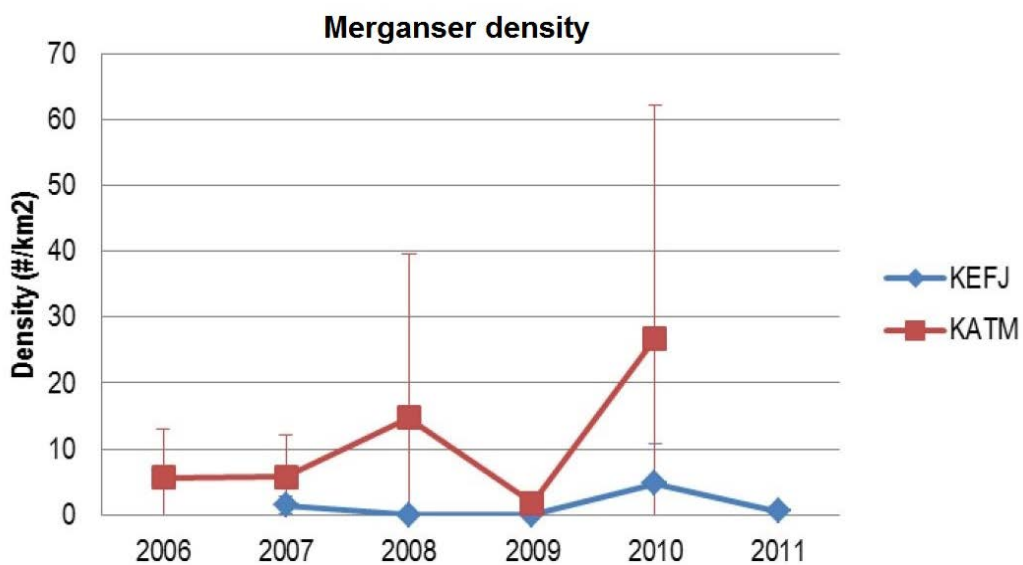


Figure 30. Density of mergansers in KATM and KEFJ, 2006-2011. Error bars indicate 95% CI. Reproduced from Coletti et al. (2013).

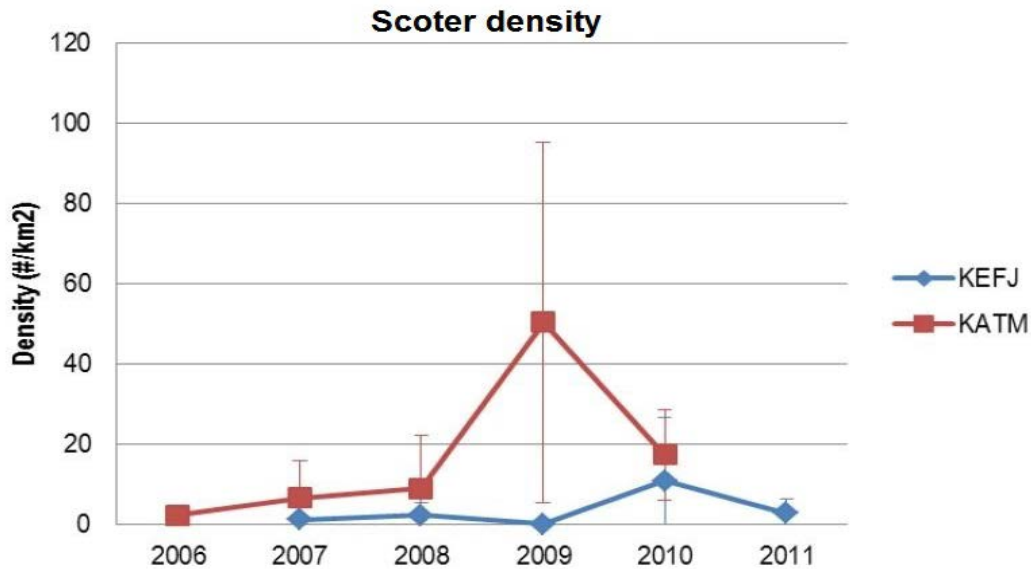


Figure 31. Density of scoters in KATM and KEFJ, 2006-2011. Error bars indicate 95% CI. Reproduced from Coletti et al. (2013).

The observed densities of some of the target species are different in winter compared with summer (Table 26). In comparing reported densities between seasons for the target species in KEFJ, black-legged kittiwakes and glaucous-winged gulls have occurred at far higher densities (many orders of magnitude) in the summer compared with winter. Pigeon guillemots also occur in substantially higher densities in summer surveys, and summer densities of cormorants (grouped species) in KEFJ are approximately double that of winter densities. Harlequin ducks, mergansers, and scoters have been observed in similar densities between winter and summer surveys. Lastly, sea duck species, such as Barrow's goldeneye, buffleheads, and scoters, migrate to the KEFJ coast to overwinter and therefore are more common in the winter (Coletti et al. 2011b, H. Coletti et al. 2012, 2013).

Table 26. Density ranges for seven target taxa from winter (2008 and 2010) and summer (2007-2011) transect surveys in KEFJ (Coletti et al. 2011a, Coletti et al. 2013).

Target taxa	Density Range	Density Range ^a
	Winter Surveys (2008, 2010) #/km ²	Summer Surveys (2007-2011) #/km ²
Black-legged kittiwake	0.05 - 0.45	~40 - 75
Glaucous-winged gull	2.49 - 20.4	~105 - 180
Harlequin duck	17.7 - 29.3	~11 - 29
Pigeon guillemot	0.34 - 0.39	~5 - 7
Cormorants (<i>grouped</i>)	11.45 - 22.1	~21 - 35
Mergansers (<i>grouped</i>)	20.4 - 2.97	~0 - 5
Scoters (<i>grouped</i>) ^b	7.0 - 13.0	~0 - 11

^a These density numbers are only rough estimates in interpreting density figures in Coletti et al. (2013) (i.e., the reproduced figures in this document).

^b The overall scoter density reported in the 2010 winter survey was 12.4/km² and in summer only in 2010 were there more than just a few birds/km².

Winter Distributions

After the 2008 winter survey it was noted that glaucous-winged gulls were observed in exposed rocky areas offshore, whereas goldeneye spp. were observed in more protected areas (Coletti et al. 2009). In the 2010 winter survey, Coletti et al. (2013) found that harlequin ducks were generally more evenly distributed along the coastline compared with Barrow's goldeneye, which were found in larger groups and in less exposed coastal locations. However, no apparent changes were observed in harlequin ducks' general distribution across KEFJ transects between the 2008 to the 2010 surveys (Coletti et al. 2011a). In addition, no clear patterns were noted in the winter distributions of the other target species (black-legged kittiwakes, pigeon guillemots, cormorants, mergansers, or scoters) between survey years 2008 and 2010.

Summer Distributions

After the 2008 summer survey, network scientists conducted analyses on the three years of KATM survey data (at the time, only two surveys were completed for KEFJ) (Coletti et al. 2009). Based upon observations of distribution patterns and with the intent to reduce variation among transects, data were stratified by three habitat types (exposed-rocky, exposed-soft, and protected-rocky). KEFJ marine bird distribution patterns during summer surveys are not specifically discussed in the recent SWAN reports. However, for maps displaying the locations (distribution) and densities of the species across KEFJ and AMNWR, refer to annual SWAN Vital Signs marine bird reports such as Coletti et al. (2011).

Productivity

Piatt (2002) notes decreasing marine bird productivity in the Gulf of Alaska since the late 1970s. Seabird productivity usually reflects, and ultimately depends on, forage fish distributions and abundance (Piatt 2002). However, studies specifically examining the productivity of marine birds in KEFJ are lacking. The abundance of breeders in each colony may provide some indication of productivity, but until further survey efforts can measure such things as fledgling success and/or more accurate estimates of population size year to year are developed, the number of breeders (adults

attending nests) observed in colony counts may not represent trends in actual productivity for each colony or each species across all colonies. Similarly, for efforts of SWAN's Nearshore Monitoring of marine birds, productivity data are only collected for black oystercatchers, addressed as a separate component in this document.

Threats and Stressor Factors

The EVOS was one of the largest human-induced environmental disasters in history. Oil from this spill affected the KEFJ coast. An estimated 42,000 - 120,000 m³ (11 - 32 million gallons) of oil were spilled into the area resulting in between 8,000 and 12,000 marbled murrelet (*Brachyramphus marmoratus*) deaths (Ralph et al. 1995). Oil from EVOS reached the KEFJ coast, but the full extent of the impacts in the park is unknown. However, harlequin ducks, Barrow's goldeneyes, and black oystercatchers were known to be greatly impacted by this spill, and lingering oil has resulted in extended recovery periods for many marine bird species (Elser et al. 2002, Coletti et al. 2011b).

Oil spills can cause initial marine bird mortality, create toxic effects, and may disrupt the ecosystem through various direct and indirect effects. Initial mortality of marine birds is caused by the removal of the insulative properties of birds' feathers when coated with oil and by toxicological effects from oil ingestion (Peakall et al. 1982, Fry and Lownstine 1985). Oil spills like EVOS may also affect marine bird populations for many years. For example, Golet et al. (2002) suggest that the EVOS may have both directly (continued oil exposure on adults birds) and indirectly (through oil-spill impacts to primary forage species) affected population recovery of pigeon guillemots in Prince William Sound, ten years after the spill. Habitat degradation also occurs from oil spills; Day et al. (1997) found that habitat use was negatively impacted for marine-oriented bird species in Prince William Sound after the spill. In fact, the Barrow's goldeneye populations are still listed as "recovering" in the 2010 Injured Resources & Services Update from the Exxon Valdez Oil Spill Trustee Council (EVOSTC 2010). In addition, foraging substrates are still recovering from the EVOS, as one site with lingering oil still exists (Irvine et al. 2006, L. Phillips pers. comm., 2012). Similarly, according to NOAA, even small amounts of hydrocarbons from oil spills can affect fish egg and embryo development (NOAA 2013).

Marine bird populations are subject to additional anthropogenic impacts such as direct mortality, or indirect effects from disease outbreaks, invasive species introductions, or anthropogenic water quality issues. Murrelets are occasionally directly affected by fisheries bycatch; they can be killed by being trapped in nets set by fishing vessels. Denlinger (2006) notes that cormorant species may be more susceptible to near-shore fisheries by-catch mortality compared with other seabird species. Gull populations can be unnaturally elevated due to human-derived food supplies and their populations can be associated with outbreaks of *Salmonella*, often present in contaminated water supplies (ADF&G 2012). Disease outbreaks such as those from *Salmonella* can potentially affect human health as well as other Alaskan marine bird species (Denlinger 2006). The Norwegian rat (*Rattus norvegicus*) is one of the most significant and damaging invasive species that threatens the endangerment and extirpation of marine and island birds (Major et al. 2006). Rats can consume eggs/young, disturb nesting sites, and lead to decreased seabird populations (Kurle 2005). Lastly,

Nagorski et al. (2010) notes that tour boats, cruise ships, and fishing vessels can lead to water degradation through the release of petroleum products, wastewater, and other discharges.

Abundance and distributions of predator species such as raptors (e.g., owls [Strigidae], eagles [Accipitridae], and falcons [Falconidae]), as well as nest predators such as ravens (*Corvus corax*) and crows (*C. brachyrhynchos*) can affect recruitment rates of marine bird species and mortality rates of foraging adult seabirds (Denlinger 2006). Glaucous gulls (*Larus hyperboreus*) are known to prey on eggs, chicks, and juveniles of other seabirds (Denlinger 2006). For example, double-crested cormorants are especially susceptible to predation from gull species where both species nest (Denlinger 2006). In addition, species such as foxes (*Vulpes vulpes* or *Alopex lagopus*), mink, bears, and otters may also prey upon marine birds (Denlinger 2006).

Prey availability is often associated with a variety of factors; commercial fishing pressures often determine abundance and distributions of nearshore fish communities, which play an important role in food availability for piscivorous marine bird species. According to Speckman (2002), prey availability is often reflected in seabird distributions. Prey availability can also be affected by nest predation, climate change, population size, etc. (Baird 1990). Baird (1990) noted that when food supplies decrease during breeding seasons, breeding birds often adapt by changing feeding habits and clutch size.

Climate change may be affecting both marine bird species and the prey upon which they feed. Changing climate regimes resulting from increasing global temperatures could shift ranges of breeding bird species northward (Hitch and Leberg 2007). For example, Kittlitz's murrelets (*Brachyramphus brevirostris*) are often associated with turbid waters, usually glacially-fed, which may be severely altered with changing flow and climate regimes. Climate change is predicted to result in sea level rises, an increase in frequency and severity of storms, and a reduction in prey availability (NABCI 2010). However, KEFJ contains many rocky headlands, and is not likely to be especially affected by sea level rises because of isostatic rebound (Hayes 1986, Pendleton et al. 2006). More importantly, ocean acidification may play a significant role in availability of calcium carbonate-shelled invertebrates at the bottom of the food chain that marine bird species, such as the black oystercatcher, consume (Lovejoy 2008, H. Coletti, pers. comm., 2012). According to Lovejoy (2008), mobilization of calcium carbonate may become increasingly difficult for invertebrates due to rising ocean acidity.

Increased tour boat disturbance of marine shore habitat is considered the most relevant impact associated with visitor use (L. Phillips, pers. comm., 2012). Since 1982, visitor use has increased twenty-fold in KEFJ, possibly leading to disturbance or displacement of wildlife, stresses to marine species due to close viewing, and nesting site damage along beaches (Nagorski et al. 2010). Cormorant species are especially susceptible to human disturbance at colonies because many adults leave their nests affording nest predation opportunities (Denlinger 2006).

Data Needs/Gaps

With the exception of the black oystercatcher, studies analyzing the productivity of marine birds within KEFJ have not been undertaken. Studies examining nest and fledgling success for target

species in KEFJ would be useful for understanding productivity of the marine bird species. Phillips (KEFJ Ecologist pers. comm., 2012) notes that productivity estimates would be helpful in better understanding relationships between productivity and currently measured aspects of marine bird community biology (e.g., changes in relative abundance over time and colony composition changes); however, time and budget constraints often limit the number and breadth of studies that can ultimately be undertaken.

Marine bird habitat in KEFJ is not well understood. One possibility in developing further understanding of marine bird habitat is to model habitat using existing transect survey data and/or seabird colony data to find possible correlations with existing biological resource descriptors contained within GIS datasets such as NOAA's National Marine Fisheries Service Alaska Region ShoreZone database (Harney et al. 2008).

Overall Condition

Condition levels for KEFJ marine bird measures are not assigned due to the limited amount of data available over time to determine trends. The purpose of SWAN's long-term monitoring efforts is to detect changes in marine bird population density and distribution over time, as an indicator of environmental conditions of the nearshore environment. Continued data collection will help determine variability and detect population trends in the future. To date, natural variability of these marine bird populations is not well understood, making confident statements of condition inappropriate. Likewise, while historical data are available for comparison to present-day colonial seabird survey efforts, any differences noted between past and present surveys are not necessarily outside of natural variations in colony size, composition or species' population size.

Seabird Colony Composition

A *Significance Level* of 2 was assigned for the measure of seabird colony composition. This measure was not assigned a *Condition Level* due to limited reference data and because current data are not yet able to produce statistically significant trends. However, apparent changes exist in marine bird colony composition between survey years 1976, 1986, and 2007-2010. In addition, eighteen new seabird colonies were discovered in 2011: eight with puffin species, four with cormorant species, three glaucous-winged gull, and three mew gull colonies (Parsons et al. 2012).

Abundance of Breeders in Seabird Colonies

A *Significance Level* of 3 was assigned for the measure of abundance of breeders in seabird colonies. This measure was not assigned a *Condition Level* due to the lack of a reference condition. According to Phillips and McFarland (2012), breeder abundance varies over the breeding season and among years. Abundance comparisons between older studies, such as Bailey (1976) and Nishimoto and Rice (1987), may only reveal general trends due to differing methodologies. However, researchers report apparent breeding populations for the historic surveys (1976 and 1986), and it appears that the number of breeding glaucous-winged gulls increased in KEFJ and then stabilized since 2007. Apparent breeding populations of cormorants are much more variable between colonies and years. This might be, in part, because cormorants are said to move colonies much more frequently than many other colonial seabirds (Denlinger 2006). Black-legged kittiwakes occur in much lower numbers compared with glaucous-winged gulls and cormorants and no trends in their abundance

were detected. In 2012, researchers conducting seabird colony surveys experimented with various techniques and combined data from subsequent year surveys in order to develop statistically valid protocols for monitoring the ledge-nesting seabird populations along the KEFJ and AMNWR coasts (Parsons et al. 2012, Dewberry et al. 2012).

Distribution of Seabird Colonies

A *Significance Level* of 1 was assigned for the measure of distribution of seabird colonies. This measure was not assigned a *Condition Level* due to differing survey methods, geographic extents of historic surveys compared with recent (2007-2010) efforts. Some of the earliest efforts documenting marine bird observations were in the summer of 1976 (Bailey 1976) and 1977 (Follows 1997) on Nuka Island, and Nishimoto and Rice during the summer of 1986 and 1987. A cooperative, interagency project began in 2011 that intends to identify spatial and temporal variability of colonial seabirds in the region (Phillips and McFarland 2012). In terms of what the park might expect in terms of changing distribution of black-legged kittiwake and glaucous-winged gull colonies, Denlinger (2006) states that colony locations are typically stable for many colonial seabirds, but that cormorants move colonies frequently. It is unclear if this is true for seabird colonies along the coast of KEFJ and AMNWR which are the focus of present-day seabird colony surveys.

Density and Distribution of Target Species


A *Significance Level* of 3 was assigned for the measure of density and distribution of target species. This measure was not assigned a *Condition Level* due to the lack of reference condition (i.e., an understanding of natural variation in the target species' densities and distributions). The distribution and density of marine birds in KEFJ have been monitored by the SWAN through annual summer surveys and biennial winter surveys since 2007. However, through 2011, 95% confidence intervals for most target species in KEFJ counts have included zero and statistical power is generally insufficient to detect trends in most of the marine bird species' densities. As surveys continue, long-term trends in some marine bird species' densities and distributions may be revealed. Coletti et al. (2011a) suggest after the 2010 survey results were analyzed, there may be a need for in-season replicate sampling and the survey design might need species-specific modifications that are based on habitat type in order to minimize variation. A data optimization exercise employing existing data will occur in 2011-2014, with analytical tools used to estimate the number of samples and the sampling frequency needed to detect particular trends and examine what may be contributing to data variation (e.g., imperfect detection of birds) (Coletti et al. 2011a).

Productivity

A *Significance Level* of 3 was assigned for the measure of productivity. This measure was not assigned a *Condition Level* due to a general lack of information relevant to KEFJ marine birds. Explicit productivity information is not available for KEFJ target marine bird species except for black oystercatchers, as the SWAN transect surveys do not measure productivity and colony data that capture counts of breeders (adults attending nests) represent only relative abundance. That is, apparent breeding populations of marine birds observed in colonies may eventually allow scientists to make inferences about each species' productivity; however, these data are not a direct indicator of productivity.

Weighted Condition Score

The overall weighted condition score (WCS) for the KEFJ marine birds component was not determined, nor was a trend in overall condition assigned because each of the measures were not assigned condition levels and statistical power to detect trends in individual measures is generally lacking. That is, not enough information is available to assign an overall condition or whether overall conditions are stable, improving or declining.

Marine Birds			
Measures	Significance Level	Condition Level	Weighted Condition Score = n/a
Seabird Colony Composition	2	0	
Abundance of Breeders in Seabird Colonies	3	n/a	
Distribution of Seabird Colonies	1	n/a	
Density and Distribution of Target Species	3	n/a	
Productivity	3	n/a	

4.4.5 Sources of Expertise

Heather Coletti, SWAN Marine Ecologist

Laura Phillips, KEFJ Ecologist

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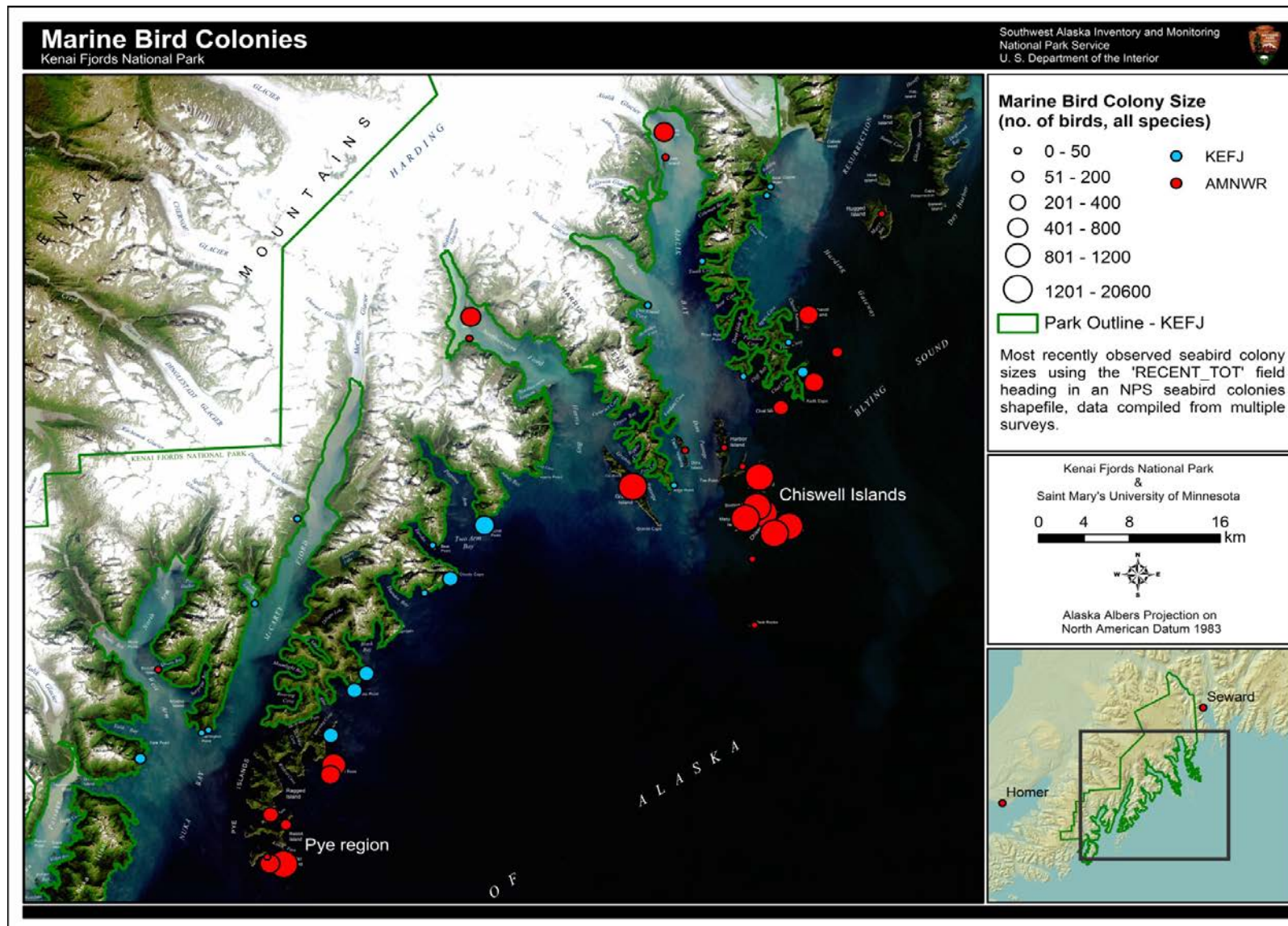


Plate 14. Marine bird colony sizes and distributions along the KEFJ coast and the Alaska Maritime National Wildlife Refuge (AMNWR). Colony sizes and distributions reflect the most recently available year's survey data, spanning 2008-2010 (NPS 2012b).

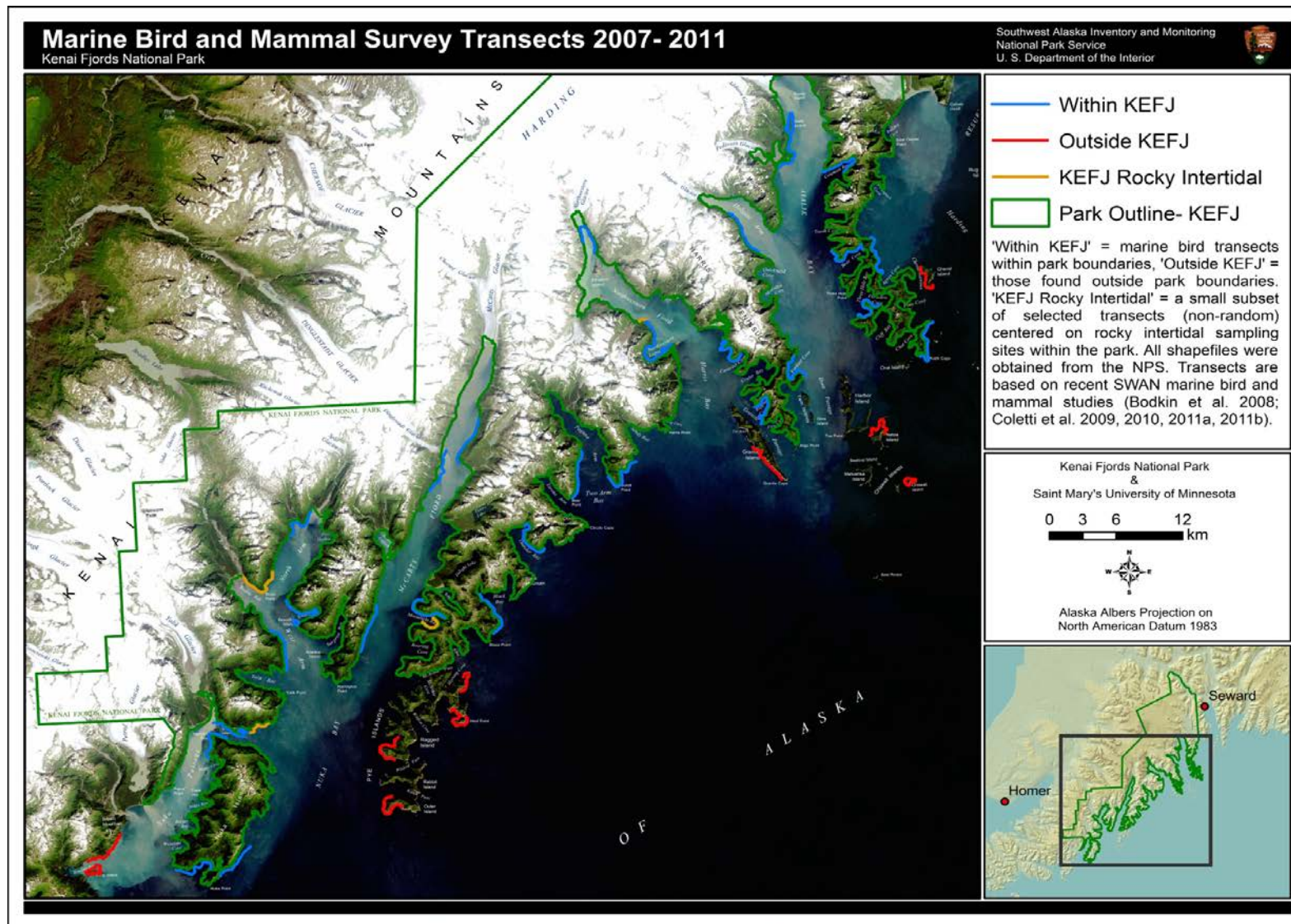


Plate 15. Marine bird and mammal survey transects for SWAN I&M studies, 2007-present. Transect locations are sampled based on weather conditions and accessibility. Spatial information derived from SWAN marine bird and mammal study transects: Bodkin et al. 2008, Coletti et al. 2009, 2010, 2011a, 2011b (NPS 2012b).

4.5 Black Oystercatcher

4.5.1 Description

The black oystercatcher (*Haematopus bachmani*) is one of the world's 11 extant oystercatcher species; all species belong to the family Haematopodidae and the genus *Haematopus* (Tessler et al. 2007). A long-lived shorebird (life expectancy can exceed 15 years) (Andres and Falxa 1995), the black oystercatcher has an estimated global population of 8,900 – 11,000 individuals and is one of North America's least abundant shorebirds (Morrison et al. 2001). Over half of the global population is believed to breed in Alaska (Bowker 2001, Brown et al. 2001, Colt et al. 2002).

Black oystercatchers depend completely upon marine shorelines at all stages of their life cycle (Andres 1998, Tessler and Garding 2005). The species favors rocky shorelines and occurs uncommonly along the Pacific coast from the Aleutian Islands south to Baja California (Figure 32) (Andres 1998, Tessler et al. 2007, Coletti et al. 2009). The largest concentration of black

oystercatchers occurs in the northern portion of their range (Alaska to southern British Columbia, Canada) during the breeding season; however, oystercatchers in this part of their range will migrate from nesting areas later in the year (exact wintering locations and migratory routes are unknown) (Andres 1994, Tessler et al. 2007).

Nesting sites are typically located above the intertidal areas, and consist of depressions in the rocky substrate (e.g., pebbles, sand, gravel, and shell materials) (Andres 1998, Tessler et al. 2007, Coletti et al. 2009) (**Photo 8**). Breeding black oystercatchers are highly territorial. The species exhibits strong site fidelity (Hazlitt and Butler 2001), a characteristic that could provide ecological benefits through familiarity with foraging sites and local predator communities (Oring and Lank 1984). Females lay one to three eggs and incubate them for 26-32 days. Eggs are especially vulnerable to opportunistic predators (e.g., common raven [*Corvus corax*], and mammals) (Vermeer et al. 1992, Lentfer and Maier 1993) during the incubation period. Unlike most shorebirds, black oystercatcher chicks are semi-precocial and are provisioned by the adults during the chick-rearing stage (which lasts approximately 38 days) (Andres and Falxa 1995).

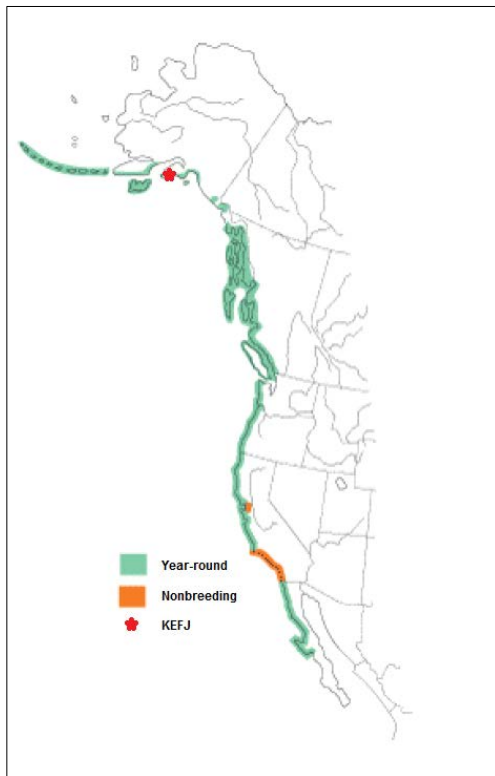


Figure 32. Distribution of the black oystercatcher. (Reproduced from Andres and Falxa 1995).

The foraging habitat of the black oystercatcher typically consists of sheltered, low-sloping gravel or rock beaches of high intertidal variation that can support invertebrate communities (Tessler et al. 2007). Black oystercatchers prey exclusively on intertidal macroinvertebrates (e.g., limpets [*Lottia*, *Acmea*, and *Colisella* spp.] and mussels [*Mytilus* spp.]) (Andres and Falxa 1995, Andres 1998, Coletti et al. 2009), and often forage in mid-intertidal zones where mussel populations are most dense (Tessler et al. 2007).



Photo 8. Black oystercatcher nest with chick and egg (Bodkin 2011).

The black oystercatcher represents a keystone species (Power et al. 1996) in KEFJ's ecosystem. The black oystercatcher has a large influence on the structure of intertidal communities that is disproportionate to its abundance (Marsh 1986a and 1986b, Hahn and Denny 1989, Falxa 1992, Coletti et al. 2009). Because of the black oystercatcher's ecological significance and size of the global population, many agencies recognize this species as one of conservation concern. The USFWS selected the species as a Bird of Conservation Concern and a Focal Species for priority conservation action (Tessler et al. 2007). Other agencies list the black oystercatcher as:

- A species of high concern within the U.S., Canadian, Alaskan, and Northern and Pacific shorebird conservation plans (Donaldson et al. 2000, Drut and Buchanan 2000, Brown et al. 2001, Hickey et al. 2003, Alaska Shorebird Working Group 2000, as cited in Tessler et al. 2007);
- A Management Indicator Species in the Chugach National Forest Plan (U.S. Forest Service 2002);
- A featured species in the Comprehensive Wildlife Conservation Strategies for the states in which it occurs (ADF&G 2005, WDFW 2005, ODFW 2005, as cited in Tessler et al. 2007);

SWAN selected the black oystercatcher as a Vital Sign of the Marine Nearshore monitoring program (Bennett et al. 2006) because it is a conspicuous species that is sensitive to disturbances (natural and anthropogenic) and it is a keystone predator in the marine nearshore community (Bennett et al. 2006, Bodkin 2011).

4.5.2 Measures

- Active nest territory density

- Productivity
- Prey species composition

4.5.3 Reference Conditions/Values

A reference condition for black oystercatchers in KEFJ was not established for this component.

4.5.4 Data and Methods

Morse et al. (2006) monitored black oystercatcher nest and chick survival in KEFJ from 2001-2004. The surveys monitored 35 to 39 breeding territories and examined the potential effects that recreational activities had on nesting success.

Nearshore Marine Vital Sign monitoring reports from 2007-2010 (Bodkin et al. 2007, Coletti et al. 2009, 2010, 2011a) reported on breeding black oystercatchers in SWAN. Since 2007, researchers have collected data regarding black oystercatcher breeding territory density, nest productivity, and the composition of hard-bodied (shelled) prey species that are brought back to the nest to provision chicks in KEFJ. The data collection and survey procedures follow the standard operating procedure (SOP) for monitoring black oystercatchers as established by Bodkin (2011). The data are collected along transects centered on the randomly selected rocky intertidal algal and invertebrate sites. Rocky intertidal sites were selected using a generalized random tessellation stratified (GRTS) sampling scheme (Stevens and Olsen, 2004). There are five transects in KEFJ and each is approximately 20 km (12.42 mi) in length (Plate 16).

The Black Oystercatcher Conservation Action Plan (Tessler et al. 2007) is a multi-agency plan that is intended to be the single strategic planning resource for the black oystercatcher throughout its range. Tessler et al. (2007) identified the five principle objectives of the plan:

1. Provide a synthesis of the current state of knowledge of black oystercatcher ecology and population status;
2. Identify important sites for oystercatcher conservation throughout their annual cycle;
3. Identify known and potential threats and develop conservation actions needed to address them;
4. Identify information needs critical to strategic conservation; and,
5. Facilitate collaboration among organizations and agencies addressing oystercatcher conservation.

4.5.5 Current Condition and Trend

Active Nest Territory Density

The black oystercatcher is not a colonial nester, and breeding pairs will often segregate themselves into distinct breeding territories (Andres 1998, Tessler et al. 2007). In fact, black oystercatchers are

extremely territorial during the breeding season, often exhibiting high levels of aggression towards conspecifics (Tessler et al. 2007).

Morse et al. (2006) selected one 150 km (93 mi) transect that was located in Aialik Bay and Northwestern Fjord, KEFJ and recorded the total number of breeding black oystercatcher pairs during each breeding season from 2001-2004 (Table 27). The number of breeding pairs during the surveys ranged from 35 (2001) to 39 (2004) with a mean of 36.8 pairs (Table 27). Mean nest density from 2001-2004 was 0.25 nests/km.

Table 27. Annual measures of reproductive success of black oystercatchers in KEFJ, from 2001-2004. Values are means \pm SE (Morse et al. 2006).

	2001	2002	2003	2004	Mean
Number of breeding pairs	35	36	37	39	36.8
Mean clutch size	2.7 \pm 0.1	2.6 \pm 0.1	2.6 \pm 0.1	2.5 \pm 0.1	2.6 \pm 0.1
Females renested (%)	31 \pm 8	50 \pm 8	32 \pm 8	44 \pm 8	40 \pm 3
Nesting success (%)	31 \pm 7	26 \pm 6	51 \pm 7	20 \pm 5	32 \pm 3
Fledging success (%)	50 \pm 12	71 \pm 12	44 \pm 10	46 \pm 15	52 \pm 6
Productivity (young per pair)	0.4 \pm 0.1	0.4 \pm 0.1	0.5 \pm 0.1	0.2 \pm 0.1	0.4 \pm 0.1

Coletti et al. (2009, 2010, 2011a) surveyed five randomly selected transects along the KEFJ coastline from Nuka Bay to Aialik Bay for nesting pairs of black oystercatchers from 2007-2010. These surveys reported density as the number of active or occupied nests per km. The mean density of active black oystercatcher nest sites at KEFJ ranged from 0.05 (2010) to 0.10 (2009) per km of shoreline from 2007-2010 (Figure 33). Figure 33 also compares the nesting density of black oystercatchers in KEFJ to the observed nesting density in Katmai National Park and Preserve (KATM), which is also in the SWAN. Nesting densities in the two parks have largely been similar from 2007-2010, although KATM did have slightly higher density values in 2007 and 2008.

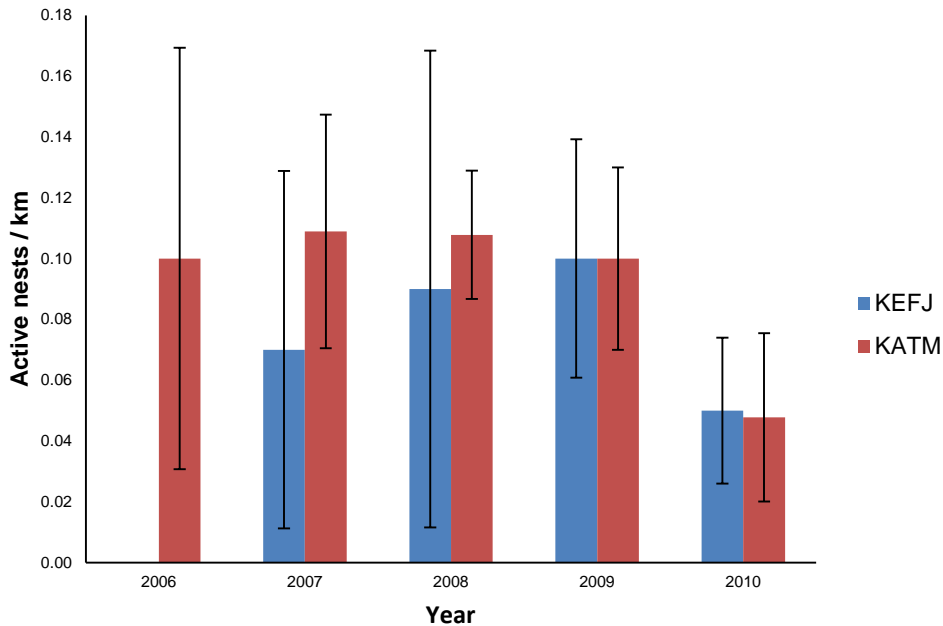


Figure 33. Mean nesting density of black oystercatchers in KEFJ and KATM, 2006-2010 (Coletti et al. 2011a).

Productivity

Productivity is a variable component of avian populations and can greatly influence a population's dynamics (Morse et al. 2006). For the black oystercatcher, productivity is largely dependent upon extrinsic threats such as tide level, predator abundance, and human disturbance levels (Andres and Falxa 1995, Morse et al. 2006, Tessler et al. 2007, Coletti et al. 2010). Long-lived species like the black oystercatcher have many opportunities to breed in their lifetime and may reduce their reproductive effort when breeding conditions become unfavorable (Stearns 1992).

Morse et al. (2006) surveyed a portion of the KEFJ coast (Figure 34) for black oystercatchers from 2001-2004. When reporting average yearly productivity, Morse et al. (2006) defined productivity as the number of fledged chicks per pair. Black oystercatcher productivity over the duration of the study ranged from 0.2 chicks per pair (2004) to 0.5 chicks per pair (2003), and the mean productivity was 0.4 chicks per pair (Table 27) (Morse et al. 2006).

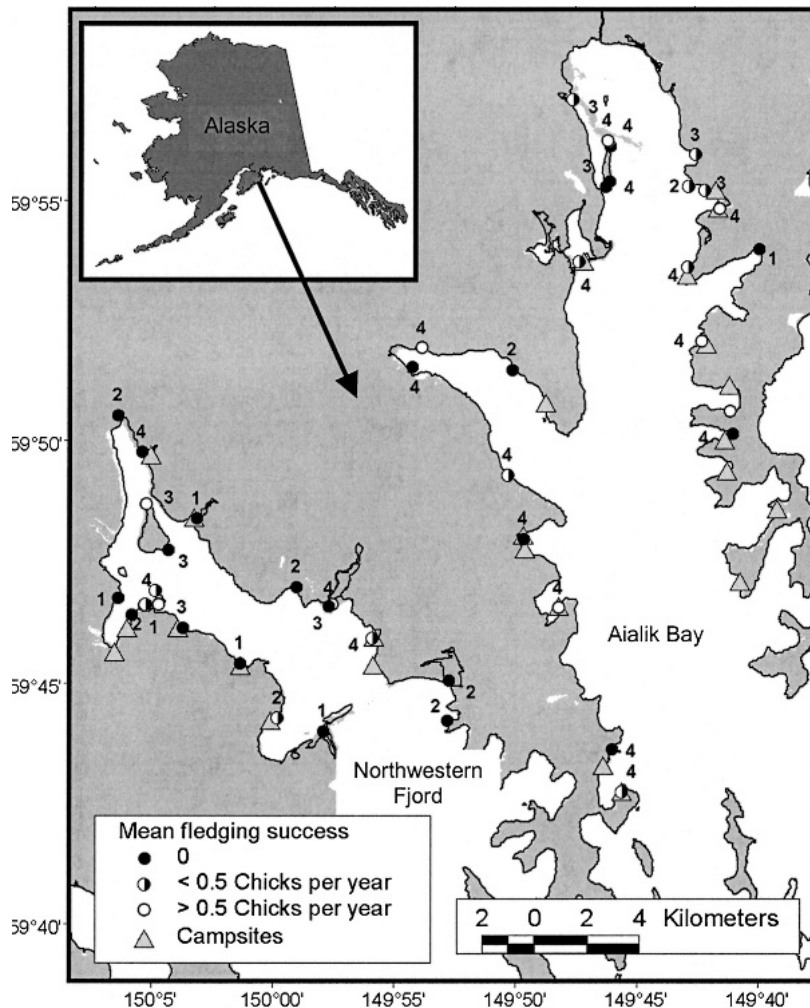


Figure 34. Study area and fledging success of all black oystercatcher breeding territories monitored from 2001-2004. The number beside each territory indicates the number of years (max. = 4) the site was occupied (Reproduced from Morse et al. 2006).

Despite observing over 500 eggs from 2001-2004, Morse et al. (2006) only observed 51 chicks fledge. Even with low productivity values, Morse et al. (2006) reported that the observed reproductive success in KEFJ was similar to estimates from other areas (see Andres and Falxa 1995, Murphy and Mabee 2000, Hazlitt 2001). Morse et al. (2006) found evidence that periods of extreme high tides lowered nesting success rates, although most nest failures observed from 2001-2004 were due to predation (65%). Predators appeared to be opportunistic; the most commonly observed predators included black bears, wolverines (*Gulo gulo*), river otters (*Lutra canadensis*), and avian species (e.g., bald eagles and common ravens).

Coletti et al. (2009, 2010, 2011a) surveyed the productivity of black oystercatchers in KEFJ from 2007-2010. However, the definition of the measure differed from Morse et al. (2006). Coletti et al. (2009, 2010, and 2011a) defined productivity as the number of chicks + eggs/nests. The mean productivity for KEFJ from 2007-2010 ranged from 0.27 (2010) to 1.92 (2009) eggs + chicks/nest (Figure 35). KEFJ productivity has been lower than KATM in all survey years except for 2009

(Figure 35). Productivity in 2010 exhibited the greatest discrepancy between the two parks, as KATM had a reported productivity of 2.20 eggs + chicks per nest, and KEFJ only had 0.27 eggs + chicks per nest (Figure 35)

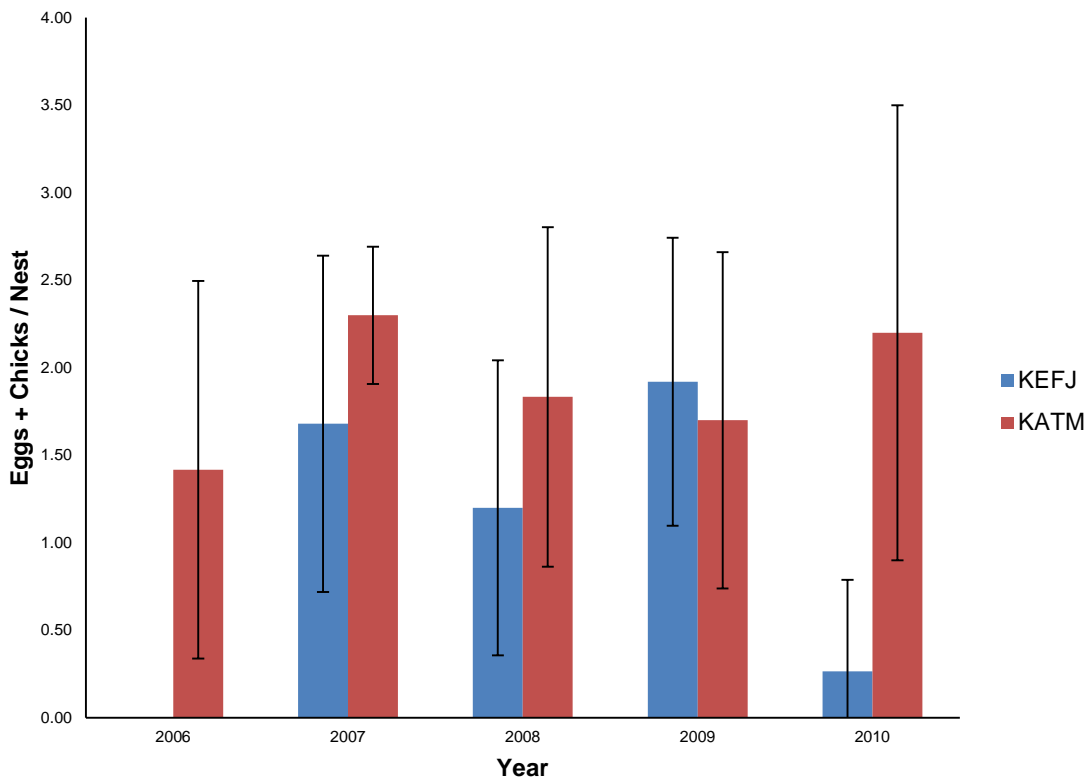


Figure 35. Productivity (eggs + chicks / nest) of active black oystercatcher nests in KEFJ from 2007-2010. (Coletti et al. 2011a). Error bars indicate 95% confidence intervals.

Because of the discrepancy in productivity definitions, an accurate comparison between the Morse et al. (2006) 2001-2004 surveys and the Coletti et al. (2009, 2010, and 2011a) 2007-2010 surveys is not advisable. These two surveys also had different monitoring durations; Morse et al. (2006) was a distinct 4-year study that aimed at answering specific research questions (i.e., what effects did recreational activities have on the productivity of black oystercatchers). The SWAN Vital Signs monitoring efforts (Coletti et al. 2009, 2010, and 2011a) are aimed at long-term monitoring with a single visit each year. These efforts do not focus on banded birds or repeated visits (Heather Coletti, SWAN Marine Ecologist, pers. comm., 2011; Laura Phillips, KEFJ Ecologist, pers. comm., 2011; Coletti et al. 2011b).

Prey Species Composition and Size

Black oystercatchers feed exclusively on marine invertebrates; small gastropod mollusks dominate the diet numerically, while mussels typically contribute the greatest prey mass (Hartwick 1976, Falxa 1992, Andres 1996, Tessler et al. 2007). Oystercatchers will bring limpets, mussels, and other prey items back to the nesting site to provision the chicks (Webster 1941, Hartwick 1976, Frank 1982,

Lindberg et al. 1987, and Coletti et al. 2010); this tendency allows researchers to collect remnant prey remains from the nests. The prey collections help researchers determine which prey species are being targeted (generally hard-shelled invertebrates), and what size of prey species are harvested by black oystercatchers. This sampling does not take into account any soft-bodied prey items that may be consumed.

Coletti et al. (2009) collected prey remains from black oystercatcher nest sites in KEFJ from 2007-2009; no prey remains were observed in 2010. Approximately 95% of the black oystercatcher prey items collected were comprised of three species of limpets (*Lottia pelta*, *L. persona*, and to a lesser extent *L. scutum*) and the Pacific blue mussel (*Mytilus trossulus*) (Figure 36). *L. pelta* comprised 29% (2007), 16% (2008), and 36% (2009) of the black oystercatcher's prey remains, while *L. persona* comprised 15% (2007), 63% (2008), and 39% (2009) of the prey remains (Figure 36). *L. scutum* was the least abundant of the limpet species, accounting for just 15% (2007), 6% (2008), and 7% (2009) of the collected prey remains. *M. trossulus* was the most abundant mussel species collected, accounting for 37% (2007), 13% (2008), and 9% (2009) of the collected prey remains (Figure 36).

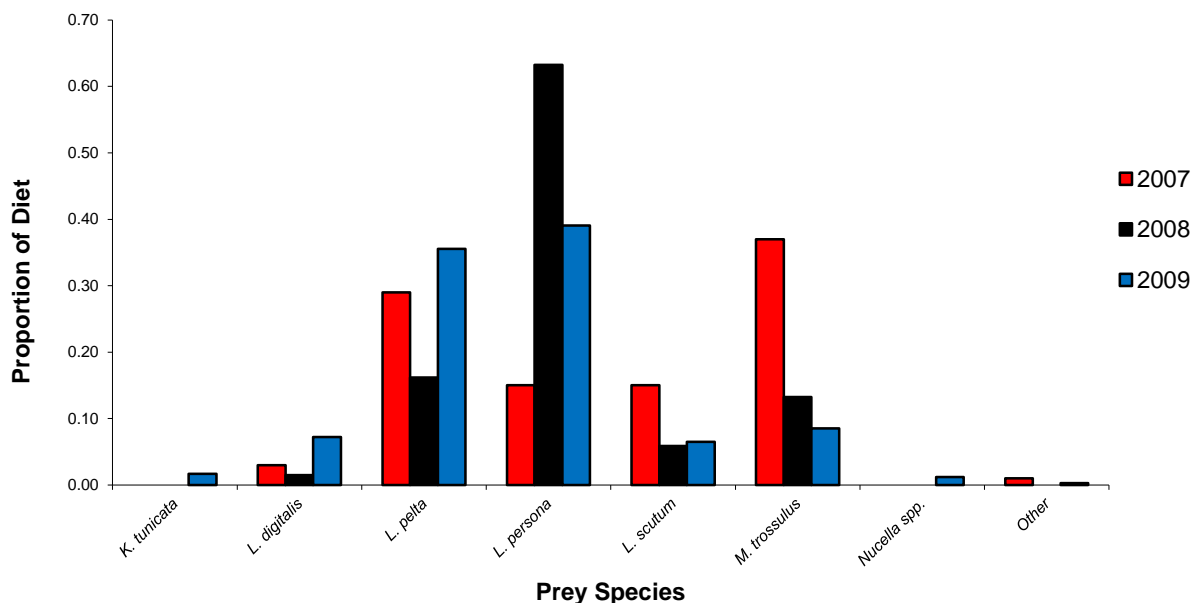


Figure 36. Species composition of prey remains collected from KEFJ black oystercatcher nests, 2007-2009 (Coletti et al. 2011a).

Coletti et al. (2009) measured prey size for all collected prey species, and reported the mean size for the two frequently observed species (*L. persona*, *M. trossulus*) (Figure 37, Figure 38). From 2007-2009, mean *L. persona* size throughout KEFJ ranged from 21.20 to 22.96 mm (Figure 37), and mean *M. trossulus* size ranged from 24.45 to 29.92 mm (Figure 38) (Coletti et al. 2011a). Figure 37 and Figure 38 also report the mean size of *L. persona* and *M. trossulus* in KATM for comparison.

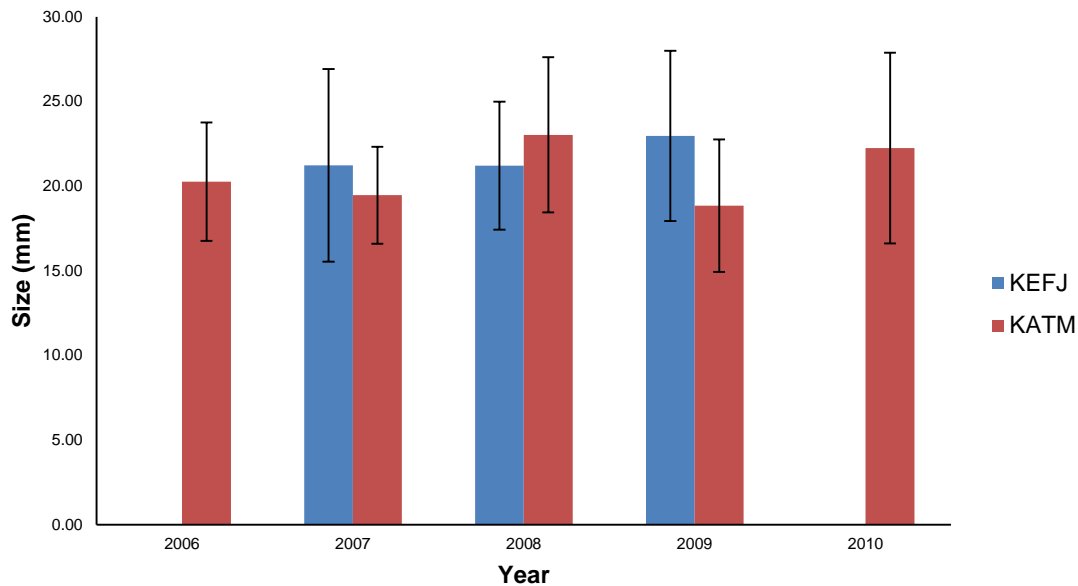


Figure 37. Mean size of *L. persona* measured at active black oystercatcher nests in KATM and KEFJ from 2006-2010. No collections occurred in KEFJ in 2006, and no prey items were observed in KEFJ in 2010 (Coletti et al. 2011a).

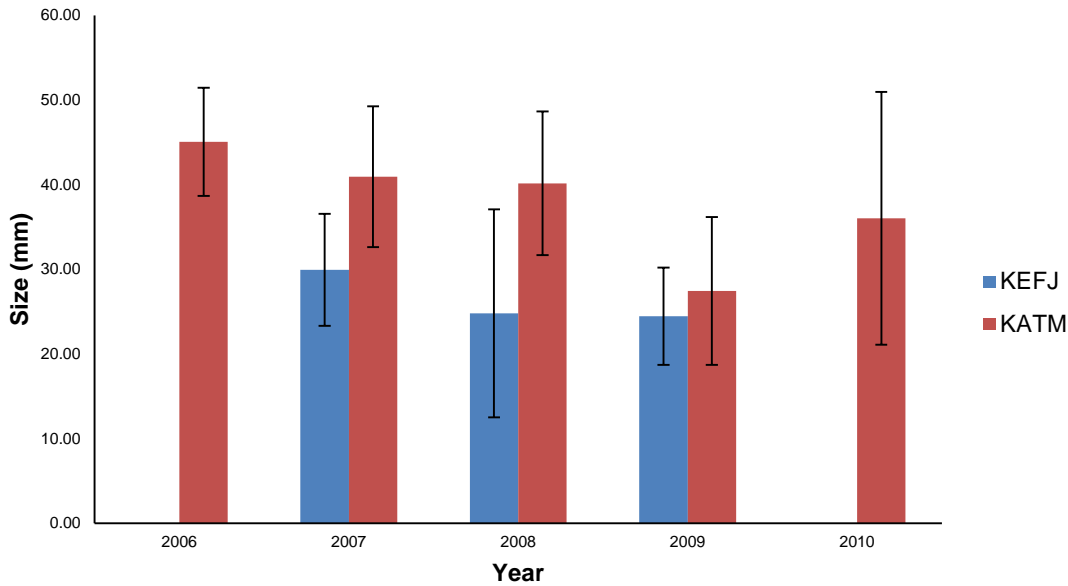


Figure 38. Mean size of *M. trossulus* at active black oystercatcher nests in KATM and KEFJ from 2006-2010. No collections occurred in KEFJ in 2006, and no prey items were observed in KEFJ in 2010 (Coletti et al. 2011a).

It appears that black oystercatchers are targeting larger individuals when foraging (Figure 36, Figure 37, Figure 38). The two frequently collected prey species (*L. persona*, *M. trossulus*) are also randomly sampled and measured during SWAN intertidal sampling; these sampling efforts have largely shown that black oystercatchers are targeting larger prey sizes than are proportionally available (Coletti et al. 2011b, Heather Coletti, pers. comm., 2011).

Threats and Stressor Factors

Human disturbances, particularly along the coastlines, pose a threat to black oystercatchers across their range, especially during the breeding season (Andres 1998, Morse et al. 2006, Arimitsu et al. 2004, 2005, 2007). Black oystercatcher populations have been affected by human-induced threats in the past; in 1989, the Exxon Valdez oil spill (EVOS) is believed to have killed between four and 20 percent of the oystercatcher population in the spill area (Andres 1994). Other instances of human-induced threats include human-introduced predators and scientific collection of oystercatchers and their eggs (Tessler et al. 2007). Tour boats that frequent black oystercatcher breeding habitats pose a threat to the oystercatcher population. The wakes from these boats (especially when they coincide with high tides) create violent waves that can crash upon shore and disturb black oystercatcher nests (Arimitsu et al. 2004, 2005, Tessler et al. 2007). In Aialik Bay in KEFJ, black oystercatchers often nest on gravel beaches that are also popular campsites for park visitors (particularly kayakers) (Morse et al. 2006). Morse et al. (2006) investigated the effects of recreational activities on black oystercatcher breeding success. While the study found that black oystercatchers appeared to be resilient to low levels of recreational disturbance, the authors suggest that as recreation levels increase, management efforts should be directed at minimizing potential disturbances at breeding locations (Morse et al. 2006).

Losses of food sources and habitats due to climate change are two of the largest concerns for coastal bird species (NABCI 2010). Ocean acidification, particularly the effect it may have on hard-shelled invertebrates, may affect the prey composition of black oystercatchers in the future (Coletti, pers. comm., 2011). Lawrence and Soame (2004) suggest that climate change could affect the reproduction of coastal invertebrates. They suggest warming global temperatures would likely uncouple and alter the phase relationship of temperature and photoperiod reproductive cues, thus reducing the reproductive success of invertebrate species that cue reproduction through photoperiods. A decrease in prey availability could present a significant threat to the black oystercatcher population in KEFJ. As stated in Coletti et al. (2011a), black oystercatcher chicks in KEFJ appear to have a diet that consists mainly of four species of invertebrates (*L. pelta*, *L. persona*, *L. scutum*, and *Mytilus trossulus*), and a change in the abundance or availability of these invertebrate species in KEFJ could alter the productivity and breeding density of black oystercatchers in the park.

Sea-level rises due to climate change are expected to inundate or fragment existing low-lying habitat (NABCI 2010). A rise in sea-level would likely alter the reproductive success of the oystercatchers, as their nesting sites occur along shorelines. Oystercatchers nesting on off-shore islands are also likely to be affected by sea-level rise, as increases in sea-levels are likely to reduce the extent of natural habitats on islands (NABCI 2010). In KEFJ, however, shorelines are experiencing either isostatic rebound or tectonic lift (Pendleton et al. 2006, Freymueller et al. 2008). These processes will likely counter and outpace sea level rise in this area, making this threat potentially less severe than it may be along other coastal areas. Secondary impacts of climate change (e.g., increased storm surges and erosion along shorelines) are likely to affect the reproductive success of breeding shorebirds worldwide (NABCI 2010).

Contaminants and pollutants (particularly polycyclic aromatic hydrocarbons [PAHs], organic pesticides, polychlorinated biphenyls [PCBs], and metals) are also threats to black oystercatcher populations (Valiella 2006). SWAN Vital Sign monitoring has recorded contaminant levels in mussel tissue at five locations in KEFJ (Coletti et al. 2009). These locations were in areas of sheltered, rocky shorelines and were in close proximity (if not the same location) to the SWAN rocky intertidal algae and invertebrate sampling sites. This contaminant monitoring revealed contamination levels that were below any levels that are considered of biological significance (Coletti et al. 2009). Mussels make up a large portion of the black oystercatcher's diet, and represent a potential pathway for contaminants to enter their bodies (Coletti et al. 2009). Elevated contaminant levels in the black oystercatcher could adversely affect reproductive capacity or long-term survival of the species.

A major threat to black oystercatchers (globally, and locally in KEFJ) is predation (Tessler et al. 2007). Predation is the most frequent cause of mortality for both eggs and chicks (Tessler et al., unpublished data, as cited in Tessler et al. 2007). Increases in the predator populations of KEFJ (e.g., Corvid populations, black bears, and bald eagles) could have significant effects on the black oystercatcher population's productivity. Laura Phillips, KEFJ Ecologist (pers. comm., 8 August 2012), has noted that glaucous-winged gulls and coyotes (*Canis latrans*) are probably the most significant increasing predators of BLOY in the park. In summer 2013, park researchers documented domestic dogs that depredated eggs and disturbed nests (L. Phillips, KEFJ Ecologist, pers. comm.)

Data Needs/Gaps

Data are limited for black oystercatchers. KEFJ staff indicated that several data gaps exist for black oystercatchers in the park. Examination of these gaps may help managers to better understand the current health of the species in the park and across its range. The data gaps identified include:

- Monitoring of adult survival rates and chick fledging rates from nesting sites are needed. Additionally, an investigation of the recruitment rates into the KEFJ population is needed;
- There is a lack of knowledge on where breeding black oystercatchers from KEFJ overwinter. The overwintering location, as well as threats, stressors, and prey base at these wintering grounds are currently understudied/unknown;
- Further sampling of the black oystercatcher's adult and chick diets is needed. More information is needed to determine how representative SWAN's diet sampling is of the actual prey being provisioned to the chicks at the nesting site. Also, determining the high priority foraging areas in the park is needed;
- Information regarding the sightability of black oystercatchers during annual surveys is needed. With only one SWAN survey per year, it would be beneficial to researchers to have an estimate of detection during surveys.

Overall Condition

The lack of baseline data for the black oystercatcher across its range makes assessing condition difficult. Part of the selection criteria used by the USFWS in selecting the black oystercatcher as a Focal Species for priority conservation action was the species' lack of baseline data to assess conservation status (Tessler et al. 2007). Research by Morse et al. (2006) and monitoring by SWAN has increased the overall knowledge of the species' status during the breeding season.

Active Nest Territory Density

KEFJ staff assigned the measure nest territory density a *Significance Level* of 3. Mean nest density from 2001-2004 was 0.25 nests/km (Morse et al. 2006). From 2007-2010, the mean density of active black oystercatcher nest sites at KEFJ ranged from 0.05 (2010) to 0.10 (2009) per km of shoreline (Figure 33). The Morse et al. (2006) and Coletti et al. (2009, 2010, 2011a) surveys utilized different methods, and a direct comparison is not appropriate. However, density estimates from KEFJ appear to be in line with density estimates across the species' range. Density estimates along rocky shorelines of the Strait of Georgia, British Columbia, Canada (0.06 nests/km); San Juan Island, Washington (0.07 nests/km); and western Prince William Sound, Alaska (0.09 nests/km) are probably typical for black oystercatchers across the North Pacific coastlines (Vermeer et al. 1992, Andres and Falxa 1995). KEFJ's density estimates have been within this range of density for almost all survey years, and because of this, this measure was assigned a *Condition Level* of 1.

Productivity

The measure productivity was assigned a *Significance Level* of 3 during KEFJ scoping meetings. While long-term trend data are lacking for the KEFJ region, studies in areas across the species' range

have revealed comparable productivity values to what has been reported in KEFJ. Andres (1996) found productivity in Prince William Sound, Alaska, to be 0.37 young/pair (0.11 SE) from 1992-1993. This productivity estimate is similar to productivity in KEFJ from 2001-2004, which was 0.40 young/pair (Morse et al. 2006). Furthermore, Andres and Falxa (1995) report that black oystercatchers' productivity across their range averages 0.25-0.95 young/pair, which would put KEFJ productivity (from 2001-2004) within this range. It appears that the low estimates of productivity in KEFJ from 2001-2004 are similar to productivity estimates from other regions (Morse et al. 2006, and citations within). While there appears to be little concern for productivity in the park at this time, more data (particularly more recent data) are needed to make such a qualitative statement. Because of this, the *Condition Level* for productivity was determined to be 1.


Prey Species Composition

KEFJ staff assigned the prey species composition measure a *Significance Level* of 3. At this time, however, *Condition Level* is unknown.

Coletti et al. (2009, 2010) collected prey remains in KEFJ from 2007-2009 (no prey remains were observed in 2010). Approximately 95% of the observed prey items adult black oystercatchers bring back to the nests to provision chicks were comprised of three species of limpets (*Lottia pelta*, *L. persona*, and to a lesser extent *L. scutum*) and the Pacific blue mussel. Continued monitoring of the prey species composition of black oystercatcher chicks, and perhaps the prey base of the adults (paying particular attention to the four species listed above), will allow for assessment of prey-species composition condition in the future. Furthermore, Coletti et al. (2011a) suggests that future monitoring may reveal correlations between black oystercatcher nesting density and prey sizes. Lower levels of black oystercatcher nesting density may lead to increased density and size in prey species along rocky intertidal sites (Coletti et al. 2011a); the reverse trend may also be possible. Continued annual monitoring of both of these parameters may help to support or disprove such a hypothesis.

Weighted Condition Score

The Weighted Condition Score for black oystercatchers in KEFJ is 0.333, indicating that the component is of low concern at this time. With the absence of a reference condition, the trend for this component was determined based on 6 years of research; current trend was estimated to be stable.

Black Oystercatcher			
Measures	Significance Level	Condition Level	Weighted Condition Score = 0.3
Active Nest Territory Density	3	1	
Productivity	3	1	
Prey Species Composition	3	n/a	

4.5.6 Sources of Expertise

Heather Coletti, SWAN Marine Ecologist

Laura Phillips, KEFJ Ecologist

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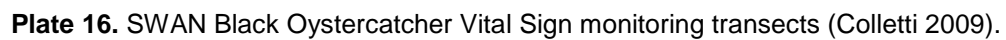
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4.6 Salmon

4.6.1 Description

Salmon are present at different times of year in over 210 unique locations in the rivers, streams, and lakes of KEFJ. These locations are documented in ADF&G's Anadromous Waters Catalog (AWC), and are segmented according to two life stages, spawning or rearing, and simple presence (ADF&G 2012a). Salmon species documented within the park include pink salmon (*Oncorhynchus gorbuscha*) (**Photo 9**), Coho salmon (*O. kisutch*), chum salmon (*O. keta*), sockeye salmon (*O. nerka*), and Chinook salmon (*O. tshawytscha*). Some of the primary drainages containing salmon in KEFJ include the Nuka and Resurrection Rivers, and Delight, Desire, and Delusion Lakes. Additional Salmonidae species found in the park are round whitefish (*Prosopium cylindraceum*) and dolly varden (*Salvelinus malma*) (NPS 2004), but little information exists regarding their abundance or distribution. According to the ADF&G Anadromous Waters Catalog (AWC), pink salmon appear to be the most widely distributed salmon species across KEFJ waters, followed by chum, sockeye, and Coho salmon. To a much lesser extent, Chinook are also found in KEFJ waters. Pink and sockeye salmon that use KEFJ waters are commercially harvested in the nearby coastal waters (ADF&G 2012a), and many of the spawning salmon provide recreational angling for park visitors.



Photo 9. Adult male (top) and female (bottom) pink salmon (USGS photo by E.R. Keeley).

Salmon play an important ecological role in KEFJ and other SWAN ecosystems (Bennett 2006). They act as a link between marine, terrestrial, and freshwater subsystems by supporting a complex food web that includes wildlife populations across these ecosystems (Hilderbrand et al. 2004). Salmon provide food for species such as orcas (*Orcinus orca*), sea lions (*Zalophus californianus*), bald eagles, and black bears in or near KEFJ. Additionally, salmon provide valuable nutrients to freshwater aquatic and terrestrial ecosystems directly through decaying of dead salmon and through the food web (Gende et al. 2002). Salmon were selected as one of the SWAN Network's Vital Signs. Long-term monitoring of salmon stocks can allow scientists to document changes in salmon populations and in the marine, terrestrial, and freshwater ecosystems which are a part of this salmon-wildlife-ecosystem relationship (Bennett et al. 2006).

Located along the eastern side of McCarty Fjord, the recently deglaciated (Post 1980, Delight and Desire Lakes, located on Port Graham Corporation lands, support some of the larger salmon runs in KEFJ and are two of the largest freshwater water bodies within KEFJ. Both lakes are within drainages that support commercial fishing for sockeye salmon (York and Milner 1995). Delusion Lake, a third recently deglaciated location (circa 1942) (Post 1980), also along the eastern side of McCarty Fjord, has only supported salmon runs since the mid-1980s (Milner and York 2001,

Hammarstrom and Ford 2011). ADF&G uses annual weir, video, or aerial surveys to monitor salmon returns in these three lakes (Edmundson et al. 2001, Hammarstrom and Ford 2011). Delight and Desire Lakes contain the only weirs in KEFJ.

4.6.2 Measures

- Individual stock escapement estimates for sockeye and pink salmon at Delight, Desire, and Delusion Lakes.
- Anadromous Water Catalog (AWC) additions (presence of anadromous fish)

4.6.3 Reference Conditions/Values

ADF&G-established salmon escapement goals are the reference conditions for individual salmon stocks examined in this assessment (three sockeye salmon stocks & one pink salmon stock) (Table 28). The NPS's enabling legislation suggests that fish and wildlife populations be managed in such a way that populations are maintained within a range of natural variability. More specifically, Section 4.4.1 of the NPS Management Policies 2006, states that:

“The Service will successfully maintain native plants and animals by:”

“preserving and restoring the natural abundances, diversities, dynamics, distributions, habitats, and behaviors of native plant and animal communities and ecosystems in which they occur.”

However, the salmon in these three lake drainages are subject to commercial purse seine fishing harvest in the Outer District of the Cook Inlet Region. The ADF&G counts fish as a part of their management using both aerial surveys and weirs. The data collected on escapement and catch provide an indication of natural variability. The ADF&G manage stocks according to escapement goals that fall within an historic range (25 - 75 percentiles).

Table 28. KEFJ salmon stock escapement goals used for referenced condition. Data and goals from Otis et al. 2010, Hammarstrom and Ford 2011.

Species	Stock	Type of Goal	Escapement Goal
Sockeye	Delight Lake	SEG ^a	7,550-17,650 salmon ^d
	Desire Lake	BEG ^b	8,800-15,200 salmon
	Delusion Lake	20- avg. ^c	1,400 salmon
Pink	Delight Lake	--	no estimates
	Desire Lake	SEG	1,900 – 20,200 salmon
	Delusion Lake	--	no estimates

^a sustainable escapement goal

^b biological escapement goal

^c no formal escapement goal established by ADF&G, 20-avg. used in this assessment for comparison to current escapement estimates.

^d this is the recommendation by Otis et al. (2010) adjusted from 5.95-12.55 (weir) thousand fish

In establishing stock-specific escapement goals, the ADF&G follows two Board of Fisheries (BOF) policies: the sustainable salmon fisheries policy and the escapement goal policy. The BOF and

ADF&G defines the biological escapement goal (BEG) and sustainable escapement goal (SEG) as follows (from policy for the management of sustainable salmon fisheries):

BEG - The escapement that provides the greatest potential for maximum sustained yield; BEG will be the primary management objective for the escapement unless an optimal escapement goal or inriver run goal has been adopted; BEG will be developed from the best biological information, and should be scientifically defensible on the basis of available biological information; BEG will be determined by the department and will be expressed as a range based on factors such as salmon stock productivity and data uncertainty; the department will seek to maintain evenly distributed salmon escapements with the bound of the BEG (from 5 AAC 36.222(F)).

SEG – A level of escapement, indicated by an index or an escapement estimate, that is known to provide for sustained yield over a 5 to 10 year period, used in situation where a BEG cannot be estimated due to the absence of a stock specific catch estimate; the SEG is the primary management objective for the escapement, unless an optimal escapement goal or inriver run goal has been adopted by the board, and will be developed from the best biological information; the SEG will be determined by the department and will be stated as a range that takes into account data uncertainty; the department will seek to maintain escapements within the bounds of the SEG (from 5 AAC 36.222(f)).

Desire Lake has a recently established BEG for sockeye salmon. If funding continues for the weir at Delight Lake, data will soon accumulate, eventually allowing the ADF&G to establish a BEG for this stock of sockeye salmon as well; for now, it uses an SEG.

Delight Lake's SEG for sockeye salmon was developed from weir counts (Otis et al. 2010). Desire Lake's BEG for sockeye salmon was calculated using a combination of aerial and weir-counts (Hammarstrom and Ford 2011). The ADF&G has not yet developed a formal escapement goal for sockeye salmon in Delusion Lake; however, the 20-year average escapement estimate (developed from aerial counts) was used for comparison to recent escapement numbers. The ADF&G estimates escapement for pink salmon in Delight and Delusion Lakes. As of 2011, there were very limited numbers of pink salmon. However, an SEG for pink salmon in Desire Lake was developed using both aerial and weir counts (Hammarstrom and Ford 2011).

In 2010, the ADF&G conducted an interdivisional salmon escapement goal review for several salmon stocks in the Lower Cook Inlet (Otis et al. 2010). Given that salmon escapements for Delight Lake have been primarily monitored by aerial and foot surveys, the established escapement indices are yet not sufficient for estimating the absolute abundance and therefore the ADF&G has not been able to establish a BEG for Delight Lake (Otis et al. 2010). After this review, the ADF&G recommended that escapement goals be updated for sockeye salmon at Delight Creek, now that a weir has been established.

A reference condition was not established for the AWC additions (presence of anadromous fish species) measure because the catalog represents a continually updated database of known salmon water bodies and has not been, in its history, a comprehensive survey. The AWC database is updated yearly and maintained by the ADF&G, and nomination forms are the only information available to recreate previous year's data and to understand changes or additions to the database over time. Trends in park-wide salmon distribution are not possible to determine using nomination forms which are used to populate the AWC database. It is not possible to differentiate between what is simply the addition of a river/stream to the database because it was never before surveyed versus a river/stream location that is truly a newly established spawning habitat for a given salmon species. AWC database locations simply represent the current state of knowledge in terms of known salmon distribution. Another reason for not establishing a reference condition for this measure is that an effort to examine the entire set of nomination/correction forms for the park was considered beyond the scope for this assessment. For any given location in the park, several nomination forms may exist that capture different species, different codes of presence and various notes describing the site and changes from previous years.

4.6.4 Data and Methods

The following sources were used for developing reference conditions or were a data source or primary reference for the current condition section.

Jones and Hamon (2005) conducted a baseline freshwater fish inventory for SWAN parks, including KEFJ. In KEFJ the authors found 13 of the 16 expected freshwater fish species in the park. While salmon and certain sport fish were not specifically targeted during the inventory process in locations where they were already known to occur, the authors found Chinook, chum, Coho, pink, and sockeye salmon, and Dolly Varden (another salmonid) in the park. The locations of each of the aforementioned species observations are displayed in Plate 17 – 20.

The ADF&G's most recent annual salmon escapement report (Hammarstrom and Ford 2011) provided annual escapement estimates of sockeye and pink salmon for the entire ADF&G-defined Lower Cook Inlet Salmon Management Area from 1990 to 2010. KEFJ is a part of both the eastern and outer districts within this management area. Relevant subdistricts to KEFJ include Resurrection Bay, Aialik Bay, and East Nuka Bay. Escapement estimates were derived from weir and/or aerial counts at various locations throughout KEFJ. The ADF&G-collected aerial and weir count data are used to assess the condition of specific sockeye and pink salmon stocks in KEFJ. Otis et al. (2010) also provided salmon escapement estimates in a review of escapement goals for salmon stocks relevant of major river systems in Lower Cook Inlet. This includes Delight and Desire lakes in KEFJ.

The ADF&G anadromous waters catalog (AWC) (ADF&G 2012a) provided GIS data containing anadromous fish-supporting streams and points showing presence, spawning, and rearing locations of five salmon species within KEFJ. Most named streams within the park in the AWC GIS dataset are tributaries of the Resurrection River; they include Exit Creek, Boulder Creek, Martin Creek, Moose Creek, Placer Creek, and Summit Creek. Other named streams as noted by the AWC as supporting anadromous fish include Babcock Creek, Crescent Beach Pond, Ferrum Creek, Nuka River and Delta, and Shelter Cove. The water bodies (primarily streams and rivers) of KEFJ in the AWC are

illustrated in three maps (coastal park sections, Plate 17 and Plate 18; and the Resurrection River, Plate 19).

Water bodies are continually added to the AWC. To warrant inclusion, water bodies must support life functions of anadromous fish species, which are verified by ADF&G fisheries biologists (ADF&G 2012c). It is possible that other water bodies within KEFJ not presently included in the AWC database may warrant inclusion and have never been surveyed or not in recent years.

Additional Literature Relevant to KEFJ Salmon Colonization and Productivity

York and Milner (1995) examined the colonization and community development of salmonids in the McCarty Fjord area of KEFJ from 1992 to 1994. The study area included the Delusion Creek system, Upper and Lower Delusion Lakes, and nearby areas of recent deglaciation. Several factors influencing salmon productivity were examined including water chemistry, chlorophyll levels, and macroinvertebrate presence (York and Milner 1995).

A study by Edmundson et al. (2001) examined documented salmon runs in pre-1989 (Exxon Valdez oil spill) and post-1989 catches within the East Nuka Bay area. The study was a limnological and fisheries study that occurred during 1997, focusing on sockeye salmon production in Delight and Desire Lakes. The comprehensive limnological surveys were conducted as part of a restoration project aimed at determining the feasibility of nutrient enrichment to restore sockeye salmon production in both lakes. Edmundson et al. (2001) presented total return, escapement, and commercial harvest data from 1975 to 1997.

Milner and York (2001) studied Delusion Creek in McCarty Fjord of KEFJ from 1992 to 1994 to investigate colonization and productivity of salmonids. The study measured the effects of stream discharge, spate events, macroinvertebrate density and abundance, and water chemistry as it relates to salmon colonization and productivity (Milner and York 2001).

4.6.5 Current Condition and Trend

Individual Stock (Delight, Desire, and Delusion Lakes) Escapement Estimates for Sockeye and Pink Salmon

The ADF&G have long-standing count data for sockeye and pink salmon at Delight, Desire, and Delusion Lakes (Hammarstrom and Ford 2011) (Figure 39). This assessment focuses on these three stocks. The location of the three lakes and all streams indicated by the AWC (ADF&G 2011b) as containing salmon are available in Plate 17 and Plate 18. Sockeye salmon escapement estimates for all locations relevant to KEFJ are available in Table 29 and pink salmon escapement estimates in Table 30.

Sockeye - Delight Lake

In combined weir and aerial counts at the outlet of Delight Lake, the 2010 escapement estimate was 23,800 sockeye, higher than the BEG range of 7,550 to 17,650 fish (Hammarstrom and Ford 2011). The average escapement estimate from 2000-2009 (14,200 fish) was within the BEG range. Only 2003 and 2004 experienced sockeye escapement estimates near the lower BEG range, 7,500 and 7,300, respectively (Figure 39).

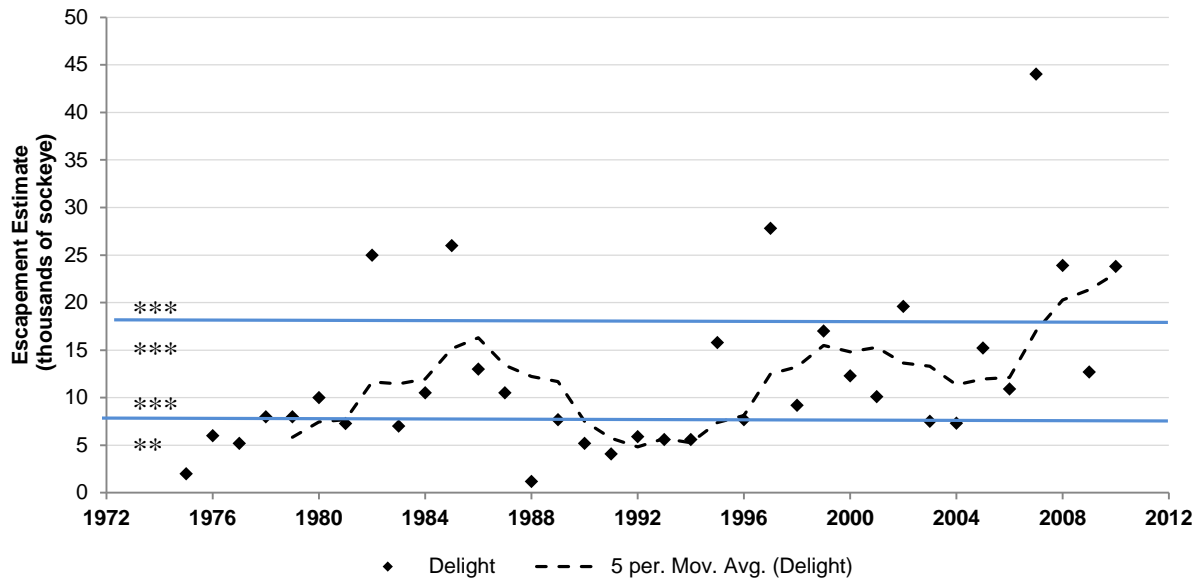


Figure 39. Delight Lake sockeye salmon escapement estimates, 1975-2010. Shown with BEG upper and lower ranges in blue. Data from Hammarstrom and Ford (2011).

The ADF&G has published data on escapement, harvest, and total run size for Delight Lake sockeye salmon; after reviewing these data in 2010, Delight Lake's escapement goals were adjusted (Otis et al. 2010). Exploitation rates from 1997 to 2010 varied from 0% to 67% and averaged 30% (Table 29) (Otis et al. 2010). Stock-specific harvest and exploitation rates are not published for Desire or Delight Lakes.

Table 29. Escapement (weir counts), commercial catch, and total run data for Delight Lake sockeye salmon, 1997-2010 (Otis et al. 2010).

Year	July 1-21 Weir Count	Commercial Harvest	Total Run	Exploitation Rate
1997	16,935	4,056	20,991	19%
1998	7,556	8,598	16,154	53%
1999	13,411	27,517	40,928	67%
2000		16,296	NA	NA
2001	12,635	4,735	17,370	27%
2002	17,655	11,672	29,327	40%
2003	6,708	12,547	19,255	65%
2004	3,842	4,623	8,465	55%
2005	13,700	0	13,700	0%
2006	10,879	1,164	12,043	10%
2007	40,403	26,442	66,845	40%
2008	21,333	977	22,310	4%
2009	5,232	0	5,232	0%
2010	23,505	3,282	26,782	12%
Average	14,907	8,708	23,031	30%
Max	40,403	27,517	66,845	67%
Min	3,842		5,232	0%
Escap. Contrast	11			
n	13			
Exploitation	30%			
Percentiles	25th-75th			
New SEG Lo	7,556			
New SEG Hi	17,655			

Note: The weir was not operated in 2000.

Weir escapement values for 2007 through 2010 are not supplemented with aerial survey counts.

Current SEG is based on a combination of peak aerial survey and weir counts.

Sockeye Salmon- Desire Lake

Desire Lake sockeye salmon escapement in 2010 was approximately 6,300 fish, measured as a peak single estimate, below the target SEG of 8,800 – 15,200 displayed in Figure 40 (Hammarstrom and Ford 2011). This 2010 point is not represented in this figure because it was only a peak single estimate; researchers noted inclement weather and poor observation conditions during the aerial surveys at Desire Lake and noted that escapement estimates in nearby Delight Lake counted in a weir were higher than the lake's 10-year average, and much higher than the lake's 20-year average. Therefore, the 2010 escapement estimate was adjusted for these factors.

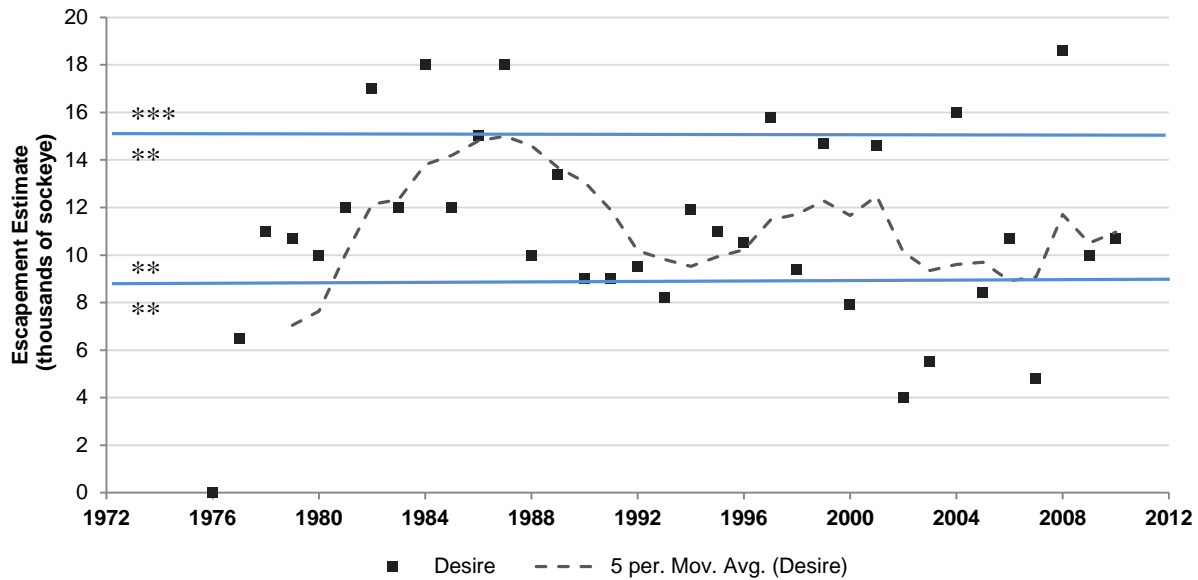


Figure 40. Desire Lake sockeye salmon escapement estimates, 1975-2010. Shown with BEG upper and lower ranges in blue. Data from Hammarstrom and Ford (2011).

Sockeye Salmon - Delusion Lake

Delusion Lake is more recently deglaciated than both Delight and Desire Lakes, having no documented salmon run until the mid-1980s. Therefore, the historic escapement estimates cover a relatively short period of time (Hammarstrom and Ford 2011). The 2010 escapement estimate for sockeye at Delusion Lake was 580 fish, less than half of the 20-year average estimated escapement of 1,400 fish. While there is no formal goal for this stock, the ADF&G have conducted aerial counts from 1990-2010. Over the period of record, estimates have ranged from a maximum of 3,600 in 2002 to a minimum of 300 in both 1990 and 1991 (Figure 41).

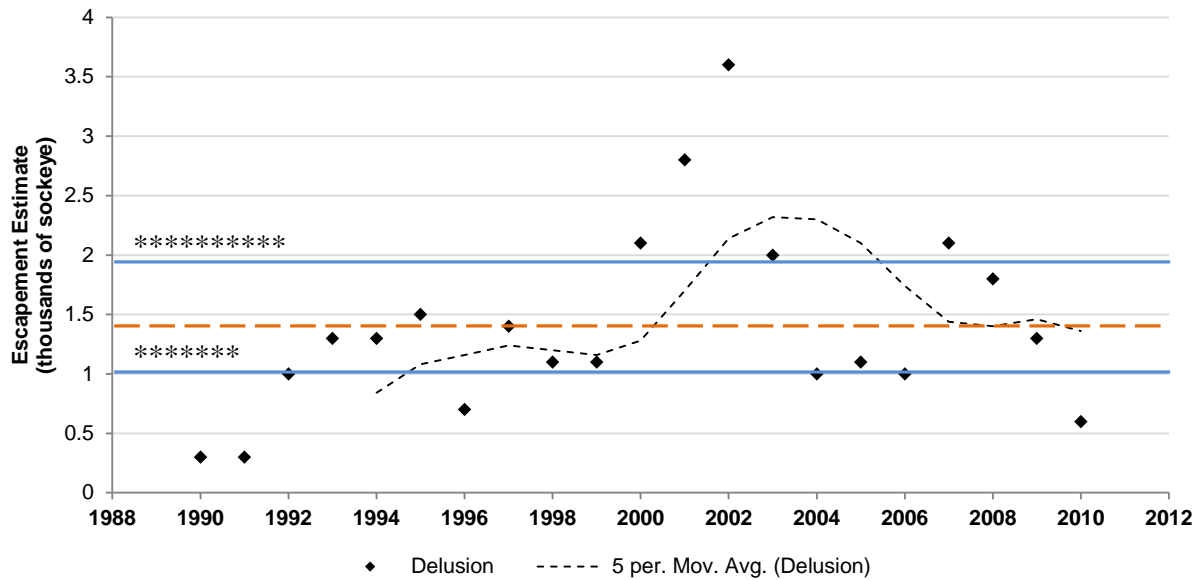


Figure 41. Delusion Lake sockeye salmon escapement estimates, 1990-2010. Shown with 20 year average line (dashed orange) and 75 & 25 percentile lines (blue). Data from Hammarstrom and Ford (2011).

Pink Salmon - Desire

While all three lake drainages (Delight, Desire, and Delusion) are noted in the AWC database as containing pink salmon, Desire Lake is the only one of these lakes for which the ADF&G estimate pink salmon escapement. As previously stated, Desire Lake's established SEG is 1,900 - 20,200 pink salmon. The 2010 escapement estimate was 3,000 pink salmon, just within the lower limit of the established SEG (Table 30). The escapement estimates have varied from a low of approximately 1,000 in 1990 to a high of 78,400 fish in 2002.

Table 30. Estimated pink salmon escapements in thousands of fish for the major spawning systems of KEFJ, 1960-2010, subset of locations from Appendix A25 in Hammarstrom and Ford (2011).

Location	1982	1983	1984	1985	1986	1987	1988	1989	1990
Desire Lake Creek	12.0	8.5	23.0	62.5	32.0	11.0	2.5	47.0	1.0
James Lagoon	6.0	5.1	4.0	9.0	6.6	1.1	1.7	4.9	3.8
Aialik Lagoon	5.0	3.0	4.0	9.4	6.0	1.5	0.7	0.8	--
Location	1991	1992	1993	1994	1995	1996	1997	1998	1999
Desire Lake Creek	1.3	0.4	19.3	--	--	--	6.2	6.8	6.8
James Lagoon	4.4	0.4	3.3	0.8	0.6	--	--	--	--
Aialik Lagoon	--	c	--	--	1.1	--	--	0.9	0.9
Location	2000	2001	2002	2003	2004	2005	2006	2007	2008
Desire Lake Creek	21.1	67.5	78.4	34.8	24.3	46.0	74.8	11.8	9.5
James Lagoon	3.9	2.3	3.1	--	--	--	--	--	--
Aialik Lagoon	--	--	--	--	--	0.8	--	--	--
Location	2009	2010	1960-2009 Average				Sustainable Escapement Goal		
Desire Lake Creek	73.9	3.0	20.6				1.9-20.2		
James Lagoon	--	--	4.2				--		
Aialik Lagoon	--	--	3.6				--		

AWC Additions (Presence)

The AWC identifies over 17,000 water bodies that are essential for spawning and rearing of anadromous fish species across the state of Alaska (ADF&G 2012b). These water bodies support essential anadromous fish life functions and are protected under Alaska Statute AS16.05.871(a). ADF&G (2012b) estimated that the number of streams presently included in the AWC represents less than 50% of the true number of Alaskan streams, lakes, or rivers that support anadromous fish species.

New lakes and streams have emerged in KEFJ since the recession of coastal glaciers; these areas provide insight into primary successional biological communities following major disturbances (Milner and Oswood no date). Within the past 100 years, salmon successfully colonized many of these glacial recession areas in KEFJ. For example, both Delight and Desire Lakes were formed in the 1920s and 1930s after the McCarty Glacier receded; and by 1975 salmon runs were supported in by these lakes (Milner 1997). Immigration slowly established a variety of anadromous fish species in upstream freshwater streams and lakes previously covered by glacial ice (Milner and York 2001). Milner and York (2001, p. 644) suggested that “salmon colonization may constitute a critical point in community development within new streams following deglaciation.”

AWC nominations can be made by anyone, but are subject to field verification before approval by the ADF&G (ADF&G 2012b). Anadromous waters nomination forms and correction forms along with a variety of supporting documents (e.g., emails, topo maps with hand drawn observation locations) are kept as a record for the continually updated AWC database. New versions of the database are typically published annually. The nomination forms, correction forms, and supporting documents capture information such as anadromous species, species life history phase (migration, spawning or rearing), location, how observation was made (e.g., minnow trap, minnow seine, aerial

survey, visual), who made catalog nominations or adjustments, and various additional notes specific to the species or locations involved. In some cases, the location (point) is moved to match new stream courses.

In reviewing a sample set of nomination forms for water bodies within KEFJ, multiple, contemporary (circa 2000s) additions and revisions to the database were found. This type of information may be useful for individuals interested in understanding the history of AWC database changes for specific locations. That is, the nomination forms could allow one to create specific location histories of AWC database adjustments. However, it may prove cumbersome to recreate a timeline or history of additions to the database for the park, as several hundred forms exist for KEFJ. Creating such a timeline of salmon nomination histories for the park may not be particularly useful in understanding things such as salmon distribution changes across the park over time. New salmon locations have been documented over time, but some of this is well documented as successional changes of recently deglaciated areas. In other cases, the increase is simply an increase in the total number of locations sampled over time. Salmon survey efforts are not systematic nor conducted at regular intervals, rather additions to the catalog are generally sporadic in nature. Therefore, the AWC nomination forms may not be particularly useful for detecting change in salmon distribution over time. The AWC is intended to represent the contemporary, “state of our knowledge” of anadromous streams and species specific locations across the state.

Locations of known occurrences of Pacific salmon species according to the AWC (2011 edition), including presence and spawning locations are displayed in Plate 20-25. Also contained within these maps (plates) are point locations of salmon observations from Jones and Hamon (2005).

Threats and Stressor Factors

Global pollutants delivered via atmospheric deposition may accumulate in salmon during their lives in the ocean. Contaminants can biomagnify to higher trophic levels, resulting in elevated contaminant levels within aquatic and terrestrial ecosystems (Jewett and Duffy 2007) when salmon return to spawning habitats in KEFJ. Jewett and Duffy (2007) assert that there is insufficient historical data to determine if mercury (Hg) concentrations in salmon are increasing, decreasing, or unchanging in recent years. Levels of methylmercury (MeHg), the most toxic form of Hg to humans, generally tend to be relatively low (<0.300 MeHg mg/kg in ppm) in Alaska salmon, but can vary greatly depending on watershed and vary some by salmon species (Jewett and Duffy 2007). However, Hg concentrations and other contaminants have been increasingly found in remote and otherwise pristine areas such as Alaska (Landers et al. 2008). For example, the Western Airborne Contaminant Assessment Project (WACAP) found that fish sampled in Alaska parks had the highest concentrations of Hg compared with the other 17 lower-48 parks sampled in the project, and that Hg deposition increased in the twentieth century from anthropogenic sources in all parks (Landers et al. 2008). However, Hg concentrations in snow and lichen samples for Alaska parks were significantly less than in lower-48 parks. In addition, Landers et al. (2008) suggests that the reasons for higher Hg in fish tissues from Alaska may be due to several factors including fish age, Hg methylation rate, watershed biogeochemical characteristics, and food web efficiency as it relates to bioaccumulation.

Still, lake sediment samples in Alaska (DENA, NOAT, and GATES) showed consistent increases in Hg flux from global sources (Landers et al. 2008).

According to the Canadian Climate Model and the Hadley Center Model, the western Cook Inlet and the Kenai Peninsula will experience a mean annual increase in air temperature of 8.5°C (15.3° F) by 2100 (Kyle and Brabets 2001). Warming water temperatures caused by climate change could reduce survival of salmon eggs and fry, slowed growth (Alderice and Velsen 1978), premature smolting and shifts in emigration timing, increased vulnerability to pollution from increases in toxicity from organic chemicals and mercury, and increased risk of disease (Alderice and Velsen 1978). According to the Alaska Department of Environmental Conservation's water quality criteria for temperature, 13 C (5.5 F) is the upper limit for salmon spawning areas, 15 C (59 F) upper limit for migration routes, and 20 C (68 F) is mortality limit (ADEC 2012). Additionally, prespawn mortalities have been tied to factors such as water temperature, high river discharges, parasites, and disease (Rand et al. 2006, Farrell et al. 2008).

Non-native fish species such as farmed Atlantic salmon (*Salmo salar*) pose a threat to native salmon species due to competition for food, stream habitat, and spawning grounds and as a potential source of disease (e.g., infectious salmon anemia [ISA]). According to an online USGS Nonindigenous Aquatic Species List and map viewer, the nearest Atlantic salmon specimens collected were in marine waters off the Kenai Peninsula (1990), in the Shelikof Strait (2002), near Kasilof, AK (2006), and at the mouth of the Copper River (2000). An online media release from Simon Fraser University in California officially reported ISA to be found on 15 October 2011, along the coast of British Columbia, Canada. While, one study found Chinook, coho, chum, and steelhead not susceptible to the disease (Rolland and Winton 2003), researchers warn that there's a potential that ISA variants could adapt to a more virulent form affecting Pacific salmon species (Wild Fish Conservancy 2012).

Commercial overharvest of salmon in the coastal waters of KEFJ remains a possibility due to the magnitude of and dependence on Pacific salmon by consumers of commercial fished salmon (ADF&G 2012b). Although the ADF&G (2012b) reported declining harvest rates in recent years, Alaskan commercial salmon catches have increased exponentially within the past 25 years (Figure 42). In 2010, sockeye catch in East Nuka Bay (part of the ADF&G-defined Outer District), which consists of Delight, Desire, and Delusion Lakes was 2,956 fish with total combined escapement of 30,687 (Hammarstrom and Ford 2011). This translates to an exploitation percentage of approximately 11%. No other stock-specific exploitation percentages are available for these lakes in KEFJ. However, the commercial salmon catch for all gear and harvest types by year and fish species for the Outer District (many of the fish are likely part of the Delight, Desire, and Delusion salmon stocks) is available in Appendix 7.

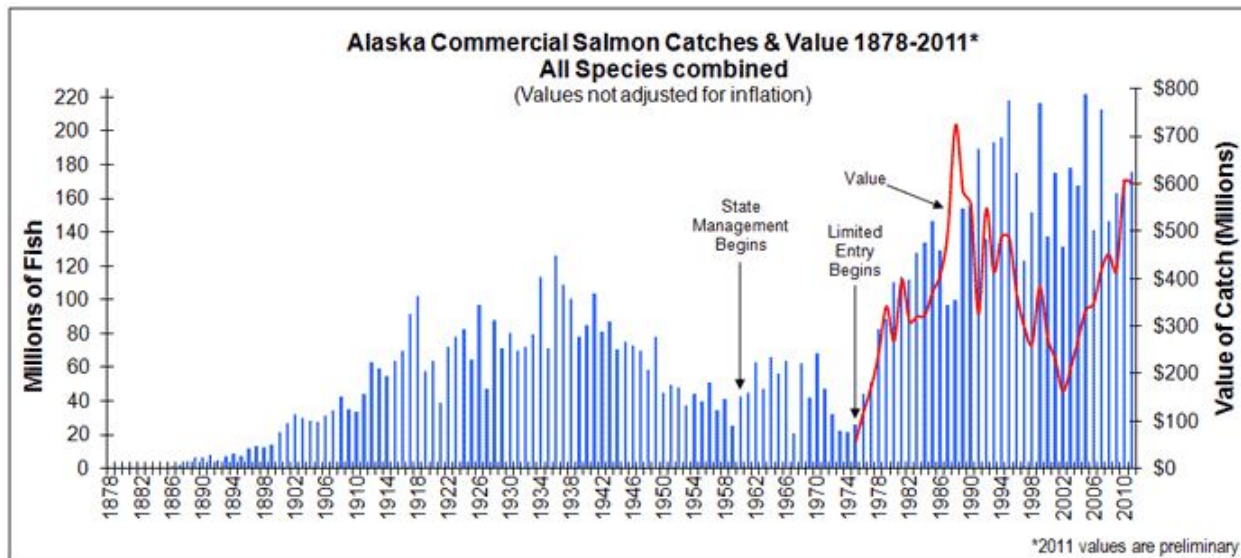


Figure 42. Commercial catches and value of Alaskan salmon species. Figure reproduced from ADF&G (2012a). Notice that values of commercial harvests were not adjusted for inflation.

Oil spills could affect the commercial salmon fishery in the Gulf of Alaska, as well as escapement rates in KEFJ water bodies. Edmundson et al. (2001) noted that East Nuka Bay commercial sockeye salmon catches immediately following the 1989 Exxon Valdez oil spill significantly declined – from an average of 29,800 prior (1975-1988) to 7,300 following the spill (Figure 43). Naturally low nutrient concentrations, chlorophyll levels, and zooplankton densities in Delight and Desire Lakes, along with oil contamination from the Exxon Valdez, were associated with decreased salmon production (Edmundson et al. 2001). Future oil spills in the region, due to high traffic shipping routes, remain a possibility (Nagorski et al. 2010). Nagorski et al. (2010, p. xvi) also suggested that cruise ships, fishing vessels, and marine cargo ships can potentially “degrade water quality by the accidental release of petroleum products, the release of wastewater or other discharges, or by resuspension of sediments.”

Data Needs/Gaps

A reference condition or set of criteria is needed to gauge health or overall condition of salmon in KEFJ. In addition, a protocol or method to capture and systematically report changes over time in salmon

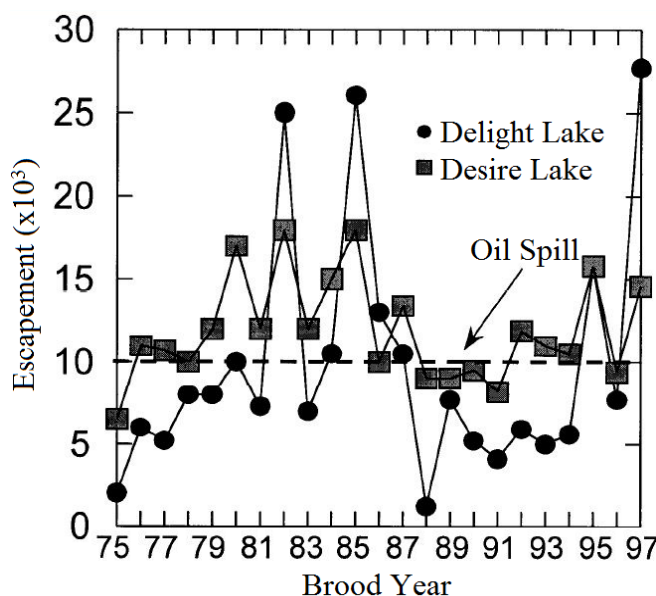


Figure 43. Annual sockeye salmon escapement into Delight and Desire Lakes, 1975-1997. Dashed line represents pre-2002 SEG's. Figure reproduced from Edmundson (2001).

distribution would be useful in identifying newly colonized salmon habitats in KEFJ.

Periodic surveys of streams of interest and an effort to survey all of the streams in the park over time would increase the understanding of species distribution. In addition, further research into salmon colonization post-deglaciation could increase the understanding of changing salmon distribution in the park.

Bennett et al. (2006) suggests that the ADF&G already has well established monitoring techniques for salmon, but that a database development would aid protocol development and testing of the salmon as a SWAN Vital Sign.

Overall Condition

Individual stock (Delight, Desire, and Delusion Lakes) escapement estimates for sockeye and pink salmon


A *Significance Level* of 3 was assigned for the measure of escapement estimates. This measure was assigned a *Condition Level* of 1, indicating that it is currently of low concern to resource managers. Delight, Desire, and Delusion Lakes provide spawning habitat for multiple species of salmon. Pacific sockeye salmon populations have historically shown fluctuating spawning escapement. However, decadal trends of sockeye salmon show increased escapement in Delight Lake; as of 2010, escapement was nearly twice the established SEG. Conversely, Desire Lake experienced decadal-long declines in average escapement. However, as of 2010, escapement was within the established SEG. Sockeye salmon populations, in terms of escapement, have ostensibly rebounded from declines in the late 1980s and early 1990s. Despite the assignment of a low concern (1) for individual stocks using escapement estimates, potential for future oil-spill events and a changing climate could put the KEFJ salmon stocks at risk.

AWC Additions (Presence)

A *Significance Level* of 2 was assigned for presence of anadromous fish in KEFJ water bodies. This measure was not assigned a *Condition Level* due to the lack of a reference condition and because an analysis was not undertaken to examine the AWC additions. Conducting such an analysis with historic nomination forms may provide location-specific histories of salmon documentation but would not necessarily produce any conclusion regarding changes in distribution of anadromous fish across the park over time. That is, the AWC nomination forms are not useful for understanding changing salmon distribution over time, rather they simply act as a record for changes to the database (i.e., the current status of our collective salmon distribution knowledge). However, access to the most contemporary version of the AWC spatial database is important for the park because new locations will likely be added in the future with continued glacier recession exposing potentially new spawning habitats. It is also likely that some water bodies not captured in the AWC database already contain small numbers of salmon, but have not yet been detected or confirmed and updated in the AWC.

Weighted Condition Score

The overall weighted condition score (WCS) for the KEFJ salmon component is 0.333, indicating that this resource is of low concern. A trend was not determined due to the lack of a reference condition for the AWC additions (presence/absence) measure.

Salmon			
Measures	Significance Level	Condition Level	Weighted Condition Score = 0.3
Escapement Estimates (Delight, Desire, and Delusion Lakes)	3	1	
Catalog Additions (Presence/Absence)	2	n/a	

4.6.6 Sources of Expertise

Laura Phillips, KEFJ Ecologist

Dan Young, LACL Fisheries Biologist

J. Johnson, ADF&G Fish Biologist, provided an historic set of AWC nomination forms relevant to KEFJ.

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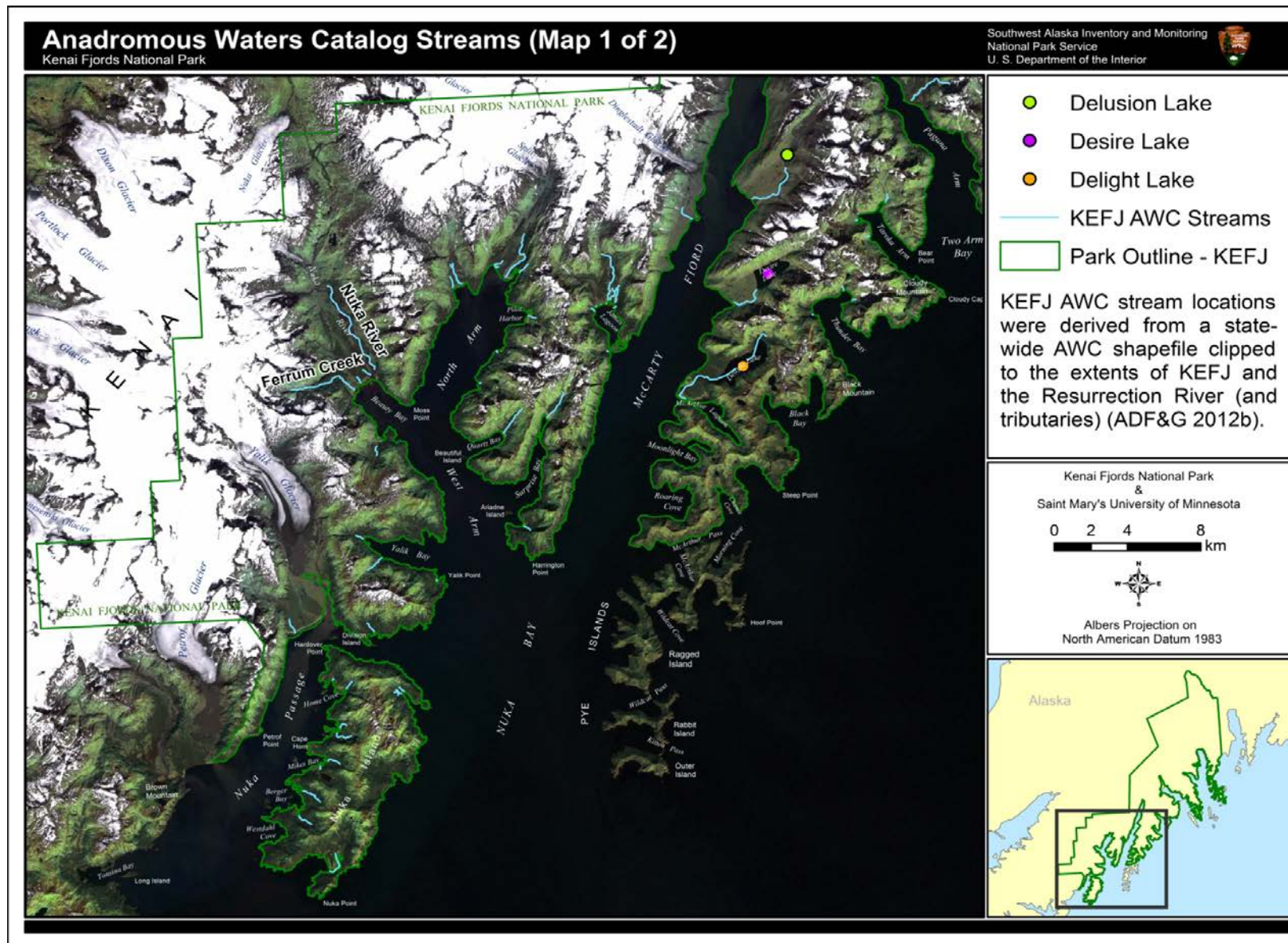


Plate 17. Streams within the southern coastal half of KEFJ identified by the AWC as anadromous water bodies (ADF&G 2012b).

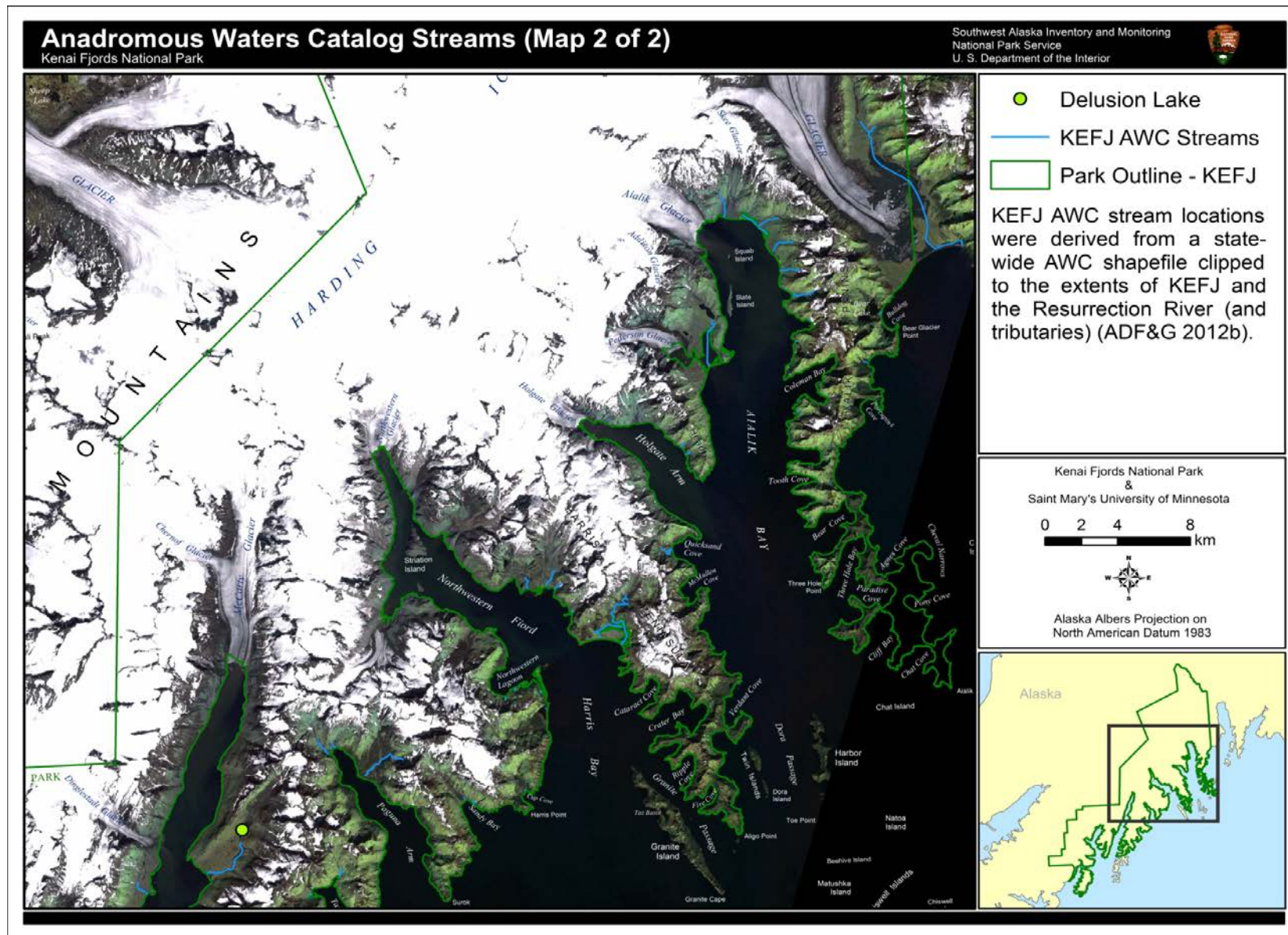


Plate 18. Streams within the northern coastal half of KEFJ identified by the AWC as anadromous water bodies (ADF&G 2012b).

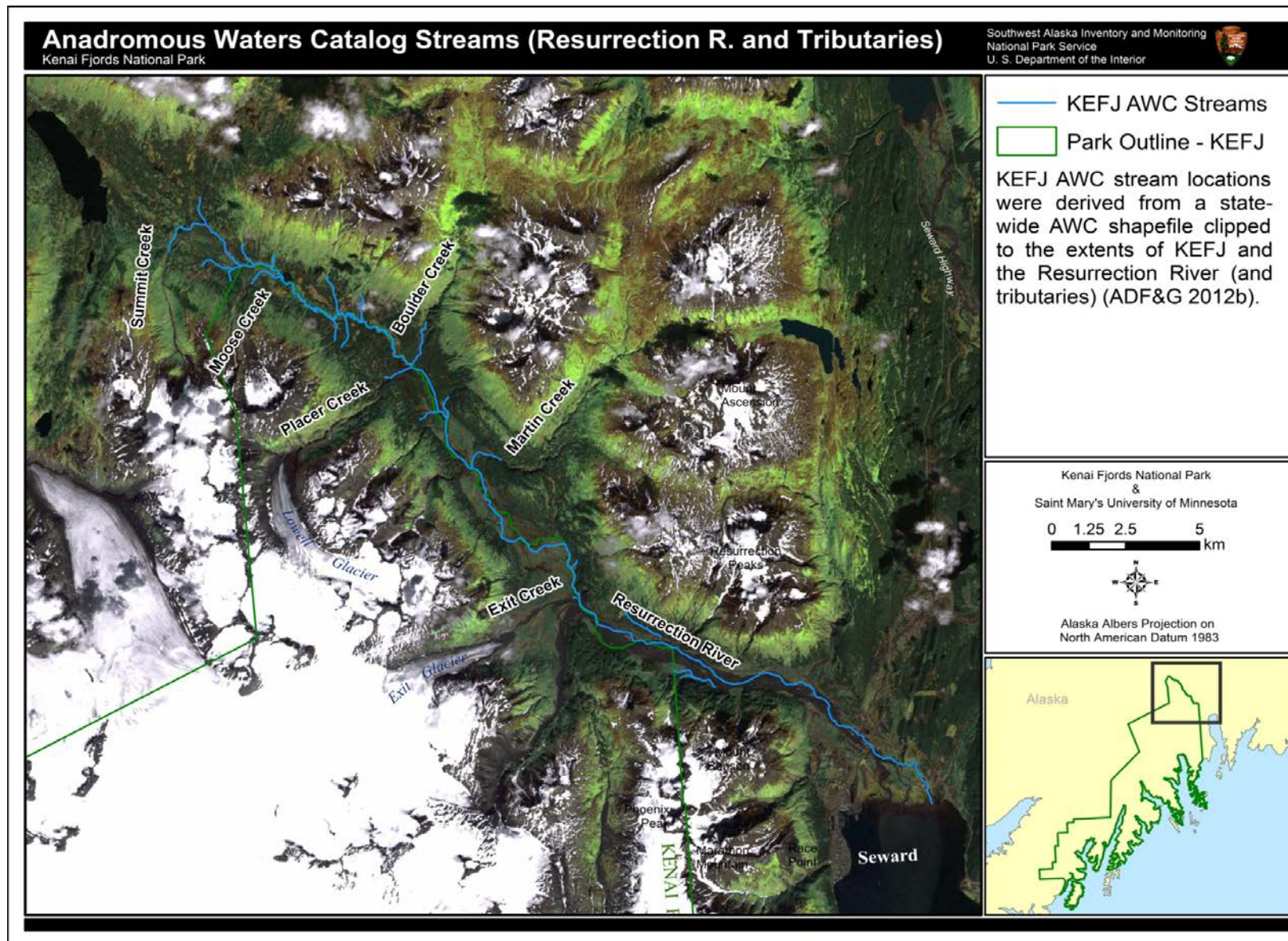


Plate 19. AWC anadromous water bodies associated with the Resurrection River along the KEFJ boundary (ADF&G 2012b).

Notes regarding the following salmon presence maps for each salmon species (Plate 20, Plate 21, Plate 22, Plate 23, and Plate 24). Salmon presence data were obtained from the Anadromous Waters Catalog, maintained by the ADF&G (2012b). For selecting anadromous fish streams, a few caveats were identified:

- 1) All line segments downstream of a given point were indicated as containing that species; so that the line representing the stream is represented by the farthest upstream point identifying an individual fish species.
- 2) If a line segment (one tabular record) intersected a point feature, the entire extent of that line segment was kept even if no additional points were located upstream for each anadromous fish species. That is, the line segment was not split into two records, rather the last upstream line segment was included regardless of where on the line segment the point fell
- 3) In selecting streams (GIS lines), all arterial streams, such as in braided rivers, not containing selected points were not included even if connected to larger channels.

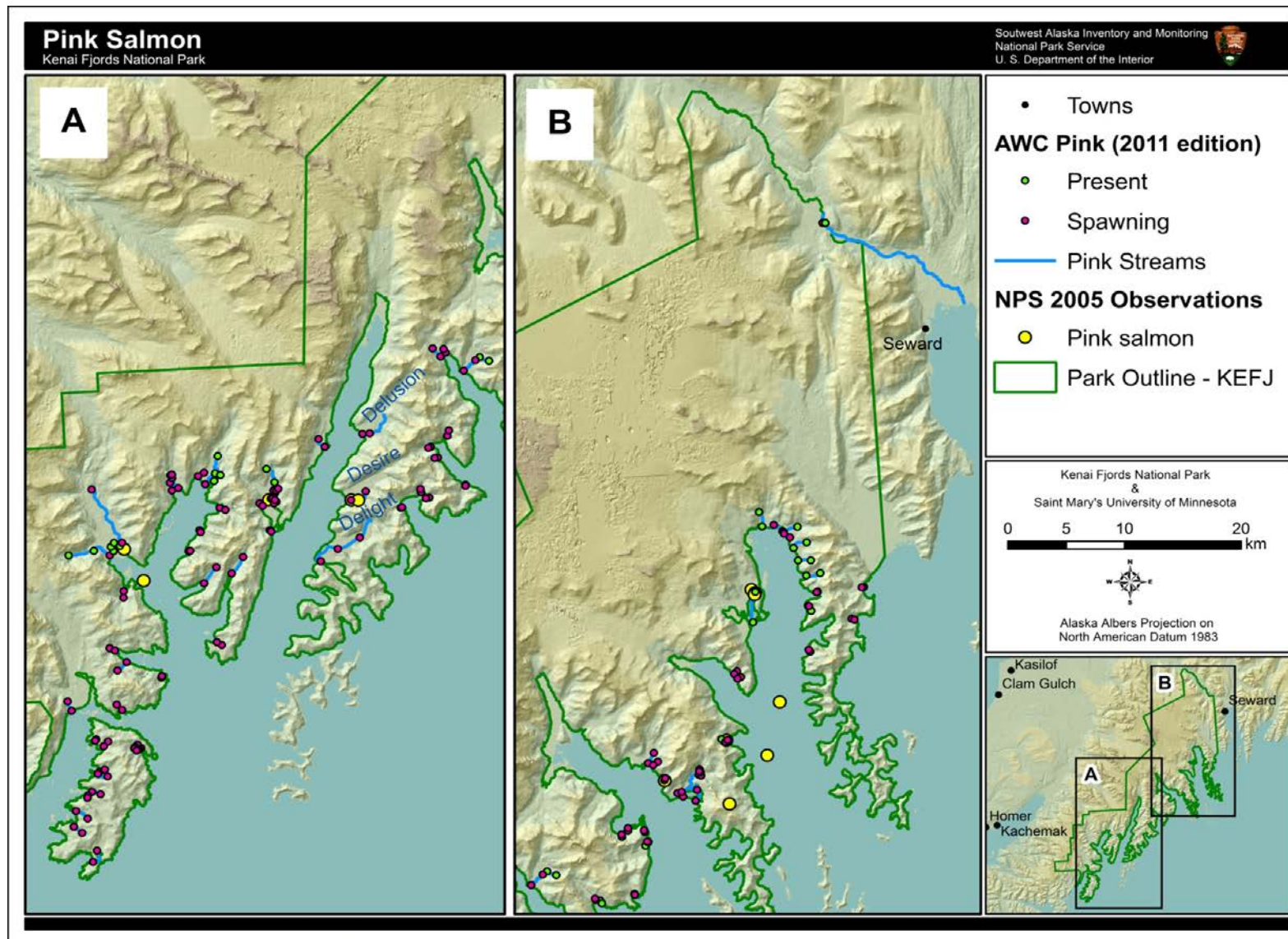


Plate 20. Known pink salmon locations and streams in KEFJ, NPS sampling and AWC data (Jones and Hamon 2005, ADF&G 2012b).

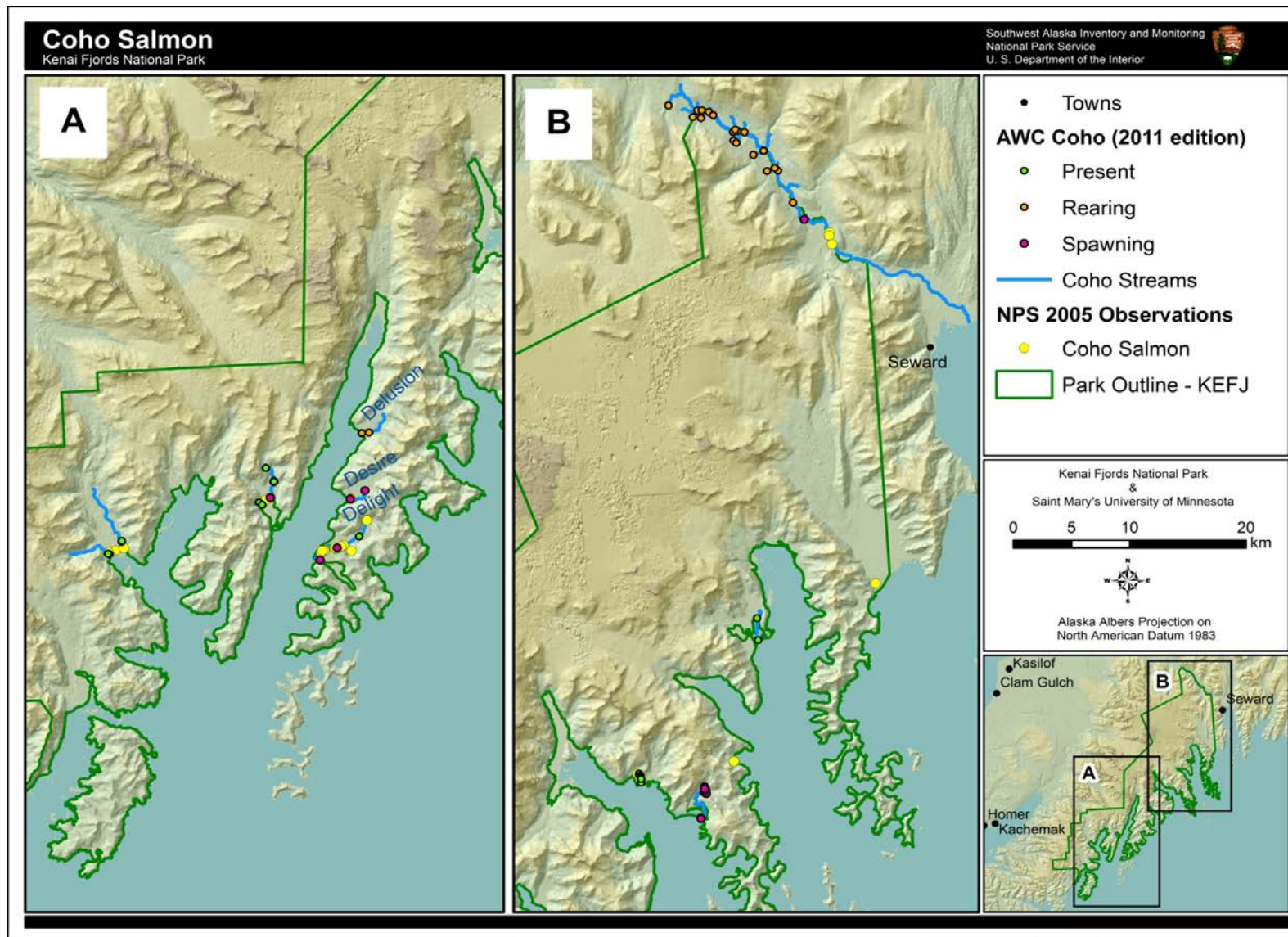


Plate 21. Known Coho salmon locations and streams in KEFJ, NPS sampling and AWC data (Jones and Hamon 2005, ADF&G 2012b).

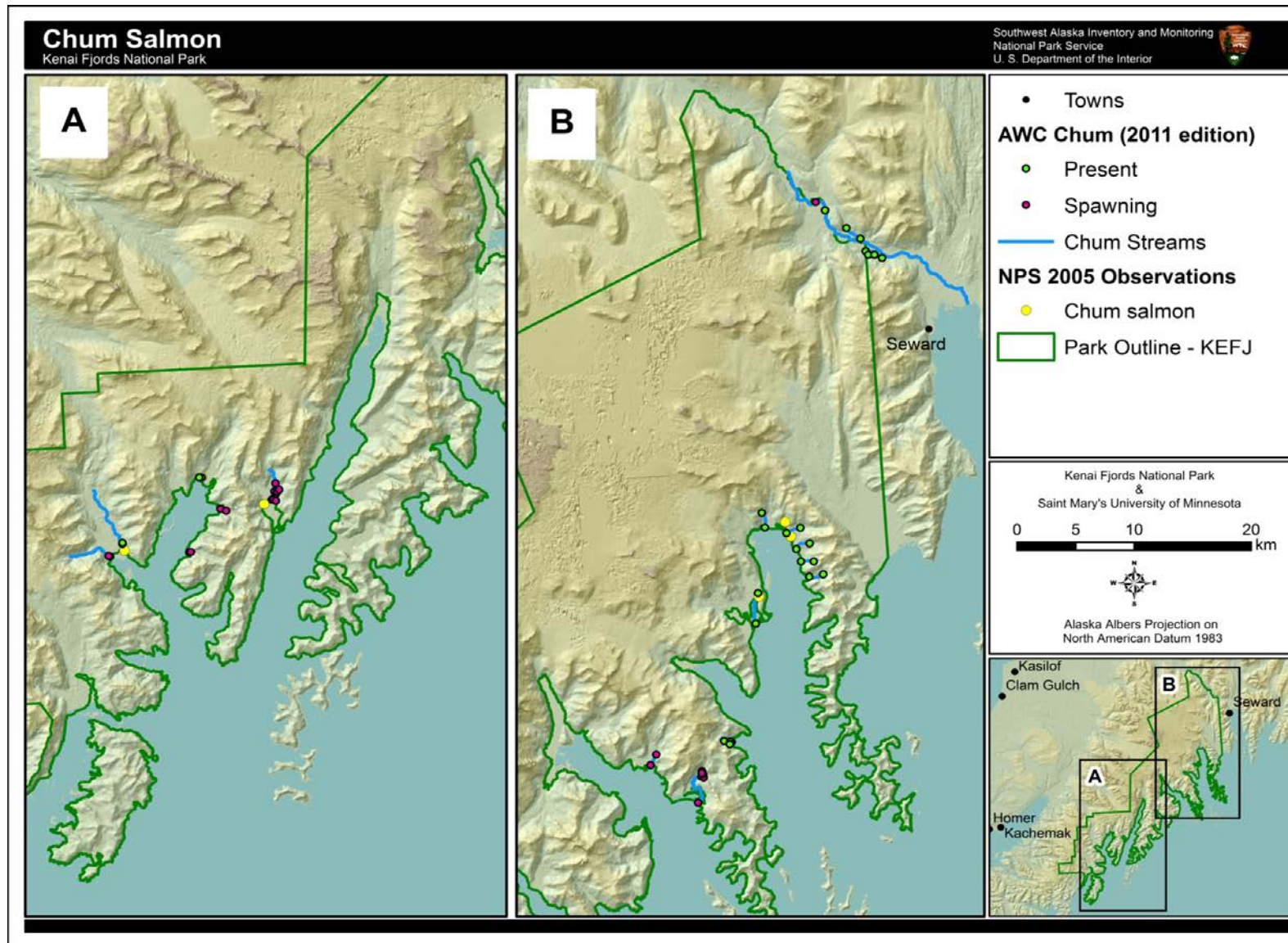


Plate 22. Known chum salmon locations and streams in KEFJ, NPS sampling and AWC data (Jones and Hamon 2005, ADF&G 2012b).

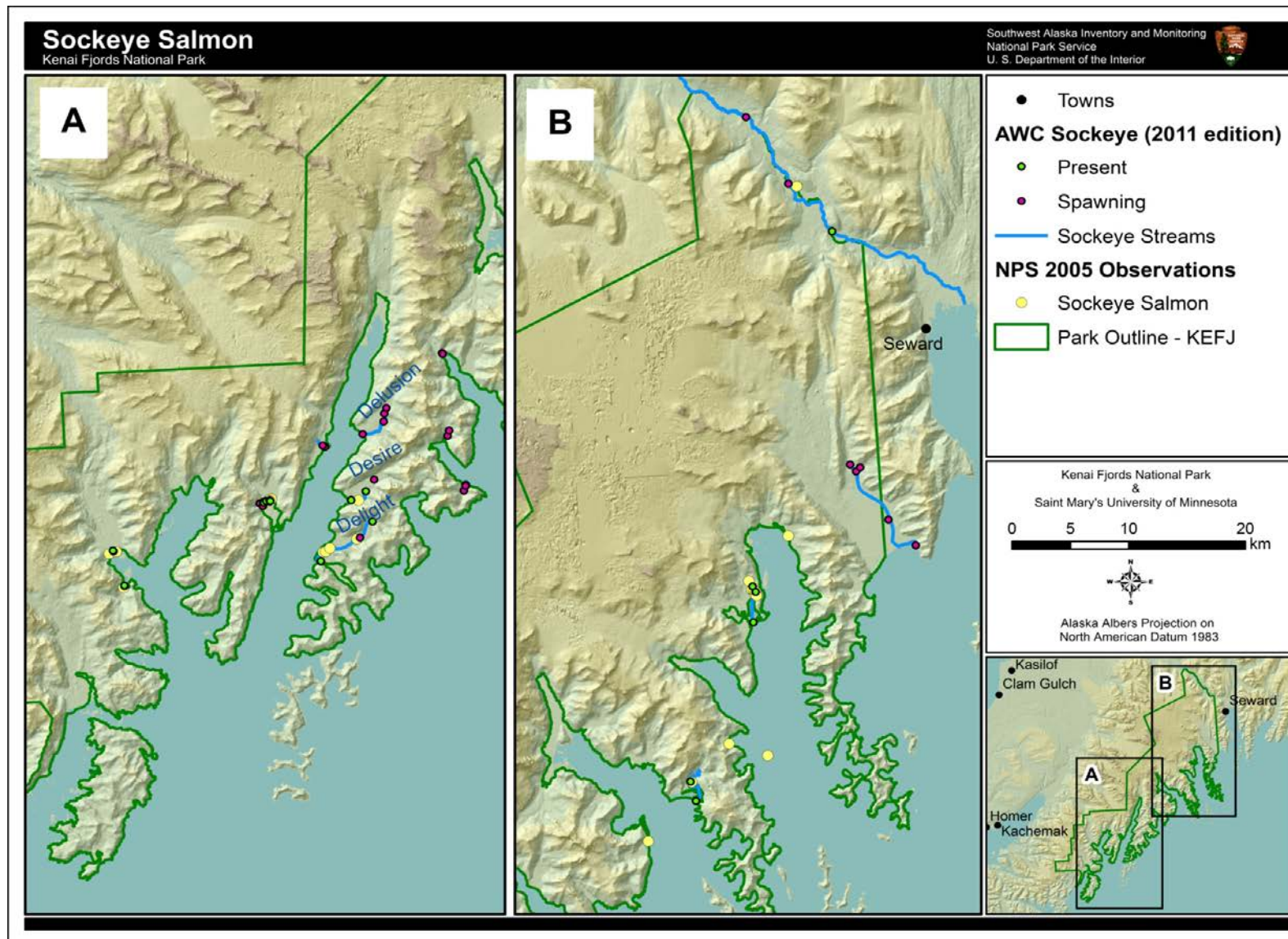


Plate 23. Known sockeye salmon locations and streams in KEFJ, NPS sampling and AWC data (Jones and Hamon 2005, ADF&G 2012b).

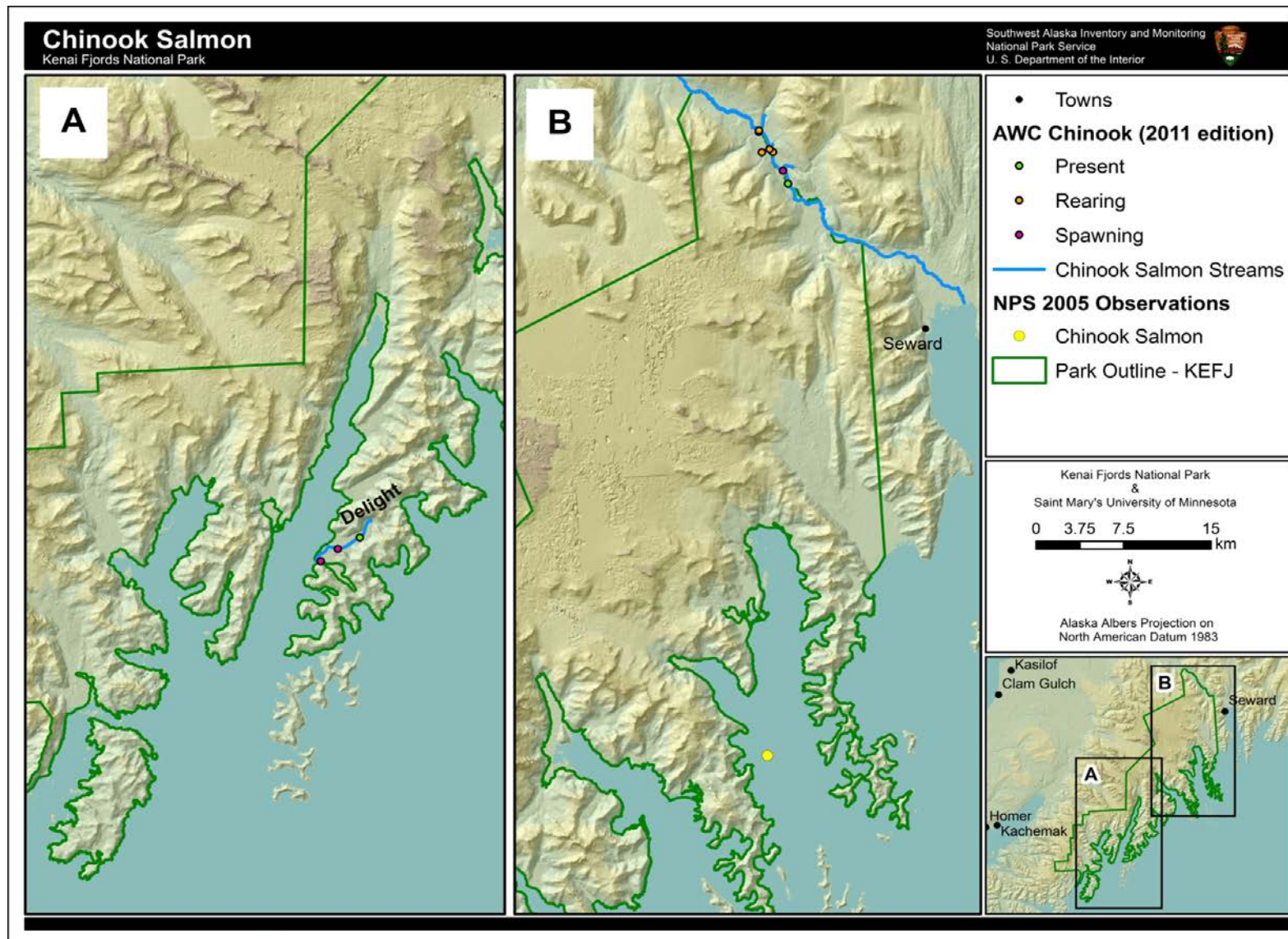


Plate 24. Known Chinook salmon locations and streams in KEFJ, NPS sampling and AWC data (Jones and Hamon 2005, ADF&G 2012b).

4.7 Hydrology – Exit Glacier Area - Exit Creek Channel Migration

4.7.1 Description

The Exit Glacier area, located in the northern portion of the park, is an important visitor use area. It is the most visited attraction/destination in the Resurrection River watershed near Seward, Alaska (USFS 2010), and Exit Glacier is just one of two glaciers accessible from Anchorage by car (Catton 2010). The Exit Glacier area is important as it offers visitors ranger-led walks and talks, opportunities to view wildlife, and an up-close view of an active glacier and the Harding Icefield. It also has economic importance in terms of commercial services provided to park visitors. The area represents the only SWAN park lands accessible via the Alaska road system. Other access to park lands is primarily through watercraft launched from Seward (e.g., boat tours, personal watercraft, commercial water taxi services, kayaks), and a limited number of visitors access park lands from Homer via boats and float planes. From the Seward Highway (State Hwy 9), Herman Leirer Road runs along the north bank of the Resurrection River for approximately 13 km (8 mi) and at the last kilometer crosses the Resurrection River near its confluence with Exit Creek (Exit Creek shown in Photo 10) (Martin 2005). The road provides access to the Exit Glacier area which includes the park's only maintained trails (a network of hiking trails near the glacier terminus and the head of the 6.4-km (4-mi) long Harding Icefield Trail), a nature center, and a 12-site campground. In 2013, visitation to this area accounted for approximately 50% of the park's annual visitation (visitors are counted at Exit Glacier, at the Seward Visitor Center, in the backcountry by rangers, on park tour boats, and on snowmobiles). According to the traffic counts at Exit Glacier in 2010, this area nearly 50 thousand visitors, with the vast majority of this visitation occurring from June through September. Herman Leirer Road is closed to vehicles during winter, but the area sees some use by the public for winter activities.



Photo 10. View of Exit Creek in the foreground and a portion of the Exit Glacier terminus in the upper right of the photo (NPS photo).

Portions of Exit Glacier area trails and the access road (Herman Leirer Road) have a history of flooding, and flood abatement and prevention in this area has been a fairly complex issue for the park (Nagorski et al. 2010). The park is concerned about flooding that has damaged the road and trails and

caused interruptions in visitor access through road closures. This assessment summarizes available literature that discusses flooding and general hydrologic conditions of the Exit Glacier area including Exit Creek and a particular, unnamed drainage that is a tributary of the creek. Exit Creek is a tributary of the Resurrection River that is fed by melt water of Exit Glacier and by rain and snow-melt runoff in the local watershed. Also presented in this assessment are photo-interpreted delineations (GIS data) of active channel positions developed using historic and contemporary aerial photography and satellite imagery of the Exit Glacier area. These historic channel positions provide indications of general channel migration patterns over approximately a 50-yr period and visual reference of historic conditions of a specific area of Herman Leirer Road that has experienced repeated inundation, providing visual evidence of historic channel observations made by Tetreau (1993). The assessment also presents some visual representations of GIS-layers derived from a 2-meter digital elevation model (DEM) of the area acquired in 2008, two watershed delineations and a stream channel network. Lastly, this assessment presents a list of hydrologic measures the park might consider in future natural resource condition assessments, and generally, to further understand hydrologic conditions in the area, which could prove useful for future flood mitigation planning efforts. Primary natural features and park infrastructure of the Exit Glacier area are identified in Figure 44.

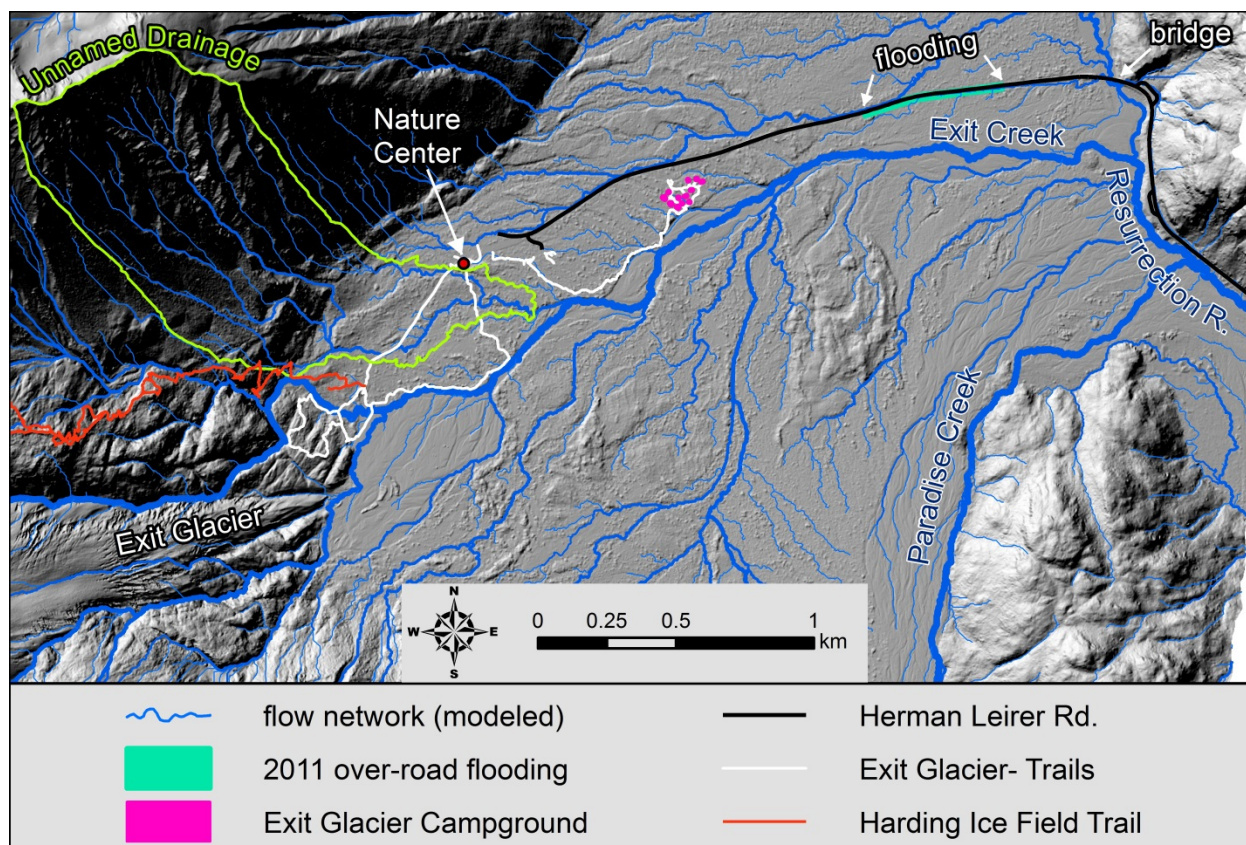


Figure 44. Primary infrastructure and natural features in the Exit Glacier area in relation to the stream channel network. The stream network in this figure is a 2-meter DEM-derived GIS layer; it is an idealized representation of flow across the DEM surface (i.e., modeled channels). Actual stream channels in this area are likely to be complicated by things such as complex flow associated with the glacier (e.g., under-glacier flow) and ever-changing in-channel sediments. The DEM used for this stream network represents ground conditions as of 30 August 2008.

4.7.2 Brief History of the Exit Glacier Area

Primary Development Chronology

Initial development of a road to Exit Glacier began in 1965, a year after the destructive Alaska Earthquake of 1964, when Seward residents recognized the need to diversify Seward's economy (USFS 2010). Residents sought to develop vehicle access to this area as a sightseeing destination (USFS 2010). Then, in 1970, a 2.8-km (1.75-mile) road on the west side of the Resurrection River (within the present-day park) was "bladed out". By the end of the 1971 construction season, the road from the Seward Highway was also completed to the east bank of the Resurrection River, but was considered too rough for passenger car use (USFS 2010).

Shortly after the park was established by the 1980 act of Congress, Alaska National Interest Lands Conservation Act (ANILCA), a pedestrian bridge was created in 1982 at the site of the present-day Resurrection River Bridge (also referred to as Exit Glacier Bridge or Bridge 1390) at the confluence with Exit Creek (Catton 2010). The first vehicle access bridge was constructed and opened to visitors by July 1986, and a hiking trail to Exit Glacier was constructed in 1988 and 1989 (Catton 2010).

Then, in the 1990s, multiple upgrades to Herman Leirer Road (the name of the road extending from the Seward Highway into the park) within the park were completed, along with significant work and expense to raise sections of the road out of Resurrection River's floodplain along the road's entire length. In 1995, a portion of the road was paved and additional culverts installed in response to that portion of the road being damaged by a flood that year. In 1998, the 2.4-km (1.5-mile) stretch of the road from the park boundary to the parking areas was reconditioned and repaved (Catton 2010). In 1997, the bridge crossing the Resurrection River was replaced with a new bridge constructed by the Federal Highway Administration (FHWA) (PEPC 2012) and still remains in 2013. The road was then repaved in 2001, and then the entire Herman Leirer Road project that stretched over a decade was completed (Catton 2010). A nature center was constructed in the Exit Glacier area in 2003 and opened to the public in 2004 (Catton 2010). Most recently, during the fall of 2012 and spring of 2013, the FHWA installed flood protection structures along a length of Herman Leirer Road that has been repeatedly flooded (WFLH 2013). The structures included rip-rap underlain with a geotextile mat along the south side of the road, riprap barbs to direct flow away from the road, shoulder paving, the placement of a concrete barrier, and embankment repair on both sides of the road (WFLH 2013).

Area Flooding

Flooding and drainage issues in the Exit Glacier area of the park discussed in reports and literature prepared by and for the park have been primarily associated with three different geographic areas: the area containing trails near the glacier terminus and the present-day nature center, a section of Herman Leirer Road west of the Resurrection River Bridge, and the Resurrection River Bridge itself. Flooding was noted early on in the park's history and, over time, as infrastructure development advanced (e.g., trail, road, and nature center construction), multiple hydrologic surveys/assessments/reconnaissance have occurred (Sloan 1983, Sloan 1985, Tetreau 1993, Barber 2003, and Martin 2005). Past hydrologic surveys/assessments tend to separate their attention to flow issues related to the trails and Nature Center (constructed in 2002) from those related to Herman Leirer Road near the Resurrection River Bridge. Before improvements were made to local drainage in the early 2000s, the Nature Center was subject to high flows from a particular unnamed drainage, a tributary of Exit Creek. However, the Nature Center has not been subject to flooding since at least 2008.

In recent years, flooding events that have caused water to over-top the road were from high flows of Exit Creek. Generally, it appears that past road flooding events were primarily due to high flows of the Resurrection River. The following provides a synopsis of the hydrologic survey/assessment efforts separated by the three general areas: the Nature Center, the nature trail, and Herman Leirer Road. However, the nature trail is not a focus of this assessment. This trail once paralleled some of the Exit Glacier outwash fan; it was subject to periodic erosion loss as Exit Creek's braided channels migrated over time (Martin 2005). High flows in the unnamed drainage and Exit Creek from 2013 storms undermined this trail, destroying it.

Trails and Nature Center

Barber (2003) represents the first field review that provides details related to flooding associated with Exit Glacier trails and drainage issues noted near the newly constructed (2002) Nature Center. Barber

(2003) identified an unnamed drainage as the source for runoff that affected the trails and the Nature Center. The author provided preliminary design computations using data on drainage area, storage area, mean annual precipitation, and mean minimum January temperature. The computations provided initial recommendations for culvert diameters and for a foot bridge installation for larger surface water flows to pass the main trail to Exit Glacier; however, the author cautioned that the design computations (estimated discharges that should be accounted for) were preliminary and recommended field notes be used to further refine recommendations.

In a later assessment, Martin (2005) again identified the unnamed drainage as the primary flood hazard for the Exit Glacier area trails and the Nature Center, recognizing that the drainage was fed by snowmelt and rainfall from the higher elevations to the north of the Exit Glacier terminus. Barber (2003) and Martin (2005) reported that this drainage was fed by a 2.8-km² (1.1-mi²) watershed. A watershed-delineation in a GIS indicates that this watershed is only 1.0 km² (0.4 mi²). Note, the discrepancy in watershed size between what was calculated in ArcGIS in this assessment and what was originally reported by Barber (2003) may be due to manmade alterations that have since occurred to the channel at the base of the slope or possibly due to the difference in resolution of the original DEM used. It appears that part of this unnamed drainage once flowed to the east towards the Nature Center and has since been redirected to flow more south toward Exit Creek (see Figure #9 in Barber (2003) and refer to Plate 25). The watershed delineation for this assessment was completed using the watershed tool from the Spatial Analyst Toolset in ESRI's ArcGIS 10.1. A 2-meter DEM (by AeroMetric) created from 2008 LiDAR data was used as the base layer. A watershed boundary was also created for Exit Creek. Both watershed boundaries were created from the 2-meter DEM and used visually-placed pour points immediately upstream of confluences. Exit Creek's pour point was placed just upstream of the Exit Creek and Resurrection River confluence, and unnamed drainage's pour point was placed just upstream of its confluence with Exit Creek. These watershed boundaries in relation to the larger area are displayed in Plate 25, while a closer view of the unnamed drainage watershed is available in Plate 26.

Martin (2005) noted that the unnamed drainage which joins Exit Creek in a series of intermorainal channels experiences the highest flows during fall months which commonly have larger and more frequent rainfall events. Martin (2005) also describes several trail stream crossings from the Nature Center to the end of the trail as too shallow and poorly formed. These include undersized culverts, insufficient bridge-spans, and two channel blockages by trail fill. Flooding has occurred in this area since the construction of the Nature Center. In response to some of the earliest flooding after the construction of the Nature Center, a diversion (temporary dike) was placed upstream of the Nature Center and culverts installed under the development to convey water past the trails and Nature Center. Martin (2005) suggested that if all unnatural flow restrictions were removed and natural processes left to keep re-working glacial deposits, infrastructure would be protected from smaller floods, but not from a large-magnitude event such as a 100-year event. In fact, Martin (2005) suggested that mitigation from such an extreme event is probably not possible. Martin (2005) recommended channel blockages from trail fill be opened and, to protect the Nature Center, the construction of a small levee on its upslope side. In recent years, the unnamed identified by Barber

(2003) is no longer the primary source of trail erosion, rather from 2009 through 2013, Exit Creek itself has been the primary source of erosion (D. Kurtz, pers. comm. 2014).

Herman Leirer Road

In 1983, when the Exit Glacier area was still a proposed development area and before the vehicle bridge construction, Sloan (1983) predicted that flood waters could overtop the existing road and could cause washouts during a large flood, but concluded that this was only a minor risk because of their infrequency, both from the Resurrection River and Exit Creek. Later, Sloan (1985) reported that flooding had already occurred in the Exit Glacier area, indicating the risk may have been greater than originally thought. At the time, Sloan (1985) concluded that some minor risk existed to roads and structures from large, infrequent floods.

Over-road flooding was also reported by Tetreau (1993). In 1993, multiple park staff completed a hydrology survey of the Exit Creek delta and adjacent area to the north that was previously known to be occupied by beavers (Tetreau 1993). They used a 200-ft tape to measure the linear extent of flood waters along Herman Leirer Road, where high water was noted to follow old stream channels that eventually intersect the road bed. Tetreau (1993) created a planimetric drawing of the area and noted significant features along the road transect, starting where floodwater channels intersected the road at 49.4 m (1,632 ft) west of the of the western end of Resurrection River Bridge. Tetreau (1993) also observed in a 1950 aerial photo that an area to the north of the road just west of the bridge was likely an active channel of Exit Creek in 1950, and then in a 1984 aerial photo found that same channel area appeared abandoned. The author suggested that the abandonment could have been from “aggradation to the north side of the road and/or the construction of the original road.” This suggests that the road may have been acting like a dike to flood waters from Exit Creek since its construction.

Barber (2003) also noted previous over-road flooding events from Exit Creek and concluded that a risk for continued road inundation remained despite road repairs and the installation of several culverts after a 1995 flooding event washed a portion of the road away. While there was a stated risk of water overtopping the road from Exit Creek, the author asserted that Resurrection River posed a greater risk in terms of floodwaters damaging Herman Leirer Road. The author delineated an area of risk for over-road flooding in a 2003 aerial photo. This was the same approximate area where the extents of two 2011 over-road flooding events were measured along Herman Leirer Road. This general over-road flooding area and specific 2011 road flooding extents are illustrated in a map in Plate 27. The location of the lone culvert in the road flooding area marks the approximate location where Tetreau (1993) measured flood water channels intersecting the road (49.4 m [1,632 ft] west of the western end of the Resurrection River Bridge). Additional culverts exist in this area, but GPS locations are currently not available. Major floods (high water events) were noted to occur in Exit Creek at times and the Resurrection River on 16 October 1986 and in 1995 (Barber 2003).

According to the Kenai Peninsula Borough (KPB) (2010), major flooding occurred in the Resurrection River (Exit Creek flows into it just downstream of the bridge) in 1946, 1961, 1962, 1977, 1986, 1989, 1993, 1995, 2002, 2006, 2007, and 2009 (KPB 2010), as well as 2010, 2011, 2012, and 2013 (Deb Kurtz, pers. comm. 2014) . The 2006 flooding was especially severe in the Seward area; heavy rains and high winds on 8 October 2006 caused flooding and mudslides which resulted in widespread road, bridge and other infrastructure damage (KPB 2011). Flood records are available for

the Resurrection River specifically at the Resurrection River Bridge (also referred to as the Exit Glacier Bridge), near to where over-road flooding has been known to occur (Table 31).

Table 31. Flood categories and historical crests for the Resurrection River at Exit Glacier Bridge. Data from the National Weather River Forecast Office through 2012.

Flood Category	Stage (ft)	Stage (m)
Major flood stage	20.00	6.10
Moderate flood stage	18.50	5.64
Flood stage	17.50	5.33
Action stage	16.00	4.88
Historical crests		
19 Sept. 2012	19.97	6.07
09 Oct. 2006	19.85	6.05
20 Sept. 1995	19.36	5.90
23 Oct. 2002	18.50	5.64
9 Sept. 1995	17.90	5.46
1 Oct. 2003	16.32	5.97
14 Sept. 2002	16.20	4.94
3 Oct. 2004	15.86	4.83
15 Sept. 2006	15.67	4.78
14 Sept. 2008	15.37	4.68
16 Dec. 2005	15.05	4.59
17 June 2004	13.94	4.25
11 June 2007	10.80	3.29

It is possible that some of the floods in the Resurrection River reported by KPB (2011) and stage heights considered flood stage by NOAA at the Resurrection River bridge (Table 31), would also present flooding issues along Exit Creek in KEFJ. However, Barber (2003) states that the Resurrection River and Exit Creek did not normally peak at the same time, but the author believed that greater flood risk to Herman Leirer Road existed from Resurrection River flooding than from Exit Creek flooding. Exit Creek stage heights have been recorded since 2007 and are available from NOAA's Advanced Hydrological Prediction Center website, however, the only flood stages established for these stage heights are a bankful gauge height at Exit Creek of 7.2 m (23.5 ft). However, NOAA warns that trails near the glacier terminus may flood at lower stages. The SWAN Freshwater Monitoring Program has made multiple attempts to obtain long-term flow measurements using in-stream instrumentation, but flow conditions have, for example, buried equipment in sediment, preventing measurements except during the lowest of flows. NOAA set up a manual stage height monitoring technique (using tape-down methods) that KEFJ interpretive staff utilize and report to NOAA each day during the summer. In 2014, USGS hydrologist, Janet Curran and others collected RTK GPS points in and around Exit Creek in an effort to further understand Exit Creek fluvial morphology.

For over-road flooding, Martin (2005) noted that the original road grade experienced flooding and part of it was washed out during the 1995 flooding event because the road bed was made entirely of fill and did not allow enough passage. Martin (2005) asserted that the culverts installed after the 1995

flooding (still in place at the time of the author's assessment) did not allow enough water exchange between Exit Creek and the Resurrection River, resulting in reduced flood conveyance (i.e., more frequent over-road flooding and erosion). Martin (2005) suggested that while the risk of flooding in this area may not represent a life-threatening risk, it could pose a hazard in potentially trapping individuals behind flood waters. Mid-summer floods result in road closures and halt all visitor activities in the Exit Glacier area to the detriment of visitor experience and commercial guiding companies.

Multiple surveys/assessments have warned that flood waters over-topping the road could cause damage to the road (Sloan 1985, Tetreau 1993, Barber 2003, and Martin 2005). Flooding events have continued to occur in the section of the road just west of the bridge since 1995. An example of active over-road flooding from September 2012 is shown in Photo 11. Recent flooding events have resulted in the deterioration of the road profile and have inundated under-road culverts installed in 1995 (Photo 12). Several flooding events have occurred in 2009, 2010, 2011, and 2012, with many of the floods resulting in road closures. Most of the 2009-2012 flooding events were in late summer through fall (August – October). For example, over-the-road flooding occurred with road closures during the following days: 1 August 2009, 16 August and 2 October 2010, 8 August and 7 September 2011, and September 2012. According to data from the Harding Icefield Remote Automated Weather Station (RAWS), most of these floods were due to large and/or repeated rainfall events. Plate 27 provides a map depicting flooding extents along the road from two recent flooding events, 26 July 2011 and 4 August 2011.



Photo 11. Example of over-road flooding on Exit Creek Road in KEFJ, just west of the Resurrection River Bridge at Exit Creek. (Photo courtesy of Western Federal Lands Highway Division, U.S. Dept. of Transportation) (WFLH 2013).



Photo 12. Flood damage and undersized culvert under Exit Glacier Road in KEFJ (Photo courtesy of Western Federal Lands Highway Division, U.S. Dept. of Transportation) (WFLH 2013). The channel along the side of the road in this image is represented by a straight stream channel path displayed in Plate 29.

Western Federal Lands Highway Division (WFHD) engineers have provided a short-term solution designed to reduce water depths and flow velocities on the roadway (PEPC 2012). This includes the installation of 670 m (2,200 ft) of barriers on the south side of the road, a 1-m (3-ft) thick layer of riprap along the roadway shoulder and fore slope (Photo 13), asphalt repairs, and the installation of nine riprap barbs. This installation was completed in 2013. These efforts are intended as an interim solution to protect the road while further study of the area's hydrology continues.



Photo 13. Riprap installation along Exit Glacier Road just upstream from Exit Creek's confluence with the Resurrection River, October 2012. (Photo courtesy of Western Federal Lands Highway Division, U.S. Dept. of Transportation) (WFLH 2013)

Resurrection River Bridge at Exit Creek (Exit Glacier Bridge)

In 2003, Barber (2003) found that no measurable change had occurred in the Resurrection River's hydraulic cross section since the bridge was constructed in 1997. However, USFS (2010) suggests that the effects of aggradation near the bridge present a potential flooding hazard. Sediment derived from upstream creeks such as Boulder, Placer, and Redman Creeks and nearby outwash from the steep alluvial channels of Exit and Paradise Creeks has aggraded near the bridge (a relatively low gradient section of the Resurrection River) and has caused decreased clearance under the Resurrection River Bridge. USFS (2010) warns that if the trend continues, the bridge may not have the clearance for high flows (flood waters) to pass.

4.7.3 Data and Methods

Active Channel Delineation

Historic aerial photographs are used in this assessment to provide indications of active channel positions of the Exit Glacier area. Several dates of historic aerial photography of the area and a satellite image from 2005 are available. Image dates selected for this analysis include 1950, 1961, 1984, 1996, 1998, and 2005. Depictions of active channel positions (boundaries of active channels) from these image dates are presented in Plate 27. The 2005 IKONOS image is considered the most spatially accurate of these images as it is orthorectified (i.e., corrected for topography and sensor angle). The 1961, 1984, and 1998 aerial photos of the Exit Glacier area used in this analysis were georeferenced to the 1996 aerial photo which was georeferenced to 59 visible ground control points.

However, the primary focus of these georeferenced photos was to capture the Exit Glacier terminus and glacial moraines in the area and the ground control points were established accordingly. Therefore, spatial accuracy for some of the photos diminishes near the photo edges, outside of these control points, especially along the eastern edge of Resurrection River (i.e., farther away from the Exit Glacier terminus). Aerial photos from other years are available for the area, but were not chosen for this analysis, because of insufficient geographic extent and/or low image resolution, depending on the image. For example, the resolution for interpreting active channels is inadequate for the black and white aerial photo from 1973. In addition, large spatial shifts in the active channels exist in the 1974 and 1996 true color aerial orthophotos; some of them represent erroneous horizontal shifts of approximately 100 m into the steep bluff immediately to the north and east of the Resurrection River Bridge. Therefore, active channels were not delineated using these aerial photos.

In the delineation (photo interpretation) of active channels for this assessment, the definition of active channel follows that of Montgomery and MacDonald (2002, p. 7): “the portion of a channel that is largely un-vegetated, at least for some portion of the year, and inundated at times of high discharge”. That is, the active channel is generally free of vegetation because it is influenced by frequent flows that are capable of moving sediment. It was decided to identify only the active channels in each aerial photo and not the wetted channel, because as Rapp and Abbe (2003, p. 18) state, “the unvegetated channel (active channel) is more consistent to use than the wetted area because the unvegetated channel represents recent bed disturbance independent of flow conditions at the time of the aerial photo.” In addition, the wetted channels are only visible in some of the more contemporary, higher resolution images. However, wetted areas or channels in aerial photos can help to approximate thalweg (line of steepest descent along a stream bed) locations. If wetted channels are visible in future high resolution images they could be used with a LiDAR DEM to approximate water surface slope (Rapp and Abbe 2003), and therefore provide additional information regarding changes in hydrologic conditions.

Rapp and Abbe (2003) suggest some limitations of planimetric analyses (the active channels delineated as a part of this assessment are planimetric in nature). The following are some general limitations offered by Rapp and Abbe (2003), but applied specifically to this assessment: 1) poorly registered images (this is a bit of a concern for accuracy and consistency of active channel locations namely in the eastern portion of the images, near the east side of the Resurrection River); 2) planimetric analyses do not measure or account for vertical channel movement (this is where repeat high resolution LiDAR DEMs and/or Real Time Kinematic [RTK] surveys could help in the future); 3) depending on resolution of the images and collateral data, active features such as secondary channels that are subject to channel occupation may be obscured in the photo and field visits may be necessary to identify these (for some of the early aerial photos of the area, image resolution is such that some small channels to the north of Herman Leirer Road may not be visible); 4) ideally, images used for this delineation would be of very similar scales, but scales vary : 1950 = 1:40,000, 1961 = 1:15,840, 1984 = 1:65,000, 1998 = 1:30,000).

The Exit Creek area is a hydrologically dynamic area, where sediment that appears to be the result of recently flowing water also occurs outside the main, braided channel of Exit Creek and outside of the

Resurrection River. These areas are also included as active channels interpreted for each photo, though it is unclear if all of these areas represent perennial or even intermittent channels or if they may be older un-vegetated or sparsely vegetated glacial deposits. It was also found to be very challenging to interpret a boundary of what might be considered the floodplain or riparian areas in the relatively high gradient, high sediment supply systems represented by Paradise and Exit Creeks.

DEM-derived GIS data (terrain analyses)

DEM-derived hydrology GIS layers were created using ESRI's ArcGIS 10.1 toolset, Spatial Analyst. The 2-meter Harding Icefield DEM (most of the northern half of the Harding Icefield), created by Aerometric was subset (reduced in area) to cover the Exit Creek watershed. The original, bare-earth DEM was created from LiDAR data collected 30 August 2008. The reported vertical accuracy of this DEM is 0.35 meters or better. It was used to create the following GIS datasets: a linear surface flow network; two watersheds, one of Exit Creek and one of the unnamed drainage noted by Barber (2003) and Martin (2005) as being the source water for high flows that have affected trails near the Nature Center; and basins (areas of zero slope).

To create these datasets, multiple GIS tools and process steps were employed. First, the subset DEM was "filled" to create a DEM for which surface flow can be modeled. Then, from this filled DEM, a flow direction raster, a flow accumulation raster, and stream raster were created. The stream raster was created by reclassifying the flow accumulation raster using a flow accumulation threshold of 1,900. The resulting stream raster and the flow direction raster were then used to create a stream order raster using the Shreve method of ordering stream magnitude. Lastly, stream order raster was converted into a vector GIS dataset (lines) to represent a network of stream channels in the Exit Creek area. The 1,900-cell threshold represents a fairly dense representation of the stream channel network to include and visualize small channels that may be largely intermittent but convey surface flows during high flow periods in the area. In addition, while the entire watershed of Exit Creek and some of the stream channels just to the north of Herman Leirer Road and west of the Resurrection River are within the extent of the 2-meter DEM, the DEM's geographic extent is not sufficient for creating an accurately modeled surface flow network for the Resurrection River and therefore, stream order representations for the Resurrection River are not accurate in this document.

Watershed delineations for the unnamed drainage and Exit Creek were also completed using Spatial Analyst. First, pour points for each watershed were visually selected using the aforementioned stream channel network overlain on available 2008 ortho imagery. The points were identified immediately upstream of their confluences with the next downstream channel. In the case of the unnamed drainage, this was located just upstream of where the stream channel network indicated its confluence with Exit Creek's main channel, and for the Exit Creek pour point, just upstream of its confluence with the Resurrection River. Each of these pour points and the flow direction raster were used as inputs to the "Watershed" tool in ESRI's Spatial Analyst to identify each individual watershed. Both outputs were then converted to vector datasets (polygons) and their areas calculated (Exit Creek Watershed and Unnamed Drainage Watershed). See Plate 25 for an illustration of the watersheds and the stream channel network in the greater Exit Creek Watershed area; see Plate 29 for

a larger scale (closer view) depiction of the stream channel network in and around the Exit Glacier Area.

Basins (i.e., depressions in the DEM) were also identified in the DEM using Spatial Analyst. This was completed by creating a slope layer (% slope for each cell) from the filled-DEM and reclassifying cells with zero percent slopes to a value of 1 and all others to a value of 0. Basins could provide indications of where water might pool or may indicate the existence of a wetland in the area (Plate 29).

4.7.4 Measure(s)

- Changes in horizontal channel position

Other Exit Creek hydrology related measures of interest to KEFJ include changes in riparian, vegetation, aggradation rates, total annual discharge, average daily discharge, peak discharge and timing, center of mass date, date of spring pulse, and channel position.

Exit Creek is a water body identified by SWAN for long-term monitoring (Shearer and Moore 2011). However, the dynamic nature of Exit Creek (e.g., variable flow, debris flows, sedimentation, and freeze/thaw cycles) has caused problems with keeping monitoring instrumentation in place long enough to obtain consistent, high quality in-stream measurements (Moore and Shearer 2011). During 2010 data collection, a pressure transducer became buried in sediment and data were therefore unusable. This is similar to previous equipment issues where instruments moved with channel migration and experienced siltation problems during some previous deployments (Shearer and Moore 2009). One of the goals of the freshwater monitoring program of SWAN was to collect stage and discharge data to develop a stage/discharge rating curve for Exit Creek, but data collection has so far been restricted to just the lowest of flows (Moore and Shearer 2011). SWAN and KEFJ will continue to explore other methods for long-term monitoring that do not involve in-stream instrument deployments. They are currently exploring the use of time-lapse photography in the Exit Creek stream corridor that could capture the progression and timing of glacial melting, stream rise, peak flows, and freeze events (Moore and Shearer 2011).

4.7.5 Current condition and trend

Changes in Channel position - Photo-interpreted Active Channels

Exit Creek is a glacial stream primarily represented by braided channels. Knighton (1998) defines braided channels as streams or channels that have two or more low-flow channels divided by bars that become inundated at bankfull stage, and channel positions that shift frequently. Four conditions exist in these braided channels that allow for their continued existence: 1) abundant bed load or high sediment supply, 2) erodible banks; 3) variable discharge; and 4) high stream power (Knighton 1998). The most active channels are topographically the lowest and abandoned channels are higher in comparison, but these can shift frequently with changing sediment loads and discharges (Knighton 1998). In testing a few locations in the 2-meter DEM, the differences in elevation between active channels and abandoned channels in Exit Creek is relatively low, sometimes less than 1 meter (1 -2

ft). According to the 2008 2-meter DEM, the active channel of Exit Creek is of relatively high gradient, with slopes of 1.5 to 4.5%.

During high water periods, Exit Creek is known to shift and rise to follow old stream channels that intersect the road (Barber 2003). Barber (2003) posed the question of what degree of risk there was that the Exit Creek channel would migrate to the north and cut into and across the road. Barber's assessment at the time was that while the area north of the river channel (north of the road, where summer 2011 flooding occurred) was generally upland, the primary risk was water overtopping the road, potentially causing severe damage. Using historic georeferenced aerial photos and IKONOS satellite orthoimagery of the area, multiple, historic active channels were identified (Plate 27). The interpreted, active channels indicate that an area just to the north and east of the recently (2011) flooded road area may have been part of the active channel in 1950, as much of this area was either barren or sparsely vegetated in the 1950 aerial photo. Tetreau (1993) also made this observation in examining a 1950 and a 1984 aerial photo, stating that the area north of the road appeared to be active or recently active and abandoned by 1984, and that the abandonment of these channels might have been from aggradation and/or from construction of the original road. Over time, it appears vegetation has established in this area and succeeded into taller shrub and forest vegetation, indicating while peak flows may still affect this area, scouring surface flow has been reduced.

Three different areas of Exit Creek appear with different channel position patterns in comparing the position of the active channel in 2005 with previous years. These seemingly distinct areas include a channel narrowing area associated with the glacial outwash fan, a stable (in terms of horizontal position) channel section, and an area in which the channel appears to be migrating slightly to the south (Plate 28). The active channel has narrowed from 1950 to 2005 in an area near the receding glacier terminus. Sloan (1983) described this area as experiencing frequent and sudden channel shifts from erosion and sediment depositions; in comparing 1950 and 1978 aerial photos, the author found the reach becoming more sinuous over time. However, over a long time period the channel appears to have become more consistently established in the older, downstream parts of the outwash fan and vegetation has established itself along the channel in this area. Just downstream of this, a short section of the active channel, approximately 475 m (1,560 ft) long, appears to have remained stable in horizontal position over this period. Barber (2003) also made this observation in viewing aerial photography of the area, stating that where the channel is restricted, it appears to be very stable. Lastly, the active channel area from the "stable channel area" downstream to Exit Creek's confluence with Resurrection River appears to have migrated slightly to the south. Despite the apparent southerly migration of the active channel over the last 50 years in this section, the extent of over-road flooding may have increased since 1993. The culvert point in Plate 27 represents the approximate location where Tetreau (1993) stated flood channels met the road. This location was approximated by measuring the road starting at the western edge of the bridge, 497 m (1,632 ft) to the west along the road. The 2011 flooding event extends approximately 366 m (1,200 ft) farther upstream than where Tetreau (1993) noted the flood channel met the road in 1993.

DEM-derived Hydrology Layers

Unnamed drainage

The DEM-derived stream channel network indicates the primary stream channel for the unnamed drainage noted by Barber (2003) and Martin (2005) (i.e., the source water for high flows that have affected trails near the Nature Center) presently (as of 2008) follows a path to the south. This is apparently contrary to what is indicated by Barber (2003) and Martin (2005). Martin (2005) refers to this stream channel (drainage) as flowing towards the Nature Center and causing flooding problems there. It appears that primary stream channel or flow path represented by the unnamed drainage has since been diverted to the south, away from the Nature Center. It also appears that the stream channel or flow path ultimately joins Exit Creek earlier than it would have before the diversion was installed. This could explain, in part, why the estimated area of the unnamed drainage reported by Barber (2003), and again by Martin (2005) is larger than the resulting watershed area found by the GIS analysis conducted as a part of this assessment. Barber (2003) originally reported that drainage (watershed) area of the unnamed watershed was 2.8 km² (1.1 mi²) and results of the GIS watershed delineation indicates the watershed is only 1.0 km² (0.4 mi²).

Exit Creek

The surface flow network (sometimes referred to as a stream network, though these lines are more accurately modeled flow paths) created for this assessment, using an accumulation threshold of 1,900 (1,900 cells, 2x2 meters) represents a relatively dense flow network. These data do not indicate the potential perennial or intermittent nature of flow within these channels; however, the larger the stream order (a Shreve stream order was used here), the more likely that a given channel will be perennial in nature. Likewise, many of the smaller stream channels (lower Shreve stream order number) identified in this GIS layer likely represent very temporary channels, especially those falling within the active channel areas of Exit Creek, as flow conditions and therefore sediments change quickly in this system. However, this stream channel network provides a visualization of flow paths as there were during late August 2008 (date of LiDAR collection). If future LiDAR data are acquired and DEMs, surface flow networks, and other DEM-derived products are created, changes in the positions of active channels and thalwegs may become apparent.

The resulting watershed area of Exit Creek (also using Spatial Analyst) was 4.9 km² (1.89 mi²).

NOTE: The entire watershed of Exit Creek and some of the surface flow paths just to the north of Herman Leirer Road and west of the Resurrection River are within the extent of the 2-meter DEM. However, the DEM's geographic extent is not sufficient for creating an accurate surface flow network for the Resurrection River.

4.7.6 Data Needs/Gaps

Long-term Exit Creek flow data have been difficult to obtain using in-stream instrument deployments (Moore and Shearer 2011). However, SWAN scientists are continuing to work with the park to determine viable methods to obtain stream flow estimates and stage heights. For example, NPS staff are currently testing the application of time-lapse photography to understand variations in local flow conditions.

Repeat, field-collected cross-section and bed material data could be collected and analyzed to understand erosion and accretion rates at various locations along Exit Creek and near the Resurrection River Bridge. This could also be combined with repeat LiDAR data collection for the area. The Aerometric LiDAR-derived 2-meter DEM for this area appears to be sensitive enough to provide reasonable accuracy for flow modeling and, if repeated, it could help further understanding of sediment budgets (e.g., Exit and Paradise Creeks transporting sediment to the Resurrection River). USFS (2010) reports that LiDAR data was collected in the Resurrection River Watershed area in 2006 and 2009, recognizing the utility for future updates to area floodplain maps.

4.7.7 Overall Condition

The condition assessment scoring methodology is not employed for this component because only one measure is examined, and information presented for this component provides a background for the issue of flooding in the Exit Glacier visitor use area and a preliminary understanding of channel position using historic aerial photography. Instead, the following acts as a summary of the primary issues in terms of data collection and flooding risk in this area.

Flow conditions in Exit Creek have been difficult to measure using typical long-term monitoring equipment as the creek is part of a very dynamic system with high gradients and large sediment loads. The hydrology of the larger Exit Glacier area including tributaries of Exit Creek (e.g., the unnamed drainage) have also been a challenge in terms of predicting high flows and flood mitigation in relation to roads and trails in the area. While historic and contemporary active channel mapping created as part of this assessment does not necessarily provide new information for this particular area's flooding issues, the creation of GIS products derived from a contemporary, high resolution DEM, such as the modeled stream channel network and the delineation of the unnamed watershed discussed by Barber (2003) and Martin (2005), provide a new visual aid of the area's surface hydrology. With further analysis using the 2-meter DEM as a base and possibly with field-collected cross section and RTK data, the park could advance their understanding of the Exit Glacier area's surface hydrology and plan for predicted future high flows.

The historic active channels (photo-interpreted GIS data) confirm earlier assessments that in 1950, an active channel or the recently active channel was just to the north of the section of Herman Leirer Road that has experienced repeated inundation (Plate 27). This might act as visual evidence that the original road bed was situated within a recently active channel area and the road may still need modifications in order to handle high flows (to convey water north and south of the road in this area between Exit Creek and the Resurrection River). In fact, the geographic extent of over-road flooding may have increased since Tetreau's (1993) planimetric measurements, because the 2011 flood event extended farther to the west (upstream) of the position along the road where Tetreau (1993) first noted flood channels meeting the road. The inundation of the road has resulted in road closures and therefore closure of the only public access to the Exit Glacier area and the only access to park lands via the road system. This represents a significant concern for the park. The Exit Glacier Area Plan (NPS 2004, p. 4) states "that natural processes (e.g., flooding, fire) may be interrupted on a limited basis to protect resources and infrastructure". Recent road work has been completed to provide some flood attenuation and road protection during high flows in this flood prone area of the road. During the fall of 2012 and the spring of 2013, crews installed riprap and repaired the road to prevent additional road damage from erosive high flows. This, however, is intended to be a short-term solution while further study of the area's hydrology can be conducted, especially as it relates to flood hazards to the road, trails, and other infrastructure in the area. USGS researchers are in the process of studying geomorphic controls on Exit Creek.

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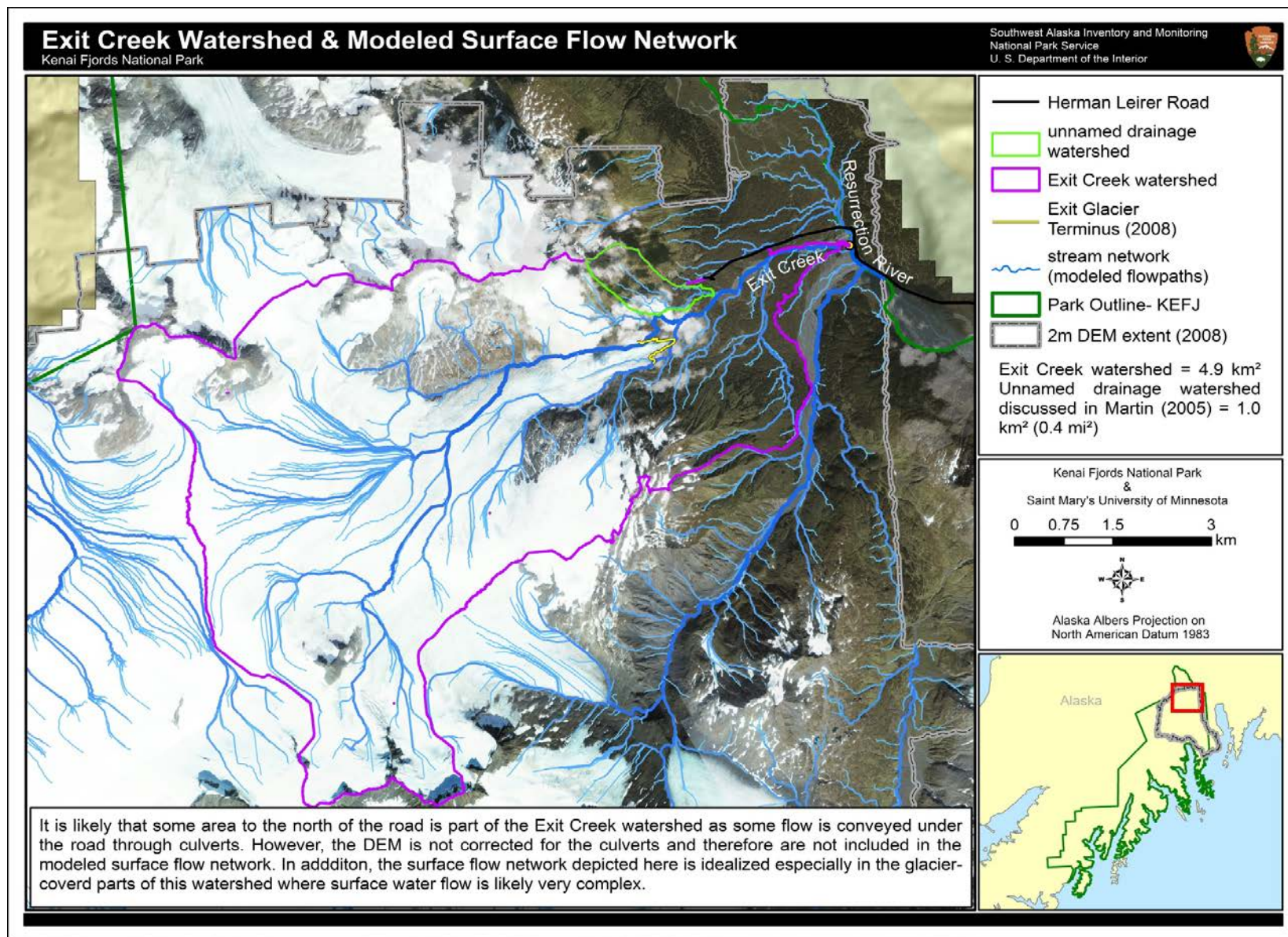


Plate 25. Exit Creek watershed boundary and modeled surface flow network created using a 2-meter DEM.

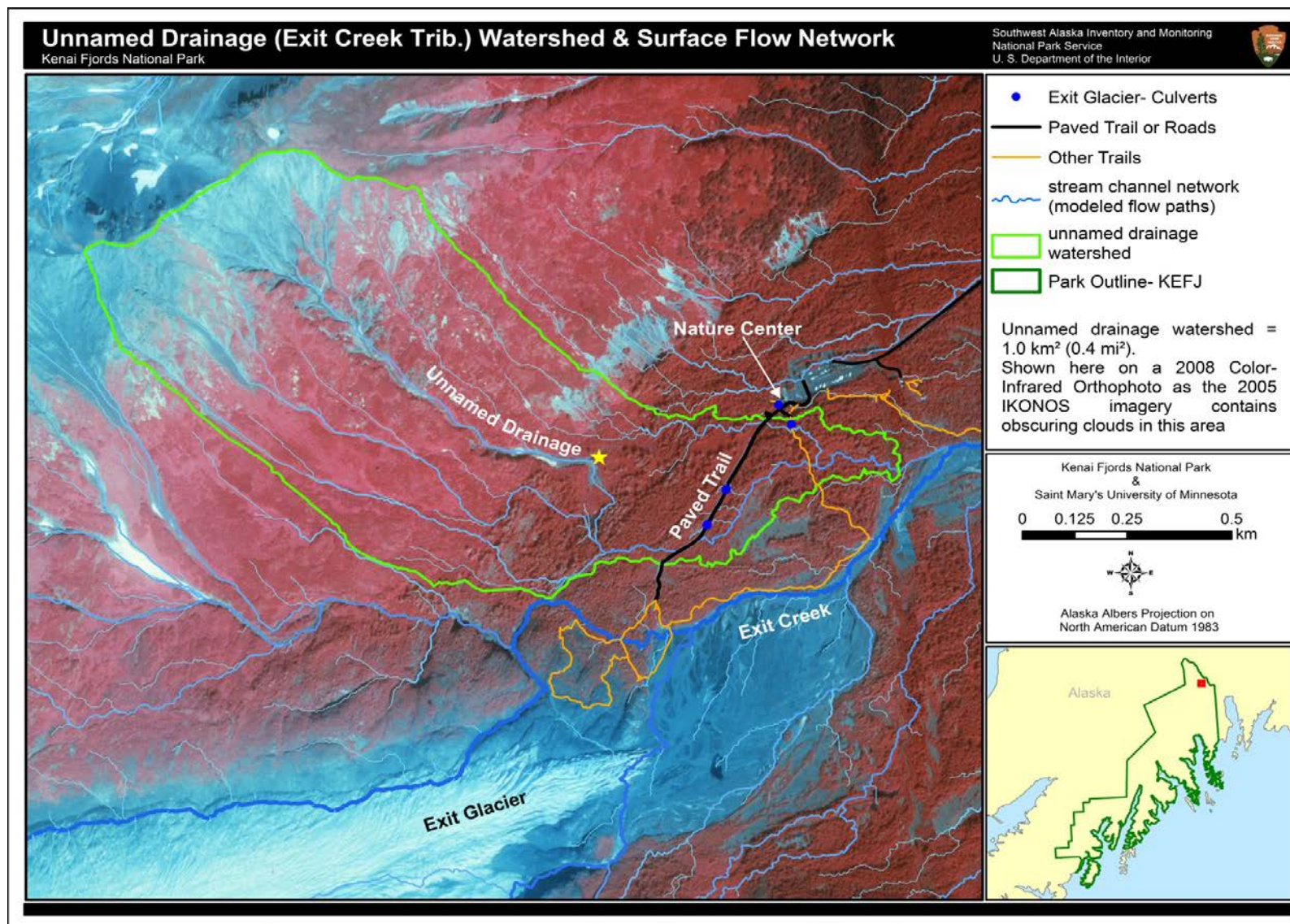


Plate 26. Watershed boundary of an unnamed drainage (a tributary of Exit Creek) and a modeled surface flow network created using a LiDAR-derived 2-meter DEM in relation to Exit Glacier Area trails. The yellow star in the map indicates the location of a potential flow path alteration, created to avoid the Nature Center, a possible reason for the differences of watershed area, ArcGIS calculated vs. reported by Barber (2005).

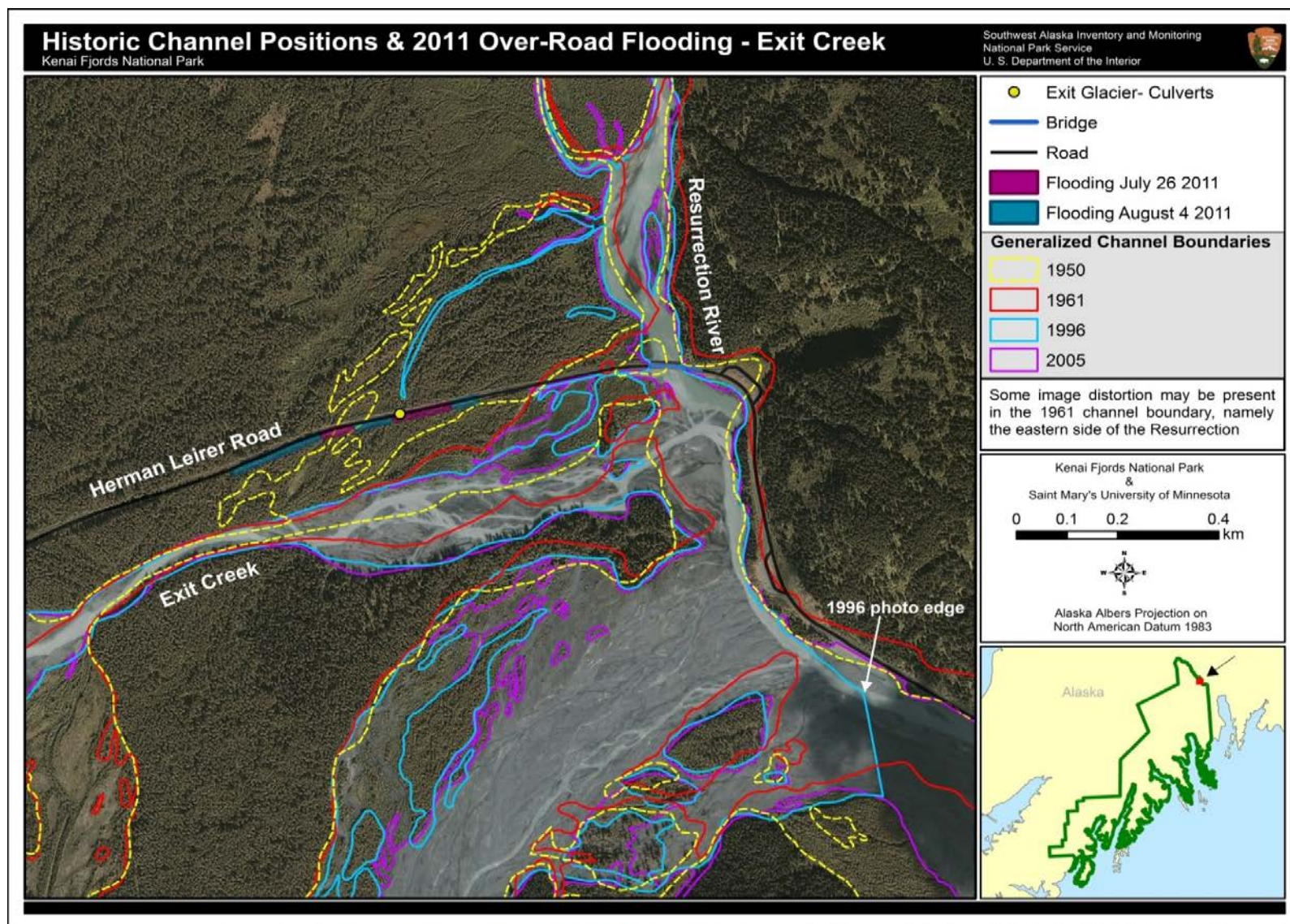


Plate 27. Photo-interpreted/delineated active channel boundaries from 1950, 1961, 1996, 2005 aerial images along a recently flooded section of Exit Creek Road. The location of the 1961 channel boundary (red) along the east side of the Resurrection River is the result of poor 1961 image alignment, not actual channel position, as the image was georeferenced to points focused nearer to the glacier terminus.

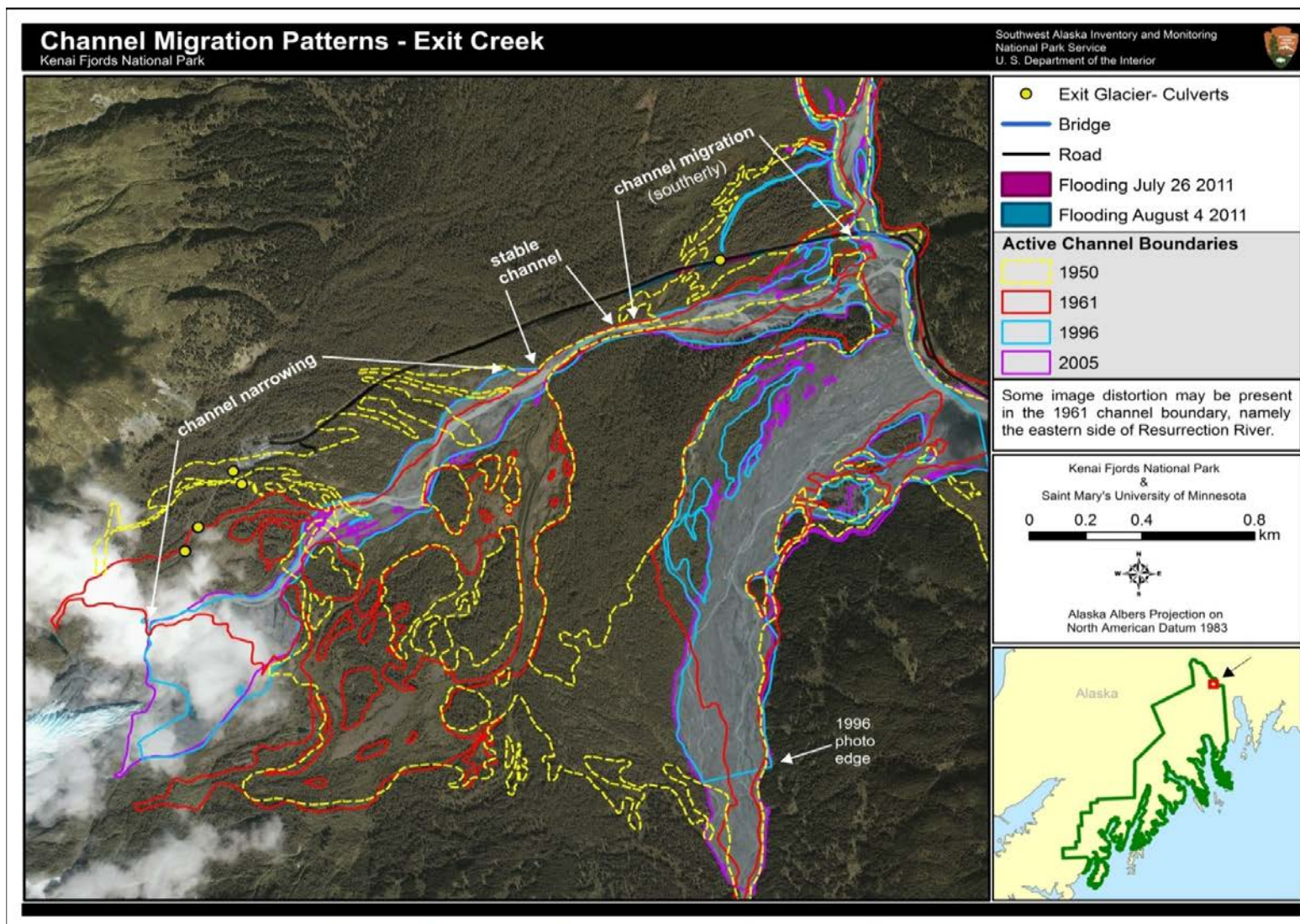


Plate 28. Channel migration patterns of Exit Creek in 1950, 1961, 1996, and 2005 images, shown here overlain on the 2005 IKONOS orthoimage mosaic of the park. Notice the general area of channel narrowing near the present-day (2005) glacier terminus, the small stable channel area, and the area where the channel has migrated slightly to the south as Exit Creek nears its confluence with Resurrection River.

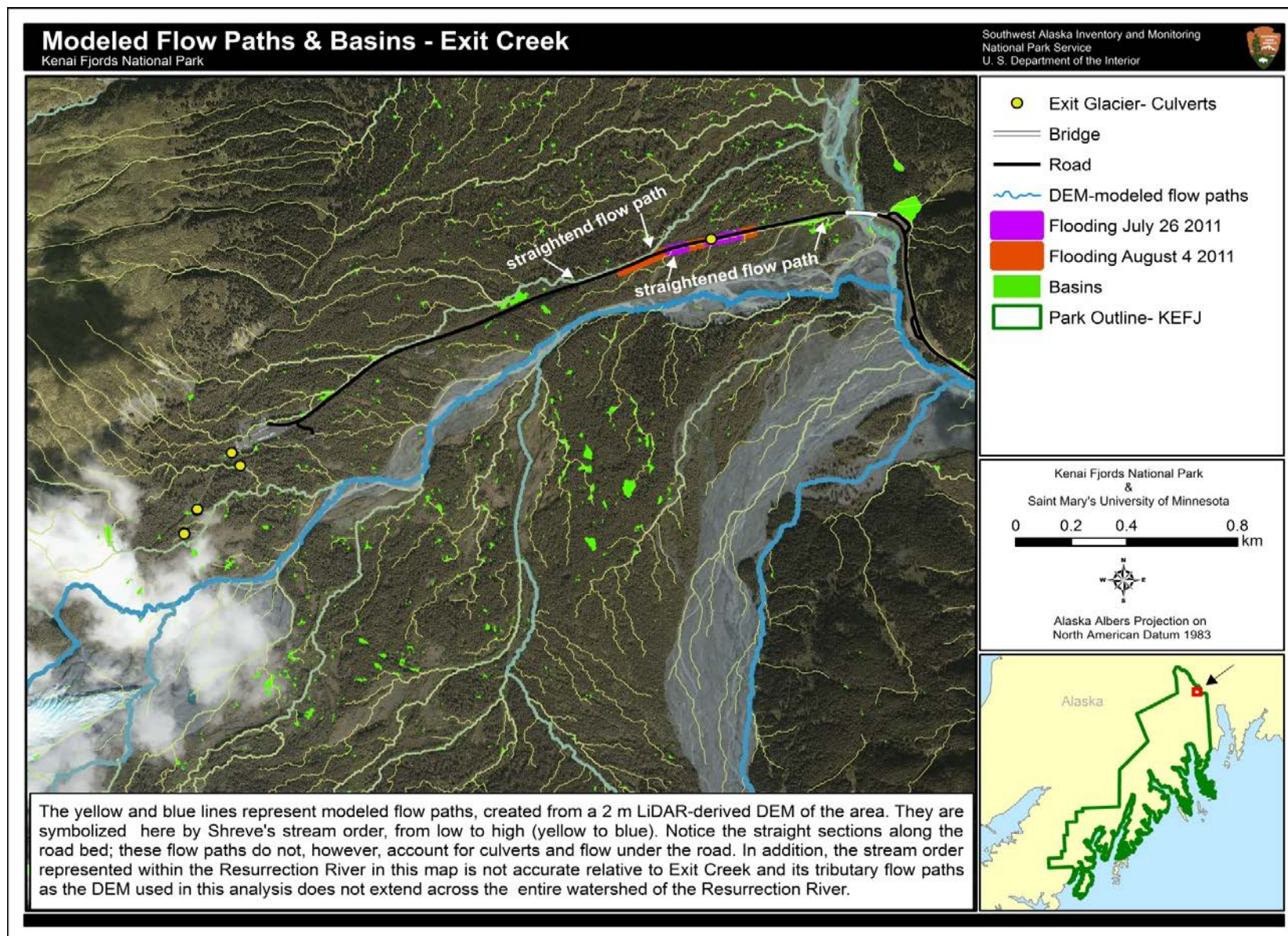


Plate 29. Modeled surface flow network, basins, and recent over-road flooding along Herman Leirer Road in KEFJ.

4.8 Glaciers

4.8.1 Description

Glaciers cover approximately 1,500 km² of KEFJ, more than half of the park's total area (Giffen and Lindsay 2011). These glaciers are part of the Harding Icefield, covering the northeastern part of the park, or the Grewingk–Yalik Glacier Complex in the southwest corner. The park's enabling legislation (ANILCA section 201[5]) specifically mentions the purpose of KEFJ is to “maintain unimpaired the scenic and environmental integrity of the Harding Icefield, its out flowing glaciers and coastal fjords and islands in their natural state” (NPS 1984).

The Harding Icefield, formed in the Pleistocene Epoch, covers 1,813 km² (700 mi²) of the Kenai Mountains, and connects over 38 glaciers, which terminate in tidewater, on land or in lakes (Hall et al. 2005). Reaching elevations in excess of 1,500 m (5,000 ft), it is the largest ice field wholly contained within the United States; slightly more than half is within the boundaries of KEFJ (Rice 1987, Aðalgeirsdóttir et al. 1998). Exit Glacier, located in the northeast corner of the ice field, is the only glacier of the Harding Icefield accessible by road (Photo 14, Rice 1987). During the 19th century Exit Glacier almost reached the Resurrection River, which is approximately 2 km (1.2 mi) below its current location (Huse 2002), and from 1950 to 1990, the glacier retreated approximately 490 m (1608 ft) (Aðalgeirsdóttir et al. 1998). The Grewingk–Yalik Glacier Complex is located a few kilometers southwest of the Harding Icefield. It is approximately 35 km by 10 km (21.7 mi by 6.2 mi); about one third resides within the KEFJ boundary, and it reaches an elevation of 1,400 m (4593 ft) above sea level. There are many outlet valley glaciers, which terminate on land and in lakes. However, this complex does not have any tidewater glaciers (Giffen et al. 2007).



Photo 14. The terminus of Exit Glacier in 2009 (NPS photo by Fiona Ritter-Davis).

Glaciers are sheets of recrystallized ice that flow under the influence of gravity (Marshak 2005). The formation of a glacier requires three conditions: abundant snowfall, cool summer temperatures, and the gravitational flow of ice. These requirements are met at KEFJ, where the Harding Icefield receives an average of 18.3 m (60 ft) of snowfall each year and the maritime weather ensures cool summers (NPS 2010). However, if the slope of the underlying bedrock is greater than 30°, the accumulation of snow will produce avalanches rather than glaciers (Marshak 2005).

In KEFJ, the formation of glacier ice can require four to 10 years (NPS 2010). This process begins with the accumulation of fresh, loosely packed snow containing 90% air, due to the space created by

its hexagonal crystals (Marshak 2005). As new layers of snow accumulate on top of the old snow, pressure increases from the weight, squeezing out air pockets and, over time, transforming the snow into a packed granular material called firn, which contains only 25% air (Marshak 2005). As melting occurs, water recrystallizes in the spaces between grains until the firn is transformed into a solid mass of glacial ice containing only 20% air (Marshak 2005).

Glacier mass balance studies determine the difference between the annual accumulation (all processes that add to the mass, i.e., snowfall) and ablation (all processes that remove mass, i.e., sublimation, melting, and calving) of a glacier during a mass balance year (Veins 1995, NPS 2010, Cogley et al. 2011). A mass balance year is 12 months long, beginning during the accumulation season and lasting until the end of the ablation season (Cogley et al. 2011). If the rate of accumulation is higher than that of ablation, the glacier will advance; however, if the rate of ablation is higher than that of the accumulation, the glacier will retreat (Marshak 2005). The accumulation zone is the area on a glacier where more mass is gained than lost, whereas the area where more mass is lost than gained is known as the ablation zone (Figure 45, Cogley et al. 2011). The accumulation area ratio (AAR) represents the ratio of the accumulation zone to the area of the glacier at the end of a mass balance year (Cogley et al. 2011). Mass balance studies can provide information on the stability of glaciers, runoff predictions, and a measurement of climatic variation and trends (Muirhead 1978).

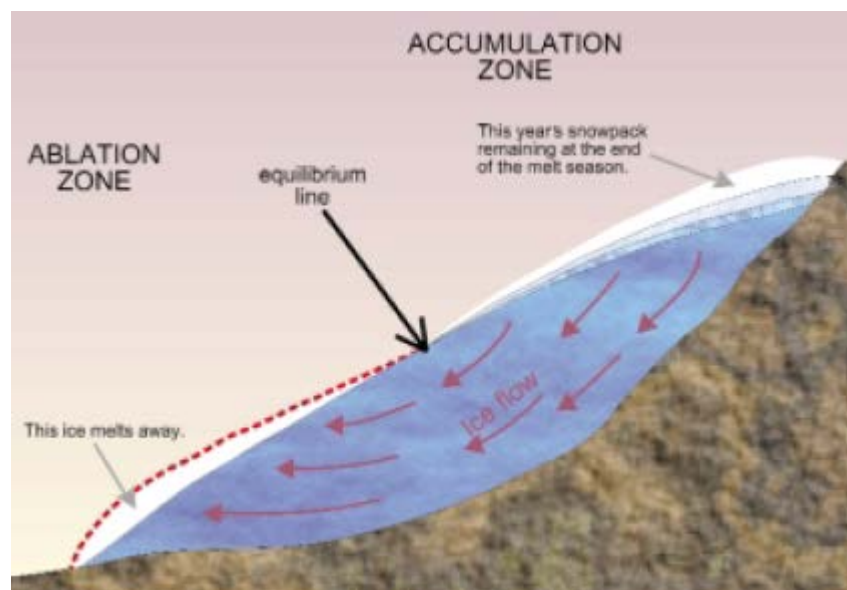


Figure 45. Illustration of a glacier showing the accumulation zone, ablation zone, and equilibrium line (Valentine et al. 2004).

Glacier snow lines define the boundary between the melting ablation zone and the snow covered accumulation zone. Late summer is the end of the ablation season, and during this time, the late summer snow line reaches its highest elevation, called the annual snow line. The annual snow line is closely related to the equilibrium line, which separates the accumulation zone from the ablation zone (Figure 45, Muirhead 1978). The equilibrium line altitude (ELA) is the spatially averaged altitude of

the equilibrium line at the end of a mass balance year (Cogley et al. 2011). The position of the snow line varies depending on the season. During winter, snow covers the entire glacier. As spring thaw occurs, the snow line moves up the glaciers. The amount of accumulation and the ablation rate together determine how far the snow line will move up the glacier before the cycle repeats (Muirhead 1978).

To uphold the park's enabling legislation, the SWAN I&M Program has identified "glacial extent" as a Vital Sign in KEFJ. Utilizing Landsat satellite imagery to monitor glaciers on a park-wide scale, the objective of this Vital Sign is to map the glacial extent boundary on a repeating decadal scale and thus identify areas where glacial cover is stable, growing, or shrinking, and estimate rates of change (Bennett et al. 2006). Glacial processes are very complex and interrelated. The measures identified in this assessment represent some of the metrics used to understand the overall condition of glaciers in KEFJ.

4.8.2 Measures

- Area
- Rate of terminus retreat
- Mass balance (surface elevation)
- Late summer season snow line
- Glacial lake outburst floods

4.8.3 Reference Conditions/Values

Landsat data (1972-81), aerial photography, historic photographs and maps acquired by scientists during early investigations of the park's glaciers provide a baseline for the condition of glaciers in KEFJ.

4.8.4 Data and Methods

Giffen et al. (2007) mapped and compared the extent of ice fields and glaciers in KEFJ by creating GIS shapefiles from Landsat data collected in 1973, 1986, and 2000. Where available, higher resolution satellite imagery and aerial photography were used to assist in the interpretation of the Landsat data.

Molnia et al. (2007) utilized repeat photography to document change at several glaciers within KEFJ. Historic photos (1909) of glaciers currently within park boundaries were found in the USGS Photographic Library. During the summers of 2004-2006, many of these sites were revisited and photos were taken from the same viewpoint as in the 1909 photos.

Arendt (2006) used airborne altimetry to measure surface elevation of 86 glaciers in Alaska, Yukon Territory, and northwestern British Columbia. The airborne altimetry data is then compared with elevation data on the base USGS topographic quadrangle maps (derived from 1950s to 1970s aerial photography) to determine changes in glacier elevation and volume over a 30 to 45 year period.

Airborne altimetry measurements have been repeated in recent years over some Alaska glaciers to identify short-term elevation and volume changes.

Hall et al. (2005) used Landsat imagery from 1973, 1986, and 2002 to explore changes in the Harding Icefield and the Grewingk-Yalik Glacier Complex. They used GIS analysis to calculate and compare glacier areas and terminus positions over time.

Aðalgeirsdóttir et al. (1997) and (1998) created airborne surface elevation profiles of 13 outlet glaciers in the Harding Icefield during 1994 and 1996. The profiles were compared to USGS 1:63,360 topography maps constructed from aerial photography taken in 1950-52 to determine the elevation and volume changes over this time interval. Furthermore, they compared different types of glaciers (land and tidewater terminating) to determine if they respond differently to large-scale climatic change.

Rice (1987) examined changes in the Harding Icefield's areal extent and surface features between the 1950s and 1980s. Rice (1987) mapped the areal extent of the Harding Icefield and adjacent area glaciers using 16 USGS 1:63,360 topographic maps, then used 1984-85 Alaska High Altitude Photography (AHAP) to remap glacier features shown on USGS topographic maps based on 1950-51 aerial photography.

Muirhead (1978) measured annual snow lines for 59 glaciers in the Sargent and Harding Icefields of the Kenai Mountains using five Landsat images. Temperature and precipitation data from four nearby weather stations were also collected during the study period. Other variables used include the distance of the glaciers from the ocean, the aspect with respect to the ocean, and prevailing winds. Then Muirhead (1978) examined the interrelationship between these variables. Finally, a multiple linear regression analysis with annual snow line elevation as the dependent variable was performed to produce several quantitative annual snow line prediction models.

4.8.5 Current Condition and Trend

Area

Rice (1987) reported the areal extent of glacier coverage on the southern Kenai Peninsula experienced a net loss of approximately 123 km² (47.5 mi²) or 5% over a 34-year period (1950 to 1984). The greatest loss occurred at tidewater glaciers near sea level and at 300-600 m (984-1968.5 ft) above sea level along the north and west areas of the Harding Icefield.

SWAN (2009a) states that the Harding Icefield complex covered 1,828 km² (705.79 mi²) in 1986 and 1,786 km² (689.58 mi²) in 2000, which is a net loss of 2.3%. These results are consistent with a similar study conducted by Giffen et al. (2007) (Table 32).

Table 32. Changes in areal extent (km²) between the years 1986 to 2000 at the Harding Icefield, Grewingk-Yalik Glacier Complex, and surrounding glaciers measured using Landsat data * (Giffen et al. 2007).

Location	1986 (km ²)	2000 (km ²)	1986 to 2000 Change in Glacier Cover (km ²)	Percent Change
Harding Icefield main body**	1,828.41	1,786.38	-42.03	-2.3%
Harding Icefield and surrounding glaciers	1,935.03	1,902.79	-32.24	-1.7%
Grewingk-Yalik Glacier Complex main body	423.37	411.69	-11.68	-2.8%
Grewingk-Yalik Glacier Complex and surrounding glaciers	444.81	424.32	-20.5	-4.6%
Harding Icefield and Grewingk-Yalik Glacier Complex and surrounding glaciers	2,379.84	2,327.11	-52.73	-2.2%
Glacier ice within KEFJ boundary	1,388.2	1,366.52	-21.68	-1.6%

*This reflects the removal of areas represented by nunataks or other areas barren of glacier ice but inside of the mapped boundary of glacier extent. ** These numbers are consistent with Aðalgeirsdóttir et al. (1998), who state that the extent of the Harding Icefield in the mid to late 1990s was ~1800 km².

Hall et al. (2005) also conducted an areal extent study of the Harding Icefield and the Grewingk-Yalik Glacier Complex. The results indicated a reduction in ice cover of approximately 3.62% from 1986 to 2002 (78 km² [30 mi²]). Most of the change occurred in the Harding Icefield; the total extent in 1986 was 1,753 km² (677 mi²), and in 2002, it was 1,679 km² (648 mi²). The Grewingk-Yalik Glacier Complex experienced less change; in 1986, the total extent was measured at 403 km² (156 mi²), and in 2002, it was 399 km² (154 mi²) (Hall et al. 2005).

Rate of Terminus Retreat

All glaciers in KEFJ experienced terminus retreat between the 1950s and 2005 (Giffen et al. 2007, NPS 2009). From the early 1950s to 2000, glaciers located in the interior (northward and westward flowing glaciers) had a recession rate of approximately 29 m/yr (95 ft/yr), while coastal glaciers (southward and eastward flowing glaciers) averaged 32 m/yr (105 ft/yr). However, coastal glacier recession increased to 78 m/yr (256 ft/yr) between 2000 and 2005 (Giffen et al. 2007, NPS 2009).

Giffen et al. (2007) measured terminus changes using data collected in 1973, 1986, and 2000. Trends indicated the rate of recession was slightly higher in KEFJ for tidewater terminating glaciers flowing to the east or south, compared to land and lake terminating glaciers that flow to the west and north; the rate of recession is slightly increasing over time (Hall et al. 2005, Giffen et al. 2007). Aialik, Bear, Holgate, McCarty and Northwestern glaciers all flow south or east and terminate in tidewater (except for Bear Glacier, which terminates in a lake). Chernof, Exit, Indian, Kachemak, Killey, Lowell, Nuka, Pedersen, Petrof, Skilak, Tustumena and Yalik are examples of west and north-flowing glaciers, terminating on land or in lakes (Giffen et al. 2007).

Giffen et al. (2007) found that the Pedersen, McCarty and Dinglestadt Glaciers to the east of the Harding Icefield all showed recession between 1951 and 2005, but showed little terminus change from 1986 to 2000. Yalik, Lowell, and Exit Glaciers showed consistent and steady retreat between 1951 and 2005. Between 2000 and 2005, Northwestern Glacier experienced an advance. To the north and west of the Harding Icefield, Tustumena, Truuli, Skilak, Dinglestadt and Kachemak Glaciers showed recession at varying annual rates. However, Skilak Glacier retreated significantly between 1986 and 2000. During this time, Bear Glacier became less secure on its terminal moraine and became buoyant, which may have contributed to an increase in the retreat of its terminus (Giffen 2007). Refer to Figure 46 for locations of major glaciers in relation to the KEFJ boundaries.

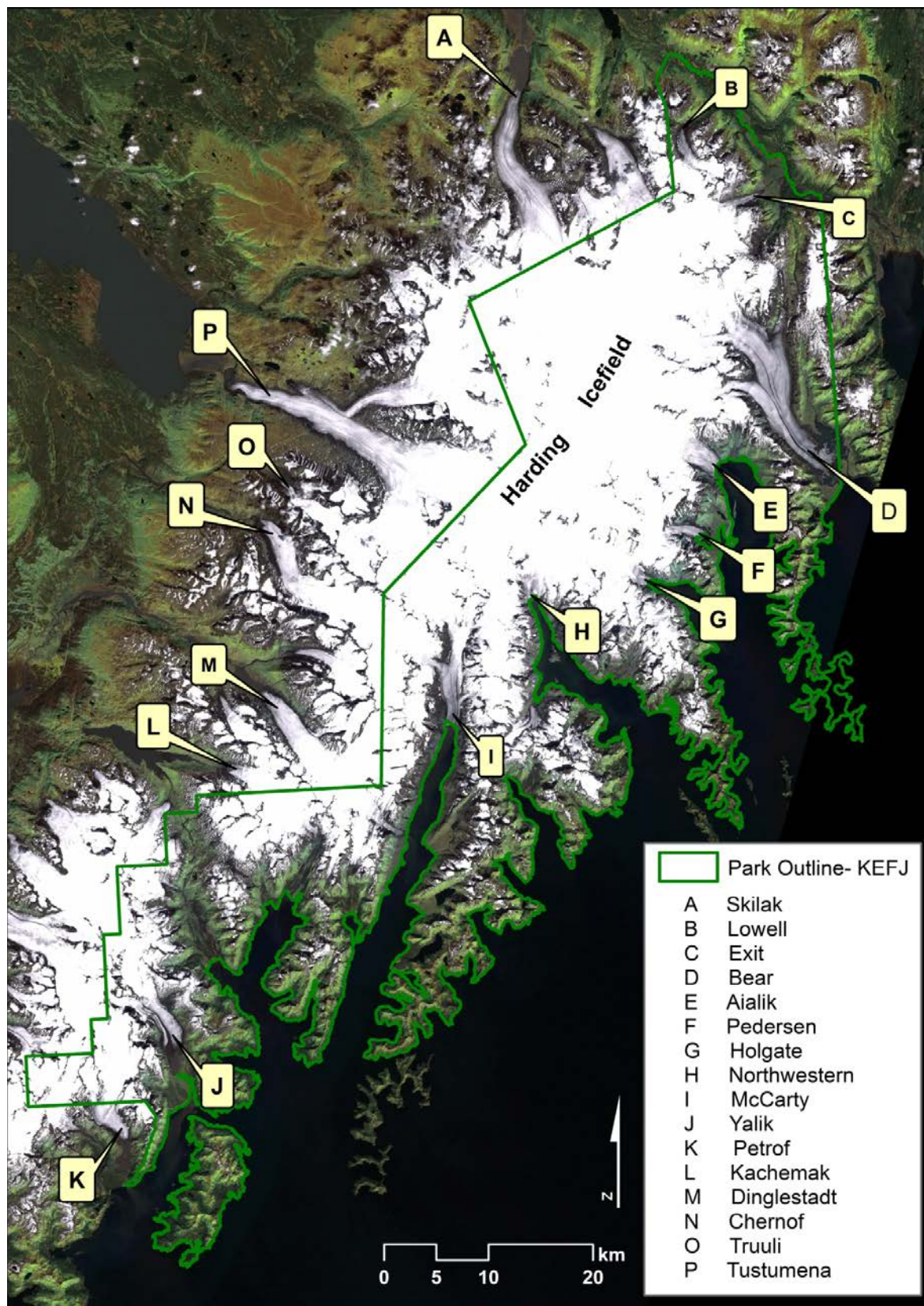


Figure 46. Major glaciers in and around KEFJ.

Hall et al. (2005) also studied the terminus change in glaciers in the Harding Icefield. Their results are summarized in Table 33.

Table 33. Change (m) of the terminus position* of selected glaciers in KEFJ, average annual rate of change (in m/yr) is shown in parentheses. A negative sign indicates that the glacier receded. Errors were determined from Hall et al. (2003) (Hall et al. 2005).

Glacier	Change (in m) from 1973-1986; average annual rate of change (in m/yr) is shown in parentheses		Change (in m) from 1986-2002; average annual rate of change (in m/yr) is shown in parentheses	
Aialik ¹	-85±136	(-7)	-95±54	(-6)
Bear ^{2,3}	Extensive recession, but difficult to measure		Extensive recession, but difficult to measure	
Chernof ³	-162±136	(-13)	-339±54	(-21)
Dinglestadt ²	-566±136	(-44)	-339±54	(-21)
Exit (south edge of terminus) ³	-134±136	(-10)	+95±54	(+16)
Holgate ¹	-319±136	(-25)	No Change	
Indian ³	-234±136	(-18)	-180±54	(-11)
Kachemak ³	-283±136	(-22)	-67±54	(-4)
Killey ³	-268±136	(-21)	-446±54	(-28)
Lowell ³	-272±136	(-21)	-708±54	(-44)
Northwestern ¹	-67±136	(-5)	-2184±54	(-137)
McCarty ¹	+583±136	(+45)	-306±54	(-19)
Nuka ³	-302±136	(-23)	No Change	
Pedersen ^{2,3}	-511±136	(-39)	-108±54	(-7)
Petrof ³	-730±136	(-56)	-371±54	(-23)
Skilak ²	-2290±136	(-176)	-1521±54	(-95)
Tustumena Northern ²	-1856±136	(-143)	+537±54	(+34)
Yalik ²	-726±136	(-56)	-579±54	(-36)

* The terminus position can be measured at various points along the edge of the glacier in each year. For each glacier, researchers chose the part of the terminus that showed the greatest change. Because of the irregularity of the terminus, and the arbitrary nature of selecting a point from which to measure, these measurements may not be repeatable.

¹ Terminates in tidewater

² Terminates in a lake

³ Terminates on land

Molnia et al. (2007) provided visual evidence of terminus retreat through a repeat photography study in KEFJ. Twentieth century glacial retreat was so extensive that many glaciers in the 1909 photos are not currently visible from the original photo locations. For example, the “iceberg filled lagoon” at Pedersen Glacier’s terminus in 1909 is now a “vegetated, outwash plain-wetland complex” (Molnia et al. 2007). Several of these photos are shown in Figure 47. More photos can be found at the National Snow and Ice Data Center’s glacier photograph collection website (http://nsidc.org/data/glacier_photo/index.html).

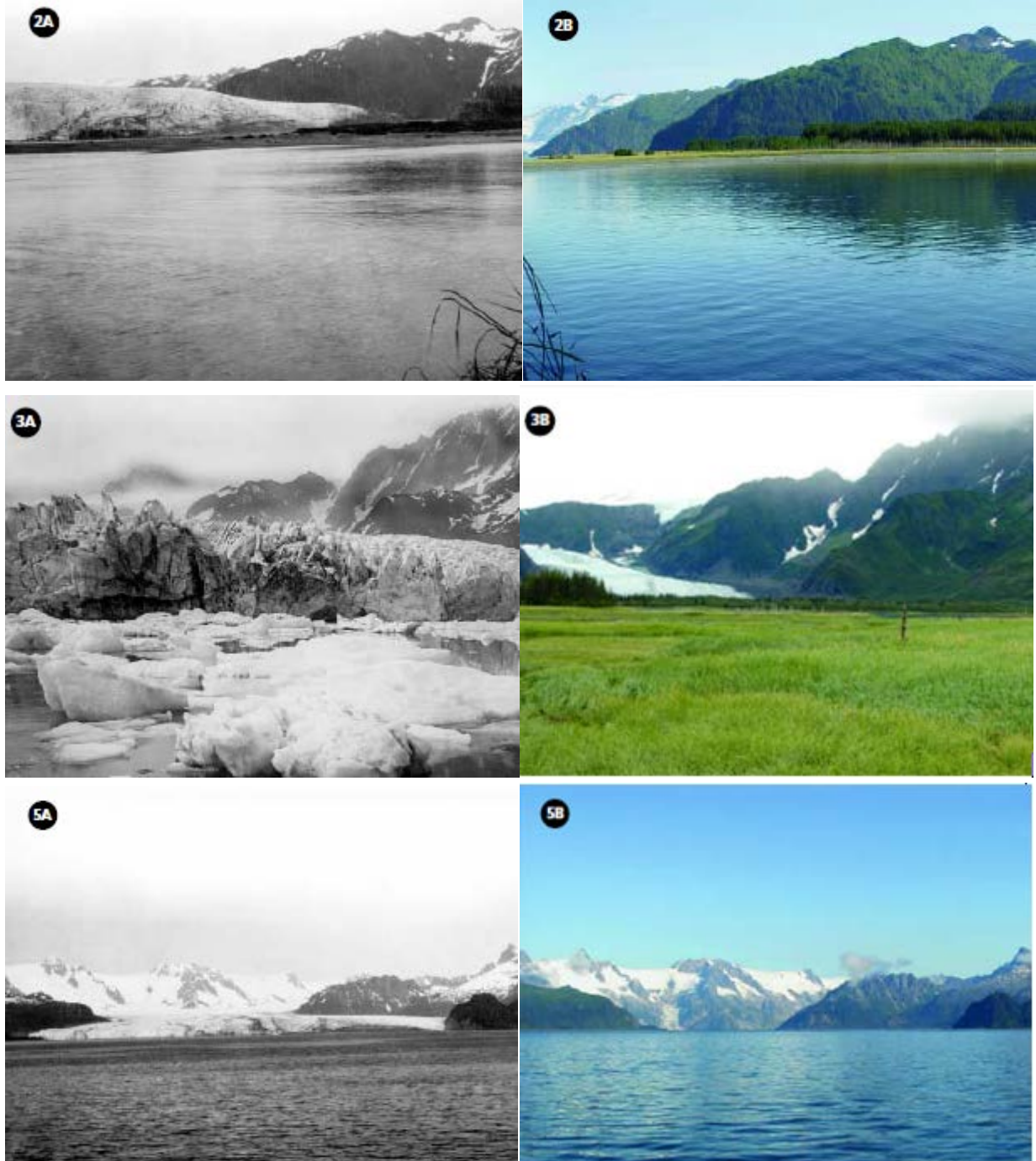


Figure 47. Repeat photographs of KEFJ glaciers in 1909 and 2004-2006. Photos 2A and 2B show the mouth of McCarty Fjord (McCarty Glacier's terminus is visible in 2A but has retreated out of view in 2B). 3A and 3B show Pedersen Glacier at Aialik Bay, while 5A and 5B show Harris Bay (Northwestern Glacier's terminus is seen in 5A but is no longer visible in 5B). Photos 2A and 5A were taken by U.S. Grant of USGS. Photo 3A is from an early 20th century postcard. Photos 2B, 3B, and 5B were taken by Bruce Molnia.

Mass Balance (surface elevation)

In 2009, park researchers initiated a mass balance study on Exit Glacier by installing stakes at four sites distributed at a range of elevations (NPS 2011a). Two additional sites were added to the project in 2010 to monitor mass balance and flow on an unnamed glacier located between Skilak and Lowell Glaciers. This effort will help researchers understand how individual glaciers and the Harding Icefield are responding to climate change (NPS 2011a).

Aðalgeirsdóttir et al. (1997) compared profiles of 13 outlet glaciers in the Harding Icefield: six in 1994 and seven in 1996. For this study, volume changes were computed by comparing profiles of glaciers to USGS 1:63,360 topography maps based on aerial photography taken in 1950-52. To account for error associated with elevation changes at higher elevation, they assumed that ice above 1,000 m (central and northern Harding Icefield) and above 1,200 m (southern Harding Icefield) experienced no elevation change over the period of study. Using the two volume calculations, they found the area mean elevation changes. Mass balance was calculated by multiplying the area mean elevation change by density and dividing by the time period (43 to 46 years, depending on the glacier). Results for individual glaciers are listed in Table 34. The total volume loss for the entire ice field was about 34 km³ (8.2 mi³), with a -21 m (-69 ft) area-average surface elevation change, or a long-term annual average net mass balance of -0.4 meters water equivalent (m w.e.) (-1.3 ft w.e.) (Aðalgeirsdóttir et al. 1997).

Table 34. Changes in volume, area-average elevation, and mass balance of glaciers located in the Harding Icefield between the early 1950s and mid 1990s (~43 yrs). (Reproduced from Aðalgeirsdóttir et al. 1997).

Name	Contour change in volume (km ³)	Change in volume with 0m (km ³)	Average ice elevation change (m)	Annual change in mass balance (m/yr w.e.)
Aialik	-2.6	0.003	-11.0	-0.2
Bear	-9.7	-7.5	-38.4	-0.7
Exit	-0.1	-0.14	-2.6	-0.1
Holgate	-1.3	-0.8	-16.3	-0.3
Skilak	-0.9	-1.1	-4.5	-0.1
Tustumena	-8.9	-6.0	-25.1	-0.5
Chernof	-2.3	-2.0	-22.6	-0.4
Dinglestadt	-2.7	-2.4	-32.4	-0.6
Kachemak	-0.9	-0.9	-16.3	-0.3
Little	-0.6	-0.5	-18.6	-0.4
McCarty	+1.5	-0.2	+6.2	0.1
Northeastern	-1.4	-1.4	-97.1	-1.8
Northwestern	-5.0	-5.0	-80.2	-1.5
<i>East of Skilak*</i>	-2.6	-0.3	-17.4	-0.3
<i>West of Skilak*</i>	-1.6	-0.8	-9.9	-0.2
<i>Lowell*</i>	-0.04	-0.1	-4.0	-0.1
<i>Pedersen*</i>	-0.3	-0.1	-5.0	-0.1

* Indicates regions or glaciers that were not profiled but elevation changes were extrapolated from neighboring glaciers.

Aðalgeirsdóttir et al. (1997) also included a correlation between the area-averaged elevation change and several variables such as the location on the ice field and aspect, area and length, surface slope, and terminus changes. When comparing the location on the ice field and aspect of glaciers, they found glaciers on the south side appear to have thinned more than those on the north side. However, they found no obvious difference in area-averaged elevation change between tidewater, lake or land terminating glaciers, with tidewater glaciers thinning by -16 m (-52.5 ft), while the land terminating glaciers thinned by -17 m (-56 ft) (Aðalgeirsdóttir et al. 1997). There was also no significant correlation between elevation change and glacier area, length, or surface slope. When examining the correlation between elevation change and the fractional change in length ($\Delta L/L$), they found some indication that glaciers that show the greatest thinning also retreat the most (Aðalgeirsdóttir et al. 1997).

A study conducted by Arendt (2006) found net balance rates and average net balance rates of select glaciers within KEFJ from 1950 to 1994/96 and from 1994/96 to 1999/2001 (Table 35). Net balance is the total volumetric change of a glacier divided by the time interval between measurements. The average net balance rate is net balance divided by the average area of the glacier at the earlier and later times (Arendt 2006). For the 1994/96 to 1999/2001 period, Arendt (2006) found land-terminating glaciers flowing from the Harding Icefield experienced an average change in net balance rate of approximately 0.070 ± 0.30 m/yr (0.23 ± 0.98 ft/yr), and 0.060 ± 0.40 m/yr (0.20 ± 1.31 ft/yr) for all glaciers, indicating that there is no significant difference between the two groups.

Table 35. Net balance and average net balance rates measured by comparison of airborne altimetry and USGS map elevations. “Early” (1950s to mid 1990s) and “recent” (mid 1990s to early 2000s) indicate map-to-profile and profile-to-profile measurements, respectively. Note that net balance of tidewater glaciers include only that portion of the glacier above sea level (Arendt 2006).

Name	Net balance early (km ³ yr ⁻¹ w.e.)	Net balance recent (km ³ yr ⁻¹ w.e.)	Average net balance rate early (m yr ⁻¹ w.e.)	Average net balance rate recent (m yr ⁻¹ w.e.)	Map year	Profile 1 Date	Profile 2 Date
Aialik	0.002±0.03	-0.010±0.006	0.02±0.35	-0.11±0.07	1950	5/29/1994	5/18/2001
Bear	-0.18±0.04	-0.205±0.009	-0.85±0.19	-1.02±0.04	1950	5/28/1994	5/18/2001
-							
Chernof	0.043±0.007	-0.016±0.003	-0.75±0.11	-0.34±0.05	1950	5/20/1996	5/18/2001
-							
Dinglestadt	0.056±0.007	-0.011±0.003	-0.82±0.10	-0.18±0.04	1950	5/19/1996	5/18/2001
-							
Exit	0.008±0.011	-0.007±0.002	-0.21±0.27	-0.18±0.06	1950	5/28/1994	5/28/2001
-							
Holgate	0.021±0.011	-0.007±0.002	-0.31±0.16	-0.10±0.04	1950	5/29/1994	5/18/2001
-							
Kachemak	0.008±0.003	0.002±0.001	-0.36±0.14	0.07±0.06	1951	5/19/1996	5/18/2001
McCarty	0.007±0.020	0.034±0.006	0.06±0.16	0.29±0.05	1950	5/19/1996	5/18/2001
-							
Skilak	0.066±0.048	-0.050±0.009	-0.33±0.24	-0.26±0.04	1950	5/29/1994	5/18/2001
Tustumena	-0.22±0.06	-0.156±0.012	-0.73±0.18	-0.54±0.04	1950	5/29/1994	5/18/2001

Dr. Chris Larsen and other scientists at the University of Alaska Fairbanks have used laser altimetry to measure changes in mass balance in the Harding Icefield by comparing repeat profiling to USGS topographic maps made in the 1950s (Larsen 2008). Their findings are summarized in Table 36.

Table 36. Mass balance (m/yr w.e.) of select glaciers flowing from the Harding Icefield (Larsen 2008).

Name	Mass Balance (m yr ⁻¹ w.e.) (1994–1999)	Mass Balance (m yr ⁻¹ w.e.) (2001–2007)
Exit	-0.67	-1.07
Skilak	-0.64	-1.12
Name	Mass Balance (m yr ⁻¹ w.e.) (1994–2001)	Mass Balance (m yr ⁻¹ w.e.) (2001–2007)
Aialik	-0.03	-0.85
Bear	-0.15	-1.98
Holgate	-0.25	-1.16
Tustumena	-0.46	-1.51
Name	Mass Balance (m yr ⁻¹ w.e.) (1996–2001)	Mass Balance (m yr ⁻¹ w.e.) (2001–2007)
Chernof	-0.12	-1.44
Dinglestadt	-0.04	-1.73
Kachemak	0.17	-1.55
McCarty	0.28	-1.47

Late Summer Season Snow Line

Regional characteristics of the Kenai Mountains presented by Muirhead (1978) indicate that the average annual snow line elevations range from 300 m (984 ft) to 1,645 m (5,397 ft) with a mean of 950 m (3,117 ft). Maritime glaciers to the south and southeast have lower snow lines than the northwest and inland glaciers (Muirhead 1978).

Meier and Post (1962) used aerial photography from 1961 to determine the equilibrium line altitude of glaciers in Alaska. They found the lowest equilibrium line altitude (below 600 m [1,968 ft]) occurred along the southern coast from the Aleutian Range through the Kenai Mountains. Furthermore, Meier and Post (1962) found the AAR to be 0.68% in the Kenai Mountains, which could indicate that in 1960-61 this area had a positive net balance, and that many of the glaciers were stable.

Viens (1995) estimated an equilibrium line altitude on Northwestern and McCarty Glaciers of about 830-920 m (2723-3018 ft), and Holgate and Aialik Glaciers to be 610-770 m (2,001-2,526 ft). On these glaciers, a significant part of their accumulation area is above the stated equilibrium line altitude, indicating that Harding Icefield is relatively non-susceptible to small variations in climatic change (Aðalgeirsdóttir et al. 1998).

Glacial Lake Outburst Floods (GLOF)

A glacial lake is created when a glacier dams meltwater in, on, beneath, or behind glacial ice. The failure of the glacial dam releases this meltwater, creating an outburst flood. The formation of a channel under, through, or over the glacial ice can also release meltwater, but generally at a slower rate and with less dramatic impacts. Post and Mayo (1971) outline causes for the release of meltwater held by glacial dams, including:

- “Slow plastic yielding of the ice due to hydrostatic pressure differences between the lake and the adjacent, less dense ice” (citing Glen 1954);
- Lifting of the ice dam through floating (citing Thorarinsson 1939);
- “Crack progression under combined shear stress due to glacier flow and high hydrostatic pressure” (citing Nichols and Miller 1952);
- Drainage through preexisting channels or between ice crystals;
- Overflow of water, generally along the ice dam’s margin (citing Liestøl 1956);
- Volcanic heat causing subglacial melting (citing Tryggvason 1960);
- Earthquakes weakening the ice dam (citing Tryggvason 1960).

Rice (1987) reports that three large glacier-dammed lakes located in KEFJ have drained, resulting in GLOFs. The first was located on the northeast flank of Bear Glacier and had an area of 1.15 km² (0.44 mi²). The second, located on the east flank of Yalik Glacier, had an area of 0.65 km² (0.25 mi²). The third lake, with an area of 0.52 km² (0.2 mi²), was located on the east flank of Petrof Glacier

(Rice 1987). In August 2008, another GLOF occurred at Bear Glacier (13 km northwest of Bear Glacier Lake), releasing a large volume of water toward Bear Glacier Lake (Figure 48, NPS 2008). Researchers from the University of Montana are currently studying lake outburst events in the Bear Glacier area to better understand the hazards they pose and to provide management recommendations (Wilcox 2009). Other locations on the Kenai Peninsula where outburst floods have occurred include Skilak and Snow Glaciers (NPS 2008).

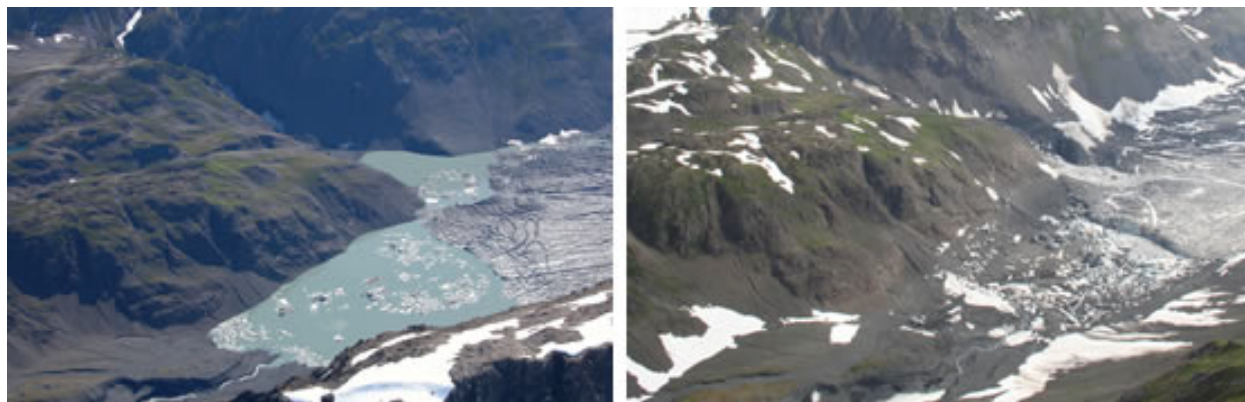


Figure 48. Photos of the unnamed glacial lake at Bear Glacier before (left photo - USGS) and after (right photo - NPS) the outburst event.

Threats and Stressor Factors

Climate Change

Climate is one of the most important factors influencing ecosystems. In Alaska, climate is constantly fluctuating on multiple temporal scales, including several natural cycles. One climate fluctuation of particular importance in Alaska is the Pacific Decadal Oscillation (PDO) (Lindsay 2011). Mantua et al. (1997) formally identified this pattern of climate variability in a study relating climate oscillation to salmon production. The PDO, which is related to sea surface temperatures in the northern Pacific Ocean, affects atmospheric circulation patterns and alternates between positive and negative phases (Wendler and Shulski 2009). A positive phase is associated with a relatively strong low pressure center over the Aleutian Islands, which moves warmer air into the state, particularly during the winter (Wendler and Shulski 2009). Some of the variation in Alaska's climate over time can be explained by major shifts in the PDO which occurred in 1925 (negative to positive), 1947 (positive to negative), and 1977 (negative to positive) (Mantua et al. 1997). Hartmann and Wendler (2005) found that much of the warming that occurred in Alaska during the last half of the twentieth century was likely due to the PDO shift in 1976-77.

However, global climate is currently changing more rapidly than in the past and "rates of change are dramatically accelerated at northern latitudes" (Lindsay 2011, p. 3, citing IPCC 2007). Global climate models suggest that high latitudes will experience the greatest climate change and variability (NPS 2011b). Arendt (2006) used data from six weather stations that represented the Kenai Peninsula (Cooper Lake Project, Kasilof, Kenai, Homer Moose Pass, and Seward) and found summer

temperatures increased by 0.1°C to 0.3°C per decade, except at Kasilof where summer temperatures changed by -0.2°C per decade, and precipitation decreased by 6.0 to 83 mm per decade.

Small glaciers are indicators of both regional and global climate change (Aðalgeirsdóttir et al. 1998, Hall et al. 2005), particularly because they exist on all continents except Australia. There is evidence that glaciers on all continents (excluding Antarctica, due to the lack of data) have been receding (Dyurgerov and Meier 1997, as cited in Hall et al. 2005). Possible climate change effects in KEFJ include reduced snowpack, earlier ice break-up on lakes, warmer winters, and wetter summers (NPS 2011b).

Land and tidewater terminating glaciers exhibit different responses to climate change. Land terminating glaciers start to thin if snowfall decreases or if temperature rises. The change in glacier thickness can occur quickly. However, it takes time to recognize change throughout the length of the glacier (Valentine et al. 2004). Therefore, the retreat of a terminus is not a sensitive indicator of recent climate change. Tidewater glaciers advance slowly and maintain a submarine shoal (i.e., the terminus rests on the sea floor rather than floating on the surface) (Valentine et al. 2004). For advancement to continue, the depth of the water at the terminus must decrease as deposition of the terminal moraine shoal (sediment and debris pushed in front of the glacier) continues (Viens 1995). As the terminus retreats from the shoal, calving will increase, which in turn will further increase the rate of retreat (Viens 1995, Valentine et al. 2004). During retreat and advance, tidewater glaciers are typically not sensitive to changes in climate (Viens 1995).

Data Needs/Gaps

Recent information regarding late summer season snow line and equilibrium line altitude is lacking. Satellite data can help approximate the equilibrium line altitude by using the late summer snow line, referred to as the transient snowline (TSL) late in the melt season. Since the efforts of Hall et al. 2005, additional, appropriate LandSat imagery has become available to map equilibrium line altitude by using snow line (e.g., 2007 and 2010 LandSat imagery). In addition, remotely sensed data such as MODIS (Moderate Resolution Imaging Spectroradiometer), can aid in identifying the annual late summer snow line and effective mass balance assessments with repeated images (Pelto 2011). Since MODIS images are captured every one to two days, the late summer snow line can be located each year, allowing scientists to quantify the mass balance gradient of a glacier. This information will help park management better understand glacial stability. Snow lines that increase in altitude over time (i.e., move “uphill”) may indicate that the equilibrium line altitude is increasing and glacial mass is being lost (refer to Figure 45). In contrast, snow lines decreasing in altitude could indicate that mass is being gained and a glacier is becoming more stable. The value (i.e., usefulness and reliability) of this information would increase as the data set grows over the years.

As a part of this project (i.e., this natural resource conditions assessment), KEFJ and SWAN staff proposed that a methodology for repeat mapping of late summer snow lines on MODIS data be developed. MODIS data is available; however, given project constraints, an effort to determine such a methodology has not yet been undertaken and therefore remains a data gap for understanding glacial change in the park.

Little is known about the ice thickness of glaciers throughout Alaska, as taking these measurements is often “difficult and labor intensive” (Truffer and Habermann 2011, p. 5). In 2010, researchers from the University of Alaska-Fairbanks used a ground-based radar system to gather ice depth data from Exit Glacier. Preliminary results indicate that ice depths range from around 50 m to greater than 450 m (Truffer and Habermann 2011). A second stage of this project, involve taking measurements from an airplane, included an NPS publication from spring of 2014. These measurements could serve as a baseline for future studies of ice thickness.

Weather stations in KEFJ are relatively new and have only collected data for a short period of record. Long-term climate data at the Harding Icefield are needed to correlate glacier dynamics with climate variations.

Until recently, hazards associated with glacier lake outburst floods in the KEFJ area had not been studied since Post and Mayo in the 1970s. Andrew Wilcox from the University of Montana studied the hydrology, hazards, and management implications of glacial lake outburst events on Bear Glacier (Wilcox 2009). He will provide park managers with up to date information on outburst events and the degree of risk associated with this hazard, as well as maps and associated data in a format suitable for park GIS use. He will also identify needs for further research and stimulate additional studies by other scientists regarding natural hazards. Initial data collection was completed in late 2011 and preliminary results are currently being analyzed and reviewed (NPS, Deb Kurtz, Natural Resource Program Manager, written communication, May 2012). The final report was not yet completed at the time of writing this section, however it is available in Wilcox et al. (2013).

Overall Condition

Area

KEFJ staff assigned the measure of glacial area a *Significance Level* of 3. Giffen et al. (2007) reported a 2.2% decrease in areal extent of the Harding Icefield and Grewingk-Yalik Glacier Complex, and Hall et al. (2005) reported a decrease of 3.62%. Lastly, Rice (1987) reported a decrease of 5% for the Harding Icefield. Evidence from these studies indicates that there is an ongoing decrease in the areal extent of glaciers within KEFJ; because of this, glacial area was assigned a *Condition Level* of 2.

Rate of Terminus Retreat

The rate of terminus retreat was assigned a *Significance Level* of 3 by KEFJ staff. In a recent study of terminus change, Giffen et al. (2007) reported that the terminus positions for a suite of 27 glaciers measured in and nearby KEFJ all experienced retreat from the 1950s to 2000. Data from the 1950s to 2000 indicates coastal glaciers average a retreat of 32 m/yr (104 ft/yr), while glaciers located in the interior average a retreat of 29 m/yr (95ft/yr)(Giffen et al. 2007). Lastly, from 2000 to 2005, Giffen et al. (2007) found the terminus retreat rate of coastal glaciers increased to a loss of 78 m/yr (256 ft/yr). Because of these findings, rate of terminus retreat was assigned a *Condition Level* of 2.

Mass Balance (surface elevation)

KEFJ assigned mass balance of glaciers within KEFJ a *Significance Level* of 3. A study conducted by Aðalgeirsdóttir (1997) found a volume loss of about 34 km³ (8.2 mi³) in the Harding Icefield, and a -21 m (69 ft) area average surface elevation change over their approximately 43 year study period (1950s to 1994/96). For the study period 1994/96 to 1999/2001, Arendt (2006) found land-terminating glaciers flowing from the Harding Icefield experienced an average change in net balance rate of about 0.070±0.30 m/yr (0.23±0.98 ft/yr), and 0.060±0.40 m/yr (0.20±1.31ft/yr) for all glaciers. Finally, most recent studies (Table 36) conducted by Dr. Larsen at UAF, indicate a significant decrease in mass balance of glaciers located in the Harding Icefield (Larsen 2008). For these reasons, mass balance was assigned a *Condition Level* of 3.

Late Summer Season Snow Line


The late summer season snow line measure was assigned a *Significance Level* of 1 by KEFJ staff. Meier and Post (1962) suggested that the equilibrium line altitude and AAR in the Kenai Mountains indicated a positive net balance. Muirhead (1978) reported lower equilibrium line altitudes in the Kenai Mountains, however Viens (1995) concluded equilibrium line altitudes for tidewater glaciers to be consistent with Meier and Post (1962). Meier and Post (1962) and Viens (1995) indicate that accumulation areas above the equilibrium line altitude are large, concluding the Harding Icefield is not vulnerable to small changes in climate (Adalgeirsdottir et al. 1998). However, these studies cannot provide information on the current condition; future studies using MODIS data could reveal a current trend in snow lines. Therefore, SMUMN GSS could not assign this measure a *Condition Level*.

Glacial Lake Outburst Floods

In KEFJ, GLOFs were assigned a *Significance Level* of 1. Loss of glacier mass can cause the failure of ice dams on glacier-dammed lakes, resulting in a sudden release of meltwater causing an outburst flood. These floods may be dangerous to visitors camping or kayaking in the area downstream of the glacier. As of 2011, The most recent GLOF occurred in 2011 at Bear Glacier (Kurtz, written communication, 2011). Very little information is currently available regarding GLOFs in KEFJ (e.g., natural frequency and magnitude, impacts, etc.); therefore, a *Condition Level* could not be assigned.

Weighted Condition Score

The Weighted Condition Score for the glacier component is 0.778, indicating an overall condition of high concern. The trend of this condition appears to be declining, as indicated by continued reduction in the areal extent of the Harding Icefield and Grewingk-Yalik Glacier Complex, evidence of termini retreat since the 1950s, and significant decreases in mass balance of glaciers in KEFJ. Unfortunately, the likely causes of this decline are beyond the control of park management and there is very little they can do to influence the condition of these resources.

Glaciers			
Measures	Significance Level	Condition Level	Weighted Condition Score = 0.8
Area	3	2	
Rate of Terminus Retreat	3	2	
Mass Balance (surface elevation)	3	3	
Late summer season snow line	1	n/a	
Glacial lake outburst floods	1	n/a	

4.8.6 Sources of Expertise

Bruce Giffen, Alaska Regional Office Geologist, National Park Service

Deborah Kurtz, Natural Resource Program Manager, Kenai Fjords National Park

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4.9 Coastal Geomorphology – Visual Changes (1950s to 2005)

4.9.1 Description

Coastal areas are dynamic and influenced by tectonic, marine, biological, glacial, and meteorological processes meeting at the land-sea interface that interact over a range of temporal and spatial scales (Bird 2008). KEFJ's shoreline and coastal features are constantly changing because of earthquakes; uplift and subsidence; snow avalanches; tectonic erosion; glacial recession and erosion; and erosion and accretion from storm-driven waves, high tides, near-shore currents, and runoff from rainfall and snow-melt (Hayes 1980, Bennett et al. 2006). Understanding coastal geomorphologic change is important because the shoreline's physical morphology affects the near-shore and terrestrial habitats of a wide array of biota (e.g., marine mammals, birds, salmon, and bears) (Bennett et al. 2006). Shoreline position changes affect the composition, relative abundance, and distributions of the park's coastal habitats (Bennett et al 2006). SWAN has identified geomorphic coastal change as a Vital Sign in their ecological monitoring framework, with plans to monitor it in KEFJ and other coastal parks within the network. While the monitoring protocol for the geomorphic coastal change Vital Sign is not yet developed, the primary questions posed are: how are the position, shape, slope, and sediment character of the shoreline changing (Bennett et al. 2006). Figure 49 provides an aerial view of the Nuka River and Ferrum Creek delta area affected by post 1964 earthquake subsidence and subsequent beach erosion. On a relatively coarse scale, this assessment identifies coastal change areas over an approximately 50-year period by comparing 1950s and 2005 aerial image sources.

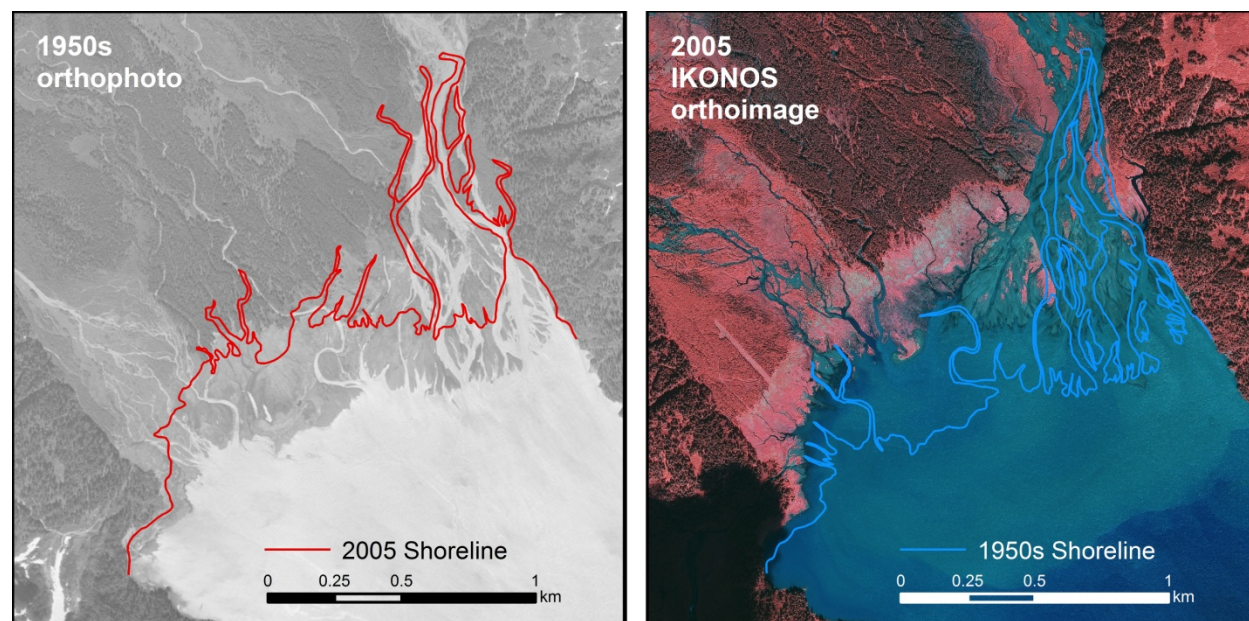


Figure 49. Example of tectonic subsidence and shoreline erosion at the river mouth deltas of Ferrum Creek and Nuka Rivers in KEFJ, 1950s orthophoto (left) shown with a 2005 shoreline delineation (red), 2005 IKONOS orthoimage mosaic (right) with a delineation of the 1950s shoreline (blue).

KEFJ is located in one of the most tectonically active areas in the world, caused by the northward movement of the Pacific Plate in relation to the North American Plate (Page et al. 1991). Earthquakes in southwestern Alaska resulting from built-up pressure between the two plates are capable of

drastically altering the shoreline geomorphology and coastal biota (Page et al. 1991). Earthquake-caused alterations to shoreline geomorphology occur through a variety of mechanisms such as vertical displacement, tsunamis, and mass movements or mass wasting events (e.g., snow avalanches, landslides, and falling rocks) (Hoyer 1971, Crowell and Mann 1998). Vertical displacement, expressed as subsidence or uplift, causes changes in the sea level relative to the coast and disrupts the dynamic equilibrium between the shoreline and local wave regimes (i.e., sediment size, sorting, shape, and shoreline cross-profiles) (Crowell and Mann 1998). Tsunamis are also generated by the displacement of the sea floor during earthquakes; they are accompanied by high-velocity currents and can cause coastal erosion and redistribution of unconsolidated beaches (Plafker 1969 as cited in Crowell and Mann 1998). Finally, mass movements from earthquakes have the ability to transport large amounts of clastic material into tidewater, at times altering the shoreline position (Crowell and Mann 1998). The 1964 Alaska earthquake triggered such an event in KEFJ, originating from a terminus of a hanging glacier in Holgate Arm (Crowell and Mann 1998).

The 27 March 1964 Alaskan Earthquake was one of the largest earthquakes recorded in North America, initially measuring 8.4-8.5 on the Richter scale for its surface magnitude (Plafker 1969); later, a 9.2 moment magnitude was measured at its epicenter (KPB 2011). The 1964 earthquake caused uplift to the east and subsidence to the west of a line of no vertical displacement. This line runs from the earthquake's epicenter in northeastern Prince William Sound, southwest to the west coast of Kodiak Island. KEFJ falls within the subsidence zone of this earthquake which includes most of the Kenai Peninsula. The 1964 earthquake caused as much as 2.4 meters (7.9 ft.) of subsidence to areas of the Kenai Peninsula. Seward, Alaska, just to the east of the park, experienced approximately 1.1 m (3.6 ft) of subsidence (Plafker et al. 1969). KEFJ park lands subsided from 0.9-1.8 m (3-6 ft) during the 1964 earthquake (Bennett et al. 2006).

This sudden tectonic subsidence resulted in drowned shorelines and the death of trees (Plafker et al. 1969). The sudden changes in beach morphology caused by the earthquake were similar to beach processes that would normally act gradually over time or ones that would be the results of short-lived storms (Stanely 1968). Because of the sudden nature of the changes, in some areas standing dead trees remain as evidence of subsided and inundated forested land, often referred to as "ghost forests". This subsidence initially resulted in a variety of effects to coastal landforms and beach processes of the Kenai Peninsula (including present-day KEFJ), Kodiak Island, and Cook Inlet (Stanely 1968). Generally, beach gradients were reduced and minor beach features were altered or destroyed immediately following the earthquake, then reappeared within a few months after the earthquake and slowly stabilized to similar pre-quake shapes (Stanley 1968). Since the 1964 earthquake and the initial subsidence that occurred, Cohen and Freymueller (2004) reported tectonic uplift of up 40 cm (15.7 inches) along some of the park's coast. Along with tectonic uplift, both post-seismic deformation (i.e., after the '64 quake) and plate coupling, isostatic rebound continues to contribute to uplift on KEFJ coast. Isostatic rebound, also referred to as a glacial isostatic adjustment is the land's response to the removal of glacial ice load on the land.

Many biological changes accompany the physical changes in coastal landforms from glacial recession and erosion. The most visually apparent change is vegetation establishment on previously

ice-covered land surfaces and newly deposited glacial materials and the eventual vegetative succession. For example, alder shrubs (e.g., *Alnus viridis*) establish quickly after deglaciation, providing nitrogen for nutrient-poor soils, enriching the environment for eventual spruce invasion (primarily Sitka spruce, *Picea stichensis*). Rice and Spencer (1990) found that after deglaciation, Sitka spruce established within 25 years at the Northwestern Glacier terminus. Post-deglaciation shrub establishment is one of the most visually apparent biological changes in comparing 1950s aerial photography to 2005 satellite imagery. Visual changes are especially prominent along shorelines associated with tidewater glaciers, present in 1950s aerial photography. Areas that were tidewater glaciers in the 1950s are, in the 2005 satellite imagery, comprised of open bays, glacial stream mouth deltas, and newly vegetated terrestrial environments. Figure 50 displays an example of recession of an unnamed tidewater glacier to the South of Striation Island in the park and the shrub establishment on the newly exposed land.

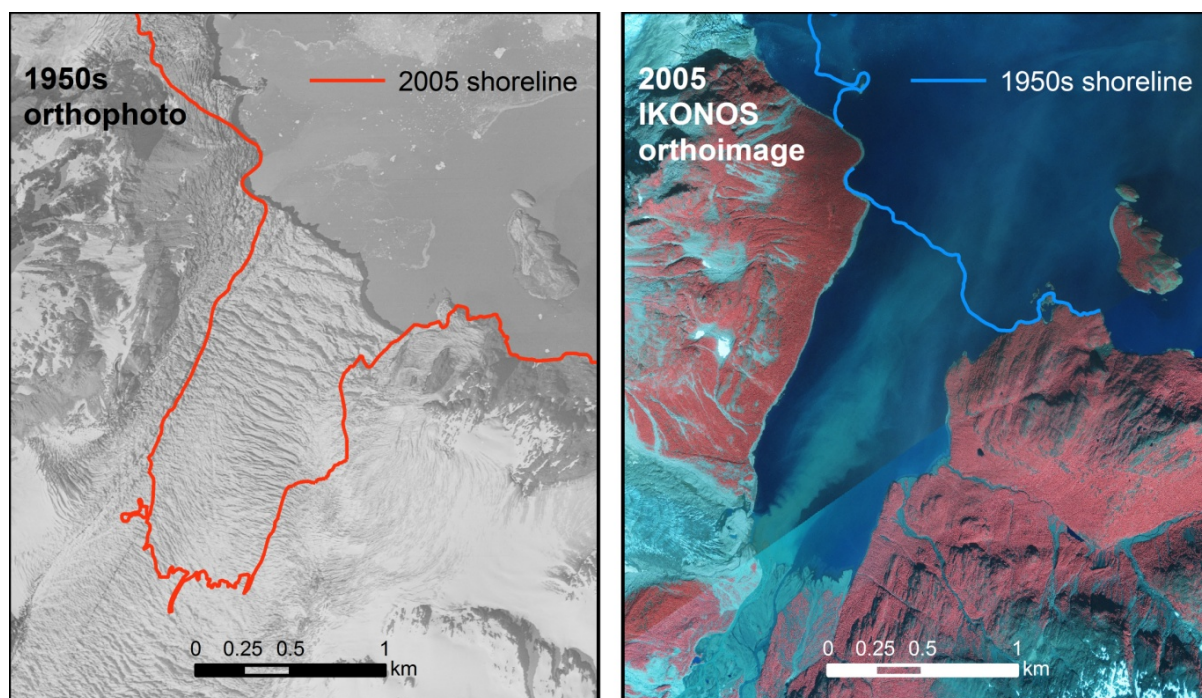


Figure 50. Glacial recession and shrub colonization in a recently deglaciated coastal area southwest of Striation Island in KEFJ, 1950s orthophoto (left) and 2005 IKONOS orthoimagery (right), 2005 shoreline (red line), 1950s shoreline (blue line). Vegetation in the 2005 imagery shows as red, due to color-infrared imagery.

4.9.2 Measures

A shoreline can be defined simply as the physical interface of land and water (Dolan et al. 1980) or as the water's edge moving to and fro as the tides rise and fall (Bird 2008). The shoreline is different than the coastline. According to Bird (2008, p. 3), "the coastline is the edge of the land at the limit of normal high spring tides; the subaerial land margin often marked by the seaward boundary of terrestrial vegetation. On cliffed coasts it is taken as the cliff foot at high spring tide level." That is, shorelines move with rising and falling tides, but coastlines are submerged only in exceptional circumstances. Because of the shoreline's dynamic nature, both temporally and spatially, the term

shoreline requires additional functional definition (Boak and Turner 2005). A wide variety of shoreline features or shoreline indicators are used in scientific literature to understand changes in shorelines over time; some of the common shoreline indicators are illustrated in Figure 51 (Boak and Turner 2005).

- A Bluff top/cliff top
- B Base or toe of bluff/cliff
- C Landward edge of shore protection structure
- D Seaward stable dune vegetation line
- E Seaward dune vegetation line
- F Erosion scarp
- G Storm/debris line
- H An old high tide water level
- I Previous high tide high water level
- J Mean high water (datum referenced)
- K Wet/dry line or runup maxima
- L Groundwater exit point
- M Instantaneous water line
- N Shorebreak maximum intensity
- O Mean lower low water line (datum referenced)
- P Beach toe/crest of beach step

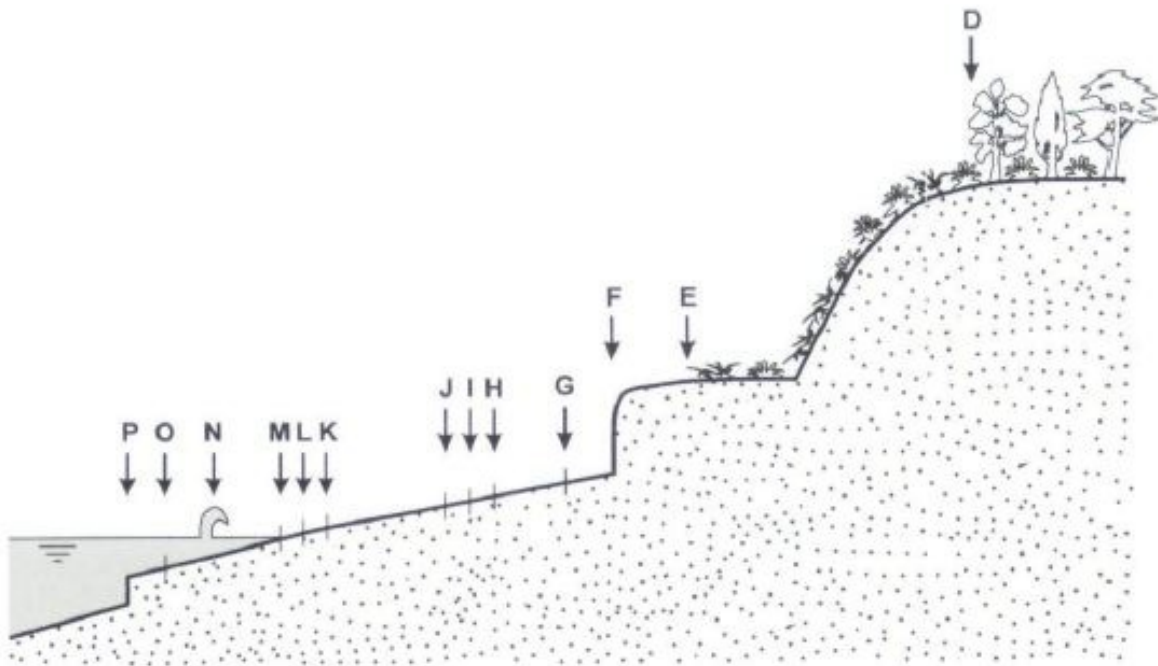
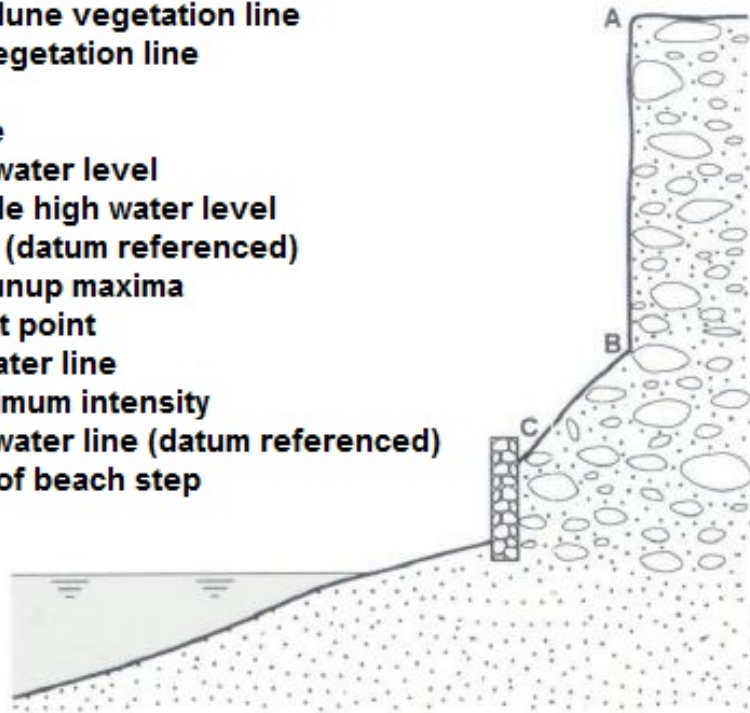


Figure 51. Sketch of the spatial relationship between many of the commonly used shoreline indicators. Reproduced from Figure 1 in Boak and Turner (2005).

Regardless of which shoreline features or indicators are used to measure shoreline change over time, Boak and Turner (2005) assert the importance in finding reliable and accurate ways to quantify how a particular shoreline indicator relates, horizontally and vertically, to the physical land-water boundary. The primary challenge to obtain accurate measurements of shoreline change is to determine a repeatable method to identify and quantify a particular shoreline indicator, given available data. As a part of the Marine Nearshore Monitoring Project, SWAN plans to use aerial videography, ground validation, and measurements of shoreline indicators (using beach profiles) to understand coastal geomorphic change over time in coastal Alaska parks (Bennett et al. 2006). This will be monitored at 10-12 year intervals using a coarse scale, and site-specific scales will employ beach profile measurements (Bennett et al. 2006).

The following measures were selected for this assessment to aid in the understanding of changing coastal geomorphology. They represent visually discernible features that should be based upon a tidal datum, for accurate measurements. These represent but a few of a range of shoreline indicators often used to investigate shoreline changes caused by ever-present forces of erosion and accretion; additional shoreline features may be identified once a methodology is developed by SWAN. Since a methodology for consistently and accurately measuring shoreline feature positions (i.e., measures listed here) is not yet developed, the measures are considered data gaps in this assessment. However, a photo interpretation/delineation effort using 1950s and 2005 image sources discussed in this assessment provides a preliminary indication of coastal areas experiencing visually significant changes along the park's shoreline over an approximately 50-yr period.

- Position of mean high water line (MHWL)
- Top and toe of bluff
- Position of foreshore and backshore vegetation

4.9.3 Reference Conditions/Values

The reference condition for this topic is not developed, though some of the oldest information available for defining shorelines is contained within maps created by the USGS. Across the country, these range from the 1880s to the 1990s vintage. In Alaska, the oldest information is from NOAA topographic surveys or from historic orthophotos, some of which are from the 1950s. These 1950s black and white orthophotos available for KEFJ are a source for describing historic shoreline conditions and are used in this assessment to identify 1950s shorelines and to identify shoreline change by comparing them to visible shorelines in the 2005 IKONOS orthoimage mosaic for the park.

Beyond the instantaneous water line (a proxy for the park's shoreline) identified for this assessment, an explicit set of defined shoreline features detectable in the available imagery and a methodology for consistently identifying these features across all of the individual historic orthophotos or the 2005 IKONOS orthoimage mosaic of the park is not yet developed. Likewise, no specific methodology is yet available that consistently and accurately identifies shoreline features such as top and toe of bluff

or one that defines foreshore and backshore vegetation positions. The identification and accurate measurement of these shoreline features may require higher resolution elevation data than the currently available 30m DEM data, along with GPS benchmarks and on-the-ground measurements. A preliminary assessment and characterization of shoreline changes using image comparison is described in the following section. However, SMUMN GSS and the Alaska Regional NPS Office are working on creating an updated mean high water line (MHWL) GIS dataset for KEFJ and other Alaska park units with coastlines. The results of this effort will provide a first step to identifying the position of primary and contemporary, tidal-referenced shoreline features.

4.9.4 Data and Methods

Historic and contemporary imagery available for the park provide base-layers for the creation of newly photo-interpreted and delineated shoreline GIS datasets for KEFJ. In addition, an existing shoreline dataset is appended with brief descriptions of the recent shoreline changes. To capture shoreline change over an approximately 50-yr period, 1950s aerial orthophotos (1950, 1951, and 1952), the oldest imagery date with the largest geographic coverage available for the park, and 2005 satellite imagery, the largest geographic coverage and the most contemporary available to date, are chosen as base imagery.

Contemporary (2005) Shoreline

Cusick (2011) notes that marine shoreline GIS data for KEFJ and other NPS units along the Alaska coast lack ties to present-day, local water levels, are older and of small geographic scale, and are generally ambiguous and inconsistent. In an effort to provide an updated, contemporary representation of the KEFJ shoreline, for this assessment the instantaneous water line (i.e., the interface of water and land or ice) is delineated for the entire shoreline visible in the 2005 IKONOS orthoimage mosaic available for the park. The instantaneous water line serves as a proxy for the park's shoreline, as it is not tidally corrected. The entire park's shoreline (for which there is imagery coverage) is delineated using heads-up digitizing in ESRI's ArcGIS 10.0. Nuka Island is excluded from this delineation as IKONOS imagery is lacking for this island in the park. The resulting GIS line dataset is referred to as *KEFJ Shoreline 2005 IKONOS*. In Figure 52, existing shoreline GIS data, originally developed for a 1:63,360 map scale used in Pendleton (2005), is overlain on 2005 IKONOS orthoimagery near the entrance to Petersen Lagoon, illustrating the GIS data's relatively small geographic scale and its limitation as a relevant, contemporary data source compared with the 2005 IKONOS imagery. The new shoreline data is delineated at a 1:3,500 scale. This line is not tidally corrected, therefore only represents the instantaneous water line, not a tidally referenced water line such as mean low water line (MLWL) or mean high water line (MHWL).

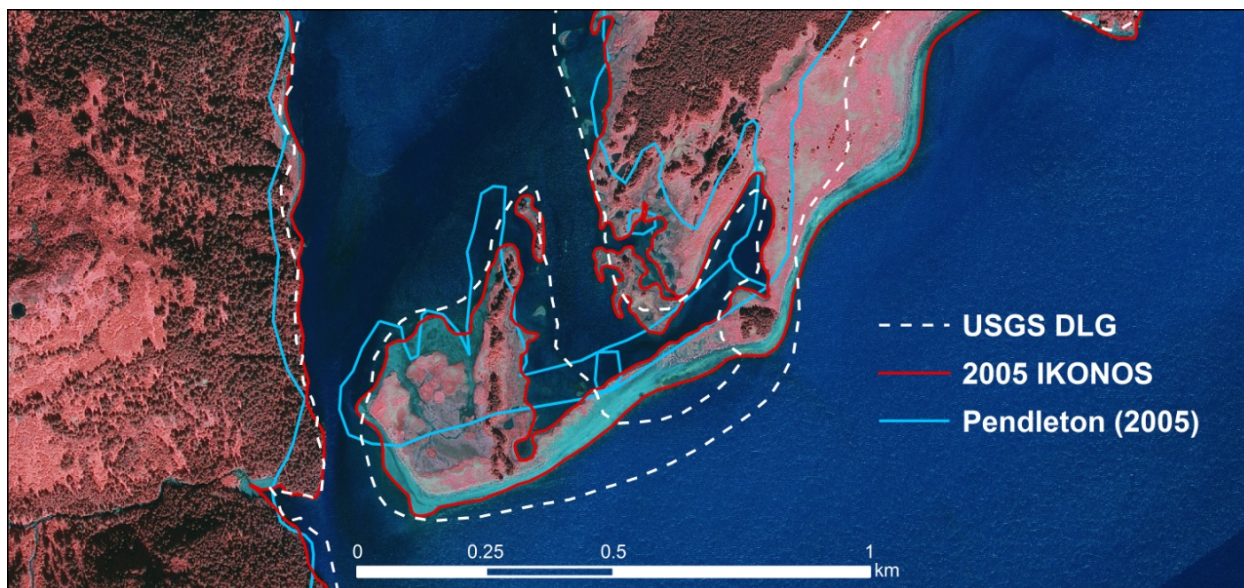


Figure 52. USGS Digital Line Graphic (DLG) shoreline data, Pendleton (2005) shoreline data, and 2005 digitized shoreline (a photo-interpreted instantaneous water line using the 2005 IKONOS orthoimage mosaic displayed here). The USGS shorelines are developed from USGS Digital Line Graph maps, revised using 1977-1985 aerial photography, scale 1:63,360. The Pendleton (2005) GIS data is based on USGS Quadrangles (1950-1990) published by the NPS in 1994, scale 1:63,360. The digitized coastline in this figure was developed at a 1:3,500 scale from the IKONOS orthoimagery.

1950s and 2005 Shoreline Change Areas

By comparing a total of 48 individual 1950s orthophotos to the 2005 IKONOS Ortho image mosaic for the park, 1950s shorelines are delineated in areas where they appear visually different in horizontal position compared with the 2005 shoreline. The resulting dataset is referred to as *KEFJ 1950s Shoreline Change Areas*. Then, a subset of the 2005 shoreline dataset is created to represent 2005 shoreline segments that have visually changed since the 1950s (i.e., a matching shoreline segments for each of the 1950s shoreline segments). Each contiguous shoreline segment is assigned a unique place name using the KEFJ satellite map annotation GIS layer. The resulting layer is called *KEFJ 2005 Shoreline Change Areas*. These unique place names along with the interpreted, primary changes associated with each shoreline change area (contiguous shoreline segments) are available in Plate 30.

Existing Shoreline Dataset Appended

Interpreted changes between the 1950s and 2005 image sources are appended to an existing shoreline GIS dataset by Pendleton (2005). This original shoreline dataset is chosen as a base dataset as it contains important variables that have strong influence on coastal evolution. These variables include: geomorphology type (landform), annual shoreline change (erosion/accretion potential), coastal slope, relative sea-level change, wave energy regime, and mean tide range (Pendleton et al. 2006). The newly appended fields include a field populated with a brief interpreted characterization of primary changes at each shoreline segment and also records where no significant visual change is apparent (recorded as “no significant visual change”). When appropriate, existing line segments (tabular records) are geographically split to better represent the geographic extent along the shoreline where

changes appear to begin and end. In separate fields, each 1950s aerial photo number and flight number used for interpreting the 1950s shoreline is recorded, providing data users a reference for individual 1950s images used in the photo interpretation. This appended dataset is referred as *KEFJ 1950 to 2005 Change Segments*.

After interpreting changes along the entire shoreline of the park, where imagery is available, a coding system is employed to group major change types and other imagery coverage issues noted during the interpretation process. Shoreline segments with prominent changes are categorized as major changes; those with lesser shoreline position changes and near-shore alterations are categorized as minor changes. Lastly, segments of the shoreline for which imagery issues exist such as clouds obscuring the shoreline, lack of imagery, or shorelines outside of the park boundaries are also identified and recorded in the *KEFJ 1950 to 2005 Change Segments* GIS dataset.

Shoreline Datasets - Purpose & Caveats

The delineated shoreline GIS datasets for the 1950s and 2005 represent instantaneous water lines. They are not tidally corrected, but serve as a proxy of the KEFJ shoreline for each date. These data are intended as an initial identification of portions or segments of the KEFJ shoreline that experienced visually evident shoreline change from the 1950s to 2005. The interpreter uses the “effects toolbar” in ESRI’s ArcMap 10.0, turning on and off or swiping imagery to identify differing horizontal water line positions between the two images. In some areas, minimal horizontal water line shift is noted. In addition, some near-shore landslides or coastal slopes with newly established shrub cover are also captured in shoreline segments. The vast majority of shoreline segments, by length, noted as experiencing change represent visual changes in the horizontal position of the instantaneous water line. Primary change areas include receded glacier termini; subsided and eroded beaches (in some cases with evidence of ghost forests); alterations in alluvial areas such as redistribution of sediment at stream mouth deltas and stream channel migration; newly established vegetation (primarily shrubs) in recently deglaciated areas; and vegetation establishment and succession in alluvial areas.

Cusick (2012) suggests that identifying various shoreline features using aerial photography or satellite imagery may be ambiguous and subjective, recognizing a large source of error in the variation in tide positions between individual photos. For example, the 1950s aerial photos range in day of year and cover multiple years; therefore, tidal positions also vary across photos. Likewise, the 2005 IKONOS orthoimage mosaic likely represents various tidal positions across the image mosaic as it is made up of several different images from multiple days of the year.

The *Change Segments* dataset (i.e., the appended Pendleton [2005] GIS dataset) is intended to provide an initial characterization of potential, primary forces that may have contributed to the visual changes apparent between the image sources. With further examination and field investigation, a more finite and robust classification of coastal processes responsible for the changing coastal geomorphology could be identified in the future. For example, the types of erosive forces such as tides, sea-level changes, cross-shore currents, stream flows, or wave action might be characterized with future work. An example of such a classification is employed in a salt marsh monitoring project

in LACL and KATM (Jorgenson et al. 2010). Some change types identified in this project include shoreline erosion or deposition, channel erosion or deposition, sedimentation, paludification (bog expansion due to a rising water table), succession (early and late), and tidal fluctuation (Jorgenson et al. 2010).

Data Extent

Nearly the entire park's coastal shoreline is delineated in *KEFJ Shoreline 2005 IKONOS*. However, IKONOS coverage is lacking for Nuka Island, and therefore it is not represented in this dataset. Similarly, coastal shoreline change detection is not possible for all of the park's coastal shoreline using the 1950s and 2005 image sources chosen for this assessment. 1950s orthophotos are lacking in some coastal areas of the park. In addition, in some areas cloud cover or shadows obscure the shoreline in one or both of the image sources, preventing change detection. These situations are recorded for all relevant shoreline segments in the *Change Segments* shoreline dataset (e.g., codes 11, 12, 14, 15) (Table 37). Lastly, the Pendleton (2005) GIS dataset, used as a base layer of the *Change Segments* dataset, lacks coverage in the southwestern portion of the park, ending just south of Yalik Point heading southwest along the KEFJ coast. However, the 1950s and 2005 images are available in this southwestern portion of the park's coastline and *1950s Shoreline Change Areas* and the *2005 Shoreline Change Areas* are delineated here.

4.9.5 Current Condition and Trend

Position of Mean High Water Line (MHWL)

The MHWL is "a tidal datum which is the average of all high water heights observed over the National Tidal datum Epoch" (NOAA 2013, p. 15). The mean high water line is "the line on a marine chart or map (hard copy or digital in a GIS) that represents the intersection of land with the water surface at the elevation of mean high water" (NOAA 2013, p. 15). Water lines such as this are traditional, datum-referenced features that define shorelines. They can be important for jurisdictional, regulatory, and scientific reasons (e.g., characterization of coastal processes affecting shoreline movement, rates of shoreline change, and potential impacts of relative sea level rise relating to resource management issues) (Mague and Foster 2008). However, accurately identifying the vertical and horizontal positions of these various features has presented long-standing challenges for coastal surveyors and cartographers (Mague and Foster 2008); variations in spatial and temporal scales affect the accurate identification, location, and cartographic representation of these waterlines (Donovan et al. 2002).

In lieu of ground measurements and tidally referenced shoreline features such as the MHWL, the following analysis summarizes shoreline change detected through image comparison and shoreline delineation in a GIS.

The total length of the 2005 KEFJ shoreline (i.e., the delineated, instantaneous waterline contained in the *KEFJ Shoreline 2005 IKONOS* dataset) is approximately 860 km or 534 mi, excluding Nuka Island as IKONOS imagery is lacking here. Approximately 31% or 270 km (167 mi) of this shoreline is identified as changed from the 1950s to 2005. This is represented in the *KEFJ 2005 Shoreline Change Areas* dataset by a total of 96 individual shoreline segments and grouped into 85 named

change areas (i.e., contiguous shoreline segments) (Plate 30). The primary observed and interpreted changes across the park's shoreline include: sediment movement (accretion and erosion) in fluvial areas such as river mouth deltas, subsidence resulting in beach erosion and vegetation loss, newly deposited material along steeply sloped shorelines and at glacial termini, and changes to near-shore land cover (primarily post-glacial recession shrub establishment). Lastly, in a couple of instances such as near Yalik Point, vegetation loss from landslides is evident.

Some of the identified change areas experienced complex and large magnitude changes in shoreline features, primarily from subsidence and beach erosion, glacier recession, or from a combination of these two forces. For example, the beach in front of the present-day (2005) Bear Glacier Lagoon migrated landward as much as 238 m (780 ft), and the once small lagoon, approximately 80 ha or 200 acres in surface area in the 1950s, expanded to nearly 1,600 ha (4,000 acres) in 2005 and exposed an entirely new shoreline. The changes in shoreline features near Pederson Glacier are also complex and of large magnitude over this roughly 50-yr period, with landward beach migration as much as 180 m (590 ft) and an approximately 100 ha (247 ac) lagoon in 1950 to a new lagoon area to the west with an additional surface area of approximately 121 ha (300 ac) in 2005.

In addition to the large magnitude changes occurring near Bear and Pederson glaciers, other shorelines with notable changes include river or stream mouth deltas such as Nuka River and Ferrum Creek Deltas in Beauty Bay, Delight Lake Creek Delta, the delta and lagoon at the Crescent Beach Pond, the delta and beach at Quicksand Cove; spits and lagoon entrances such as the entrance to James Lagoon, the entrance to McArthur Lagoon, Northwestern Lagoon and Spit; glacier terminus areas such as the McCarty Glacier, Northwestern Glacier and an unnamed glacier to the southwest, Holgate Glacier, and Aialik Glacier; and beaches such as in Verdant Cove, McMullen Cove, and at Bulldog Cove.

The *KEFJ 1950 to 2005 Change Segments* dataset represents the shoreline as it was mapped from its original sources; it is based on an existing shoreline dataset from Pendleton (2005) which was created using a 1:63,360 map scale. Shoreline changes are noted in this dataset, using appended fields, according to the comparison of 1950s and 2005 image sources. Existing line segments were split when necessary to spatially correlate with the shoreline as it appears in the 2005 IKONOS orthoimage mosaic. While the original shoreline data co-registers poorly to the shoreline as it appears in the 2005 image mosaic, changes are captured in the dataset as a way to preserve existing shoreline characteristics in the dataset and to summarize changes according to these characteristics.

The majority of the shoreline, approximately 68% of the entire length, in the *KEFJ 1950 to 2005 Change Segments* dataset has no evidence of large-scale, visual changes (code 0, Table 37). Approximately 168 km (105 mi) or 20% of the shoreline's total length is considered to be major changes (codes 1-6 in the *Change Segments* dataset, Table 37). Approximately 20 km (13 mi) or 3% of the total shoreline length in the *Change Segments* dataset experienced changes of lesser magnitude, those considered minor changes (change codes 7-10, & 19) (Table 37). Lastly, approximately 10% of the shoreline length or 70 km (43.5 mi) had some photo or boundary issues.

Table 37. Codes, change type descriptions, and photo issue descriptions for interpreted shoreline segments. A summary of the Change Segments GIS dataset which uses the Pendleton (2005) shoreline GIS line data as a base layer.

Code	% of total shoreline length (~722 km)	Description ³	Primary Associated Landforms ⁴
0	66.5	no large scale visual changes evident	rock cliff (45); cliff w/gravel beach (17); gravel beach, narrow (13); gravel fan (6); blank (4); gravel flat wide (3); ramp w/ gravel beach, narrow (2); cliff w/gravel beach (2); rock ramp, narrow (2); sand and gravel beach, narrow (2)
<i>Major Changes¹</i>			
1	5.0	glacial recession primary change (25)	calving glacial terminus (32); gravel flat wide (16); gravel beach, narrow (13); sand and gravel fan (10); gravel fan (9); cliff w/ gravel beach (9); rock cliff (8); cliff w/gravel beach (3)
2	10.2	erosion/subsidence (47)	gravel beach, narrow (25); sand & gravel beach, narrow (21); sand & gravel flat (18); blank (12); gravel flat wide (9), sand & gravel fan, wide (5), mudflat (4); sand beach (2); ramp w/ gravel beach, narrow (1)
3	0.8	stream channel sediment (4)	gravel flat wide (54) sand & gravel beach, narrow (36); gravel fan (10)
4	2.3	vegetation establishment/succession (11)	rock cliff (33), gravel flat wide (32), cliff w/ gravel beach (17); gravel beach, narrow (13); gravel fan (5); sand and gravel beach, narrow (2)
5	1.6	subsidence w/ evidence of ghost forest	sand & gravel flat (44); sand & gravel fan, wide (21); gravel beach, narrow (19); mudflat (10); gravel flat wide (7)
6	0.9	landslide occurred since 1950s (8)	gravel beach, narrow (43); cliff w/ gravel beach (32); rock cliff (25)
Subtotal: 21.1			
<i>Minor Changes²</i>			
7	0.4	minor stream related sediment changes	gravel fan (93); cliff w/ gravel beach (7)
8	2.1	minor subsidence/erosion	gravel beach, narrow (36); gravel fan (27); sand & gravel flat (10)
9	0.2	minor vegetation establishment/succession	sand & gravel beach, narrow (100)
10	0.1	minor landslide occurred since 1950s	cliff w/ gravel beach (100)
19	0.1	sediment increase near shoreline (i.e., terrestrial expansion)	gravel fan (100)
Subtotal: 2.9			

Table 37. Codes, change type descriptions, and photo issue descriptions for interpreted shoreline segments. A summary of the Change Segments GIS dataset which uses the Pendleton (2005) shoreline GIS line data as a base layer. (continued)

Code	% of total shoreline length (~722 km)	Description ³	Primary Associated Landforms ⁴
<i>Photo or boundary issues</i>			
11	2.8	issues with the 1950s photos (e.g., shadows, clouds, distortion, etc.)	cliff w/gravel beach (30); rock cliff (24); cliff w/ gravel beach (23); gravel beach, narrow (9), gravel fan (5)
12	1.3	issues with the IKONOS imagery (e.g., shadow, clouds, distortion, etc.)	cliff w/ gravel beach (28); sand and gravel beach narrow (26), rock cliff (23), gravel fan (13), gravel beach, narrow (11)
13	0.6	outside park, changes not interpreted	rock cliff (65); gravel beach, narrow (23); sand and gravel fan, wide (9); cliff w/ gravel beach (3)
14	4.9	lacks photo coverage	rock cliff (53); gravel fan (21); cliff w/ gravel beach (9); sand and gravel flat (6); gravel flat wide (4); sand and gravel fan, wide (4); gravel beach, narrow (3); cliff w/ gravel beach (2)
Subtotal:	9.7		

¹ Major and minor change categories represent a subjective separation in the magnitude of change associated with each shoreline segment given the associated code. Major changes (1-6) are shoreline segments (instantaneous water lines) with very prominent, obvious changes to coastal landforms and/or shifts in waterline positions. For the purpose of this assessment, these are considered unlikely to be erroneously identified as change (i.e., false positives) because of tidal position differences between image sources or slight image distortion issues.

² Shoreline segments considered minor changes (7-10, & 19) capture changes of less prominence or of a lower magnitude in terms of shifting horizontal waterline positions. Shoreline segments characterized as minor changes may be influenced to a greater degree by sources of error such as tidal position at time of photography or image distortions than the shoreline segments considered major changes.

³ Percentage of total length of major change shoreline segments.

⁴ Each landform is shown with the percent of total length by change type in parenthesis, according to the Pendleton (2005) GIS data used as the base layer. NOTE: the Pendleton (2005) GIS data do not cover the entire coastline of the park. Data are lacking south and west of Yalik Point and along Nuka Island. Roughly 30 km (18.6 mi) of the shoreline segments in this dataset do not contain a landform designation (i.e., "blank" landform type), because these segments are added to the original dataset by delineating the 2005 shoreline in the southwest portion of the park (not Nuka Island), extending the original dataset's shoreline coverage. In addition, the base data do not register well with the 2005 IKONOS imagery used in the interpretation process, therefore, the percentages by length for each change description should be used with caution as changes observed in the 1950 to 2005 image comparison may not line up with particular landforms being identified in the older, smaller scale shoreline data used by Pendleton (2005).

In summarizing other existing attributes contained within the original Pendleton et al. (2005) dataset for major change segments (codes 2-6), excluding areas directly related to glacier recession (i.e., newly exposed shorelines), a few patterns emerge. The entire dataset for the park has a mean tidal range of 2.5 m and a relative sea level rise of -1.46 mm/yr. However, a range of values are represented for annual shoreline change potential, coastal slope percentages, geomorphic rankings, wave energy estimates, and relative change potential indices (Table 38). Most of the change segments (72% by length) were of relatively high erosion potential (4). The vast majority of the change segments (92% by length) were associated with coastal slopes of 16%, and a large proportion of them (74% by length) were of a high geomorphic ranking such as cobble beaches, estuaries, and lagoons. Associated wave energy estimates were generally moderate (2), at 61% by length. Lastly, these change areas were primarily associated with moderate relative change potential rankings between 3.5 to 5.

Table 38. Major change segments and select, associated shoreline characteristics in the Pendleton (2005) GIS dataset. Only major changes are represented here, specifically change codes 2-6 (refer to Table 37 for change code descriptions).

Characteristic	Value	% of total length*
Annual Shoreline Change (<i>unit-less change potential estimate from erosion/accretion</i>)		
change not likely	2	7
change may or may not occur	3	21
change likely	4	72
Coastal Slope (<i>% slope</i>)		
	9	2
	11	6
	16	92
Geomorphic Ranking (<i>unit-less</i>)		
Very low: rocky cliffed coasts	1	7
Low: medium cliffs, indented coasts	2	5
Medium: low cliffs, glacial drift, alluvial plains	3	9
High: cobble beaches, estuary, lagoon	4	74
Very High: barrier beaches, sand beaches, salt marsh, mud flats, deltas	5	6
Wave (<i>mean significant wave height, a unit-less estimate of wave energy</i>)		
Low	1	21
Moderate	2	61
High	3	18
Relative Change Potential Index (<i>a unit-less ranking of the potential for shoreline change due to sea level rise</i>)		
	1.4	0.7
	1.7	3.4
	2.0	1.6
	2.8	1.0
	3.0	4.0
	3.5	15.1
	3.7	0.7
	4.0	1.7
	4.2	5.7
	4.5	4.0
	4.9	0.1
	4.9	45.3
	5.2	1.3
	5.5	0.1
	5.7	0.1
	6.3	1.5
	6.9	0.2
	8.0	3.3
	8.5	1.2
	9.8	0.3

*The accuracy of these percentages are unknown as the Pendleton (2005) GIS dataset co-registers poorly with the 2005 IKONOS orthoimage mosaic and therefore some spatial inaccuracy is present.

The majority of the *Change Segments* by total length were associated with calving glacier termini or beaches, flats, or fans with variations of sand or gravel surfaces. These shoreline areas are especially dynamic due to receding glacier termini, changing wave regimes, terrestrial-derived sediment

regimes, and the effects of subsidence post-1964 earthquake. Shoreline segments considered major changes (change codes 1-6) were associated with the following landforms: gravel beach, narrow (21% of the total length of major change segments); gravel flat wide (15%); sand and gravel flat (13%); sand and gravel beach, narrow (13%), calving glacier terminus (8%), rock cliff (8%) (this is likely erroneous and possibly the result of geographic registration issues of the original shoreline data versus the shoreline in the 2005 IKONOS orthoimage mosaic); cliff with gravel beach (7%); sand and gravel fan, wide (4%); gravel fan (4%); mudflat (3%); sand and gravel fan (3%); sand beach (1%); ramp with gravel beach, narrow (1%); and gravel beach (<1%).

Position of Foreshore and Backshore Vegetation

Foreshore and backshore vegetation are additional shoreline features used to further define coastal shorelines. Like waterlines, their positions along the shore are subject to geomorphic and biological changes over time. In comparing the two image sources, changes in the position of foreshore and backshore vegetation are visible in some stream mouth deltas, barrier beaches, and spits along the KEFJ coast. However, a methodology is not yet in place for consistently identifying these features. An example of photo-interpreted foreshore and backshore vegetation positions on 2005 orthoimagery is illustrated along a barrier beach near the entrance to Pederson Lagoon (Figure 53). Notice the position of the 1950s water line indicating that significant subsidence and erosion likely occurred here.

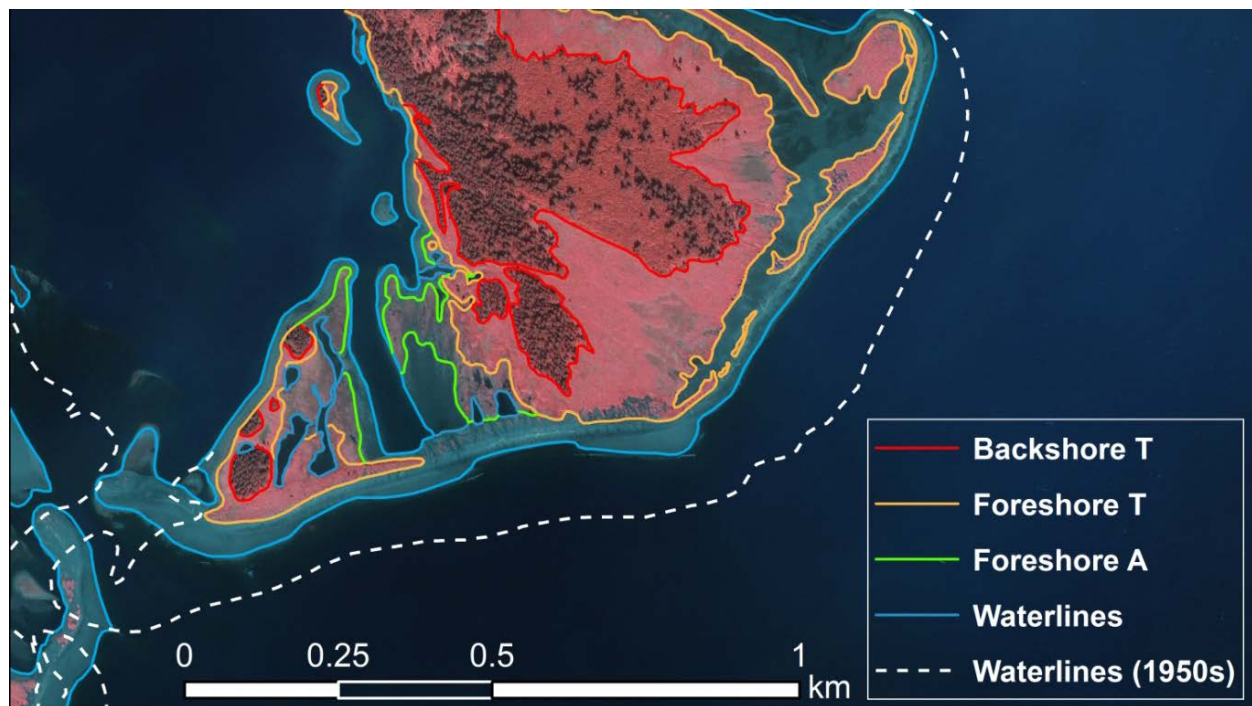


Figure 53. Example of 2005 waterlines (instantaneous, not tidally corrected or referenced), foreshore vegetation positions (T = terrestrial and A = aquatic), and backshore vegetation positions along a barrier beach near the entrance to Pedersen Lagoon in KEFJ: 1950s water lines (dashed white line), 2005 water lines (blue lines), foreshore aquatic vegetation (green lines), foreshore terrestrial vegetation (orange lines) and backshore terrestrial vegetation (red lines). Refer to ID No. 34 in Plate 30 for its general location in the park and Appendix 8 for a brief description of this change area (shoreline segment).

Vegetation can also change directly from mass wasting events such as landslides. An area of multiple landslides is evident along a steep shoreline near the entrance to Nuka Bay in KEFJ (Figure 54).

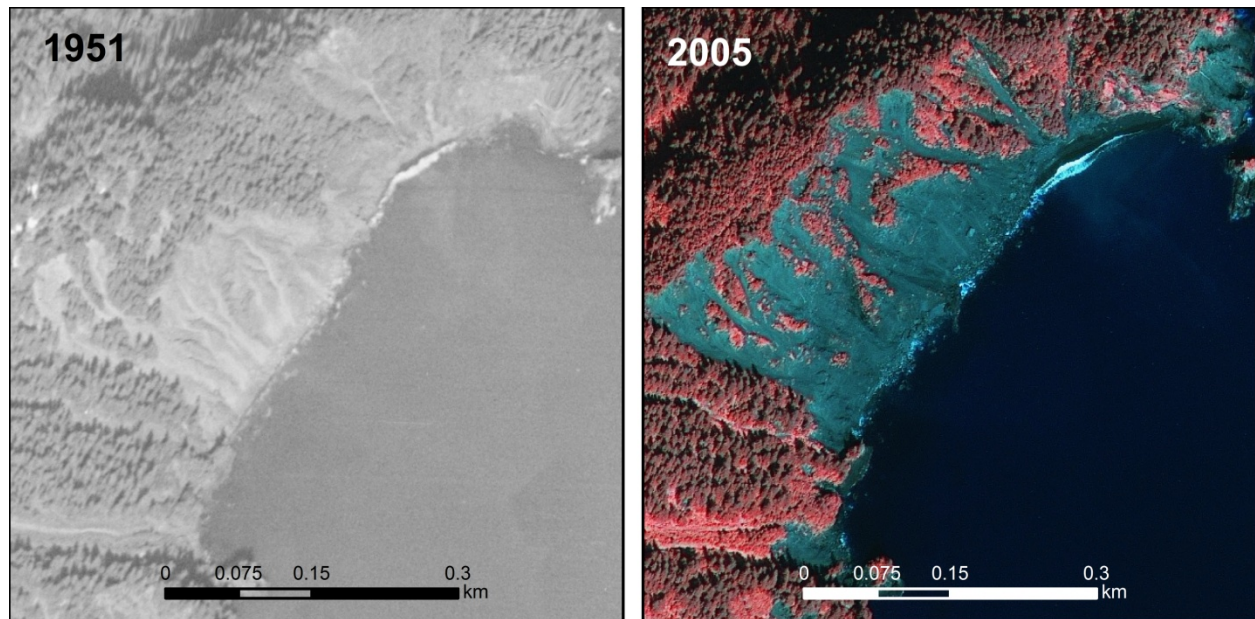


Figure 54. Landslide evidence in comparing 1950s orthophotos (left) to 2005 IKONOS orthoimagery (right) near Yalik Point in KEFJ. *Refer to ID No. 85 in Plate 30 for its general location in the park and Appendix 8 for a brief description of this change area (shoreline segment).*

Another phenomenon resulting from geomorphic changes along the coast are the formation of “ghost forests”. These are coastal stands of dead, bleached trees killed by saltwater inundation when the land subsided from the 1964 Alaskan Earthquake. After the land subsides, the area is repeatedly inundated by saltwater and tidal beach sediments are deposited and an emergent and or shrub dominated wetland with dead standing trees is created. An example of such a forest along the Seward Highway near Girdwood, AK is shown in Photo 15.



Photo 15. Ghost forest wetland along the Seward Highway near Girdwood, AK (NPS Photo).

Another location with significant shifts in foreshore and backshore vegetation positions and evidence of ghost forests is the river mouth delta area of Nuka River (Figure 55).

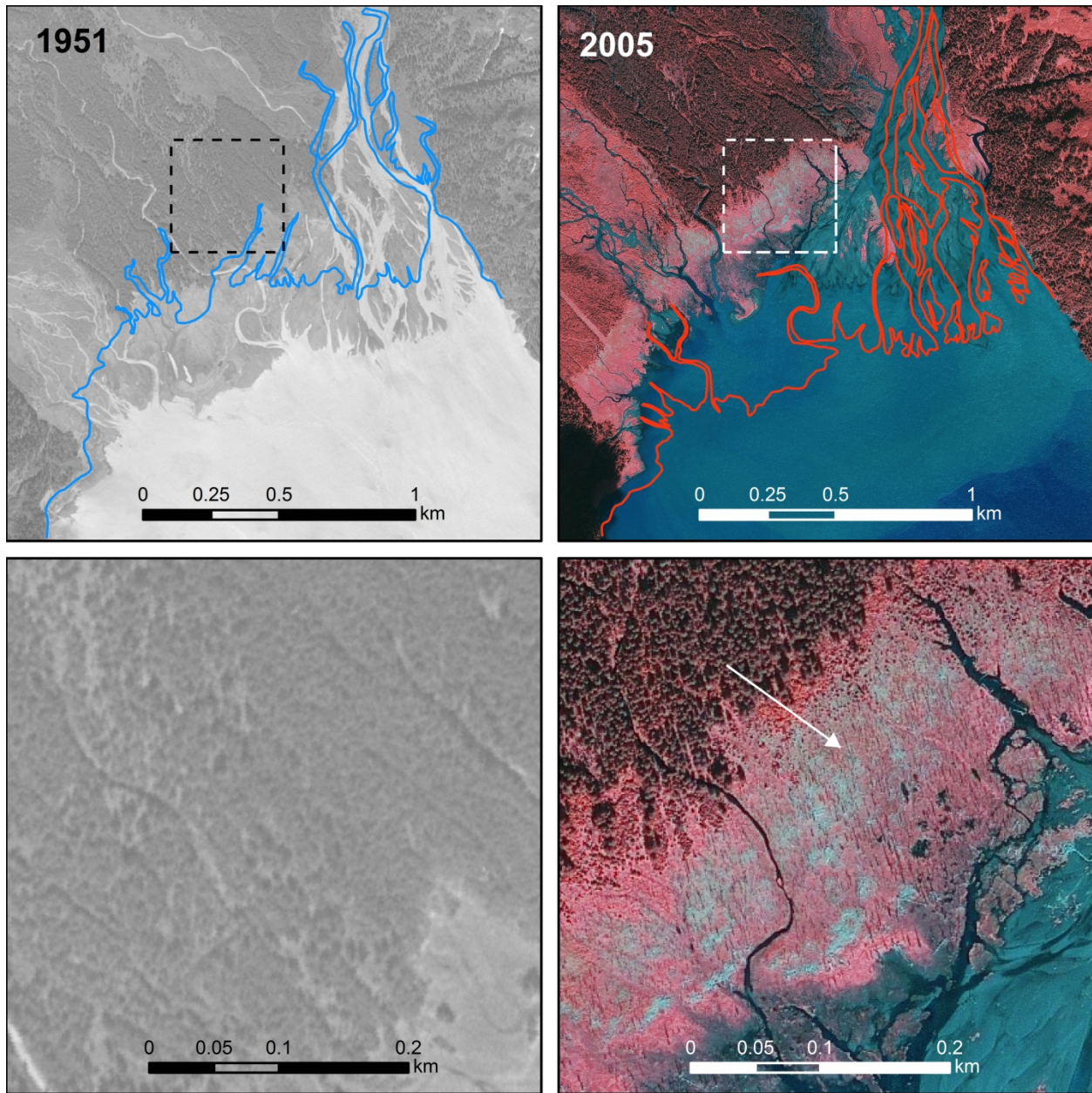


Figure 55. Comparison of foreshore and backshore vegetation positions in 1951 and 2005 orthoimages of the river mouth delta areas of Ferrum Creek (left portion of the upper images) and Nuka River (in the right portion of the upper images). The top row of images compares delineated shorelines from 1951 (left) and 2005 (right). The bottom row of images provides a closer aerial view of the vegetation changes in an area between Ferrum Creek and Nuka River deltas, each of their extents indicated by the dashed boxes in the upper row of images. Notice the ghost forest as indicated by the arrow in the lower right-hand image. Refer to ID No. 60 in Plate 31 for its general location in the park and Appendix 8 for a brief description of this change area (shoreline segment).

Through photo interpretation, several other locations were found to contain ghost forests (listed with change area name followed by ID No. from Plate 30): Babcock Creek Delta (ID No. 6), Beauty Bay Cove South (11), James Lagoon Entrance (33), McArthur Lagoon (38), portions of North Arm E Beach 5 (47, North Arm Stream Delta 1 (48), Nuka R. and Ferrum Cr. Delta (60), Paguna Arm

Stream Delta SE (62), Petroff Point (68), Pilot Harbor Stream Delta (69), Quartz Bay (70), Verdant Cove (78), and in Yalik Point Cove (84). Refer to Plate 30 for the entire list of 2005 change areas (contiguous shoreline segments).

In addition to locating ghost forests by photo interpretation, querying the available National Wetlands Inventory (NWI) data for the park contained within the Alaska NPS Permanent Dataset results in locations of potential ghost forests. If large enough, ghost forests may be represented in the National Wetland Inventory (NWI) GIS data mapped on 1980s aerial photography. In the Cowardin et al. (1976) classification used by NWI, these areas are classified as Estuarine, Intertidal, Forested, Dead / Emergent, Persistent, Irregularly Flooded wetlands, as indicated by the code: E2O5/EMIP (HDR Alaska 2008). Using an SQL query for these NWI codes, several locations are found within the boundaries of KEFJ, primarily along the shores of Nuka Island. However, the largest area of ghost forest found through this query is at the river mouth delta of Nuka River illustrated in Figure 55.

Top and Toe of Bluff

The top and toe of coastal bluffs are also features often included in mapped shoreline characteristics (Mague and Foster 2008). Measuring the positions of these features may help understand shifts in their horizontal and vertical positions over time and the associated changes to vegetation and habitat. Isostatic rebound and the 1964 earthquake have likely caused changes in the positions of the top and toe of bluffs. Identifying the top and toe of coastal bluffs with an acceptable vertical and horizontal position accuracy is not possible using photo interpretation on historic aerial photography, satellite imagery, and contemporary 30 meter DEMs available for the park. This measure is a data gap until a protocol or methodology is developed to accurately define and measure top and toe of bluff positions.

Threats and Stressor Factors

Using a GIS modeling approach, Pendleton et al. (2006) created a GIS dataset indicating the relative vulnerability to shoreline change due to sea-level rise for the shoreline of KEFJ. The authors' model examined several different parameters' contributions to coastal change: geomorphology, regional coastal slope, rate of relative sea-level change, historical shoreline change rates (erosion/accretion), mean tidal range, and wave energy regime. A range of values and characteristics were categorized in to five relative change potential classes for the U.S. Pacific coast: very low, low, moderate, high, and very high (Table 39).

Table 39. Range for vulnerability ranking of variables on the U.S. Pacific Coast (Table in Pendleton et al. 2006).

Variable	Very Low 1	Low 2	Moderate 3	High 4	Very High 5
Geomorphology	rocky cliff coasts, fjords	medium cliffs, indented coasts	low cliffs, glacial drift, alluvial plains	cobble beaches, estuary, lagoon	barrier beaches, sand beaches, salt marsh, mud flats, deltas, mangrove, coral reefs
Annual Shoreline Change (erosion/accretion potential)	N/A	change not likely	change may or may not occur	change likely	N/A
Coastal Slope (%)	>14.7	10.90 - 14.69	7.75 - 10.98	4.60 - 7.74	<4.59
Relative Sea-Level Change (mm/yr)	0-1.8	1.8-2.5	2.5 - 3.0	3.0 - 3.4	>3.4
Wave Energy Regime (Mann 1998)	N/A	low	moderate	high	N/A
Mean Tide Range (m)	> 6.0	4.0 - 6.0	2.0 - 4.0	1.0 - 2.0	<1.0

Pendleton et al. (2006) then applied these vulnerability rankings to the KEFJ coast data and calculated a change potential index (CPI) by combining ranks for each variable. Areas with a high relative coastal change potential index indicate areas that may be more likely to change in response to future sea-level changes. The following geomorphic types fall into the five relative change-potential categories in KEFJ: 1) very high change-potential - sand beaches, mudflats, or calving tidewater glaciers; 2) high change-potential - gravel and cobble beaches; 3) moderate change-potential - alluvial fans and glacial deposits along the shore; 4) low change-potential - medium cliffs and rock platforms; 5) very low change-potential - vertical rock cliffs (Pendleton et al. 2006). Generally, tidewater glacier areas and outer-coast unconsolidated sediment areas (beaches) exposed to high wave energies are the shorelines determined to be most vulnerable to coastal change from sea-level changes in KEFJ (Pendleton et al. 2006). These change potential categories along the park's coast are displayed in Figure 56 (Pendleton et al. 2006).

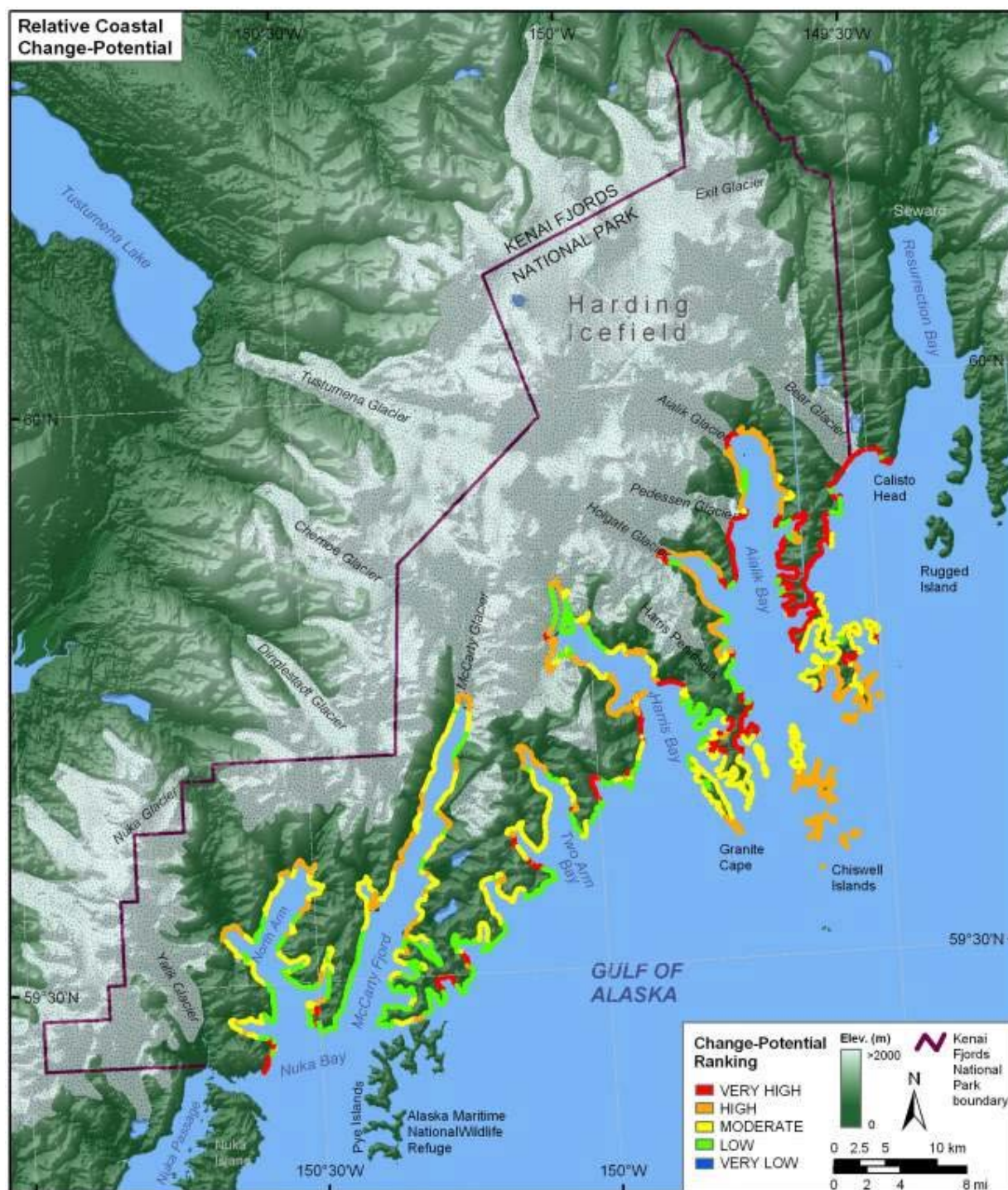


Figure 56. Relative coastal change-potential for KEFJ. The colored shoreline represents the relative coastal change-potential index (CPI) determined from the six variables. The very high change-potential shoreline is located along sandy pocket beaches where shoreline change-potential and significant wave heights are highest. The low change-potential shoreline is located along rock cliffs which are usually within sheltered locations in the fjords (Pendleton et al. 2006).

The Intergovernmental Panel on Climate Change (IPPC) estimates that global average sea level will rise between 0.18 to 0.59 m (0.6 to 2 ft) in approximately the next 85 years (by the end of the 21st century) (Solomon et al. 2007). However, while many U.S. locations have seen increases in sea levels, sea levels near KEFJ have been trending downward because uplift rates have outpaced the rise of global sea level. According to the NOAA Sea Levels Online Viewer, sea levels in Seward, Alaska (station 9455090) have decreased at a rate of -1.74 mm/year from 1964 to 2006 (NOAA 2013). Larsen et al. (2001) found an annual uplift rate of 10.4 ± 1.0 mm in Seward at permanent tide gauges.

Another important aspect related to changing coastal geomorphology in KEFJ is the potential for glacial lake outburst floods to occur. On 19 August 2008, a local sea kayak guiding company noticed unusually high water levels and standing waves at the mouth of Bear Glacier Lake (NPS 2008). Later, after viewing it from a helicopter, NPS staff determined that a lake dammed by Bear Glacier drained suddenly, releasing a minimum estimate of 7,500 acre-feet of water (NPS 2008) (Figure 57). According to a GIS delineation on the 2005 IKONOS satellite image mosaic for KEFJ, this unnamed lake's approximate surface area was 45 ha in the summer of 2005 (Figure 58). Outburst floods like this are a concern for park management because they can create dangerous boating conditions such as increased iceberg calving, standing waves and strong currents, or the sudden redistribution of sediments and debris in channels and have the potential of flooding down-glacier campsites (NPS 2008).

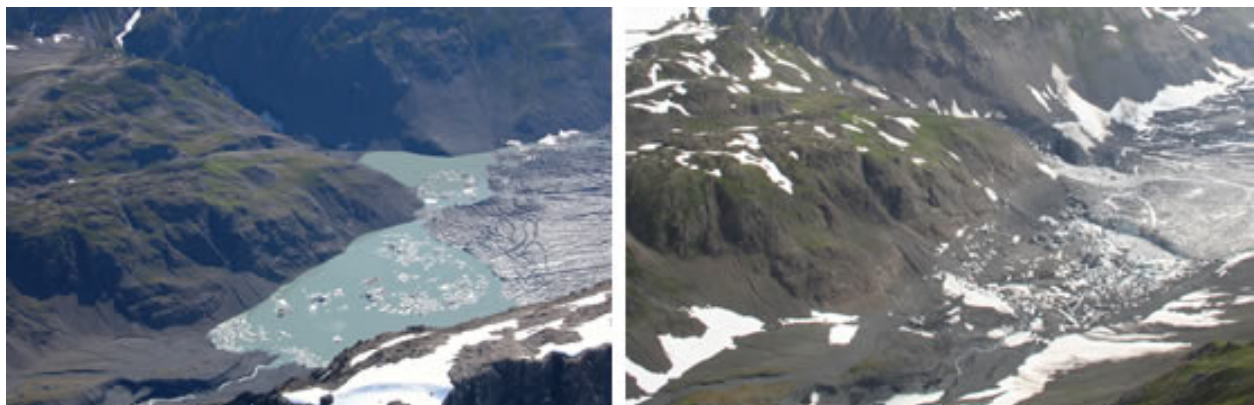


Figure 57. Before and after photographs of the unnamed, glacier-dammed lake. The lake water drained down-glacier toward Bear Glacier Lake, which is to the right and out of view in the photos. USGS photo 6 August 2005 and NPS photo 19 August 2008 (NPS 2008).

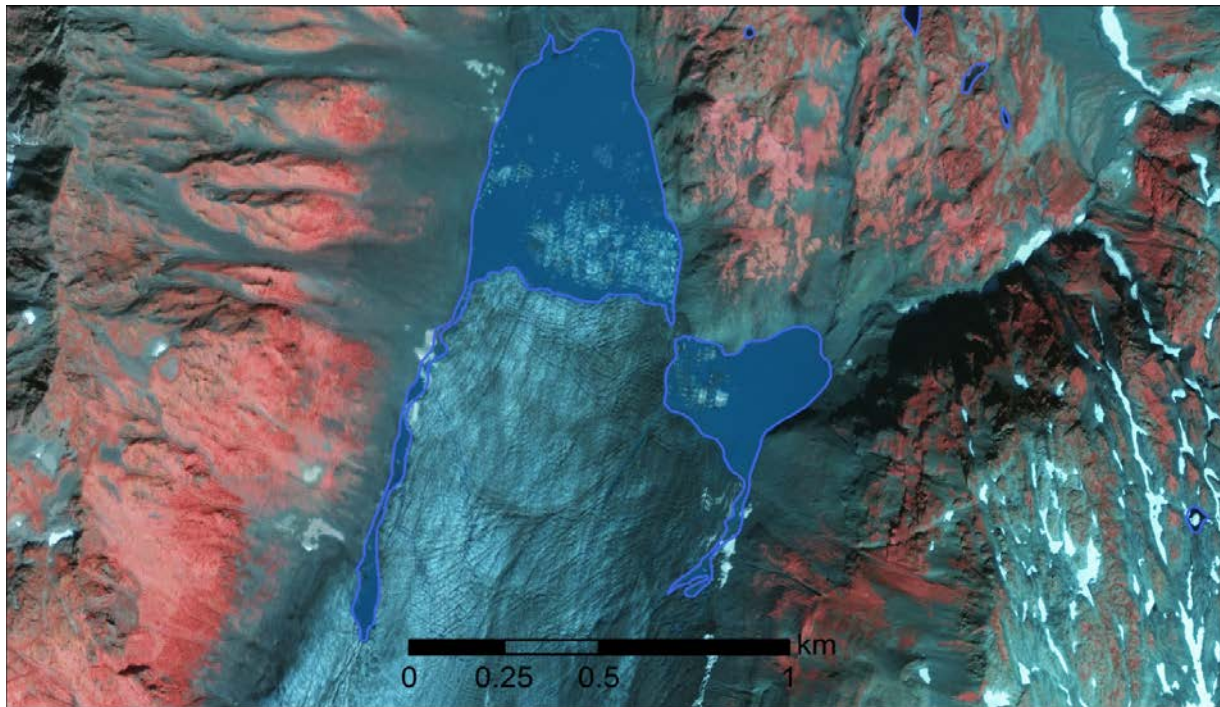


Figure 58. Unnamed glacier-dammed lake in 2005 IKONOS orthoimagery. The lake appearing in two parts, delineated in blue, is approximately 45 ha (111 acres) in surface area.

Data Needs/Gaps

Digital shoreline data are important for several Alaska NPS units with coastlines, including KEFJ, because the MHWL is typically the jurisdictional boundary of Alaska National Parks. Digital shoreline data may also be used for a variety of scientific purposes. However, much of the existing digital shoreline data used by the NPS are out of date and are of small scale, typically 1:80,000 or smaller. Cusick (2011) suggests that shoreline mapping techniques that involve identification of vegetation lines, high water marks or wet/dry lines are often ambiguous and subjective in nature and that accurate mapping requires GPS-derived elevation data tied to local tidal datum. Likewise, Boak and Turner (2005) assert that accurate shoreline detection techniques for measuring shoreline changes require objectivity, robustness, and repeatability.

SMUMN GSS is presently working with the NPS Alaska Regional Office to edit and finalize digital coastline (shoreline) data for KEFJ and four other Alaska parks. The purpose of this project is to create accurate, contemporary, and defensible digital shoreline datasets for Alaska coastal parks, and to submit these data to the National Hydrography Dataset's (NHD) master geodataset. Together, the NPS and SMUMN GSS have created a protocol for this process, addressing many scenarios encountered during the compilation and editing of existing base datasets, including how to handle updates of offshore island or rocks, interior depiction of mean high water present in NOAA data, man-made waterfront structures, and glacial extents. The NOAA extracted vector shoreline (EVS) data and the electronic navigational chart (ENC) data are the best available vector coastline data delineating the high water line (HWL) or the MHWL, because they have been tidally corrected. The

resulting data are intended to replace the existing USGS topographic shoreline data, the base layer used in the Pendleton (2005) GIS model and for this assessment in identifying shoreline change.

SMUMN GSS is also working with AK NPS to use newly acquired digital elevation models (DEMs) derived from interferometric synthetic aperture radar (IFSAR) to create shoreline features of the NHD and rivers, lakes, and other water bodies not included in the NOAA EVS data. While this portion of the project is not intended to update the existing NHD, it is intended to evaluate and document various techniques and associated estimates of quality assurance and manual editing required to complete this in KEFJ and four other Alaska NPS park units.

Additional historic coastal aerial photography is available for the park from the 1980s and 1990s. Future work could also examine these image sets along with the 1950s and 2005 imagery to capture shorelines or shoreline features for these dates. Figure 59 provides an example of the four image dates in a coastal area near James Lagoon of KEFJ that experienced significant visual change.

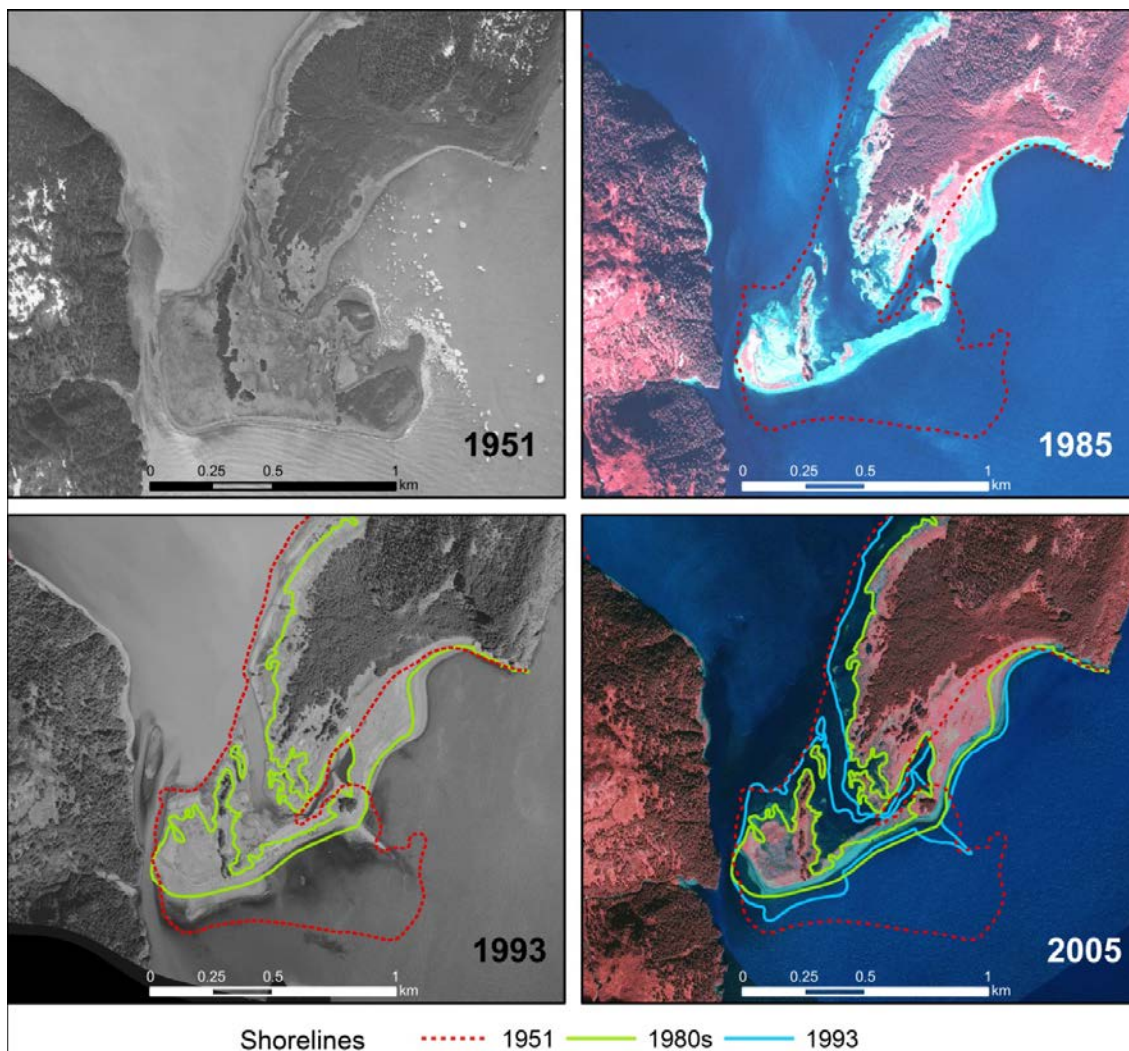


Figure 59. Aerial orthophotos from 1951, 1985, and 1993, and 2005 IKONOS orthoimagery of a changing coastal shoreline at the entrance to James Lagoon in KEFJ.

Shoreline positions derived from the 1950s, 1980s, 1990s, and 2005 images could be used as inputs to the Digital Shoreline Analysis System (DSAS). The DSAS, produced by the USGS's Woods Hole Science Center, works as an extension to ESRI's ArcGIS 10.x. The DSAS uses multiple shoreline positions and a user-generated baseline as inputs and creates transects to measure distances, including the shoreline change envelope and net shoreline movement (Figure 60). The DSAS also creates statistics such as end point rate, least squares regression, weighted least squares regression and supplemental statistics for least and weight regressions (Thieler et al. 2009).

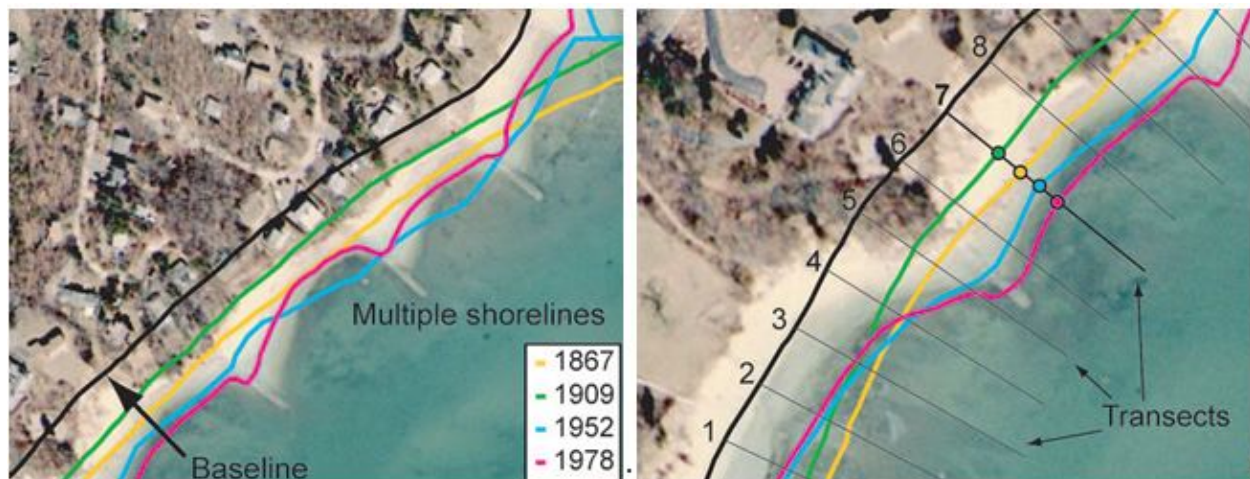


Figure 60. Example of shoreline inputs (left) and resulting transects (right) from the Digital Shoreline Analysis System (DSAS) (Thieler et al. 2009).

Another possibility to more accurately measure shorelines and changes over time is with the use of time-average images; these can improve the temporal nature of shoreline indicators (Boak and Turner 2005). Along with time averaged images, Boak and Turner (2005) suggest that high resolution digital elevation models are also needed to more accurately understand shoreline features and change. Similarly, Cusick (2011) suggests building a GPS backbone (i.e., establishing a geodetic control network using GPS units), establishing new tidal stations, and using LiDAR-derived elevation data to more accurately measure and monitor the shoreline of Alaska park units. Historic benchmarks exist along the park's coast and could be used to help establish additional, nearby bench marks. In a 1989 Department of Interior memorandum to an incident commander, a mining engineer tech sent tidal bench mark information from the U.S. Coast and Geodetic Survey, U. S. Department of Commerce Environmental Science Services Administration. Tidal bench marks are established at several locations along the park's coast, containing the computed mean high water elevation for each bench mark location. These include the following general locations; Camp Cove (aka Verdant Cove), Paguna Arm, Chance Lagoon, Shelter Cove, and Nuka Island (Table 40).

Table 40. Tidal bench mark (BM) locations and 1965 tidal measurements along the KEFJ coast. (Unpublished Department of the Interior memo containing information from the U.S. Coast and Geodetic Survey, Dept. of Commerce Environmental Science Services Administrations from 1951 and 1965)

	Camp (Verdant) Cove, Harris Peninsula	Paguna Arm, Two Arm Bay	Chance Lagoon, Chance Cove	Shelter Cove, Beauty Bay, West Arm, Nuka Bay	Nuka Island (North End), Nuka Passage, Nuka Bay
No. of BMs	5	3	3	3	3
Year(s) of BM establishment	1912 & 1965	1928	1930	1972	1930
1965 Tide Measurements (ft)					
Highest Tide*					16.00
MHHW	10.70	11.00	11.00	11.40	11.50
MHW	9.70	10.00	10.10	10.50	10.60
Half Tide	--	--	--	--	6.00
MTL	5.50	5.65	5.75	5.95	--
MLW	1.30	1.3	1.40	1.40	1.40
MLLW	0.00	0.00	0.00	0.00	0.00
Lowest Tide*					-4.00

*estimated

Lastly, SWAN is using transects to develop shoreline profiles and to monitor shoreline changes in select coastal areas of LACL and KATM (Jorgenson et al. 2010, NPS 2011). In LACL, shoreline profiles were created from measurements in 1992, 1994, 2004, and 2011, representing the longest repeated field measurements of coastal shoreline change in the network (NPS 2011). This work identifies changes in vertical and horizontal positions of specific coastal landforms at specific locations over time. This methodology and methods employed by Jorgenson et al. (2010) could be repeated in select areas of KEFJ. The visual comparison of 1950s aerial photography and the 2005 IKONOS satellite orthoimagery and the resulting shoreline change segment GIS data could be used in locating specific shorelines and prioritizing shoreline segments along the vast coastal shoreline of the park to employ such field methods.

Overall Condition

All lengths and areas presented below are approximated, rounded to the nearest km or ha.

According to photo interpretation of 1950s and 2005 aerial image sources, much of the present-day (2005) shoreline has not changed significantly over the approximately 50-yr period. The entire 2005 delineated shoreline (*KEFJ Shoreline 2005 IKONOS*) extends a total of 842 km (523 mi). In comparing the 2005 shoreline to 1950s imagery, approximately 291 km (162 mi) or 31% of this shoreline by length experienced visually evident changes. Over one quarter (27%) of the total length of the shoreline change was due to glacier recession revealing 78 km (48.5 mi) of newly exposed shoreline. For example, Northwestern Glacier receded over 6 km (3.7 mi) from the 1950s to 2005, creating nearly 19 km (11.8 mi) of new shoreline. Other glacier recessions resulting in new shorelines include McCarty Glacier with 7 km (4.3 mi) of new shoreline, an unnamed glacier southwest of Striation Island (or southwest of Northwestern Glacier) with 7 km (4.3 mi) of new

shoreline, and Pederson Glacier with 16 km (10 mi) of new shoreline. Approximately 30 km (18.6 mi) of new shoreline was revealed as Bear Glacier receded from 1950 to 2005. Most of this new shoreline falls within the park's boundary. Most of the other shoreline areas with visual changes appear to be related primarily to subsidence and erosion (i.e., lasting effects of the 1964 earthquake and continued sediment movement). The most prominent example found in the park, by comparing the 1950s to 2005 images, is the apparent beach movement in front of the present-day Bear Glacier lagoon; it migrated landward as much as 238 m (780 ft).

A total of 106 individual change areas or contiguous shoreline segments (*KEFJ 2005 Shoreline Change Areas*) are identified along the KEFJ coast and grouped into a total of 85 named locations (Plate 30). Locations of many of the prominent change areas are identified in Plate 30 and Plate 31 with each ID number identified in Plate 30. The primary observed and interpreted changes include: sediment movement (accretion and erosion) in stream mouth delta areas, subsidence resulting in beach erosion and vegetation loss (in some cases with ghost forest signatures in aerial imagery), newly deposited material at the shoreline along steeply sloped coasts and at glacial termini, and changes to near-shore land cover, primarily post-glacial recession shrub establishment. Only in a couple of cases is vegetation loss evident from terrestrial landslides. Changes in shoreline position near the terminus of Bear Glacier, including the associated barrier beach and lagoon and a similar area near Pederson Glacier, are complex and of large magnitude. Other shorelines with notable changes include river mouth delta areas such as Nuka River and Ferrum Creek Deltas in Beauty Bay, Delight Lake Creek Delta, the delta and lagoon at the Crescent Beach Pond, the delta and beach at Quicksand Cove; spits and lagoon entrances such as the spit at the entrance of James Lagoon, the spit and entrance to McArthur Lagoon, Northwestern Lagoon and Spit; glacier terminus areas such as the McCarty Glacier, Northwestern Glacier and an unnamed glacier to its southwest, Holgate Glacier, and Aialik Glacier; and beaches such as in Verdant Cove, McMullen Cove, and the barrier beach at Bulldog Cove.

Most of the park's coastal shoreline change occurring over this ~50-year period, in terms of horizontal distance, was associated with glacier recession that exposed new shorelines, changes associated with 1964 earthquake-caused subsidence and subsequent erosion, and changes associated with fluvial and glaciofluvial processes. However, the shoreline is constantly changing through erosion and accretion from natural events (e.g., wave regimes, stream sediments, and storm surges) and over a longer period of time, a combination of tectonic activity and isostatic rebound-effects from glacier recession causes sea level differences to vary greatly within short distances along the Kenai coast (Hayes 1980). Landforms associated with sandy or gravel beach areas are complex, and are especially subject to constant change. A thorough understanding of how multiple factors may have contributed to changes at each shoreline location over this time period and into the future will require further investigation, such as ground validation and beach profile measurements.

The GIS data resulting from the photo-interpreted comparison of 1950s aerial images and 2005 satellite images represent areas of visually evident changes along the park's coastal shoreline. The resulting data also contain preliminary interpretations of the likely causes for the observed changes in the coastal shoreline and associated landforms. These data can provide a base dataset for future

geomorphologic assessments, a starting point for understanding where the shoreline experienced geomorphic coastal change over this time period. Future site visits could act to confirm or dispute initial change characterizations, and future assessments could include mapping/delineation of additional shoreline indicators once a methodology is established, field measurements (e.g., beach profiles) in areas of high management importance or scientific interest, and additional GIS analyses to measure shoreline changes overtime (e.g., using the Digital Shoreline Analysis System).

4.9.6 Sources of Expertise

Deborah Kurtz, Natural Resource Program Manager, KEFJ

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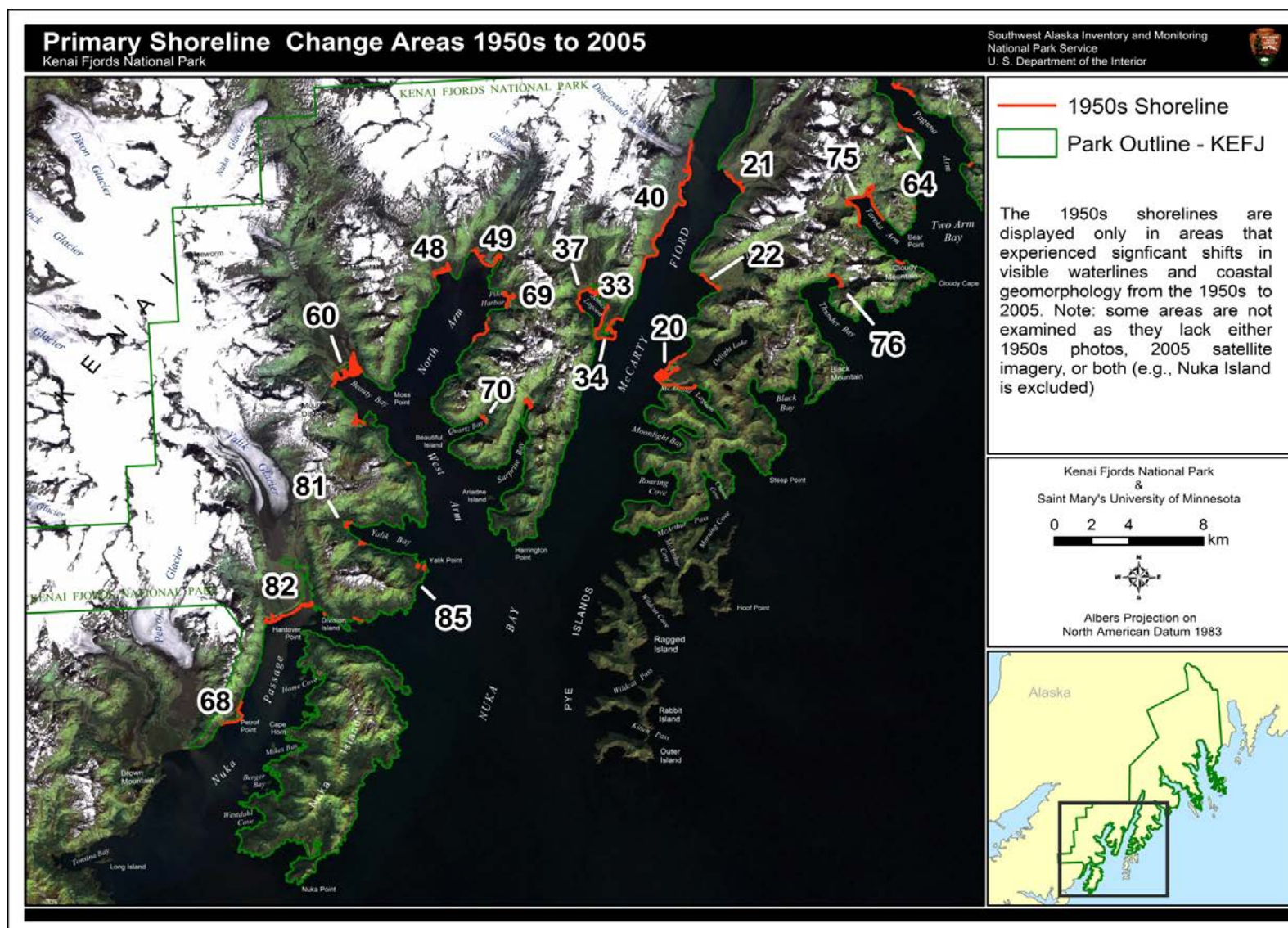


Plate 30. Coastline changes observed in comparing 1950s orthophotos to 2005 IKONOS orthoimagery. Areas of significant morphological change are represented here by displaying 1950s delineated shoreline segments (instantaneous, visible waterlines) on a 2001 LandSat image. Refer to Appendix 8 for location names and primary observed changes for each numerical label in the map. Map 1 of 2 (southwest portion of park).

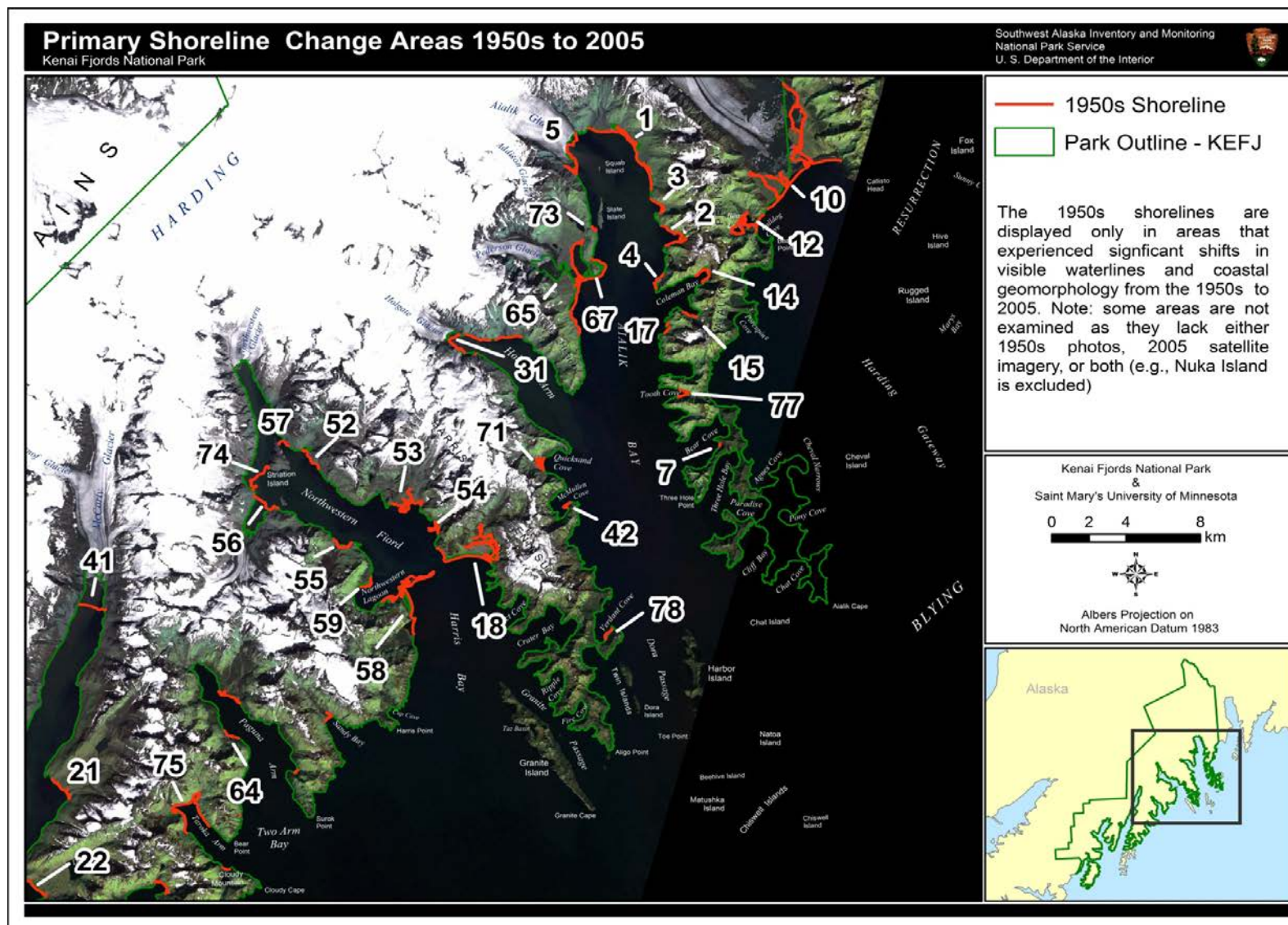


Plate 31. Observed shoreline changes comparing 1950s orthophotos to 2005 IKONOS orthoimagery. Areas of significant morphological change are represented here by displaying 1950s delineated shoreline segments (instantaneous, visible waterlines) on a 2001 LandSat image. Refer to Appendix 8 for location names and primary observed changes for each numerical label. Map 2 of 2 (northeast portion of park).

Chapter 5 Discussion

Chapter 5 is intended to provide a summary of assessment findings and discuss the overarching themes or observations that have emerged for the featured components. The data gaps and needs identified for each component are also summarized here.

5.1 Component Data Gaps

The identification of key data and information gaps is an important objective of NRCAs. Data gaps or needs are those pieces of information that are currently unavailable, but would help to inform the status or overall condition of a key resource component in the park or would allow the park to develop a more thorough understanding of the topic in order to inform possible management decisions. Data gaps exist for all resource components assessed in this NRCA. Table 41 provides a detailed list of the data gaps identified in this assessment by component. Each data gap or need is discussed in further detail in the individual component assessments (Chapter 4).

Table 41. Identified data gaps or needs for components featured in this assessment.

Component	Data Gaps/Needs
Landform – Coastal Landing Areas	<p>Further verification of the potential landing areas (PLAs) dataset using local knowledge and/or field visits.</p> <p>A characterization of landing area use type(s) (e.g., kayak stop-over, overnight camping, water taxi drop off/no overnight use)</p> <p>Travel distances from primary origins (e.g., Seward) to landing areas</p> <p>Changes of quantity and locations of marine debris and logs in relation to landing areas</p> <p>Interpretation of 1993 coastal aerial photography for the identification of marine debris and logs</p>
Black Bear	<p>General lack of bear distribution and abundance data after 2007, which are only focused on four major bays of the park. Robinson et al. (2007) data may act as baseline information for future comparison for bear population in these four bays.</p> <p>An assessment of the consistency of reporting of brown and black bear-human interactions in the BHIMS database. Consistent reporting into the future may yield increased confidence in any perceived changes in human-bear interactions, specifically at coastal sites and in the Exit Glacier area of the park.</p>
Bald Eagles	<p>Accuracy of park-wide eagle population estimates can be increased with continued nest occupancy and success monitoring (dual-observers).</p> <p>Accuracy of park-wide eagle population estimates can be increased with the optimization of the number of sample routes and total occupancy</p> <p>Bald eagle diet data (i.e., the understanding of specific prey-base in the park) is lacking</p> <p>Bald eagle wintering and nonbreeding ecology has not been study specifically in the park</p>

Table 41. Identified data gaps or needs for components featured in this assessment. (continued)

Component	Data Gaps/Needs
Marine Birds	<p>Productivity of target marine birds, excluding black oystercatchers, has not been undertaken in the park (i.e., nest and fledgling success of SWAN surveys' target marine bird species)</p> <p>Overall marine bird habitat(s) is/are not explicitly identified or characterized in the park</p>
Black Oystercatcher	<p>Monitoring of adult and fledgling survival rates</p> <p>Investigation of recruitment rates in the park's BLOY population</p> <p>Overwintering locations of the park's breeding populations and threats, stressors, and prey base at these wintering sites</p> <p>Further BLOY adult and chick diet sampling and determination of high priority foraging areas in the park</p> <p>Sight-ability (detectability) of BLOYS during annual SWAN surveys</p>
Hydrology – Exit Glacier Area – Exit Creek Channel Migration	<p>Viable methods for collecting long-term flow data for Exit Creek (e.g., one possibility is repeat time-lapse photography of changing flow conditions)</p> <p>Repeat LiDAR data could also help understand sediment budgets and possibly further understanding of flooding hazards in the Exit Creek area</p>
Glaciers	<p>Recent (since Hall et al. 2005) late summer snow line and equilibrium line altitude data is lacking</p> <p>Recent satellite data (e.g., 2007 and 2010 LandSat and MODIS) could be used to identify the annual late summer snow lines</p> <p>GLOF hazards are not well understood in KEFJ. However, recent work has been conducted by Andrew Wilcox (University of Montana) regarding hydrologic hazards on Bear Glacier. This information was not available at time of writing, but is available in Wilcox et al 2014</p>

Table 41. Identified data gaps or needs for components featured in this assessment. (continued)

Component	Data Gaps/Needs
Coastal Geomorphology	<p>Existing digital shoreline data are no longer contemporary; they were created for small scale geographic use. New shoreline data needs to be created using objective, robust, and repeatable methods in order to accurately measure/detect shoreline changes. These methods could involve GPS-derived elevation data tied to local tidal datums (i.e., a GPS geodetic control network and new tidal stations would increase shoreline feature measurement accuracies)</p> <p>Digital Elevation Models (DEMS) from interferometric synthetic aperture radar (IFSAR) will be used to create new digital shoreline features.</p> <p>The Digital Shoreline Analysis System (DSAS) is a tool that could potentially be utilized to detect changes in shoreline positions along the park's coastline from existing 1950s, 1980s, 1990s, 2005, and additional aerial images taken in the future.</p> <p>Additional mapping of digital shorelines from 1980s and 1990s aerial photographs could provide further insight into the past ~60 years of shoreline change.</p> <p>Time-averaged images along with high resolution DEMS could measure shoreline changes over time for specific coastal areas.</p> <p>Shoreline profiles are being developed using transect measurements in order to understand changes.</p>
Sensitive Vegetation Communities - Nunataks	<p>Miller et al. (2006) conducted vegetation sampling in some KEFJ nunataks in the Harding Icefield and estimated change in nunatak area from 1950-2005 for several sites in KEFJ. However, at the time 1950s aerial photography was not completely orthorectified for the park. Therefore a data gap exists in terms of the total number and extent of nunataks in KEFJ. Further use of the 1950s aerial photography and 2005 satellite imagery may help fill this gap. However, peaks surrounded by snow/ice need to have been free of ice and snow since the last glacial maximum to be considered a nunatak and therefore mapping these peaks would only represent possible nunataks; further field investigations would be required to confirm.</p>

Many of the park's data needs involve the challenge of determining ways to effectively sample and monitor biological phenomenon in order to increase statistical confidence and to ensure long-term monitoring techniques are possible, given difficult environmental conditions. To increase statistical confidence, it might mean continuing to improve the sampling techniques of existing survey efforts or, in some cases, designing an entirely different approach in terms of long-term data collection. Most of the to-date efforts to monitor the components addressed in this assessment have been conducted in the face of challenging environmental conditions and relatively limited funding, especially given, in many cases, large geographic extents to be covered and remote locales to reach with limited modes of transportation. Some statistical confidence will increase by simply repeating the existing surveys to increase the total number of samples (e.g., years), as some sampling methods have only been repeated for a few consecutive years. For example, marine bird counts from both park-driven efforts and in SWAN nearshore monitoring efforts have been collected using the same methods for less than a decade.







Other components, such as surface hydrology at Exit Glacier, would benefit from more consistent sampling efforts (both timing and methodology); some of these needs are being addressed through recently implemented SWAN monitoring efforts.

5.2 Component Condition Designations

Table 42 displays each of the components outlined in the original NRCA framework created for this project. It is important to remember that the graphics represented are simple symbols for the overall condition and trend assigned to each component. Because the assigned condition of a component (as represented by the symbols in Table 42) is based on a number of factors and an assessment of multiple literature and data sources, it is strongly recommended that the reader refer back to each specific component assessment in Chapter 4 for a detailed explanation and justification of the assigned condition. Condition designations for some components are supported by existing datasets and monitoring information and/or the expertise of NPS staff, while other components lack historic data, a clear understanding of reference conditions (i.e., what is considered desirable or natural), or even current information.

Six of these components utilized the assessment methodology in which each measure is scored and then used to determine overall condition. For these components, an overall condition score and condition graphic is displayed in the table. Bald eagles and marine birds were considered to have insufficient data to reasonably score the majority of the measures; therefore they were assigned an unknown overall condition with an unknown trend, indicated using white circles with no arrows. Black bear populations in KEFJ appear to be in good condition, and as of yet, no indications suggest that this condition is likely to change. Although there was no defined reference condition, six years of available data suggest that black oystercatchers are in good condition in KEFJ and it also appears that this has been stable. Finally, significant scientific evidence was coalesced indicating that ice fields and glaciers in or near the park have been recently thinning and receding. According to climate predictions, it appears the thinning and receding trend (also the worsening condition) of glaciers will continue into the future.

Table 42. Summary of current condition and condition trend for featured NRCA components.

Component	Weighted Condition Score	Condition*
Ecosystem Extent and Function		
<i>Landform</i>		
Landing Areas (beaches)	Assessed, but no condition graphic assigned/determined	
Biological Composition		
<i>Mammals</i>		
Black bear	0.3	
<i>Birds</i>		
Bald Eagles	N/A	
Marine Birds	N/A	
Black oystercatcher	0.3	
<i>Fish</i>		
Salmon	0.3	
Physical Characteristics		
<i>Geologic & Hydrologic</i>		
Hydrology	Assessed, but no condition graphic assigned/determined	
Glaciers	0.8	
Coastal Geomorphology – changing shoreline features	Assessed, but no condition graphic assigned/determined	

*Refer to condition graphic descriptions in the following figure.






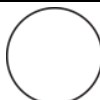




Condition Status		Trend in Condition		Confidence in Assessment	
	Warrants Significant Concern		Condition is Improving		High
	Warrants Moderate Concern		Condition is Unchanging		Medium
	Resource is in Good Condition		Condition is Deteriorating		Low
	<p>An open (uncolored) circle indicates that current condition is unknown or indeterminate; this condition status is typically associated with unknown trend and low confidence</p> <p><i>(explanation is required if a trend symbol or a medium/high confidence band is shown)</i></p>				

Figure 61. Description of symbology used for individual component assessments.

5.3 Park-wide Condition Observations

5.3.2 Biological Composition

Ecological Communities

Freshwater Aquatic Communities

Freshwater aquatic communities are examined by SWAN Vital Signs monitoring under the heading “freshwater flow systems” with surface hydrology, freshwater chemistry, resident lake fish, and salmon as Vital Signs within this monitoring heading. The topic of surface hydrology as it relates to the Exit Glacier visitor area is dealt with as a specific topic or component under the physical characteristics heading in this assessment. Freshwater chemistry and resident lake fish in KEFJ are not dealt with in this assessment. However, that status of specific stocks of important salmon species in KEFJ were examined (see below).

Intertidal Communities

In SWAN Vital Signs, intertidal aquatic vegetation is monitored under the heading “marine near-shore”. The following vegetation falls under this Vital Sign: kelp, other algae, and seagrass. The NPS

is interested in measuring this Vital Sign at two scales: 1) broad-scale, with decadal changes in distribution and occurrences of canopy kelps, eelgrass, and surfgrass using aerial video; and 2) a narrow or small-scale at intensive sampling sites in order to detect annual changes in species composition, distribution, and relative abundance of kelps.

Terrestrial Vegetation Communities

Terrestrial vegetation monitoring is organized under the SWAN Vital Signs Monitoring heading “landscape dynamics and seasonal processes”. Network-level efforts to monitor terrestrial vegetation is occurring at multiple scales; 1) at a landscape-scale, changes in broad vegetation categories from the 1950s to the mid-2000s are examined through remotely-sensed data; and 2) at a community scale, plot-level data is collected to gain insight on stand structure, species composition, a variety of environmental variables, lichen species composition, and tree diameters (Miller 2013).

Sensitive Vegetation Communities

Nunataks occur throughout the Harding Icefield in KEFJ and support vegetation communities considered to be potentially sensitive in the face of a warming climate. Nunatak vegetation inventories specific to a few KEFJ sites were completed in 2005 (Miller et al. 2006).

Mammals

Black Bear

The condition of black bears in KEFJ is currently of low concern. On the Kenai Peninsula, black bears are considered abundant and are relatively common along coastal areas of KEFJ. Due to this species occurring along the coast, there is a distinct possibility of interactions with park visitors who use coastal areas, such as landing beaches. For most recent years of data available, there have been fewer bear-human interactions reported to the park.

Birds

Bald Eagles

Due to limited contemporary data regarding productivity and a limited understanding of temporal changes in nest distribution, condition for this species is considered unknown at this time. Concerns regarding the effects of human use on distribution and nest occupancy are also unknown. Until a better understanding of utilized landing areas is reached, these effects will remain unknown.

Marine Birds

Overall, data describing reference condition for marine birds in KEFJ are limited. Right now, SWAN is implementing a long-term monitoring strategy that will help to detect changes in density and distribution of marine birds in the park.

Black Oystercatcher

Like the marine birds component, baseline data that support a firm reference condition for black oystercatcher are unavailable. SWAN is implementing a monitoring protocol for this species; as data continue to become available, discerning condition and trend will be easier.

Fish

Salmon

Recently deglaciated; Delight, Desire, and Delusion Lakes in KEFJ all support salmon spawning. ADF&G monitors salmon escapement to these lakes. Trends in escapement in these lakes have been variable. Delight Lake escapement has increased over the past decade and Desire Lake has declined. However, sockeye escapement as a whole has increased since the late 1980s and early 1990s.

Stressors to salmon are numerous. Pollutants, climate change, invasive species, and commercial harvest all pose risks to salmon escapement within the park. Oil spills are also a threat that could have catastrophic impacts, as was the case with the Exxon Valdez oil spill in 1989.

5.3.4 Physical Characteristics – Geologic & Hydrologic

Hydrology

Exit Creek was the focal point of the hydrology assessment for this project. Using imagery from multiple time steps (1950, 1961, 1984, 1996, 1998, and 2005), channel positions were interpreted in a GIS to provide the park with a history of channel migration. The data presented in the component section of the document, highlight the changes in the channel configuration at Exit Creek.

The dynamic nature of Exit Creek makes monitoring and predicting flooding implications on park resources difficult. The data in this assessment supports future work, possibly using field-collected cross sectional data, which will continue to explain the dynamics of this system.

Glaciers

The condition of the park's glaciers was designated as high concern. Climate change is the main cause for concern regarding this component. The area of glaciers and the Harding Ice Field in KEFJ have decreased and both interior and coastal glaciers are retreating (29 m/yr and 32 m/yr, respectively). With continued climate change, it is expected that glaciers will continue to decrease in area and mass. However, this is obviously out of the control of park management.

Coastal Geomorphology

From 1950 through 2005, about 291 km (162 mi) of shoreline in KEFJ experienced visually apparent changes. Most of this change was due to glacial recession. For example, Northwestern Glacier receded more than 6 km (3.7 mi) and this exposed nearly 19 km (11.8 mi) of shoreline. McCarty Glacier, Pederson Glacier, and some unnamed glaciers also displayed similar phenomena.

Over the 50-year period from 1950 through 2005, change also occurred due to the 1964 earthquake via subsidence and subsequent erosion. In addition, waves, storm surges, and stream sedimentation also cause coastal changes. These changes, especially as the effect sandy or gravel beach areas are complex, could be better explained using ground validation and beach profile measurements.

5.3.5 Park-wide Threats and Stressors

Climate change is the most relevant, long-term threat to KEFJ resources. Ignoring anthropogenic climate change, Alaska already experiences cyclical shifts in weather and climate because of the

Pacific Decadal Oscillation (PDO). Depending on the phase of the PDO, warmer or cooler air pushes into the northern latitudes for extended periods of time, causing shifts in temperature and precipitation regimes.

If a global warming trend persists, glacial melt, and shifts in wave regimes would change the dynamic of KEFJ. From 1950 through 2005, the recession of glaciers resulted in exposure of new shoreline, streams, and revegetation of once-covered bare ground. Places in higher latitudes, such as KEFJ, are anticipated to experience greater rates of change and higher variability.

For biological resources analyzed in this assessment many concerns stem from climate change. Salmon may experience decreased survival of eggs and fry, slowed growth, premature smolting, and shifts in onsets of runs. For marine birds, concerns regarding climate change focus on losses of food sources and habitat. With changes in food source abundance, species such as the black oystercatcher may be susceptible to decreased reproductive success as invertebrate prey species shift in abundance and location. Similarly, concerns regarding bald eagles focus on changes in prey abundance, as well as the general shifts in temperature and precipitation.

Another threat to resources in KEFJ is oil spills. The Exxon Valdez oil spill caused plant and animal mortality and still impacts resources locations within the park. The Valdez Marine Terminal, Drift River Marine Terminal, Nikiski Oil Terminal are all potential sources of future oil spills, as well as platforms in Cook Inlet. Coupling the mortality with persistence of oil in key habitat areas, oil spills have long-lasting impacts on marine birds. For salmon, following Exxon Valdez, commercial harvest numbers declined significantly. Within KEFJ, escapement to Delight and Desire lakes declined markedly in the years following the spill.

Marine debris is a threat that park staff identified during project scoping. However, the specific effects on key resources within the park is largely unknown at this time.

5.3.7 Literature Cited

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Appendices

Appendix 1. KEFJ NRCA References - data mining by Deborah Kurtz of KEFJ. Note: this is a summarized list of references. A Microsoft Excel file contains references' title, date, reference type, scanned name, assession no., catalog no., location (NPS server), NR Info (yes, no), NRInfo listing of download, and comments for each record.

Component	Author	Title	Date	Scanned Name
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Bald Eagles	Bowman, T.	EVOS Restoration Notebook: Bald Eagle (<i>Haliaeetus leucocephalus</i>)	1999	BowmanT_1999_KEFJ_BaldEaglesEVOSNotebook_571318
Bald Eagles	Bowman, et. al.	Bald Eagle Nesting Chronology in Prince William Sound, Alaska, and Timing of Reproductive Surveys	1992	BowmanT_1992_AK_BaldEagleNestChronologyPWS_547954.pdf
Bald Eagles	Bowman, et. al.	Effects of the <i>Exxon Valdez</i> Oil spill on Bald Eagles	1993	BowmanT_1993_EVOSBaldEagles.pdf
Bald Eagles	Bowman, et. al.	Estimates of the Bald Eagle Population Potentially at Risk by the Exxon Valdez Oil Spill	1991	BowmanT_1991_KEFJ_EstimatesBaldEaglePopulationAtRiskEVOS
Bald Eagles	Bowman, et. al.	Bald Eagle Population in Prince William Sound after the <i>Exxon Valdez</i> Oil Spill	1997	Bowman_etal_1997_BAEA_aerial_survey.PDF
Bald Eagles	Bowman, et. al.	Bald Eagle Survival and Population Dynamics in Alaska after the <i>Exxon Valdez</i> Oil Spill	1995	BowmanT_etal_1995_BAEA_survival_EVOS.pdf
Bald Eagles	Bowman, T.D. and Schempf	Detection of Bald Eagles during Aerial Surveys in Prince William Sound, Alaska	1999	Bowman_Schempf_1999_BAEA_aerial_survey.PDF
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Component	Author	Title	Date	Scanned Name
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Bald Eagles	Tetreau, M.D.	Bald Eagle Nest Surveys in Kenai Fjords National Park, 1986 to 1990	1991	TetreauM_1991_KEFJ_BaldEagleNestSurvey_13148.pdf
Bald Eagles	Tetreau, M.D.	Bald Eagle Surveys on the Coast of Kenai Fjords National Park, 1986-1995	1995	TetreauM_1995_KEFJ_BaldEagleSurveyRept_548300.pdf
Bald Eagles	Tetreau, M.D.	Bald Eagle Surveys on the Coast of Kenai Fjords National Park, 1986-1995	1996	TetreauM_1996_KEFJ_BaldEagleSurvey_547980.pdf
Bald Eagles	Tetreau, M.D.	Bald Eagle Surveys on the Coast of Kenai Fjords National Park, 1986-1996	1996	TetreauM_1996_KEFJ_BaldEagleSurveyRept_548344.pdf
Bald Eagles	Tetreau, M.D.	Bald Eagle Surveys on the Coast of Kenai Fjords National Park, 1997 and 1998	1998	TetreauM_1997-98_KEFJ_BaldEagleSurveyRept_548298.pdf
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Bald Eagles	Unknown	Bald Eagle Nest Locations-1995	1995	AuthorUnknown_1995_KEFJ_CoastalEagleAerieSurveyMaps_KEFJ-00118_KEFJ1581
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Component	Author	Title	Date	Scanned Name
Bald Eagles	Unknown	Bald Eagle Nest Locations-1989 Bird Rescue Survey	1989	AuthorUnknown_1989_KEFJ_CoastalEagleAerieSurveyMapsBirdRescue_KEFJ-00118_KEFJ1584
Bald Eagles	Unknown	Bald Eagle Nest Locations-1989 Nuka Bay	1989	AuthorUnknown_1989_KEFJ_CoastalEagleAerieSurveyMapsNukaBay_KEFJ-00118_KEFJ1581
Bald Eagles	Unknown	Bald Eagle Nest Locations-1988	1988	AuthorUnknown_1988_KEFJ_CoastalEagleAerieSurveyMaps_KEFJ-00118_KEFJ1582
Bald Eagles	Unknown	Bald Eagle Nest Locations-1989	1989	AuthorUnknown_1989_KEFJ_CoastalEagleAerieSurveyMaps_KEFJ-00118_KEFJ1581
Bald Eagles	Unknown	Bald Eagle Nest Locations-1992	1992	AuthorUnknown_1992_KEFJ_CoastalEagleAerieSurveyMaps_KEFJ-00118_KEFJ1581
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Black Bear	Everitt, C.	An evaluation of tourism impacts on six mammal species at Exit Glacier, Kenai Fjords National Park: The identification of possible geographic conflict areas and impact monitoring strategies	2001	EverittC_2001_KEFJ_TourismImpactsMammalsExitGlacier.pdf
Black Bear	Follows, D.	Update of Hunting Harvest	1977	FollowsD_1977_KEFJ_UpdateHuntingHarvest
Black Bear	French, B.	Black Bear Ecology and Response to Human Activity in Kenai Fjords National Park	2001	FrenchB_2001_KEFJ_BlackBearEcology_548290.pdf
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Black Oystercatcher	McFarland, B.A. and Konar	Physical and biological habitat preferences of black oystercatcher breeding territories in Kenai Fjords National Park, Alaska	2007	McFarlandB_2007_KEFJ_BLOYhabitat_AnnualReport_070926.pdf
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Black Oystercatcher	Unknown	1998 Black Oystercatcher Survey	1998	AuthorUnknown_1998_KEFJ_BlackOystercatcherSurveyMap.pdf
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Climate	Searby, H.W.	Coastal Weather and Marine Data Summary for Gulf of Alaska, Cape Spencer Westward to Kodiak Island	1969	SearbyH_1969_KEFJ_CoastalWeatherMarineData
Climate	Soil Conservation Service	Bradley Lake Hydroelectric Project Snow Survey 1985	1985	SCS_1985_KEFJ_BradleyLakeSnowSurveyRept_550391
Climate	Soil Conservation Service	Bradley Lake Hydroelectric Snow Survey Report 1979-1985	1985	SCS_1985_KEFJ_BradleyLakeSnowSurveyRept_550391.pdf
Climate	Soil Conservation Service	Bradley Lake Hydroelectric Project Snow Survey 1986	1986	SCS_1986_KEFJ_BradleyLakeSnowSurveyRept_550394
Climate	Unknown	Kenai Fjords Weather and Climate Summary	nd	AuthorUnknown_nodate_KEFJ_WeatherClimateSummary
Climate	Unknown	Snow Survey Management Protocol	2004	KEFJRM_1999_KEFJ_SnowSurveyManageProtocols_548374.pdf

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Coastal Geomorphology	Farichild, L.	Long Beach' Eco-assessment Team Trip	2003	FairchildL_2003_KEFJ_LongBeachEcoAssessment.pdf
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Coastal Geomorphology	Hayes, M.O.	Oil Spill Vulnerability, Coastal Morphology, and Sedimentation of Outer Kenai Peninsula and Montague Island	1994	Hayes_1980_KEFJ_OilSpillVulnerabilityCoastalMorphologySedimentation.pdf
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Coastal Geomorphology	National Academy of Sciences	The PreEarthquake Holocene (Recent) Record of Vertical Shoreline Movements, extracted from: The Great Alaska Earthquake of 1964	1971	NationalAcademySciences_1971_KEFJ_RecentVerticalShorelineMovements
Coastal Geomorphology	Pendleton et al.	Relative Coastal Change-Potential Assessment of Kenai Fjords National Park USGS Open-File Report 2004-1373	2004	PendletonE_2004_KEFJ_CoastalChangePotentialAssessmentKenaiFjords.pdf
Coastal Geomorphology ; Marine Birds; Bald Eagles	Follows, D.S.	The Role of Nuka Island in a Kenai Fjords National Park Proposal	1977	FollowsD_1977_KEFJ_RoleNukaIsland
Environmental Quality	Harwell, M.A.	Ecological Significance of Residual Exposures and Effects from the Exxon Valdez Oil Spill	2006	Harwell_2006_EcologicalSignificanceResiduesEVOS.pdf

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Environmental Quality	Lindsay, C. and F. Klasner	Annual Climate Summary for 2007-2008: Kenai Fjords National Park	2009	LindsayC_KEFJ_2009_Annual_Climate_Report.pdf
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General	Dennis, J.G.	National Park Service's Research in Alaska-1972-76	1977	NPS_1977_NPSResearchAlaska
General	Department of the Interior	Harding Icefield-Kenai Fjords National Monument 1973 Master Plan	1973	DOI_1973_KEFJ_HardingIcefield_59684
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General	Gilbert, C. and D. Follows	Kenai Fjords Trip Reports	1975	GilbertC_1975_KEFJ_KenaiFjordsTripReports
General	Hahr, M.	Resource Management News 2008	2008	HahrM_2008_KEFJ_ResourceManagementNews.
General	KEFJ	20 Years Later...Exxon Valdez Oil Spill	2009	KEFJ_EVOS_1989-2009_qa.pdf
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Component	Author	Title	Date	Scanned Name
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General	Martin et al.	Kenai Fjords National Park Exit Glacier Visitor Experience and Resource Protection Plan Progress Report On use of Natural Resources Preservation Program (NRPP) funding 2001	2001	MartinE_2001_KEFJ_NRPPReport_548162.pdf
General	Unknown	Environmental Assessment/ Draft Development Concept Plan Kenai Fjords National Park Alaska	1981	NPSDenverServiceCenter_1981_KEFJ_EnvironmentalAssesment_39839.pdf
General	Unknown	Resource Management News	2009	KlasnerF_2009_KEFJ_ResourceManagement_661271.pdf
General	Unknown	Development Conceptual Plan Kenai Fjords National Park Exit Glacier Area	1982	KEFJ_1882_KEFJ_EGDevConceptPlan_31812.pdf
General	Unknown	Kenai Fjords National Park General Management Plan	1984	KEFJ_1984_KEFJ_GeneralManagePlan_547840.pdf
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General	Unknown	Resource Management Plan and Environmental Assessment	1982	AuthorUnknown_1982_KEFJ_ResourceManagementPlanEnvironmentalAssessment.pdf
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Glaciers	Adalgeirsdottir, G.	Surface Elevation and Volume Changes on the Harding Icefield, Southcentral Alaska	1997	AdalgeirsdottirG_1997_KEFJ_SurfaceElevationVolumeChangeHardingIcefield.pdf
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Glaciers	Ahlstrand, Gary M.	Dendrochronological evidence of the recent history of Exit Glacier	1983	AhlstrandG_1983_KEFJ_EGDendrochronologicalEvidence_30770.pdf
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Glaciers	Field, W.O.	Observations of Glacier Behavior in Southern Alaska	1957	FieldW_1957_KEFJ_ObservationsGlacierBehavior.pdf
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Glaciers	Hall et al.	Changes in the Harding Icefield and the Grewingk-Yalik Glacier Complex	2005	HallD_2005_KEFJ_ChangesInTheHardingIcefield.pdf
Glaciers	Hall et al.	Change Analysis of Glacier Ice Extent and Coverage for three Southwest Alaska Network (SWAN) Parks – Katmai National Park and Preserve, Kenai Fjords National Park, and Lake Clark National Park and Preserve	2005	HallD_2005_KEFJ_GlacierExtentFinalReport_598618.pdf
Glaciers	Hamilton T.D. and Rice	Kenai Fjords and the Harding Icefield	nd	HamiltonT_nodate_KEFJ_KenaiFjordsHardingIcefield.pdf
Glaciers	Hanson, T.	Photogrammetric And Mechanical Analysis Of Glaciers With An Emphasis On Tidewater Glacier Dynamics	2005	HansonT_2005_KEFJ_TidewaterGlacierDynamics_Body_full.pdf
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Glaciers	Muirhead, B.	Glacier Annual Snowlines in the Kenai Mountains of Alaska as Derived from Satellite imagery: Measurement, Evaluation of Influencing Factors, and Some Multiple Regression Prediction Models	1978	MuirheadB_1978_KEFJ_GlacierAnnualSnowLinesSatelliteImagery_56081.pdf
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Glaciers	Unknown	Exit Glacier- Flowing at a Glacial Pace	2009	KEFJ2009_ExitGlacier_FlowTransmit.pdf
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Glaciers	Unknown	McCarty Fjord	nd	AuthorUnknown_nodate_KEFJ_McCartyGlacierHistory.pdf
Glaciers	Unknown	1988 Environmental Assessment Harding Icefield Tours Concession Permit Kenai Fjords National Park Alaska	1988	AuthorUnknown_1988_KEFJ_EnvironmentalAssessmentHardingIcefieldToursConcessionPermit
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Glaciers	Whitney, P.C.	The Recent Retreat of McCarty Glacier, Alaska	1932	WhitneyP_1932_KEFJ_RecentRetreatMcCartyGlacierAlaska.pdf
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Glaciers	Wiles, G.C.	Glacier Response to Contrasting Climatic Regimes, Kenai Peninsula, Alaska	1991	WilesG_1991_KEFJ_GlacierResponseContrastingClimaticRegimes.pdf
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Glaciers	Wiles, G.C. and P.E. Calkin	Late Holocene, high-resolutionglacial chronologies and climate, Kenai Mountains, Alaska	1994	WilesG_1994_KEFJ_LateHoloceneGlacialChronoClimateKenaiMtns.pdf
Glaciers	Wiles, G.C. and P.E. Calkin	Neoglaciation in the Southern Kenai Mountains, Alaska	1989	WilesG_1989_KEFJ_NeoglaciationSouthernKenaiMountains.pdf
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Harbor Seals, Marine Birds	Murphy, E.C. and A.A. Hoover	Research Study of the Reactions of Wildlife to Boating Activity along Kenai Fjords Coastline	1981	MurphyE_1981_KEFJ_WildlifeReactionsToBoating_105786.pdf
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Hydrologic & Geologic	Bradley, D. and T. Donley	Geologic Map of Kenai Fjords National Park and Vicinity Draft	1995	BradleyD_1995_KEFJ_GeologicMap_547858.pdf
Hydrology	Alaska Power Authority	Bradley Lake Hydroelectric Project Mitigation Plan	1985	AlaskaPowerAuthority_1987_KEFJ_MitigationPlan_547892
Hydrology	Army Corps of Engineers	Reanalysis of the Bradley Lake Hydroelectric Project	1978	ArmyCorpOfEngineers_1978_KEFJ_ReanalysisBradleyLake_547878
Hydrology	Army Corps of Engineers	Information Brochure Bradley Lake Hydroelectric Project	1979	ArmyCorpofEngineers_1979_KEFJ_BradleyLakeHydroProjectInfoBrochure
Hydrology	Barber, W.F.	Field Review of Exit Glacier Area near Seward, Alaska	2003	BarberW_2003_KEFJ_FieldReviewExitGlacierArea_630377.pdf

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Component	Author	Title	Date	Scanned Name
Hydrology	Dearborn et al.	Water Resources Data of the Seward Area, Alaska U.S. Geological Survey Water Resources Investigations 79-11	1979	DearbornL_1979_KEFJ_WaterResourcesDataSeward.pdf
Hydrology	Eckley, N.	Desire Creek Stream Survey	1991	EckleyN_1991_KEFJ_DesireCreekStreamSurvey
Hydrology	Higgins, S.	Water Resources Inventory, Aialik Bay District	1991	HigginsS_1991_KEFJ_WaterResourcesInventoryAialikBayDistrict
Hydrology	Jones, S.H.	Summary of Hydrologic and Hydraulic Data Collected at Resurrection River a Bridge 1390 and Exit Glacier Road, near Seward, August-October, 1986Alaska	1987	JonesS_1987_KEFJ_ResurrectionRiverHydrologicData_569005.pdf
Hydrology	Jones, S.H.	Flood of October 1986 at Seward, Alaska	1988	JonesS_1988_KEFJ_SewardFlood1986_48490.pdf
Hydrology	KEFJ	Exit Glacier Creek Measurement	2002	KEFJRM_2002_KEFJ_ExitCreekMeasureProtocols_548376.pdf
Hydrology	Lamke, R.D. and Zenone	Probable Hydrologic Changes Resulting from the Proposed Nuka River Diversion at the Bradley Lake, Alaska Hydroelectric Project	1986	LamkeRD_1986_KEFJ_HydrologicChangeNukaRiverDiversi on
Hydrology	Lucke, T.	Trip Report Kenai Fjords NP- Nuka River August18-22, 1986	1986	LuckeT_1986_KEFJ_WRDNukaRTripRept_547882.pdf
Hydrology	Martin, M.	Floodplain reconnaissance at Exit Glacier and other areas, KEFO	2005	MartinM_2005_KEFJ_FloodplainReconExitGlacier_642259.pdf
Hydrology	Nortech	Interim Report Review of Icing Studies, Bradley Lake Hydroelectric Project	1987	Nortech_1987_KEFJ_BradleyLakeIcingStudiesInterimRept_550202
Hydrology	Rice, B.	Nuka River Trip Report	1986	RiceB_1986_KEFJ_NukaRiverTripRept_547880.pdf
Hydrology	Rice, B.	Kenai Fjords National Park Water Resources Inventory	1991	RiceB_1991_KEFJ_WaterResourcesInventoryProtocol
Hydrology	RM Consultants, Inc.	Preliminary Engineering Report Bradley Lake Construction Camp	1987	RMConsultants_1987_KEFJ_BradleyLakeDamsiteConstCamp_550301.pdf
Hydrology	RM Consultants, Inc.	Preliminary Engineering Report Bradley Lake FERC Upper Construction Camp	1987	RMConsultants_1987_KEFJ_BradleyLakeEngineeringReport_550300
Hydrology	Sloan, C.E.	Hydrology of the Exit Glacier Area near Seward, Alaska	1983	SloanC_1983_KEFJ_EGHydrology_63282.pdf

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Component	Author	Title	Date	Scanned Name
Hydrology	Sloan, C.E.	Water Resources and Hydrologic Hazards of the Exit Glacier Area Near Seward, Alaska	1985	SloanC_1985_KEFJ_EGHydrologicHazards_135402.pdf
Hydrology	Tetreau, M.D.	Hydrology Survey- Exit Creek Delta and Beaver Pond Area	1993	TetreauM_1993_KEFJ_HydrologySurveyExitCreek_630375.pdf
Hydrology	Troutman, J.	Bradley Lake Trip Report	1993	TroutmanJ_1993_KEFJ_BradleyLakeTripRept_18820.pdf
Hydrology	Troutman, J.	August 2000 Bradley Lake Trip Report	2000	TroutmanJ_2000_KEFJ_BradleyLakeTripRept_548360.pdf
Hydrology	Unknown	Environmental Assessment Nuka River Diversion: Bradley Lake Hydroelectric Project	1986	AKRO_1986_KEFJ_NukaRiverBradleyLakeEnviroAssess_547874.pdf
Hydrology	Unknown	Stream Survey Field Reports and Datasheets	1991	UnknownAuthor_1991_KEFJ_StreamInventoriesReportsData sheets
Hydrology	Unknown	Kenai Peninsula Area Fact Sheet: Hydrology (from Keyman Collection)	nd	AuthorUnknown_nodate_KEFJ_KenaiPeninsulaHydrology
Hydrology	Unknown	Bradley Lake Project Final Supplemental Environmental Impact Statement	1985	UnknownAuthor_1985_KEFJ_FinalSupplementalEISBradley Lake
Hydrology	Unknown	State of Alaska Department of the Interior Nuka Diversion Briefing Book	1986	UnknownAuthor_1986_KEFJ_NukaDiversionBriefingBook_1 of3
Hydrology	Unknown	Finding of No Significant Impact Nuka River Diversion Project, Bradley Lake Hydroelectric Project, Alaska	nd	UnknownAuthor_nodate_KEFJ_FONSINukaDiversionBradleyHydroelectric
Hydrology, Coastal Geomorphology	Nelson, S.W. and T.D. Hamilton	Guide to the Geology of the Resurrection Bay- Eastern Kenai Fjords Area	1989	NelsonS_1989_KEFJ_ResurrectionBayGeology_58718.pdf
Hydrology; Oceanography	Unknown	Suspended Sediment ExitCreek, Resurrection River and Resurrection Bay	1987	UnknownAuthor_1987_KEFJ_SuspendedSedimentExitCreek Resurrection Bay
Hydrology; Water Quality and Soil Interface; Salmon	Milner, A. and M. Atwood	Stream Community Development Following Glacial Recession in Coastal Alaska	nd	MilnerA_nodate_KEFJ_StreamCommunityDevelopmentGlacialRecession

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Component	Author	Title	Date	Scanned Name
Hydrology; Water Quality and Soil Interface; Salmon	York, G.S.	A Thunderous silence. Running Water - a magazine of rivers and streams	1994	YorkG_1994_KEFJ_ThunderousSilence
Intertidal Communities	ADNR	A Report on the Oiling to Environmentally Sensitive Shoreline, The Exxon Valdez Oil Spill	1993	ADNR_1993_KEFJ_EVOS-ESI-ShorelineOiling-incomplete_569302.pdf
Intertidal Community	Dean, T.A and J.L Bodkin	Protocol Narrative for Marine Ecosystem Monitoring in the Southwest Alaska Network of National Parks	2010	DeanT_2011_SWAN_NearshoreMarineProtocolNarrative_20110202
Intertidal Communities	Feder et al.		1979	FederH_1979_KEFJ_ResurrectionAialikBaySeaGrant_97243.pdf
Intertidal Communities	Ferren	Alaska Invasive Species	ND	Ferren_ND_AlaskaInvasiveSpeciesWorkingGroup
Intertidal Communities	Ferren	European Green Crab Monitoring Program	2010	Ferren_2010_EuropeanGreenCrabMonitoringProgram
Intertidal Communities	Irvine, G. and J. Cusick	Geographical Extent and Recovery Monitoring of Intertidal Oiled Mussel Beds in the Gulf of Alaska Affected by the <i>Exxon Valdez</i> Oil Spill	1995	IrvineG_1995_KEFJ_ExtentRecoveryIntertidalMusselBedsEVOS.pdf
Intertidal Communities	Lees, D.C. and Rosenthal	An Ecological Assessment of the Littoral Zone along the Outer Coast of the Kenai Peninsula for State of Alaska , Department of Fish & Game	1977	LeesD_1977_KEFJ_LittoralZoneKenaiPeninsula.pdf
Intertidal Communities	Lees, D.C. and Driskell	Annual Report for National Park Service Intertidal Reconnaissance Survey to Assess Composition, Distribution, and Habitat of Marine/Estuarine Infauna in Soft Sediments in the Southwest Alaska Network	2006	LeesD_2006_KEFJ_IntertidalReconnaissance.PDF

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Component	Author	Title	Date	Scanned Name
Intertidal Communities	Lees, D.C. and Driskell	Intertidal reconnaissance survey to assess composition, distribution, and habitat of marine/estuarine infauna in soft sediments in the Southwest Alaska Network	2006	LeesD_SWAN_MarineInvert_Inventory_652653.pdf
Intertidal Communities	Lees, D.C. and Driskell	Annual Report for National Park Service Intertidal Reconnaissance Survey to Assess Composition, Distribution, and Habitat of Marine/Estuarine Infauna Inhabiting Soft Sediments in the Southwestern Alaska Networks	2004	LeesD_2004_KEFJ_IntertidalReconnaissance
Intertidal Communities	Miller, K.A. and D.O. Duggins	1989 Intertidal Surveys: Kenai Fjords National Park	1989	MillerK_1989_KEFJ_IntertidalSurveys
Intertidal Communities	Miller, K.A. and D.O. Duggins	Pre- and Post-Oil Intertidal Biological Assessments in Kenai Fjords National Park	1990	MillerK_1990_KEFJ_PrePostOilIntertidalBiologicalAssessment.pdf
Intertidal Communities	Stekoll et al.	Coastal Habitat Injury Assessment: Intertidal Communities and the <i>Exxon Valdez</i> Oil Spill	1996	StekollM_1996_IntertidalCommunitiesEVOS.pdf
Intertidal Communities	Unknown	Mussel Bed Survey: Memo, Data and Maps	1993	AuthorUnknown_1993_MusselBedSurvey
Intertidal Communities	Unknown	Pre-oil Intertidal Surveys in Kenai Fjords National Park	1989	AuthorUnknown_1989_KEFJ_PreOilIntertidalSurvey.pdf
Intertidal Communities; Black Oystercatcher	Bodkin et al.	Nearshore Marine Vital Signs Monitoring in the Southwest Alaska Network of National Parks	2009	ColettiH_2009_KEFJ_MarineNearshoreAnnualReport.pdf
Intertidal Communities; Black Oystercatcher	Coletti et al.	Nearshore Marine Vital Signs Monitoring in the Southwest Alaska Network of National Parks	2010	ColettiH_2010_SWAN_MarineNearshoreMonitoringNRDS_20100611.pdf

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Component	Author	Title	Date	Scanned Name
Land cover	Unknown	Kenai Peninsula Area Fact Sheet: Ecosystems (from Keyman Collection)	nd	AuthorUnknown_nodate_KEFJ_KenaiPeninsulaEcosystems
Landform	Harper, J.	2002 Aerial Video Imaging Survey, Outer Kenai, Alaska (24-28th, June 2002)	2002	HarperJ_2002_KEFJ_VideoTracklines_591108.pdf
Landform	Harper, J.	Shore-Zone Mapping of the Outer Kenai Coast, Alaska	2003	HarperJ_2003_KEFJ_ShoreZoneMapping_591110.pdf
Landform	Mann, D.	A Large Earthquake Occurring 700 to 800 Years Ago in Aialik Bay, Southern Coastal Alaska	1995	MannD_1995_KEFJ_EarthquakeAialik_654439
Landform	Mann, D.	Geological and Paleo-Environmental Investigations in Kenai Fjords National Park during the 1993 SAIP Survey	1995	MannD_1995_KEFJ_GeoPaleoEnvironmInv_550704
Landform	Spencer, P.	Ecological subsections mapping of alaska national park units	2002	AKSubsections_Overview.pdf
Landform	Tande, G.F.; Michaelson	Ecological Subsections of Kenai Fjords National Park	2001	TandeG_2001_KEFJ_EcoSubsections_572283.pdf
Landform, Glaciers	Post, A.	The Alaska Earthquake March 27, 1964 Effects on Hydrologic Regimen Glaciers	1967	PostA_1967_AK_EarthquakeEffectsOnGlaciers_550859.pdf
Landform; Intertidal Communities	Irvine et al.	Persistence of 10-year old Exxon Valdez oil on Gulf of Alaska beaches: The importance of boulder-armoring	2006	IrvineG_2006_EVOS_PersistOilBoulderArmor_632676.pdf
Landform; Intertidal Communities	Irvine et al.	Multi-year Persistence of Oil Mousse on high Energy Beaches Distant from the Exxon Valdez Spill Origin	nd	IrvineG_nodate_KEFJ_PersistenceOilMousseBeachesEVOS
Marine Birds	Arimitsu, M.L.	Environmental Gradients And Prey Availability Relative To Glacial Features In Kittlitz's Murrelet Foraging Habitat	2009	Arimitsu_2009_Environmental_gradients_and_pre_availability_relative_to_glacial_features_in_KIMU_foraging_habitat_MS_thesis.pdf
Marine Birds	Arimitsu et al.	Kittlitz's and Marbled Murrelets in Kenai Fjords National Park, South-Central Alaska: At-Sea Distribution, Abundance, and Foraging Habitat, 2006–08	2010	ArimitsuM_2010_KEFJ_KIMUSeaDistributionAbundance.pdf

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Component	Author	Title	Date	Scanned Name
Marine Birds	Arimitsu et al.	Kittlitz's and Marbled Murrelets in Kenai Fjords National Park, Alaska: At-sea Distribution and Abundance, and Foraging Habitat	2008	ArimitsuM_KEFJ2007_Murrelet-Progress-Report.pdf
Marine Birds	Bailey, E.P.	Breeding Seabird Distribution and Abundance Along the South Side of the Kenai Peninsula, Alaska	1976	BaileyE_1976_KEFJ_BreedingSeabirds_18982.pdf
Marine Birds	Bailey, E.P.	Breeding Bird Distribution and Abundance in the Barren Islands, Alaska	1976	BaileyE_1976_KEFJ_BreedingBirdsBarrenIslands
Marine Birds	Bailey, E.P.; B. Rice	Assessment of Injury to Seabird and Marine Mammal Populations Along the Southeast Cost of the Kenai Peninsula, Alaska from the Exxon-Valdez Oil Spill during Summer 1990	1989	BaileyE_1989_KEFJ_SeabirdInjury_550835.pdf
Marine Birds	Crenshaw, R.	Memorandum re: Field Trip Report to Nuka Island and Petrof View Disposal Site	1982	CrenshawR_1982_KEFJ_MemoReNukaIsland.pdf
Marine Birds	Day, R.H. and Nigro	Status and Ecology of Kittlitz's Murrelet in Prince William Sound, 1996-1998	1999	na
Marine Birds	Day et al.	Use of Oil-Affected Habitats by Birds after the <i>Exxon Valdez</i> Oil Spill	1993	DayR_1993_KEFJ_BirdsHabitatAfterExxonValdez.pdf
Marine Birds	DeVelice et al.	Characterization of Upland Habitat of the Marbled Murrelet in the Exxon Valdez Oil Spill Area	1995	DeVelice_et_al_1994_EVOSreport.pdf
Marine Birds	Dragoo, D.E.	Counts of Black-Legged Kittiwakes at the Chiswell and Barren Islands, Alaska, in 1992	1992	DragooD_1992_KEFJ_KittiwakeCount_548030.pdf
Marine Birds	Dragoo et al.	Breeding Status and Population Trends of Seabirds in Alaska in 1999	1999	DragooD_2000_AKRO_BreedStatPopSeabirdsAK1999_549856.pdf
Marine Birds	Gage, T.	Murre Carcass Survey for Nuka Bay District 1998	1998	GageT_1998_KEFJ_CommonMurreCarcassSurveyNukaBay_548330.pdf
Marine Birds	Gibson, D.D.	Letter re: Caspian Tern Sighting in Nuka Bay	1990	GibsonD_1990_KEFJ_CaspianTernNukaBayConfirmationLetter.pdf

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Component	Author	Title	Date	Scanned Name
Marine Birds	Gilbert, C.	Trip Report- Aialik Peninsula and Vicinity	1975	GilbertC_1975_KEFJ_TripReportAialik
Marine Birds	Goatcher et al.	Differentiation and Interchange of Harlequin Duck Populations Within the North Pacific	1999	GoatcherB_1999_KEFJ_DiffInHarlequinDuckPopNPacific_622115.pdf
Marine Birds	Greffenius, L.; Meehan	Glaucous-winged Gull Colony Nest Count, Squab Island, Aialik Bay, Alaska	1990	GreffeniusL_1990_KEFJ_GlaucousWingedGullColonyNestCountSquabIsland.pdf
Marine Birds	Hahr, M.	Seabird Colony Survey Trip Report 2007 Kenai Fjords National Park	2007	HahrM_2007_KEFJ_SeabirdColonyTripReport.pdf
Marine Birds	Hahr, M.	2008 Seabird Colony Survey Trip Report Kenai Fjords National Park & Alaska Maritime National Wildlife Refuge	2008	HahrM_2008_KEFJ_SeabirdColonyTripReport.pdf
Marine Birds	Hahr, M.	2008 Northwestern Fjord Ground-Nesting Marine Bird Inventory	2008	HahrM_2008_NWGround-nesting_Bird_Inventory.pdf
Marine Birds	Hatch, S.	1993 Results of Aerial Seabird Survey	1993	HatchS_1993_KEFJ_SeabirdAerialSurveyResults
Marine Birds	Irons et al.	Nine Years After The Exxon Valdez Oil Spill: Effects On Marine Bird Populations In Prince William Sound, Alaska	2000	Irons_2000_EVOSMarineBirds.pdf
Marine Birds	Kissling, M.L.	Kittlitz's Murrelet Information Needs Workshop: Meeting Summary	2009	Summary of Kittlitz's Murrelet Information Needs Workshop 15&16December2009.pdf
Marine Birds	Kissling et al.	Understanding Abundance Patterns Of A Declining Seabird: Implications for Monitoring	2007	Kissling et al 2007 KIMU monitoring.pdf
Marine Birds	Kuletz, K.J.	EVOS Restoration Notebook: Marbled Murrelet <i>Brachyramphus marmoratus marmoratus</i>	1997	KuletzK_1997_KEFJ_MarbledMurreletEVOSNotebook_569323.pdf
Marine Birds	Kuletz, K.J.	EVOS Restoration Notebook: Pigeon Guillemot <i>Cephus columba</i>	1998	KuletzK_1998_KEFJ_PigeonGuillemotEVOSNotebook_569324.pdf
Marine Birds	Kuletz, K.J.	Marbled murrelet abundance and breeding activity at Naked Island, Prince William Sound, and Kachemak Bay, Alaska, before and after the Exxon Valdez oil spill	1994	KuletzK_1994_KEFJ_MarbledMurreletAbundanceBreedingEVOS.pdf
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Marine Birds	Marks, D.	Marbled Murrelet Nest on Beach Notes and Map	1993	MarksD_1993_KEFJ_MarbledMurreletNestBeach
Marine Birds	McFarland, B.	Seabird Colony Trip Report 2009 Kenai Fjords National Park & Alaska Maritime National Wildlife Refuge	2009	McFarlandB_2009_KEFJ_SeabirdColonyTripReport.pdf
Marine Birds	Meehan J	Seabird Survey Protocol	1992	MeehanJ_1992_KEFJ_SeabirdSurveyProtocols_KEFJ-00115_KEFJ1578
Marine Birds	Meehan, R., et al.	Implications of Climate Change for Alaska's Seabirds	no date	Seabirds AK climate change.pdf
Marine Birds	Menning, K.	Final Report 1994 Harlequin Duck (<i>Histrionicus histrionicus</i>)	1994	MenningK_1994_KEFJ_HarlequinDuckFinalRept_548042.pdf
Marine Birds	Menning, K.	Common Murre (<i>Uria aalge</i>)	1994	MenningK_1994_KEFJ_CommonMurre.pdf
Marine Birds	Menning, K.	1994 Nuka Bay Horned Puffin Observations	1994	MenningK_1994_KEFJ_HornedPuffinObservations.pdf
Marine Birds	Menning, K.	Pigeon Guillemot (<i>Cepphus columba</i>) 1994 Final Report	1994	MenningK_1994_KEFJ_PigeonGuillemotFinalReport
Marine Birds	Murphy et al.	Dietary Changes and Poor Reproductive Performance in Glaucous-Winged Gulls	1984	MurphyE_1984_AK_Glaucous-WingedGullsDiet_550526.pdf
Marine Birds	Murphy et al.	Intracolony Variability during Periods of Poor Reproductive Performance at a Glaucous-winged Gull Colony	1992	MurphyE_1992_KEFJ_GullColony_66296.pdf
Marine Birds	Nysewander et al.	Effects of the Exxon Valdez Oil Spill on Murres: A Perspective From Observations at Breeding Colonies	1993	Nysewander_1993_EVOSEffectsCOMU.pdf
Marine Birds	Odenbaugh, T.	Harlequin Duck Brood Survey- August 1993	1993	OdenbaughT_1993_KEFJ_HarlequinDuckBroodSurvey
Marine Birds	Phillips, L.	Seabird Colony Survey Report 2010 Kenai Fjords National Park & Alaska Maritime National Wildlife Refuge	2010	PhillipsL_2010_KEFJ_SeabirdColonyTripReport.pdf
Marine Birds	Piatt, J.	Species at Risk Proposal: Dramatic population declines in the Kittlitzs murrelet: assessing the magnitude and potential causes of the decline	2002	PiattJ_2002_KEFJ_KittlitzMurreletProposal_548278.pdf

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Component	Author	Title	Date	Scanned Name
Marine Birds	Piatt, J. and M. Arimitsu	2007 Summary of Kittlitz's and Marbled Murrelet Research in Alaska	2007	KIMU_MAMU_2007_summary_USGS.pdf
Marine Birds	Piatt, J.F.	Response of Seabirds to Fluctuations in Forage Fish Density	2002	PiattJ_2002_SeabirdFluctuationForageFish.pdf
Marine Birds	Piatt, J.F. and P. Anderson	Response of Common Murres to the <i>Exxon Valdez</i> Oil Spill and Long-Term Changes in the Gulf Of Alaska Marine Ecosystem	1996	PiattJ_1996_KEFJ_OilEffectsCOMU_550711.pdf
Marine Birds	Piatt, J.F. and T.I. van Pelt	Mass-mortality of Guillemots (<i>Uria aalge</i>) in the Gulf of Alaska 1993	1997	PiattJ_1997_KEFJ_MortalityOfGuillemots_548260.pdf
Marine Birds	Piatt, J.F. and T.I. van Pelt	A wreck of Common Murres (<i>Uria aalge</i>) in the Northern Gulf of Alaska during February and March 1993	1993	PiattJ_1993_KEFJ_CommonMurresWreck_550858.pdf
Marine Birds	Piatt, J.F. and W.J. Sydeman	Seabirds as indicators of marine ecosystems	2007	PiattJ_2007_SeabirdsIndicatorsMEPS.pdf
Marine Birds	Piatt et al.	Protocols for long-term monitoring of seabird ecology in the Gulf of Alaska	2004	PiattJ_2004_LongtermMonitoringSeabirdEcology.pdf
Marine Birds	Piatt et al.	Status Reciew of the Marbled Murrelet (<i>Brachyramphus marmoratus</i>) in Alaska and British Columbia	2006	PiattJ_2006_StatusMarbledMurreletAKBC.pdf
Marine Birds	Piatt et al.	Seabirds as Indicators of Marine Ecosystems: An Integrated NPRB Science Plan for Alaska	2006	PiattJ_2006_NBRBSeabirdResearch.pdf
Marine Birds	Rice, B.	Discovery of Marbled Murrelet Nest	1991	RiceB_1991_KEFJ_MarbledMurreletNest_32677.pdf
Marine Birds	Rice, B.	Murrelet Survey Report	1991	RiceB_1991_KEFJ_MurreletSumRept_548046.pdf
Marine Birds	Romano et al.	Kittlitz's and Marbled Murrelets in Kenai Fjords National Park, Alaska: At-sea Distribution and Abundance, and Initial Observations of Radio-marked Kittlitz's Murelets	2006	RomanoM_2006_KIMUMAMUSeaDistributionAbundance
Marine Birds	Rosenberg, D.H. and Petrula	Status of Harlequin Ducks in Prince William Sound, Alaska after the <i>Exxon Valdez</i> oil Spill, 1995-1997	1998	RosenbergD_1998_PostEVOSStatusHarlequinDucksPWS.pdf

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Component	Author	Title	Date	Scanned Name
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Marine Birds	Roseneau et al.	Common Murre Population Monitoring at the Barren Islands, Alaska, 1997	1997	Roseneau&Byrd_AnnualReports_1997-97144-Annual.pdf
Marine Birds	Roseneau et al.	Common Murre Population Monitoring at the Chiswell Islands, Alaska, 1998	1998	Roseneau&Byrd_AnnualReports_1998-98144A-Annual.pdf
Marine Birds	Sanger, G.A. and M.B. Cody	Survey of pigeon guillemot colonies in Prince William Sound, Alaska: restoration project 93034 final report	1994	SangerG_1994_PuigeonGuillemotColoniesPWS.pdf
Marine Birds	Schre, R.	Audubon Society Chiswell Island Trip Bird List	1983	ScherR_1983_KEFJ_AudubonTripBirdListChiswells.PDF
Marine Birds	Smith, A. K. and Menning	Pigeon Guillemot (<i>Cepphus columba</i>) Survey	1994	SmithA_1994_KEFJ_McCarthyPigeonGuillemontSurvey_548034.pdf
Marine Birds	Smith, G. and K. Link	Oil Spill Damage Assessment Wildlife Observation Data Sheet Squab Island	1989	SmithG_1989_KEFJ_OilSpillDamageAssessmentSquabIsland.pdf
Marine Birds	Stephensen, and Irons	Comparison Of Colonial Breeding Seabirds In The Eastern Bering Sea And Gulf Of Alaska	2003	Stephensen_2003_SeabirdsBearingGOA.pdf
Marine Birds	Tetreau, M.	Gull colony counts by coastal rangers and biological technicians	2006	TetreauM_2006_KEFJ_GullColonyCountsBackground.pdf
Marine Birds	Tetreau, M.	1992 Memo re: Report to Date on Dead Murres in the Seward Area	1992	Tetreau_1992_KEFJ_DeadMurresSeward
Marine Birds	Tetreau, M.D. and Troutman	Evaluation of Nesting potential for Pigeon Guillemots (<i>Cepphus columba</i>) along Selected Sections of the Coast of Kenai Fjords National Park	1994	TetreauM_1994_KEFJ_EvalNestPotentialPigeonGullemotsCoast_548036.pdf
Marine Birds	Unknown	Surveys of Marbled Murrelet Activity on the Southern Kenai Peninsula	1993	AuthorUnknown_1993_KEFJ_Draft-MarbledMurreletActivity_569277.pdf
Marine Birds	Unknown	2010 Coastal Mortality Report	2011	KEFJ_2010_CoastalMortalityReport
Marine Birds	Unknown	Kenai Fjords National Park Seabird Survey Database	nd	DOC048.PDF

Appendix 1. KEFJ NRCA References - data mining by Deborah Kurtz of KEFJ. Note: this is a summarized list of references. A Microsoft Excel file contains references' title, date, reference type, scanned name, assession no., catalog no., location (NPS server), NR Info (yes, no), NRInfo listing of download, and comments for each record. (continued)

Component	Author	Title	Date	Scanned Name
Marine Birds	Unknown	Seabird Survey Data Sheets	1992	AuthorUnknown_1992_KEFJ_SeabirdDataSheets_KEFJ-00115_KEFJ1578
Marine Birds	Unknown	1998 Common Murre Carcass Survey	1998	TetreauM_1998_KEFJ_CommonMurreCarcassSurvey
Marine Birds	Unknown	Email re: 1997 Seabird die-off	1997	AuthorUnknown_1997_EmailReSeabirdDieoff
Marine Birds	Unknown	1998 Murre Carcass Surveys Data and Map	1998	AuthorUnknown_1998_KEFJ_MurreCarcassSurveyData
Marine Birds	Unknown	1998 Murre Wreck	1998	AuthorUnknown_1998_KEFJ_MurreWreck
Marine Birds	Unknown	1994 Report of Dead Seabirds	1994	AuthorUnknown_1994_KEFJ_DeadSeaBirdReport
Marine Birds	Unknown	Common Murres in Chiswell Islands	nd	AuthorUnknown_nodate_KEFJ_CommonMurresChiswellIslands.pdf
Marine Birds	Unknown	Nesting of Glaucous-winged Gulls, Kenai Fjords, Alaska	1987	AuthorUnknown_1987_KEFJ_NestingGlaucousWingedGulls.pdf
Marine Birds	Unknown	Squab Island Glaucous-wing Gull Nesting Survey	1988	AuthorUnknown_1988_KEFJ_SquabIslandGlaucous-wingGullNestingSurvey
Marine Birds	Unknown	Glaucous-winged Gull Nest Count McCarty Fjord	1992	AuthorUnknown_1992_KEFJ_GlaucousWingedGullNestCountMcCartyFjord.pdf
Marine Birds	Unknown	Squab Island Gull Colony Count	1992	AuthorUnknown_1992_KEFJ_SquabIslandGullColonyCount.pdf
Marine Birds	Unknown	Summary of Black-legged Kittiwakes in the Chiswell Islands in 1992	1992	AuthorUnknown_1992_KEFJ_Black-leggedKittiwakesChiswellIslands.pdf
Marine Birds	Unknown	Chiswell Islands 1992 Trip Report	1992	AuthorUnknown_1992_KEFJ_ChiswellIslandsTripReport.pdf
Marine Birds	Unknown	Summary of Murre Counts in the Chiswell Islands in 1992	1992	AuthorUnknown_1992_KEFJ_MurreCountsChiswellIslands.pdf
Marine Birds	Vequist, G.W. and Nishimoto	Seabird Survey on the Coast of Kenai Fjords during the Exxon-Valdez Oil Spill	1990	VequistG_1990_KEFJ_OilSpillSeaBirds_110442.pdf
Marine Birds	Vequist, G.W. and Nishimoto	Between Year Comparison of Seabird Populaitons of the Kenai Fjords Coast	1990	VequistG_1990_KEFJ_SeabirdPopulationsComparison.pdf
Marine Birds	Vequist, G.W. and Nishimoto	Seabird Survey on the Coast of Kenai Fjords during the Exxon-Valdez Oil Spill	1989	VequistG_1989_KEFJ_SeabirdSurveyEVOS
Marine Birds	Wiens, J.A.	Recovery of Seabirds Following the <i>Exxon Valdez</i> Oil Spill: An Overview	1993	WiensJ_1993_KEFJ_RecoverySeabirdsExxonValdez.pdf
Marine Birds	Wolfe, D. and D. Killian	Gull Colony Nests, Dinglestadt Island, McCarty Fjords, Nuka Bay	1990	WolfeD_1990_KEFJ_GullColonyNestsDinglestadtIslandMcCartyFjord.pdf

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Component	Author	Title	Date	Scanned Name
Marine Birds	Youkey, D.	Murrelet Summary Report	1991	YoukeyD_1991_KEFJ_MurreletSummaryReport
Marine Birds, Bald Eagles, Sea Otters, Harbor Seals	Nishimoto, M. and B. Rice	A Re-Survey of Seabirds and Marine Mammals along the South Coast of the Kenai Peninsula, Alaska during the Summer of 1986	1987	NishimotoM_1987_KEFJ_Re- surveySeabirdsMarineMammals_101280.pdf
Marine Birds, Black Oystercatcher, intertidal communities	Day et al.	Effects of the <i>Exxon Valdez</i> Oil Spill on Habitat Use by Birds along the Kenai Peninsula, Alaska	1997	DayR_1997_KEFJ_ExxonOilSpillEffectOnBirdHabitat_57771 6.pdf
Marine Birds, Harbor Seals	Bailey, E.P.	Distribution and Abundance of Marine Birds and Mammals Along the South Side of the Kenai Peninsula, Alaska	1977	BaileyE_1977_KEFJ_KenaiMarineBirdMammal_143123.pdf
Marine Birds, Harbor Seals	Bailey, E.P.; B. Rice	Assessment of Injury to Seabird and Marine Mammal Populations Along the Southeast Cost of the Kenai Peninsula, Alaska from the Exxon-Valdez Oil Spill during Summer 1989	1989	BaileyE_1989_KEFJ_EVOSSeabirdMarineMammalInjuryPop _568998.pdf
Marine Birds, Harbor Seals	Bailey, E.P.; B. Rice	Assessment of Injury to Seabird and Marine Mammal Populations Along the Southeast Cost of the Kenai Peninsula, Alaska from the Exxon-Valdez Oil Spill during Summer 1989 with Appendices	1989	BaileyE_1989_KEFJ_AssessmentInjurySeabirdMarineMamm alEVOS+Appendices.pdf
Marine Birds; Bald Eagle	Janik, C.A. and Schempf	Peale's peregrine falcon (<i>Falco peregrinus pealei</i>) studies in Alaska June 12-24, 1985	1985	JanikC_1985_KEFJ_PealesPeregrineFalconStudiesAlaska.p df
Marine Birds; Bald Eagle	Unknown	Seabird and Eagle Densities Map	1976	AuthorUnknown_1976_KEFJ_SeabirdEagleDensitiesMap
Marine Birds; Bald Eagle	Unknown	Kenai Peninsula Area Fact Sheet: Migratory Birds, Sea Birds, Raptors and Endangered Species (from Keyman Collection)	nd	AuthorUnknown_nodate_KEFJ_KenaiPeninsulaBirds
Marine Birds; Harbor Seals	Unknown	1990 Seabird and Marine Mammal Observations	1990	AuthorUnknown_1990_KEFJ_SeaBirdMarineMammalObserv ations.pdf

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Component	Author	Title	Date	Scanned Name
Marine Birds; Harbor Seals	Van Pelt, T.I. and J.F. Piatt	Population status of Kittlitz's and Marbled Murrelets and surveys for other marine bird and mammal species in the Kenai Fjords area, Alaska	2003	VanPeltT_2003_KEFJ_KitlitzMarbledMurreletsMammalsPop _569337.pdf
Marine Birds; Harbor Seals; Sea Otters	Follows, D.	Seabird-Marine Mammal Survey and General Reconnaissance of Southern Kenai Coast	1976	FollowsD_1976_KEFJ_SeabirdMarineMammalSurvey
Marine Birds; Harbor Seals; Sea Otters	Menning, K.	1994 Nuka Bay Wildlife Sightings	1994	MenningK_1994_KEFJ_NukaBayWildlifeSightings.pdf
Marine Birds; Harbor Seals; Sea Otters	Unknown	1989 Spring Wildlife Counts	1989	AuthorUnknown_1989_KEFJ_SpringWildlifeCounts.pdf
Marine Birds; Harbor Seals; Sea Otters; Bald Eagles	Unknown	1992 Wildlife Sightings Maps	1992	AuthorUnknown_1992_KEFJ_WildlifeSightingsMaps
Marine Birds; HarboSeals; Sea Otters; Oceanography : EVOS	Unknown	Summaries of Scientific Papers oresented at the Symposium on Environmental Toxicology and Risk Assessment	1993	AuthorUnknown_1991_KEFJ_SummariesSymposiumEnviron mentalToxicologyRiskAssessment
Marine Birds; HarboSeals; Sea Otters; Oceanography : EVOS	Unknown	Summary of Effects of the <i>Exxon Valdex</i> Oil Spill on Natural Resources and Archaeological Resources	1991	AuthorUnknown_1991_KEFJ_EffectsEVOSNaturalArchaeolo gicalResources
Marine Birds; Sea Otters	Agler et al.	Estimates of marine bird and sea otter abundance in lower Cook Inlet, Alaska during summer 1993 and winter 1994 : final report	1995	AglerB_1995_KEFJ_MarineBirdSeaOtterCookInlet.pdf

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Component	Author	Title	Date	Scanned Name
Marine Birds; Sea Otters	Agler et al.	Winter Marine Bird and Sea Otter Abundance of Prince William Sound, Alaska: Trends following the <i>T/V Exxon Valdez</i> Oil Spill from 1990-94	1995	AglerB_1995_WinterMarineBirdSeaOtterAbundancePWS.pdf
Oceanography	Carpenter, T.	Pandalid Shrimps in a Tidewater Glacier Fjord, Aialik Bay, Alaska	1983	CarpenterT_1983_KEFJ_AialikBayPandalidShrimp_89628
Oceanography	Gay III, et al.	Hydrography of McCarty Fjord, Northwestern Fjord, and Aialik Bay, Kenai Fjords National Park, Alaska	1998	GayS_1998_KEFJ_HydrographyMcCartyNorthwesternAialik
Oceanography	Reimnitz et al	Detrital Gold and Sediments in Nuka Bay, Alaska USGS Professional Paper 700-C	1970	ReimnitzE_1970_KEFJ_DetritalGoldSedimentsNukaBay
Oceanography	Short et al.	Slightly Weathered Exxon Valdez Oil Persists in Gulf of Alaska Beach Sediments after 16 Years	2007	ShortJ_2007_KEFJ_16yrLingeringOil_642344.pdf
Oceanography	Strom et al.	Cross-shelf gradients in phytoplankton community structure, nutrient utilization, and growth rate in the coastal Gulf of Alaska	2006	Strom_2006_SewardLineGOAOceanography.pdf
Oceanography	Thompson, T.S.	Oceanic and Nearshore Research and Monitoring in the Northern Gulf of Alaska	2004	ThompsonT_2004_SWAN_OceanNearshoreResrch_568315.pdf
Oceanography	Unknown	Warming Ocean Slows Phytoplankton Growth	2009	KEFJ2009_OceanWarmingPhytoplankton.pdf
Oceanography	Whitney, J.	Alaska Oceanographic Circulation Diagrams and Graphics	2009	WhitneyJ_2009_KEFJ_AlaskaOceanCirculation.pdf
Physical Characteristics	Martin et al.	Geology and Mineral Resources of Kenai Peninsula, Alaska	1915	MartinG_1915_KEFJ_GeologyMineralResourcesKenaiPeninsula
Salmon	ADFG	Catalog of waters important for spawning, rearing or migration of anadromous fishes	2009	na
Salmon	Edmundson et al.	Limnological and Fisheries Investigations Concerning Sockeye Salmon Production in Delight and Desire Lakes- Restoration 2001		EdmundsonJ_2001_FisheryInvestigationsDelightDesireLakes_630379.pdf

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Component	Author	Title	Date	Scanned Name
Salmon	Kelly, M.D.	Fish and Aquatic Habitat Surveys of Exit Glacier Road Wetlands 1992-1993	1993	KellyM_1993_KEFJ_EGRoadWetlands_548124.pdf
Salmon	Menning, K.	Final Report 1994 Pink Salmon (<i>Oncorhynchus gorbuscha</i>)	1994	MenningK_1994_KEFJ_PinkSalmonFinalRept_548052.pdf
Salmon	Menning, K.	Final Report 1994 Sockeye Salmon (<i>Oncorhynchus nerka</i>)	1994	MenningK_1994_KEFJ_SockeyeSalmonFinalRept_548054.pdf
Salmon	Milner, A. and G.S. York	Factors Influencing Fish Productivity in a Newly Formed Watershed in Kenai Fjords National Park, Alaska	2001	MilnerA_2001_KEFJ_FishProductivity_548142.pdf
Salmon	Unknown	Kenai Peninsula Area Fact Sheet: Fishery Resources (from Keyman Collection)	nd	AuthorUnknown_nodate_KEFJ_KenaiPeninsulaFisheries
Salmon	Wright, A.	Exit Glacier Carrying Capacity Study Fish Inventory and Distribution Draft Report	2000	WrightA_2000_KEFJ_EGFishInventory_548050.pdf
Salmon; Water Quality and Soil Interface	Milner, A.M.	Fisheries and Water Quality Investigations in Kenai Fjords National Park	1990	MilnerA_1990_KEFJ_FisheriesWaterQuality.pdf
Salmon; Water Quality and Soil Interface	O'Keefe, T.	Freshwater Research and Monitoring in Southwest Alaska	2005	OKeefeT_2005_SWAN_Freshwater_620348.pdf
Salmon; Water Quality and Soil Interface	York, G.S. and A. Milner	Colonization and Community Development Mechanisms of Aquatic Invertebrates and Salmonids in Kenai Fjords National Park, Alaska	1993	YorkG_1993_KEFJ_AquaticInvertebratesSalmonidsColonies_25192.pdf
Salmon; Water Quality and Soil Interface	York, G.S. and A. Milner	Colonization and Community Development Mechanisms of Aquatic Invertebrates and Salmonids in Kenai Fjords National Park, Alaska	1994	YorkG_1994_KEFJ_AquaticInvertebratesSalmonidsColonies_168728.pdf
Salmon; Water Quality and Soil Interface	York, G.S. and A. Milner	Colonization and Community Development of Salmonids and Benthic Macroinvertebrates in a New Stream within Kenai Fjords National Park, Alaska	1996	YorkG_1996_KEFJ_SalmonidsMacroinvertColoniesNewStream_548058.pdf

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Component	Author	Title	Date	Scanned Name
Salmon; Water Quality and Soil Interface	York, G.S. and A. Milner	Colonization and Community Development Mechanisms of Aquatic Invertebrates and Salmonids in Kenai Fjords National Park, Alaska	1995	YorkG_1995_KEFJ_AquaticInvertebratesSalmonidsColonies.pdf
Sea Otters	Bodkin, J.	Sea Otters	2003	BodkinJ_2003_KEFJ_SeaOtter.pdf
Sea Otters	Bodkin, J. and D. Monson	Sea Otter Population Structure and Ecology in Alaska	no date	BodkinJ_nodate_KEFJ_SeaOtterDistributionAbundance.pdf
Sea Otters	Bodkin, J.L. and Ballachey	EVOS Restoration Notebook: Sea Otter <i>Ehydra lutris</i>	1997	BodkinJ_1997_KEFJ_SeaOtterEVOSNotebook_569303.pdf
Sea Otters	Bodkin et al.	Results of the 2002 Kenai Peninsula and Lower Cook Inlet Aerial Sea Otter Survey	2003	BodkinJ_2003_KEFJ_KenaiPenSeaOtterSurvey_632646.pdf
Sea Otters	Coletti et al.	Sea Otter Abundance in Kenai Fjords National Park: Results from the 2010 Aerial Survey	2010	Coletti_2010_SeaOtterAbundanceInKenaiFjordsNationalPark
Sea Otters	Garshelis, D.L. and Garshelis	Results from the 2010 Aerial Survey	1984	GarshelisD_1984_KEFJ_MovementManagementSeaOtters.pdf
Sea Otters	Johnson, A.M.	Status of Alaska Sea Otter Populations and Developing Conflicts with Fisheries	1982	JohnsonA_1982_KEFJ_SeaOtterPopFisheries_551094.pdf
Sea Otters	Prince William Sound Conservation Alliance	Sea Otter History and Exxon Valdez Recovery	no date	PWSCA_nodate_SeaOtterHistoryRecovery.pdf
Sea Otters	Schmidt, W.T.	Distribution and Abundance of Sea Otters in Kenai Fjords	1983	SchmidtW_1983_KEFJ_SeaOtterDistribution_32949.pdf
Sea Otters	US DOI	The Sea Otter in the Eastern Pacific Ocean	1969	DOI_1969_SeaOtterEasternPacificOcean
Sea Otters	USFWS	Conservation Plan for the Sea Otter in Alaska	1994	USFWS_1994_KEFJ_ConservationPlanSeaOtter_569331.pdf
Sensitive Vegetation Communities (nunataks)	Bryden, W.	Final Report for Vegetation Community Characterization for Exit Glacier Study Area, Summer 2002	2004	BrydenW_2004_KEFJ_VegetationCommunityCharacterization

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Component	Author	Title	Date	Scanned Name
Sensitive Vegetation Communities (nunataks)	Carlson, M.L., et al.	Southwest Alaska Network, Vascular Plant Inventory, Summary Report	2005	CarlsonM_2005_SWAN_VascularPlantSummaryReprt_642393.pdf
Sensitive Vegetation Communities (nunataks)	Carlson, M.L., et al.	Kenai Fjords National Park [2003] vascular plant inventory final annual report.	2004	CarlsonM_2005_KEFJ_VascularPlant2003AnnReprt_591200.pdf
Sensitive Vegetation Communities (nunataks)	Heusser, C.J.	Nunatak Flora of the Juneau Icefield	1954	HeusserC_1954_NunatakFloraJuneaulcefield.pdf
Sensitive Vegetation Communities (nunataks)	Miller, A.	Trip Report – Reconnaissance of vascular plants on Weather Station Ridge, Harding Icefield, KEFJ	2004	MillerA_2004_KEFJ_WeatherStaRidgeNunatakFieldReprt_631684.pdf
Sensitive Vegetation Communities (nunataks)	Miller, A. and P. Spencer	Vascular Plant Inventory and baseline monitoring of Nunatak Communities 2005 Lake Clark National Park and Preserve Kenai Fjords National Pak	2006	MillerA_2006_SWAN_NunatakVascPlantsReprt_631687.pdf
Sensitive Vegetation Communities (nunataks)	Unknown	Trip Report- Reconnaissance of Vascular Plants on Weather Statrion Ridge, Harding Icefield, KEFJ	2004	UnknownAuthor_2004_KEFJ_ReconnaissanceVascularPlantsHardingIcefield
Water Quality and Soil Interface	Shearer, J.	Water Quality Monitoring in Exit Creek	2008	shearerj_2007_KEFJ_ExitCr_WQmonitoring_projectbrief_080512.pdf
Water Quality and Soil Interface	Rinella, D. and D. Bogan	Habitat Assessment And Biological Inventory Of The Upper Nuka River, Kenai Fjords National Park	2009	UAA-ENRI Nuka River report_revised.pdf
Water Quality and Soil Interface	Shannon & Wilson, Inc.	Removal Action Summary, Beauty Bay Mine, Kenai Fjords National Park, Alaska	2006	ShannonWilson_2006_KEFJ_BeautyBayMineReport_642323

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Component	Author	Title	Date	Scanned Name
Water Quality and Soil Interface	Shousky, J.A. and S.K. Golden	Taroka Lake Survey	1997	ShouskyJ_1997_KEFJ_TarokaLakeSurvey_548372.pdf
Water Quality and Soil Interface	Skibeness, S.	Baseline Water Quality Testing	2001	SkibenessS_2001_KEFJ_BaselineWaterQuality_630378.pdf
Water Quality and Soil Interface	Unknown	Environmental Assessment Exit Glacier Restroom and Water Facilities Kenai Fjords National Park Alaska	2000	NPS_2000_KEFJ_EGRestroomWaterFacilityEnvAssess_548112.pdf
Water Quality and Soil Interface	Unknown	Nuka Bay Field Trip Report	2000	NPS_2000_KEFJ_NukaBayFieldTripRept_548084.pdf
Water Quality and Soil Interface	Unknown	Macroinvertebrate Count Field Data Sheets	2000	AuthorUnknown_2000_KEFJ_MacroinvertebrateSurveyData Sheets_KEFJ-00134_KEFJ1649
Water Quality and Soil Interface	Unknown	Application for Exit Glacier Road Developement	1976	AuthorUnknown_1976_KEFJ_ApplicationforExitGlacierRoad Developement_KEFJ-00146_KEFJ5297
Water Quality and Soil Interface	Wright, A.	Macroinvertebrate Survey Report	2000	WrightA_2000_KEFJ_MacroinvertebrateSurveyExitCreek_547944
Water Quality and Soil Interface	Wright, A.	Baseline Water Quality Testing	2001	WrightA_2001_KEFJ_BaseWaterQuality_548324.pdf
Water Quality and Soil Interface	Wright, A.	Benthic Macroinvertebrate Surveys Exit Creek System	2001	WrightA_2001_KEFJ_BenthicMacroinvertebrateSurvey_642289.pdf
Water Quality and Soil Interface	Wright, A.	Exit Glacier Fish and Wildlife Report in Conjunction with Exit Glacier Carrying Capacity	2000	WrightA_2000_KEFJ_FishWildlifeSurvey2000_KEFJ-00134_KEFJ1651

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Component	Author	Title	Date	Scanned Name
Water Quality and Soil Interface; Hydrology	Unknown	1987 Field Report of Creek Surveys in Beauty Bay and Surprise Bay	1987	AuthorUnknown_1987_KEFJ_BeautyBaySurpriseBayCreekS urveys

Appendix 2. Marine debris collection statistics for Resurrection Bay Conservation Alliance (RBCA) marine debris monitoring beaches in KEFJ (2009-2012).

Beach Name	Length (miles)				No. of Filled Bags				Pieces (unbagged)				Weight (lbs)				% fishing	No. of Yrs.
	'09	'10	'11	'12	'09	'10	'11	'12	'09	'10	'11	'12	'09	'10	'11	'12		
North Bulldog*	--	--	--	--	--	8	--	--	n/a	8	--	--	--	165	--	--	50	1
South Bulldog*	1	1	1	--	6	6	6	--	5	3	1	--	210	115	210	--	30	2
Porcupine Cove*	1	1	--	--	46	19	--	--	14	5	--	--	1310	320	--	--	35	2
Pinnacle	--	0	--	--	--	9	--	--	--	8	--	--	--	125	--	--	35	1
Verdant island Beach	--	--	--	1	--	--	--	11	--	--	--	7	--	--	--	255	35	1
Verdant Cove Beach	--	--	--	1	--	--	--	1	--	--	--	0	--	--	--	10	10	1
Taroka 1*	0	--	0	0	6	--	8	10	7	--	2	4	400	--	145	275	43	3
Taroka 2	0	--	0	--	3	--	3	--	1	--	0	--	80	--	35	--	60	2
Taroka 3	0	--	0	--	16	--	24	--	3	--	2	--	600	--	570	--	60	2
Taroka 4*	1	--	1	--	46	--	6	--	50	--	3	--	2350	--	170	--	67	2
Taroka 5	0	--	--	0	6	--	--	19	10	--	--	14	650	--	--	495	55	2
Taroka 6*	1	--	1	--	32	--	5	--	20	--	1	--	1100	--	90	--	63	2
Thunder 1	0	0	0	--	147	30	16	--	60	53	3	--	5660	1225	203	--	51	3
Thunder 2	0	0	0	--	40	26	7	--	20	9	1	--	1750	525	115	--	44	3
Thunder 3*	0	0	0	--	6	2	2	--	3	1	1	--	700	50	40	--	60	3
Thunder 4	0	0	0	--	8	5	2	--	20	2	1	--	450	140	75	--	61	3
Paguna 1*	--	--	1	--	--	--	3	--	--	--	2	--	--	--	110	--	50	1
Paguna 2*	--	--	1	--	--	--	1	--	--	--	0	--	--	--	5	--	50	1
Paguna 3*	--	--	1	--	--	--	2	--	--	--	1	--	--	--	70	--	50	1
Totals:	5.419	2.758	7.418	2.208	362	105	85	41	213	89	18	25	15260	2665	1838	1035	48 (ave)	

* Indicates beaches associated with known campsite areas (i.e., landing areas or beaches).

-- Indicates no data collected.

Appendix 3. NPS certified list of marine bird species present within KEFJ (NPS 2012a).

Family	Scientific Name	Common Name	Occurrence	Abundance	Residency	Nativity
Target Species*						
Anatidae	<i>Bucephala islandica</i>	Barrow's goldeneye	Present in Park	Uncommon	Resident	Native
Anatidae	<i>Histrionicus histrionicus</i>	Harlequin duck	Present in Park	Common	Breeder	Native
Anatidae	<i>Mergus merganser</i>	Common merganser	Present in Park	Uncommon	Breeder	Native
Anatidae	<i>Mergus serrator</i>	Red-breasted merganser	Present in Park	Common	Breeder	Native
Alcidae	<i>Cephus columba</i>	Pigeon guillemot	Present in Park	Common	Breeder	Native
Charadriidae	<i>Haematopus bachmani</i>	Black oystercatcher	Present in Park	Common	Breeder	Native
Laridae	<i>Larus glaucescens</i>	Glaucous-winged gull ^a	Present in Park	Abundant	Breeder	Native
Laridae	<i>Rissa tridactyla</i>	Black-legged kittiwake ^a	Present in Park	Common	Breeder	Native
Phalacrocoracidae	<i>Phalacrocorax auritus</i>	Double-crested cormorant ^a	Present in Park	Common	Breeder	Native
Phalacrocoracidae	<i>Phalacrocorax pelagicus</i>	Pelagic cormorant ^a	Present in Park	Common	Breeder	Native
Phalacrocoracidae	<i>Phalacrocorax urile</i>	Red-faced cormorant ^a	Present in Park	Common	Breeder	Native
Other Marine Species						
Anatidae	<i>Anas acuta</i>	Northern pintail	Present in Park	Uncommon	Breeder	Native
Anatidae	<i>Anas americana</i>	American wigeon	Present in Park	Uncommon	Migratory	Native
Anatidae	<i>Anas clypeata</i>	Northern shoveler	Present in Park	Rare	Migratory	Native
Anatidae	<i>Anas crecca</i>	Green-winged teal	Present in Park	Common	Breeder	Native
Anatidae	<i>Anas discors</i>	Blue-winged teal	Probably Present	NA	NA	Unknown
Anatidae	<i>Anas penelope</i>	Eurasian wigeon	Present in Park	Occasional	Migratory	Native
Anatidae	<i>Anas platyrhynchos</i>	Mallard	Present in Park	Uncommon	Breeder	Native
Anatidae	<i>Anas strepera</i>	Gadwall	Present in Park	Uncommon	Unknown	Native
Anatidae	<i>Anser albifrons</i>	Greater white-fronted goose	Present in Park	Occasional	Migratory	Native
Anatidae	<i>Aythya affinis</i>	Lesser scaup	Probably Present	NA	NA	Unknown
Anatidae	<i>Aythya collaris</i>	Ring-necked duck	Present in Park	Occasional	Migratory	Native
Anatidae	<i>Aythya marila</i>	Greater scaup	Present in Park	Uncommon	Resident	Native

^a These species are monitored both in transect surveys as a part of the SWAN near-shore monitoring and counted in seabird colonies in KEFJ and nearby AMNWR lands

Appendix 3. NPS certified list of marine bird species present within KEFJ (NPS 2012a). (continued)

Family	Scientific Name	Common Name	Occurrence	Abundance	Residency	Nativity
Anatidae	<i>Aythya valisineria</i>	Canvasback	Present in Park	Occasional	Migratory	Native
Anatidae	<i>Branta bernicla</i>	Brant	Present in Park	Uncommon	Resident	Native
Anatidae	<i>Branta canadensis</i>	Canada goose	Present in Park	Uncommon	Migratory	Native
Anatidae	<i>Bucephala albeola</i>	Bufflehead	Present in Park	Common	Migratory	Native
Anatidae	<i>Bucephala clangula</i>	Common goldeneye	Present in Park	Uncommon	Resident	Native
Anatidae	<i>Chen canagica</i>	Emperor goose	Probably Present	NA	NA	Unknown
Anatidae	<i>Clangula hyemalis</i>	Long-tailed duck	Present in Park	Uncommon	Resident	Native
Anatidae	<i>Cygnus buccinator</i>	Trumpeter swan	Present in Park	Rare	Migratory	Native
Anatidae	<i>Cygnus columbianus</i>	Tundra swan, Whistling swan	Present in Park	Occasional	Migratory	Native
Anatidae	<i>Lophodytes cucullatus</i>	Hooded merganser	Probably Present	NA	NA	Unknown
Alcidae	<i>Aethia cristatella</i>	Crested auklet	Probably Present	NA	NA	Unknown
Alcidae	<i>Brachyramphus brevirostris</i>	Kittlitz's murrelet	Present in Park	Uncommon	Breeder	Native
Alcidae	<i>Brachyramphus marmoratus</i>	Marbled murrelet	Present in Park	Common	Breeder	Native
Alcidae	<i>Fratercula cirrhata</i>	Tufted puffin	Present in Park	Common	Breeder	Native
Alcidae	<i>Fratercula corniculata</i>	Horned puffin	Present in Park	Common	Breeder	Native
Alcidae	<i>Uria aalge</i>	Common murre	Present in Park	Common	Breeder	Native
Alcidae	<i>Uria lomvia</i>	Thick-billed murre	Present in Park	Rare	Breeder	Native
Ardeidae	<i>Ardea herodias</i>	Great blue heron	Present in Park	Rare	Migratory	Native
Charadriidae	<i>Charadrius semipalmatus</i>	Semipalmated plover	Present in Park	Common	Breeder	Native
Charadriidae	<i>Pluvialis dominica</i>	American golden-plover	Present in Park	Rare	Migratory	Native
Charadriidae	<i>Pluvialis squatarola</i>	Black-bellied plover	Present in Park	Uncommon	Migratory	Native
Laridae	<i>Larus argentatus</i>	Herring gull	Present in Park	Uncommon	Migratory	Native
Laridae	<i>Larus canus</i>	Mew gull	Present in Park	Common	Breeder	Native
Laridae	<i>Larus hyperboreus</i>	Glaucous gull	Present in Park	Uncommon	Migratory	Native
Laridae	<i>Larus philadelphia</i>	Bonaparte's gull	Present in Park	Common	Migratory	Native

^a These species are monitored both in transect surveys as a part of the SWAN near-shore monitoring and counted in seabird colonies in KEFJ and nearby AMNWR lands

Appendix 3. NPS certified list of marine bird species present within KEFJ (NPS 2012a). (continued)

Family	Scientific Name	Common Name	Occurrence	Abundance	Residency	Nativity
Laridae	<i>Larus ridibundus</i>	Common black-headed gull	Present in Park	Occasional	Vagrant	Native
Laridae	<i>Sterna aleutica</i>	Aleutian tern	Present in Park	Occasional	Vagrant	Native
Laridae	<i>Sterna caspia</i>	Caspian tern	Probably Present	NA	NA	Unknown
Laridae	<i>Sterna paradisaea</i>	Arctic tern	Present in Park	Common	Breeder	Native
Scolopacidae	<i>Actitis macularia</i>	Spotted sandpiper	Present in Park	Common	Breeder	Native
Scolopacidae	<i>Aphriza virgata</i>	Surfbird	Present in Park	Rare	Migratory	Native
Scolopacidae	<i>Arenaria interpres</i>	Ruddy turnstone	Present in Park	Rare	Migratory	Native
Scolopacidae	<i>Arenaria melanocephala</i>	Black turnstone	Present in Park	Uncommon	Migratory	Native
Scolopacidae	<i>Calidris acuminata</i>	Sharp-tailed sandpiper	Probably Present	NA	NA	Unknown
Scolopacidae	<i>Calidris alba</i>	Sanderling	Probably Present	NA	NA	Unknown
Scolopacidae	<i>Calidris alpina</i>	Dunlin	Present in Park	Uncommon	Migratory	Native
Scolopacidae	<i>Calidris mauri</i>	Western sandpiper	Present in Park	Common	Migratory	Native
Scolopacidae	<i>Calidris melanotos</i>	Pectoral sandpiper	Present in Park	Uncommon	Unknown	Native
Scolopacidae	<i>Calidris minutilla</i>	Least sandpiper	Present in Park	Uncommon	Breeder	Native
Scolopacidae	<i>Calidris ptilocnemis</i>	Rock sandpiper	Present in Park	Rare	Migratory	Native
Scolopacidae	<i>Calidris pusilla</i>	Semipalmated sandpiper	Present in Park	Rare	Migratory	Native
Scolopacidae	<i>Gallinago delicata</i>	Wilson's snipe	Present in Park	Common	Breeder	Native
Scolopacidae	<i>Heteroscelus incanus</i>	Wandering tattler	Present in Park	Common	Migratory	Native
Scolopacidae	<i>Limnodromus griseus</i>	Short-billed dowitcher	Present in Park	Uncommon	Migratory	Native
Scolopacidae	<i>Limnodromus scolopaceus</i>	Long-billed dowitcher	Probably Present	NA	NA	Unknown
Scolopacidae	<i>Limosa fedoa</i>	Marbled godwit	Present in Park	Rare	Migratory	Native
Scolopacidae	<i>Limosa haemastica</i>	Hudsonian godwit	Probably Present	NA	NA	Unknown
Scolopacidae	<i>Numenius phaeopus</i>	Whimbrel	Present in Park	Uncommon	Migratory	Native
Scolopacidae	<i>Phalaropus fulicaria</i>	Red phalarope	Present in Park	Rare	Migratory	Native
Scolopacidae	<i>Phalaropus lobatus</i>	Red-necked phalarope	Present in Park	Common	Migratory	Native

^a These species are monitored both in transect surveys as a part of the SWAN near-shore monitoring and counted in seabird colonies in KEFJ and nearby AMNWR lands

Appendix 3. NPS certified list of marine bird species present within KEFJ (NPS 2012a). (continued)

Family	Scientific Name	Common Name	Occurrence	Abundance	Residency	Nativity
Scolopacidae	<i>Tringa flavipes</i>	Lesser yellowlegs	Present in Park	Uncommon	Migratory	Native
Scolopacidae	<i>Tringa melanoleuca</i>	Greater yellowlegs	Present in Park	Common	Migratory	Native
Scolopacidae	<i>Tringa solitaria</i>	Solitary sandpiper	Present in Park	Occasional	Unknown	Native
Stercorariidae	<i>Stercorarius parasiticus</i>	Parasitic jaeger	Present in Park	Rare	Unknown	Native

^a These species are monitored both in transect surveys as a part of the SWAN near-shore monitoring and counted in seabird colonies in KEFJ and nearby AMNWR lands

Appendix 4. Species composition and abundance at seabird colonies in KEFJ for all surveys (1976-2011) analyzed by Parsons et al. (2012). Colony survey locations listed from west to east; from Nuka Bay to Resurrection Bay. Appendix modified from Parsons et al. (2012).

Colony/Spp.	1976	1986	2007	2008	2009	2010	2011
35 Point							
Glaucous-winged gull	30	-	95	*	90	*	33
Red-faced cormorant	10	-	-	*	-	*	27
Double-crested cormorant	-	12	5	*	-	*	-
Pelagic cormorant	-	25	-	*	1	*	1
Cormorant sp.	-	-	-	*	-	*	-
Harrington Point							
Glaucous-winged gull	-	-	166	*	1	*	-
Red-faced cormorant	-	29	-	*	-	*	-
Double-crested cormorant	-	-	18	*	-	*	-
Pelagic cormorant	-	12	-	*	-	*	-
Horned puffin	10	-	-	*	-	*	-
Harrington Point West							
Glaucous-winged gull	-	85	-	*	4	*	50
Red-faced cormorant	-	-	-	*	-	*	5
Double-crested cormorant	-	-	-	*	41	*	32
Pelagic cormorant	20	-	-	*	-	*	15
East Arm (James Lagoon)							
Glaucous-winged gull	120	-	-	*	-	*	-
East Arm North							
Arctic Tern	6	-	-	*	-	*	-
Glaucous-winged gull	40	162	-	*	4	*	7
McCarty Fjord							
Mew gull	*	*	*	*	*	*	9
Delusion							
Mew gull	*	*	*	*	*	*	18
Chance Cove							
Horned puffin	*	*	*	*	*	*	8
Steep Point							
Glaucous-winged gull	50	226	139	*	171	*	169 ²
Red-faced cormorant	-	-	-	*	-	*	19 ²
Double-crested cormorant	-	-	-	*	1	*	-
Pelagic cormorant	40	46	-	*	27	*	11 ²
Tufted puffin	-	-	-	*	11	*	-
Cormorant spp.	-	-	-	*	-	*	8 ²

Appendix 4. Species composition and abundance at seabird colonies in KEFJ for all surveys (1976-2011) analyzed by Parsons et al. (2012). Colony survey locations listed from west to east; from Nuka Bay to Resurrection Bay. Appendix modified from Parsons et al. (2012). (continued)

Colony/Spp.	1976	1986	2007	2008	2009	2010	2011
Black Bay							
Glaucous-winged gull	-	-	-	*	91	*	237 ³
Red-faced cormorant	-	-	-	*	14	*	4 ³
Double-crested cormorant	-	-	20	*	69	*	-
Pelagic cormorant	14	-	27	*	31	*	11 ³
Cormorant spp.	-						3 ³
Horned puffin	140	-	-	*	11	*	-
Tufted puffin	-	-	1	*	16	*	2 ³
Common murre	-	-	3	*	11	*	-
Thunder Bay East							
Glaucous-winged gull	*	*	*	*	*	*	9
Thunder Bay East B							
Pelagic cormorant	*	*	*	*	*	*	2
Nack Triangle							
Glaucous-winged gull	-	-	-	*	11	*	-
Red-faced cormorant	40	-	-	*	-	*	9
Black-legged kittiwake	-	-	-	*	-	*	0
Pelagic cormorant	20	-	-	*	-	*	23
Neck Triangle B							
Pelagic cormorant	*	*	*	*	*	*	11
Cloudy Cape							
Glaucous-winged gull	-	-	285	*	215 ⁸	*	163 ⁷
Black-legged kittiwake	-	22	-	*	-	*	-
Red-faced cormorant	-	-	-	*	2 ⁸	*	-
Double-crested cormorant	-	-	40	*	35 ⁸	*	-
Pelagic cormorant	-	-	-	*	70 ⁸	*	1 ³
Cormorant sp.	-	-	-	*	-	*	-
Horned puffin	-	-	-	*	2 ⁸	*	5
Tufted puffin	-	-	-	*	7 ⁸	*	9
Cloudy B							
Glaucous-winged gull	*	*	*	*	215 ⁸	*	-
Red-faced cormorant	*	*	*	*	2 ⁸	*	-
Double-crested cormorant	*	*	*	*	35 ⁸	*	23 ⁷
Pelagic cormorant	*	*	*	*	70 ⁸	*	5 ⁵
Cormorant sp.	*	*	*	*	-	*	-
Horned puffin	*	*	*	*	2 ⁸	*	-
Tufted puffin	*	*	*	*	7 ⁸	*	3 ²

Appendix 4. Species composition and abundance at seabird colonies in KEFJ for all surveys (1976-2011) analyzed by Parsons et al. (2012). Colony survey locations listed from west to east; from Nuka Bay to Resurrection Bay. Appendix modified from Parsons et al. (2012). (continued)

Colony/Spp.	1976	1986	2007	2008	2009	2010	2011
Surok Point							
Glaucous-winged gull	20	-	427	*	311	*	303 ⁴
Red-faced cormorant	-	-	-	*	2	*	2
Double-crested cormorant	-	-	9	*	27	*	2 ⁴
Pelagic cormorant	140	1	33	*	72	*	3 ⁴
Tufted puffin	-	-	-	*	15	*	5
Horned puffin	-	-	-	*	4	*	4 ²
Surok B							
Pelagic cormorant	*	*	*	*	*	*	5
Sandy Bay							
Horned puffin	*	*	*	*	*	*	3
Tufted puffin	*	*	*	*	*	*	2
Northwestern Lagoon							
Arctic tern	150	-	-	*	*	*	-
Glaucous-winged gulls	170	-	-	*	*	*	-
Mew gull	90	-	-	*	*	*	-
NW Glacier							
Glaucous-winged gull	*	*	*	*	*	82	180
NW Glacier B							
Glaucous-winged gull	*	*	*	*	*	*	32
Try Triangle							
Horned puffin	10	-	-	*	-	*	-
17 Cove							
Horned puffin	10	-	-	*	-	*	-
Cliff Bay							
Double-crested cormorant	-	-	30	*	-	-	-
Pelagic cormorant	-	-	17	*	-	11	4
Horned puffin	3	-	28	*	-	-	4
Aialik Cape							
Glaucous-winged gull	-	-	-	98	-	-	-
Black-legged kittiwake	-	-	-	3	-	-	-
Red-faced cormorant	-	74 ¹	-	-	99	51	-
Double-crested cormorant	-	-	-	9	66	26	23 ⁵
Pelagic cormorant	-	63 ¹	-	22	66	104	-
Cormorant sp.	-	8 ¹	-	-	2	-	-
Horned puffin	60	-	27	9	4	10	41
Tufted puffin	-	-	-	17	6	-	-

Appendix 4. Species composition and abundance at seabird colonies in KEFJ for all surveys (1976-2011) analyzed by Parsons et al. (2012). Colony survey locations listed from west to east; from Nuka Bay to Resurrection Bay. Appendix modified from Parsons et al. (2012). (continued)

Colony/Spp.	1976	1986	2007	2008	2009	2010	2011
East Aialik Peninsula							
Horned puffin	20	-	-	*	12	*	-
Cheval Narrows							
Horned puffin	*	*	*	*	*	*	16
Porcupine Cove							
Horned puffin	*	*	*	*	*	*	8
Spire Cove C							
Horned puffin	*	*	*	*	*	*	5
Spire Cove B							
Horned puffin	*	*	*	*	*	*	3
Spire Cove							
Red-faced cormorant	-	-	-	*	-	-	3 ⁶
Pelagic cormorant	-	-	-	*	11	-	10 ⁶
Cormorant sp.	-	-	-	*	-	15	-
Horned puffin	30	-	-	*	30	1	9
Bear Glacier Point B							
Horned puffin	*	*	*	*	*	*	2
Bear Glacier Point							
Glaucous-winged gull	-	-	-	32	-	*	-
Black-legged kittiwake	-	-	-	23	-	*	-
Double-crested cormorant	-	-	-	7	-	*	-
Pelagic cormorant	-	-	12	14	-	*	-
Horned puffin	50	-	19	4	7	*	12
Bulldog Cove							
Horned puffin	*	*	*	*	*	*	4

* Denotes colonies were not surveyed.

— Denotes no observations of species/nest at colony.

¹ Aialik Cape and 300 Island (No name) in AMNWR are combined in the 1986 survey data.

² Average of counts from two visits.

³ Average of counts from three visits.

⁴ Average of counts from four visits.

⁵ Average of counts from seven visits.

⁶ Average of counts from eight visits.

⁷ Average of counts from nine visits.

⁸ Cloudy Cape and Cloudy B colonies are combined in the 2009 survey.

Appendix 5. Species and densities (standard error) of target marine birds in nearshore marine transects in KEFJ, 2007-2009. Table compiled from Bodkin et al. (2008) and Coletti et al. (2009, 2010, 2011b).

Species	2007 average density (#/km2)	SE	2008 average density (#/km2)	SE	2009 average density (#/km2)	SE
Barrow's goldeneye (<i>Bucephala islandica</i>)	0.19	0.14	1.61	0.96		
Black-legged kittiwake (<i>Rissa tridactyla</i>)	45.78	21.59	28.13	23.06	81.82	76.05
Black oystercatcher (<i>Haematopus bachmani</i>)	0.74	0.03	0.52	0.17	1.29	0.07
Black scoter (<i>Melanitta nigra</i>)	0.13	0.10	0.03	0.03		
Common murre (<i>Uria aalge</i>)	34.41	18.03	22.01	15.43		
Double-crested cormorant (<i>Phalacrocorax auritus</i>)	7.72	4.36	1.05	0.39	1.68	0.76
Glaucous-winged gull (<i>Larus glaucescens</i>)	180.19	56.86	116.61	36.65	119.19	40.06
Harlequin duck (<i>Histrionicus histrionicus</i>)	12.45	8.87	19.88	12.57	15.92	8.26
Horned puffin (<i>Fratercula corniculata</i>)	7.34	2.88	9.35	3.67		
Pelagic cormorant (<i>Phalacrocorax pelagicus</i>)	9.80	3.62	10.05	3.99	13.48	6.66
Pigeon guillemot (<i>Cephus columba</i>)	6.49	1.34	9.96	1.23	4.63	1.31
Red-faced cormorant (<i>Phalacrocorax urile</i>)	7.97	5.39	6.18	3.57	7.33	3.31
Surf scoter (<i>Melanitta perspicillata</i>)	1.00	0.52	0.15	0.15	0.07	0.07
Tufted puffin (<i>Fratercula cirrhata</i>)	51.06	27.56	30.89	15.84		
Unidentified cormorant (<i>Phalacrocoracidae</i> sp.)	8.84	3.47	1.89	0.66	6.69	2.67
Unidentified duck (<i>Anatidae</i> sp.)	0.20	0.10	0.10	0.07		
Unidentified merganser (<i>Mergus</i> sp.)	0.09	0.07				
Unidentified puffin (<i>Fratercula</i> sp.)	0.22	0.11				
Unidentified scoter (<i>Melanitta</i> spp.)			1.31	1.31	0.04	0.04
White-winged scoter (<i>Melanitta fusca</i>)	0.04	0.04	0.59	0.59		

Appendix 6. Estimated sockeye salmon escapement in thousands of fish for the major spawning lake systems of Lower Cook Inlet: 1975-2010. Escapement data compiled from Edmundson (2001) and Hammarstrom and Ford (2011).

Year	Delight Lake	Desire Lake	Delusion Lake ⁴	Aialik Lagoon (aka Pedersen Lagoon ⁴)
1975	2.0	6.5	--	--
1976	6.0	11.0	--	--
1977	5.2	10.7	--	--
1978	8.0	10.0	--	--
1979	8.0	12.0	--	--
1980	10.0	17.0	--	--
1981	7.3	12.0	--	--
1982	25.0	18.0	--	--
1983	7.0	12.0	--	--
1984	10.5	15.0	--	--
1985	26.0	18.0	--	--
1986	13.0	10.0	--	--
1987	10.5	13.4	--	--
1988	1.2	9.0	--	--
1989	7.7	9.0	--	--
1990	5.2	9.5	0.3	5.7
1991	4.1	8.2	0.3	3.7
1992	5.9	11.9	1.0	2.5
1993	5.6	11.0	1.3	3.0
1994	5.6	10.5	1.3	7.3
1995	15.8	15.8	1.5	2.6
1996	7.7	9.4	0.7	3.5
1997	27.8 ¹	14.7 ¹	1.4	11.4
1998	9.2 ¹	7.9	1.1	1.9
1999	17.0 ²	14.6	1.1	3.8
2000	12.3	4.0	2.1	4.3
2001	10.1	5.5	2.8	5.1
2002	19.6 ¹	16.0	3.6	6.1
2003	7.5 ²	8.4	2.0	5.4
2004	7.3 ²	10.7	1.0	10.1
2005	15.2 ²	4.8	1.1	5.3
2006	10.9 ²	18.6	1.0	4.8

¹ - Weir counts.

² - Combination of weir, video, and/or aerial counts.

³ - No formal escapement goal established.

⁴ - Data unavailable for Delusion and Aialik Lakes prior to 1990

⁵ - New sustainable escapement goals (SEG's) implemented for the first time beginning with the 2002 season.

Appendix 6. Estimated sockeye salmon escapement in thousands of fish for the major spawning lake systems of Lower Cook Inlet: 1975-2010. Escapement data compiled from Edmundson (2001) and Hammarstrom and Ford (2011). (continued)

Year	Delight Lake	Desire Lake	Delusion Lake⁴	Aialik Lagoon (aka Pedersen Lagoon⁴)
2007	44.0 ²	10.0	2.1	5.4
2008	23.9 ²	10.7	1.8	4.2
2009	12.7	16.0	1.3	3.1
2010	23.8 ²	6.3	0.6	5.3
1975-1989 average	9.8	12.2	--	--
1990-1999 average	10.4	11.4	1.0	4.8
2000-2009 average	16.4	10.5	1.9	5.4
1990-2009 average (20 yr)	13.4	10.9	1.4	5.1
1975-2009 average	11.9	11.5		--
SEG ⁵	5.95-12.55	8.8-15.2	-- ³	3.7-8.0

¹ - Weir counts.

² - Combination of weir, video, and/or aerial counts.

³ - No formal escapement goal established.

⁴ - Data unavailable for Delusion and Aialik Lakes prior to 1990

⁵ - New sustainable escapement goals (SEG's) implemented for the first time beginning with the 2002 season.

Appendix 7. Commercial salmon catch for all gear and harvest types in numbers of fish by species in the Outer District, Lower Cook Inlet, 1990-2010. Appendix A8 in Hammarstrom and Ford (2011).

Year	Chinook	Sockeye	Coho	Pink	Chum	Total
1990	2	17,404	74	191,320	614	209,414
1991	2	6,408	12	359,661	14,337	380,423
1992	0	572	1	146	181	900
1993	2	4,613	119	159,159	970	164,863
1994	0	5,930	993	13,200	32	20,155
1995	12	17,642	1,272	192,098	474	211,498
1996	0	14,999	96	7,199	3	22,297
1997	0	6,255	63	129,373	1,575	136,266
1998	0	15,991	45	102,172	611	118,819
1999	3	51,117	1,482	32,484	2,062	87,148
2000	2	21,623	20	306,555	302	328,502
2001	0	7,339	5	48,559	408	56,311
2002	0	21,154	74	569,955	3,810	594,993
2003	1	26,615	4	281,663	137	308,420
2004	2	11,082	13	42,636	27,911	81,644
2005	0	1	3	110,195	12,524	122,723
2006	3	3,198	1,139	1,121,892	12,883	1,139,115
2007	1	32,461	113	147,409	49	180,033
2008	0	1,704	0	467,592	100,819	570,115
2009	1	8	9	853,037	35,126	888,181
2010	0	3,003	16	272,427	22,463	297,909
20 yr. avg. (1990-2009)	2	13,306	277	256,815	10,741	281,091
1990-1999 avg.	2	14,093	416	118582	2086	135178
2000-2009 avg.	1	12,519	138	194949	19397	427004
2010 % of Total	0.00%	1.01%	0.01%	91.45%	7.54%	100.00%

Source labeled in Hammarstrom and Ford (2011) was the ADF&G ticket database *Unpublished*.

Appendix 8. Shoreline change area (contiguous, linear shoreline segments represented by the instantaneous water line in the 2005 IKONOS orthoimage mosaic of KEFJ) ID numbers, names, geographic descriptions, and primary interpreted changes associated with each change area. Locations for many of these shoreline change areas are available in Plate 30 or Plate 31.

ID No.	Shoreline Area Name	Geographic Description	Primary Changes (interpreted)
1	Aialik East 1	shoreline east of Aialik glacier and Squab Island including multiple stream deltas	significant beach erosion/subsidence, vegetation loss
2	Aialik East 2	shoreline east of Slate Island	beach erosion/subsidence, minor vegetation loss
3	Aialik East 3	shoreline southeast of Slate Island	beach erosion/subsidence
4	Aialik East 4	shoreline just north of Coleman Bay	beach erosion/subsidence, vegetation loss
5	Aialik Glacier	shoreline on west side of Aialik glacier and the glacier terminus itself	relatively minor changes to horizontal position of glacier terminus, some changes in glacial sediments
6	Babcock Creek Delta	Babcock Creek Stream delta at the end of Surprise Bay	beach erosion/subsidence, stream delta sediment changes, vegetation loss, small ghost forest
7	Bear Cove	southern lobe of Bear Cove	minor beach erosion/subsidence or tidal position discrepancy
8	Bear Glacier and Lagoon	Iceberg filled Lagoon and Bear Glacier terminus	glacier recession, newly formed lagoon and new glacier terminus positions
9	Bear Glacier Lagoon Island*	new islands in lagoon	newly formed island with vegetation established
10	Bear Lagoon Beach	Barrier beach in front of Bear Lagoon/Bear Glacier	beach erosion/subsidence, massive changes in the area, channel migration, vegetation establishment/succession. <i>Mann (1998) noted that the 64 quake caused steepening and inland-migration of the barrier beach here.</i>
11	Beauty Bay Cove South	cove with stream deltas on south shore of Beauty Bay	minor beach/stream delta erosion/subsidence, some vegetation loss, minor ghost forest

* Feature represented by multiple records (i.e., line segments) in the GIS dataset.

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ID No.	Shoreline Area Name	Geographic Description	Primary Changes (interpreted)
12	Bulldog Cove	Bulldog Cove and Bear Lake	beach erosion/subsidence, channel migration, vegetation establishment
13	Cloudy Mountain Cove	small cove near Cloudy Mountain at entrance to Taroka Arm	very minor beach erosion/subsidence
14	Coleman Bay End	shoreline at the end of Coleman Bay	beach erosion, vegetation establishment
15	Coleman Bay South	shoreline along south portion of Coleman Bay	minor beach erosion or tidal discrepancy
16	Coleman Entrance 1	shoreline just outside entrance to Coleman Bay to the south	minor beach erosion/subsidence, minor vegetation loss
17	Coleman Entrance 2	shoreline just outside entrance to Coleman Bay to the south	minor beach erosion/subsidence, minor vegetation loss
18	Crescent Beach Pond	beach and pond with stream delta along the east and north shoreline near the entrance to Northwestern Fjord	significant beach erosion/subsidence, river mouth changes in sediment, vegetation establishment and succession
19	Crescent Beach Pond Island	mudflat island inside of Crescent Beach Pond	newly established mudflat
20	Delight Lake Creek Delta	stream delta and beach near Delight Creek	significant beach erosion/subsidence, stream delta changes, foreshore vegetation establishment
21	Delusion Lake Stream Delta	stream delta and beach near Delusion Lake Creek	stream channel migration, minor beach erosion, vegetation establishment inland
22	Desire Lake Creek Delta	stream delta, small lagoon, barrier beach, mudflat at the outlet of Desire Lake Creek	significant beach erosion/subsidence, stream delta changes, foreshore vegetation establishment

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Appendix 8. Shoreline change area (contiguous, linear shoreline segments represented by the instantaneous water line in the 2005 IKONOS orthoimage mosaic of KEFJ) ID numbers, names, geographic descriptions, and primary interpreted changes associated with each change area. Locations for many of these shoreline change areas are available in Plate 30 or Plate 31. (continued)

ID No.	Shoreline Area Name	Geographic Description	Primary Changes (interpreted)
23	Dinglestadt Glacier Stream Delta	alluvial fan associated with the Dinglestadt Glacier	tidewater glacier terminus converted to glacial outwash area, increase in sediment at shoreline and vegetation establishment
24	Division Island Beach 1	small beach north of Nuka Island, east of Division Island	minor beach erosion/subsidence
25	Division Island Beach 2	small beach north of Nuka Island, east of Division Island	minor beach erosion/subsidence
26	Division Island Beach 3	small beach north of Nuka Island, east of Division Island	minor beach erosion/subsidence
27	Division Island Beach 4	small beach north of Nuka Island, east of Division Island	minor beach erosion/subsidence
28	Division Island Beach 5	small beach north of Nuka Island, east of Division Island	minor beach erosion/subsidence
29	Holgate Beach North 1	narrow beach along north shoreline of Holgate Arm	very minor changes in beach (possibly erosion)
30	Holgate Beach North 2	narrow beach and small stream delta along north shoreline of Holgate Arm	very minor changes in beach (possibly erosion), includes a small stream delta
31	Holgate Glacier	Holgate Glacier and one unnamed glacier just to south	glacier recession, newly exposed rock cliff with vegetation establishment upslope, new tidewater glacier terminus position
32	Holgate Landslide South	minor landslide/stream outwash just south and east of Holgate Glacier	minor landslide and stream outwash increased sediment into bay

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Appendix 8. Shoreline change area (contiguous, linear shoreline segments represented by the instantaneous water line in the 2005 IKONOS orthoimage mosaic of KEFJ) ID numbers, names, geographic descriptions, and primary interpreted changes associated with each change area. Locations for many of these shoreline change areas are available in Plate 30 or Plate 31. (continued)

ID No.	Shoreline Area Name	Geographic Description	Primary Changes (interpreted)
33	James Lagoon Entrance East	immediate Eastern Shore of James Lagoon	dramatic erosion/subsidence, rearrangement of sediment, barrier beach formation, vegetation changes, some ghost forest
34	James Lagoon Spit	spit at entrance to James Lagoon	dramatic erosion/subsidence, rearrangement of sediment, barrier beach formation, vegetation changes
35	James Lagoon Spit Island 1	island and mudflat associated with spit at entrance to James Lagoon	dramatic erosion/subsidence, rearrangement of sediment, vegetation changes
36	James Lagoon Spit Island 2	island and mudflat associated with spit at entrance to James Lagoon	dramatic erosion/subsidence, rearrangement of sediment, vegetation changes
37	James Lagoon Stream Deltas	multiple stream deltas at end of James Lagoon	dramatic erosion/subsidence, rearrangement of sediment, barrier beach formation, vegetation changes
38	McArthur Lagoon Ghost Forest	area near Delight Creek outlet and McArthur Lagoon	significant beach erosion/subsidence, stream delta changes, foreshore vegetation establishment, small ghost forest development
39	McArthur Lagoon North	north shoreline of McArthur Lagoon	significant beach erosion/subsidence, foreshore vegetation establishment
40	McCarty Fjord West Shore	western shoreline, seaward of Dinglestad Glacier outwash	stream channel migration and minor beach erosion, vegetation succession up slope (shrub establishment)
41	McCarty Glacier	newly exposed shoreline and receding McCarty Glacier terminus	glacier recession, newly exposed shoreline and open water fjord, new tidewater glacier terminus position
42	McMullen Cove	beach near entrance to McMullen Cove	beach erosion/subsidence, minor vegetation loss and beach shape change (<i>Mann 1998 noted steepening and inland-migration of barrier beach here</i>)

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Appendix 8. Shoreline change area (contiguous, linear shoreline segments represented by the instantaneous water line in the 2005 IKONOS orthoimage mosaic of KEFJ) ID numbers, names, geographic descriptions, and primary interpreted changes associated with each change area. Locations for many of these shoreline change areas are available in Plate 30 or Plate 31. (continued)

ID No.	Shoreline Area Name	Geographic Description	Primary Changes (interpreted)
43	North Arm East Beach 1	very small beaches on east side of North Arm	minor beach erosion/subsidence
44	North Arm East Beach 2	very small beaches on east side of North Arm	minor beach erosion/subsidence
45	North Arm East Beach 3	very small beaches on east side of North Arm	minor beach erosion/subsidence
46	North Arm East Beach 4	very small beaches on east side of North Arm	minor beach erosion/subsidence
47	North Arm East Beach 5	small beach and small stream delta	beach erosion/subsidence, vegetation loss , small ghost forest
48	North Arm Stream Delta 1	stream delta northwest end of North Arm	beach erosion/subsidence, changing stream delta sediments, vegetation loss, ghost forest
49	North Arm Stream Delta 2	stream delta northeast end of North Arm	stream delta sediment erosion/subsidence, large riparian shrub establishment area
50	North Arm Stream Delta 2a	eastern portion of stream delta	minor erosion
51	North Arm Stream Delta 2	eastern portion of stream delta	minor erosion
52	Northwestern Fjord East 1	stream delta on east shoreline of Northwestern Fjord directly east of Striation Island	newly exposed glacier fed stream, significant area of vegetation establishment
53	Northwestern Fjord East 2	multiple stream deltas along the eastern shoreline of Northwestern Fjord	river channel and delta sediment change, beach erosion/subsidence, significant backshore vegetation establishment
54	Northwestern Fjord East 3	stream delta along the eastern shoreline of Northwestern Fjord	minor beach erosion, stream sediment change, some vegetation establishment

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Appendix 8. Shoreline change area (contiguous, linear shoreline segments represented by the instantaneous water line in the 2005 IKONOS orthoimage mosaic of KEFJ) ID numbers, names, geographic descriptions, and primary interpreted changes associated with each change area. Locations for many of these shoreline change areas are available in Plate 30 or Plate 31. (continued)

ID No.	Shoreline Area Name	Geographic Description	Primary Changes (interpreted)
55	Northwestern Fjord South	stream delta and glacier outwash area on the southwest shoreline of Northwester Fjord	glacier recession, newly exposed shoreline with increased sediment and riparian shrub establishment
56	Northwestern Fjord Southwest	glacier recession area on western shores of Northwestern Fjord and South of Striation Island	newly exposed shoreline, vegetation establishment upslope
57	Northwestern Glacier	glacier recession area including Northwestern Glacier itself and two unnamed glaciers terminating at tide water on western shore of Northwestern Fjord	newly exposed shoreline, vegetation establishment upslope
58	Northwestern Lagoon and Spit	spit and shoreline along the southern shore of Northwestern Lagoon and along a portion of western Harris Bay	beach erosion/subsidence, vegetation loss, spit rearrangement
59	Northwestern Lagoon Beach North	beach along the northern shoreline of Northwestern Lagoon	beach erosion/subsidence, minor foreshore vegetation loss
60	Nuka River & Ferrum Creek Deltas	end of Beauty Bay multi-stream/river delta area	significant river mouth delta erosion/subsidence, veg. loss, ghost forest, channel migration, riparian shrub establishment
61	Paguna Arm Entrance Landslide	western shoreline of the entrance to Paguna Arm	very minor landslide
62	Paguna Arm Stream Delta SE	small stream delta and cove along south east shoreline of Paguna Arm	minor beach erosion/subsidence, small ghost forest
63	Paguna Arm Stream Deltas NE	stream deltas along north east shoreline of Paguna Arm	beach erosion/subsidence, vegetation loss, stream channel migration

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ID No.	Shoreline Area Name	Geographic Description	Primary Changes (interpreted)
64	Paguna Arm West	western shore of Paguna Arm near small Lagoon	minor beach erosion/subsidence, minor vegetation loss
65	Pederson Glacier	long shoreline including a portion of western Aialik Bay and the Pederson Lagoon	significant loss of glacial outwash/beach erosion/subsidence, vegetation succession
66	Pederson Glacier Island*	Islands in Pederson Lagoon	new islands in lagoon
67	Pederson Lagoon Spit	barrier beach and shoreline of the entrance to Pederson Lagoon	significant beach erosion/subsidence, vegetation succession
68	Petroff Point	In Nuka Passage	beach erosion, foreshore vegetation loss and backshore ghost forest
69	Pilot Harbor Stream Delta	stream delta and cove associated with Pilot Harbor	beach erosion/subsidence, vegetation loss, small ghost forest
70	Quartz Bay Stream Delta	stream delta at the end of Quartz Bay	beach erosion/subsidence, vegetation loss, very small ghost forest
71	Quicksand Cove	beach and stream delta in Quicksand Cove	minor beach erosion/subsidence, minor changes to stream sediment, some vegetation succession. <i>Mann (1998) notes that the 64 quake steepened and caused inland-migration of the barrier beach here.</i>
72	Sandy Bay Beach	small beach and stream delta at the end of Sandy Bay	minor beach erosion/subsidence
73	Slate Island	small beach west of Slate Island	beach erosion/subsidence, vegetation loss
74	Striation Island	north shoreline of Striation Island	newly exposed shoreline of Striation Island

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ID No.	Shoreline Area Name	Geographic Description	Primary Changes (interpreted)
75	Taroka Arm	end of Taroka Arm with two primary stream deltas west and east	beach erosion/subsidence, spit changed shape to west
76	Thunder Bay Stream Deltas	two primary stream deltas at the northeaster end of Thunder Bay	beach and stream delta erosion/subsidence, minor vegetation loss
77	Tooth Cove	end of Tooth Cove	minor beach erosion/subsidence
78	Verdant Cove	beach along southwest shore of Verdant Cove	significant beach erosion/subsidence, ghost forest signature. <i>Mann (1998) noted that the 64 quake steepened and caused inland-migration of the barrier beach here.</i>
79	West Arm Cove	small cove west and stream delta along shore opposite Beautiful Island	minor beach erosion & changes in stream delta sediment
80	Yalik Bay Cove South	cover Yalik Bay on south shore	minor beach and stream delta erosion, vegetation loss
81	Yalik Bay End	end of Yalik Bay	beach and stream delta erosion, vegetation loss
82	Yalik Glacier Stream Delta*	north of Nuka Island	beach erosion/subsidence, foreshore vegetation loss, backshore veg. est., changing stream channel and delta sediments
83	Yalik Point Cove 1	small cove exposed to Nuka Bay	minor beach erosion/subsidence
84	Yalik Point Cove 2	small cove and stream delta protected from Nuka Bay	beach and stream delta erosion/subsidence, vegetation loss, very minor ghost forest near pond
85	Yalik Point Landslides	steep shoreline just south of Yalik Point	evidence of landslides that removed vegetation on slope

* Feature represented by multiple records (i.e., line segments) in the GIS dataset.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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