National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Sitka National Historical Park

Natural Resource Condition Assessment

Natural Resource Report NPS/SITK/NRR—2012/525

ON THE COVER
Totem along forest trail in Sitka National Historic Park
Photograph by: Pete Hanson

Sitka National Historical Park

Natural Resource Condition Assessment

Natural Resource Report NPS/SITK/NRR—2012/525

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The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado publishes a range of reports that address natural resource topics of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

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Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

This report is available from the Southeast Alaska Network (SEAN) (http://science.nature.nps.gov/im/units/sean/) and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/nrpm/).

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Executive Summary

As a unit in the National Park Service (NPS), SITK is responsible for the management and conservation of natural resources within its boundaries. This mandate is supported by the National Park Service Organic Act of 1916, which directs the NPS to:

> Conserve the scenery and natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such a manner and by such means as will leave them unimpaired for the enjoyment of future generations.

Despite a small footprint (approximately 43 hectares) relative to most Alaska NPS units, SITK contains a diverse set of land forms and vegetation, including the Indian River and its floodplain, river delta, estuary, beach, and intertidal wetlands. The convergence of the Indian River, the coastal rainforest, and the sea provides a biologically rich environment. The hydrologic processes of the river and tidal waters, along with good water quality, support riparian communities and intertidal wetlands provide essential habitat for native fish and wildlife species.

The Natural Resource Condition Assessment (NRCA) Program aims to provide documentation about the current conditions of important park natural resources through a spatially explicit, multi-disciplinary synthesis of existing scientific data and knowledge. Findings from the NRCA, including the report and accompanying map products, will help SITK managers to:

- develop near-term management priorities,
- engage in watershed or landscape scale partnership and education efforts,
- conduct park planning (e.g., Resource Stewardship Strategy),
- report program performance (e.g., Department of the Interior‘s Strategic Plan ―land health” goals, Government Performance and Results Act).

For the purpose of this NRCA, NPS and Saint Mary‘s University of Minnesota, GeoSpatial Services (SMU GSS) staff identified 10 key resources, natural resource topics that are currently of the greatest concern to park management, referred to as ―components” in the assessment. The final project framework identified measures, stressors, and reference conditions for each component. The objectives were to synthesize and report on current conditions of key park resources, using existing information, to evaluate critical data and knowledge gaps, and to highlight selected existing stressors and emerging threats to resources or processes.

This study involved reviewing existing literature and data for each of the components in the framework and, where appropriate, analyzing data in order to provide summaries. Existing data for each measure were compared to reference conditions (when possible) and a weighted scoring system was applied to express the current condition of each component. Weighted condition scores range from zero to ten and were divided into three condition categories: low concern, moderate concern, and significant concern. Each component section of this document contains a summary of available information regarding the current conditions of these resource components. The discussions represent the most recent published literature available, but in some cases also include unpublished park data and the perspectives of the park biologist and NPS experts.

A few threats or stressors have been identified that apply to multiple resources within the park. These include climate change, reduced streamflow from water diversions, social trails potentially reducing forest regeneration, and invasive non-native plants. Scientists project temperatures in southeast Alaska will increase at an average rate of about 0.6°F (0.3° C) per decade, for an overall change in annual temperature of 6°F (3.3°C) by 2080. Although precipitation will increase slightly, an increase in evapotranspiration due to warmer temperatures will lead to drier conditions, particularly in the summer and fall. This has the potential to impact nearly every natural resource component discussed in this assessment. The Indian River experiences extreme low flow periods which are worsened by water diversions upstream of the park. Park management have noted a number of social trails off established trails, crossing natural areas in the park, in which vegetation trampling and soil compaction is of concern. Generally, non-native invasive plants in SITK are confined to developed areas of the park (i.e., around the visitor center and parking lot). However, invasive mountain ash trees are common in natural areas of the park.

SITK has been studied intensively by scientists over the last several decades, covering a variety of natural and cultural resource topics, including a recent (2004) coastal watershed assessment. However, many scientific data gaps remain that could inform managers of the current conditions of park natural resources. Some data needs are in the process of being addressed with new SEAN monitoring protocols and survey/inventory efforts (e.g., a land cover / vegetation map, airborne contaminants monitoring). Other examples of data gaps include developing an understanding of intertidal ecosystem health and the effects of social trail use on forest regeneration.

The majority of SITK's resources included in this assessment were considered to be in good or moderate condition. Freshwater and intertidal water/habitat quality and the status of invasive species are considered in good condition with either stable or unknown trends. Air quality and forests are in moderate condition with unknown and declining trends, respectively. Indian River hydrology is the only component designated with a condition of significant concern, primarily due to issues with water diversions and low flows. This issue also has implications for interrelated components such as fish and water/habitat quality of the river. Several components (land and coastal birds, landform/land cover, and fish) were not assigned a condition score due to a lack of current information or clearly defined reference conditions. Their condition is therefore considered largely unknown.

Acronyms and Abbreviations

ADEC – Alaska Department of Environmental Conservation

ADF&G – Alaska Department of Fish and Game

CBS – City and Borough of Sitka

DNR – Department of Natural Resources

EPA – Environmental Protection Agency

EPMT – Exotic Plant Management Team

GIS – Geographic Information System

GLBA – Glacier Bay National Park and Preserve

I&M – Inventory and Monitoring

KLGO – Klondike Gold Rush National Historical Park

NPS – National Park Service

NRCA – Natural Resource Condition Assessment

SEAN – Southeast Alaska Network

SITK – Sitka National Historical Park

SMU GSS – Saint Mary‘s University of Minnesota, Geospatial Services

SSSC – Sitka Sound Science Center

USFS – United States Forest Service

USFS FHP – United States Forest Service, Forest Health Program

USFWS – United States Fish and Wildlife Service

USGS – United States Geological Survey

WCS – Weighted Condition Score

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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”. For these condition analyses they also report on trends (as possible), critical data gaps, and general level of confidence for study findings. The resources and indicators emphasized in the project work depend on a park‘s resource setting, status of resource stewardship planning and science in identifying high-priority indicators for that park, and availability of data and expertise to assess current conditions for the things identified on a list 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 logical reference
- conditions/values to compare current condition data against[3,4]
- emphasize spatial evaluation of conditions and GIS (map) products[5]
- summarize key findings by park areas[6]
- follow national NRCA guidelines and standards for study design and reporting products

> ***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*

Although current condition reporting relative to logical forms of reference conditions and values is the primary objective, NRCAs also report on trends for any study indicators where the underlying data and methods support it. Resource condition influences are also addressed. This can include past activities or conditions that provide a helpful context for understanding current

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[1] However, 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 reporting 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
[4] 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”)
[5] As possible and appropriate, NRCAs describe condition gradients or differences across the park for important natural resources and study indicators through a set of GIS coverages and map products
[6] 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 a area-by-area basis: 1) by park ecosystem/habitat types or watersheds, and 2) for other park areas as requested

park resource conditions. It also includes present-day condition influences (threats and stressors) that are best interpreted at park, watershed, or landscape scales, though NRCAs do not judge or report on condition status per se for land areas and natural resources beyond the park‘s boundaries. Intensive cause and effect analyses of threats and stressors or development of detailed treatment options is outside the project scope.

Credibility for study findings derives from the data, methods, and reference values used in the project work—are they appropriate for the stated purpose and adequately documented? For each study indicator where current condition or trend is reported it is important to identify critical data gaps and describe 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: 1) to assist selection of study indicators; 2) to recommend study data sets, methods, and reference conditions and values to use; and 3) to help provide a multi-disciplinary review of draft study findings and products.

NRCAs provide a useful complement to more rigorous NPS science support programs such as the NPS Inventory and Monitoring Program. 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 bring in relevant non-NPS data to help evaluate current conditions for those same vital signs. In some cases, NPS inventory data sets are also incorporated into NRCA analyses and reporting products.

In-depth analysis of climate change effects on park natural resources is outside the project scope.

However, existing condition analyses and data sets developed by a NRCA will be useful for subsequent park-level climate change studies and planning efforts.

NRCAs do not establish management targets for study indicators. Decisions about management targets must be made through sanctioned park planning and management processes. NRCAs do provide science-based information that will help park managers with an ongoing, longer term effort to describe and quantify their park‘s desired

Important NRCA Success Factors …

Obtaining good input from park and other NPS subjective 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 resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning[7] and help parks report to government accountability measures[8].

Due to their modest funding, relatively quick timeframe for completion and reliance on existing data and information, NRCAs are not intended to be exhaustive. Study methods typically involve 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 our present data and knowledge bases across these varied study components.

NRCAs can yield new insights 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 credible and has practical uses for a variety of park decision making, planning, and partnership activities.

Over the next several years, the NPS plans to fund a NRCA project for each of the ~270 parks served by the NPS Inventory and Monitoring Program. Additional NRCA Program information is posted at: http://www.nature.nps.gov/water/NRCondition_Assessment_Program/Index.cfm

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)

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[7] NRCAs are an especially useful lead-in to working on a park Resource Stewardship Strategy(RSS) but study scope can be tailored to also work well as a post-RSS project

[8] 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

Chapter 2 Introduction and Resource Setting

2.1 Introduction

2.1.1 Enabling Legislation

Sitka National Historical Park was first dedicated as a public park in 1890 by President Benjamin Harrison (Antonson and Hanable 1987). On 23 March 1910, Sitka became a National Monument with a Presidential Proclamation from President William H. Taft. In 1972, according to Public law 92-501, Sitka National Monument expanded in area and was re-designated Sitka National Historical Park (NPS 1998). The national historical park was established to preserve the battleground and Russian Memorial from the 1804 Battle of Sitka as well as the site of the Kiks.ádi fort Shiskinoow (Moynahan et al. 2008). The park protects totem poles from the Tlingit and Haida historical collection and various structures and land associated with the Russian Bishop‘s House (Moynahan et al. 2008). The park intends to foster any other natural resources that relate to the history of the area (Moynahan et al. 2008).

2.1.2 Geographic Setting

Sitka National Historical Park (SITK) encompasses 45.7 ha (113 ac) of coastal lowland and riparian forest, near Sitka, Alaska (Moynahan et al. 2008). SITK is located at the mouth of the Indian River, one of the park‘s primary natural features. It also provides one of the biggest attractions; during the summer, visitors can view migrating and spawning salmon in the river (NPS 1999). The Indian River, the Pacific Ocean, and the coastal rainforest join within the park, creating a biologically diverse ecosystem suitable for a range of species (Moynahan et al. 2008). SITK is located in the town of Sitka, in Sitka County with a population of 8,881 people (U.S. Census 2010). SITK lies approximately 32 km (20 mi) away from the Fairweather – Queen Charolette Fault system. This system is referred to as a ―transform fault zone”, and is rather large in size (Chaney et al. 1995, p. 8). Uplift landforms, which are common on the shores of SITK, were formed primarily by the activity of this fault system and heavy storm waves. The Indian River delta was also uplifted (ca 9,000 yrs ago) and now rests above sea level (Chaney et al. 1995).

The soils found in SITK are characteristic of the geologically active region of southeast Alaska. The uplifted beach and beach meadows have poorly developed soils due to the high waters and strong tidal activity. Mafic-tephra deposits, specific to the Pleistocene-age, are spread throughout the higher elevations (>12 m asl) of the park from the last eruption of Mount Edgecumbe (Chaney et al. 1995, NPS 2006). The upland terraces and lowlands have the most developed soil in the park. These soils are well drained and shallow (NPS 1999, 2006). The lowland areas have organic soils resting on bedrock and soils that have formed in volcanic ash. Less developed soil with greater amounts of organic matter can be found in the present floodplain because of flood frequency and the presence of red alder (*Alnus rubra*), which can fix atmospheric nitrogen (NPS 2006). The Indian River bed is abundant in gravel, cobbles, and boulders with low amounts of silt and smaller sediment (Moynahan et al. 2008).

The park has a marine climate, and receives an average annual precipitation of 253 cm (99.6 in) (NPS 1999). The majority of this precipitation is rainfall, deposited primarily in the months of September through November (NPS 1999). However, the mountainous areas of the Indian River watershed develop a considerable amount of snow pack which provides an input of freshwater to the Indian River much of the year (NPS 1999). Temperature and precipitation normals, defined as the arithmetic mean computed over three consecutive decades, are available for SITK from the years 1971-2003 and are shown in Table 1.

Table 1. Monthly temperature and precipitation normals (1949-2010) for Sitka (JAPONSKI AP) (Western Regional Climate Center 2011).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Temperature (ºC)													
Max	3.5	4.7	5.8	8.7	11.7	14.3	15.9	16.7	14.5	10.3	6.4	4.4	9.8
Min	-1.1	-0.3	0.2	2.3	5.3	8.4	10.7	11.1	8.8	5.3	1.8	0	4.1
Average Precipitation (cm)													
Total	18.6	15.7	15.1	11.8	11.4	8.2	10.9	17.1	28	33.8	24.5	21.5	216.6

2.1.3 Visitation Statistics

Over the past decade, SITK has averaged 265,000 visitors annually (NPS 2011). Annual visitation rates have increased greatly over the years. In 1967 there were approximately 25,000 visitors; now there can be anywhere from 160,000 to 300,000 visitors a year (NPS 1999). People visit from all over the world to participate in the park‘s many activities, such as walking, wildlife viewing, picnicking, and enjoying year-round interpretive talks, walks, and demonstrations (NPS 1999). Tourists can access the park by plane or ferry. However, the most popular form of transport is by cruise ships, which anchor just off shore from the park (NPS 1999). The Indian River is a large attraction for many of the tourists that visit SITK (NPS 1999). It functions as a medium of recreation and provides access to other activities within the park (NPS 1999).

2.2 Natural Resources

2.2.1 Ecological Units and Watersheds

SITK is part of the EPA‘s Coastal Western Hemlock-Sitka Spruce Forests Level III Ecoregion and is near the Pacific Coastal Mountains Ecoregion (Plate 1). The following are descriptions of these ecoregions respectively.

> 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).
>
> 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).

The Commission of Environmental Cooperation also provides an ecological unit categorization and description. SITK lies within the ecological region called the ―Marine West Coast Forests" (CEC 1997). This region extends from the mainland and offshore islands of the Pacific Coast of Alaska south to northern California (CEC 1997). The Marine West Coast Forest region contains the wettest climates in North America and extremely productive forestland (CEC 1997). Sedimentary and igneous rocks lay underneath the mountainous topography that is consistently interrupted by glacial valleys (CEC 1997). The Pacific Ocean greatly moderates the climate of this region (CEC 1997).

SITK is located in the Indian River watershed (Plate 1). The Indian River is a mature river, draining approximately 3,157 ha (7,800 ac) of the central Baranof Island Mountains (NPS 1999, Moynahan et al. 2008). The topography is steep and the stream flow fluctuates rapidly in response to precipitation (NPS 1999). Rainfall that hits the watershed drains within 12 to 24 hours after it has fallen to the ground (NPS 1999). SITK has no true lakes within its watershed (Moynahan et al. 2008).

The intertidal zones within the park boundary are owned by the State of Alaska, but a lease gives SITK the authority to manage these intertidal lands. According to Moynahan et al. (2008, p. 15), ―This unique management situation underlies a pronounced interest of the park‗s natural resource staff in intertidal issues."

2.2.2 Resource Descriptions
SITK contains a variety of habitats, such as estuary, wetland, beach fringe, meadow, an anadromous fish-supporting river, intertidal land/water, and temperate rainforest (NPS 1999). The park lies within the spruce-hemlock-cedar region of the temperate forest biome, which is widely distributed across the northern portion of North America (NPS 1999). Vegetation in the park primarily consists of coastal temperate rainforest species typical of southeast Alaska (NPS 1999).

Most of the park‗s forest cover is secondary growth: western hemlock (*Tsuga heterophylla*) and red alder that have replaced Sitka spruce (*Picea stichensis*) stands over time (NPS 1999). While older Sitka spruce trees remain in the canopy, little spruce regeneration is occurring in SITK. Areas lacking canopy cover are heavily influenced by the presence of ferns and herbs, and shrubs, such as blueberry (*Vaccinium* spp.), salmonberry (*Rubus spectabilis*), and devil‗s club (*Oplopanax horridus*) (NPS 1999). This temperate rainforest and the variety of habitats contained within the park supports a wide diversity of plant species; SITK has documented a total of 165 vascular plants and 172 nonvascular plants within its boundaries (Moynahan et al. 2008).

Eighteen mammalian species are known to occupy SITK, some more common than others (NPS 2008). Salmon in the Indian River attract various mammals such as brown bears (*Ursus arctos*), river otters (*Lontra canadensis*), and mink (*Neovison vison*) (Moynahan et al. 2008). The river otter is the most common of these species in the park, while brown bears and mink are considered rare or uncommon. The red squirrel (*Sciurus vulgaris*), a non-native species, is another common mammal found in the park (NPS 2008). The rainforest is key habitat for SITK mammals, providing cover from heavy winter storms (Smith-Middleton and Alanen 2008).

A wide variety of bird species, both land and coastal birds, use the park because of its diversity of habitats. One hundred and fifty different species of birds have been documented within the park boundaries (Moynahan et al. 2008). According to NPSpecies (2008), the most common land birds include; common raven (*Corvus corax*), herring gull (*Larus argentatus*), the bald eagle (*Haliaeetus leucocephalus*), chestnut-backed chickadee (*Poecile rufescens*), and belted kingfisher (*Ceryle alcyon*). Some waterfowl species are mallards (*Anas platyrhynchos*), great blue heron (*Ardea herodias*), and harlequin ducks (*Histrionicus histrionicus*). The seabirds commonly found include common murres (*Uria aalge*), tufted puffins (*Fratercula cirrhata*), and pelagic cormorants (*Phalacrocorax pelagicus*) (NPS 2008).

There are 24 native fish species that are present in the park (NPS 2008). Many fish reside and spawn in the Indian River. Coho, pink, and chum salmon (*Oncorhynchus* spp.) are some of the anadromous fish known to spawn in the river (Smith-Middleton and Alanen 1998). The river also contains populations of Dolly Varden trout (*Salvelinus malma malma*), rainbow trout (*Oncorhynchus mykiss*), and coast range sculpin (*Cottus aleuticus*) which can be anadromous or nonanadromous (Smith-Middleton and Alanen 1998).

SITK's intertidal zone and estuarine area is 20 ha (50 acres) or 44% of the park, and provides habitat for seastars, limpets, chitons, polychaete worms, barnacles, clams, crabs, shrimp, and snails (Moynahan et al. 2008). Marine fishes found in these areas include varying species of rockfish, gunnels, surfperch, sculpins, greenlings, and tubesnouts (Moynahan et al. 2008). No threatened or endangered species are known to occur in the park (NPS 1999).

2.2.3. Resource Issues Overview

SITK's natural setting has been altered over the past century by logging, trail installation, road construction, gravel dredgeing, erosion control features, an ashphalt plant, and generally increasing human activity (NPS 1999). SITK has many different habitats that need long-term monitoring. The Indian River corridor will be the most monitored portion of the park. These are areas of importance because they are vital to "the growth and propagation of fish, other aquatic life, and wildlife" (NPS 1999, p. 54). Development surrounding the Indian River watershed is of concern because of its potential effects on water quality and quantity (NPS 1999). Water quality has been monitored in several areas (e.g., Neal et al. 2004) to look for sources of pollution and to protect the river from any pollutants that may enter these areas (NPS 1999). Long-term Indian River water quality monitoring by NPS in a location slightly upstream of the park boundary began in 2010 and will continue indefinitely from May through October annually (Nagorski et al. 2012). Forest habitat also needs monitoring. A Vegetation Inventory and Forest Health Assessment was conducted by the Environmental Health and Protection group in 1994; they recommended the initiation of a hazardous tree monitoring program to reduce the spread of invasive species and diseases (e.g., heart rot fungi, dwarf mistletoe, and spruce needle aphid defoliation) (NPS 1999). Coastal/ beach habitat would also benefit from a monitoring plan. SITK has done some marine/intertidal monitoring of the macrobiota near the shore; however, the park only monitored in 1999, 2002, and 2003 (Moynahan et al. 2008). The park has limited baseline data characterizing coastal resources, so a resource inventory and monitoring program is recommended to predict and identify potential stressors (NPS 1999). A long-term protocol for this effort is in development by SEAN and SITK staff.

Erosion has been another point of concern for SITK's monuments and landscape, specifically on the northeastern side near the mouth of the Indian River (NPS 1999). Factors that have been increasing erosion in the park's river channel include the gravel extract from the river bed and fill from public land surrounding the park boundary (Moynahan et al. 2008). This issue has not been revisited by the park in recent times.

Climate change is a growing concern. SITK is expected to become warmer and drier over the next century (SNAP et al. 2009). Moynahan et al. (2008, p. 28) stated that climate change is an ―important anthropogenic driver of landscape change". Longer growing seasons will be a result of the warming climate, which may shift vegetation type and alter ecological processes (Moynahan et al. 2008). Climate change may also be a contributing factor in the population decline in boreal toads (*Bufo boreas boreas*) and the spread of disease and invasive species (Moynahan et al. 2008).

Diseases and insects that currently threaten the forest inside SITK and in adjacent areas include heart rot fungi, hemlock dwarf mistletoe (*Arceuthobium tsugense*), and spruce needle aphid (*Elatobium abietnum*) (NPS 1999). Heart rot fungi found in coastal Alaska affects western hemlock and Sitka spruce. These two tree species tend to be more susceptible because of their thinner bark (Hennon 1995). Hemlock dwarf mistletoe is a parasitic plant that does not photosynthesize on its own; in southeast Alaska, it mostly affects western hemlock (USFS 2011). Sitka spruce are the main target of the spruce needle aphid; they feed on old needles causing other needles to drop and making the tree more susceptible to other insect pests (Alaska DNR 2000). All of these threats may increase in the park if climate change increases the annual minimum temperatures and therefore the active period for these pathogens.

Invasive and non-native plants are a concern for park management, because of their ability to quickly alter the structure and composition of vegetation communities within the park, which ultimately affects other biota that depend upon native vegetation (Moynahan et al. 2008). As of 2010, 27 non-native plant species have been documented in the park (Auer and Link 2010). Several species of particular concern due to their capacity to spread rapidly include: Japanese knotweed (*Polygonum cuspidatum*), creeping buttercup (*Ranunculus repens*), dandelion (*Taraxacum officinale*), and European mountain ash (*Sorbus aucuparia*) (Moynahan et al. 2008).

Tourism has greatly increased in the park over the last 50 years, likely affecting the marine intertidal zone, where tourists arrive by the thousands on cruise ships (NPS 1999). Cruise ships and motorized vehicles emit particles such as sulfur dioxide that can generate poor visibility in the park (Moynahan et al. 2008). Tourists contribute to trail erosion and widening, making maintenance necessary to sustain the trails (NPS 1999).

2.3 Resource Stewardship

2.3.1 Management Directives and Planning Guidance

According to the park's general management plan, the primary goal at SITK is to create an experience that will be of great value to a diversity of visitors that also reflects the mission of the

NPS without losing sight of the park‘s historic significance (NPS 1998). The purpose and objectives established in the SITK General Management Plan (NPS 1998) are as follows:

- Preserve and interpret the site of the last major resistance of Alaska Native people to Russian colonization.

- Preserve and interpret the battleground and fort site of 1804.

- Preserve and interpret the site of the former village of the Kiks.ádi clan.

- Preserve and interpret the numerous totem poles that were present in the park in 1910.

- Preserve and interpret the Russian Bishop‘s House, an area that illustrates a part of the early history of what is now the United States by commemorating czarist Russia‘s exploration and colonization of Alaska.

- Preserve the Russian Memorial, the site of the memorial to a Russian midshipman and six sailors who were killed in the 1804 Battle of Sitka.

The park‘s resource management program ―attempts to fulfill the broad legislative purposes identified with the enabling legislation for the park and the mandates for management of NPS units" (NPS 1999, p. 16). SITK‘s Resources Management Plan (NPS 1999) outlines specific natural resource objectives for the future including:

- The park‘s natural resources and processes are conserved and protected. The protection of cultural resources takes precedence in implementing natural and cultural resource policies.

- Natural processes, including the action of water, are allowed to continue unimpeded in natural zones.

- Ecological processes and conditions associated with the Indian River and adjacent riparian areas are protected. A healthy, viable river and riparian system sustains wildlife populations. Water quality and minimum streamflows needed to sustain the dependent biota of the Indian River, particularly native fish populations, are maintained.

- The estuarine and other intertidal habitats and resources are protected, preserved, and interpreted.

- The rainforest and other vegetative communities are preserved, protected, and interpreted.

In addition to natural resources, management works to protect cultural resources such as museum collections, exhibits, all loaned items, and attraction sites such as the Totem Trail, the fort site, the battleground, and the Russian Memorial (Moynahan et al. 2008). SITK‘s Resources Management Plan (NPS 1999) also outlines specific cultural resource objectives for the future including:

- A comprehensive, systematic research program for cultural resources, arranged in priority order, exists. Ongoing research and baseline data collection are integrated into sound, accepted cultural resource management practices.

- Museum collections and display exhibits are stored and protected in appropriate facilities. A comprehensive museum management program ensures that the park effectively deals with the full range of related needs.

- All items loaned to the park by the Tlingit are protected and preserved. The National Park Service provides proper storage and protection of these artifacts. The Tlingit have access to their artifacts.

- Priorities are assigned to future acquisitions according to their support of the park‘s purpose and significance.

- The park‘s totem poles are stored, protected, preserved, and displayed.

- The park‘s cultural resources are protected from damage by erosion.

- An approved policy for the use of ethnographic objects gives local people specific direction about how to preserve and use items in the park‘s museum collections.

- The Totem Trail, the fort site, the battleground, and the Russian Memorial are protected and managed as historic landscapes.

- The location of the fort site and the battleground are confirmed and commemorated.

- A Tlingit memorial has been established to commemorate the Alaska Native participants in the 1804 battle and the subsequent Survival March, and these subjects are included in park interpretation.

- Visitors to the Russian Bishop‘s House can enjoy exhibits and interpretive presentations without undue wear and tear on the structure and its furnishings. The respectful, dignified ambience in this facility is worthy of a place of worship. NPS policies and partnership activities with nearby landowners and the city protect the setting and the historic scene from incompatible development.

- Building 29 (another Russian-American period structure on the National Register of Historic Places) is preserved and protected.

2.3.2 Status of Supporting Science

The park has conducted and commissioned research studies and monitoring programs to ensure the protection of its resources. NPS staff have researched important geological features in the park as well as monitoring the instream flow of the Indian River, erosion, and water quality. Uplift is a key natural feature forming the landscape in SITK. The park commissioned a study on the geomorphology of the land, with the purpose of gaining adequate knowledge to develop a strategy for conducting future archeological studies (Chaney et al. 1995).

SITK's monitoring program for the Indian River instream flow allows the park to check if water levels are suitable for native fish habitat, especially in the lower channels. The park established four stream gages, two of which became permanent to collect data, including discharge measurements (NPS 1999). Erosion, another concern along the Indian River, has been monitored by the park since 1991. Starting in 1995, data was collected semiannually from transect rods that were positioned at the northeastern mouth of the river. Staff also check the data from these rods after severe storms or high tides (NPS 1999). The park has measured water quality as well, specifically near the asphalt plant site. The monitoring efforts at this site began in 1996, following the development of the Monitoring Plan for Asphalt Plant Remediation (NPS 1995), and ceased in 2006 after the State of Alaska determined that no additional monitoring was required. To date SITK has collected limited data from upstream (NPS 1999), though the park is now monitoring water quality in the Indian River just upstream of the park as part of the SEAN freshwater water quality Vital Sign

The Southeast Alaska Network (SEAN) Inventory and Monitoring Program identified key resources for each park in the network that represent the overall health of that park. These key resources are called ―Vital Signs." Vital Signs are identified for each park to prioritize future monitoring (Table 2) (Moynahan et al. 2008).

Table 2. SEAN Vital Signs selected for monitoring in SITK (Moynahan et al. 2008). Those in bold are Vital Signs for which the network will develop protocols and implement monitoring, while those in italics are currently being monitored by the park, another NPS program, or by another federal or state agency. The network will collaborate with these other monitoring efforts.

Category	**SEAN Vital Sign**
Air and Climate	**Airborne contaminants, weather and climate**
Geology and Soils	**Streamflow**
Water	*Freshwater benthic macroinvertebrates and algae,* **freshwater contaminants, freshwater water quality, marine contaminants**
Biological integrity	*Invasive/exotic plants,* **intertidal communities**
Human use	*Human uses and mode of access*
Landscapes (ecosystem patterns and processes)	**Landform and landcover**

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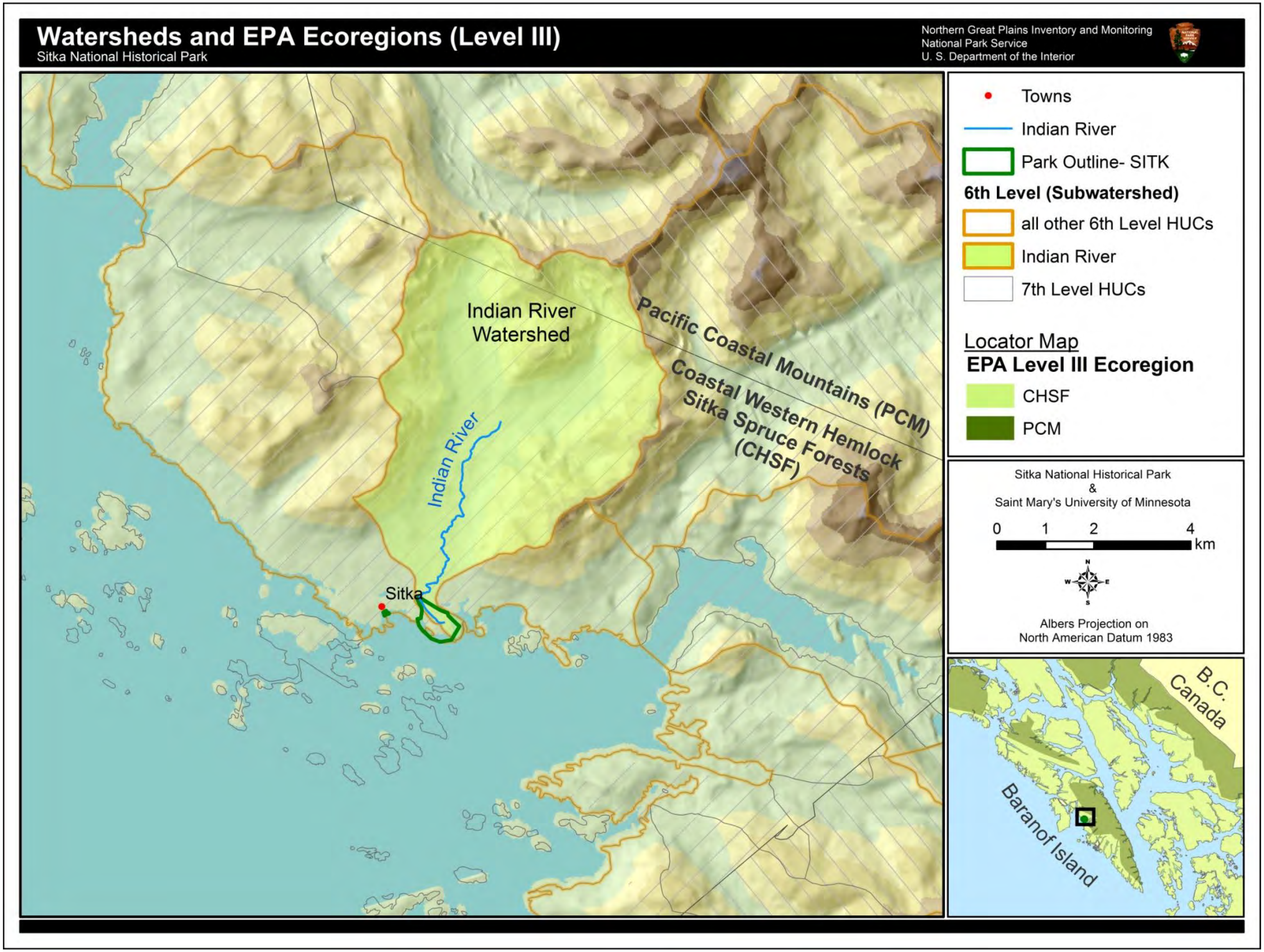

Plate 1. Primary watersheds and EPA level III ecoregiona of SITK. (Hydrologic Unit Codes [HUCs] from the National Hydrography Dataset).

Chapter 3 Study Scoping and Design

This NRCA is a collaborative project between the National Park Service (NPS) and Saint Mary‘s University of Minnesota Geospatial Services (SMU GSS). Project stakeholders include the SITK resource management staff and SEAN Inventory and Monitoring Program staff. Before embarking on the project, it was necessary to identify the specific roles of the NPS and SMU GSS. A preliminary scoping meeting was held, and a task agreement document was created cooperatively between the NPS and SMU GSS.

3.1 Preliminary scoping

A preliminary scoping meeting was held in August 2010. At this meeting, SMU GSS and NPS staff confirmed that the purpose of the SITK 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 SITK managers. Certain constraints were placed on this NRCA, including the following:

- 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 and priorities are primarily driven by SITK resource management.

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 SITK 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: SITK resource staff, NRInfo, Inventory and Monitoring Vital Signs, 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 when possible.

- 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 Study Design

3.2.1 Component Framework, Focal Study Resources and Components

<u>Selection of Resources and Measures</u>
As defined by SMU GSS in the NRCA process, a ―framework” is developed for a park or preserve. This framework is a way of organizing, in a hierarchical fashion, bio-geophysical resource topics considered important in park management efforts. The primary features in the framework are key resource components, measures, stressors, and reference conditions.

―Components” in this process are defined as natural resources (e.g., anadromous fish), ecological processes or patterns (e.g., beach formation), or specific natural features (e.g., old-growth forest) that are considered important to current park management. Each key resource component has one or more ―measures” that aid in defining the current condition of a component being assessed in the NRCA. Measures are defined as those values or characterizations that evaluate and quantify the state of ecological health or integrity of a component. In addition to measures, current condition of components may be influenced by certain ―stressors” which are also considered during assessment. A ―stressor” is defined as any agent that imposes adverse changes upon a component. These typically refer to anthropogenic factors that adversely affect natural ecosystems, but may also include natural processes or disturbances such as floods, fires, or predation (adapted from GLEI 2010).

During the SITK NRCA scoping process, key resource components were identified by NPS staff and are represented as ―components” in the NRCA framework. While this list of components is not a comprehensive list of all the resources in the park, it includes resources and processes that are unique to the park in some way or are of greatest concern or highest management priority in SITK. Several measures for each component, as well as known or potential stressors, were also identified in collaboration with NPS resource staff.

<u>Selection of Reference Conditions</u>
A ―reference condition” is a benchmark to which current values of a given component‘s measures can be compared to determine the condition of that component. A reference condition may be a historical condition (e.g., flood frequency prior to dam construction on a river), an established ecological threshold (e.g., EPA standards for air quality), or a targeted management

goal/objective (e.g., a caribou herd of at least 200 individuals) (adapted from Stoddard et al. 2006).

Reference conditions in this project were identified during the scoping process using input from SITK resource staff. In some cases, reference conditions represent a broadly-stated goal in the park‘s enabling legislation. For example, relating to fish in the Indian River, the enabling legislation states, ―…water quality and minimum streamflows needed to sustain the dependent biota of the Indian River, particularly native fish populations, are maintained.” In other cases, existing data are compared to data collected in similar environments (e.g., other SEAN parks or the Tongass National Forest). Finally, peer-reviewed literature and established ecological thresholds also help to define appropriate reference conditions. The identification of reference conditions for individual components in this assessment was a challenging task as the topics can be complex, often lacking explicitly stated NPS desired conditions. Some components do not yet have a well developed reference condition; instead, information that speaks to each measure are presented and interpreted.

<u>Finalizing the Framework</u>
An initial framework (hierarchical table) was adapted from the organizational framework outlined by the H. John Heinz III Center for Science‘s ―State of Our Nation‘s Ecosystems 2008” (Heinz Center 2008). Key resources for the park were adapted from the SEAN Vital Signs monitoring plan (Moynahan et al. 2008) and natural resource reports from SITK. This initial framework was presented to park resource staff to stimulate meaningful dialogue about key resources that should be assessed. Significant collaboration between SMU GSS analysts and NPS staff was needed to focus the scope of the NRCA project and finalize the framework of key resource to be assessed.

The NRCA framework was finalized in September 2010 following acceptance from NPS resource staff. It contains a total of 10 components (Table 3) and was used to drive analysis in this NRCA. This framework outlines the components (resources), most appropriate measures, known or perceived stressors and threats to the resources, and the reference conditions for each component for comparison to current conditions.

Table 3. Framework for the Sitka National Historical Park natural resource condition assessment.

Component	Measures	Stressors	Reference Condition
Ecosystem Extent and Pattern			
Landform / Land Cover	Area of vegetation community types, surficial geology types	Isostatic uplift; climate change; aggregate removal; large logs washing up on shore disrupting natural sedimentation	Cultural landscape management
	Surficial geology types		
Biological Components			
Land Birds (breeding birds)	Species richness and diversity	Loss of wintering habitat; climate change; change in vegetation types	Birds of Sitka National Historical Park checklist
	Change in abundance of species of concern		
	Percent present of expected		
Coastal Waterbirds	Species richness and diversity	Loss of wintering habitat; climate change; change in vegetation types	Birds of Sitka National Historical Park checklist and the SITK wildlife observation database
	Change in the abundance of the yellow-billed loon (species of concern)		
	Percent present of expected		
Invasive & Non-native Species	Didymo status	Climate change; increasing development near park; increasing visitation; urban landscape	Presence of didymo
	Area infested with non-native and invasive flora		Absence of non-native flora
	Weighted invasive score		Zero
	Non-native fauna		Absence of non-native fauna
Anadromous & Non-anadromous Freshwater Fish	Population status	Low flow condition in river; non-native and invasive species; algal blooms, straying of hatchery raised salmon	Existence of anadromous fish in the Indian River
	Escapement		
Forests	Native species regeneration	Drought; insect attacks; disease; invasive flora; urban landscape/development near park	Not yet determined
	Insect and disease damage		

Table 3. (continued) Framework for the Sitka National Historical Park natural resource condition assessment.

Component	Measures	Stressors	Reference Condition
Chemical and Physical Characteristics / Environmental Quality			
Chemical Parameters			
Air Quality	Lichen contaminants	Long-range transport; cruise-ships	Baselines and standards from Tongass National Forest and national forests in the Pacific Norwest
	Lichen community composition		
	Sulfur and nitrogen oxide concentrations		NPS air quality standards
Intertidal Water Quality / Habitat Quality	Mercury	Long-range transport; vessel traffic; point sources of pollution	Not yet determined
	Persistent organic pollutants (POPs)		
	Fecal coliform		
	Water temperature	Climate change; low streamflow; upstream development; algal blooms	
	Dissolved oxygen		
	Turbidity		
	Community composition of sensitive macroinvertebrates		
Freshwater Water Quality / Habitat Quality (Indian River)	Mercury	Long-range transport; point sources; urban landscape/development near park	Current data from Indian River monitoring to detect change overtime
	Persistent organic pollutants (POPs)		
	Fecal coliform	Point sources	
	Water temperature	Climate change; low streamflow; upstream development; algal blooms	
	Dissolved oxygen		
	Turbidity		
	Community composition of sensitive macroinvertebrates		
Physical parameters			
Hydrology (Indian River)	Total annual discharge	Diversions; reduced sediment transport (dams); armored shoreline; PDO; climate change	Range of historic values; upper gauge data compared to lower gauge data
	Minimum discharge during salmon spawning and rearing		

3.2.2 General Approach and 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.

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 SITK 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 provided by NPS staff (Alaska Regional Office and SITK). Access was also granted to NPS online data and literature sources, such as NatureBib and NPSpecies (now IRMA – Integration of Resource Management Applications). Additional data and literature were also 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.

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 and recommendations from NPS reviewers and sources of expertise including NPS staff from SITK and some personal communication from other outside agency staff. Specific approaches to data development and analysis can be found within the respective component assessment sections located in Chapter 4 of this report.

Scoring Methods and Assigning Condition

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 of 1-3) of the importance of each measure in explaining the condition of the component; each significance level is defined in Table 4. 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.

Table 4. 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.

After each component assessment is completed (including any possible data analysis) a condition level is assigned for each measure. This is based on a 0-3 integer scale and reflects the data mining efforts and communications with park experts (Table 5).

Table 5. 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.

After the significance levels (SL) and condition levels (CL) are assigned, a weighted condition score (WCS) is calculated via the following equation:

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

The resulting WCS value is placed into one of three possible categories: condition of low concern (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 1 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 condition of low concern. Gray circles are used to represent situations in which there is currently insufficient data to make a statement about the condition of a component. The arrows inside the circles indicate the trend of the condition of a resource component. An upward pointing arrow indicates the condition of the component has been improving in recent times. A right-pointing arrow indicates a stable condition or trend 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. A gray, triple-pointed arrow is reserved for situations in which the trend of the component‘s condition is currently unknown.

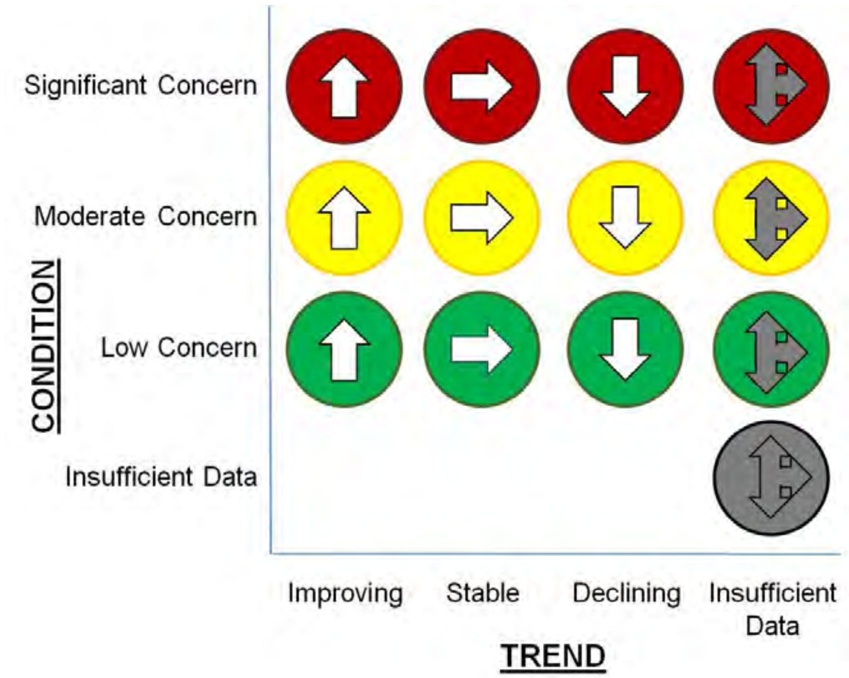

Figure 1. Symbols used for individual component assessments with condition of concern designations along the vertical axis and trend designations along the horizontal.

Preparation and Review of Component Draft Assessments

The preparation of draft assessments for each component was a highly cooperative process among SMU GSS analysts and SITK and other NPS staff. Though SMU 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 conference call 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.

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 SITK 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 resource experts.

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 in the park. Also emphasized are interrelationships that occur among a given component and other resource components included in the broader assessment.

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 SMU 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. 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 who wish 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 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 section‘s ―Literature Cited” section.

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Chapter 4 Natural Resource Conditions

This chapter presents the background, analysis, and condition summaries for the 10 key resource components in the project framework. The following sections discuss the key resources and their measures, stressors, and reference conditions. The summary for each component is arranged around the following sections:

1. Description
2. Measures
3. Reference Condition
4. Data and Methods
5. Current Condition and Trend (including threats and stressor factors, data needs/gaps, and overall condition)
6. Sources of Expertise
7. Literature Cited

The order of components follows the project framework (Table 3):

4.1 Landform/Land Cover
4.2 Land Birds
4.3 Coastal Waterbirds
4.4 Invasive & Non-native Species
4.5 Anadromous & Nonanadromous Freshwater Fish
4.6 Forests
4.7 Air Quality
4.8 Intertidal Water Quality/Habitat Quality
4.9 Freshwater Quality/Habitat Quality (Indian River)
4.10 Hydrology (Indian River)

4.1 Landform / Land cover

Description

Landform and land cover dynamics are driven by the geological patterns and processes that affect terrestrial, marine, and freshwater environments (Moynahan et al. 2008). Measures used to evaluate land cover and landform include area of vegetation types, surficial geology, and glacial extent (Moynahan et al. 2008). Landform / land cover is listed as one of the 12 core SEAN Vital Signs, indicating that it is a top priority and of importance to the park (Moynahan et al. 2008). The Inventory and Monitoring Program (I&M) land cover map for SITK is expected to be created in 2012.

SITK consists of 46 hectares (113 acres) of riparian forest and coastal lowlands, as well as tidelands in Sitka Sound and the Indian River (Moynahan et al. 2008). The park contains roughly 800 m (2,624 ft) of the Indian River that bisects the park and creates two separate landmasses known as the west and east peninsulas. Each peninsula is shaped by different processes; where the west peninsula is largely impacted by uplifted beach deposits, the east is affected by wave erosion (Chaney et al. 1995). The west peninsula has an elevation peak of 12.5 m (41 ft) above sea level. This peak emerged from the ocean about 5,500 years ago (Chaney et al. 1995). The east peninsula is more geologically complex and is a compilation of floodplains and abandoned river channels. Chaney et al. (1995) noted that the river channel alters the landform of the east peninsula by alternating between eroding and depositing sediments.

Chaney et al. (1995) provides eight maps showing the landform evolution in the park between 5,500 years ago and CE 1804. The eruption of Holocene Mt. Edgecumbe approximately 8,570 years ago coincided with significant uplift in the area (Chaney et al. 1995). A thinner, more recent ash deposit occurred approximately 4,030 to 4,310 years ago (Chaney et al. 1995). The oldest landforms within the park are thought to have formed from the influence of storm waves about 5,500 years ago. Furthermore, it is likely that the SITK land area was unavailable to human occupation during that time due to regional uplift resulting in the inundation of habitable land by storm waves. Since then, landforms and land cover have changed dramatically, including uplift of nearly 3 m (9 ft) within the last 1,700 years (Chaney et al. 1995). Chaney et al. (1995) also mention that much of the current shoreline has undergone varied geomorphic processes and does not reflect the historical shoreline extent. Smith-Middleton and Alanen (1998) overlaid an 1850 Russian survey map and a 1993 survey, illustrating that significant changes have occurred in the park‘s shoreline.

Most of the SITK landforms originated from late Wisconsin glacial deposits and have been shaped by isostatic rebound, plate tectonics, human use, ocean tides (coastal wave erosion), and the Indian River‘s erosion and deposition processes (Chaney et al. 1995, Eckert et al. 2006). Parent material in the area consists primarily of volcanic ash and cinder left from blanketing ash over 9,000 years ago (Nowacki et al. 2001). Remnant beach, meadow, terrace, and sand bar comprise much of the historic landform still present within SITK. Current geological landforms within SITK include active beach, uplifted beach, active river channel, abandoned river channel, floodplain, and bedrock outcrop (Chaney et al. 1995). Surficial deposits are derived from various rock types such as greywacke, schist, and phyllite (USFS 1993, Nowacki et al. 2001). Alluvium, ablation till, and sand and gravel in the area originate from the head of the Indian River and its various tributaries (USFS 1993).

According to Moynahan et al. (2008, p. 55), it is important to monitor park landform because, ―changes in landform and land cover types occur rapidly in SEAN parks in response to climate-mediated glacial retreat and primary succession, isostatic rebound, and tectonic activity." However, since SITK encompasses a relatively small area compared to parks such as Glacier Bay National Park (GLBA), changes in landform may not be as pronounced or apparent. Long-term status and trends based on the configuration of these key landforms were listed as notable measurable objectives for future Vital Sign monitoring. Because of the relatively high cost and effort to the SEAN for protocol development and data collection, results will not be available until the end of the 2013 fiscal year (Moynahan et al. 2008).

Another important aspect of landforms in SITK is the historical and cultural resources they contain, such as artifacts from pre-European civilizations. Chaney et al. (1995), suggests that landforms of the park are important to understand in order for management to develop a research design and strategy for future archeological and geological surveys. Historic alterations of the landscape are apparent for at least the last 10,000 years, including both natural geological and anthropogenic changes (Chaney et al. 1995). Smith-Middleton and Alanen (1998) present a very detailed landscape history of the park that includes discussions of humans' roles in landscape change and the natural processes that exert landscape change (e.g., geological and vegetation succession).

Vegetation community composition and extent in the park is, in part, determined by the underlying landform and land cover dynamics. According to USFS (1993), SITK is within the spruce-hemlock-cedar region of the temperate rainforest biome. However, the park contains enough habitat diversity to support several plant associations and community types; these include western hemlock (*Tsuga heterophylla*)/blueberry (*Vaccinium* spp.), western hemlock/devil's club (*Oplopanax horridus*), Sitka spruce (*Picea sitchensis*)/devil's club-salmonberry (*Rubus spectabilis*), Sitka spruce/salmonberry, red alder (*Alnus rubra*)/salmonberry, red alder, red alder-Sitka spruce/salmonberry, grass-umbel, and estuarine communities (USFS 1993). The vegetation in the upland region of SITK has long been dominated by coastal temperate rainforest typical of Southeast Alaska, consisting of Sitka spruce and western hemlock (Nadeau and Lyons 1987, Eckert et al. 2006). A closed-canopy western hemlock forest is found on nearly all stable landforms in the park; multiple layers of tree cover and woody debris are characteristic of old growth forest (Eckert et al. 2006, NPS 2008). Red alder shrubs are found along the Indian River.

Measures

- Area of vegetation community types
- Area of landforms

Reference Conditions/Values

Given the cultural and historical emphasis of the park, the reference condition for landform and land cover is their status before significant anthropogenic alterations of landform or vegetation occurred (e.g., the World War II period gravel dredging operations or the subsequent installations of riprap to the riverbank). These anthropogenic alterations are addressed in the threats and stressors section of this assessment. Natural succession factors, both allogenic and autogenic in nature, also drive landscape change (landform and land cover) in the park. These include erosion and deposition processes in the Indian River, isostatic uplift (specifically in the uplifted beach area), and wave action on the shoreline (Smith-Middleton and Alenan 1998). In addition, localized natural disturbances such as windthrow, storm surges, and river flooding affect vegetation succession, which influences the land cover composition of the park. It is important to differentiate natural processes from anthropogenic alterations to the landscape which, according to Smith-Middleton and Alanen (1998), have been occurring successively since at least the battle of 1804.

It is important to note that the 1998 General Management Plan outlines management strategies to preserve the cultural conservation zone. This zone contains the Totem Trail, the historic Tlingit fort and battleground sites, and the Russian Memorial. For example, in the Tlingit fort and battleground sites, shoreline vegetation will be actively managed to restore views of the sea and to restore the ―spatial qualities" of the sites (NPS 1998). Overall vegetation management is to be based on the management zone goals and the recommendations of the cultural landscape report (NPS 1998).

Smith-Middleton and Alanen (1998) overlaid an 1850 Russian survey of the park area and a 1993 survey (Figure 2); the comparison suggests that significant changes have occurred in the position of the Indian River and the shape and size of landforms within the present-day park.

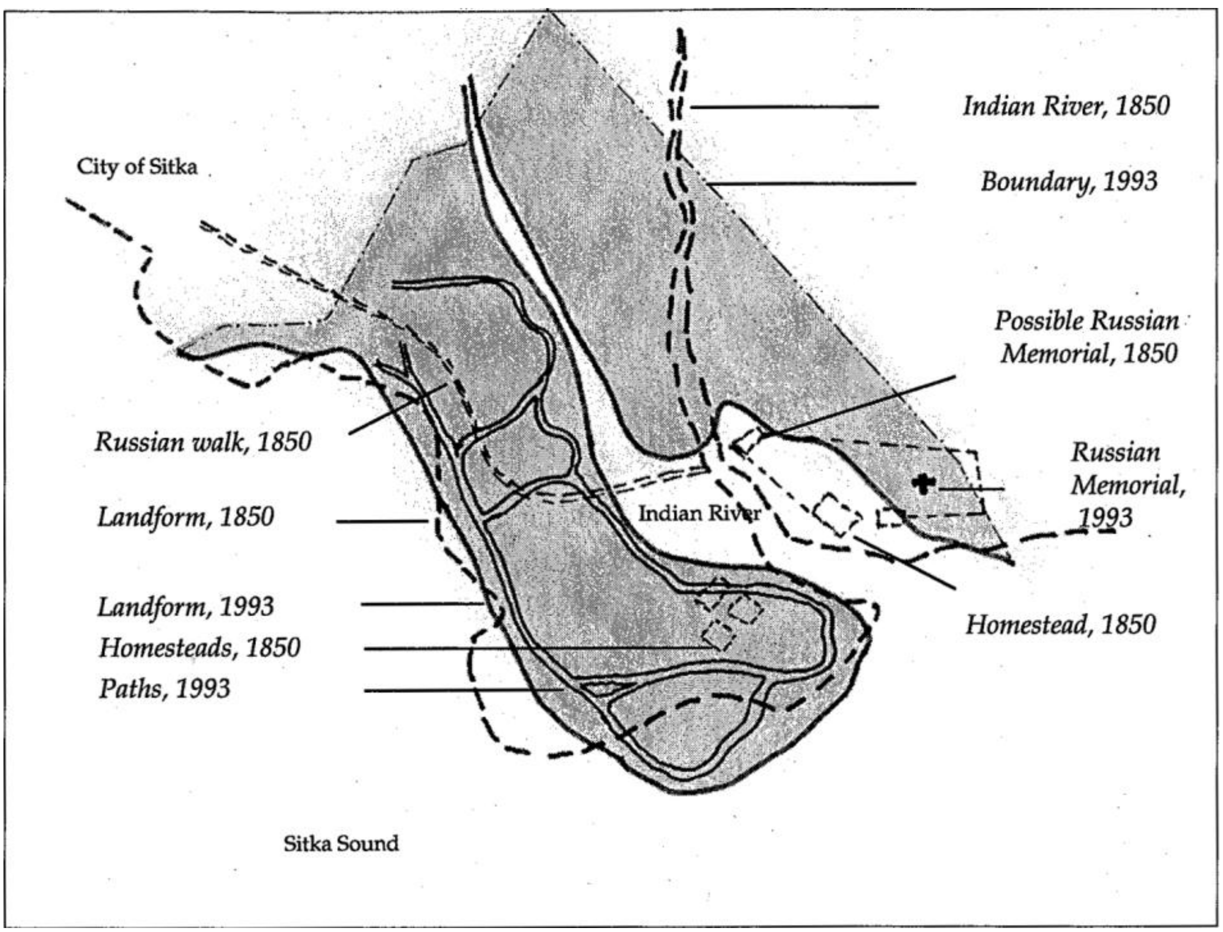

Figure 2. Overlay of 1850 Russian survey and 1993 survey of SITK. The shaded area represents the 1993 landform. Scale: 1":600". Reproduced from Smith-Middleton and Alanen (1998).

Chaney et al. (1995) measured five beach profiles along both sides of the park peninsula, examining both the slope and the extent. These 1994 measurements provide baseline information to be used for comparison in identifying future erosion and accretion. According to Chaney et al. (1995, p. xiv), ―relic beach ridges and other evidence of sediment accretion in response to wave-driven berm development and regional uplift has been documented" on the west peninsula (west of the Indian River). It is nearly impossible to reconstruct the geomorphology of the east peninsula (east of the river) for reference, due to several human-influences including the construction of Sawmill Creek Road, placement of fill along an old wagon road, bioturbation (soil displacement and mixing) from tree fall, and crosscutting minor drainage channels (Chaney et al. 1995).

To date, SITK does not possess quantifiable estimates for the area of each vegetation community type (i.e., land cover or vegetation map data specifically in a GIS format). Land cover mapping efforts are scheduled to begin in 2012 and be completed in one to two years. However, Smith-Middleton and Alanen (1998) synthesized historic maps and interpreted historic photographs to create diagrams of the plant communities (vegetation associations) in the park area for several dates starting as early as 1803 through 1965. Figure 3, Figure 4, Figure 5, and Figure 6 from Smith-Middleton and Alanen (1998) illustrate plant communities starting in 1870-1890 (when the area first became a public park, after a long-established pattern of trail use) and various dates up until 1964. These maps provide illustrations of the historic extent of the primary vegetation types since the area has been a park, and the differences between them illustrate the dynamic nature of the vegetation classes over these time-periods. Refer to Smith-Middleton and Alanen (1998) for plant community interpretations of plant communities prior to 1870.

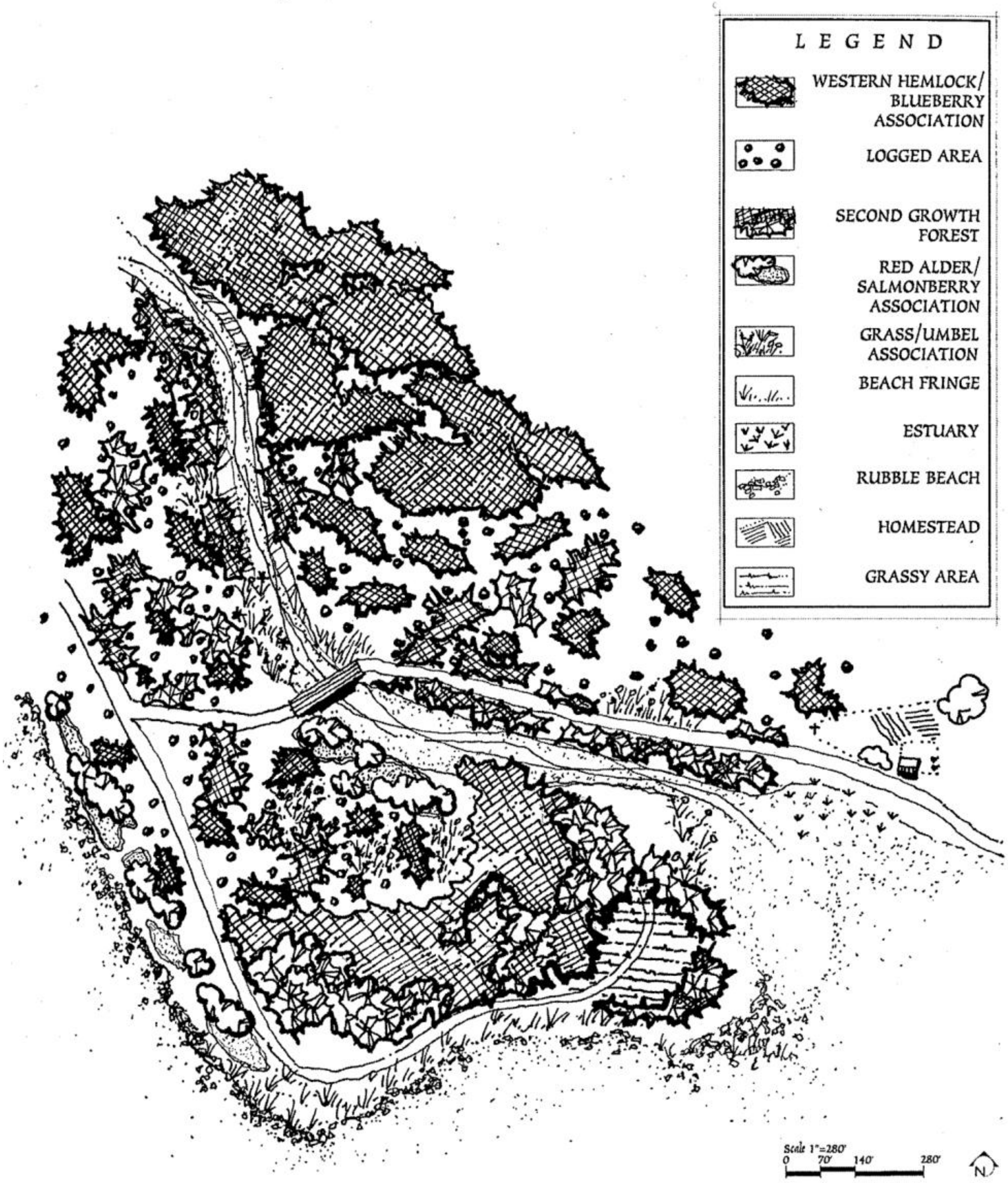

Figure 3. Plant communities, 1870-1890, in what is now SITK. Reproduced from Smith-Middleton and Alanen (1998).

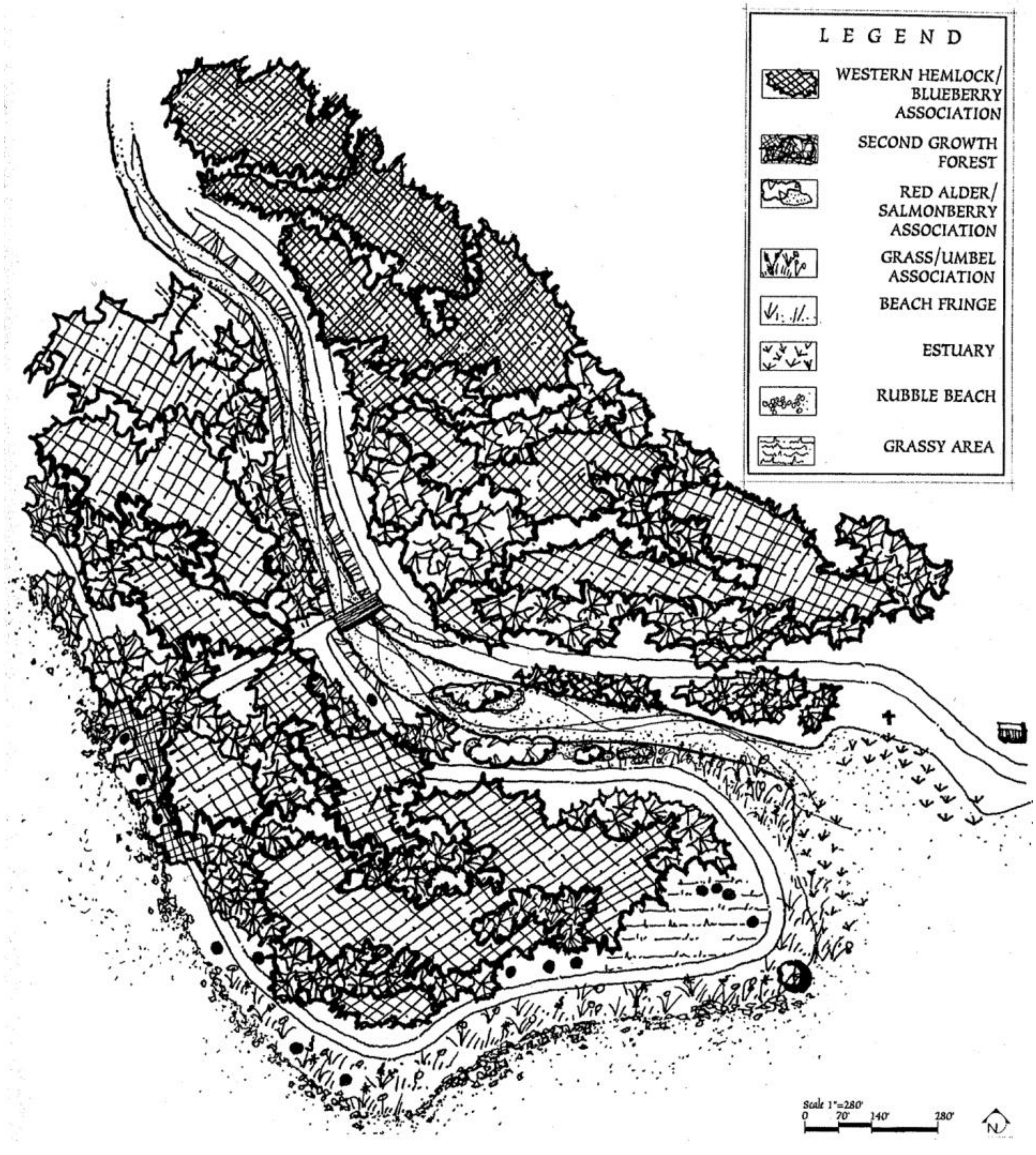

Figure 4. Plant communities, 1900-1910, in what is now SITK. Reproduced from Smith-Middleton and Alenen (1998).

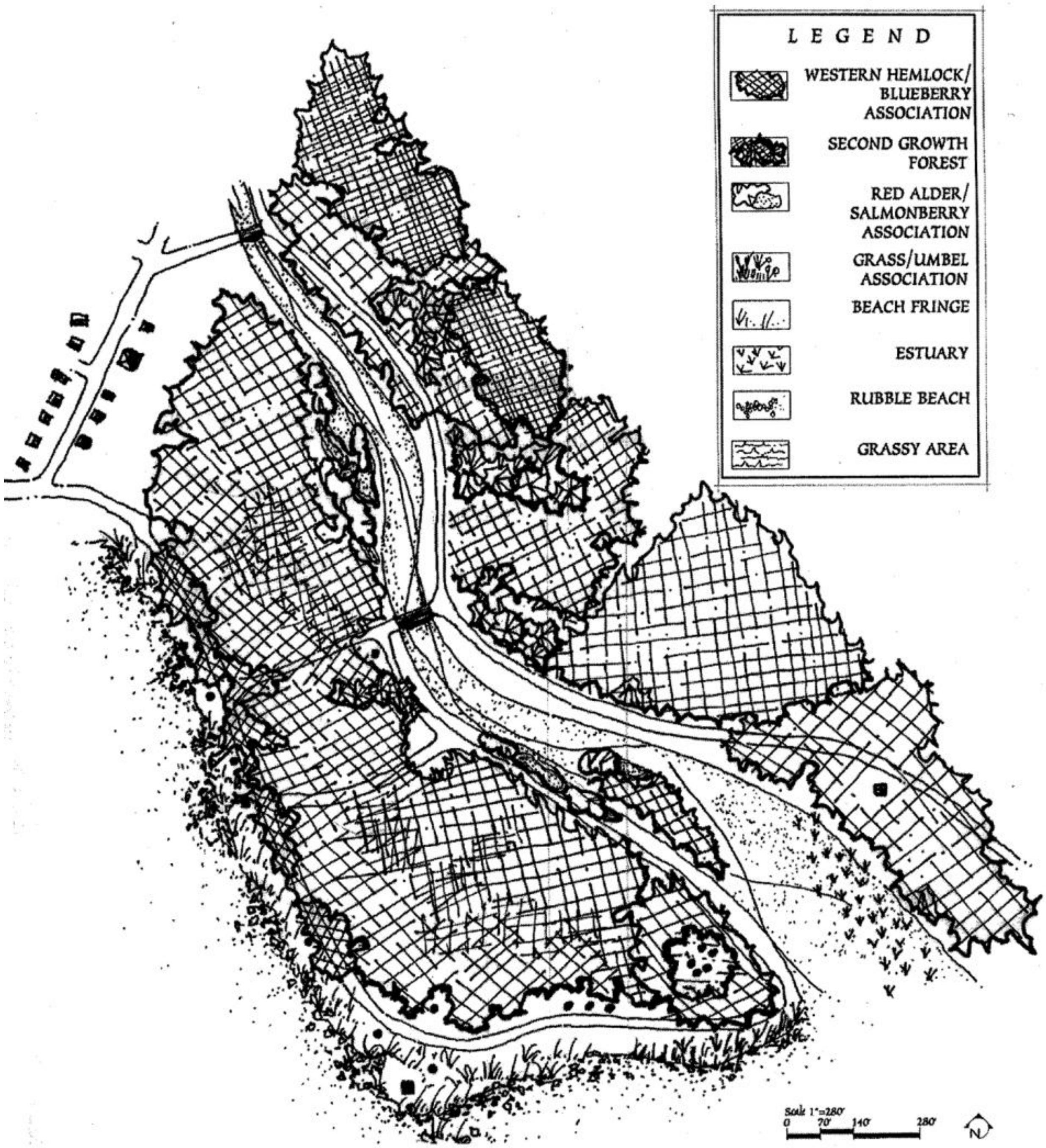

Figure 5. Plant communities, 1929, in what is now SITK. Reproduced from Smith-Middleton and Alanen (1998).

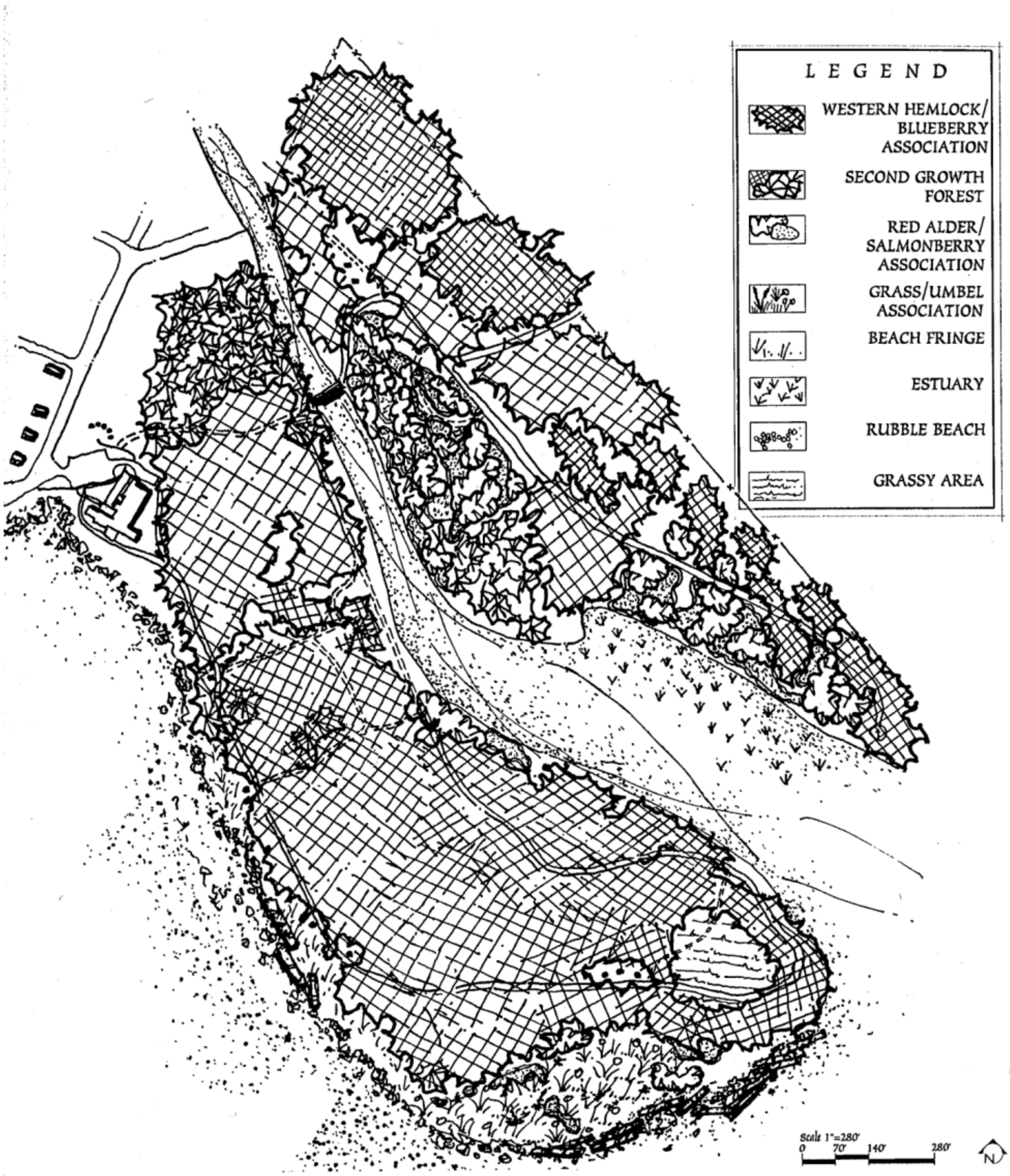

Figure 6. Plant communities, 1965, in what is now SITK. Reproduced from Smith-Middleton and Alanen (1998).

Data and Methods

Several literature sources provide historic and contemporary landform and land cover information relevant to the park. The following studies provide insight into landform and land cover composition and dynamics.

Landform

Chaney et al. (1995) provided a baseline report that models the chronology of landform evolution in SITK over the past 5,500 years. The report was compiled based on aerial photography, cartography, published and unpublished literature, NPS topographic mapping data, and information collected during eight days of fieldwork in 1994 (Chaney et al. 1995). The NPS used this field study to develop a historical landform dataset. A local model was created using analyses of these elements and is shown as a GIS layer in Plate 2.

For an historic perspective of landforms in SITK, Smith-Middleton and Alanen (1998) provide a detailed cultural and natural landscape assessment of the park in which they track the evolution of the landscape by individual landscape areas.

In July 2002, Hart Crowser Inc. (2002) conducted wetland delineation over 2.6 ha (6.5 ac) in the northwest area of SITK. This was done in order to prepare a conceptual management plan and environmental assessment for the area, as conducted by the NPS (Hart Crowser Inc. 2002).

Land cover

The U.S. Forest Service (USFS 1993) gathered information to classify ecosystems/ecological units within SITK. These units represent a combination of geology and landforms (described by Chaney et al. 1995), soil, and vegetation. They also identify the major vegetation types associated with each ecological unit.

Smith-Middleton and Alanen (1998) provide vegetation descriptions and hand-drawn maps of vegetative classes (based on interpretation of historic information such as literature and photography) in the park starting in 1804 through 1965. Multiple maps ranging from 1900 to 1965 are presented in the reference condition section of this assessment, as they provide an historic reference for land cover in the park.

Moynahan et al. (2008) identified threats to land cover and outlined a monitoring protocol to determine the ―status and long-term trends in the areal extent and configuration" of land cover within and on lands influencing the park (Moynahan et al. 2008, p. C-22).

The Alaska Exotic Plant Management Team (EPMT) has undertaken inventories and monitoring of invasive plant species in the park since 2004 (Auer and Link 2010). These are related to land cover since in some cases invasive plant species can alter plant community composition to such a degree that a different land cover classification may be justified, depending on the scale and purpose of a land cover mapping effort. Presently, most invasive plants occur in the highly developed areas of the park (e.g., surrounding the Visitor Center). Currently, European mountain ash (*Sorbus aucuparia*) trees are the only invasive species with significant cover occurring in natural areas of the park.

Current Condition and Trend

Area of Landform Types

Little data are available that specifically estimate the area of each landform type in the park. However, research has examined the chronology of landforms in the park. SITK's landforms are primarily a result of late Wisconsin glacial deposits —shaped by isostatic rebound, plate tectonics, human use, ocean tides, and the Indian River" (Eckert et al. 2006, p. 13). Regional uplift, as well as ocean and river processes have created the multi-aged river terraces, floodplains, beach ridges, and tidal meadows seen in the park today (Eckert et al. 2006). SITK encompasses most of the Indian River delta, and its landform is comprised mainly of alluvium soil (Chaney et al. 1995). The delta is asymmetrical because the course of the river has been altered by storm waves; these waves push alluvium deposits back into the river channel (Chaney et al. 1995). Chaney et al. (1995) note that at some point during the past 9,000 years, the existing delta was uplifted above sea level and formed uplifted beaches, floodplains, and abandoned channels. Southeast Alaska lies on the Fairweather-Queen Charlotte fault, and Chaney et al. (1995) reported that a fault is thought to run through the middle of SITK, due to the linearity of the Indian River. Southeast Alaska has experienced several recorded earthquakes and is considered a seismically active location (Chaney et al. 1995).

Several natural forces have driven or continue to drive landform change within the park; these include plate tectonics, glaciation, local sea level change, beach development, river dynamics and delta development, tephra (volcanic material) deposition, soil development, and floral and faunal turbation (Chaney et al. 1995). Anthropogenic influences include dredging, road building, bridges, totem sites, power transmission lines, a former asphalt plant (discontinued in 1958), erosion control (e.g., riprap along river banks), trailer court fill, dam construction and water diversion, building construction, World War II gunnery emplacements, and fort site disturbance (e.g., excavation, landscaping) (Chaney et al. 1995). Since 1804, human disturbance has altered the natural landscape of the park including early Russian homestead development, military, and NPS activities. According to Chaney et al. (1995, p. 97), —the magnitude of human impacts has, in recent times, dramatically altered the natural processes which have formed the physical landscape of the park."

As with most rivers and streams, the concentrated surficial geology of the Indian River Delta consists primarily of flood plain alluvium created through fluvial processes (Chaney et al. 1995). Outcrops of bedrock are rare in SITK with the park primarily resting on sediments carried in by the Indian River (Chaney et al. 1995). SITK contains 20 ha (50 ac) of intertidal zone comprised of gravel, cobble, and sand beaches (Moynahan et al. 2008), which is described by Chaney et al. (1995, p. 12) as —the most dynamic and complex physical environment on earth". Constant wave action plays the biggest role in the alteration of coastal surficial geology types (Chaney et al. 1995).

Area of Vegetation Community Types (i.e., land cover)

The Alaska NPS is interested in the area of each vegetation community type in its parks to monitor vegetation dynamics and ecological change. To date, specific area estimates are not yet available, but SEAN is beginning vegetation/land cover mapping in SITK and KGLO beginning in 2012. Existing information is primarily limited to USFS forest assessments in the early 1990s.

According to USFS (1993), most of the park is covered in secondary growth, and areas of the park with an open canopy have well-developed understories, whereas areas with dense canopies have limited shrub, forb, and fern layers. There are over 165 vascular and 172 nonvascular plant species documented within SITK (Moynahan et al. 2008). These plant species occur among the seven ecological units within SITK: estuary, uplifted beach meadow, uplifted beach, floodplain, stream terrace, moraine, and lowlands (USFS 1993). Table 6 is a summary of the vegetation types within each ecological unit. These ecological units are displayed in Figure 7.

Table 6. Ecological units of SITK and their corresponding primary vegetation types.

Ecological Unit	Vegetation Type
Floodplain	Alder communities
Moraine	Hemlock/blueberry, spruce/salmonberry
Lowlands	Hemlock/blueberry
Estuary	Salt- and flood- tolerant plant species
Uplifted beach	Hemlock/blueberry, hemlock/devil's club, alder communities
Uplifted beach meadow	Grass-umbel meadow, red alder-spruce/salmonberry communities
Stream terrace	Secondary and old growth forests with hemlock/blueberry and hemlock/devil's club plant associations

Figure 7. Ecological units of SITK. Reproduced from USFS (1993).

Estuaries exist on both sides of the Indian River, bordered by Crescent Harbor and Jamestown Bay (USFS 1993). The plants that thrive in this unit are salt- and flood- tolerant species that become more diverse closer to shore (USFS 1993). The Indian River estuary includes vegetation types such as hairgrass (*Deschamsia* spp.) in the less-flooded estuarial land, sedge communities (*Carex* spp.) in the tidal regions containing higher salinity, and marine algal species along with sparse terrestrial vegetation in the continually flooded areas (Eckert et al. 2006). The uplifted beach meadow unit supports grass-umbel meadow species and red alder-spruce/salmonberry communities (USFS 1993).

The hemlock/blueberry plant association covers most of the uplifted beach unit, but other associations in this unit include hemlock/devil‘s club northwest of the Fort site and alder communities at the tip of the southeast end of the park (USFS 1993). Floodplains lay adjacent to the Indian River with alder communities (*Alnus* spp.) and regenerating conifers that are occasionally removed by major flood events (USFS 1993). The stream terrace unit is simply old floodplain that lines the Indian River at a slightly higher elevation. It supports secondary growth and old growth forests with plant associations such as hemlock/blueberry and hemlock/devil‘s club (USFS 1993). Moraine units support the western hemlock/blueberry plant association as well as a small area of spruce/salmonberry community (USFS 1993). The final ecological unit is the lowlands, which occur above the moraine only on the west peninsula of the Indian River, supporting a hemlock/blueberry plant association (USFS 1993).

Hart Crowser Inc. (2002) conducted a wetland determination for a small area (2.6 ha) in a mesic coniferous forest area in the northern portion of SITK. The authors found three small wetlands (totaling less than 0.2 ha), classified as unconsolidated bottom wetland (SP-4), closed western hemlock-Sitka spruce forest (hydric) (SP-5), and mixed scrub-herbaceous (SP-8) (Hart Crowser Inc. 2002). The predominant species found in the SP-4 sample site was skunk cabbage (*Lysichiton americanus*) and substrate was considered bare with less than 30% emergent vegetation cover (Hart Crowser Inc. 2002). Hart Crowser Inc. (2002), classified sample area SP-5 as a hydric closed western hemlock-Sitka spruce vegetation type, with open canopy due to its young age. Plants that dominated this sample site included western hemlock, Sitka spruce, fool‘s huckleberry (*Menziesia ferruginea*), early blueberry (*Vaccinium ovalifolium*), lady fern (*Athyrium filix-femina*), and skunk cabbage. SP-5 also contained variable tree canopy cover and a well-developed shrub stratum in open canopy areas (Hart Crowser Inc. 2002). SP-8 was classified as mixed scrub-herbaceous type consisting of deciduous scrub and herbaceous hydric vegetation (Hart Crowser Inc. 2002). Species present at the SP-8 site included the typical well-shaded western hemlock-Sitka spruce forest upslope, red alder forest type downslope, and no rooted trees in the alluvial terrace area. Salmonberry, skunk cabbage, lady fern, and three-leaf foamflower (*Tiarella trifoliata*) were the dominant plants, with scattered patches of devil‘s club.

Since 2004, several non-native invasive plant species have been noted and monitored in SITK by the EPMT (Auer and Link 2010). However, non-native invasive species account for a relatively small percentage of the park‘s total vegetation and are primarily limited to high-traffic, high visitor-use areas including trails, the Visitor Center, the Russian Bishop‘s House and much of the totem park monument area (Auer and Link 2010, C. Smith. pers. comm., 2011). Notable invasive species include: Japanese knotweed (*Polygonum cuspidatum*), European mountain ash, and creeping buttercup (*Ranunculus repens*). Many of the non-native invasive plants have been controlled since the inception of the EPMT. More information about non-native and invasive species can be found in section 4.4 of this report.

<u>Threats and Stressor Factors</u>

Isostatic uplift is a natural land process in SITK; within the last 9,000 years, lands have experienced an upward geologic shift between 12.2 and 19.9 m (40-65 ft) (Eckert et al. 2006). Isostatic uplift is gradual uplift that occurs after a glacier has melted; the ground rebounds upward in response to the change in weight. Figure 8 shows the viscous mantle material flowing to the area of glacial displacement (Motyka 2007). There is substantial lag time for the viscous upper mantle to respond to the change in weight and for the earth to rise (Motyka 2007). Glacier rebounds can alter sea levels and may cause increases in erosion (Larsen et al. 2005). Historical land level changes are credited to regional uplift in southeast Alaska (Chaney et al. 1995). Substantial uplift began in the region around 1770 CE (Larsen et al. 2005) with glacier retreat occurring at increasing rates over the past 100-200 years (Eckert et al. 2006). As of 2005, uplift was occurring in the region at a rate of 3-4 mm/year (0.12-0.15 in/year) (Larsen et al. 2005). Southeast Alaskan isostatic uplift is ―the world‘s fastest present-day glacio-isostatic uplift yet, which has been documented using Global Positioning System (GPS)" (Larsen et al. 2005, p. 548). The Lynn Canal shorelines that lie north of SITK have risen between 3 and 5.7 m (9.8 and 18.7 ft) from uplift over the past 250 years (Eckert et al. 2006). However, SITK experiences some of the lowest rates of uplift in the southeast Alaska region at about 1 to 2 mm (0.4 to 0.8 in) per year (Eckert et al. 2006).

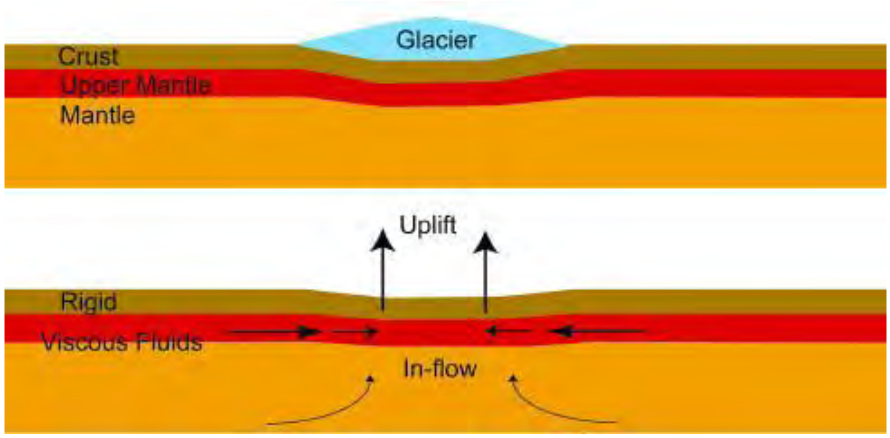

Figure 8. Process of uplift that occurs after glacial melting (Motyka 2007).

The Indian River is significantly influenced by mature secondary growth forests upstream in the forested riparian zones (Moynahan et al. 2008). These forests produce large woody debris - typically large trees that fall directly into and across the stream, creating immobile log barriers, jams, and root clumps (Moynahan et al. 2008). The terrestrial systems that line the river are also continuously altered by fallen trees, which mix and displace the soils (Chaney et al. 1995). While this represents a natural process, it is projected that the amount of woody debris entering waterbodies will increase with climate change, because shifts in climate affect the microbial processing of organic material in terrestrial systems (Eckert et al. 2006).

Historic anthropogenic disturbances have been occurring in the SITK area since the earliest Tlingit resident settlements (Smith-Middleton and Alanen 1998). Establishment of villages, fishing and hunting camps comprised the early changes attributed to the native Alaskans (Antonson and Hanable 1987). European settlers, specifically Russian and Spanish explorers arriving in the mid-18th century, transformed the land by establishing outposts, log forts, trading posts and bridges (Smith-Middleton and Alanen 1998). Following the battle of 1804 between Russian explorers and native Tlingit Indians, the landscape was changed to reflect Russian economic interests and cultural traditions (Smith-Middleton and Alanen 1998). According to Smith-Middleton and Alanen (1998), the inhabitants "cut down trees, built homes, hospitals, churches, and schools, and planted gardens" while also creating trails for recreational use, dramatically altering the native Tlingit landscape at Sitka (Antonson and Hanable 1987, Chaney et al. 1995, Smith-Middleton and Alanen 1998).

The 1867 sale of Russian America to the United States turned Sitka into a frontier town, which led to the construction of roads and improvements to existing settlements (Smith-Middleton and Alanen 1998). Businesses and residences were developed in the area that now comprises SITK along with documented trails and a footbridge (Smith-Middleton and Alanen 1998). In 1890, the current SITK extent was established as a public park. During this time, the Kiks.ádi Fort site was marked and kept cleared at the point of the SITK peninsula, and a Russian memorial area was created across the Indian River channel (Smith-Middleton and Alanen 1998). Soon after, from 1900 to 1920, native Alaskan totems were erected, becoming a centerpiece of the park (Antonson and Hanable 1987, Chaney et al. 1995). Tourism continued to grow into the 20th century with continual development of the land adjacent to the Indian River (Smith-Middleton and Alanen 1998). Eventual mining activities and the establishment of a cemetery and expanded cultural trails contributed to the further anthropogenic modification of land cover (Smith-Middleton and Alanen 1998). A significant amount of logging has been done within the boundaries of the park, starting in the early 1800s with Russian occupants and continuing into the 1900s to provide lumber for construction of nearby gold rush boom towns such as Dyea and Skagway (Antonson and Hanable 1987, Nowacki et al. 2001, C. Smith, pers. comm., 2011).

According to Smith-Middleton and Alanen (1998, p. 203), little growth occurred from 1920 to 1940; the park was poorly maintained and used by the residents as a city park, playground, and as a place ―to target shoot at metal signs." In the early 1940s, totem pole rehabilitation occurred along with the creation of rustic benches, rebuilt cribbing along the Indian River, a landscaped park entrance, and the introduction of pit toilets (Smith-Middleton and Alanen 1998). Smith-Middleton and Alanen (1998) describe some restoration occurring along the Indian River in the post-war years, as well as the construction of visitor facilities and expansion of the fort site clearing. From 1940 to the late 1950s, the park served as a source of gravel that supplied contractors with materials with which to build a U.S. military base at Sitka (Smith-Middleton and Alanen 1998). The park saw the degraded integrity of the Indian River and its shores in Sitka Sound. Stream-bank armoring and gravel mining substantially altered the geomorphology and surface water dynamics of the park. According to Moynahan et al. (2008), alterations to the river channel, from river bed gravel extract and fill used for the adjacent trailer park expansion, resulted in increased erosion, threatening park resources. Mining removed 3 million cubic yards of gravel, which created giant pools within the intertidal area of the park (Irvine and Madison 2008). Gravel dredging at the mouth of the Indian River began in 1939 and continued until the early 1960s, while offshore dredging continued sporadically until 1979 (Chaney et al. 1995, Smith-Middleton and Alanen 1998, Irvine and Madison 2008). Large magnitude erosion along the river, intensified by dredging, became a serious issue, particularly following the Navy‛s creation of a 10-60 m wide and 1-10 m deep pit at the river mouth between 1939 and 1941 (Chaney et al. 1995). Erosion intensified primarily because of the increase in gradient the dredging caused, and the gravel removal may have caused the river to meander towards the giant pools in the intertidal zone (C. Smith, pers. comm., 2011). During this time, an old pump house was removed from the riverbank, along with several logjams in the Indian River, causing further erosion (Smith-Middleton and Alanen 1998). The Indian River breached old riprap, and new riprap was installed by the battlefield site on the west bank of the river (Figure 9).

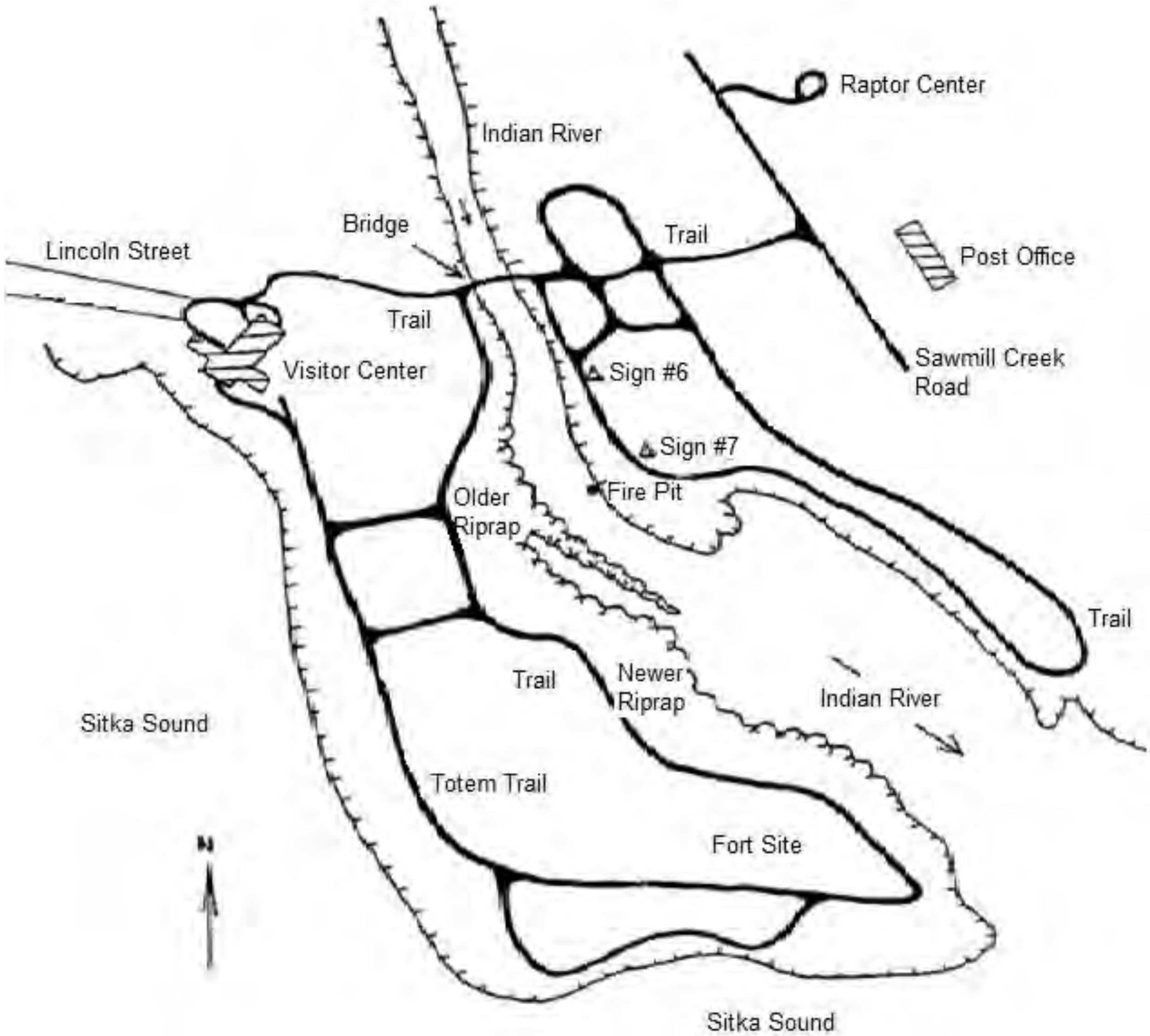

Figure 9. Sketch of SITK from 1992 showing locations of old and new riprap, as well as various trails and landmarks within the park. Figure reproduced and modified from Chaney et al. (1995).

More recently, in the 1980s and 90s, the beaches of SITK have been affected by large pulp-logs that washed up on shore from a nearby paper mill. This mill closed in 1993, but for 25 years prior, the washed up logs acted as a barrier to wave action, affecting shoreline processes and accelerating the growth of plants behind the logs in the uplifted beach area, representing a major change to the beach profile. Much of this vegetation changed from predominately low grasses and herbaceous plants to red alder shrubs and salmonberry (Smith-Middleton and Alanen 1998).

Within the past 45 years, several boundary changes have occurred; however, according to Smith-Middleton and Alanen (1998), relatively small-scale transitions have not resulted in major alterations to SITK's landscape. Over time, these changes in and around park lands have influenced landscape dynamics, although perhaps at less intensity and lower rates when compared to parks in more developed parts of the country, and contributed to the cultural landscape of the area, according to Moynahan et al. (2008).

Trail and road construction and improvement have occurred continuously throughout the park for many years (Chaney et al. 1995). Social trails, those created by visitors walking off designated paths, were noted in the general management plan (NPS 1998) as having an impact on the park‘s vegetation. Today, park staff are walking these trails with GPS units and cameras to document their locations and visual appearances (C. Smith, pers. comm., 2011). C. Smith originally anticipated the project to map these trails would be complete by the end of the 2011 summer, but the trails were much more extensive than originally suspected (pers. comm., 2011). Social trails may disrupt native plant communities, introduce non-native species, and promote erosion.

An additional stressor to the landscape of the park is the urbanization of land surrounding the park (Eckert et al. 2006). Residential development upstream from SITK could affect water quality and quantity in the Indian River (Moynahan et al. 2008). Human development around the park also has the potential to radically alter its ground water dynamics (Moynahan et al. 2008). These two impacts could potentially alter the river‘s erosional and depositional processes, and therefore landform dynamics. To date, development near SITK has occurred mainly in the lower watershed areas, as the upper watershed is surrounded by U.S. Forest Service lands (Eckert et al. 2006). Residential housing units have been developed adjacent to the park during the past decade, with an additional 180 acres zoned for development (Neal et al. 2004). Development may also occur on land currently owned by Sheldon Jackson College and the city and borough of Sitka (CBS), potentially altering large land areas in the watershed (Eckert et al. 2006). Other human impacts include the addition of contaminants and silt to the river and water diversions, which can affect the chemistry and flow of the Indian River (Moynahan et al. 2008).

Climate change is a threat to the terrestrial habitat of the park, which is primarily a form of wetland (Moynahan et al. 2008). Climate change has the capability to alter most, if not all the land cover and landforms in SITK. The melting of permanent snowfields in the upper reaches of the Indian River watershed could cause a short-term increase in runoff and streamflow, which could alter streamflow and sedimentation in the park (Eckert et al. 2006). Plant productivity and distribution is projected to change with climate (Eckert et al. 2006) and warming may increase the threat of non-native species invasion (Auer and Link 2010).

Data Needs/Gaps

Reference conditions for this component by park management zone are unclear. Park managers would be able to better understand how landform/land cover relate to the historical and cultural resources that reside within the park boundaries if clear management goal(s) by park zone were agreed upon. SITK has created a cultural landscape management plan, but it is undecided whether to proceed with the recommended actions (C. Smith, pers. comm., 2012).

Alterations in the geologic landscape since the 1994 (Chaney et al. 1995) field survey of physical landscapes in SITK have not been documented. Physical transformations in geologic time tend to encompass long periods of time, spanning hundreds if not thousands of years. However, with stressors such as climate change and log deposition possibly affecting the landscape at increasing rates, more observations and current data are needed to better understand these changes.

As previously mentioned, the NPS does not have available GIS data layers displaying current SITK landform or land cover. Land cover GIS datasets representing the composition of various landform and vegetation classifications would be helpful in determining any changes over time. The SEAN is developing a long-term landform and land cover monitoring plan with the goal of mapping and classifying landform/land cover elements (e.g., alluvial deposits, shoreline features, plant communities) (Moynahan et al. 2008). A project has recently been funded to create a vegetation map (i.e., land cover) for SITK starting in 2012. With new baseline data becoming available, future condition assessments may provide a more complete and comprehensive evaluation of this component.

While a historic reference condition for the park is currently incomplete, at least in terms of comparable GIS datasets for change detection, early aerial photos exist and along with map interpretations of vegetation made by Smith-Middleton and Alanen (1998), may be helpful in quantifying historic land cover.

Overall Condition

The Chapter 3 methodology for assigning condition was not applied to landform/land cover, given the complexity of the historic human alterations to the park's landscape, the dynamic natural factors affecting landform and land cover in the park, and the lack of specificity in the reference point or conditions to which current conditions should be compared. In characterizing the park's landscape, Smith-Middleton and Alanen (1998) discuss significant changes in both landforms and plant communities of the park over time. Chaney et al. (1995) also describe the geological processes and changes in detail and suggest that major anthropogenic changes to landform and land cover occurred throughout the 20th century (e.g., gravel dredging operations, pulp mill logs washing ashore, rip-rap and other erosion control installations). The physical landscapes of the park have been highly modified by these human activities. However, Smith-Middleton and Alanen (1998) concluded that the park's landscape has since (in the last 25 years of the 20th century) largely stabilized and matured.

The topic of landform and land cover change in SITK has not been specifically revisited in nearly 20 years. New information examining the vegetation (land cover) in SITK may provide a more current understanding of park-wide changes.

Sources of Expertise

The primary source of local information and reviews for this section was Craig S. Smith, SITK Biologist.

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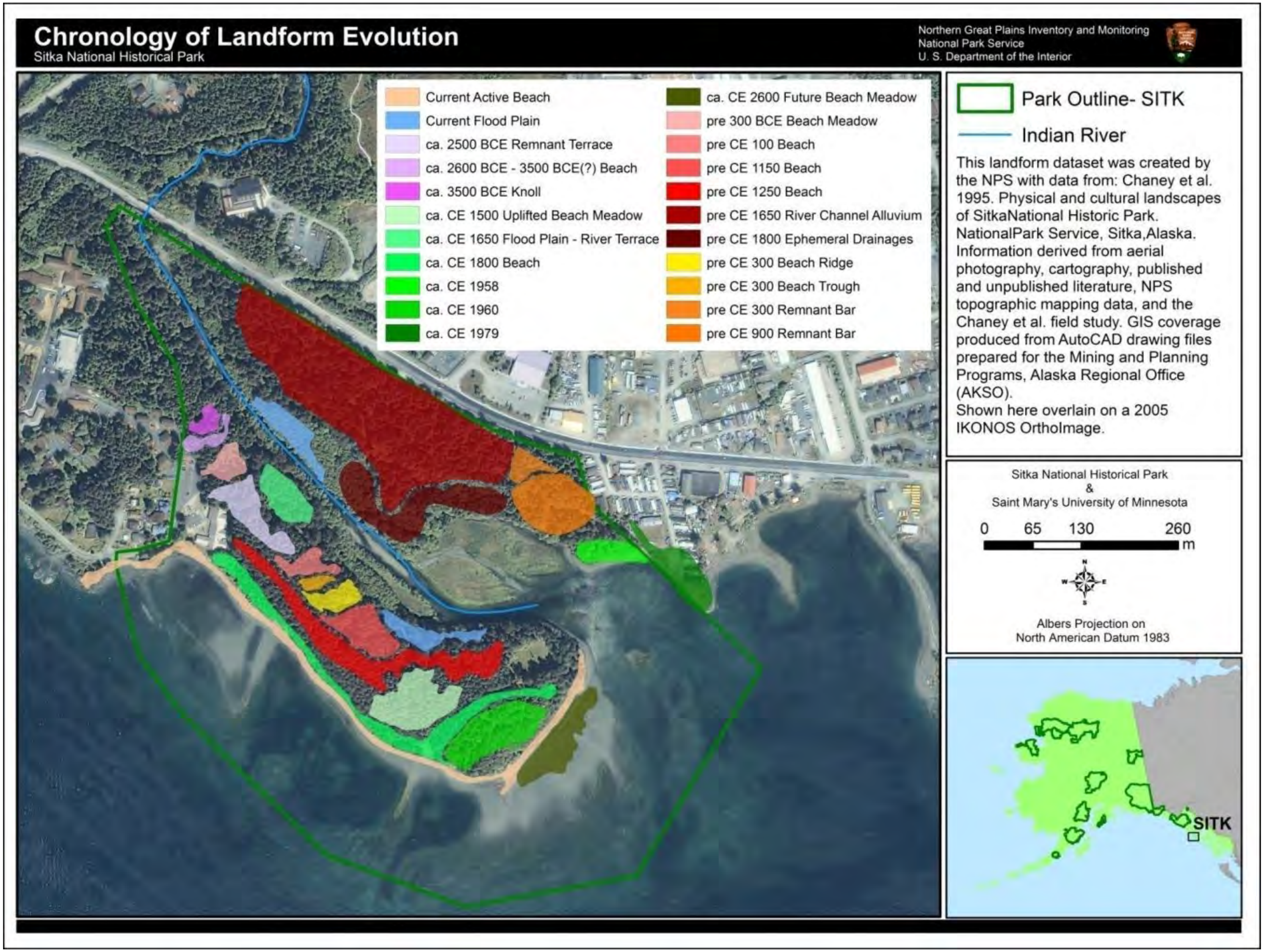

Plate 2. Chronology of landform evolution in SITK (Chaney et al. 1995).

4.2 Land Birds

Description

Land birds are bird species that have a principally terrestrial life cycle (Rich et al. 2004). Bird populations often act as excellent indicators of an ecosystem‘s health (Morrison 1986, Hutto 1998, NABCI 2009). Birds are typically easy to observe and identify, and bird communities often reflect the abundance and distribution of other organisms with which they co-exist (Blakesley et al. 2010). Despite the small size of SITK, there are several unique habitats available to land bird species: temperate rainforests, open meadows, estuaries, an anadromous river, and a semi-protected intertidal shoreline (NPS 2008). Monitoring of the park‘s land bird species may help SITK resource managers better gauge the health of these unique ecosystems.

Photo 1. Varied thrush (NPS Photo).

Measures

- Species richness and diversity
- Change in abundance of species of concern
- Percent of expected species present

Reference Conditions/Values

The reference condition for land birds in SITK is the Birds of Sitka National Historical Park checklist. This checklist can act as a baseline for the presence of bird species in the park and may help to identify potential migratory influxes or declines in species.

Marlys E. Tedin and Marjorie L. Ward of Sitka, Alaska, assembled this checklist in 2001 and have updated the list sporadically since then. This checklist includes all bird species that visit SITK, including shorebirds. For this assessment, SMU GSS has revised this checklist by only including land bird species as defined by Rich et al. (2004) (Appendix 1). In total, there are 68 land bird species included in the checklist, with an additional 17 species listed as ―accidental" species in the park. An accidental species is one that has only been seen a few times in a particular region, which is typically far out of the species‘ normal home range (National Geographic Society 2008).

Data and Methods

The NPS Certified Bird Species List (NPS 2011) (Appendix 1) for SITK was used for this assessment. This list represents all of the bird species confirmed in the park. For this component, only bird species considered land birds (as defined by Rich et al. 2004) were included. SMU

GSS removed coastal bird species from this list, as these species are discussed separately in Chapter 4.3 of this document.

The SITK breeding bird survey route is part of the large-scale North American Breeding Bird Survey (BBS), which began in 1966 and is coordinated by the U.S. Geological Survey (USGS) and the Canadian Wildlife Service (Robbins et al. 1986). The standard BBS route is approximately 40 km (25 mi) long with survey points at every 0.8 km (0.5 mi).

Only BBS route 03122 (Sitka Route) crosses within the park boundaries (Plate 3). The survey begins ½ hour before sunrise, and at each survey point the number of birds seen and heard within a 0.4 km (0.25 mi) radius during a three minute interval is recorded. The route was surveyed in 2000, and again from 2002-2010 (USGS 2011). For this assessment, only data from the portion of the BBS that is within SITK administrative boundaries is included. Data for the entire 03122 route can be accessed at the BBS website: https://www.pwrc.usgs.gov/BBS/PublicDataInterface/index.cfm.

The Sitka, AK Christmas Bird Count is part of the International Christmas Bird Count (CBC), which started in 1900 and is coordinated internationally by the Audubon Society. The Sitka, AK CBC is near SITK (the count extends into SITK's boundaries), and has been conducted annually since 1974-75 (no counts were conducted from 1979-1981). Multiple volunteers survey an area within a 24 km (15 mi) diameter on one day, typically between 14 December and 5 January. The center point of the 24 km diameter is the town of Sitka, AK (57.0667°N, -135.3667°W) (Plate 3). Unlike the BBS, the CBC surveys outside of the park and documents overwintering and resident birds that are not territorial and singing; therefore they should not be directly compared with that of the BBS, which occurs during late spring or early summer.

The total number of species and individuals are recorded each year; data for the CBC near SITK are current through the 2009-2010 winter. SMU GSS made a few adjustments to the CBC data. These adjustments included:

- Entries of yellow-shafted flicker and red-shafted flicker were treated as one species (northern flicker [*Colaptes auratus*]).

- Entries of northern shrike or great grey shrike were treated as the same species as both are accepted common names of *Lanius excubitor*.

- Entries for dark-eyed juncos (*Junco hyemalis*) included both the Oregon and slate-colored races.

- One year of fish crow (*Corvus ossifragus*) observations were removed because this species does not occur in Alaska (its home range is along the Atlantic Coast of the United States).

SITK has also created a database to capture wildlife observations in the park. These data are simply a collection of observations (2002-2010), not the results of a scientific survey. The majority of the bird species observations are coastal birds; therefore the database was not used for this assessment.

Current Condition and Trend

<u>Species Richness and Diversity</u>

NPS Certified Species List
The species richness and diversity measure allows simultaneous assessment of abundance or presence for the entire land bird community. This measure can also indicate overall habitat suitability for land birds. The NPS Certified Bird Species List contains 83 land bird species (Appendix 1). This list, however, does not allow for an analysis of species richness as no data are collected other than the presence of the listed species. Compared to the reference condition, the NPS Certified Species List is lacking two species that are listed on the reference condition (Say‘s phoebe [*Sayornis saya*], and common nighthawk [*Chordeiles minor*]).

Breeding Bird Survey
An index count is a method that tallies the number of bird detections during surveys of points, transects, or other defined regions (Kendeigh 1944, Verner 1985, Bibby et al. 1992, Ralph et al. 1995, Rosenstock et al. 2002). Index counts are frequently used to quantify land bird species‘ distribution, occurrence, habitat relationships, and population trends (Rosenstock et al. 2002). Notable examples of long-term population index counts in SITK are the North American BBS and the CBC.

Species counts for each year of the BBS were calculated and are shown in Figure 10. The average number of species observed on the SITK BBS from 2000-2010 was 15.6, which is well below the number of species on the reference condition list (85). However, the reference condition list for SITK includes migratory, non-breeding, and uncommon species, which may not be present during the breeding season or the period when the BBS is conducted. Furthermore, the sampling methods and timing may not be intensive enough to capture all of the species listed on the SITK reference condition list.

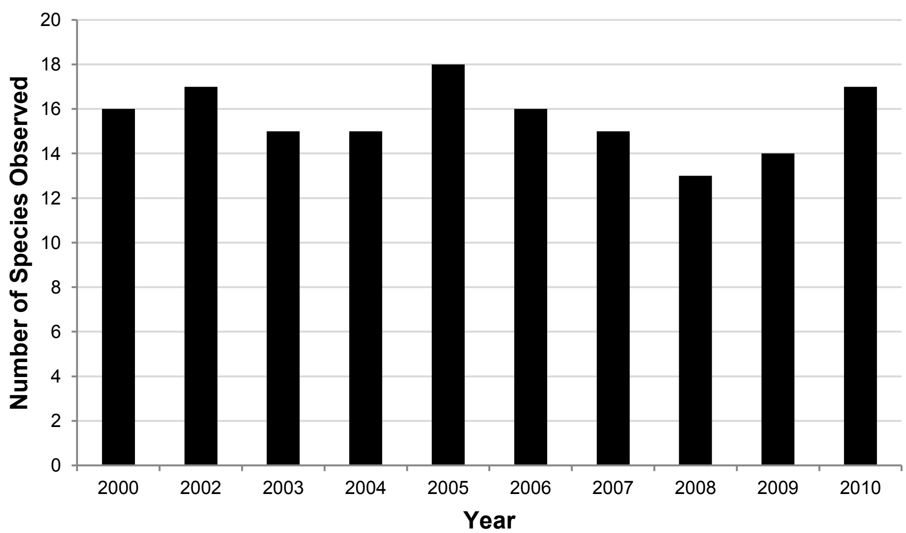

Figure 10. Number of species detected during Breeding Bird Surveys in SITK from 2000-2010.

There does not appear to be an increasing or decreasing trend in species richness over time (Figure 10). However, there may be undetected changes in species richness of native species compared to non-native species, or in Neotropical migrant species compared to resident species. Such changes would not be evident in Figure 10.

Christmas Bird Count

The total number of bird species identified annually during the SITK CBC from 1974-2010 is represented in Figure 11. The average number of species observed was 22.4. There is no discernible increasing or decreasing trend for the duration of the CBC (Figure 11). Care must be taken when interpreting count data such as these, as the data are largely dependent upon the effort of the observers. The counts may not provide an accurate depiction of the species richness in SITK.

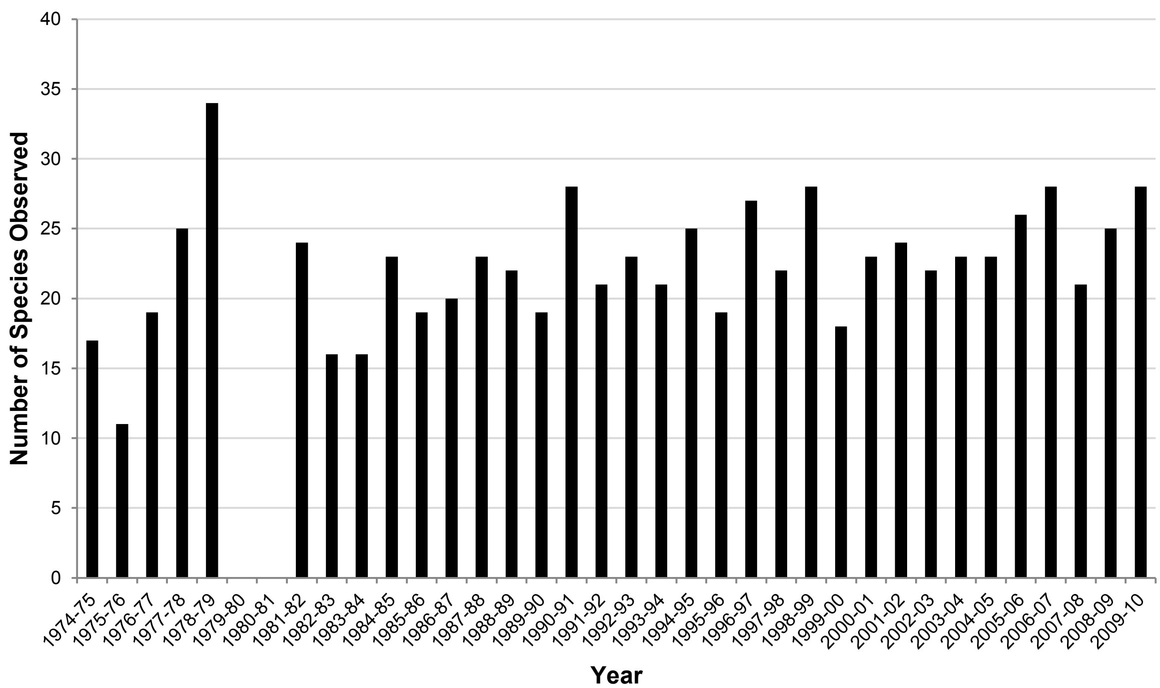

Figure 11. Number of species observed during the SITK Christmas Bird Counts from 1974-2010. No Christmas Bird Counts were performed from 1979-1981.

<u>Change in Abundance of Species of Concern</u>

Many different agencies and lists define land bird species of concern. This assessment focused on species of concern from the following conservation lists:

- The Audubon Alaska WatchList 2010 (Kirchoff and Padula 2010)
- Alaska WatchList 2005 (Stenhouse and Senner 2005)
- The National Audubon Society WatchList 2007 (NAS 2007)

- The U.S. Fish and Wildlife Service (USFWS) Birds of Conservation Concern 2008 (USFWS 2008)

- Partners in Flight Species of Regional Importance for Bird Conservation Region (BCR) 10 (Northern Rockies) (RMBO 2005)

- International Union for the Conservation of Nature (IUCN) Red List of Threatened Species, Version 2011.1 (IUCN 2010)

NPS Certified Bird Species List
The NPS Certified Bird Species List includes 18 species of conservation concern (NPS 2011). Because this list does not survey species annually, an assessment of the change in abundance of these species using this data source is not possible.

Breeding Bird Survey
For this assessment, only land bird species that were observed on ≥50% of the BBS surveys are addressed. From 2000-2010, eight land bird species of concern meeting this criterion were identified during SITK BBS efforts (Figure 12, Figure 13). For these species, any apparent trends in abundance must be interpreted with caution as nine years is a relatively short period of time to determine abundance trends, and no statistical significance has been determined for these data.

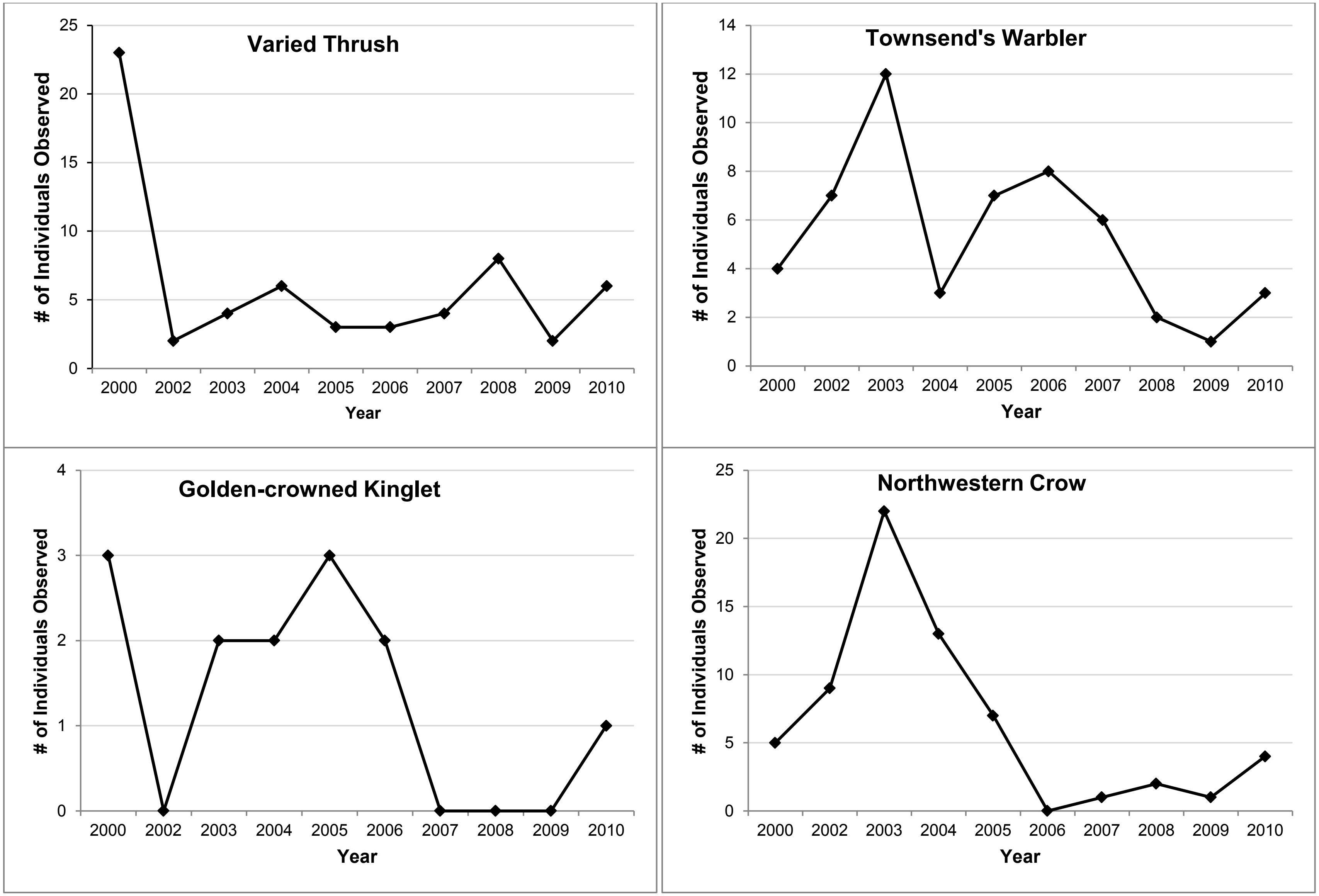

Figure 12. Change in abundance of four land bird species of concern (varied thrush, Townsend's warbler, golden-crowned kinglet, and northwestern crow) during the SITK Breeding Bird Survey from 2000-2010.

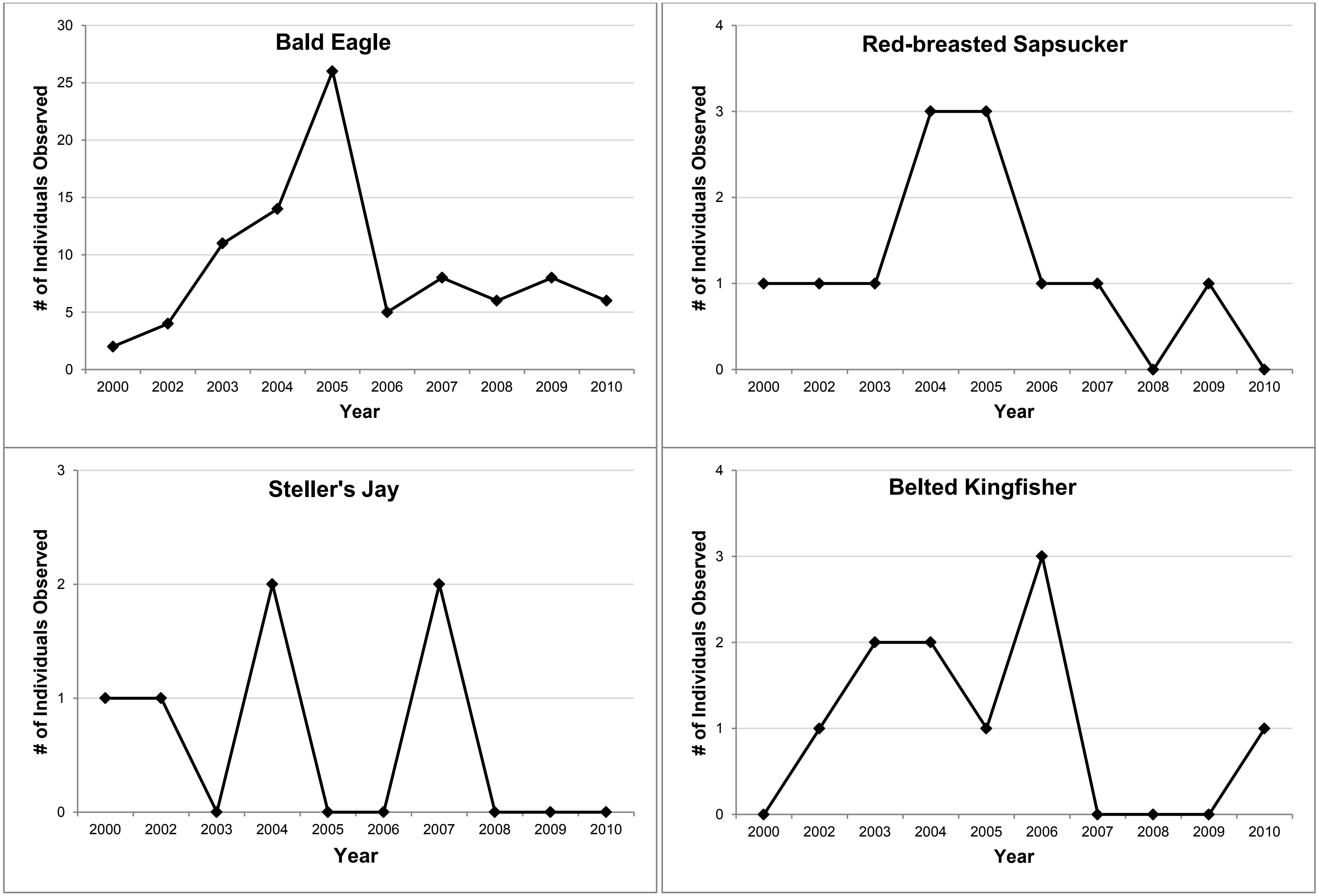

Figure 13. Change in abundance of four land bird species of concern (bald eagle, red-breasted sapsucker, chestnut-backed chickadee, and belted kingfisher) during the SITK Breeding Bird Survey from 2000-2010.

The species included in Figure 12 and Figure 13 were listed as Partners in Flight Species of Regional Importance for BCR 10 (Northern Rockies) (RMBO 2005). Additionally, the varied thrush (*Ixoreus naevius*) (Photo 1) was listed on the National Audubon Society WatchList (NAS 2007), and was identified as a Red List species of concern by Kirchoff and Padula (2010). While the species is currently abundant across its range (global population is an estimated 26 million individuals), Kirchoff and Padula (2010) reported that the population is declining by 3-4% per year. The major threat to the species is the loss of mature forest due to extensive logging in its home range. In 2000, 23 varied thrushes were observed during the SITK BBS, and from 2002-2010 observations ranged from two to eight individuals (Figure 12).

There were two species of land birds, the Townsend‘s warbler (*Dendroica townsendi*) and the red-breasted sapsucker (*Sphyrapicus ruber*), that were observed on the BBS and were not identified during other survey efforts in the park. The Townsend‘s warbler is a summer resident of the SITK region and winters primarily in Mexico (CLO 2011). In the southern portion of the species‘ breeding range (Oregon and Washington coasts), the Townsend‘s warbler will hybridize with the hermit warbler (*Dendroica occidentalis*) (Rohwer and Wood 1998). Global population trends for the Townsend‘s warbler appear to be stable (CLO 2011). Observations during the SITK BBS from 2000-2010 have fluctuated from one to 12 individuals (Figure 12).

The red-breasted sapsucker has a year-round range that includes the park. SITK is located in the Pacific Avifaunal Biome (Rich et al. 2004). A majority of the red-breasted sapsucker‘s global population (which is estimated at 2.5 million individuals) occurs within this biome (Rich et al. 2004). Forestry practices that remove snags have led to a decrease in the abundance of this species in some areas of the Pacific Avifaunal Biome (Walters et al. 2002). The number of observations during the SITK BBS has been low, with peak observations of three individuals occurring in 2004 and 2005 (Figure 13).

Christmas Bird Count

Only land bird species that were observed on $\geq$50% of the counts in the CBC data are included in this assessment. From 1974-2010, seven land bird species of concern met this criterion during SITK CBC efforts (Figure 14, Figure 15).

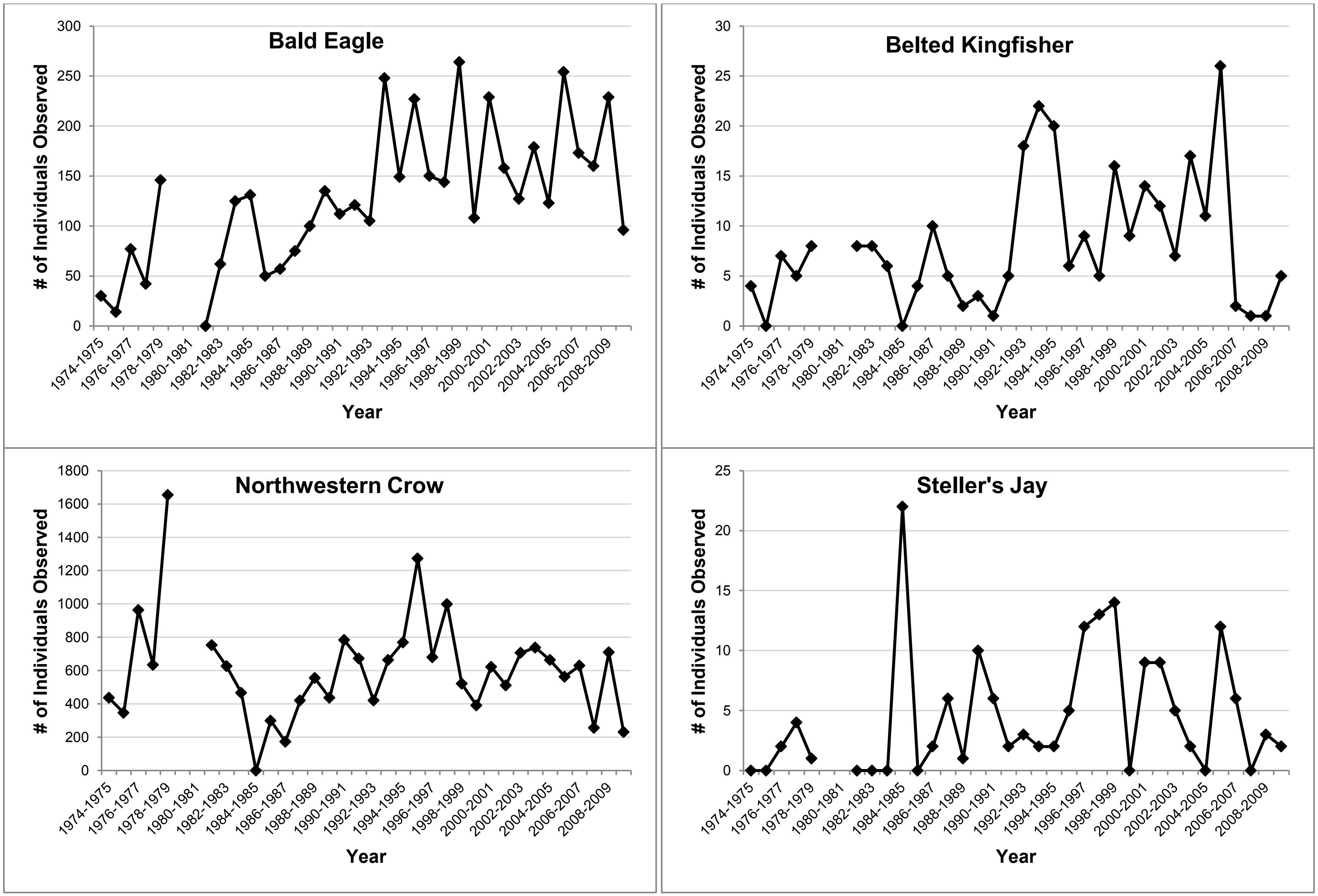

Figure 14. Change in abundance of four land bird species of concern (bald eagle, belted kingfisher, northwestern crow, and Steller's jay) during the SITK Christmas Bird Count from 1974-2010. The disconnected trend line is due to no counts being performed from 1979-1981.

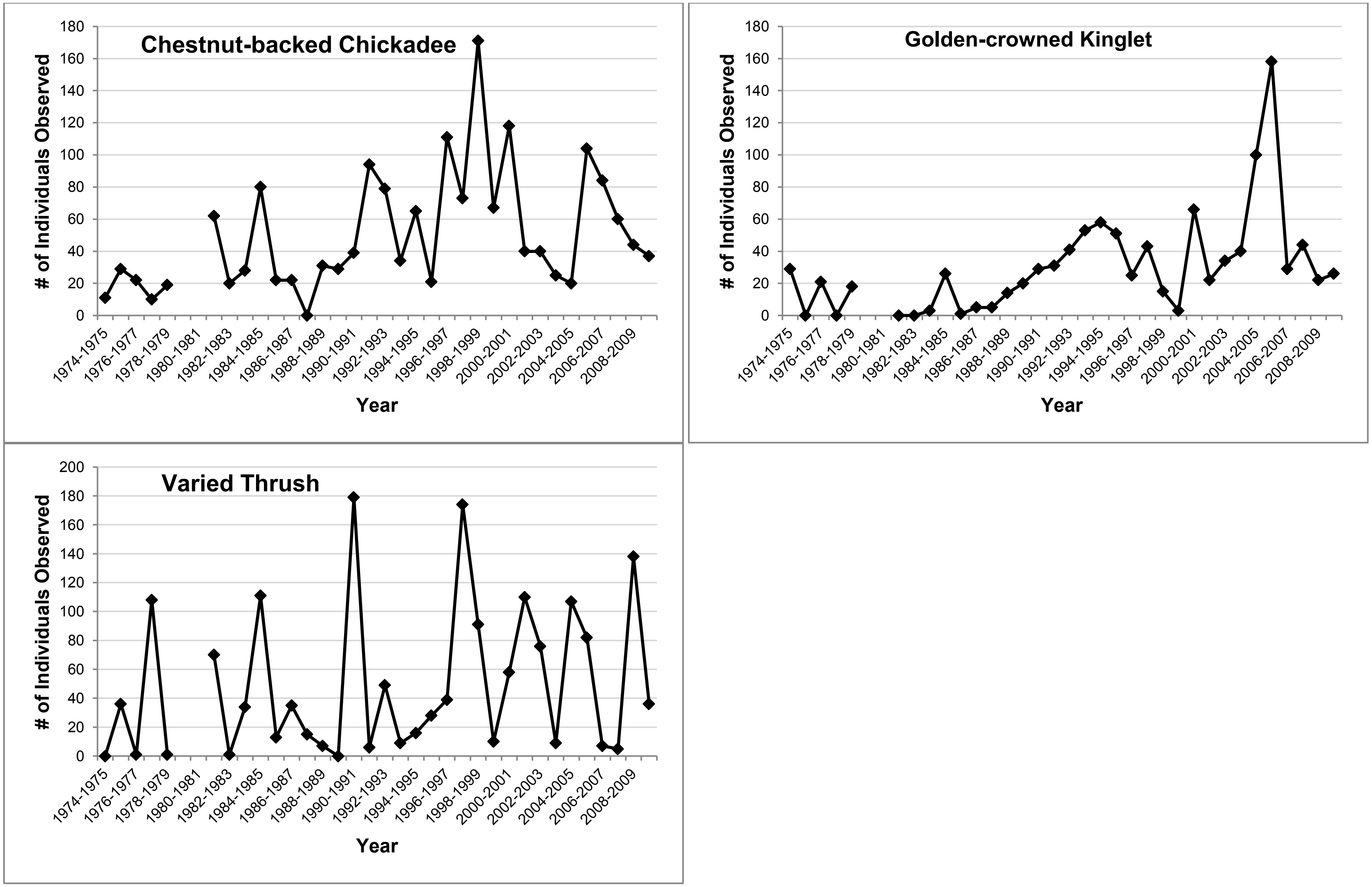

Figure 15. Change in abundance of three land bird species of concern (chestnut-backed chickadee, golden-crowned kinglet, and varied thrush) during the SITK Christmas Bird Count from 1974-2010. The disconnected trend line is due to no counts being performed from 1979-1981.

The SITK CBC represents a near-continuous data source for wintering birds in SITK since 1974, and trends may be more evident in Figure 14 and Figure 15 when compared to Figure 12 and Figure 13. Much like the BBS results, all of the species included in Figure 14 and Figure 15 were listed as Partners in Flight Species of Regional Importance for BCR 10 (Northern Rockies) (RMBO 2005). Additionally, the varied thrush was listed on the National Audubon Society WatchList (NAS 2007) and was identified as a Red List species of concern by Kirchoff and Padula (2010).

Wells et al. (1996) found dramatic year-to-year changes in wintering abundance of the varied thrush in North America. A biennial cyclic change in abundance within most of the species' breeding range was evident, and this pattern was also evident in CBC data which showed abundance peaks every 2-3 years. A similar trend is seen in the SITK CBC data. While an overall increasing or decreasing trend may not be evident, there are definitive spikes and decreases in the CBC observations every 2-3 years. Dramatic reductions in varied thrush observations on the SITK CBC may not be indicative of a population decline, but rather a regional population fluctuation that occurs every 2-3 years, as was suggested by Wells et al. (1996).

Percent of Expected Species Present

No specific surveys have been conducted in SITK to determine the percent of expected species present. However, when comparing the three data sources available for this assessment (NPS Certified Bird Species List, BBS, and CBC) to the reference condition, a very rough estimate can be created.

Breeding Bird Survey

Twenty-seven land bird species were identified along the portion of the SITK BBS route that crosses through SITK boundaries. The reference condition list for SITK identifies 85 land bird species. Thus, roughly 32% of expected species have been identified in SITK using the BBS data from 2000-2010.

Christmas Bird Count

The SITK CBC identified 65 land bird species from 1974-2010, while the reference condition for SITK land birds identifies 85 species. Thus, roughly 76% of expected species have been identified in SITK using the CBC data from 1974-2010.

Threats and Stressor Factors

One of the major threats facing the land bird population of SITK is the loss of wintering habitat. SITK has a large wintering bird population, as is evident from the CBC data. Specific threats to the habitat in the SITK area include logging and removal of old-growth forests and urbanization in the town of Sitka.

For Neotropical migrants, the loss of wintering habitat in the tropics represents a significant threat. The quality of habitat located on a species' wintering grounds has been shown to directly influence the breeding success of long-distance migratory species (Norris et al. 2003). Loss of critical wintering habitat for the migratory land birds of SITK may result in a decrease in productivity and occupancy in SITK.

One of the major threats facing bird populations across all ecosystem types is habitat/land cover change (Morrison 1986). Altered habitat, whether natural or human-induced, can compromise the reproductive success or survival rates of species adapted to a specific habitat. Reduction in available stopover habitat along migratory routes has been proposed as a potential cause of population decline in some migratory species (Moore et al. 1995, Swanson et al. 2003). A change in land cover, whether it is in SITK or along the migratory flyway/wintering grounds, could drastically alter the species composition of the park.

One of the driving forces of land cover change is climate change. As global temperatures change, bird species may adjust by moving their home range north (Hitch and Leberg 2007). As this occurs, species associated with more southern habitats may encroach on native species' home ranges in northern habitats.

Data Needs/Gaps

An intensive bird survey during the breeding season would help park managers to better understand the species composition of the park. With the small size of the park, a reliable estimate of population size, occupancy, and productivity could be obtained. Repeated surveys could also allow for long-term trend monitoring.

While the CBC and BBS provide some baseline information on the land bird population of the park, they are momentary surveys and are not intensive. The CBC data may be misleading as many of the observations occur outside of SITK boundaries. Park-specific monitoring efforts could provide greater insights into the species richness, diversity, changes in abundance of species of concern, and the percent of expected species present.

Overall Condition

Species Richness and Diversity

SITK staff assigned the measure species richness and diversity a *Significance Level* of 3. BBS and CBC data do not appear to show an increasing or decreasing trend, although there are only 9 years of BBS data for the SITK route. Continued monitoring of this route may provide greater insight into potential trends in breeding bird richness and diversity. At this time however, there is no evidence to suggest that the richness and diversity of the land bird population is at risk. For this reason, the species richness and diversity measure was assigned a *Condition Level* of 1.

Change in Abundance of Species of Concern

The change in abundance of species of concern measure was assigned a *Significance Level* of 2. Despite having several species of conservation concern within SITK boundaries, the trend data for these species is inadequate for assessing this measure's condition at this time.

Only two organized surveys take place at SITK (BBS and CBC), and the BBS only provides 9 years worth of data (which may be an insufficient amount of time to observe long-term trends) at a very small number of sample locations. Furthermore, the BBS takes place during a time that would not survey migratory land bird species. The CBC efforts survey areas outside of SITK and it is impossible to know if the species of concern identified on these surveys were occurring within SITK boundaries. This survey identifies primarily overwintering birds and does not identify many of the breeding species within the park.

Percent of expected species present
The measure percent of expected species present was assigned a *Significance Level* of 3. No estimates of this measure have been conducted to date. The estimates provided in this assessment are only rough estimates based on the existing data and surveys from the park and do not represent quantifiable values of this measure. Because of this data gap, a *Condition Level* for this measure cannot be assigned.

Weighted Condition Score (WCS)
A Weighted Condition Score for Land Birds in SITK was not assigned because >50% of the measures had unknown *Condition Levels*.

Sources of Expertise
The primary sources of local information and reviews for this section were Craig S. Smith, SITK Biologist, and Geof Smith, former SITK Biologist.

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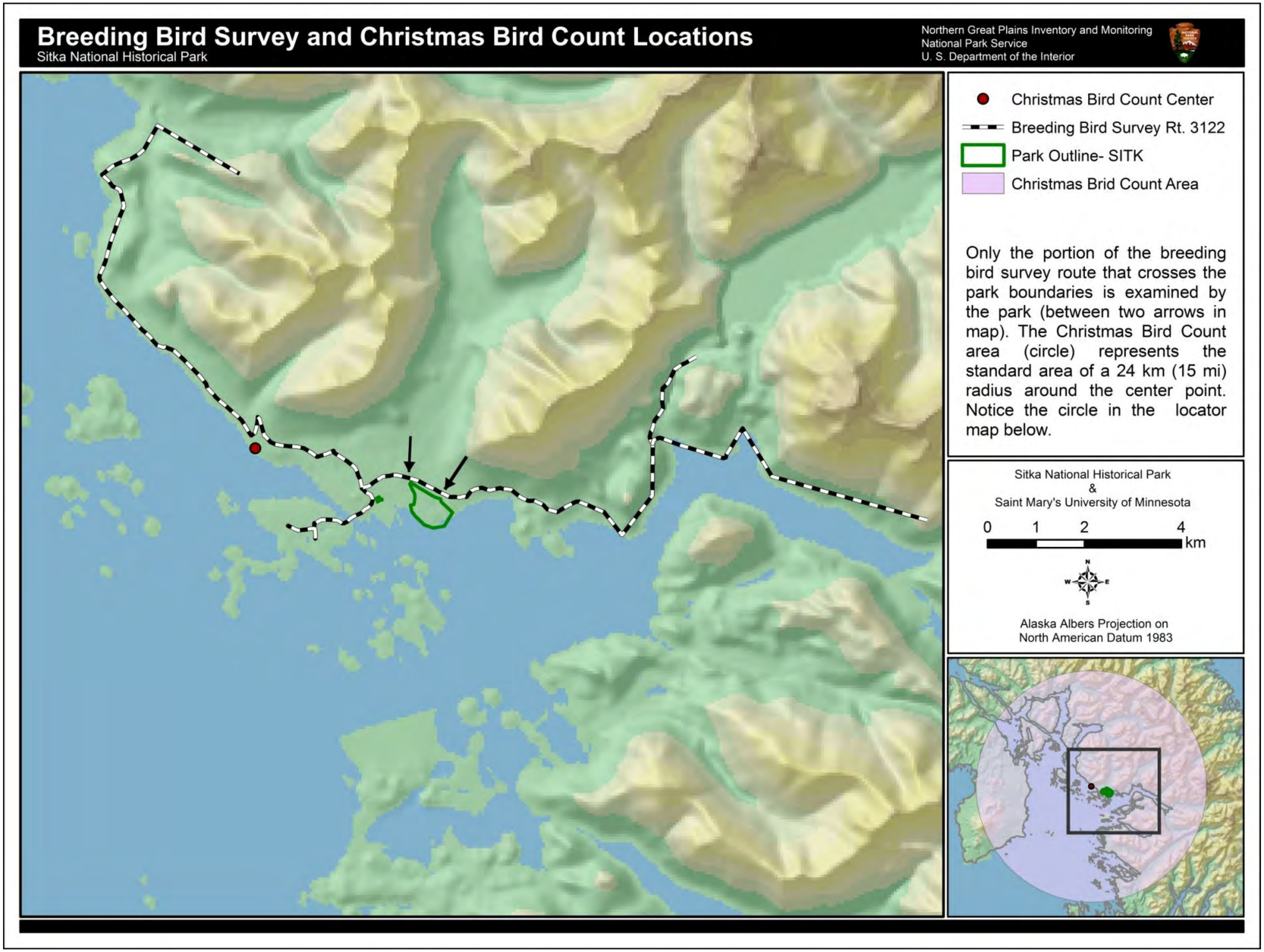

Plate 3. North American Breeding Bird Survey and Christmas Bird Count locations relevant to SITK.

4.3 Coastal Waterbirds

Description

The term ‘coastal waterbirds” refers to the species of birds in SITK that rely on the coastal habitat of the park. In this assessment, coastal waterbirds specifically refers to birds of the orders Ciconiiformes (shorebirds, excluding species formerly of the order Falconiformes), Anseriformes (ducks and their allies), and Gruiformes (cranes and their allies) (Sibley and Ahlquist 1990). One example species is depicted in Photo 2.

Photo 2. Barrow's goldeneye (*Bucephala islandica*) (NPS Photo).

Coastal areas occupy less than 10% of the land area of the United States, yet these areas support over 170 bird species (NABCI 2009). The bird species present in SITK come to the park because of its proximity to alpine, rainforest, and coastal ecosystems (Piazza 2001). SITK lies along major migratory flyways and is a temporary refuge for many species of birds throughout the year (Piazza 2001).

Shorebirds have very long migrations and frequently pass through the SITK area. According to Piersma and Lindström (2004), there are nine shorebird flyways that originate in the tundra and disperse in southerly directions.

Photo 3. Shorebirds (short-billed dowitcher, black-bellied plover, black turnstone).

Bird populations often serve as excellent bioindicators for specific ecosystems, and can act as an early warning signal when an ecosystem is in trouble (NABCI 2009). Coastal waterbirds are a very visible part of SITK‘s ecosystem and landscape; a decline in these species would be one of the first visible symptoms of a stressed oceanic ecosystem (NABCI 2009). For this reason, coastal waterbirds represent an important component of the SITK community.

Measures

- Species richness and diversity
- Change in abundance of yellow-billed loon
- Percent of expected species present

Reference Conditions/Values

The wildlife observation database acts as the reference condition for the species richness and diversity measure. The 2007 Birds of Sitka National Historical Park Checklist will provide the reference condition for the percent of expected species present by identifying the species that are to be expected within the park (Appendix 2)

Data and Methods

The Birds of Sitka National Historical Park Checklist was used in this assessment (Appendix 1). This checklist identifies 153 species of birds, along with 38 additional species classified as ―accidental" species. The list was revised by Merlys E. Tedin and Marjorie L. Ward in 2001, and minor updates have been completed since 2001 (most recently in 2007). For this assessment, SMU GSS made one adjustment to the data and removed all bird species that were not coastal waterbirds.

The SITK breeding bird survey route is part of the large-scale North American Breeding Bird Survey (BBS), which began in 1966 and is coordinated by the U.S. Geological Survey (USGS) and the Canadian Wildlife Service (Robbins et al. 1986). The standard BBS route is approximately 40 km (25 mi) long with survey points at every 0.8 km (0.5 mi).

Only BBS route 03122 (Sitka Route) crosses within the park boundaries (Plate 3). The survey begins ½ hour before sunrise, and at each survey point the number of birds seen and heard within a 0.4 km (0.25 mi) radius during a three minute interval is recorded. The route was surveyed in 2000, and again from 2002-2010 (USGS 2011). For this assessment, only data from the portion of the BBS that is within SITK administrative boundaries is included. Data for the entire 03122 route can be accessed at the BBS website:
https://www.pwrc.usgs.gov/BBS/PublicDataInterface/index.cfm.

The Sitka, AK Christmas Bird Count is part of the International Christmas Bird Count (CBC), which started in 1900 and is coordinated internationally by the Audubon Society. The Sitka, AK CBC is near SITK (the count extends into SITK's boundaries), and this CBC has been conducted annually since 1974-75 (no counts were conducted from 1979-1981). Multiple volunteers survey an area within a 24 km (15 mi) diameter on one day, typically between 14 December and 5 January. The center point of the 24 km diameter is the town of Sitka, AK (57.0667°N, -135.3667°W) (Plate 3). Unlike the BBS, the CBC surveys outside of the park and documents overwintering and resident birds that are not territorial and singing; therefore the results should not be directly compared with those of the BBS, which occurs during late spring or early summer. The total number of species and individuals are recorded each year; data for the CBC near SITK are current through the 2009-2010 winter. SMU GSS only included the CBC data that was specific to coastal waterbirds. For a summary of the CBC data regarding the remaining bird species in the park, consult Chapter 4.2.

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SITK staff has also created a database to capture wildlife observations in the park. These data are simply a collection of observations (2002-2010), and are not the results of a scientific survey. A list of species observed and the number of unique records are presented in Appendix 3.

Current Condition and Trend

Species Richness and Diversity

Breeding Bird Survey

Species counts for each year of the BBS were calculated and are shown in Figure 16. The average number of coastal waterbird species observed on the SITK BBS from 2000-2010 was

1.80. This number is strikingly low, but when one considers that the BBS follows a non-coastal road in the park, the result is not too surprising. Many of the coastal waterbird species present in the park are likely missed during on-road surveys such as the SITK BBS.

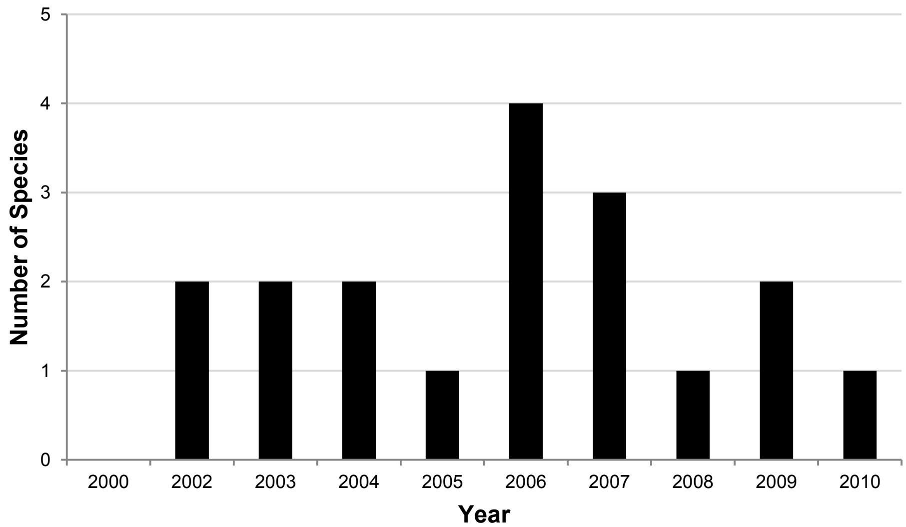

Figure 16. Number of coastal waterbird species detected during Breeding Bird Surveys in SITK from 2000-2010.

The number of individual coastal waterbirds is also counted during the SITK BBS (Figure 17). The average number of individual coastal waterbirds observed on the SITK BBS from 2000-2010 was 5.10. Much like the total number of species observed on the SITK BBS, this number is very low. A survey that focused on the shoreline of the park would almost undoubtedly produce higher counts for both the number of species and the number of individuals observed.

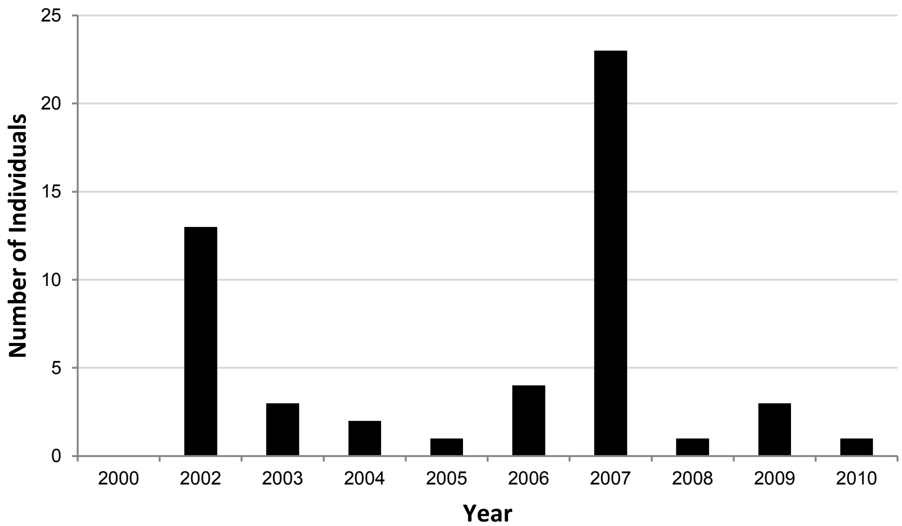

Figure 17. Number of coastal waterbird individuals detected during Breeding Bird Surveys in SITK from 2000-2010.

Christmas Bird Count

The total number of coastal bird species identified annually during the SITK CBC from 1974-2010 is represented in Figure 18. The average number of species observed was 35. Care must be taken when interpreting count data such as these, as the data are largely dependent upon the effort of the observers. The counts may not provide an accurate depiction of the species richness in SITK.

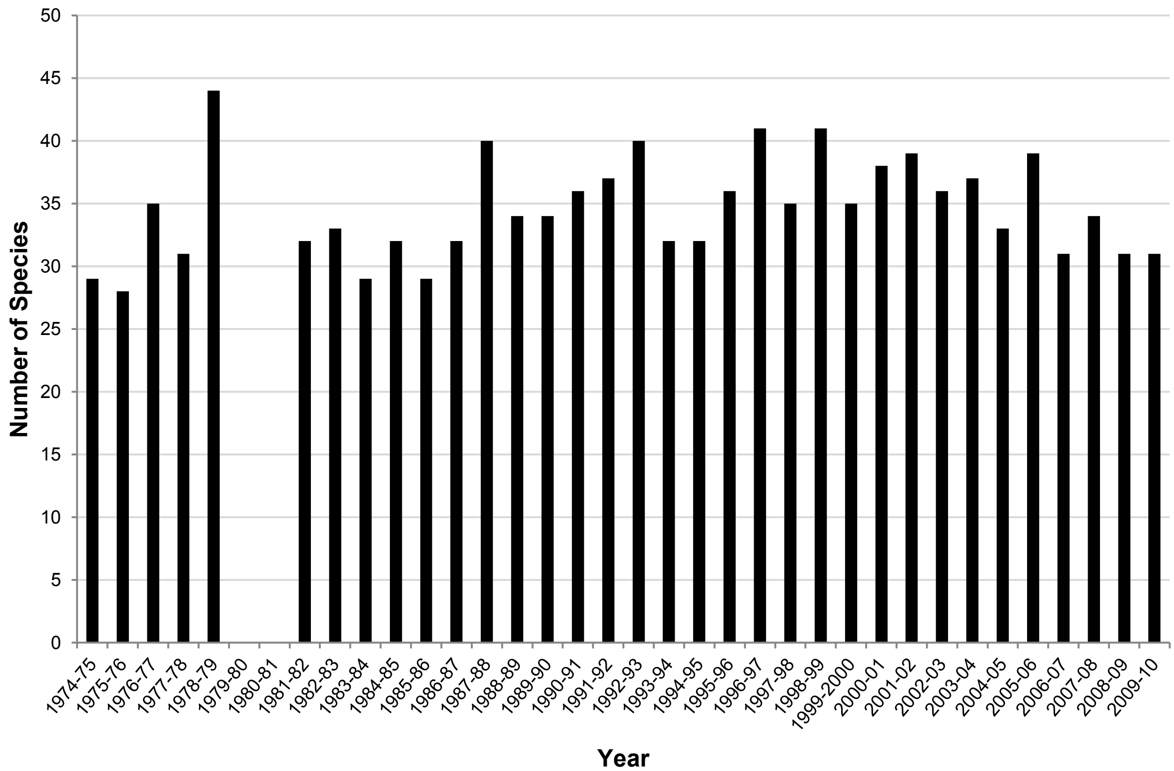

Figure 18. Number of coastal waterbird species observed during the SITK Christmas Bird Counts from 1974-2010. No Christmas Bird Counts were performed from 1979-1981.

The number of individuals observed during the SITK CBC is represented in Figure 19. The average number of individuals identified during the SITK CBC from 1974-2010 was 2,573. The number of individuals observed per year was much more dynamic than the number of species observed per year. This may be attributed to observer effort or bias, or may be a trend that warrants further investigation by the park. The species with the highest average number of individuals observed from 1974-2010 included the glaucous-winged gull (*Larus glaucescens*) (456), common merganser (*Mergus merganser*) (236), Barrow's goldeneye (208), and the herring gull (*Larus argentatus*) (182).

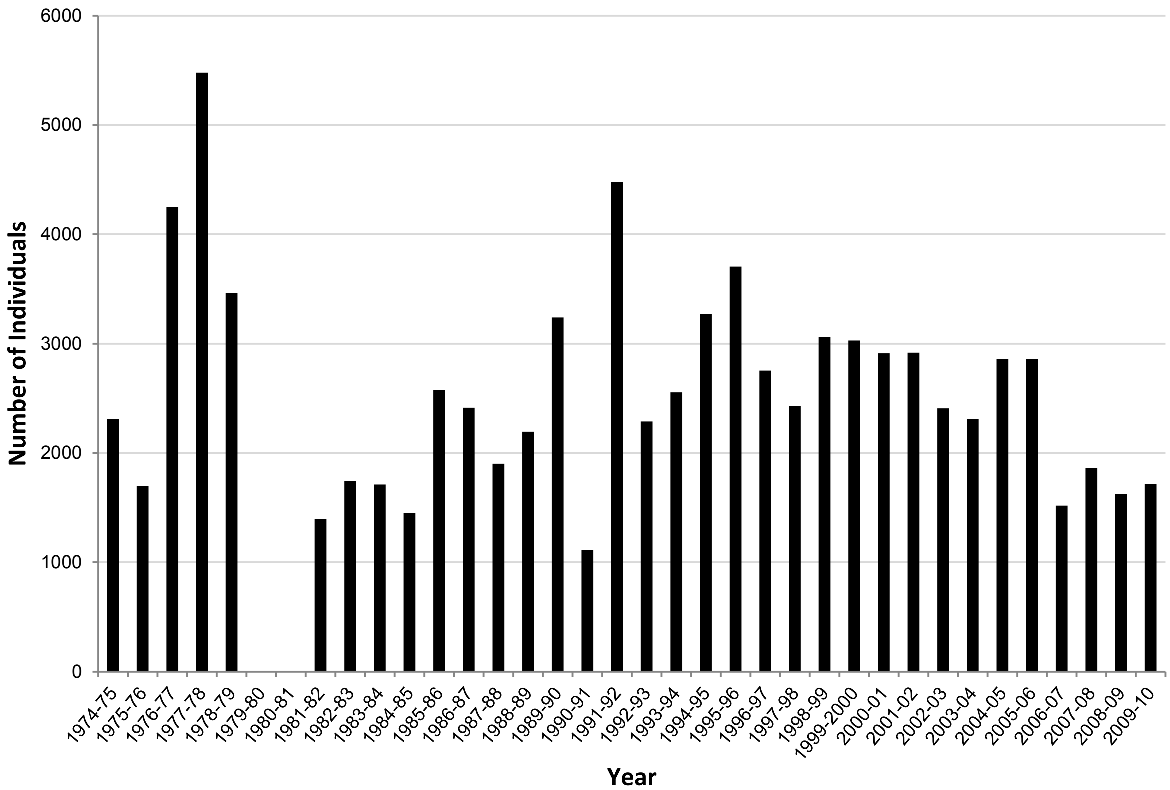

Figure 19. Number of coastal waterbird individuals observed during the SITK Christmas Bird Counts from 1974-2010. No Christmas Bird Counts were performed from 1979-1981.

SITK Wildlife Observation Database

SITK staff has recorded anecdotal observations of wildlife species as they occur in the park since 2002. Among these observations are records of coastal waterbirds. Fourteen coastal waterbirds had 20 or more unique observations in the SITK wildlife observation database. These 14 species are shown in Table 7.

Table 7. Coastal waterbird species with 20 or more unique observations in the SITK wildlife observation database.

Common Name	Scientific Name	Common Name	Scientific Name
green-winged teal	*Anas crecca*	marbled godwit	*Limosa fedoa*
black turnstone	*Arenaria melanocephala*	black-bellied plover	*Pluvialis squatarola*
northern pintail	*Anas acuta*	short-billed dowicther	*Limnodromus griseus*
American wigeon	*Anas americana*	Canada goose	*Branta canadensis*
greater yellowlegs	*Tringa melanoleuca*	dunlin	*Calidris alpina*
northern shoveler	*Anas clypeata*	least sandpiper	*Calidris minutilla*
western sandpiper	*Calidris mauri*	Harlequin duck	*Histrionicus histrionicus*

Change in Abundance of Yellow-billed Loon

The yellow-billed loon (*Gavia adamsii*) (Photo 4) is a migratory species that breeds in northern Russia, Canada, and Alaska beginning in early June (Byrkjedal et al. 2000, BLI 2010). Loon breeding habitat typically consists of vegetated shorelines near bodies of water that do not completely freeze and have ample prey fish and nest protection (Snow and Perrins 1998, BLI 2010). The wintering range of the species extends along the southern coast of Alaska and the eastern coast of Russia, Japan, and Korea (USFWS 2009)

The diet of the yellow-billed loon primarily consists of fish but invertebrates are also consumed opportunistically (Byrkjedal et al. 2000, BLI 2010).

Photo 4. Yellow-billed loon (*Gavia adamsii*) (USFWS Photo, Ted Swen)

Currently, the global population is estimated at 16,000 – 32,000 individuals, while the Alaskan population is estimated at 3,000-4,000 individuals (USFWS 2009). In 2010, the International Union for the Conservation of Nature and Natural Resources (IUCN) classified the yellow-billed loon as a ―near threatened" species. The yellow-billed loon is suspected to be undergoing a population decline, exacerbated by excessive subsistence harvesting and contamination due to heavy metals and oil spills (BLI 2010). Exact harvest statistics are unknown, but a 2007 record of 1,000 individuals harvested in the Bering Sea region indicates that subsistence harvest may be substantially impacting the yellow-billed loon population across its range (Snow and Perrins 1998, USFWS 2009, BLI 2010).

While SITK does not have a monitoring program in place at this time, there are records of the yellow-billed loon from the annual CBC in the park. Observations have been sporadic (Figure 20), and most of the observations from the CBC occurred between 1984 and 1993. Since 1993, the yellow-billed loon has only been observed in six (35%) of the 17 CBCs (Figure 20).

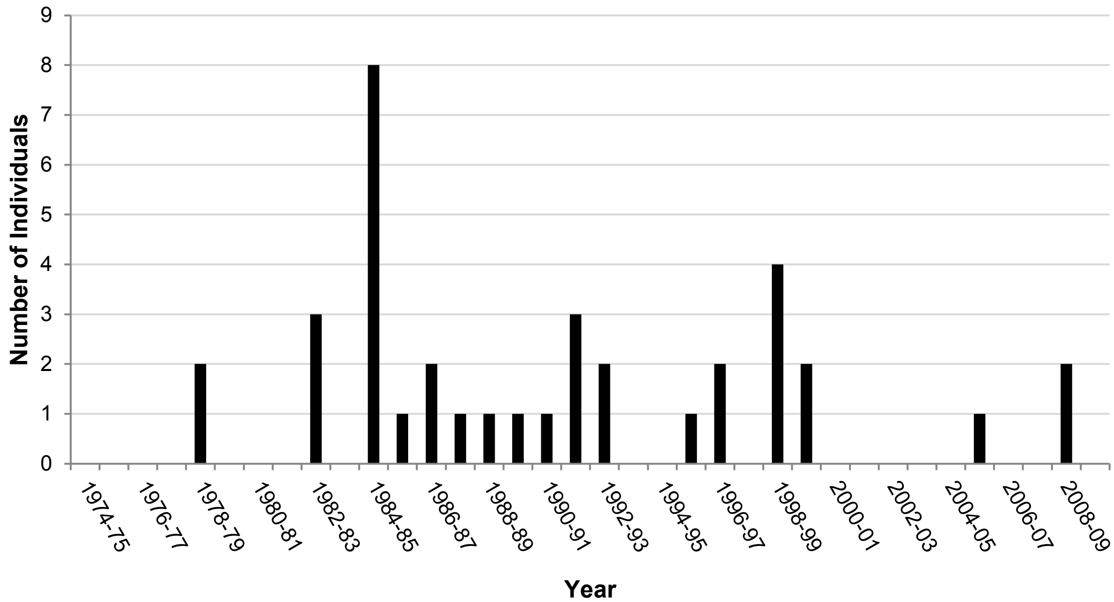

Figure 20. Number of yellow-billed loons observed during the SITK CBC from 1974-2010.

Percent of Expected Species Present
No specific surveys have been conducted in SITK to determine the percent of expected species present. While the park does have data from CBC, BBS, and the wildlife observation database, these data are not specific to coastal waterbirds and may not be accurate enough to identify all of the coastal waterbirds that are present. A specific investigation documenting the number of expected species actually observed compared to the reference condition would provide an accurate source of data for this measure.

Threats and Stressor Factors
The loss of habitat and food availability are among the largest global concerns for coastal birds (NABCI 2010). These losses are not restricted to the habitat within SITK, however, as many migratory coastal waterbirds are experiencing a loss of suitable wintering habitats. The quality of habitat located on a species' wintering grounds has been shown to directly influence the breeding success of long-distance migratory species (Norris et al. 2003). Loss of critical wintering habitat for the migratory coastal waterbirds of SITK may result in a decrease in productivity and occupancy in SITK.

Climate change presents a major threat for coastal waterbirds; NABCI (2010) found that a great majority of coastal species show medium or high vulnerability to climatic change. 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). Furthermore, as global temperatures change, bird species may adjust by moving their home range north (Hitch and Leberg 2007). As this occurs, non-native species may encroach on native waterbird species' home ranges.

Data Needs/Gaps
A formal definition of a coastal waterbird would benefit park managers, especially when organizing a waterbird specific initiative. An intensive coastal waterbird survey during the

breeding season would help park managers to better understand the species composition of the park. With the small size of the park, a reliable estimate of population size, occupancy, and productivity could be obtained. Repeated surveys could also allow for long-term trend monitoring. A similar survey could be used to focus solely on the yellow-billed loon population in the park. This would allow park managers to have a better understanding of the current population size and status in SITK.

Overall Condition

Species Richness and Diversity
SITK staff assigned the measure species richness and diversity a *Significance Level* of 3. However, SMU GSS was unable to assign a *Condition Level* to this component due to a lack of long term trend data. The establishment and repetition of a monitoring program will provide managers with the ability to gauge the health of this component in the future.

Change in Abundance of Yellow-billed Loon
This measure was assigned a *Significance Level* of 2 by SITK staff. There are no long-term trend data for this component, and SMU GSS was unable to assign the measure a *Condition Level*.

Percent of Expected Species Present
SITK staff assigned this measure a *Significance Level* of 3. However, there has been no formal analysis of the percent of expected species in SITK and SMU GSS was unable to assign the measure a *Condition Level*.

Weighted Condition Score (WCS)
Because SMU GSS was unable to assign *Condition Levels* for the measures of this component, a Weighted Condition Score was not assigned.

Sources of Expertise
The primary source of local information and reviews for this section was Craig S. Smith, SITK Biologist.

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4.4 Invasive and Non-native Species

Description

Non-native species, also referred to as exotic or alien species, are classified as organisms introduced into an ecosystem, living outside of their native range, although not inherently seen as beneficial or problematic (Krcmar-Nozic et al. 2000). In contrast, invasive, non-native species are generally easily established and have the potential to spread and establish in natural areas, often due to high fecundity (NPS 2009). Invasive species threaten ecosystem stability, integrity, and sustainability in a time of fluctuating global climate patterns, increased disturbance - both natural and human caused - and expanding human populations (Von Holle and Simberloff 2005). Stein et al. (2000) suggest that invasive species are the second greatest threat to biodiversity after habitat loss. They are introduced in a myriad of different ways, including human transportation, accidental or intentional release, and wastewater discharge (Fay 2002, Koons et al. 2003). Impacts of invasive species have tended to be underestimated because their spread can be slow, over years or decades (Koons et al. 2003). The impacts of invasive species are a growing concern, both on local and global scales, especially their effect on ecosystems and biodiversity (Schrader and Hennon 2005). Tausch (2008) states that, ―increases in invasive plant species usually results in a loss of services from the affected ecosystems."

Invasive, non-native plant species can directly affect native plants by monopolizing or controlling limiting resources, and change ecosystems by altering soil stability, colonizing open substrates, promoting erosion, affecting the accumulation of litter or other soil resources, and altering natural fire regimes (Brooks et al. 2004). Invasive species are a concern to resource managers because they threaten the genetic integrity of native flora through hybridization, and can change the structure and function of ecosystems through alterations of geochemical and geophysical processes (Ruesnik et al. 1995, D'Antonio et al. 2001). Invasive species can also outcompete native plant species and have the potential to impact fish and wildlife species, as well as their corresponding habitats (Heutte and Bella 2006). Likewise, establishment of invasive plants can directly result in the loss of habitat and food sources for wildlife including fish, birds, insects and mammals (NPS 2009).

In the past few decades, non-native invasive species have increased exponentially in Alaska and around the park. This is due mainly to increased human activity in the area. The Alaska Exotic Plants Information Clearinghouse (AKEPIC) data portal is a database and mapping application created in cooperation with the NPS, U.S. Forest Service, Bureau of Land Management (BLM), Alaska Department of Natural Resources (DNR), U.S. Fish and Wildlife Service (USFWS), and Alaska Natural Heritage Program (AKNHP) (AKEPIC 2011). This project provides a visual display of various plant species introductions in Alaska on a spatial and temporal scale. In fact, using the AKEPIC data portal, an exponential trend can be seen in introductions, with the majority of new introduced species becoming established in the past 30 years (Koons et al. 2003, AKEPIC 2011).

SITK is susceptible to continual invasions by non-native plant taxa because many different plant species thrive in the mild climate of Southeast Alaska. For example, European mountain ash trees have invaded native plant communities in the park (Link 2009). Many other invasive non-native plants are present but are confined to lawns, forest edges adjacent to lawns, and other open and disturbed visitor use areas. Japanese knotweed, an invasive forb, has invaded the park by seed from nearby ornamental and naturalized plants, but its presence is monitored, along with other invasive plant species. There are several pernicious species that have been recently introduced into the Alaska National Park system, specifically SITK (e.g., snow-in-summer [*Cerastium tomentosum*] in 2006 and perennial sow thistle [*Sonchus arvensis*] in 2007) (Link 2007). Therefore, regular monitoring and eradication projects are essential in reducing and eradicating encroaching invasive species in national park units such as SITK (Link 2009, Auer and Link 2010). The NPS Exotic Plant Management Team (EPMT), park staff, and participants in AmeriCorps Tribal Civilian Community Corps (TCCC) conduct continual control efforts on Japanese knotweed and other invasive plant species (Densmore 2001, Auer and Link 2010).

In the NPS, invasive species that pose a threat to or displace native populations are controlled or eradicated (Ebbert and Byrd 2002, NPS 2006, Rapp 2009, NOAA 2010). For those non-native species already present and found to interfere with natural processes, native species, or natural habitats, appropriate and feasible methods of control and removal are undertaken (NPS 2006).

Non-native fauna are another important area of concern for SITK. There are relatively few invasive mammal introductions in Alaska compared to the lower 48 states and, as many introductions were not well-documented, it is unclear whether some Alaskan species are native or non-native (Bailey 1993). Not all introduced species are considered harmful or unwanted. Nevertheless, some non-native species may directly interfere with native birds through predation or loss of nesting habitat, as well as changes in vegetation caused by overgrazing and trampling. Overpopulation and food web disruption are important effects related to introduced faunal species.

As with terrestrial species, relatively few aquatic invasive species have become established in Alaska compared to other regions. This is due in part to strict plant and animal transportation laws, Alaska‘s geographic isolation, a small human population, and a colder northern climate (Fay 2002). Despite the low number of introductions to date, Alaska is certainly vulnerable to invasive species introduction. Potential introduction pathways include aquaculture (e.g., fish farms), the intentional movement of game or baitfish, the movement of large ships (e.g., cruise ships, fishing vessels) and ballast water from the United States West Coast and Asia, construction equipment, trade of live seafood, and contaminated fishing gear brought to Alaskan waters (Koons et al. 2003, ADF&G 2011).

Community events aiming to include park supporters and visitors in invasive species control have been recently undertaken, including the first annual SITK family weed pull in 2009. This event involved treating creeping buttercup (*Ranunculus repens*) near the Visitor Center and SITK coastline (Link 2009). Also, BioBlitz 2010, a one-day count of all known invasive marine species in the Whiting Harbor and Totem Flats areas, helped identify marine tunicates and invertebrates, as well as creating response plans, education, and eradication plans (NOAA 2010).

Measures

- *Didymo* status
- Area infested with non-native and invasive flora
- Weighted invasive score (flora)
- Non-native fauna

Reference Conditions/Values

The reference condition for SITK is absence of exotic flora with ―zero" as an overall weighted invasive score (i.e., conditions prior to the introduction of both non-native flora and fauna). A park completely free of all non-native plant species is likely an unrealistic expectation, though referencing this can still prove useful in determining the overall status of non-native flora and fauna, especially those species considered invasive. Although there is not currently a ranking system in place for invasive mammalian or aquatic species, the absence of these species will be used as a reference condition for this measure.

A notable exception to a park completely free of non-native plant species are ornamental species considered historic. According to Auer and Link (2010, p. 14), ―ornamental plantings at SITK should represent the cultural history of the park." The garden in front of the Russian Bishop‘s House should reflect the Russian occupation of Sitka, Alaska. If ornamental species were not planted during the period of Russian occupation, they should not be planted near historic structures in the park (Auer and Link 2010). Near the Visitor Center, the landscape should reflect the natural ecology of Baranof Island (Auer and Link 2010, ADNR 2010).

Across North America, reports of invasive species have increased exponentially in the late 20th century due to increased globalization (Ebbert and Byrd 2002, Carlson and Shephard 2007). It is unknown exactly when invasive species were first introduced into SITK. Studies documenting invasive plant species in the park and removal of unwanted species were not undertaken until 2000. In 2004, EPMTs began removing pernicious non-native and invasive species found in and around the park, including along the park‘s trail system, as well as all of its historical landmarks and monuments (McKee 2004). Although surveys of all non-native and invasive plants have occurred in SITK since 2000, the goal starting in the 2004 field season was to accurately map disturbed areas of the park and to document any new non-native plant introductions by creating a park inventory (Link 2007). In 2006, focus shifted to re-treatment of specific invasive plants, monitoring to detect changes, and looking for new introduced species (Link 2007).

Data and Methods

Exotic plant management teams were established in order to control the introduction of non-native and invasive plant species in the National Park System. The Alaska EPMT trains existing park staff, partially funds seasonal park staff, and provides internship support positions in each park (Million and Rapp 2010). In addition to eradicating infestations and completing restoration projects, the EPMT maps accessible areas where invasive species are present (Rapp 2005). EPMT GIS data and observations from SITK invasive species management reports, compiled following each field season, were the main source of data for this assessment. Information was also gleaned regarding other invasives (e.g., marine and freshwater species, mammals, birds) from noted observations and park staff communication.

Data collection and invasive monitoring of non-native and invasive plant species officially began in SITK in 2004 with an inventory and baseline of these species established in the 2004-2005 seasons. Starting with the 2006 season, work shifted from inventory to control, including re-treatment, monitoring, and identification of new invasive species (Rapp 2006). Areas of focus included the most frequently used trails, coastline, the high-traffic footbridge, and the historic battle site (Figure 21). While there has been some variation in survey effort and extent from year to year, effective control and management has been consistent according to McKee (2004) and Rapp (2006).

Figure 21. Map of SITK, reproduced from Auer and Link (2010).

Current Condition and Trend

<u>*Didymo* status</u>

Photo 5. *Didymosphenia geminata*. EPA photo (2011).

Didymosphenia geminata (Photo 5), commonly referred to as *Didymo*, is an invasive and nuisance benthic diatom that can form masses extending over 1 km once established, persisting for several months at a time (Spaulding and Elwell 2007, Whitton et al. 2009). *D. geminata,* also known as ―rock snot” or ―toilet paper algae,” produces extracellular stalk material that attaches to stream bottoms and covers them with thick fibrous benthic mats; blooms of this species can completely cover surfaces, which may reduce invertebrate production and also inhibit oxygen penetration, thus risking damage to incubating salmon eggs (Spaulding and Elwell 2007, USFWS 2007). Furthermore, these dense algal blooms block sunlight and disrupt ecological processes, causing a decline in native plant and animal life (EPA 2011). One of the main disseminators of *Didymo* is fishing equipment; boot tops, neoprene waders, and felt-soles in particular, which provide a site where cells can remain viable for up to 40 days even outside of an aquatic environment (Kilroy et al. 2006). As of January 2011, use of felt-soles is prohibited in fresh waters of Southeast Alaska in order to curb *Didymo*‘s spread (Dunker 2009).

Although native to parts of Alaska and much of the United States, *Didymo* occurred historically in northern latitudes only in low nutrient waters; now it can be found in more nutrient-rich water and at lower latitudes (EPA 2011). Climate change, local fishing, and increasing development near the town of Sitka, combined with continually rising park visitation have likely all contributed in some form to the growing prevalence of *Didymo* (C. Smith, pers. comm., 2011). In North America, historical reports of *D. geminata* are sparse and voucher specimens are uncommon. *D. geminata* also has a great potential to spread to other ecosystems (Spaulding and Elwell 2007). Figure 22 illustrates the potential for future invasion in Southeast Alaska and much of North America, given suitable didymo‘s habitat (EPA 2011).

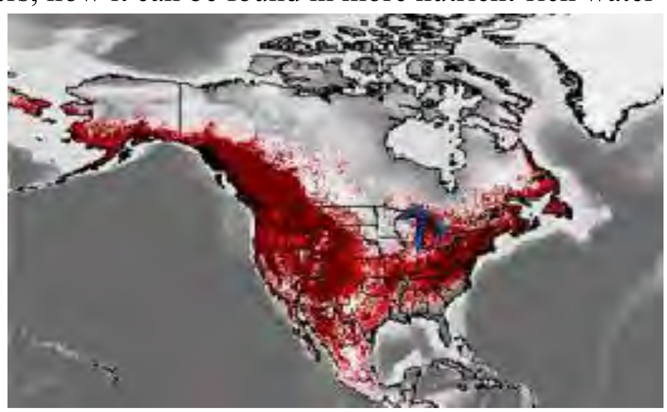


Figure 22. Map of North America showing regions where suitable stream habitats for *D. geminata* are located. Map by Kris McNyset, U.S. EPA.

Didymo has been found within the Indian River of SITK during invertebrate sampling (C. Smith, pers. comm., 2011). It was first detected in the Indian River in 2006 and has been present in subsequent surveys, except for 2009, a relatively high water year (USFWS 2007, NPS 2010; C. Smith, pers. comm., 2011). As of 2011, the abundance and distribution of *Didymo* in the Indian River appears stable. Though not currently abundant (C. Smith, pers. comm., 2011), attention should be paid to its presence. A clearly defined plan of action has not been established for addressing the spread, presence, or abundance of *Didymo* in the park. It is not currently a nuisance species although a comprehensive quantitative monitoring strategy for the Indian River should be developed in the future (C. Smith, pers. comm., 2011).

Although the diatom‘s environmental impact has been debated (Whitton et al. 2009), the spread of this non-native species cannot be denied. Over the past 20 years, the rate of *Didymo* spread has not shown any signs of slowing and it will most likely continue invading new northern environments (Whitton et al. 2009). Spaulding and Elwell (2007, p. 22) offer two recommendations for addressing the spread of *Didymo*: developing an outreach effort ―to inform and involve the public and government agencies"; and developing a research approach that will allow scientists to ―address the behavior and impacts of this organism."

Significant effort is put into reducing the risk of spread to additional rivers. Bothwell et al. (2006) postulate that some of the severe nuisance problems involving this invasive species may decrease naturally as seen on Vancouver Island located further south. In the meantime, Whitton et al. (2009) suggest it is important to monitor *Didymo* and prevent its spread while studying its ecology to develop control measures suitable for river management.

Area Infested With Non-native and Invasive Flora

Throughout Alaska, over 330 non-native plant species have been documented, accounting for approximately 15% of the total flora (Carlson and Shephard 2007, Carlson et al. 2008), with new non-native species documented every year. Non-native plant surveys have been carried out on NPS lands in Alaska since 2000. Surveys provide baseline data used in creating and establishing long-term control plans for invasive plant species in the National Park System. A variety of different invasive and non-native plant species have been introduced into SITK in recent years (Auer and Link 2010) (refer to Appendix 4 for a current plant species list for SITK). These plants are introduced to the park by visitors, through the escape of ornamentals from lawns and gardens in the town of Sitka (Photo 6), and through construction and maintenance activities in the park (Photo 7). Invasive plants usually occur in open, previously disturbed areas. Forested areas are heavily shaded, providing protection against most invasive species, since most are ruderal species, adapted to disturbed sunny environments (C. Smith, pers. comm., 2011). Table 8 summarizes the extent (area) of specific invasive plant species using GIS data from the Alaska EPMT.

Photo 6. An infestation of Japanese knotweed in a private garden near the boundary of SITK (NPS photo).

Photo 7. Japanese knotweed with clustered flowers in summer months (NPS photo).

Table 8. Summary of key invasive plant species found in and around SITK including area and percentage of land cover based on the most current EPMT 2010 tables and GIS shapefiles from Auer and Link (2010).

Common Name	Scientific Name	Area (m^2)	Percentage of total survey area (%)
perennial cornflower	*Centaurea montana*	47	0.0085
mouse-ear chickweed	*Cerastium fontanum*	836	0.1505
snow-in-summer	*Cerastium tomentosum*	17	0.0030
foxglove	*Digitalis purpurea*	2,130	0.3836
oxeye daisy	*Leucanthemum vulgare*	393	0.0707
yellow toadflax	*Linaria vulgaris*	1,590	0.2862
reed canarygrass	*Phalaris arundinacea*	28	0.0051
common plantain	*Plantago major*	1,287	0.2317
Japanese knotweed	*Polygonum cuspidatum*	3,309	0.5958
common buttercup (tall buttercup)	*Ranunculus acris*	10,386	1.8702
creeping buttercup	*Ranunculus repens*	226,625	40.8089
common sheep sorrel	*Rumex acetosella*	117	0.0210
birdseye pearlwort	*Sagina procumbens*	1,593	0.2868
European mountain-ash (Rowan tree)	*Sorbus aucuparia*	55,468	9.9882
common dandelion	*Taraxacum officinale* ssp. *officinale*	118,677	21.3703
white clover	*Trifolium repens*	71,141	12.8104
none	None	60,768	10.9426
other	Other	924	0.1663
Total:		555,333	100

In SITK, the number of known invasive plant species remains low at around 30 species as of 2010 (Auer and Link 2010). However, the number has been growing since 2004 when a total of nine non-native plant species were documented in the park, the same number found in the original surveys of 2000 (Densmore et al. 2001, McKee 2004). Although high-traffic areas within the park may appear to be dominated by invasive species, most invasions occur only near disturbed areas, with the exception of European mountain ash (C. Smith, pers. comm., 2011).

The areas surveyed for invasive plant species in SITK included all park trails as well as other areas of anthropogenic disturbance such as parking lot edges and the developed area around the Visitor Center. Particular attention was paid to the presence of Japanese knotweed, which was originally documented in 2000 and is a species of concern due to its ability to spread along riparian corridors (Shaw and Seiger 2002). Another species of particular concern for the EPMT is creeping buttercup, which has been a mainstay in the park since the earliest surveys. Creeping buttercup is the most widespread invasive species in the park, making its control a management priority since it aggressively displaces native plant species (Rapp 2006, Auer and Link 2010). However, buttercup is mostly confined to high-traffic trail areas and infrastructure (C. Smith, pers. comm., 2011). Other significant species of concern include European mountain-ash and reed canary grass (*Phalaris arundinacea*), both due to their potential to spread and displace native species, especially in areas of slight disturbance (Rapp 2006).

Although not confirmed within SITK boundaries as of 2010, reed canary grass, yellow toadflax (*Linaria vulgaris*), and perennial sow thistle are three species in particular that have either been historically found outside of the park or on nearby islands (Carlson and Shephard 2007). *Spartina* spp., a fast-growing marshwater genus of cord-grass, has not yet been discovered in Alaska, but studies on northerly spread along the coast suggest that *Spartina* spp. could spread from existing infested areas and become established in many Alaskan estuaries (Morgan and Sytsma 2010). It is important to continue monitoring for these species in particular to avoid introducing them inside the park boundaries. According to Morgan and Sytsma (2010), if introduced, the *Spartina* spp. population should be eradicated to eliminate exponential growth. Successful eradications, although rare, have occurred in sites that were less than one acre in size (Morgan and Sytsma 2010).

European mountain ash is well-established in the coastal rainforest areas of the park, an otherwise natural area (native plant community, free of development). This species‘ seeds are spread continually by birds such as thrushes and waxwings and by small mammals (Dickinson and Campbell 1991). It is also commonly used as an ornamental tree in Sitka, representing a persistent seed source.

A management plan for mountain ash removal in the park is currently being developed (C. Smith, pers. comm., 2011). Although herbicides are not presently being used in the park, SITK may be a candidate for herbicide use in the future (C. Smith, pers. comm., 2011). A potentially effective removal method is the frill method, in which an herbicide is applied to exposed cambium or where the tree is felled and the herbicide is applied to the cut stump to prevent resprouting (AKEPMT 2012).

The small size of SITK makes it relatively easy to monitor and control invading plant species, but Auer and Link (2010) suggest that park managers remain vigilant. Cost increases exponentially and control feasibility decreases each year a non-native species is left to spread unchecked (Link 2008, NPS 2009). SITK has been fortunate thus far in avoiding major infestations of non-native and invasive species, but eradication programs as well as EPMT surveys must continue. Extremely invasive species such as Japanese knotweed must be the focus of ongoing monitoring and control (C. Smith, pers. comm., 2011). In some cases, available resources must be put towards control efforts that will prove most beneficial. For example, control of Japanese knotweed or European mountain ash may take precedence over species such as common dandelion (*Taraxacum officinale*), which may present a never-ending battle with little gain in ecological protection (C. Smith, pers. comm., 2011).

Weighted Invasive Score (Flora)

The identification of species with the greatest potential for establishment and spread was highlighted as a necessary action in a strategic plan for noxious and invasive plant management in Alaska (Carlson and Shephard 2007). Most non-native species that are introduced are not well-adapted to the new environment and do not establish viable populations (Taylor and Hastings 2005). Furthermore, many of these species have rather limited dispersal capabilities, thereby increasing the chance of successful control in small populations. Additionally, introductions usually involve a small number of individuals and smaller populations are much more susceptible to extirpation through human eradications (Taylor and Hastings 2005). Of those species that can become established, only a small subset proceeds to invade native ecosystems (Taylor and Hastings 2005). These highly invasive plants effectively compete for resources and usually have aggressive reproductive strategies (Schrader and Hennon 2005). For example, certain species may be abundant seed producers or sprout aggressively. In other species, such as Japanese knotweed, rhizomes or vegetative pieces can facilitate spreading (Carlson et al. 2008). Invasive plants frequently create dense-growth thickets and release viable seed that can remain in soils for more than three years. When there is ground disturbance, many of these opportunistic seeds take root, germinate, and push out native plant communities, although some invasives do not need such disturbances (Schrader and Hennon 2005).

Invasiveness assessment models generally consist of a series of questions evaluating spatial characteristics, biological characteristics, known or potential impacts on important resources (e.g., biodiversity, water resources, etc.), and ease of control (Carlson et al. 2008). The ranking systems are generally designed to be ―robust, transparent, and repeatable in order to aid land managers and the broader public in identifying problematic non-native plants and for prioritizing control efforts" (Carlson et al. 2008, p. 3). As with many ranking systems, these ranks are somewhat subjective and may change gradually over time as new or revised information becomes available (Carlson et al. 2008). Essentially, these rankings can be used by land managers to help determine treatment priorities given limited resources.

Alaska non-native plant species are ranked on a scale of zero to 100 (Carlson et al. 2008, ANHP 2011) with values falling between 22 and 87 as of 2011. Of the species found to date in SITK, three have an invasive ranking of 60 or greater, indicating a significant threat for invasion. Individual values for SITK can be found in Table 9. The ranked species range from known harmful species, such as Japanese knotweed with a score of 87, to the more benign pineapple weed (*Matricaria discoidea*), with a ranking of 32 (Schrader and Hennon 2005). Presence or absence of certain species in specific years could be due to misidentification by staff and volunteers, or simply due to overlooking the species (C. Smith, pers. comm., 2011).

Table 9. Summary of invasive plant species found near SITK, presence inside the park, years of observation and invasiveness weed rankings. Table modified from Auer and Link (2010) and Carlson et al. (2008).

Common Name	Taxon	Inside park?	Source of Observation (a)	AK Weeds Ranking (b)
Shepherd's purse	*Capsella bursa-pastoris*	Yes	2, 9	40
Perennial cornflower	*Centurea montana*	Yes	4, 5, 6, 7, 8, 9	not ranked
Mouse-ear chickweed	*Cerastium fontanum*	Yes	2, 4, 5, 6, 7, 8, 9	36
Snow-in-summer	*Cerastium tomentosum*	Yes	5, 6, 7, 8, 9	not ranked
Lambsquarters	*Chenopodium album*	Yes	2	37
Foxglove	*Digitalis purpurea*	Yes	1, 2, 3, 4, 5, 6, 9	51
Oxeye daisy	*Leucanthemum vulgare*	Yes	1, 2, 3, 4, 6, 7, 8, 9	61
Yellow toadflax	*Linaria vulgaris*	Yes	4	69
Campion	*Lychnis/Silene*	Yes	4	42
Apple	*Malus pumila*	Yes	4, 5, 6, 7, 8	not ranked
Pineapple weed	*Matricaria discoidea*	Yes	2, 3, 4, 6, 8, 9	32
Forget-me-not	*Myosotis scorpiodes*	Yes	4, 5, 6, 7, 8, 9	54
Reed canarygrass	*Phalaris arundinacea*	No	4, 8, 9	83
Common timothy	*Phleum pratense*	Yes	2, 4, 8, 9	56
Common plantain	*Plantago major*	Yes	1, 2, 3, 4, 5, 6, 7, 8, 9	44
Annual bluegrass	*Poa annua*	Yes	2, 8	46
Kentucky bluegrass	*Poa pratensis*	Yes	2, 8	52

Table 9. (continued) Summary of invasive plant species found near SITK, presence inside the park, years of observation and invasiveness weed rankings. Table modified from Auer and Link (2010) and Carlson, et al (2008).

Common Name	Taxon	Inside park?	Source of Observation (a)	AK Weeds Ranking (b)
Black bindweed	*Polygonum convolvulus*	Yes	2, 8	50
Japanese knotweed	*Polygonum cuspidatum*	Yes	1, 2, 3, 4, 5, 6, 7, 8, 9	87
Sweet cherry	*Prunus avium*	Yes	4, 5, 6, 7, 8, 9	not ranked
Creeping buttercup	*Ranunculus repens*	Yes	1, 2, 3, 4, 5, 6, 7, 8, 9	54
Rugosa rose	*Rosa rugosa*	Yes	5, 6, 7, 8, 9	72
Common sheep sorrel	*Rumex acetosella*	Yes	1, 4, 5, 6, 7, 8	51
Curly dock	*Rumex crispus*	Yes	4, 8, 9	48
Bitter dock	*Rumex obtusifolius*	Unknown	1	48
Birdseye pearlwort	*Sagina procumbens*	Yes	4, 8, 9	39
European mountain-ash	*Sorbus aucuparia*	Yes	2, 3, 4, 5, 6, 7, 8, 9	59
Perennial sow thistle	*Sonchus arvensis*	No	4	73
Common dandelion	*Taraxacum officinale*	Yes	1, 2, 3, 4, 5, 6, 7, 8, 9	58
Red clover	*Trifolium pratense*	Yes	2, 4, 8, 9	53
White clover	*Trifolium repens*	Yes	1, 3, 4, 5, 6, 7, 8, 9	59

(a) Sources of observation
1 = 2000 baseline Invasive Plant Inventory
2 = 2002 AKNHP Vascular Plant Survey
3 = 2004 EPMT Invasive Plant Inventory
4 = 2005 EPMT Invasive Plant Inventory
5 = 2006 EPMT Invasive Plant Inventory
6 = 2007 EPMT Invasive Plant Inventory
7 = 2008 EPMT Invasive Plant Inventory
8 = 2009 EPMT Invasive Plant Inventory
9 = 2010 EPMT Invasive Plant Inventory

(b) Alaska invasiveness ranking based on the threat to native ecosystems in Alaska from low (0) to high (100) (Carlson et al. 2008). Invasiveness scores:
>80 = Extremely Invasive
70-79 = Highly Invasive
60-69 = Moderately Invasive
50-59 = Modestly Invasive
40-49 = Weakly Invasive
< 40 = Very Weakly Invasive

Individual invasiveness rankings were obtained from the Alaska Natural Heritage Program (ANHP 2011), maintained by the University of Alaska Anchorage, and Carlson et al. (2008). Not all species found in Alaska were assigned a rank in the ANHP (2011) or Carlson et al. (2008) ranking system. The lack of a score does not necessarily imply a lack of invasiveness; but rather, some species were not prioritized for these reports. Species without a weed ranking were excluded from calculations of a weighted invasive score. The developed equation used for the calculation of a weighted invasive score is:

$$\text{Weighted Invasive Score (WIS)} = \frac{\sum(Areasp * Ranksp)}{\sum(Areasp)}$$

Data on species area within the park were available for 14 specific species with invasiveness rankings (Auer and Link 2010, Carlson et al. 2008). The species with the five highest invasive ranks can be found in Table 10. The overall park weighted invasive score was 50.

Table 10. Weighted invasive score (WIS), number of invasive species, and top five invasive species (by rank) for SITK (Data from AKEPMT 2010). Invasive rankings (in parentheses) from Carlson et al. (2008) and ANHP (2011).

WIS	Species	Top Five Species by Invasive Rank (Confirmed Within Park)
50	14	1. Japanese knotweed (*Polygonum cuspidatum*) (87)
		2. Rugosa rose (*Rosa rugosa*) (72)
		3. Yellow toadflax (*Linaria vulgaris*) (69)
		4. Oxeye daisy (*Leucanthemum vulgare*) (61)
		5. European mountain-ash (*Sorbus aucuparia*) (59) & White clover (*Trifolium repens*) (59)

The scoring methodology presented above does not take into account the percent cover of each species. To explore including percent cover, a weighted invasive score was also calculated for the most recent available year of data (2010).

$$\text{Weighted Invasive Score (WIS)} = \frac{\sum(Areasp * Percent\ Coversp * Ranksp)}{\sum(Areasp * Percent\ Coversp)}$$

When taking percent cover into account using the EPMT GIS data, the weighted invasive score increased to 55 (AKEPMT 2010).

The overall weighted invasive score of 50 and the modified score of 55, based on inclusion of percent cover, only serve as an informal evaluation of invasive plants in the park. Percent cover can possibly change from year to year. Furthermore, because of annual EPMT monitoring and control of a park encompassing such a small area, the overall weighted invasive score may not tell the entire story of the condition of invasives. Weighted invasive scores calculated for each year may not necessarily be comparable because of variation in effort or survey area.

<u>Non-native Fauna</u>

Non-native fauna have become established in areas in and around SITK. There are several non-native mammal and fish species that adversely affect the SITK ecosystem. Avian species such as European starlings (*Sturnus vulgaris)*, Eurasian collared doves (*Streptopelia decaocto*), and brown-headed cowbirds (*Molothrus ater*) have been sighted near Glacier Bay National Park (GLBA), located about 100 miles northwest of SITK (Rapp 2009). Martens *(Martes americana*) and red squirrels (*Tamiasciurus hudsonicus*) are two mammalian species of concern. Red squirrels were introduced to the region in the 1930s and are now commonplace, while the rough skin newt (*Taricha granulose*), although not documented in the park, was accidentally released in the town in 2004 and has become established in the area (Miller 2005, Link 2009).

Within Alaska, there is growing concern about the invasion of non-native marine species. Species already present along the west coast of North America but not yet in Alaska include European green crab (*Carcinus maenas*) and Chinese mitten crab (*Eriocheir sinensis*) (Rapp 2009). Sitka is considered a ―hot-bed" for invasive aquatic species, although most have not been seen in the park (C. Smith, pers. comm., 2011). Crescent and Jamestown Bays, part of Sitka Sound, have been identified as potential green crab habitat and the NPS will begin setting traps to determine their presence in 2012 (C. Smith, pers. comm., 2011). Non-native tunicate species have already been detected in Alaskan waters, including the introduction of *Didemnum vexillum* (Photo 8) in 2010 in Sitka (Rapp 2009, NOAA 2010). Seen as a major detriment to the marine ecosystem, *D. vexillum* is a species of particular concern to SITK since its discovery just outside of the park in 2010 (NOAA 2010). Major steps have been taken to educate the public about its dispersal and efforts are underway to prevent its spread (Cohen et al. 2011).

Photo 8. *Didemnum vexilum* on oyster lantern net (left) at Whiting Harbor Oyster Farm, Sitka, AK, 12 June 2010, with close-up (right) (photos by Linda Shaw, NOAA 2010).

European black slugs (*Arion ater*), New Zealand mud snails (*Potamopyrgus antipodarum*) and several other species of invasive slugs are encroaching on SITK, if not already present (Koons et al. 2003, Forsyth 2004, Gotthardt 2010). Atlantic salmon (*Salmo salar*) is a marine fish species that has the potential to invade, given the proper habitat. The softshell clam (*Mya arenaria)* is an aquatic mussel species of concern in Alaska. Several other organisms including spiders, earthworms, ants, and other non-native invertebrates are all likely present within the park (Koons et al. 2003). Although some information on these species remains speculative, awareness may be the first step in identifying potential future problems.

Although invasion of non-native fauna seems to be relatively slowed based on increased awareness and education about harmful invasive species, there is still great potential for new introductions (McClory and Gotthardt 2008). It is unrealistic to believe that all invasive mammals, birds, aquatic species, and other organisms can be completely eradicated to reflect pre-settlement conditions. It is more realistic to continue to monitor present invasive species and new introductions so an already precarious situation does not become an even bigger problem. It may also be just as important to preserve native species as it is to eradicate non-native invasives. As seen with current trends, Alaska may become even more susceptible to harmful invaders in the future; therefore, the only defense may be increased awareness through monitoring programs and continued community involvement.

Threats and Stressor Factors

The major threats and stressors to park-wide environmental conditions include: climate change, increasing development near the park, rising park visitation, and the diverse and growing urban landscape. All of these stressors may have implications for the spread or source of invasive species. First, climate change is a major factor in the spread and impact of invasive plant species (Tausch 2008). Changing seasonal temperature patterns and precipitation distribution also tend to favor invasive species (Brooks et al. 2004). This could lead to simplified ecosystems, stressed native plant species, and a slow northerly shift of native plant communities (Tausch 2008). Warming trends in much of Alaska are expanding invasive plant ranges and invasive potential (Densmore et al. 2001).

Increasing park development is a major factor that influences the spread and introduction of certain opportunistic invasive species. Construction activities provide establishment sites for several early invasive plant species. While development within the park has been kept to a minimum, construction occurred on Sawmill Creek Road and the nearby bridge in 2008 and 2009, with further construction work performed around the Visitor Center (Auer and Link 2010). According to Auer and Link (2010), there is a possibility that these construction projects may have introduced new invasive plants to these areas. Efforts to reduce anthropogenic disturbance such as habitat disturbance and tree removal will continue to facilitate an expanding native plant community (Link 2007).

Construction fill and topsoil control are often contaminated with invasive plants; management of these, as well as fertilizer that encourages growth of certain invasives, would promote retention of much of SITK‘s rich species diversity (Densmore et al. 2001). Densmore et al. (2001) suggests that quick revegetation of disturbed areas would also be beneficial to preserving species richness. Aquatic threats include cruise ships, shipping, and cargo vessels, all of which have the potential to transport invasive species in ballast water when discharging at an Alaskan port (Koons et al. 2003). Sitka is also a major port for fishing vessels, which travel between the lower forty-eight states and various parts of Alaska and can transport non-native and invasive organisms on their hulls or in cooling systems.

Rising visitation rates could potentially spread invasive plant seeds which can attach to clothes and shoes, thereby introducing the organism to other areas unintentionally (Densmore et al. 2001, Koons et al. 2003). Increased summer traffic and a steady influx of cargo ships are likely responsible for many newly introduced species (Auer and Link 2010). Areas of high visitor usage such as the Visitor Center, Russian Memorial, battle site, and trails continue to be areas of high priority, especially in the removal and treatment of invasive species (Link 2009, Auer and Link 2010).

Data Needs/Gaps

Rapp (2006) mentions that, as of 2006, no park-wide documentation of non-native insects or diseases has occurred in SITK. This information could potentially help park managers better understand and manage other potential threats to SITK‘s natural and cultural resources. Further study of increasing human disturbance on these communities would also be beneficial to park management. Ongoing mapping of invasive plant species is needed to track and monitor changes in condition over time.

Overall Condition

SITK staff assigned all measures (*Didymo* status, area infested with invasive flora, weighted invasive score, and exotic fauna) a *Significance Level* of 3, indicating they are of high importance in understanding the overall condition of invasive flora and fauna in SITK.

Didymo Status

The status of *Didymo* in SITK was assigned a *Condition Level* of 1 due to the relatively low occurrence of didymo in SITK streams. Although cited by park staff as an area of concern, it is not currently considered a nuisance species (C. Smith, pers. comm., 2011).

Area Infested With Non-native and Invasive Flora

SITK‘s area infested with invasive flora measure was assigned a *Condition Level* of 1. The park is generally in good condition with regard to invasive species, especially compared with national parks within the contiguous United States (C. Smith, pers. comm., 2011). Extremely invasive species such as Japanese knotweed and those that have recently increased in number such as European mountain ash should be monitored closely by EPMT and park staff (C. Smith, pers. comm., 2011).

Weighted Invasive Score (Flora)

The invasive plant species weighted invasive score was assigned a *Condition Level* of 1 for this assessment. Based on the available EPMT reports (2004-2010) and communication with Craig Smith, a stable trend can be reported. There have been few introductions over the past decade, and several invasive species eradications. However, as seen with the AKEPIC data portal, numbers of invasive species have dramatically increased in Alaska within the past 30 years, especially in Southeast Alaska. While the *Condition Level* reflects the current observations within SITK in recent years, it is important to be aware of potential future threats. This measure may be more useful in future assessments when scores can be compared over time; a higher score would indicate an increase in invasive plants and subsequent habitat degradation whereas a lower score would signify habitat improvement and invasive species eradication.

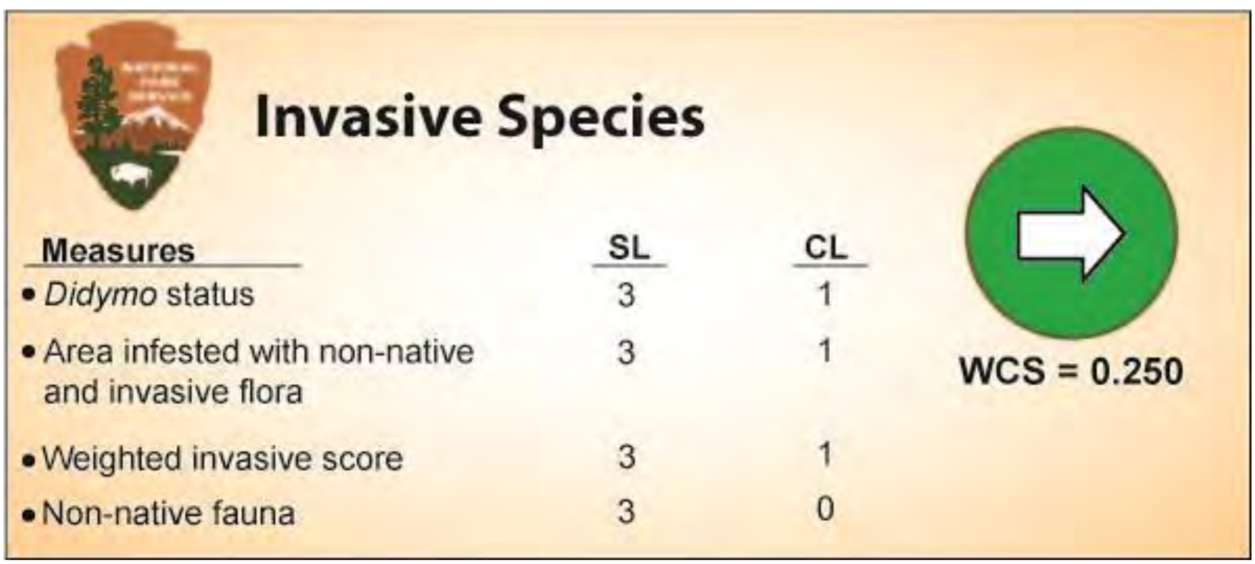
Non-native Fauna

SITK‘s non-native fauna measure was assigned a *Condition Level* of 0. Although there are undoubtedly non-native fauna species present within SITK, little monitoring and control have been conducted for these species (C. Smith, pers. comm., 2011). Currently, non-native fauna are not of major concern in SITK.

Weighted Condition Score (WCS)

The Weighted Condition Score (WCS) for SITK non-native and invasive species was determined to be 0.250, which indicates good overall condition with a stable trend. The control and annual monitoring of invasive and non-native species in SITK has resulted in a generally stable trend based on the available years of data (2000-2010) (C. Smith, pers. comm., 2011). The overall goal to eliminate invasive flora and non-native fauna is ideal but probably not feasible. Invasive plants have been found in most park locales and non-native marine, freshwater, as well as mammalian species have also been documented. According to several EPMT field season reports (McKee 2004, Rapp 2006, Link 2009, Auer and Link 2010), invasive non-native plant species occur mainly in disturbed areas including trails, roadways, the town of Sitka and many popular high-traffic areas within the park. There have been eradications of several invasive species within the park in recent years including perennial cornflower and snow-in-summer in 2009 (Link 2009), as well as three additional species in 2010 (Auer and Link 2010). Effort has also varied between years due to the level of field staffing and time of year. An increased focus on control and monitoring of aggressive species has been a priority in recent years (Link 2008). Although invasive populations are being controlled through increased awareness and action, there is still a cause for concern.

Sources almost universally state that early detection, regular monitoring, and recognition of susceptible areas are all essential in effective invasive species management (Densmore et al. 2001, Tausch 2008, Auer and Link 2010, C. Smith, pers. comm., 2011). However good-natured or idealized, these ideas present a challenge to managers because it is usually not possible to understand ecosystem susceptibility until after the particular species has arrived (Tausch 2008). Prevention is always the best, least damaging, least expensive, and most effective method of invasive species control. Unfortunately, constraints on personnel or resources may not allow for constant year-round monitoring, and in some cases it is not practical. When prevention is simply not possible, a contingency such as rapid response must be undertaken — using a quick calculated strategic approach to restoration and rehabilitation (Tausch 2008). SITK has many areas that are yet unaffected by non-native species, especially in many of the established native plant communities (Auer and Link 2010). Therefore, continued monitoring and restoration plantings are encouraged (Auer and Link 2010). The maintained landscape of SITK should 'reflect the local flora and cultural history of the area" (Auer and Link 2010, ADNR 2010, p. 4).



<u>Sources of Expertise</u>
The primary source of local information and reviews for this section was Craig S. Smith, SITK biologist.

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4.5 Anadromous and Nonanadromous Freshwater Fish

Description

The Indian River flows through SITK, providing habitat that sustains several species of anadromous fish and a few nonanadromous fish species (Arimitsu et al. 2003). Anadromous fish are those that spend their adult life at sea and return to their natal freshwater streams to spawn (NPS 2009). The anadromous species that inhabit SITK use the Indian River for migration, spawning, incubation of eggs, and rearing of young (NPS 2009). Park staff explain the lifecycle and spawning activities of Pacific salmon to park visitors each summer during the peak of the salmon run within the Indian River (Hyra 1987). Anadromous species include four species of Pacific salmon (pink salmon [*Onocorhynchus gorbuscha*, Photo 9], Chinook salmon [*O. tshawytscha*], chum salmon [*O. keta*], and coho salmon [*O. kisutch*]), the anadromous form of rainbow trout (*O. mykiss*) known as steelhead, Dolly Varden char (*Salvelinus malma*), and possibly cutthroat trout (*O. clarkii*) (Williams 2001, NPS 2009, ADF&G 2011b). Pacific salmon species, but not steelhead, spawn only once and die, contributing vital ―marine-derived nutrients" (MDN) to a nutrient-poor river system. This is essential in the maintenance of a healthy watershed, thus this resource should be protected in SITK (Eckert et al. 2006).

Photo 9. Pink salmon swimming upstream to spawn in the Indian River in SITK (NPS 2010).

Nonandromous species or those that live in the Indian River year round, include resident rainbow trout (*O. mykiss*), threespine stickleback (*Gasterosteus aculeatus*), and coastrange sculpin (*Cottus aleuticus*) (NPS 2009). The Alaska Department of Fish and Game (ADF&G) considers Chinook salmon that enter the Indian River as strays, most likely from the local fish hatchery, but they probably came into the river occasionally in the past, as sockeye salmon (*O. nerka*) do today (ADF&G, Eric Coonradt, Fisheries Biologist, pers. comm., 2011). This component focuses on the freshwater portion of the Indian River as it flows through the park, as this is where most resource management concerns and monitoring efforts related to SITK fish are invested.

Measures

- Resident fish (nonanadromous) population status
- Anadromous fish population status (native escapement)

Reference Conditions/Values

A precise definition of reference conditions for anadromous and nonanadromous fish in the Indian River is not yet developed. However, SITK's resources management plan suggests, broadly, what the reference condition may be for Indian River fish: ―Ecological processes and conditions associated with the Indian River and adjacent riparian areas are protected. A healthy, viable river and riparian system sustains wildlife populations. Water quality and minimum streamflows needed to sustain the dependent biota of the Indian River, particularly native fish populations, are maintained" (NPS 1999, p. 16).

Data and Methods

NPS (2011) analyzed the streamflow characteristics of the Indian River and historic diversions used by the Sheldon Jackson College hatchery.

Eckert et al. (2006) summarized and analyzed data obtained on fish and macroinvertebrates from the Neal et al. (2004) report.

Paustian and Hardy (1995) measured channel morphology, described streambed characteristics, and evaluated fish habitat using a hierarchical stream habitat classification approach.

The ADF&G is responsible for compiling the Anadromous Waters Catalog and Atlas (AWC), which identifies the streams, rivers, and lakes used by anadromous fish for spawning, rearing, or migrating in Alaska. Fish surveys are important for managing habitat and sport, personal use, subsistence and commercial fisheries (ADF&G 2011a). The ADF&G conducts surveys in the area by aircraft, boat and on foot.

Park staff and the SEAN Inventory and Monitoring program continue to monitor streamflow (water quantity) and water quality of the Indian River.

Current Condition and Trend

Resident Fish Population Status (nonanadromous)

Year-round resident fish of the Indian River include rainbow trout, coastrange sculpin, and threespine stickleback (NPS 2009). However, other fish species may use portions of the Indian River (freshwater) during a part of their life cycles. For example, the eggs of eulachon (*Thaleichthys pacificus*), which spawn primarily in the intertidal zone and estuarine areas, may exist in the freshwater environment of the river. Juvenile Pacific staghorn sculpin (*Leptocottus armatus*) are plentiful in the lower tide-affected river. Other species that may spend a portion of their life cycle in freshwater are sharpnose sculpin (*Clinocottus acuticeps*) and rainbow smelt (*Osmerus mordax dentex*). Species present in sampling efforts that also may spend time in freshwater include cutthroat trout, shiner perch (*Cymatogaster aggregata*), Pacific herring (*Clupea pallasi pallasi*), and starry flounder (*Platichthys stellatus*). These, however, are not considered resident species. There are currently no population (abundance) data available on these resident fish species within SITK. The only information available is ―presence only" data (i.e., a species was found during sampling efforts). Eckert et al. (2006) compiled data from three different studies on species found within the Indian River. These data are presented in Appendix 5.

Anadromous Fish Population Status (native escapement)

Fish habitat in the Indian River is well suited for pink and chum salmon (Paustian and Hardy 1995). Pink and chum salmon enter the park at the mouth of the Indian River every year between the middle of July through September to spawn (NPS 2011). Pink salmon are likely native to the Indian River (Coonradt, pers. comm., 2011); pink salmon numbers are much higher than any other salmon species found in the river (Table 11) (ADF&G 2011c). Coho salmon then enter the park and rest in large pools from September through November, but spawn outside of the park (NPS 2011).

There is no escapement goal on salmon returns for the Indian River (Eckert et al. 2006). Escapement data has been obtained by indices of foot and aerial surveys since the mid-1980s; the ADF&G typically conducts these surveys during the peak of the salmon run (Shaul and Tydingco 2006). These indices differ from weir and mark-recapture methods in that they are applied estimates and not exact.

Table 11. Peak escapement estimates from foot and aerial surveys in the Indian River. Unpublished data received from Eric Coonradt of the ADF&G (ADF&G 2011c).

Year	Pink Salmon (aerial count)	Chum Salmon (foot count)	Coho Salmon (foot count)
1962	500	--	--
1963	300	--	30
1964	300	--	--
1965	500	--	--
1966	300	--	--
1967	150	--	--
1968	--	--	--
1969	500	--	--
1970	--	--	--
1971	300	--	--
1972	200	--	--
1973	500	--	--
1974	--	--	--
1975	--	--	--
1976	--	--	--
1977	17,500	--	--
1978	2,000	--	--
1979	5,991	--	96
1980	2,893	125	110
1981	16,000	4	32
1982	12,000	--	125
1983	21,000	--	55
1984	6,000	--	175
1985	11,000	--	86
1986	10,000	286	93
1987	3,000	1372	53
1988	1,651	556	--
1989	--	--	603
1990	1,750	500	20
1991	--	--	--
1992	--	--	--
1993	800	--	--
1994	55,000	--	--
1995	14,000	--	--
1996	185,000	500	--
1997	260,000	--	--
1998	66,000	--	--

Table 11. (continued) Peak escapement estimates from foot and aerial surveys in the Indian River. Unpublished data received from Eric Coonradt of the ADF&G (ADF&G 2011c).

Year	Pink Salmon (aerial count)	Chum Salmon (foot count)	Coho Salmon (foot count)
1999	160,000	500	--
2000	85,000	2210	--
2001	90,000	1000	--
2002	68,000	152	--
2003	270,000	--	--
2004	73,000	2215	--
2005	376,200	300	--
2006	46,000	360	583
2007	75,600	690	--
2008	75,000	--	--
2009	87,400	300	--
2010	91,000	--	138

Historically, the Indian River did not have a wild population of Chinook salmon (NPS 2011). However, since at least 2000, Chinook salmon have been spawning successfully in the Indian River (NPS 2011). These spawning Chinook are strays from the local fish hatchery and should not be considered a natural species by park management (NPS 2011). The local hatchery is planning to increase the production amount for three species of salmon including chum (10 million), coho (250,000), and pink (3 million) salmon (SSSC 2010).

Threats and Stressor Factors

Low flow events that occur in the Indian River during incubation or the intergravel phase of life limit salmon production, as well as salmon movement upstream (Nadeau and Lyons 1987, NPS 2011). Spawning salmon lay their eggs in a redd, a streambed depression created by spawning salmon in which the eggs are deposited (Nadeau and Lyons 1987). During periods of low flow, redds can become exposed to dangers such as freezing temperatures, dewatering, oxygen depletion, or a lack of metabolic waste removal (Nadeau and Lyons 1987). Periods of low flow are especially dangerous for pre-emergent fry, as their lack of mobility jeopardizes their survival (Nadeau and Lyons 1987). Invasive species can enter the park through fish farms, aquaculture, transport on or in ballast water from ships or fishing vessels, live seafood trade, or sport fishing gear (Eckert et al. 2006). The Aquatic Nuisance Species Management Plan, developed by the ADF&G, hopes to prevent invasions of such species and to minimize their impact on the ecosystem (Eckert et al. 2006). The northern pike (*Esox lucius*) and Atlantic salmon pose a threat to the native salmon and trout populations in portions of Alaska (Fay 2002). Approximately 3,000 farmed Atlantic salmon are estimated to be immigrating into Alaska every year from accidental releases in Washington and British Columbia (Eckert et al. 2006). Farmed Atlantic salmon are a threat because they bring in disease, colonize, destroy habitat, interbreed, and compete with or prey upon native salmonid species (Eckert et al. 2006). This particular species has not been detected in SITK but their eventual arrival is likely (Eckert et al. 2006). Both the Atlantic salmon and the northern pike also threaten resident fish such as rainbow and steelhead trout (Fay 2002). According to Eckert et al. (2006), no comprehensive survey exists on aquatic invasive species in SITK. Atlantic salmon could possibly spawn successfully in the Indian River (G. Smith, pers. com., 2012).

Harmful algal blooms (HABs) result from a boom in the population of phytoplankton that produce toxins (Eckert et al. 2006). Mortality among marine birds, mammals, fish, and illness in humans can result from HABs (Eckert et al. 2006). Symptoms and effects can vary; for example, some are paralytic, diarrhetic, or neurotoxic to the body (Eckert et al. 2006). HABs have been documented for centuries, but documentations have been increasing in frequency and location over the last few decades (Eckert et al. 2006). Algal blooms that are not —harmful” can still be problematic to an ecosystem.

The diatom *Didymosphenia geminata*, also called didymo or rock snot, was first detected in the Indian River in 2006 and has been present in subsequent surveys, except for 2009, a relatively high water year (USFWS 2007, NPS 2010; C. Smith, pers. comm., 2011). Didymo can form dense mats and exhibit invasive behavior by dominating streambeds. Also, in extended low water periods in the spring, the filamentous green algae *Ulothrix zonata* can form dense blooms, particularly in the lower river within the park. High bloom density has been seen trapping and killing emerging salmon fry. Neal et al. (2004) found pennate diatoms (species of algae) to be another species that tend to dominate the algal community of the Indian River. Further upstream from the park, cyanobacteria (blue-green algae) accounted for most of the algal biomass during sampling efforts, while other green algae and cyanobacteria (blue-green algae) species dominate within the park (Neal et al. 2004). Twenty-four species of algae were identified at the Indian River at Sitka gauging station (15087700), with 35 species at the Indian River near Sitka station (15087690) during this study. The species that dominated were the cyanobacteria *Pseudanabaena* spp. and the diatom *Hannaea arcus* (Neal et al. 2004). Continued benthic diatom monitoring (2006-2010) has detected over 50 species in the Indian River within the park (NPS 2010). The park‘s understanding of algal blooms in the Indian River would benefit from more research and monitoring, specifically on biomass cover (C. Smith, pers. comm., 2011). However, from 2006 to 2010, G. Smith sampled benthic diatoms in the Indian River, recording the relative abundance of many different species along with several other species characteristics such as pH tolerance, oxygen requirement, and motility. Additional analysis of this data and future monitoring may be needed to detect trends in diatoms and other algae in the river.

<u>Data Needs/Gaps</u>

Sufficient sampling across years, within years, and among populations of anadromous and nonanadromous fish alike would better inform condition of these resources. Without these data, it is not possible to confidently state the condition of fish populations in the Indian River. However, the ADF&G estimates of pink salmon provide some indication of the population status. Chum and coho data are quite limited and contain several gaps in annual counts. Chinook salmon found in the river are considered to be hatchery strays, but their status year to year is not well understood. Data is severely limited for all other species of fish in the Indian River, in terms of understanding population or abundance. Studies of anadromous fish to date have not distinguished naturally spawned fish from hatchery strays.

<u>Overall Condition</u>

SITK staff assigned each of the measures a *Significance Level* of 3, indicating they are both important for understanding the overall status of fish in the Indian River within SITK.

Resident Fish (Nonanadromous) Population Status

SITK's resident fish measure was assigned a *Condition Level* of n/a. Currently there are no studies that contain information specifically on the abundance or population of resident fish within SITK. Without data, an analysis on the population status is not possible. However, little concern, outside of low flows, exists regarding the habitat for resident fish in the Indian River.

Anadromous Population Status (Native Population Status)
SITK's anadromous population status measure was assigned a *Condition Level* of n/a. There are consistent sampling data within and across years, but this consistent data only exists for pink salmon. Without information on all anadromous species, a condition level cannot be determined for the entire population. A primary concern regarding anadromous salmon is the influx of hatchery bred salmon. These salmon threaten to alter the conditions for natural run salmon that depend on spawning resources in the river.

Weighted Condition Score (WCS)
The Weighted Condition Score (WCS) (see Chapter 3 for methodology) for freshwater water quality in SITK was not determined due to an overall lack of available data and no specific population numbers (reference conditions) that would indicate healthy populations of resident or anadromous fish.

Periods of low flow threaten all species of fish within the Indian River as well as encourage algal blooms. This is an area of high concern, but without proper data, it is inappropriate to make an assertion on just how severe the situation is for fish within the Indian River. Additionally, the increased input of hatchery fish will have an effect on the dynamic of the river, but without proper data it will difficult to determine the severity of the threat.

Anadromous and Non-anadromous Fish

Measures	SL	CL
• Resident fish (Non-anadromous) populations status	3	N/A
• Anadromous fish population status (Native population status)	3	N/A

WCS = N/A

Sources of Expertise

The primary source of local information and reviews for this section was Craig S. Smith, SITK biologist. Geof Smith, former SITK biologist, also reviewed this section and provided additional information.

Eric Coonradt, ADF&G fisheries biologist, Sitka, Alaska office, provided data and information regarding salmon in the Indian River.

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4.6 Forests

Description

SITK lies within the spruce-hemlock-cedar region of the temperate rainforest biome (USFS 1993). Despite its small size, the park contains a variety of habitat types including temperate and semi-temperate rainforests, open meadow areas, estuary, the mouth of the Indian River, and uplifted beaches, all generally characteristic of southeastern Alaska (Lipkin 2005). Western hemlock, red alder, and Sitka spruce are present within the park; these are common canopy species in the area‘s temperate rainforest (USFS 1993). Other small tree or shrub species present in the park include Sitka alder (*Alnus viridis*), crab apple (*Malus* spp.), Sitka willow (*Salix sitchensis*), and several currant species (*Ribes* spp.) (USFS 1993, 1994). Photo 10 offers an example of a SITK forest scene.

Photo 10. Forest in SITK (NPS Photo).

Western hemlock/blueberry is the most common forest plant association in SITK (USFS 1993). This plant association is also one of the most abundant forest types in all of Alaska, usually found from near sea level to just below the cold mountain hemlock zone, primarily on steeper hills and mountain slopes (Martin et al. 1993, as cited in USFS 1993). Western hemlock/devil‘s club is another forest plant association dominated by western hemlock trees that is found in the park. The third forest plant association, Sitka spruce/devil‘s club-salmonberry is dominated by Sitka spruce, but hemlock and spruce regeneration is common in the understory. Lipkin (2005) more broadly groups these three associations as the spruce/western hemlock closed-canopy forest type.

The park contains stands of the western hemlock/blueberry plant association in various successional stages due to human disturbance impacts and wind-throw events (USFS 1993). In addition to forest types, the park contains plant community types representing various successional stages that, with the stabilization of land surfaces and lack of major disturbances over time, could succeed to forest types (USFS 1993). These plant associations include red alder/salmonberry, red alder, and red alder-Sitka Spruce/Salmonberry (USFS 1993).

The northeastern corner of the park exhibits characteristics of old growth forest, including multiple canopy layers, trees of varying diameters, large-limbed trees, snags, and old coarse woody debris on the ground (USFS 1993). The floodplain portion of SITK is primarily composed of alder species (USFS 1993). In comparing park forest stands to nearby non-park old growth forest stands, USFS (1993) found that trees were taller in the park. Two large spruce trees in the park are thought to be between 400 and 500 years old, representing the oldest trees within

SITK (Bill Dougan, USDA Forest Service, pers. comm., November 1992, as cited in USFS 1993). The overstory in most of the park was estimated to range between 100 and 125 years old (USFS 1993). Figure 23 shows the species composition of trees at least one inch in diameter within five SITK ecological units (USFS 1993, 1994).

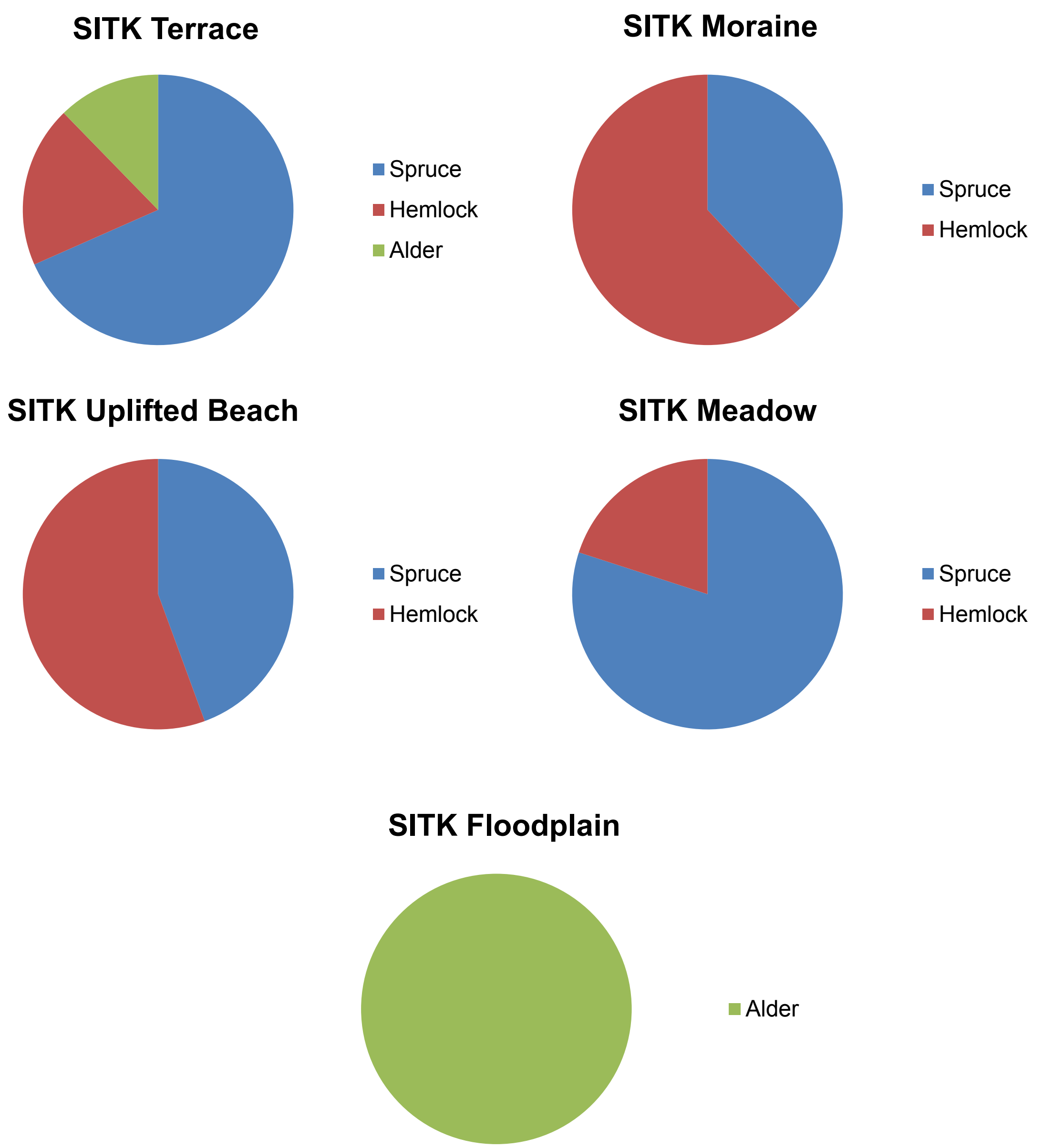


Figure 23. Species composition for five ecological units within SITK (terrace, moraine, uplifted beach, meadow, and floodplain) based on the number of trees of 1-inch diameter and larger on timberland" (USFS 1993, 1994). SITK also contains a small number of yellow-cedar trees, not reflected in these samples.

Measures

- Native species regeneration
- Insect and disease damage
- Understory species diversity

Reference Conditions/Values

There is currently no reference condition for this component. Ideally, the reference condition would be the forest composition and indications of natural forest regeneration in the park prior to human disturbance, as well as detailed information on the levels of insect and disease damage over a long period of record. However, there is no specific data defining this. Despite this, current regeneration rates, tree ages, and comparison of nearby non-park old growth stands to in-park old growth stands as reported in the early 1990s by the USFS (1993, 1994) can provide some indications for the overall status of the forested areas of the park.

It is important to note that in addition to insect and disease damage to SITK's forests, portions of the park were once logged and cleared for trails, roads, and structures (USFS 1993). The park has also experienced several human-related disturbance factors (reproduced from USFS 1993):

> Trail construction and maintenance;
> Understory clearing by jail inmates (ceased in the 1920s);
> Gravel dredging and spoils deposition;
> Upstream stabilization work and road construction for project;
> Use of park for defense (Tlingit-Russian battle and WWII machine gun pits);
> Asphalt plant and tailings deposition;
> Sheldon Jackson College cottages;
> Sawmill Creek Road;
> Fallen timber sawing and clearing throughout the park in the past;
> Trimming in interpretive and recreational areas of park;
> Use of park by hikers, joggers, anglers, pets, etc.

According to Lipkin (2005), there is a possibility that flora may have changed in sections of the park as a result of isostatic rebound or succession.

Data and Methods

USFS (1993) conducted a three-phase inventory of SITK, which included pre-mapping, field verification, and final field mapping of the park's landforms, vegetation, geology, and soils. The purposes of the inventory were to classify and map ecosystems of the vascular and non-vascular plant species at SITK and to develop a forest stand profile/history with recommendations on stand health and potential hazard trees in high visitor use areas. The recommendations, descriptions, and comparisons of vegetation between the park and the nearby Chatman Area of the Tongass National Forest provide the most recent assessment of forest health in SITK. However, this information is now over 18 years old.

USFS (1994) set out to create a baseline inventory of the vegetation resources within SITK, and to assess these resources. Potentially hazardous trees and trees that were affected by insect damage were mapped along the trails in the park (USFS 1994). This report addresses forest regeneration within the various park ecological units, as well as damage from disease and insects.

Schrader and Hennon (2005) created an assessment of invasive aquatic and terrestrial organisms that have been documented, as of 2004, in the ecosystems of Alaska. This provides information about potential threats to the forests of SITK.

According to the USFS (2010), every year (1989-2010) in either July or August the U.S. Forest Service's State and Private Forestry, Forest Health Protection (FHP) program, together with the Alaska DNR Division of Forestry's Forest Health Protection Program, conducts statewide aerial detection surveys. These surveys are meant to detect signs of damage, and may not accurately display the actual area of the damage (NPS PDS 2011). The resulting annual report offers information on specific beetles, defoliators, invasive pests, stem diseases, shoot blights and cankers, foliar diseases, and root diseases. Although the scale of this information is not particularly applicable to the small size (scale) of the park, it represents the general trend of forest damage agents in the vicinity that are detectable by aerial survey methods.

Current Condition and Trend

Native Species Regeneration

The forests in SITK are primarily composed of western hemlock and Sitka spruce, with alder as the primary shrub/understory species (USFS 1994). According to Lipkin (2005, p. 7), "the total number of vascular plant species listed as Expected in SITK is 169, of which 156 (93%) are now either verified by a voucher (114) or by reliable reports of experienced botanists (42)". However, USFS (1993) stated that SITK lacked common undergrowth species typical of the western hemlock/blueberry association, likely because of human impacts on the vegetation.

A few plant associations represent the forest types in SITK: western hemlock/blueberry, western hemlock/devil's club, and Sitka spruce/devil's club-salmonberry. Other plant associations found in the park are either grasses or estuarine communities. Western hemlock regenerates densely, best in well-mixed organic soil and mineral soils, and will likely become dominant if the forest is left undisturbed (USFS 1994). USFS (1993) compared the percent cover of western hemlock/blueberry association within the park to the unmanaged old growth stands across the Chatham Area of the Tongass National Forest. They found that blueberry and low-growing plants were low in numbers within the park compared to areas outside the park. Another parameter, constancy, measures how frequently a specific species occurs within the plant association. Figure 24 compares the constancy of various species in the two locations (USFS 1993).

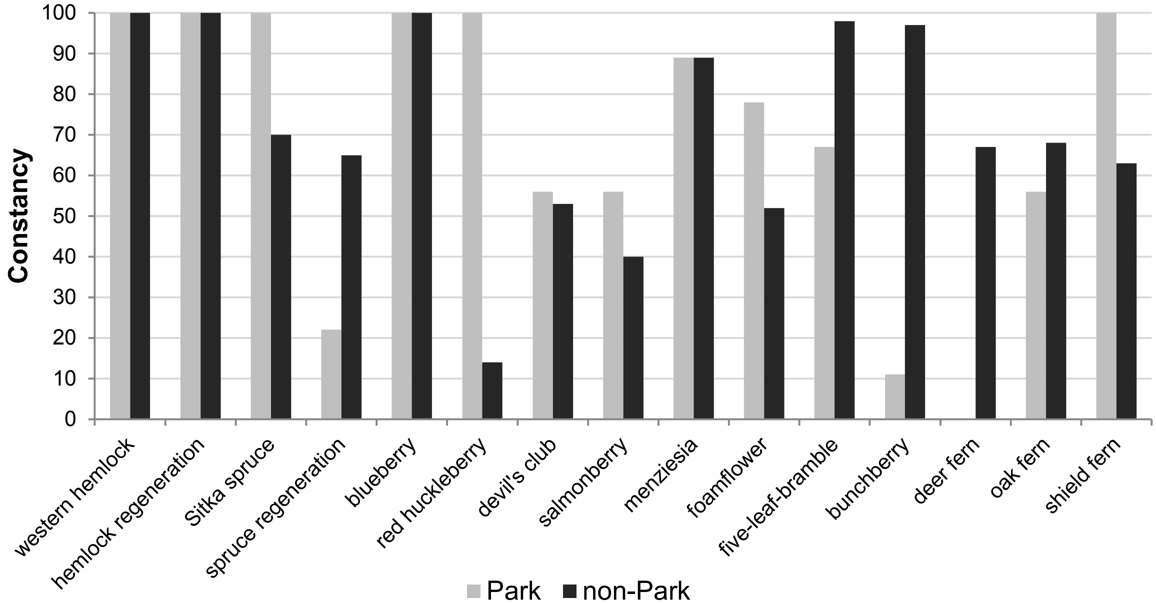


Figure 24. Comparative constancy values for western hemlock/blueberry plant associations in SITK, and unmanaged old growth stands across the Chatham Area of the Tongass National Forest (non-park). The park contained nine plots and the non-park contained 88 plots. Reproduced from USFS (1993).

The western hemlock/devil‘s club association is dominated by western hemlock with an understory of devil‘s club (USFS 1993). USFS (1993) found this association in the uplifted beach and stream terrace ecological units within SITK. The canopy of this association in SITK is generally closed, with frequent gaps; however, because of hemlock regeneration the canopy is multi-layered in areas.

The Sitka spruce/devil‘s club-salmonberry association is located on the patches of land that likely have soil water movement form old channels of the Indian River (USFS 1993). Sitka spruce dominates this forest type, and devil‘s club and salmonberry dominate the understory. Hemlock and spruce regeneration is common; however, the undergrowth for this association is also sparse because of human disturbance within SITK (USFS 1993). The percent cover of devil‘s club, salmonberry, three-leaf foamflower, bunchberry (*Cornus canadensis*), and oak and shield fern (*Gymnocarpin dryopteris* and *Dryopteris austriaca*) was much lower in the park plots. Figure 25 compares the constancy of species in the Sitka spruce/devil‘s club-salmonberry association within SITK to the old growth stands across the Chatham Area of the Tongass National Forest (USFS 1993). The comparison illustrates the low level of understory growth in the park compared with the non-park vegetation plots, especially in blueberry, bunchberry, deer fern and oak fern.

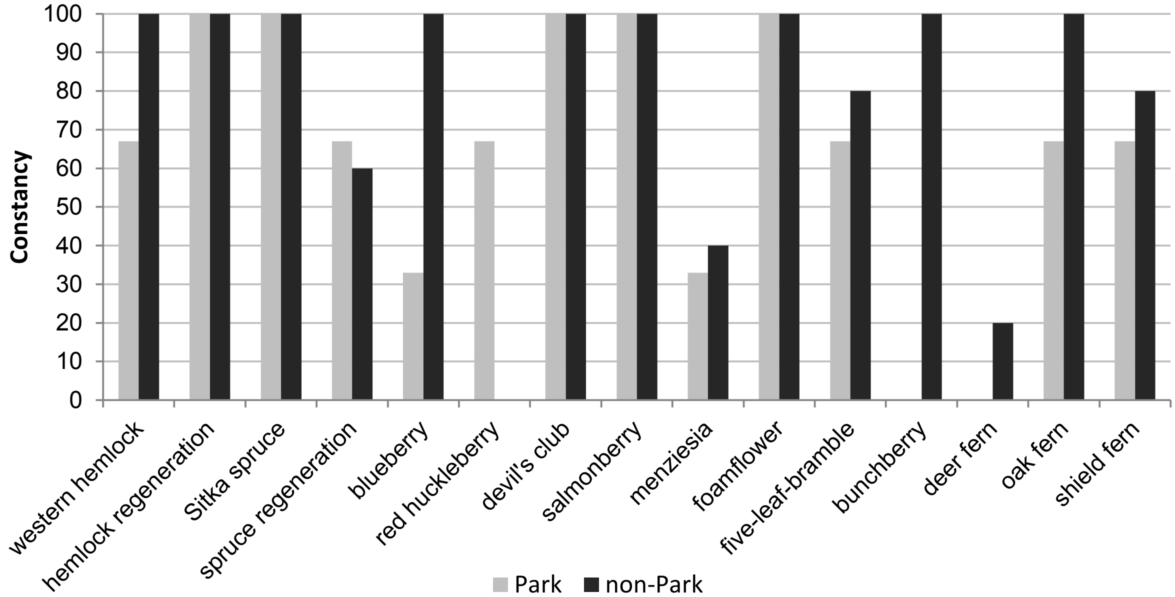


Figure 25. Comparative constancy values for Sitka spruce/devil's club-salmonberry plant association in SITK and in the unmanaged old growth stands across the Chatham Area of the Tongass National Forest (non-park). The park contained three plots and the non-park contained five plots. Reproduced from USFS (1993).

The Sitka spruce/salmonberry association is another forest type with an open canopy. This community is considered successional in the park, established in response to past disturbance. USFS (1993) did no comparison between park and non-park plots of percent cover or constancy of understory vegetation. The various red alder associations are successional stages as well that may succeed to other plant associations, typically to a spruce association, and also were not evaluated for regeneration or percent cover.

Insect and Disease Damage

NPS (2006) management policy states that the understanding, maintenance, restoration, and protection of natural resource integrity, leaving natural and native processes unimpaired, is a core belief of the NPS. Therefore, these natural processes, including insects and diseases, are allowed to proceed unless they are somehow altered by human activities. In the case of non-native or invasive species and diseases, removal and remediation is undertaken.

A primary forest damage agent in SITK and in the nearby Sitka spruce forests of the Tongass National Forest is the spruce needle aphid (*Elatobium abietinum*) (abbreviated SNA in USFS aerial survey GIS data) (Photo 11). It is an invasive insect species that is suspected to have arrived in Alaska approximately 80 years ago (Schrader and Hennon 2005). Also, with increased temperatures from global climate change, Schrader and Hennon (2005) suggest that it has caused more damage in Alaska in recent history. It affects all species of spruce, but causes the most damage to Sitka spruce trees (USFS 1993). The spruce aphid feeds on older needles of the Sitka spruce and then progresses to newer needles, which causes defoliation (USFS 2008). Evidence of illness first appears in the inner lower portions of spruce crowns (USFS 1994). According to USFS (1994), feeding intensity is greatest in the late winter and early spring months but often remains undetected, going unnoticed until dying and falling needles begin to appear in the later months of the year. Aphid population fluctuations and damage are a natural occurrence in the park (USFS 1993). The female can reproduce asexually, which contributes to exploding populations that generally follow mild winters (USFS 1994). Fluctuations are dependent on fall and winter temperatures, because aphids feed actively during these months, and are vulnerable to sub-freezing temperatures (USFS 1994). Schrader and Hennon (2005) and USFS (2009) consider this insect an invasive forest pest but, according to the NPS, it is considered a naturally occurring native pest species.

In 1992, there was a substantial defoliation of Sitka spruce in the park from an aphid outbreak (Figure 26) (USFS 1994). The USFS aerial forest damage surveys also detected SNA damage in SITK and surrounding areas during 1994, 2001, and 2002. Notable SNA damage areas were detected within 10 km of the park via USFS aerial surveys during 2001 and 2004 (Plate 4). In 2007, little defoliation occurred around Sitka from the spruce aphid, and outbreaks seemed to be declining because of several cold winter events (USFS 2008). SNA damage was not detected in the USFS aerial survey data in the Sitka area from 2008 to 2010.

Photo 11. Spruce aphid, image courtesy of USFS FHP.

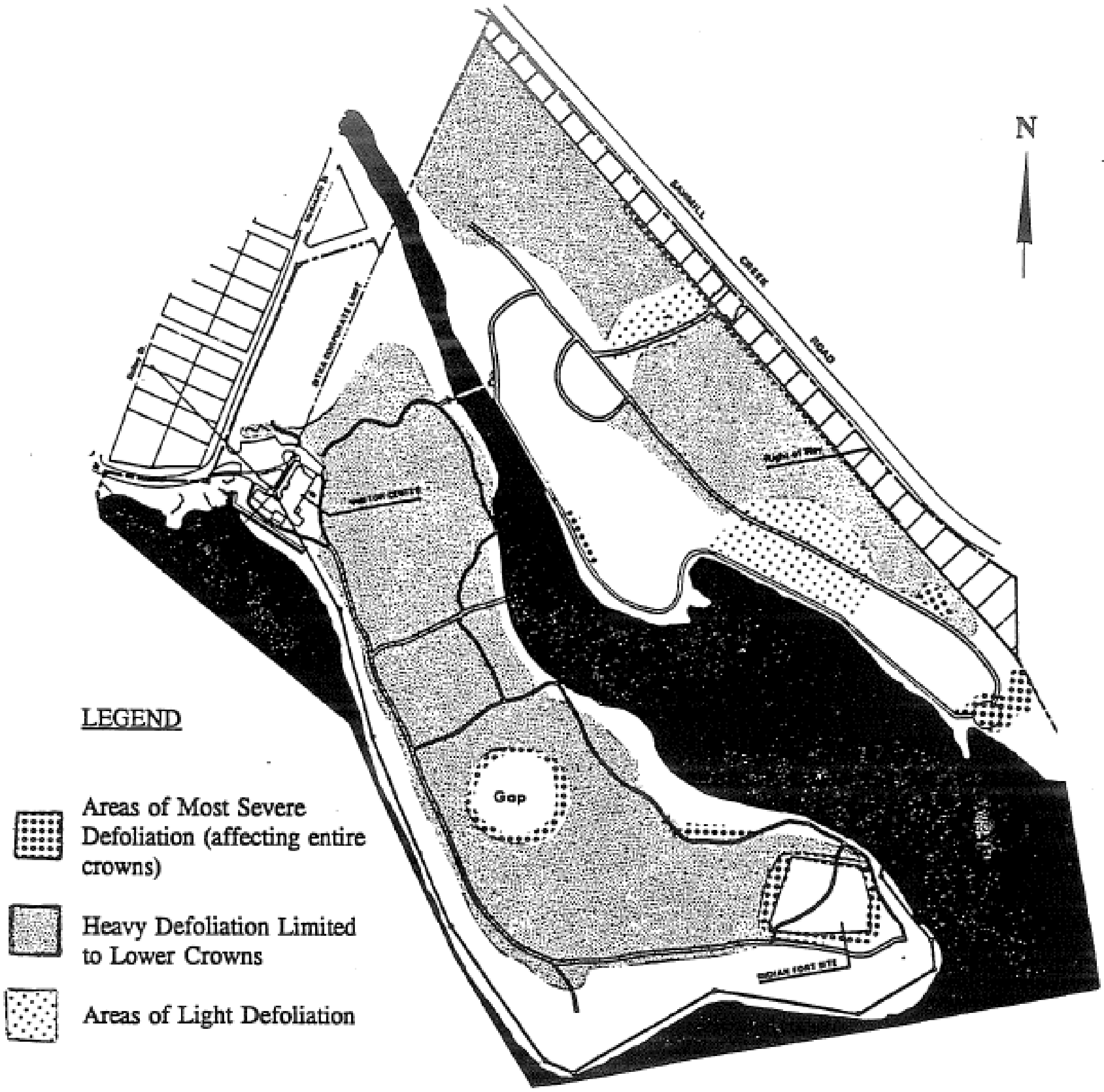


Figure 26. Spruce needle aphid defoliation observations from March 1993 after aphid activity in 1992 in SITK (USFS 1994).

Disease from pathogens (e.g., naturally occurring wood decay fungi, root diseases, dwarf mistletoe, canker fungi) generally goes undetected in aerial surveys (USFS 2010). The most common wood decay seen in the park is red belt fungus (*Fomitopsis pinicola*) (USFS 1993). Red belt fungus infects spruce and hemlock trees causing heart and sap rot, which interferes with the growth of the trees (USFS 1993). Two kinds of root diseases are present within SITK and affect all tree species: Annosus root disease (*Heterobaasidion annosum*) and Armillaria root disease (*Armillaria* spp.) (or shoestring root rot) (USFS 1993). Annosus root disease affects old growth trees, specifically western hemlock, by causing root rot and butt rot, growth loss, and tree mortality (USFS 1993). Armillaria root disease decomposes recently dead or dying trees by rapidly colonizing root systems (USFS 1993). Rarely is the disease the primary cause of mortality, but it may contribute to mortality in already stressed trees (USFS 1993).

Another damage agent, the hemlock dwarf mistletoe (*Arceuthobium tsugense*), is a common parasitic plant associated with western hemlock. It has uncommonly affected several Sitka spruce trees on the northwestern edge the park (USFS 1994). The hemlock dwarf mistletoe bears small seeds that the female plant shoots up into the air. These seeds adhere to branches and begin to thrive on the tree by inserting roots into the live tissues of the tree. Initially, infestation causes swelling, but after several years the branches experience distorted radial growth called witches-brooms and the upward growth of the tree is stunted (USFS 1994) (**Photo 12**). Hemlock dwarf mistletoe is a naturally occurring species in the park, and according to SITK and NPS management policy (NPS 2006), natural processes, including pests and diseases, are allowed to proceed unimpaired unless this process is altered by human activities. The USFS (1994) notes that hemlock dwarf mistletoe does not hinder any major management objectives; instead, it enhances structural diversity and wildlife habitat by creating gaps in the forest canopy, which allows new regenerating trees to take the place of dead trees. Figure 27 displays the distribution of the disease within SITK as observed in 1993. The present status of this disease is undocumented.

Photo 12. Hemlock tree with dwarf mistletoe in SITK (NPS Photo).

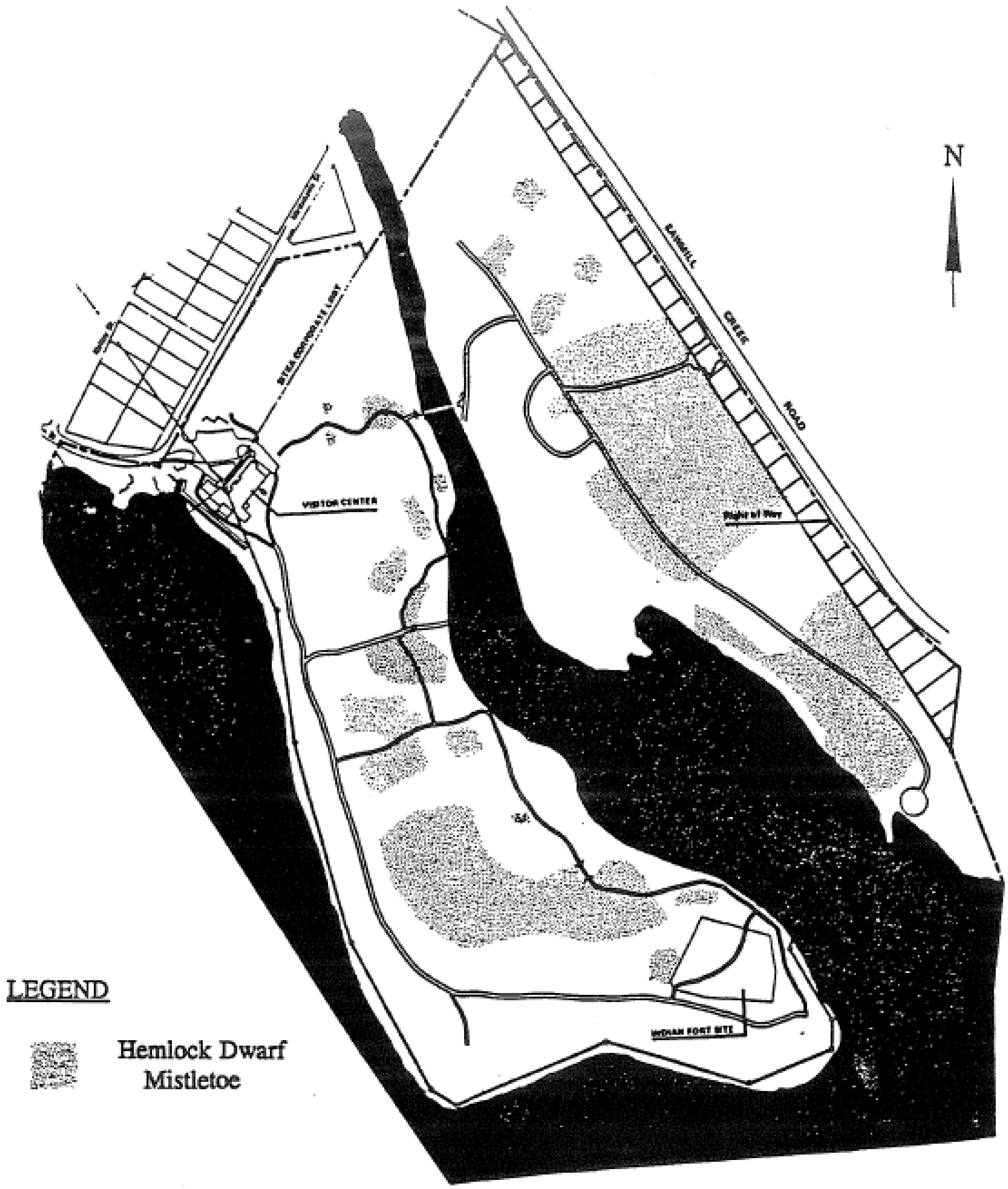


Figure 27. Observed 1993 distribution of hemlock dwarf mistletoe in SITK (USFS 1994).

Only in instances where there is a clear connection between human impact (including climate change) and increasing pathogens or pests (those that could be considered an unwanted impact) are removal efforts undertaken (C. Smith, pers. comm., 2012). Insects and diseases such as SNA and hemlock dwarf mistletoe are considered natural processes and are currently allowed to continue unimpaired within SITK.

Schrader and Hennon (2005) mention that trees lack genetic resistance to introduced diseases or pathogens because in many cases they did not co-evolve. Because of a relatively small number of native tree species in Alaska, it is possible that Alaskan forests may be at an elevated risk of infection due to a narrower genetic base (Schrader and Hennon 2005). Schrader and Hennon (2005) also note that tree pathogens have been introduced to Alaska but their spread has thus far been limited. They also mention that the North American Forest Commission's national database on invasive tree pathogens (EXFOR) has very few entries that currently threaten native Alaskan tree species. However, at least 13 pathogens not yet documented in Alaska have been identified as potential threats to native species such as spruce, cedar and pine. These include *Chrysomyxa abietis* (foliar rust of spruce) and the pine wilt nematode (*Bursaphelenchus xylophilus*) among others (Schrader and Hennon 2005). Introduced non-native insects such as sawyer beetles (*Monochamus* spp.) and amber-marked birch leafminers (*Profenusa thomsoni*) could also act as vectors for several diseases and pathogens, and are considered one of the most serious threats to Alaskan forest ecosystems (Mattson 1997, as cited in Schrader and Hennon 2005).

Understory Species Diversity

According to USFS (1993), blueberry, red huckleberry (*Vaccinium parvifolium*), rusty menziesia (*Menziesia ferruginea*), and western hemlock regeneration dominate the understory within the park moraine, lowlands, uplifted beach, and parts of the stream terrace. USFS (1994) reported that understory trees were becoming scarce and those that remained did not take advantage of the newly available space. Craig Smith (pers. comm., 2011) notes that alder is currently the primary understory species in the park. The understory appears to be more impacted by human disturbance than the forest canopy. It is strongly affected by social trails and compacted soils (C. Smith, pers. comm., 2011). This measure lacks both baseline data and current detailed information that could be utilized to detect change in understory species diversity. Baseline data exist for invasive and exotic species within SITK in Rapp (2006), but these data are explored more in depth in Chapter 4.4 of this report.

Threats and Stressor Factors

Insects and diseases are natural sources of tree damage and mortality. One agent that has caused significant damage to spruce trees is the spruce needle aphid. However, park managers must maintain the park's natural processes and leave this process to occur unimpaired. On the other hand, non-native invasive insects are the most serious threat to Alaskan forests, as well as forests in the rest of the United States (Mattson 1997, Schrader and Hennon 2005). These insects cause defoliation and tree mortality, and would readily trigger management action. Non-native insect species established in Alaska include the larch sawfly (*Pristiphora erichsonii*), alder woolly aphid (*Prociphilus tessellatus*), spruce needle aphid (*Elatobium abietnum*), and amber-marker birch leaf miner (*Profenusa thomsoni*) (Schrader and Hennon 2005).

USFS (1994) found that heart rot fungi were the most serious threat to the park of all diseases and insects, because they were the leading cause of potentially hazardous trees. Potentially hazardous trees are defined as trees or portions of trees that can fall and cause injury or damage to a potential target. These potentially hazardous trees pose a serious threat to the safety of park visitors, making it an important management issue to the park.

Introduced pathogens in Alaska pose a threat to SITK's forests. According to an assessment of the current status of invasive species in Alaska's ecosystems (emphasizing the two national forests in the state), several tree pathogens have been introduced into Alaska; fortunately, no Alaskan forests have been affected on a widespread scale (Schrader and Hennon 2005). This is because the available hosts for such diseases are limited in Alaskan trees. There are 13 known pathogens that would cause damage to the native tree species if introduced into Alaska, including foliar rust of spruce (*Chrysomyxa abietis*), cedar shot hole (*Didymascella chamaecypari*), resinous stem canker (*Cistella japonica*), foliar and stem cankering pathogen of cedars (*Seiridium cardinale*), root disease of cedar (*Phytophthora lateralis*), and foliar disease of birch (*Taphrina betulina*). Schrader and Hennon (2005) state that foliar rust of spruce species is the most threatening.

Currently, there are few invasive plant populations in Alaska, but in time, these populations are expected to expand and may compromise natural ecosystems and habitats (Schrader and Hennon 2005). The Alaska Exotic Plant Information Clearinghouse (AKEPIC) database and the Weed Ranking Program are examples of programs that work to rank and track invasive plant species within Alaska. For more information on these programs or non-native and invasive species in the park, refer to Chapter 4.4 of this report.

Urban landscape and developments near the park subject the forests and other vegetation communities to disturbance (USFS 1994). Portions of the park have been logged or cleared for trails and gardens (USFS 1994). Streveler (1969) notes that many of the large flat-topped logs found in SITK, specifically near the fort site, indicate selective logging possibly occurring in the early 1900s. Streveler (1969) found more recent evidence of selective logging at the southern edge of the forest north of the Indian River and, based on estimates, the logging occurred from about 1935 to 1940. Other forms of disturbance to the park include gravel dredging, understory clearance, soil deposition, stream stabilization, and road construction (USFS 1994). According to the USFS (1994), these types of disturbances limit the development of classic old growth within SITK.

SITK resource staff is in the process of identifying and mapping all of the social trails (walking trails beyond the established, maintained trails) in the park. The information resulting from these efforts will aid managers in determining how they might manage trails in the future. Resource staff have noted a significant number of social trails bisecting the park. These may be negatively affecting regeneration of understory forest species (C. Smith, pers. comm., 2011). The 1998 General Management Plan for SITK (NPS 1998) outlines management strategies to preserve the cultural conservation zone and lists social trails as a significant natural resource issue. This includes the creation of an informal trail system connecting Totem Trail loops to other major park trails (NPS 1998).

A natural factor affecting forest vegetation in the nearby Tongass National Forest is deer browsing; however, USFS (1993) noted that little deer browsing was apparent in their vegetation sampling and forest assessment at SITK, likely due to the frequent presence of humans and dogs.

Data Needs/Gaps

There are little to no data on the measures of native species regeneration or understory species diversity in the park. The information contained within the USFS (1993, 1994) reports is now over 17 years old. In order to understand how the SITK forest is changing, it would be valuable to reassess the condition of the forest to understand understory diversity and forest species regeneration rates.

Rapp (2006) mentions that as of 2006, no park-wide documentation of non-native insects or diseases has occurred in SITK. This information could potentially help park managers better understand and manage potential threats to SITK's forest resources.

Overall Condition

SITK staff assigned the measures native species regeneration and understory species diversity *Significance Levels* of 3, and the insect and disease damage measure a *Significance Level* of 2.

Native Species Regeneration

SITK's native species regeneration measure was assigned a *Condition Level* of 2. While there are no current regeneration data to compare with the information presented in the USFS (1993) ecological inventory, the authors of the inventory suggested that lack of development of undergrowth species in the Sitka spruce/devil's club-salmonberry association was likely due to disturbances caused by pets, people, and past park practices. They note that areas apparently not affected by these disturbances contain forbs and ferns in higher abundance. They also compared percent cover of vegetation plots in SITK to forest stands in the Chatham Area of the Tongass National Forest, and found that the park was lacking in some of the common undergrowth shrub, forb, and fern species.

Insect and Disease Damage

SITK's insect and disease measure was assigned a *Condition Level* of 0. While most of the damage documented to date is from native species, there are multiple considerations regarding forest damage in SITK. Damage can affect the aesthetic value of the park's forested areas, and in some cases, large snag (dead) trees resulting from insect and disease-caused mortality can present hazards to park visitors. It is unclear if the levels of insect and disease damage are typical of a healthy forest or if there may be some other stressor factors that are contributing to the current insect and disease damage. Since no large scale forest damage is apparent in the USFS aerial forest damage survey data, this measure was given a *Condition Level* of 0. There is some concern over dead trees because they can become hazardous depending on their proximity to trails, park infrastructure, and cultural or historic features, potentially putting park visitors at risk. The effects of non-native insect species and diseases are relatively low; however, more studies may be needed in order to understand the full effects of native and non-native insects and diseases.

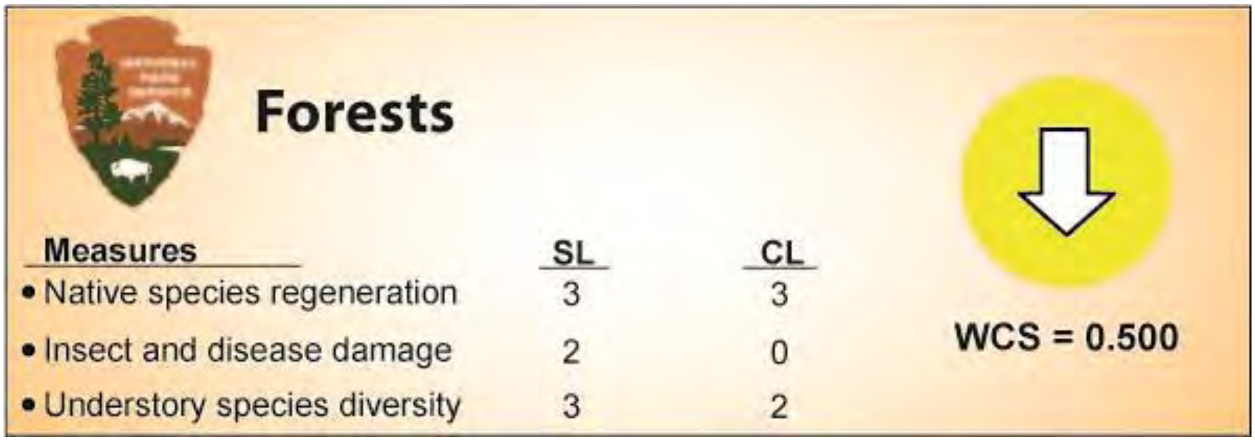
Understory Species Diversity

SITK's understory species diversity measure was assigned a *Condition Level* of 2. The understory within the park is heavily affected by social trails (walking trails off designated paths), and Craig Smith, SITK biologist, sees this as a large concern for the park's forest understory. The park is in the process of inventorying and mapping these trails (C. Smith, pers. comm., 2011).

Weighted Condition Score (WCS)

The Weighted Condition Score (WCS) (see Chapter 3 for methodology) for forests in SITK is 0.500. A WCS of 0.500 represents an overall condition that is of moderate concern. This moderate concern has the potential to increase within the park. Aphid populations increase with warming temperatures, and SITK has already seen increases in temperatures. In addition, visitor use in SITK will likely increase and cause more human disturbance within the park's understory.

Park management is currently mapping the social trails that threaten species regeneration and understory diversity in order to first understand the extent of social trail use. Further management action may be warranted to reduce the number and extent of these trails to protect forest regeneration in SITK.



Sources of Expertise

Craig Smith, SITK Biologist, provided local expertise and review of this assessment.

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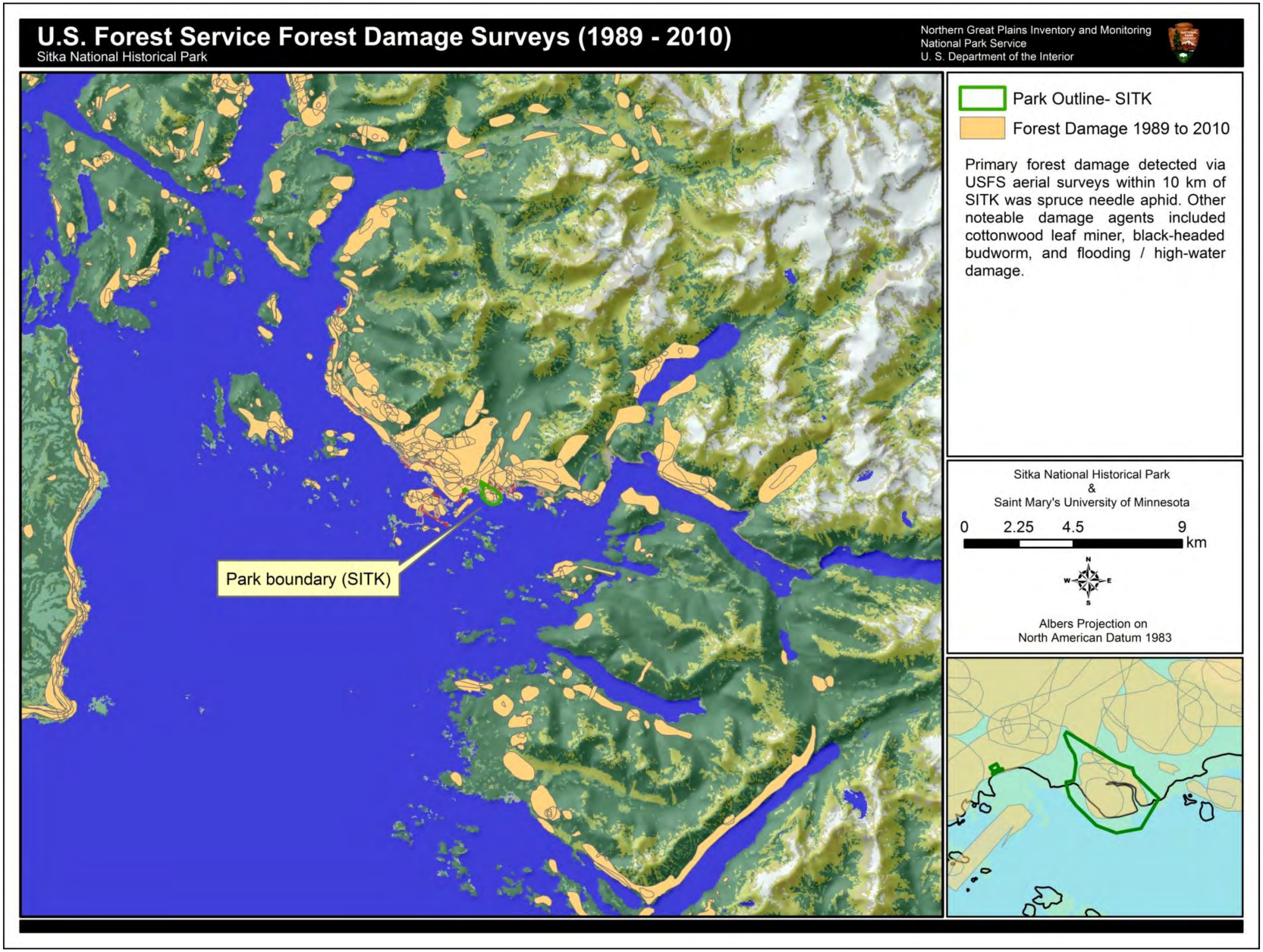

Plate 4. Cumulative forest damage from aerial surveys surrounding SITK (1989 to 2010) (USFS 2010). Note, primary damage represented here is from the spruce needle aphid, but other forest damage agents are represented as well.

4.7 Air Quality

Description

The air quality of southeast Alaska is generally believed to be among the most pristine in the world due to its low population densities, lack of large-scale industrial development, and vast wildland areas (Moynahan et al. 2008). However, this high air quality is currently threatened by global industrial pollution and local sources, such as cruise ships. The potential impacts of air pollution at SITK include diminished visibility for visitors, degradation of forest health, changes to ecological structure (e.g., replacement of pollution-sensitive species with pollution-tolerant species), alteration of soil and aquatic chemistry, and bioaccumulation of ecological contaminants (Furbish et al. 2000). Air quality is of high value to SEAN park managers, and contaminants from global sources are a growing concern due to their possible impacts on a wide variety of SEAN Vital Signs (Moynahan et al. 2008). SEAN has begun sampling air quality in SITK (Photo 13).

Photo 13. Air quality sampler (NPS photo).

Lichens are often used to monitor air quality since they absorb nutrients directly from their surroundings (Furbish et al. 2000, Blett et al. 2003). Relatively low levels of sulfur, nitrogen, and some heavy metals adversely affect many lichen species, causing changes in growth and reproduction, physiological processes (e.g., photosynthesis), and morphological appearance (Blett et al. 2003, USFS 2007). Some pollutants may even lead to the elimination of particularly sensitive species, altering lichen community composition (Blett et al. 2003, Schirokauer et al. 2008). Studies have found that sensitivity to air pollution among lichens varies by growth form. Fruticose or shrubby lichens are generally most sensitive, foliose or leafy lichens are moderately sensitive, while crustose or flat lichens are least sensitive (Blett et al. 2003). Epiphytic lichens from the genera *Alectoria*, *Bryoria*, *Ramalina*, *Lobaria, Nephroma*, and *Usnea* are thought to be some of the most sensitive (Blett et al. 2003).

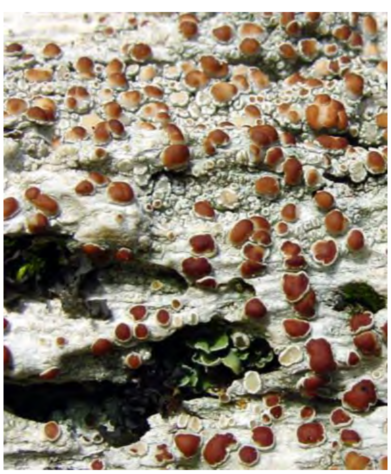

Photo 14. Lecanora xylophila (lichen) in SITK (NPS photo).

Lichens are considered an integral part of the temperate rain forest ecosystem of southeastern Alaska (LaBounty 2005). They play a key role in nutrient and hydrological cycles and are valuable sources of forage, shelter, and nesting materials for a variety of wildlife species (Blett et al. 2003). Lichen tissue sampling and community composition surveys have therefore been included as two key components of the SEAN air quality monitoring protocol (Schirokauer and Geiser 2009).

Measures

- Lichen contaminants
- Lichen community composition
- Nitrogen oxides
- Sulfur dioxide

Reference Conditions/Values

Baselines and standards from Tongass National Forest in Alaska and national forests in the Pacific Northwest for lichen contaminants and community composition are used as the reference conditions for this assessment. The NPS air quality standards are used for sulfur and nitrogen oxides (Table 12).

Table 12. National Park Service Air Resources Division air quality index values (NPS 2010).

Condition	Wet Deposition of N or S (kg/ha/yr)
Significant Concern	>3
Moderate	1-3
Good	<1

Data and Methods

Network monitoring reports and other literature were provided by park and SEAN staff. Sulfur and nitrogen oxide deposition data for the park were provided by David Schirokauer, project co-manager of the SEAN air quality monitoring program.

Current Condition and Trend

Lichen Contaminants

Some contaminants, such as nitrogen and sulfur, are both quickly absorbed and quickly leached out of lichens (Schirokauer et al. 2008). High nitrogen and sulfur concentrations are therefore strong indicators of current air pollution. Heavy metals, such as lead and zinc, may persist in lichen tissues for ten or more years, bioaccumulating over time (Furbish et al. 2000, Schirokauer et al. 2008). Elevated levels of heavy metals are rare in nature and are usually strong indicators of anthropogenic air pollution (Schirokauer et al. 2008). Metals vary in their toxicity to lichens and can be classified into three groups (Blett et al. 2003):

1) Class A metals (potassium, calcium, strontium) are characterized by a strong preference for O_2-containing binding sites and are not toxic;
2) Class B metals (silver, mercury, copper) tend to bind with nitrogen and sulfur containing molecules and are extremely toxic to lichens, even at low levels;
3) Borderline metals (zinc, nickel, lead) are intermediate, and can be detrimental by themselves or in combination with SO_2.

Sampling of lichens for contaminants occurred at one site within SITK in 2008 and 2009 as part of the SEAN monitoring program. The site is located along the Indian River in a mixed Sitka spruce-red alder forest with an understory of salmonberry. Of the three lichen species selected as bioindicators by SEAN, NPS staff collected two at SITK: *Hypogymnia inactiva* and *Platismatia glauca* (Photo 15). Samples were taken during the late summer near the end of the tourist season because bioaccumulation of contaminants is likely highest at this time of year (Schirokauer and Geiser 2009). Samples were tested for concentrations of various elements including nitrogen, sulfur, phosphorus, magnesium, aluminum, copper, mercury, lead, boron, and nickel (Schirokauer et al. 2008).

Photo 15. The lichens *Hypogymnia inactiva* (left) and *Platismatia glauca* (right) (photos courtesy of Karen Dillman, in Geiser et al. 2010).

Tissue analysis of lichen samples from SITK found levels of sulfur and nitrogen above the thresholds established by the U.S. Forest Service for Tongass National Forest for both *H. inactiva* and *P. glauca* (Figure 28; Schirokauer and Geiser 2009, Geiser et al. 2010). Phosphorous concentration in *P. glauca* was at the Tongass threshold level while chromium in *H. inactiva* was near threshold level (Schirokauer and Geiser 2009). All other contaminants were below established threshold levels.

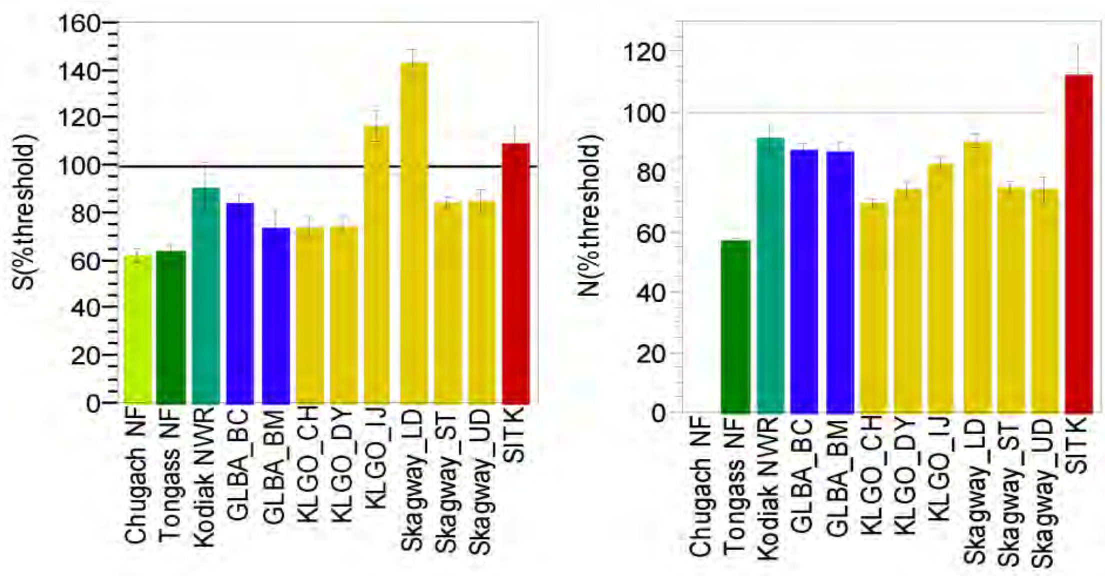

Figure 28. 2008 levels of sulfur and nitrogen in lichens at southeast Alaska National Parks. Error bars indicate one standard error while horizontal lines indicate clean-site thresholds for the Tongass National Forest established by Dillman et al. 2007 (Geiser et al. 2010).

Lichen Community Composition

During a 2005 inventory, LaBounty (2005) collected and identified 85 species of lichen within Sitka National Historical Park, including 12 of the 17 most common macrolichens in southeast Alaska according to Geiser et al. (1994). These common species were found in all forested vegetation types in the park, while an additional six species were found in most forested communities (Table 13; LaBounty 2005). The majority of forest lichen species were trunk and branch epiphytes. A species known to be sensitive to air pollution, *Usnea longissima*, was found sporadically throughout the park, with the highest frequency of occurrence in the northeastern section (LaBounty 2005). ―Notable by their absence,” according to LaBounty (2005), ―were *Lobaria oregana* and *Cladonia bellidiflora*.”

Table 13. Common macrolichens found in all or most forest communities within SITK (LaBounty 2005).

Species found in all forest communities		**Species found in most forest communities**
Alectoria sarmentosa ssp. *sarmentosa*	*Peltigera britannica*	*Hypogymnia physodes*
Bryoria trichodes ssp. *americana*	*Platismatia glauca*	*Hypotrichyna sinuosa*
Cavernularia hultenii	*Platismatia herreri*	*Tuckermanniopsis chlorophylla*
Cladonia squamosa	*Platismatia lacunosa*	*Usnea filipendula*
Hypogymnia entermorpha	*Platismatia norvegica*	*Parmelia sulcata*
Lobaria linita	*Sphaerophorus globosus*	*Parmelia squarrosus*

LaBounty (2005) found that total lichen cover of conifer trunks in the forest was relatively low, although the number of lichen epiphytes on the trunk increased with light exposure. She also noted that the red alder growing adjacent to the bike path and Sawmill Creek Road supported fewer lichens than those growing elsewhere in the park, perhaps due to car exhaust or a change in microclimate due to the road (LaBounty 2005).

Nitrogen Oxides

An Ogawa passive air sampler was deployed at SITK's Indian River study site during the summers of 2008 and 2009 as part of the SEAN monitoring program. Nitrogen oxide deposition (NO_3 and NH_4) rates were 0.24 kg/ha in 2008 and 0.18 kg/ha in 2009 (Schirokauer 2011). According to NPS standards, this is in good condition. Weekly nitrogen oxide concentrations from 2008 are shown in Figure 29.

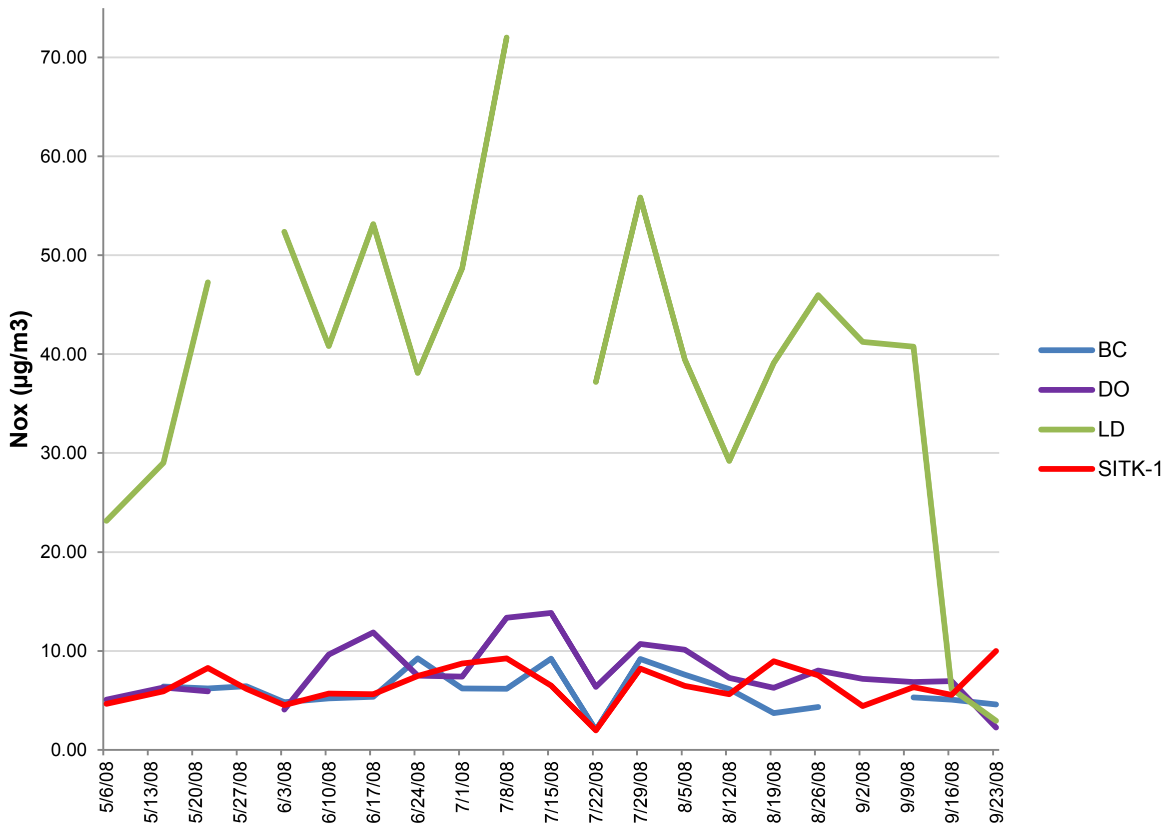

Figure 29. Weekly nitrogen oxide concentrations at SITK, in comparison to other SEAN parks (Schirokauer 2011). The LD and DO samples were taken at Klondike-Gold Rush National Historical Park while the BC sample came from Glacier Bay National Park.

Sulfur Dioxide

Sulfur dioxide deposition at SITK's Indian River sampling site was 1.71 kg/ha in 2008 and 2.21 kg/ha in 2009 (Schirokauer 2011), which is considered in moderate condition by NPS standards. Weekly sulfur dioxide concentrations from 2009 are shown in Figure 30.

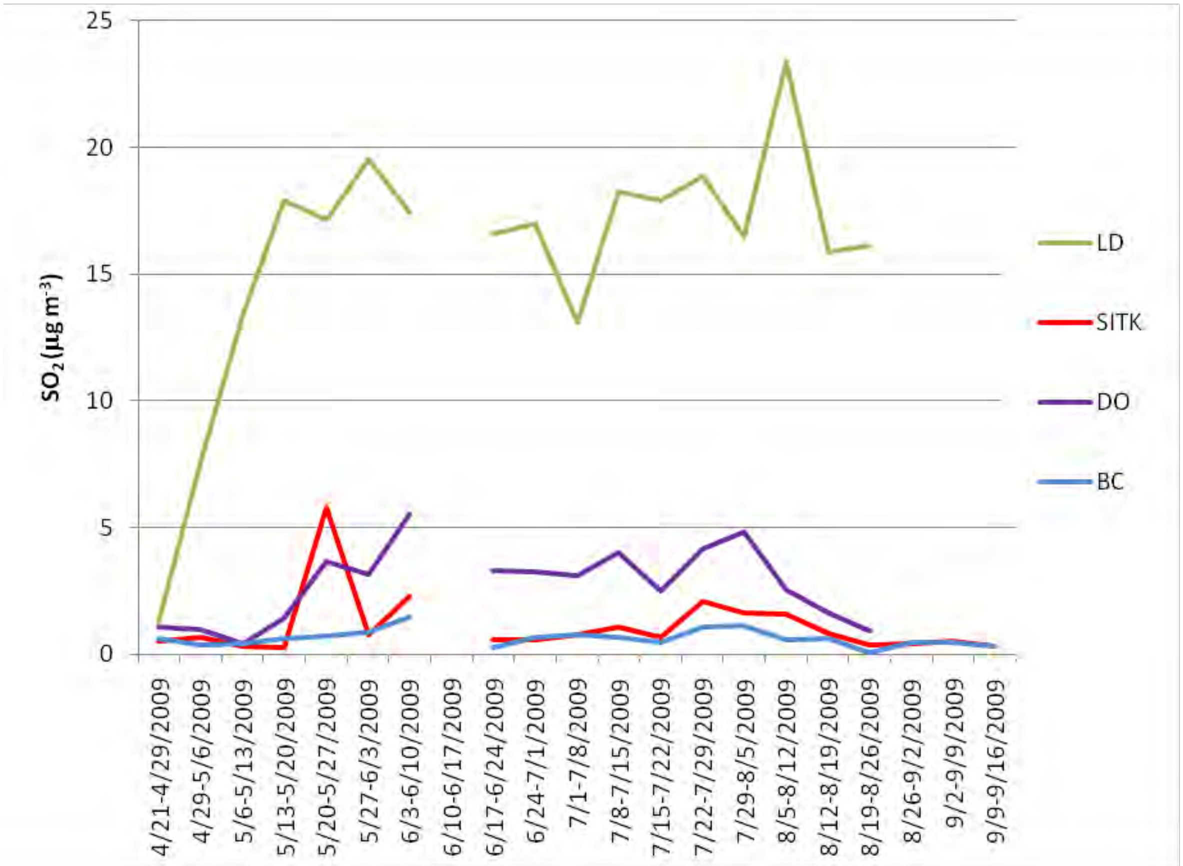

Figure 30. Weekly sulfur dioxide concentrations at SITK, in comparison to other SEAN parks (Schirokauer 2011). The LD and DO samples were taken at Klondike-Gold Rush National Historical Park while the BC sample came from Glacier Bay National Park.

Threats and Stressor Factors

Long-range Transport of Airborne Contaminants
Some of the airborne contaminants in SITK may be coming from international sources such as power plants, smelters, agriculture, and other sources in Europe and Asia. These pollutants, including sulfur and nitrogen compounds, toxic heavy metals, and pesticides, are transported across the Pacific Ocean to Alaska on high-altitude air currents (Landers et al. 2008). The significance of airborne contaminants transported to the park from international sources is expected to increase as global development increases (AK DEC 2002).

Landers et al. (2008) analyzed lichen tissue samples from Glacier Bay National Park, 150 km north of SITK, and from the Stikine-LeConte Wilderness in Tongass National Forest, approximately 185 km to the southeast. Airborne contaminants were found in both samples, including pesticides, polycyclic aromatic hydrocarbons (PAHs, combustion by-products), and PCBs (industrial compounds). If such contaminants are present in these locations, it is likely that they are also present and possibly bioaccumulating in SITK.

Cruise Ship Emissions
Of the 1.7 million visitors traveling to Alaska in 2007, 60% traveled by cruise ship, nearly all passing through southeast Alaska (McDowell Group 2007, as cited in Moynahan et al. 2008). Cruise ships emit nitrogen and sulfur dioxides, PAHs, and metals (Geiser et al. 2010). A study in southwestern Alaska determined that ship emissions significantly increase the atmospheric concentrations of both sulfur and nitrogen dioxides (Porter 2009). These gasses are usually regulated by the Clean Air Act; however, mobile sources such as ships are not currently regulated by state or federal agencies (Schirokauer et al. 2008).

Data Needs/Gaps
Continued sampling and analysis of both lichens and sulfur and nitrogen oxides in the air will be necessary before any trend in the condition of SITK‘s air quality can be determined. Information regarding the effects of mercury on lichens, particularly a threshold level, is also lacking (Schirokauer, pers. comm., 2011).

Overall Condition
SITK staff assigned a *Significance Level* of 3 to the lichen contaminants, nitrogen oxides, and sulfur dioxide measures and a *Significance Level* of 2 to the lichen community composition measure. Community composition was deemed less significant due to the fact that a severe fire may have swept through the park in the late 1800s, which could have seriously impacted the lichen community (Streveler 1969). It is unknown what effects would still be evident in today‘s lichen community composition.

Lichen Contaminants
Lichen contaminants were assigned a *Condition Level* of 2. Sulfur and nitrogen levels in lichens from Sitka were above thresholds established for Tongass National Forests (Figure 28), yet all other contaminants were below threshold levels.

Lichen community composition
Lichen community composition received a *Condition Level* of 1, as there is currently no evidence of serious degradation within the community. A species known to be sensitive to air pollution, *Usnea longissima*, has also been found in the park.

Nitrogen oxides
Nitogen oxide deposition levels in the park are in good condition according to NPS air quality standards and therefore received a *Condition Level* of 0.

Sulfur dioxide
Sulfur dioxide deposition at Sitka was assigned a *Condition Level* of 2, since the 2008 and 2009 measurements fell within the moderate condition range based on NPS standards.

Weighted Condition Score (WCS)
The Weighted Condition Score (WCS) (see Chapter 3 for methodology) for air quality in Sitka is 0.424. A WCS of 0.424 represents an overall condition of moderate concern.

Due to a lack of historical and/or long-term data, the trend for air quality at the park is currently unknown. As the SEAN monitoring program continues gathering data, a clearer picture of both the condition and trend of air quality at SITK will form.

Sources of Expertise
The primary source of expertise for this assessment was David Schirokauer, natural resource program manager at Klondike Gold Rush National Historical Park and project co-manager of the SEAN air quality monitoring program.

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4.8 Intertidal Water Quality / Aquatic Habitat Quality (Intertidal)

Description

The intertidal zone and estuarine areas comprise nearly half (44%) of SITK's total acreage (Moynahan et al. 2008), which makes these areas extremely important to the park. SITK contains approximately 1 km (0.62 mi) of shoreline and 19 ha (50 ac) of tidelands leased from the city of Sitka and the State of Alaska (Eckert et al. 2006). SITK's general management plan named the protection of the intertidal zone as one of the highest natural resource priorities for the park (Moynahan et al. 2008). Intertidal monitoring is a Vital Sign that has been selected for long-term monitoring by SEAN (Irvine and Madison 2008). The SITK intertidal zone contains gravel, cobble, and sand beaches, as seen in Photo 16 at low tide and Photo 17 and Photo 18 at high and low tides, respectively. Water-bird feeding, salmon migration, and provision of essential clam bed habitat are just a few of the important functions of the SITK intertidal zone (Sundberg 1981).

Photo 16. Intertidal area with herring spawn in SITK (NPS photo).

Photo 17. SITK beach at high tide (Irvine and Madison 2008).

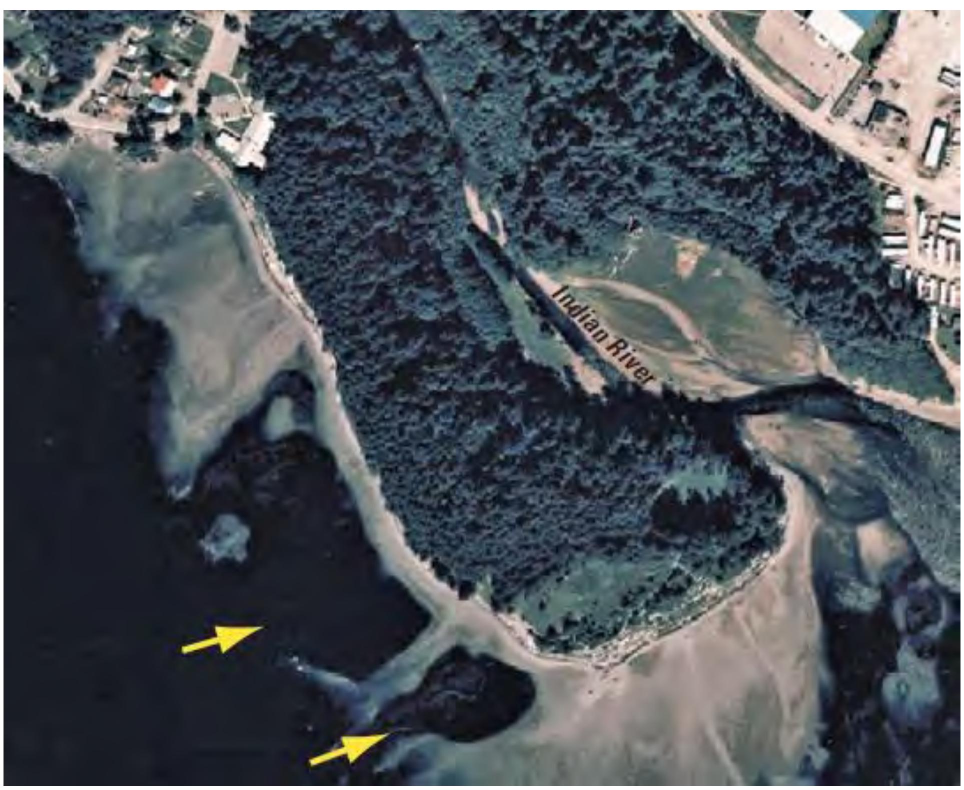

Photo 18. Intertidal zone of SITK beach exposed when the tide is out. Arrows indicate the two large pool areas where previous excavations for gravel occurred (Irvine and Madison 2008).

Intertidal and estuarine habitats sustain a variety of aquatic life including seastars, limpets, chitons, polychaete worms, barnacles, crabs, clams, snails, and shrimp along with many other marine species (Moynahan et al. 2008).

The State of Alaska technically owns the intertidal and estuarine zones that surround the park boundaries, but the park has the authority to manage these areas (Sundberg 1981, Eckert et al. 2006, Moynahan et al. 2008). SITK is greatly influenced by the prevailing currents, particularly the Alaska Coastal Current, and it is the most ―upstream" (south) national park in a string of eight coastal parks that border the Gulf of Alaska in the southeast portion of the state (Irvine and Madison 2008). At the convergence of two distinct biogeographical provinces, SITK may be first to experience directional climate change such as increasing water temperature, rising sea levels, and a northerly shift of species' ranges (Irvine and Madison 2008).

Water quality and aquatic habitat are of great importance to SITK because of their impact on natural biological processes. According to Irvine and Madison (2008, p. 1), ―Marine intertidal areas usually consist of highly productive biological communities with links to both aquatic and terrestrial ecosystems." Therefore, physical characteristics of water, including those analyzed in this report (water temperature, dissolved oxygen, and turbidity), are essential in evaluating the overall condition of the SITK intertidal zone. Moynahan et al. (2008) also lists marine invertebrates as an important resource issue of concern. Bioindicators, such as community composition of sensitive macroinvertebrates, can be used to evaluate overall aquatic habitat condition. Over 200 invertebrate species are known to reside in the SITK intertidal zone, many of which are good indicators of overall ecosystem condition (Moynahan et al. 2008). Irvine and Madison (2008) mention that the data obtained through a well-designed monitoring system in the intertidal zone provide invaluable information that can increase understanding, reveal intricate patterns of change, and create a useful impact assessment for overall management for parks such as SITK.

Contaminants like mercury (Hg), persistent organic pollutants (POPs), and polycyclic aromatic hydrocarbons (PAHs) threaten the health and existence of the diverse array of intertidal organisms in SITK. According to Eckert et al. (2006), mercury and POPs are the two global contaminants that are of the highest concern in Alaska. Other activities that can have adverse impacts on intertidal habitat conditions in SITK include increased turbidity and oil spills; gravel dredging with the destruction of spawning areas, mussel habitat, and plant communities; vehicle traffic; and alteration of currents and intertidal mixing reduction resulting in highly concentrated pollutants (Sundberg 1981).

Measures

- Mercury
- Persistent organic pollutants (POPs)
- Polycyclic aromatic hydrocarbons (PAHs)
- Water temperature
- Dissolved oxygen
- Turbidity
- Community composition of sensitive macroinvertebrates

Reference Conditions/Values

Intertidal zones in and around Glacier Bay National Park (GLBA), located about 150 km north of SITK, are thought to be less affected by anthropogenic stressors than SITK because of lower visitor rates and less overall boat traffic. However, this may not necessarily translate to lower contaminant levels, as cruise ship traffic in GLBA is significantly higher than in SITK (C. Smith, pers. comm., 2011). Protocol for intertidal studies conducted by Irvine (2002) in GLBA was modified for SITK (Irvine and Madison 2008), due to the fact that GLBA contains much more intertidal zone than SITK. Since GLBA is the closest area that has had similar intertidal water quality monitoring (Irvine 2002), it is logical to use this park as a reference condition. Examining water quality information and intertidal habitat has been a major area of study for SEAN. By using another SEAN park such as GLBA as a reference condition, it is possible to examine, evaluate, quantify, and assess values against an area of similar intertidal protocol and geographic proximity.

Physical water quality references such as historic values can be used for overall condition assessment. Historic data for SITK is limited (NPS 1998). Previous water quality studies (Eckert et al. 2006, Tallmon 2011) and intertidal water quality standards from the Alaska Department of Environmental Conservation (ADEC) (ADEC 2005) provide essential reference conditions for overall intertidal ecosystem health. Although ADEC state criteria are not specifically for SITK, they provide a baseline for interpretation of parameters such as water temperature, dissolved oxygen, and turbidity.

Established state criteria for selected measures are listed in Table 14. Note that there are no specified state criteria for allowable levels of mercury or POPs. Absence of mercury and POPs is ideal.

Table 14. Selected water quality criteria for SITK intertidal zones. Standards for all parameters refer to the criteria for the ―growth and propagation of fish, shellfish, other aquatic life, and wildlife" (ADEC 2005). Table modified from Eckert et al. 2006.

Parameter	Criteria
Petroleum, Hydrocarbons, Oils and Grease	Total aqueous hydrocarbons (TAqH) in the water column may not exceed 15 µg/L. Total aromatic hydrocarbons (TAH) in water may not exceed 10 µg/L. There may be no concentrations of petroleum hydrocarbons, animal fats, or vegetable oils in shoreline or bottom sediments that cause deleterious effects to aquatic life. Surface waters and adjoining shorelines must be virtually free from floating oil, film, sheen, or discoloration.
Dissolved Gas/Oxygen	Surface dissolved oxygen concentration in coastal water may not be less than 6.0 mg/L for a depth of 1 meter except when natural conditions cause this value to be depressed. D.O. may not be reduced below 4.0 mg/L at any point beneath the surface. D.O. concentrations in estuaries and tidal tributaries may not be less than 5.0 mg/L except where natural conditions cause this value to be depressed. In no case may D.O. levels exceed 17 mg/L. The concentration of total dissolved gas may not exceed 100% of saturation.
Water Temperature	May not cause the weekly average temperature to increase more than 1°C. The maximum rate of change may not exceed 0.5°C per hour. Normal daily temperature cycles may not be altered in amplitude or frequency.
Turbidity	May not reduce the depth of the compensation point for photosynthetic activity by more than 10%. May not reduce the maximum secchi disk depth by more than 10%.

Data and Methods

According to Irvine and Madison (2008), the Alaska NPS region began developing coastal monitoring and inventories for parks with marine coastline in 1989. Eckert et al. (2006) reported that data from an NPS (1998) study that monitored water quality parameters at the east bank of the mouth of the Indian River in 1996 and 1997 is cited as some of the earliest sampling of brackish waters in SITK. The establishment of an intertidal monitoring program at SITK began in 1999. Intertidal monitoring was conducted in 2002 and 2003 by Gail Irvine of the USGS in order to develop monitoring programs for many coastal parks in Alaska (Irvine 2002, Eckert et al. 2006, C. Smith, pers. comm., 2011). In collaboration with the NPS and SITK, the USGS developed a specific protocol to monitor intertidal communities present in the SITK tidelands.

Primary SEAN objectives in SITK include tracking of all contaminants at specific locations through biannual collection of mussel tissue samples (Moynahan et al. 2008). The ―Mussel Watch Program" (MWP) is a nationwide monitoring program of marine environments which includes sediment and tissue chemistry of bivalves (Kimbrough et al. 2008). Monitoring has occurred at SITK in recent years with periodic sampling for toxin detection (C. Smith, pers. comm., 2011). Mussel Watch is an effective way to monitor long-term effects of environmental factors such as cruise ships, oil spills, and various other pollutants in bivalves (C. Smith, pers. comm., 2011). In 2009, collected samples came from in front of the Visitor Center, Crescent Harbor, and near the mouth of the Indian River (Photo 19) (Tallmon 2011). For comparison between sites thought to be contaminated and those that were relatively pristine, several sites (thought to be slightly degraded) were chosen non-randomly and used as control points (Tallmon 2011). Areas in GLBA were also sampled for mussels and sediment. Samples from SEAN parks were analyzed for POPs, PAHs and a variety of other metals (Tallmon 2011).

Photo 19. Mussel sampling locations in Sitka Sound near SITK (NPS photo).

ShoreZone is a project sponsored by multiple agencies and organizations that conducted aerial surveys of intertidal regions of SITK in 2004 (Eckert et al. 2006). Intertidal and shallow subtidal areas were surveyed aerially (Photo 20) in order to identify substrate, shoreline morphology, and the biota of intertidal and nearshore habitats. An online database including digital maps, aerial photographs, and GIS data layers was created using this method of coastal habitat mapping (Eckert et al. 2006). From this survey, essential biota distributions and nearshore habitat were identified.

Photo 20. Tidelands near SITK (Photo by ShoreZone, July 2004).

Water quality in receiving waters at the Sitka wastewater facility is monitored by the city and borough of Sitka (CBS) (Eckert et al. 2006). Monitored parameters include dissolved oxygen, temperature, secchi disk depth and turbidity. The CBS has monitored these receiving waters since the 1980s in accordance with their permit and, to date, have not been in violation of any state water quality standards (Eckert et al. 2006). The Beach Environmental Assessment and Coastal Health (BEACH) Act, an October 2000 law, states that ―coastal water monitoring should take place in areas used recreationally, and especially in areas that are close to a pollution source" (EPA 2005, as cited in Eckert et al. 2006, p. 37). In accordance with this law, beaches in SITK have been evaluated as ―low risk" (Eckert et al. 2006).

The Environmental Monitoring and Assessment Program (EMAP) surveyed and sampled much of Sitka Sound and southeast Alaska in 2004. Several parameters were sampled at 40 stations and evaluated, including suspended solids, temperature, dissolved oxygen, contaminants, and invertebrates (Eckert et al 2006). ―Core Alaskan EMAP coastal indicators" include a variety of physical and chemical parameters such as dissolved oxygen, water temperature, sediment quality, and benthic fauna (ADEC 2005). A 2008 SEAN study of intertidal Vital Signs obtained water quality information from 24 stations within GLBA (Moynahan et al. 2008).

A survey was conducted in summer 2007 in order to identify eelgrass and associated grass shrimp (*Hippolyte clarki*) habitat, as well as to create a species list of macroinvertebrates found in SITK (Shirley and Baldwin 2007). Baseline information was gathered for SITK, including the identification of 254 species of marine macroinvertebrates. Starting at the northwest corner of the park, a transect line was created that continued along the beach to the lowest tidal area, then extending to a point west of Cobb Island. According to Shirley and Baldwin (2007), the purpose of extending the transect far outside the park boundaries was to permit sampling at varying depths from the littoral zone to greater depths. PAH levels were also determined for this study through sediment and various biota samples (Shirley and Baldwin 2007).

Current Condition and Trend

Mercury

Mercury is a pollutant of high concern, especially in Alaska (Eckert et al. 2006). Its pervasiveness is predicted to increase along with human populations and with the continued reliance on coal as an energy source (Landers et al. 2008). Mercury is directly delivered from industrial pollution in Asia to southeast Alaska (Moynahan et al. 2008), including SITK. The bioavailable form of mercury is methylmercury, which is 100 times more toxic than elemental mercury, with a capability to bioaccumulate in many organisms (Moynahan et al. 2008). A periodic study of murre eggs (*Uria* spp.) in the Gulf of Alaska, which included a location in Sitka Sound, showed high levels of methylmercury (Nagorski et al. 2011).

According to Kimbrough et al. (2008), some areas of southeast Alaska may experience naturally elevated levels of certain metals; southeast Alaska is generally characterized as an area of low metal contamination with areas of slightly elevated readings. Eckert et al. (2006) reported mercury levels of 0.1 µg/L for each of the four observations taken on the east bank at the mouth of the Indian River (however, at least half of the observations were half of the detection limit). According to Eckert et al. (2006, p. 10), ―sediment cores collected in nearby GLBA indicate that rates of mercury deposition in the area have been rising consistently since the Industrial Revolution." In fact, three sediment collections in GLBA lakes have shown that mercury accumulation rates are presently double pre-Industrial Revolution rates (Engstrom and Swain 1997, as cited in Eckert et al. 2006). Furthermore, deposition of mercury in GLBA ―did not show the recent declines (since the 1960s) observed at sites in the continental U.S. where regional mercury emissions have been reduced" (Pacyna and Pacyna 2002, as cited in Eckert et al. 2006, p. 43). Southeast Alaska mercury levels may be heavily influenced by remote source emissions and from Asian countries‘ continually increasing output (Pacyna and Pacyna 2002).

Tallmon (2011) reported that intertidal zone metal contaminants, including mercury, were low and relatively insignificant in the SEAN parks, with only a few specific sites reaching higher detectable levels. Most of these increased levels were from pre-selected control sites such as Bartlett Cove in GLBA and Crescent Harbor in SITK, which may have been affected by oil spills or other anthropogenic events (Tallmon 2011; C. Smith, pers. comm., 2011). Furthermore, compared to the rest of the contiguous United States, mercury was found at consistently low levels for all collections (Tallmon 2011). Tallmon (2011) found that levels of contamination were slightly lower in 2009 than 2007 and were consistent overall with recently published MWP reports. SITK seems to contain relatively low levels of mercury despite several elevated samples, including Crescent Harbor.

Still, these numbers were found to be relatively low when compared to the contiguous United States (Kimbrough et al. 2008, Tallmon 2011). Mussel Watch found that levels of mercury were low in the sampled SEAN parks (<0.03ppm) (Tallmon 2011). Although mercury levels in SITK are slightly higher than samples from GLBA, mercury levels are still considered low. These slightly elevated levels may be due to the increased traffic, higher concentration of human populations, and smaller geographic extent compared to parks such as GLBA (Tallmon 2011). Figure 31 shows concentrations of mercury from mussel samples in SITK and GLBA locations.

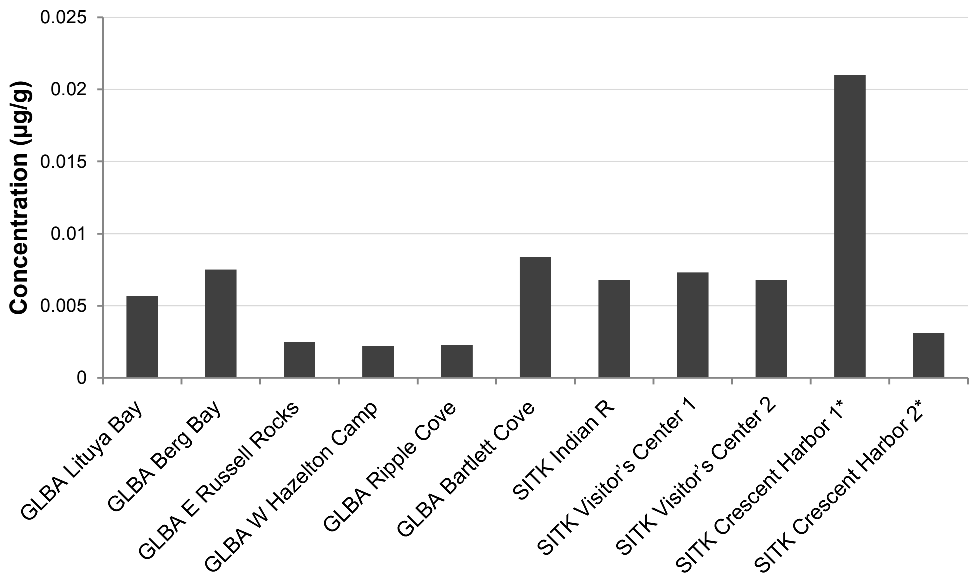

Figure 31. Mercury contaminant levels in mussel samples collected from GLBA, SITK, and nearby areas. Concentrations are reported as µg/g wet tissue. GLBA Lituya Bay, SITK Visitor Center 1, SITK Indian River, SITK Crescent Harbor 1, and GLBA Berg Bay locations sampled in 2007; all others sampled in 2009. *indicates selected control site as described in text. Data from Tallmon (2011).

Persistent Organic Pollutants (POPs)

Persistent organic pollutants (POPs) are very stable organic compounds that concentrate in the bodies of many different organisms (Eckert et al. 2006). Twelve highly dangerous POPs threaten ecosystem integrity, and alarmingly have not been extensively evaluated or monitored (Eckert et al. 2006). Furthermore, POP levels also have not been historically monitored in SITK specifically (Eckert et al. 2006). POPs can be harmful because of their long-range transport, high toxicity levels, persistence, and their ability to bioaccumulate (EPA 2002). A reduction in many of these contaminants is expected with the implementation of the Stockholm Convention that pledged to phase out these POPs (Eckert et al. 2006). However, POPs have been used in Alaska by mills, mines, power plants, smelters, and military installations and are still being released into the environment in many other forms (EPA 2002).

Of the major POP groups analyzed by Tallmon (2011) in SEAN parks, levels were found to be relatively low when compared to levels in the contiguous United States (Kimbrough et al. 2008). This study found that only two samples contained detectable ΣCHLD levels, ΣDDT levels were far below 5 ppb in most samples, and ΣHCH levels were nearly all below detection limits. Tallmon (2011) found that detection limits for ΣPCB levels were achieved in many samples in the SEAN. "The sites with relatively high ΣPCB levels for the SEAN region have heavy human use, and the three highest levels are from the SITK area, including one SITK site and two outside the park" (Tallmon 2011, p. 16). ΣPBDE levels were below 10 ppb in all sampled parks and locations (Tallmon 2011). Stable patterns and trends for all monitored POPs, as well as contamination over given time periods, can be seen from baseline conditions (Tallmon 2011).

High polychlorinated biphenyl (PCB) levels were found in mussels and murre eggs in the SITK intertidal zone by a 2007 Nagorski et al. (2011) study. Another study also found that eggs from St. Lazaria Island, located near SITK, had the highest PCB levels throughout all of the sampled SEAN areas (Kucklick et al. 2002, Vander Pol et al. 2004; D. Tallmon, University of Alaska Southeast, pers. comm., 2009, as cited in Nagorski et al. 2011). These results show that SITK, as well as the surrounding area, may be disproportionately affected by the atmospheric deposition of PCBs. Another possible source of these elevated levels is anthropogenic causes such as air and water discharge from a nearby pulp mill, which operated from 1959 to 1993 (ADEC 1999). Elevated PCB levels were also found in terrestrial vegetation and walleye pollock (*Theragra chalcogramma*) in GLBA (Tallmon 2011). Again, numbers for the various selected POPs were generally low throughout the SEAN, including SITK, despite these elevated sites. Concerning harmful POPs, Tallmon (2011) states that most contamination occurs on a local level, and that heavy seasonal vehicle traffic, aquatic or terrestrial, is most likely the main contributor to these elevated POP levels.

Polycyclic Aromatic Hydrocarbons (PAHs)

Shannon and Wilson Inc. (1995, as cited in Eckert et al. 2006) found that all PAH levels were acceptable at the former Indian River asphalt site near the mouth of the Indian River, with no volatile or aromatic hydrocarbons greatly exceeding background levels. Generally low levels of PAH contaminants were found throughout the SEAN network by the Mussel Watch program in 2007 and 2009 (Tallmon 2011). PAH levels were above 100 ppb (=ng/g) in four samples with another four between 10 and 70 ppb (Tallmon 2011). Remaining samples were all below 10 ppb (Tallmon 2011). Samples with detectable PAH levels occurred in the selected control sites, where levels of contaminants were assumed to be elevated (Tallmon 2011). As seen in Table 14, total aqueous hydrocarbons (TAqH) in Alaska should not exceed 15 ppb and total aromatic hydrocarbons (TPAH) should not exceed 10 ppb. Tallmon (2011, p.15) states that, —these sites appear to be impacted by either creosote or petrochemicals associated with internal combustion engines.” Near SITK, two areas of elevated TPAH levels were identified. These were found in sediment samples near the SITK Visitor Center in 2007 and in mussels from Crescent Harbor, just outside of the park boundaries, in 2009 (Tallmon 2011). High TPAH levels of 406.01 ppb and 949.22 were found near the SITK Visitor Center and in Crescent Harbor respectively (Tallmon 2011). Appendix 6 contains the complete results of contaminant sampling in SEAN parks.

Control sites, presumably impacted by engine additives and emissions, provided the majority of detectable TPAH readings. Tallmon (2011) concluded that the high TPAH levels discovered in mussels at these two sites were due to combustion engine and petroleum sources. PAH levels in southeast Alaska are relatively low and the general conclusion is that contamination of mussels in the SEAN parks is low (Eckert et al. 2006, Landers et al. 2008, Tallmon 2011). As with POP levels, PAH contamination is considered to originate from local point sources rather than distant sources (Landers et al. 2008, Tallmon 2011). POP and TPAH concentrations from selected GLBA and SITK sample sites can be found in Figure 32.

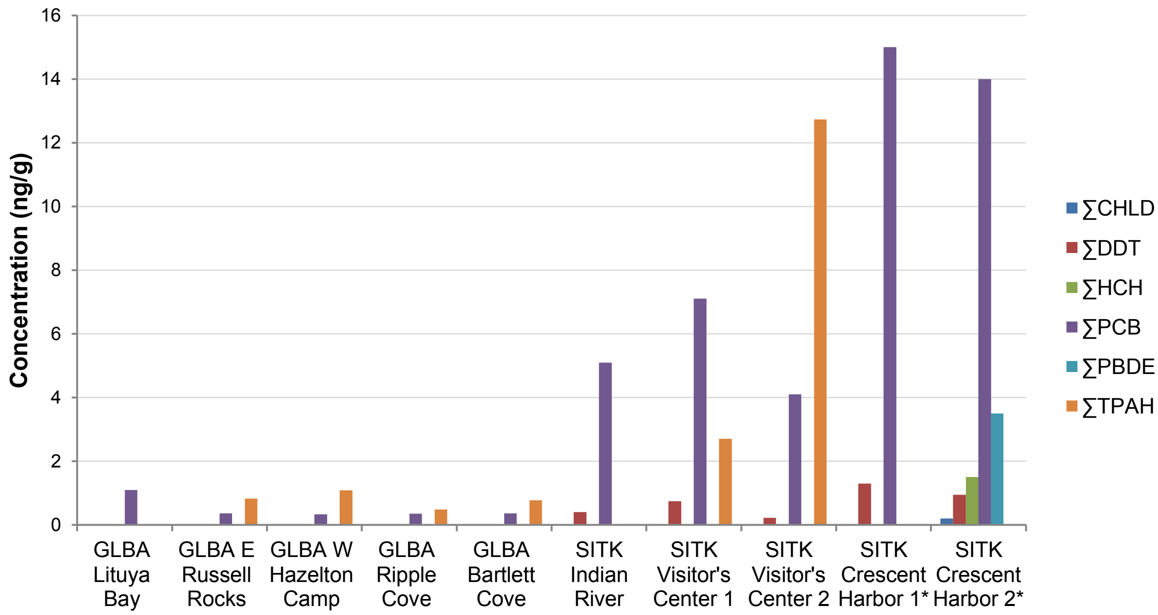

Figure 32. Selected POP and TPAH contaminant levels in mussel samples collected from GLBA, SITK, and nearby areas. Concentrations are reported as ng/g wet tissue. ∑TPAH level (949.22 ng/g) was excluded from SITK Crescent Harbor 2 due to scale. GLBA Lituya Bay, SITK Visitor Center 1, SITK Indian River, and SITK Crescent Harbor 1 locations sampled in 2007; all others sampled in 2009. Absent columns correspond to samples that were below quantifiable limits or not analyzed due to high expenses. *indicates selected control site as described in text. Data from Tallmon 2011.

Water Temperature

Eckert et al. (2006) suggest that water temperature is a physical parameter that must be continually monitored. Water temperature along the SITK shoreline was found to be within acceptable levels, although long term intertidal monitoring has not occurred (Eckert et al. 2006). Water quality monitoring conducted by the CBS also determined that temperature measurements were all within acceptable ranges (Eckert et al. 2006).

Dissolved Oxygen

Dissolved oxygen was monitored on several occasions in Sitka Sound and found to be within adequate levels. Although no quantifiable data were provided by Eckert et al. (2006) in their report, it is noted that dissolved oxygen, as one of the parameters monitored by EMAP and CBS, was within acceptable permit levels in Sitka Sound.

Turbidity

Marine watercraft traffic is cited by the NPS (1998) as a source of potential anthropogenic contaminants and habitat disruption. Eckert et al. (2006) stress that potential exists for increased cruise ship traffic to dramatically influence turbidity levels in Sitka Sound, although according to Craig Smith (pers. comm., 2012), an increase is not expected in the coming years. Marine vessels can affect SITK's water quality by resuspending sediments in marine waters through vessel movement. This can cause increased turbidity, thereby interfering with filter feeding organisms and decreasing water quality by reducing light penetration (NPS 2003). According to Eckert et al. (2006, p. 50), ―the effects to water quality in SITK are most likely temporary and limited to the immediate area of vessel traffic." However, the far-reaching impacts of cruise ships on the water quality of Sitka Sound are largely unknown (Eckert et al. 2006). Moynahan et al. (2008) mention turbidity as one of the secondary parameters for monitoring by the NPS Water Resources Division (WRD). It is not currently one of the Alaskan EMAP core coastal indicators (ADEC 2005).

Community Composition of Sensitive Macroinvertebrates
As with freshwater environments, water quality of a marine waterbody can be determined by the the community composition of biological diversity. Marine benthic invertebrates are good indicators of overall system health because of their response to pollutants (EPA 2011). Several genera of marine invertebrates thrive in the marine environment along the shores of SITK and in Sitka Sound. This intertidal region provides essential habitat for a diverse group of marine biota including sensitive macroinvertebrates, intertidal vegetation, and various algal species. Although it is harder to assess marine/estuarine conditions than freshwater conditions, several reference conditions and bioindicators have been developed (EPA 2011). Macroinvertebrates such as polychaetes, a tolerant class of marine worms, are used as biological indicators due to their longer lifespan and limited mobility, which is helpful in assessing certain environmental stressors (EPA 2011). Large crabs are another targeted mobile species that are potential indicators, as they are likely to be impacted by human activity (Irvine and Madison 2008).

The 2007 study by Shirley and Baldwin (2007) focused on creating a park inventory rather than looking for specific sensitive organisms. The process included using vertical transects, point-intercept sampling, band surveys of large mobile invertebrates and quadrat sampling of smaller mobile invertebrates (Irvine and Madison 2008). Sampling was conducted for sessile organisms and mobile macroinvertebrates in order to produce basic data on abundance, presence, available substrates, and spatial distribution (Irvine and Madison 2008). The goal was to establish three years of data to analyze the effectiveness of the sampling design and changes in intertidal species. Although an area of more than 5,000 m^2 was surveyed each year, the large mobile invertebrates of interest were rare according to Irvine and Madison (2008). A complete list of invertebrates found in this survey, as reported by Irvine and Madison (2008), can be found in Appendix 7.

Threats and Stressor Factors
Moynahan et al. (2008) identified vessel effects, toxic leachates from an old asphalt plant, and water quality as three general areas of concern for SITK. Other adverse impacts to SITK marine habitat include accidental oil spills and alteration of nearshore currents that reduces mixing (Eckert et al. 2006, Moynahan et al. 2008). Additional potential stressors include harmful algal blooms (HABs) and abnormal pH levels sometimes resulting in eutrophication (Eckert et al. 2006, Moynahan et al. 2008).

Vessel traffic in the area includes commercial fishing vessels, subsistence and sport fishing vessels, pleasure craft, and cruise ships, which all have the potential to impact the water quality of SITK's intertidal zones by resuspending sediment and leaking pollution (Eckert et al. 2006). The resuspension of sediments threatens water quality by increasing turbidity and affecting the filtering process of filter feeding organisms (Eckert et al. 2006). Pollution can include graywater (shower, laundry, and galley sink waste), blackwater (treated sewage), hazardous waste, solid waste, and marine debris (Eckert et al. 2006). In addition, vessel traffic has the potential to introduce exotic and invasive species into the park (Eckert et al. 2006). Eckert et al. (2006) state that compared to other regions in the U.S., vessel traffic within SITK is low.

The Sitka wastewater facility located near the SITK boundary is monitored by the CBS and has been in compliance with appropriate permits. As of 2005, water quality standards for this facility have been within acceptable limits (Eckert et al. 2006). An asphalt batch plant established and subsequently closed in the 1950s remains a concern for point source pollution (Eckert et al. 2006). Runoff of storm water at the site is treated by swales and grass-lined ditches that provide natural treatment and filtration. Moynahan et al. (2008) notes that nutrient loading may be elevated in the intertidal zone, due to the contribution of fish processing plants in Sitka Sound. Tallmon (2011) attributes many of the elevated contaminant levels found in SITK to these point sources.

Climate change is a major issue currently facing the NPS, including SITK. Change in global climate may greatly affect water resources including tidal levels, water flow, glacier extent, and water temperature (Eckert et al. 2006). According to Moynahan et al. (2008), ecosystem functions are greatly influenced and ultimately driven by weather and its associated annual patterns. Park aquatic ecosystems may be negatively affected by weather pattern disruptions, especially those driven by global climate change (Moynahan et al. 2008). Slight changes in temperature have the potential to change snow to rain earlier in the season, thereby affecting streamflows and other physical parameters (Eckert et al. 2006). Eckert et al. (2006, p. 58) suggest an ―automated continuous data collection procedure with transmittal of information to national databases with parameters including temperature, precipitation, etc."

Many anadromous and resident marine fish are present within the park, and some use the intertidal zone within SITK as breeding grounds. During and after the Second World War, extensive gravel mining occurred in the intertidal coastal areas of SITK (Eckert et al. 2006, C. Smith, pers. comm., 2011). Over 1.5 million cubic yards of material, used for military needs and construction of the local airport, was excavated, leaving giant pool areas and greatly altering the habitat of the intertidal zones (Photo 18). Gravel dredging can destroy salmon spawning habitat and marine plant communities; however, this practice was discontinued in the late 1970s (Eckert et al. 2006). Nearshore development has since been kept to a minimum along SITK‘s boundary, although coastal development was cited as a potential marine and intertidal problem by Eckert et al. (2006). Tidal exchange and current patterns could potentially be affected if major coastal developments were undertaken (Eckert et al. 2006).

SITK, like most of coastal Alaska, is subjected to long-range transport of airborne contaminants (Eckert et al. 2006, Moynahan et al. 2008). Air masses travel from Asia over the Pacific Ocean and hit the coast of the United States; these air masses carry significant amounts of contaminants that undergo a process called ―orographic precipitation" (Moynahan et al. 2008). This precipitation forms when the air mass quickly increases in elevation and condenses to fall as rain, which can contain the previously airborne contaminants.

One threat to the integrity of marine macroinvertebrates is the introduction of invasive species into this aquatic ecosystem. The species of greatest concern is the green crab, which has become established in many areas as far north as British Columbia and is of high concern to the park

(Eckert et al. 2006, C. Smith, pers. comm., 2011). Invasion of essential macroinvertebrate habitat by green crab would be a great detriment to the stability of intertidal habitat.

<u>Data Needs/Gaps</u>
A key data need essential to the evaluation of intertidal contaminants such as mercury, POPs and PAHs is a long-term monitoring and evaluation plan for SITK. Inconsistent data or gaps in reporting lead to an inability to confidently assess the condition and any trends in the intertidal zone. Also, long-term monitoring plans for the SITK intertidal zone including annual water quality data would be ideal for assessment of this component. Information outlining the effects of cruise ships on turbidity and water quality parameters may provide better insights into water quality impairments.

Eckert et al. (2006, p. 56) provide other recommendations for further investigation including: monitoring of nearby development efforts, identification of sensitive early warning species such as mussels, a survey of nearby vessels during high-use periods to identify potential risk areas, and –integration of information into centralized and web-accessible GIS."

<u>Overall Condition</u>
SITK staff assigned contaminant measures—mercury, POPs, PAHs— a *Significance Level* of 3. Water temperature, dissolved oxygen, turbidity, and community composition of sensitive macroinvertebrates were given *Significance Levels* of 2.

Mercury
SITK‘s mercury measure was assigned a *Condition Level* of 1. This measure is not currently of great concern to resource managers. Despite a lack of available long-term trend data, levels of mercury in SITK are reported to be low (NPS 1998, Tallmon 2011) to slightly elevated (Eckert et al. 2006). There are no established criteria regarding acceptable levels of mercury. Historical data are also sparse or nonexistent for the park. SITK and southeast Alaska are sure to be impacted by mercury levels in the future; further monitoring and evaluation must be done in order to better quantify the threat posed by mercury and other hazardous metals.

Persistent Organic Pollutants (POPs)
SITK‘s POPs measure was assigned a *Condition Level* of 1. This measure is not currently of great concern to resource managers. There are no established criteria regarding acceptable levels of POPs. Again, reports ranged from mixed (Eckert et al. 2006) to positive outlooks (Tallmon 2011). Tallmon (2011) cited low overall levels of POP contaminants. Several areas of higher contamination levels were present in or near SEAN parks, specifically SITK, although these locations were close to more concentrated human populations and other point sources (Tallmon 2011). Even though the Stockholm Convention may reduce the threat of many of these pollutants, –the limited number of studies to date strongly suggests that the threats posed by POPs deserve further evaluation and monitoring" (Eckert et al. 2006).

Polycyclic Aromatic Hydrocarbons (PAHs)
SITK‘s PAH measure was assigned a *Condition Level* of 1. This measure is not currently of great concern to resource managers. There are no established criteria for acceptable levels of PAHs. More data are needed to fully understand the impacts and overall effects of PAHs in SITK. Low levels of total PAH contamination (TPAH) were detected throughout the SEAN parks as noted

by Tallmon (2011). Mussel Watch found that mussel contamination in SEAN parks was low, suggesting relatively pristine intertidal conditions (Tallmon 2011). Sampling by Tallmon (2011) showed mostly undetectable TPAH readings throughout the SEAN. Higher PAH concentrations were found at two locations near SITK, but are still considered relatively low. Tallmon (2011) notes that these elevated PAH levels are likely a regional concern and are not likely to pose any long-term threats to the park or ecosystem.

Water Temperature
Water temperature in SITK was assigned a *Condition Level* of 0. This measure is not a current concern to resource managers. Although historical data are sparse, no problems concerning elevated water temperature have been cited. There are no documented cases where water temperature exceeded acceptable limits.

Dissolved Oxygen
The *Condition Level* of dissolved oxygen in the SITK intertidal zone and nearby Sitka Sound was assigned a 0. This measure is not a current concern to resource managers. Eckert et al. (2006) note that SITK intertidal water quality is high and dissolved oxygen is in line with prescribed parameters.

Turbidity
The measure of turbidity in SITK was assigned a *Condition Level* of 0. Turbidity in the SITK intertidal zone is not currently a major area of concern to resource managers. Previous monitoring studies have shown that turbidity is at acceptable levels. Increased sedimentation along SITK‘s intertidal zones, as well as increased oceanic turbidity from human activities, such as pleasure craft, is an area worthy of future monitoring.

Community Composition of Sensitive Macroinvertebrates
SITK‘s community of sensitive marine macroinvertebrates measure was given a *Condition Level* of 0. This measure is not a current concern to resource managers. The presence of over 200 invertebrate species indicates good habitat quality and diversity (Moynahan et al. 2008). The introduction of or increases in certain invasive species such as the green crab or the tunicate species *Didemnum vexillum* may be a detriment to the SITK intertidal zone and the marine ecosystem in the future (C. Smith, pers. comm., 2011).

Weighted Condition Score (*WCS*)

The Weighted Condition Score (WCS) for intertidal water quality in SITK was determined to be 0.176. Condition values in the intertidal water quality measures indicate generally good intertidal health.

According to Eckert et al. (2006), the estuaries and intertidal areas of SITK have high water quality, and there are only minor water quality impairments or possible problems in the park. Monitored parameters including dissolved oxygen, temperature, secchi disk depth and turbidity were all found to be within allowable limits.

Intertidal Water / Habitat Quality

Measures	SL	CL
• Mercury	3	1
• Persistent organic pollutants (POPs)	3	1
• Polycyclic aromatic hydrocarbons (PAHs)	3	1
• Water temperature	2	0
• Dissolved oxygen	2	0
• Turbidity	2	0
• Community composition of sensitive macroinvertebrates	2	0

WCS = 0.176

Sources of Expertise

The primary source of local information and reviews for this section was Craig S. Smith, SITK Biologist.

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4.9 Freshwater Water / Habitat Quality

Description

The physical and chemical properties of water are factors that determine habitat characteristics for aquatic species; therefore, alteration or degradation of these properties can have detrimental effects on habitat and subsequently on the related freshwater and terrestrial ecosystems. This assessment reports on seven measures of water quality and aquatic habitat quality in the primary freshwater waterbody in the park, the Indian River (Photo 21) and its floodplain. Mercury, persistent organic pollutants (POPs), water temperature, dissolved oxygen, turbidity, and the community composition of sensitive macroinvertebrates are relevant to the river‘s water quality and aquatic habitats. The Indian River watershed, located near Sitka, Alaska, drains an approximate area of 3,260 ha (8,055 ac) (Eckert et al. 2006) and flows through SITK into Jamestown Bay from the mountains north of the town and park. The park itself lies within the Indian River watershed, which is characterized by steep topography and well-drained soils (Paustian and Hardy 1995, Williams 2001). The section of the Indian River that runs through SITK is approximately 1 km (0.64 mi) long and includes the entire mouth of the river (Eckert et al. 2006). This section of the Indian River is described in Eckert et al. (2006, p. 13) as a ―low gradient, gravel-cobble bed, alluvial channel." The stream flow of the Indian River fluctuates rapidly in response to precipitation (Williams 2001). With changes in flow, muskeg wetlands in the watershed become important for holding and releasing water, as well as filtration of storm water runoff (Eckert et al. 2006). However, low conductivity values collected in 2010 and 2011 suggest that groundwater influence on observed flow patterns is low in comparison to surface run-off (Sergeant et al. 2012a; Sergeant et al. 2012b).

Photo 21. Indian River (NPS photo).

While SITK supports a variety of aquatic habitats including river delta, estuaries, floodplain channels, and coastal intertidal areas, the Indian River itself is central to biotic resources in the park (Eckert et al. 2006). The river is also a primary freshwater resource in the region, and is important for wildlife, and the growth and propagation of fish, shellfish, and other aquatic life. It is an important source of drinking water and a resource for aquaculture, visitor recreation, and industry (Eckert et al. 2006). A number of stakeholders maintain water rights to the Indian River and have a direct interest in preserving the quality of this water resource. According toWilliams (2001), monitoring water quality and quantity in the Indian River is important. Protection of water quality also involves monitoring for concentrations of mercury, persistent organic pollutants (POPs), and fecal coliform, as well as water temperature, dissolved oxygen levels, turbidity, and the community composition of sensitive macroinvertebrates.

Mercury is an elemental pollutant with a complex life cycle in the atmosphere and biosphere, which leads to difficulty in detecting its origin (Landers et al. 2008). Anthropogenic sources of mercury (e.g., combustion, smelting, and petroleum refining) are thought to account for 75% of the mercury that enters the atmosphere, with the remainder originating from geologic and biogenic sources (Landers et al. 2008). Mercury is entering national parks in Alaska through atmospheric deposition from local, regional, and trans-Pacific sources (Landers et al. 2008). In water, mercury converts to methylmercury, a neurotoxin that biomagnifies in the aquatic food web (EPA 2010).

POPs are toxic chemicals that can be transported over long distances by wind and water (EPA 2002). They are lipid soluble and bioconcentrate in the fatty tissue of organisms, negatively affecting organisms at higher trophic levels. These chemicals may cause physical, behavioral, and reproductive abnormalities to the environment, wildlife, and human life (EPA 2002). POPs enter the water system via effluent releases (e.g., industrial waste), atmospheric deposition, runoff, and by other means (EPA 2002). Currently, 90 countries have agreed to reduce the production and use of 12 specific POPs under a treaty called the Stockholm Convention formulated by the United Nations Environment Programme (UNEP) (EPA 2002). These 12 POPs, known as the ―dirty dozen", are aldrin, cholrdane, dichlorodiphenyltrichloroethane (DDT), dieldrin, endrin, heptachlor, hexachlorobenzene, mirex, toxaphene, polychlorinated biphenyls (PCBs), dioxins, and furans (EPA 2002). The United States has already stopped production of many POPs mentioned in the agreement, but POPs are still unintentionally released from industrial processes and combustion (EPA 2002).

The presence of fecal coliform bacteria indicates contamination of a waterbody from human or animal fecal material; the detection of fecal coliform colonies in water bodies may indicate the presence of pathogenic microorganisms (Mau and Pope 1999, USGS 2010). Possible sources of fecal coliform in the Indian River include sewage, storm water runoff, boating waste, malfunctioning septic systems, and animal waste (Eckert et al. 2006).

Water temperatures are important for specific biological processes including fish metabolism, growth rates, and oxygen solubility (Eckert et al. 2006). Water temperature greatly influences water chemistry and the organisms that live in aquatic systems. Not only can temperature affect the ability of water to hold oxygen, it also affects biological activity and growth within water systems (Eckert et al. 2006, USGS 2010). All aquatic organisms, from fish to insects to zoo- and phytoplankton, have a preferred or ideal temperature range for existence (USGS 2010). As temperature increases or decreases too far past this range, the number of individuals able to survive eventually decreases. In addition, higher temperatures allow some compounds or pollutants to dissolve more easily in water and can be more toxic to aquatic life (USGS 2010). Salmonid larvae are particularly sensitive to warm temperatures, so increases in temperature are problematic for streams that support salmon populations, such as the Indian River.

Dissolved oxygen (DO) is critical for aquatic organisms. Fish and zooplankton absorb dissolved oxygen from the water to survive (USGS 2010). Oxygen enters water from the atmosphere by direct contact and river turbulence and from oxygen-producing photosynthetic organisms such as benthic algae and cyanobacteria. As the amount of DO drops, it becomes more difficult for water-based organisms to survive (USGS 2010). The concentration of DO in a water body is closely related to water temperature; cold water holds more DO than does warm water (USGS

2010). Therefore, DO concentrations are subject to seasonal fluctuations as low temperatures in the winter and spring allow water to hold more oxygen, and warmer waters in the summer and fall hold less oxygen (USGS 2010). The hydraulic characteristics of the stream, photosynthetic or respiratory activity of stream biota, and the quantity of organic matter present also contribute to high or low levels of dissolved oxygen (Neal et al. 2004). Neal et al. (2004) suggest that management and monitoring of dissolved oxygen levels is particularly important in SITK, as a number of species prominent in the park require high levels of dissolved oxygen at every stage in their life cycle, including salmonids and many macroinvertebrates.

Turbidity is the amount of fine particle matter (i.e., clay, silt, plankton, microscopic organisms, or finely divided organic or inorganic matter) suspended in water and measured by the scattering effect that solids have on light that passes through water (USGS 2010). For instance, the more light that is scattered, the higher the turbidity measurement will be. The suspended materials that make water turbid can absorb heat from sunlight, increasing the water temperature in waterways and reducing the concentration of dissolved oxygen in the water (USGS 2010). The scattering of sunlight by suspended particles decreases photosynthesis by plants and algae, which contributes to decreased DO concentrations in the water (USGS 2010). Suspended particles also irritate and clog the gill structures of many fish or amphibians, making it difficult to thrive (USGS 2010). Higher turbidity indicates increased siltation, which can clog interstitial space in riverbed gravels. This in turn can reduce intergravel habitat and smother salmonid eggs and macroinvertebrates and reduce flow through the gravel that delivers DO to organisms and removes waste products. Increase in siltation will reduce salmonid production.

Benthic macroinvertebrates are indicators of the biological health of aquatic ecosystems (Paustian and Hardy 1995). Abundance of the orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) (EPT) particularly sensitive to changes in their environment and will disappear or be reduced if aquatic conditions deteriorate and other more tolerant organisms will replace them. A high percentage of EPT taxa indicates an unimpaired stream with good water quality (Paustian and Hardy 1995).

The Indian River and its watershed extend well outside of SITK boundaries, and therefore, most of the current issues within the watershed lie outside the park (Eckert et al. 2006). According to Eckert et al. (2006), biotic, physical, and chemical parameters such as specific conductance, pH, water temperature, dissolved oxygen, and suspended sediment, indicate that the water quality of the Indian River is good to excellent based on the available data. Changes in three measures in particular - water temperature, dissolved oxygen, and turbidity - have the potential to affect not only the chemical composition of the Indian River but also many of the organisms that live in the river, including sensitive macroinvertebrates.

Measures

- Mercury
- Persistent organic pollutants (POPs)
- Fecal coliform
- Water temperature
- Dissolved oxygen
- Turbidity
- Combination of metrics to determine community composition of sensitive macroinvertebrates (i.e., percent EPT taxa, percent noninsect taxa, percent scraper taxa, pollution tolerance, etc.)

Reference Conditions/Values

One task embodied by the mission of the NPS is ―preserving and protecting water resources and water dependent environments in parks" (NPS 1998, p. 1). Likewise, according to NPS Management Policies (4.6.3 Water Quality) regarding the park‗s water quality the NPS should ―work with appropriate governmental bodies to obtain the highest possible standards available under the Clean Water Act for the protection of park waters; take all necessary actions to maintain or restore the quality of surface waters and groundwaters within the parks consistne with the Clean Water Act and all other applicable federal, state, and local laws and regulations…" (NPS 2006). Ensuring the integrity of park water quality and aquatic habitat, due to its importance in sustaining natural, aquatic park ecosystems and supporting human consumptive and recreational use, is fundamental to successfully addressing this task. One set of reference conditions for water quality in SITK are the criteria set forth by the NPS-funded assessment of coastal water resources and watershed conditions at SITK (Eckert et al. 2006), as well as the Environmental Protection Agency (EPA). However, SEAN suggests examining Indian River water quality data overtime to detect changes. Therefore, current water quality data can act as reference conditions to compare with data collected in the future. The criteria for the majority of the water quality parameters are listed in Table 15. There are no standardized criteria for acceptable levels of POPs in water bodies. Instead, presence and concentration of these compounds are typically recorded over time to understand trends. Likewise, there is no standard for abundance of macroinvertebrates, but many metrics have been developed to compare species composition overtime and with index streams used as a reference to indicate trends in water quality. Historic readings of water temperature, dissolved oxygen, and turbidity either do not exist or are incomplete for much of the Sitka region. While the upper drainage of the river has been historically gaged by the USGS since 1980 at two water quality monitoring sites (one approximately 1.9 km upstream of SITK and the other just outside of the park boundary), very little additional data exists concerning historical water quality or macroinvertebrate diversity. Water quality data collected was collected in 2010 and 2011, and macroinvertebrate data was collected from 2009 to 2011.

Table 15. Selected water quality standards for the state of Alaska (ADEC 2003). Standards for all parameters except fecal coliform bacteria refer to the criteria for the -growth and propagation of fish, shellfish, other aquatic life, and wildlife". Fecal coliform bacteria refers to the -Water Recreation—contact recreation" criterion (Eckert et al. 2006). No state standards have been set for POPs or macroinvertebrates.

Parameter	Criteria
Mercury	Levels should be less than 0.0002 mg/L (Neal et al. 2004).
Fecal coliform bacteria	In a 30-day period, the geometric mean of samples may not exceed 100 FC/100 mL, and not more than one sample, or more than 10% of the samples if there are more than 10 samples, may exceed 200 FC/100 mL.
Water temperature	May not exceed 20ºC at any time. The following maximum temperatures may not be exceeded, where applicable: Migration routes 15ºC Spawning areas 13ºC Rearing areas 15ºC Egg and fry incubation 13ºC For all other waters, the weekly average temperature may not exceed site-specific requirements needed to preserve normal species diversity or to prevent the appearance of nuisance organisms.
Dissolved oxygen	Dissolved oxygen needs to measure below 17 mg/L and above 7 mg/L at all times.
Turbidity	May not exceed 25 nephelometric turbidity units (NTU) above natural conditions. For all lake waters, may not exceed 5 NTU above natural conditions.

Data and Methods

Although long-term aquatic habitat monitoring has not been consistent throughout the history of SITK, several studies have been undertaken. Studies and assessments by Paustian and Hardy (1995) in 1994, the NPS (1998), and USGS (Neal et al. 2004) in 2001-2002 provide several baseline surveys that were used in evaluating the condition and trend of certain measures such as contaminants affecting water quality and the presence of harmful chemicals, POPs, or various macroinvertebrates. Paustian and Hardy (1995), for example, used detailed channel cross-section surveys and longitudinal profiling along the thalweg of the Indian River in SITK to measure channel morphology. They used a simple pebble count procedure to describe streambed characteristics and evaluated fish habitat using a hierarchical stream habitat classification approach. Their report provides some of the earliest monitoring and baseline data available in SITK, as well as the first assessment of the overall freshwater aquatic habitat in the park.

NPS (1998) compiled a baseline inventory and analysis of the water quality in SITK. Data were obtained from six of the EPA's national databases: (1) Storage and Retrieval (STORET) water quality database management system; (2) River Reach File (RF3); (3) Industrial Facilities Discharge (IFD); (4) Drinking Water Supplies (DRINKS); (5) Water Gages (GAGES); and (6) Water Impoundments (DAMS) (NPS 1998). There were only three observations on temperature; two occurred at the Indian River at Sitka (station 15087700) located 1 km upstream of the mouth of the Indian River in June of 1967 and 1968, with the third occurring in October 1982.

In 2001 and 2002, the NPS and USGS examined a number of water quality parameters on the Indian River to determine the effects of recent development, as well as to identify a baseline for comparison in future studies of water quality (Neal et al. 2004). Samples were obtained from two different collection sites; the Indian River near Sitka (station 15087690) and the Indian River at Sitka (station 15087700). Using cross-sectional measurements, the water quality parameters examined included specific conductance, pH, water temperature, and concentration of dissolved oxygen (Neal et al. 2004). Data for this particular study was gathered over 6-8 week intervals; 11 samples were taken from each site (Neal et al. 2004).

In June and July of 2007, Nagorski et al. (2009) examined 19 streams in and immediately adjacent to SEAN National Park units including SITK. Samples of streamwater, suspended particulates, streambed sediments, benthic macroinvertebrates, and juvenile coho salmon were collected to determine a baseline of contaminant concentrations and evaluate spatial differences in their occurrence (Nagorski et al. 2009).

Since 2007, NPS has measured water temperature at the upper and lower Indian River stream gages, which record water surface elevation and temperature every fifteen minutes. Beginning in 2010, the NPS installed a YSI (Yellow Springs Institute) water quality sonde at the lower Indian River gage site. This sonde records water temperature, dissolved oxygen, pH, and specific conductivity every hour and typically operates from May through October.

NPS data were obtained from Geof Smith (former SITK biologist). Sampling and identification of Indian River macroinvertebrates in STIK was conducted from 2002 to 2010. Sampling methods used were those of the Environment and Natural Resources Institute (ENRI 1999), University of Alaska Anchorage (adapted from Barbour et al. 1999). Specimens were collected from all major habitat types (e.g., riffle, pool, run, undercut bank) in a 100-meter reach. A subsample of 300 organisms was sorted in a laboratory and identified to the lowest practical taxon, generally to the genus (ENRI 1999). Various metrics were applied to determine water quality; macroinvertebrate taxa tolerance levels were assigned based on the Northwest Region (Idaho) criteria published by the EPA (Appendix 8) (Barbour et al. 1999).

Current Condition and Trend

Mercury

According to Nagorski et al. (2009), the Indian River had some of the lowest levels of filtered total mercury of the 19 studied streams throughout southeast Alaska (0.3-0.4 ng/L), as well as filtered methylmercury. This is likely because the Indian River is a recently formed stream, whereas other water bodies are older and have had more time to accumulate mercury (Nagorski et al. 2009). Eckert et al. (2006) summarized the work completed by Neal et al. (2004), and reported levels of mercury found in sediment samples to be 0.06 µg/L and 0.07 µg/L at the lower and upper gage stations in 2001 and 2002. In addition, the document summarizes the NPS (1998) data findings of 0.1 µg/L of mercury between June 1996 and July 1997. Mercury levels did not exceed state criteria in any of these studies. However, mercury was found in seabird eggs on islands in Sitka Sound (Christopher et al. 2002, as cited by Eckert et al. 2006), which according to Eckert et al. (2006), indicated levels of mercury may be a higher concern to southeast Alaska in comparison to other regions of Alaska. This pollutant is expected to affect the environment for decades to come (Eckert et al. 2006).

Persistent Organic Pollutants (POPs)
Nagorski et al. (2009) found that the Indian River in SITK had the highest levels of PCBs compared to the Skagway and Taiya River watersheds in KLGO and 16 watersheds within Glacier Bay National Park and Preserve (GLBA). However, none of these measurements exceeded criteria for protecting human and wildlife health (Nagorski et al. 2009). Total PCB levels (the sum of 40 different types) were measured in juvenile coho salmon at 8.2 ng/g wet weight based on the whole fish (Nagorski et al. 2009). The total DDT levels in juvenile coho salmon were 1.3 ng/g wet weight, also based on the whole fish (Nagorski et al. 2009). Other POP levels such as dieldrin, aldrin, mirex, BDEs (brominated diphenyl ethers), CHLDs (chlordanes), HCHs (hexachlorocyclohexanes), and HCB (hexachlorobenzene) were below the level of quantification in juvenile coho salmon (Nagorski et al. 2009). Elevated PCB levels were also found in murre eggs and intertidal mussels in the Sitka area (Vander Pol et al. 2004, Nagorski et al. 2009).

Fecal Coliform
According to the Alaska Department of Environmental Conservation (ADEC 2003), ~~"in~~ a 30-day period, the geometric mean for samples may not exceed 100 FC/100 mL, and not more than one sample, or more than 10% of the samples if there are more than 10 samples, may exceed 200 FC/100 mL" (p. 6). Fecal coliform are the only bacteria that are likely to measure above ambient water levels from diluted wastewater that is dumped by small marine vessels (Eckert et al. 2006). There has been one instance where fecal coliform levels exceeded state regulations within the Park in a drainage ditch that flowed from Sheldon Jackson College property through the park and into the Indian River (Eckert et al. 2006). A dye test showed that the drainage came from a college housing unit. In subsequent testing, fecal coliforms did not go above the state limit (G. Smith (pers. comm., 2011). Testing of the ditch ended in 2005. Pockets of fecal coliforms were found in the intertidal zone of the Park in 2001. Some of it was determined to be human contamination. However, the source of this fecal coliform was never determined G. Smith (pers. comm., 2011).

Water Temperature
According to the ADEC (2003), water temperatures should never exceed 20º C to protect the biota within the river (Table 15). Eckert et al. (2006) indicated that the water temperature of the Indian River ranged between 0ºC and 10.5ºC, which is considered good to excellent for the organisms that inhabit the river. Nagorski et al. (2009) also found water temperature of the Indian River to be excellent, with water quality parameters found to be within acceptable ranges for fish survival (7.9ºC). Neal et al. (2004) found water temperatures ranging from 0ºC to 10.5ºC between April 2001 and August 2002 at the downstream site, Indian River at Sitka, which is closer to the park (Figure 33). Neal et al. (2004) also indicated slightly larger ranges in water temperature at the downstream site. The authors noted the ranges in water temperature at the Indian River sites were seasonal.

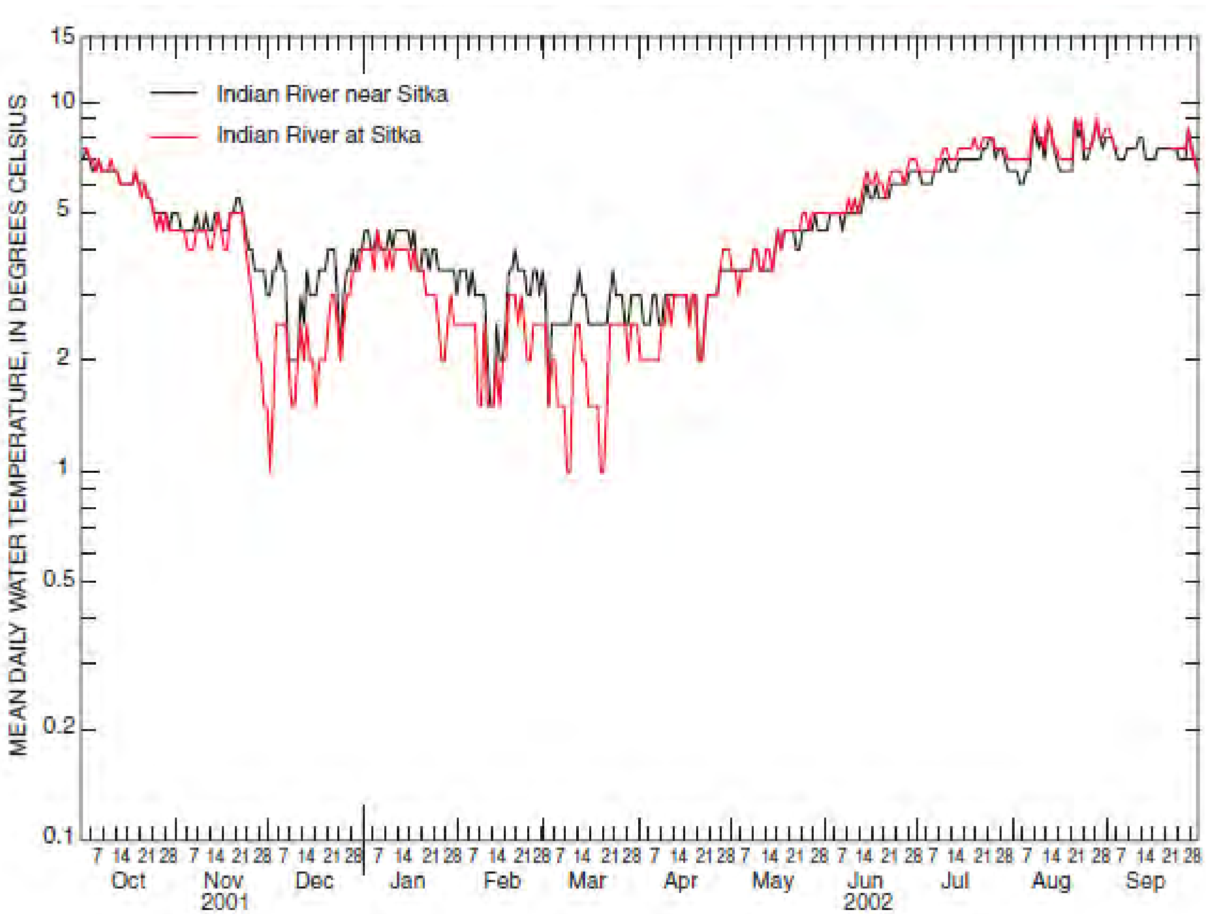

Figure 33. Mean daily water temperature of Indian River near Sitka (Station 15087690) and Indian River at Sitka (station 15087700), October 2001 through September 2002. Reproduced from Neal et al. (2004).

More recently, the water temperature of the Indian River has been monitored consistently within the park, and measurements exist across several years at both gages. Unpublished temperature data (NPS 2011) spanning nearly five years of monitoring are displayed in Figure 34 and Figure 35. Note that at both sites, water temperatures rarely exceeded a daily maximum of 10°C over the period of record. The maximum temperature at both sites, 10.93°C, was reached on 18 August 2009. As found in the studies conducted by Neal et al. (2004) and Nagorski et al. (2009), all temperature measurements were below the maximum threshold established by the ADEC.

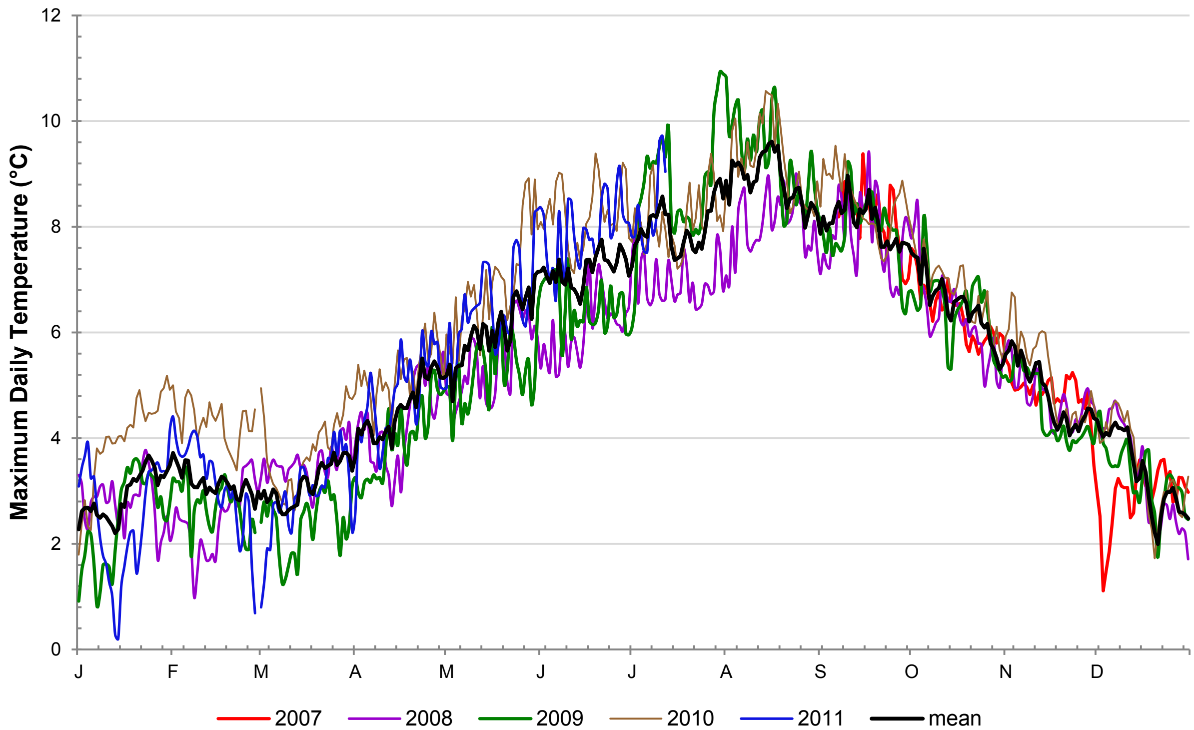

Figure 34. Maximum daily temperature of the Indian River at Sitka (Station 15087700) (NPS 2011 unpublished data received from Craig Smith).

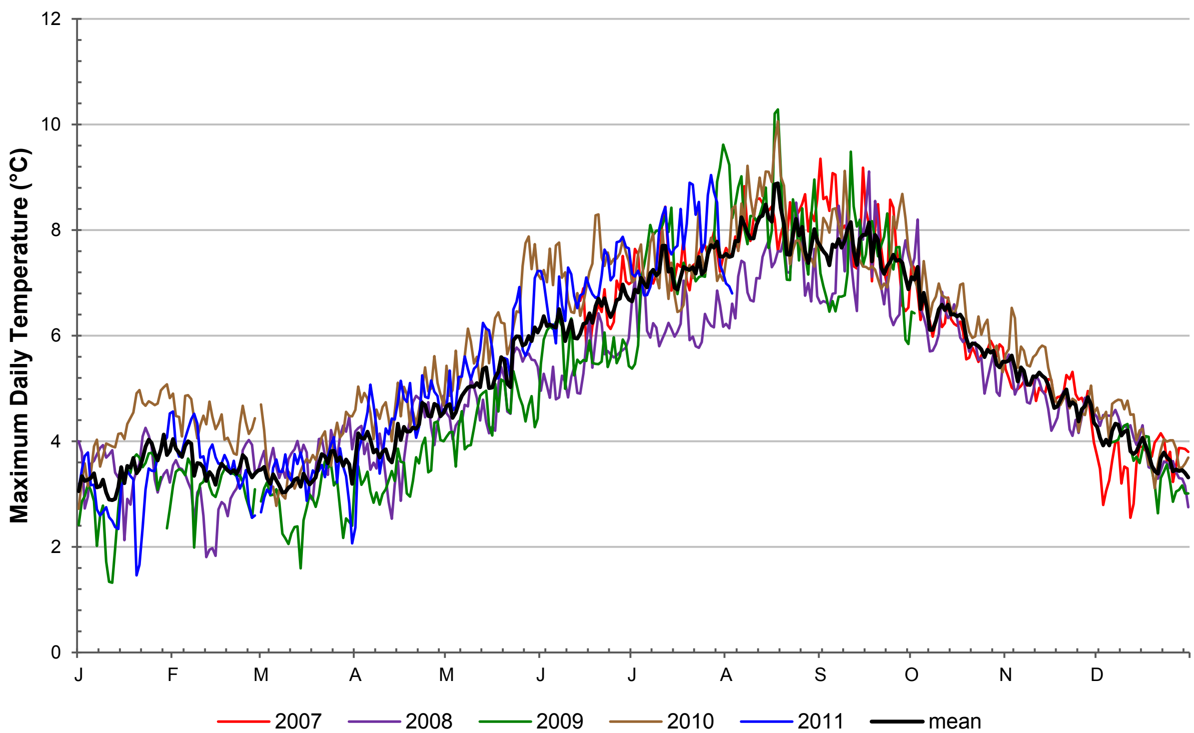

Figure 35. Maximum daily temperature of the Indian River near Sitka (Station 15087690) (NPS 2011 unpublished data, received from Craig Smith).

Dissolved Oxygen (DO)
The Indian River is an oligotrophic system with a DO range of 11.2 mg/L to 14.1 mg/L (Neal et al. 2004). Eckert et al. (2006) stated that DO levels of the Indian River were adequate to support populations of salmonids and other fish species (11.3 mg/L to 14.1 mg/L) and indicated good to excellent health of the river. Nagorski et al. (2009) also found the Indian River‘s DO to be within acceptable ranges for fish survival (13.0 mg/L).

Turbidity
Turbidity varies throughout the year but is principally driven by heavy rain events. This is especially evident in the September through December period - the high rain months in the Sitka area (ADEC 2002). Eckert et al. (2006) noted that suspended sediment was low, ranging from 0 to 4 mg/L, with little variation upstream and downstream, although sediment load increased during high flow events. Nagorski et al. (2009) found the Indian River had the lowest turbidity of all the streams sampled in their study. Eckert et al. (2006) classified the Indian River as having no detectable turbidity problem. Considering that turbidity has not been an issue in the Indian River in the past, SEAN decided not to monitor this physical water quality parameter at SITK. Eckert et al. (2006) mentions that although the presence and effects of cruise ships are largely unknown, increased turbidity of ocean water from the stirring up of bottom sediments and increase in sedimentation of the intertidal zone is one potential area of concern to SITK‘s 50 acres of intertidal zone. It is unclear whether this concern presents any detrimental effects to the park‘s freshwater environment.

Community composition-based sampling of Sensitive Macroinvertebrates
The diversity of aquatic insect communities has proven to be a very useful indicator of water quality, due to differential tolerance of macroinvertebrates to pollutants and other disturbances to aquatic systems (Milner and Oswood 1991). Furthermore, macroinvertebrates can indicate the health of a system over time prior to sampling rather than only at the time of sampling, as with chemical analysis (Paustian and Hardy 1995). Limited information and baseline data exist for macroinvertebrates in SITK prior to 1994 (Paustian and Hardy 1995) when two sets of macroinvertebrate samples were collected from the Indian River in the vicinity of the SITK foot bridge in early May. This was a relatively quick assessment to gather baseline data to assess water quality conditions in the park. The macroinvertebrate portion of Paustian and Hardy (1995) was a supplement to this report and the work was completed by Major and Milner (1994). An additional sample was collected in the fall, upstream near the USGS gaging site (RM 2) to act as a control site, since it was reported by the authors to not contain spawning salmon and was not affected by human disturbances (Paustian and Hardy 1995). However, G. Smith (pers. comm., 2012) consulting with Dan Rinella and Dan Bogan of ENRI, asserts that these two sample locations represent different habitats (e.g., differing stream gradients, temperature, and amounts of pool and riffle structures). G. Smith (pers. comm., 2012) also notes that spawning usually occurs at both locations and that marcroinvertebrate numbers and composition may be skewed when conducting September sampling because salmon totally disrupt the benthic environment in the spawning process (G. Smith, pers. comm., 2012). Therefore, caution needs to be used when comparing the upper site to the lower site when assessing overall water quality based on the limited information from one this one study.

Never the less, the metrics for flood plain channel types in the Indian River included the presence of EPT genera, EPT/total individuals ratio, percent dominant taxa and Hilsenhoff‘s

Family Biotic Index (FBI). In 1994, all four metrics indicated good water quality at the gaging station control (RM 2). Two of the metrics (EPT ratio and percent dominant taxa) indicated slight water quality impairment for the two stations within the Park. These stations had –relatively low EPT diversity and were dominated by Diptera (true flies), specifically Chironomidae, which contain many pollution-tolerant genera" (Paustian and Hardy 1995, pg. 23). Another Dipteran family that is relatively important in the Indian River is Simuliidae (black flies.

Eckert et al. (2006) reported an abundance of individuals from the EPT orders collected in the Indian River, which indicates excellent water quality. Water quality degradation could reduce these taxa. Other macroinvertebrates found in the Indian River were from the order Diptera, specifically the family Chironomidae (Eckert et al. 2006). Many members of this family are pollution-tolerant, and although they tend to be dominant in degraded waters, they can also be found in areas with good water quality, (Eckert et al. 2006). Though far less diverse than Chironomidae, Simuliidae is another important Dipteran family in the Indian River. Only one genus is known from the Indian River (*Prosimulium*), this genus lives in clean water (tolerance value of 3) and its presence would not indicate degraded water quality conditions (G. Smith, pers. comm., 2012). Fewer macroinvertebrate taxa were collected in the Indian River (lower diversity) relative to many high-quality streams in the contiguous United States, but the numbers, including EPT taxa, were typical for streams in Alaska (Neal et al. 2004).

More recent macroinvertebrate sampling efforts, conducted through the 2000s have resulted in just over nine years of data in SITK. Macroinvertebrates were collected, sorted, identified, and stored in SITK. One metric that proved useful to evaluate Indian River water quality from these samples was to assign a tolerance level to each taxon collected, based on the EPA's published list (Borbour et al. 1999) (Appendix 8). Tolerance values are derived from other research conducted in a particular section of the country. The Sitka area is considered to be in the Northwest because of taxonomic affinities with other rivers in the Northwest Region. In this case, the research used by the EPA was conducted in Idaho. Tolerance values can be used with other metrics to access water quality, using macroinvertebrate sampling..

Consultation with ENRI staff was invaluable. SITK staff relied on theirexpertise, reports and protocols extensively when developing a macroinvertebrate monitoring program and establishing a Stream Team Program in the park. The ENRI lab was also used to identify diatoms and Chironomids from Indian River samples (G. Smith, pers. comm., 2012).

Eckert et al. (2006) warned that diminished streamflow and changes in sediment dynamics in the lower channel of the Indian River may damage habitats used by macroinvertebrates. Given the presence of a pollution tolerant species and the lack of a high relative diversity, Paustian and Hardy (1995) concluded that there might have been a slight impairment in the water quality along the lower region of the Indian River. However, after several years of more recent macroinvertebrate data collection, this conclusion was not reaffirmed by G. Smith. Macroinvertebrate sampling in the park by Smith (June or July 2002-2010) and the Stream Team program (May) has indicated excellent water quality in the Indian River.

Threats and Stressor Factors
Eckert et al. (2006) provided a recent, comprehensive list and discussion of threats and stressors to the park, including the following: long-range transport of airborne contaminants, vessel traffic, point source pollution, urban landscape/development, climate change, and harmful algal blooms. Eckert et al. (2006) acts as the primary source for this section unless otherwise noted.

Stressors of aquatic habitat include climate change, water diversion, upstream development and algal blooms. The majority of airborne contaminants are carried to Alaska via long-range atmospheric pathways (Pacyna and Pacyna 2002). Pacyna and Pacyna (2002) report that Asia is a major contributor to long-range airborne contaminants, as weather patterns travel to the west coast of Alaska from the east coast of Asia. Geographically variation in contaminant concentration, in terms of how they are transported and deposited, is poorly understood. However, studies have shown that airborne pollutants tend to accumulate in Alaska (Pacyna and Pacyna 2002). Levels of mercury and POPs have shown significant increases in Alaska within the last few decades; detectable levels have been found in the fat of a variety of mammals and have caused eggshell thinning in raptors (Pacyna and Pacyna 2002).

vessel traffic can have a large impact on water quality, in particular by disturbing bottom sediments, which may interfere with filter feeding organisms and possibly cause suffocation. The effects of cruise ships on water quality are unknown, especially in freshwater habitats. Indian River water quality is protected under the Geographic Response Strategy (GRS) that was created by the Alaska Department of Environmental Conservation and other agencies to protect a specific sensitive area from oil impacts following a marine vessel spill. Cruise ship and small vessel traffic as well as marine/intertidal stressors are discussed further in section 4.8 of this assessment.

Point source pollution from the Indian River asphalt plant, the former Sheldon Jackson College Aquarium and Hatchery (now operated by the Sitka Sound Science Center), and petroleum spills from marine vessels threatens the Indian River. Located near the mouth of the river, the Indian River asphalt site was in business from 1957-1961 (Shannon and Wilson Inc. 1995). Since 1990, contamination from weathered diesel and asphalt-range material has been detected in the area. Barrels filled with diesel fuel were buried on the Indian River asphalt plant site, and began to leak in the 1990s (Shannon and Wilson Inc. 1995). Storm events erode away the soil and pollutants leach into the groundwater. It is suspected that contaminant exposure will only increase from this particular site.

In 2001 the park purchased 6.5 acres of land from from SJC (G. Smith, pers. comm., 2012). Part of the purchase agreement was to allow the three drainages on that property to continue through the park and into the Indian River. The drainage on the far northwest portion of this area appears to be natural, the second is Indian River overflow water that was diverted for fish hatchery use, and the third is a drainage that comes from housing units just outside the park. Fecal coliforms were found above the state standard in the latter drainage during one sampling. The park later installed a culvert in this drainage and covered it with soil to alleviate a safety hazard to children and to remove the unsightly appearance of the drainage ditch. The water from the housing unit continues to drain through the park via this culvert and into the Indian River. Water quality and nutrient sampling was conducted on the housing drainage and the natural drainage up to 2005. The Indian River return flow from the hatchery was a macroinvertebrate sampling site used by the Steam Team program. Pollution from petroleum spills present another point source, which can be damaging to the environment regardless of the size of the spill. Petroleum can enter SITK via leaks, spills, or discharge of bilge or ballast water; discharge from a two-stroke engine; and accidental release through a vessel grounding or collision. Water quality data for the Indian River were collected in 1996 and 1997 by Shannon and Wilson Inc. as a part of a Phase II Site Assessment of the Indian River asphalt plant site. This study observed no violations of the EPA's water quality criteria.

Increasing upstream development can potentially have an effect on downstream aquatic habitat conditions. Runoff from developed and urbanized areas poses a threat to the water quality of SITK; however, these effects are yet undetectable (Makepeace et al. 1995). Although construction activities have been kept to a minimum, development near the Indian River has occurred mainly in the lower areas of the watershed. Continued increases in residential development in the Indian River watershed could threaten the water quality of the Indian River (NPS 2010). Recent development projects include a "landfill, a public safety academy driver training course, Sitka Counseling and Prevention Services (SCPS) housing and parking improvements, Sitka and Indian River trail improvements, and a City and Bureau of Sitka (CBS) Electrical Department extension" (CBS 2004, as cited in Eckert et al. 2006, p. 46). Each of these development plans has the potential to negatively affect watershed health and overall Indian River water quality. There is concern around the idea of developing a new deepwater cruise ship dock that could disrupt the mixing of fresh and ocean water in the estuarine areas.

The diversity and extent of climate change effects are unknown, but may be significantly more severe at higher latitudes. Climate change is a very serious threat to freshwater quality in Alaska, specifically to water released into the Indian River via ice melt and precipitation in the form of rain. Increased temperatures raise the amount of ice melt runoff, which can alter the amount of in-stream sediment and streamflow (i.e., discharge). In addition, changes in runoff can alter the "composition of the substrate and habitat complexity of the stream" (Williams 1989, p. 54). High temperatures and elevated carbon dioxide levels will affect plant productivity and distribution, which then affects the leaf litter quality and amount that enters streams and rivers (Meyer and Pulliam 1992, as cited in Eckert et al. 2006). There is potential for a reduction of stream temperatures from increased snowmelt, which may decrease primary production. Lower stream temperatures from increased snowmelt could affect or eliminate certain invertebrates (Lloyd et al. 1987, as cited in Eckert et al. 2006).

Harmful algal blooms (HABs) result from a population boom of phytoplankton that produce toxins. They can cause mortality among marine birds, mammals, and fish, and illness in humans (Anderson et al. 2000, as cited in Eckert et al. 2006). They vary in symptoms and effects; for example, some are paralytic, diarrhetic, or neurotoxic to the body. The diatom *Didymosphenia geminate*, also called didymo or Rock Snot, was first detected in the Indian River in 2006 and has been present in subsequent surveys, except for 2009, a relatively high water year (USFWS 2007; C. Smith, pers. comm., 2011, SITK Diatom Monitoring 2006-2010). Didymo can form dense mats and exhibits invasive behavior by dominating streambeds. Also, in extended low water periods in the spring, the filamentous green algae *Ulothrix zonata* can form dense blooms, particularly in the lower river within the park. Density of the blooms have been seen to trap and kill emerging salmon fry. Twenty-four species of algae were recorded in the Indian River at Sitka (station 15087700), and 35 species were identified at Indian River near Sitka (station

15087690) during the Eckert et al. (2006) study. The species that dominated the counts were from the cyanobacteria genus *Pseudanabaena* and the diatom species *Hannaea arcus* (Neal et al. 2004). Neal et al. (2004) observed that pinnate diatoms (species of algae) dominated the majority of samples. Further upstream from the park, cyanobacteria (blue-green algae) accounted for most of the algal biomass; green and cyanobacteria (blue-green algae) accounted for the algal biomass within the park (Neal et al. 2004). Continued benthic diatom monitoring (2006-2010) has detected over 50 species in the Indian River within the park (SITK Diatom Monitoring 2006-2010). The diatoms that were consistently the highest in relative abundance during this period include *Achnanthidium minutissimum, Diatoma mesodon, Hannaea arcus, Synedra ulna,* and *Didymosphenia geminate*. All generally require cold, oxygen-rich water. The dominate filamentous green algae in the Indian River is *Ulothrix zonata,* also a cold water species. HABs have been documented for centuries, but have recently increased in frequency and location over the last few decades (Anderson et al. 1995, as cited in Eckert et al. 2006). To date there have been no reported HABs in the Indian River, although didymo remains a species of concern that is worthy of close monitoring.

Data Needs/Gaps

Eckert et al. (2006) suggests that Indian River water quality needs consistent monitoring on all parameters. It is noted, however, that an –all-parameter, all the time" approach to monitoring can be cost prohibitive; C. Smith, notes that this approach may not be necessary as, generally speaking, water quality of the Indian River as it flows through the park is well characterized and SEAN Vital Signs monitoring is collecting temperature, DO, pH and conductivity from May through October annually (pers. comm., 2011).

Other data gaps suggested in the Eckert et al. (2006) report include monitoring of erosion and storm runoff and monitoring of mercury and POP levels. The authors suggest that erosion and stormwater monitoring would assist management in understanding what chemicals are entering the river after storm events, and how they are affecting the biota by looking for a decline in sensitive macroinvertebrate populations. HABs need more research and management, specifically on biomass cover (C. Smith, pers. comm., 2011). Monitoring mercury and POP levels may be necessary because current monitoring in the rest of the state suggests levels of these contaminants are a major concern. If these contaminants are present in SITK, monitoring programs will need to have an understanding of what contaminants are in the park in order to manage them. Eckert et al. (2006) also recommend that monitoring these parameters would give the park a better idea of and reference for the levels of pollutants that exist in the watershed. Finally, it was emphasized that all development activities should be monitored before, during, and after activity to discover and understand the effects that development activities have on the park (Eckert et al. 2006).

Overall Condition

SITK staff assigned all measures (mercury, POPs, fecal coliform, water temperature, dissolved oxygen, turbidity, and community composition monitoring of sensitive macroinvertebrates) a *Significance Level* of 3, indicating they are of equal importance in understanding the overall condition of water quality in the Indian River in SITK.

Mercury
SITK's mercury measure was assigned a *Condition Level* of 1 due its presence within southeast Alaska, and its expected increase in presence. Mercury levels recorded within the Indian River were some of the lowest throughout Nagorski et al.'s (2009) study within the southeast Alaska region. The reported levels in Nagorski et al. (2009) and Eckert et al. (2006) did not exceed the established mercury limits as listed in Neal et al. (2004) (Table 15). With the data available, the condition level of this parameter is considered to be of low concern; even though concentrations of mercury are low within SITK, the pollutant is still present. Future monitoring of these levels should be conducted, considering the threat it poses in the southeast Alaska region. The very limited data available on this measure make it difficult to understand if mercury levels in the park are affecting SITK's freshwater water quality. The SEAN has prioritized the completion of a freshwater contaminants protocol that will incorporate mercury sampling.

Persistent Organic Pollutants
SITK's persistent organic pollutants measure was assigned a *Condition Level* of 1 due to elevated detection levels compared to other locations nearby. Higher levels of POPs were detected in SITK than other areas of study within Southeast Alaska. High POP levels could be attributed to contaminated air transported from Asia, because there are no known sources of these pollutants in North America since their production has been banned for years (Nagorski et al. 2009). It is important that POP levels are monitored carefully because of their potentially severe effects on the biota.

Fecal Coliform
SITK's fecal coliform measure was assigned a *Condition Level* of 1. There have been few documented instances of fecal coliform within the park. A former park biologist detected it in a drainage ditch that flows through SITK to the Indian River and it was detected in the intertidal zone one year (G. Smith, pers. comm., 2011); the source of this contaminant was never determined. No new incidences of its presence have been reported. Future sampling to detect fecal coliform is important as new sources can emerge from development within the watershed.

Water Temperature
SITK's water temperature measure was assigned a *Condition Level* of 0. This measure is currently of no concern to the park, because consistent monitoring has not detected any cases where water temperature exceeded limits that threaten the ecosystem. By comparing data from recent years 2005-2011 (Figure 34 and Figure 35), it is evident that the water temperature of the Indian River is very consistent and does not exceed the criteria determined to sustain salmonid reproduction or living conditions (Table 15).

Dissolved Oxygen
SITK's dissolved oxygen measure was assigned a *Condition Level* of 0. All studies have shown that dissolved oxygen levels within the Indian River indicate excellent water quality. Currently, dissolved oxygen levels are monitored by SEAN.

Turbidity
SITK's turbidity measure was assigned a *Condition Level* of 0. The Indian River is a clear water river, and previous monitoring has shown that turbidity is not an area of concern within the park. As a result of the park's confidence in this parameter's condition, monitoring efforts have ceased.

Community Composition of Sensitive Macroinvertebrates
SITK's community composition of sensitive macroinvertebrates measure was assigned a *Condition Level* of 0. This measure is of no concern to the park given the repeated identification of taxa that are indicative of excellent water quality.

Weighted Condition Score (WCS)
The Weighted Condition Score (WCS) for freshwater water quality in SITK is 0.143. A WCS of 0.143 indicates that this component is of low concern. Given data implications and park management opinions, condition of this component in the park is stable.

According to Eckert et al. (2006, p. 9), ―the Alaska Department of Environmental Conservation does not list the Indian River or any area nearby that could affect the Indian River as a contaminated site. This watershed is considered to be healthy and is relatively pristine, and does not violate any of the criteria for Alaska's water quality standards." Based on the available information, the water quality of the Indian River is stable and of high quality (Eckert et al. 2006). Impairments to the park are listed in

Table **16**.

Freshwater Water Quality

Measures	SL	CL
Mercury	3	1
Persistent organic pollutants (POPs)	3	1
Fecal coliform	3	1
Water temperature	3	0
Dissolved oxygen	3	0
Turbidity	3	0
Community composition of sensitive macroinvertebrates	3	0

WCS = 0.143

Table 16. Potential for impairment of SITK water resources. Reproduced from Eckert et al. (2006). EP = existing problem, PP = potential problem - limited data, OK = no detectable problem, NA = not applicable.

Indicator	Freshwater/Indian River	Estuary	Marine/Intertidal
Water Quality			
Eutrophication	OK	OK	OK
Contaminants	PP	PP	PP
Hypoxia	OK	OK	OK
Turbidity	OK	OK	OK
Pathogens	OK	OK	OK
Habitat Disruption			
Physical benthic impacts	OK	OK	OK
Coastal development	PP	PP	PP
Altered flow	EP	OK	OK
Erosion/Sedimentation	EP	EP	OK
Altered salinity	NA	OK	OK
Other Indicators			
Harmful algal blooms	NA	PP	PP
Aquatic invasive species	PP	PP	PP
Impacts from fish/shellfish harvesting	PP	OK	OK
Climate change	PP	PP	PP

Sources of Expertise

The primary source of local information and reviews for this section was Craig S. Smith, SITK biologist. An additional source of local information, specifically on macroinvertebrate studies and benthic diatom sampling within SITK was Geof Smith, former SITK biologist, presently an aquatic ecologist at Voyageurs National Park.

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4.10 Hydrology

Description

The Indian River is an important natural feature within SITK (Nadeau and Lyons 1987). It provides habitat for both marine and freshwater species in the park. Anadromous fish use the river for migration and for various stages of reproduction (Eckert et al. 2006). The river runs through the middle of the park, and the park boundaries enclose the lower reach of the river and the majority of its delta (Eckert et al. 2006). The river flows southwest into Sitka Sound, draining a 31.6 km^2 (12.2 mi^2) watershed (Hyra 1987).

Precipitation runoff is the primary water source for the Indian River‘s flow; thus, flow rates of the river generally fluctuate with the amount of precipitation received in the watershed (Neal et al. 2004). The watershed responds rapidly to rain events because of its quickly draining, steep topography (Neal et al. 2004). The Indian River produces a hydrograph typical of southeast Alaskan coastal streams with periods of high flow during the wetter fall months, and low flow during the late winter and early spring (Neal et al. 2004). Most rainfall occurs in the fall months of September-November (the ―rainy season") from region-wide storms (Neal et al. 2004). Typically, the rainy season gives the river a base flow of 40-50 cubic feet per second (cfs) (Hyra 1987). However, it is currently the low flow periods that are of particular concern to the park.

Water rights exist on the Indian River where water is allocated to a number of different stakeholders including the National Park Service (Table 17). Sheldon Jackson College (SJC) and the City and Borough of Sitka Alaska (CBS) each created separate streamflow diversions that influence the hydrology of the river downstream (Neal et al. 2004). In order to maintain the integrity of the biota within the Indian River, the ADF&G has reserved an instream flow range of 35 to 101 cfs depending on the time of year (NPS 2011). An important aspect of present-day SWAN and SITK monitoring efforts is to quantify how much water each stakeholder uses currently, so water rights issues can be resolved in a way that protects the natural resources and benefits the stakeholders.

Table 17. Summary of water rights and usage of the Indian River in SITK. Information from this table on the state water rights came from Alaska Department of Natural Resources (2010). ADL stands for Alaska Division of Lands and LAS stands for Land Administration System. CBS's water rights for emergency use only are not included in the analyses as cited by NPS (2011).

Type of water right	Number	Year of priority date	Owner	Status	Duty	Notes
Federal reserved	—	1890	National Park Service	Not adjudicated	Not quantified	—
ADL (state)	43671	1914	SSSC	Certified	30 cfs	Under review
ADL (state)	43672	1914	City and Borough of Sitka (CBS)	Certified	3.87 cfs	For emergency use only
ADL (state)	101686	1980	CBS	Received	5.41 cfs	For emergency use only
LAS (state)	12236	1989	Alaska Department of Fish and Game(ADF&G)	Certified	35-101 cfs	See Neal and others, 2004, p. 20, for diversion schedule

The SJC hatchery used a diversion flume (an artificial channel/trough for conducting water), as well as a 12-inch pipe that once supplied water to the college‘s fish hatchery. SJC closed in 2007, and hatchery ownership was transferred to the Sitka Sound Science Center (SSSC) (NPS 2011); SSSC recently obtained a permit to operate the hatchery. The original SJC diversion dam is still in place about 1.3 km (0.8 mi) upstream from the mouth of the river (Neal et al. 2004). The other diversion facility, owned by CBS, is 2.3 km (1.4 mi) upstream from the mouth of the Indian River.

The CBS only needs water from the river a few days out of the year (Neal et al. 2004), whereas SSSC has water demands year round. According to the hatchery water use plan, the average annual diversion for the hatchery is 11 cfs, and the average annual use approximately 6.5 to 7.7 cfs (NPS 2011). Water from the diversions is used to maintain salmon incubation, rearing, adult holding/fish ladder, and the raceway (NPS 2011). SSSC has two distribution systems from the river to the hatchery, and another system controlled by a gate valve that exports water back to the river (Neal et al. 2004). The hatchery‘s water right has allowed them to use 30 cfs or more, but the hatchery has generally not measured their water use (NPS 2011). This flow is more than half of the river‘s flow during low flow periods, and at times, may lower water levels sufficiently to impede the upstream passage of salmon. Until recently, more water was diverted than actually used by the hatchery, with the excess flow returned to the river downstream of the SSSC site. This excess diversion further reduced streamflow in approximately 1.2 km (0.75 mi) of the river (C. Smith, pers. comm., 2011). The hatchery‘s water right and current water use are being reviewed by the Alaska Department of Natural Resources. Figure 36 provides a depiction of the park, water diversion features, and dams, while Figure 37 is a schematic of the river, water diversions, facilities, and other features associated with SSSC (NPS 2011). Plate 5 includes gage locations in relation to park boundaries, and the park boundary in relation to the entire Indian River watershed.

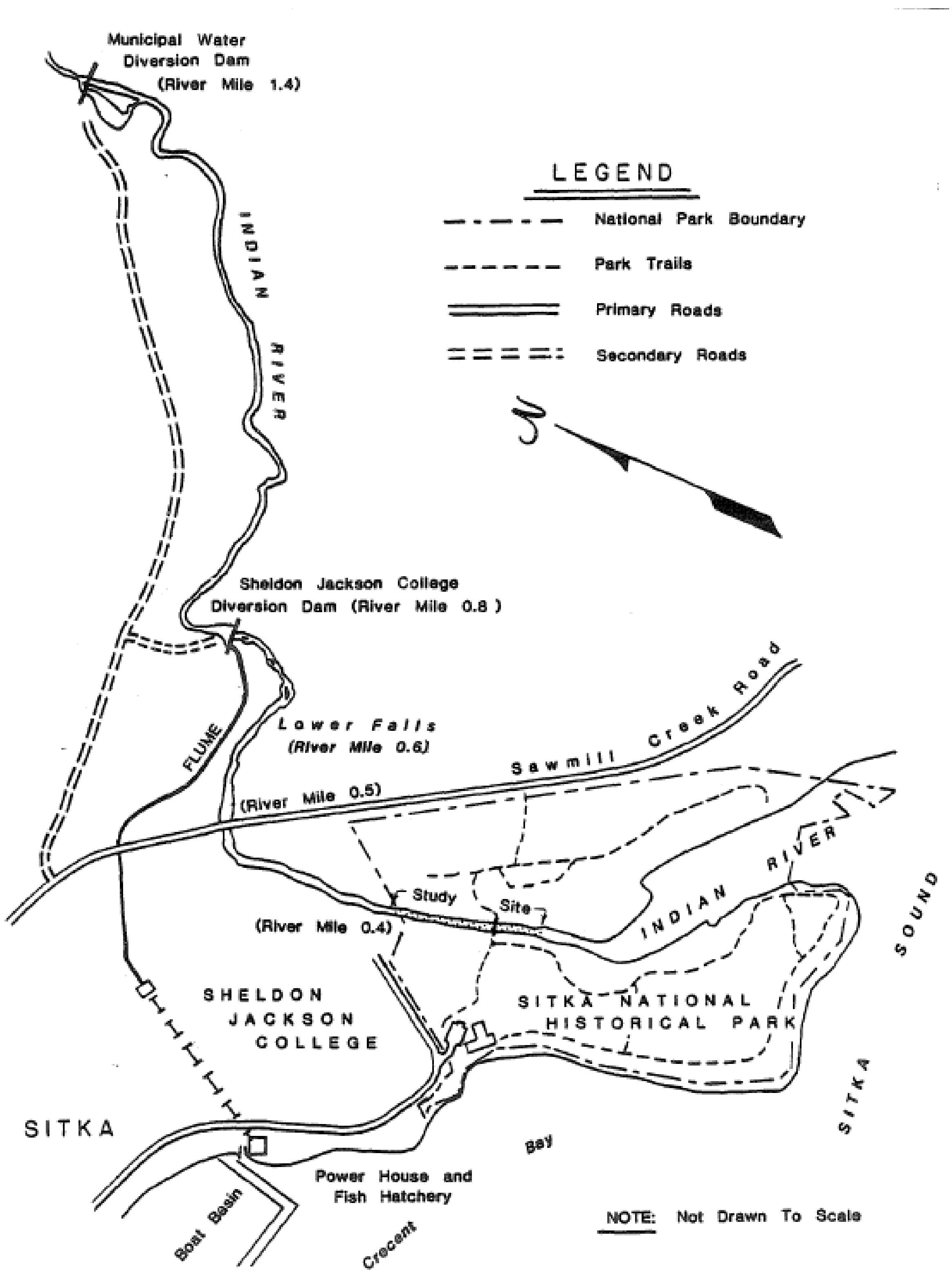


Figure 36. Map of SITK including other facilities, dams, and boundaries. Reproduced from Nadeau and Lyons (1987).

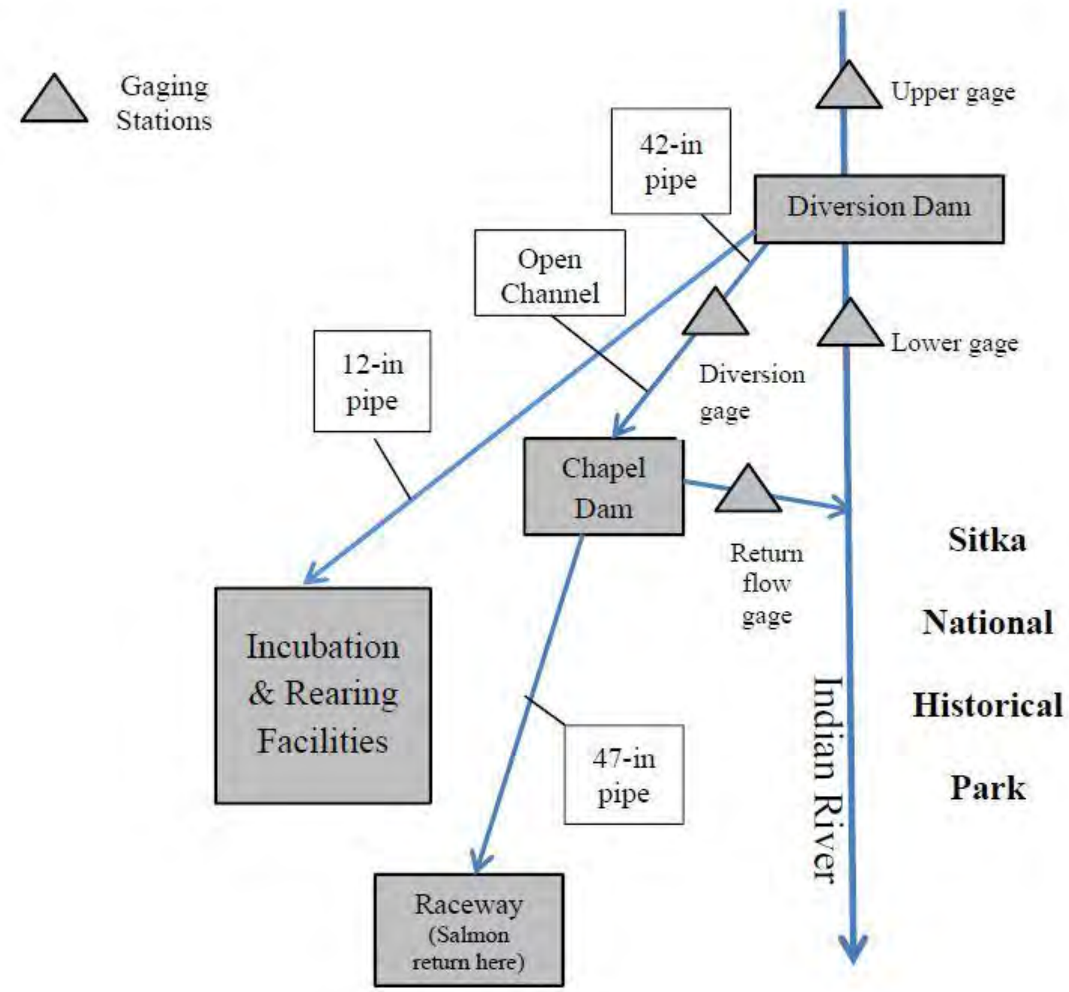


Figure 37. A schematic of the Indian River, diversions, facilities, and other features associated with SSSC and SITK; schematic is not to scale. Reproduced from NPS (2011).

Measures

- Average annual discharge of the Indian River
- Minimum discharge of the Indian River during salmon spawning and rearing

Reference Conditions/Values

Primary concerns regarding the hydrology of the Indian River are the periods of low flow, and how these affect the ecosystem of the Indian River. The reference condition for this component is the range of historic discharge values for periods of natural low flow within SITK. Natural low flow is characterized as the natural discharge of the river without water diversions. In addition to the range of historic values, the upper gage data (discharge, temperature, etc.) may serve as a comparison for lower gage data. However, the difference in discharge between the upper and lower gages does not provide an accurate estimate of the water volume (cfs) diverted from the river.

Data and Methods

Two primary stream gages are in operation on the Indian River near SITK. The USGS National Water Information System database provided annual, monthly, and daily discharge values for both gages (USGS 2011). The park has operated two gages since 2007 in approximately the same locations as the USGS gages. Gage 15087690 is located 2.3 km (1.4 mi) from the mouth of the Indian River well outside the park boundaries, and measures the natural flow and discharge of the Indian River (operated by the USGS 1980-1993, and re-established in 1998). The second gage (15087700 (established in 1998), is located just above SITK's north boundary, approximately 1 km (0.6 mi) and downstream of the SSSC and CBS diversions. This gage drains an area that is 19% larger than the first gage upstream.

Neal et al. (2004) studied water quality and streamflow at two sites on the Indian River. One site was located in an undeveloped area upstream at gage 15087690, and the other site was in a developed area on a lower section of the river at gage 15087700. Researchers examined water temperature, specific conductance, water quality, streamflow, streambed sediment, and biological data from these gages. These data provided information on potential changes in flow and identified differences in water quality parameters between sites. Data collected for this particular study occurred over six- to eight-week intervals during the 236-day study period. Gage 15087690 was considered the control of the two gages, measuring natural flow and discharge, while gage 15087700 was used to measure volume of water from the SJC and CBS diversions (Neal et al. 2004). By comparing these two gages, the effects of development on the river could be determined (Neal et al. 2004). In addition, the authors suggested that the results could help establish a baseline water-quality data base for the Indian River. However, NPS (2011) found that the difference in flow between the upper gage (150876900) and lower gage (15087700) does not accurately measure the amount of water diverted, because it fails to take into account the amount of water that is gained or lost between these two points (approximately 1.3 km).

Current Condition and Trend

Average Annual Discharge of the Indian River

The range of average annual discharge between 1981 and 2005 was 66.0-122.5 cfs for gage 15087690 (Figure 38), and 64.0-132.0 cfs between 1999 and 2010 for gage 15087700 (Figure 39) (USGS 2011).

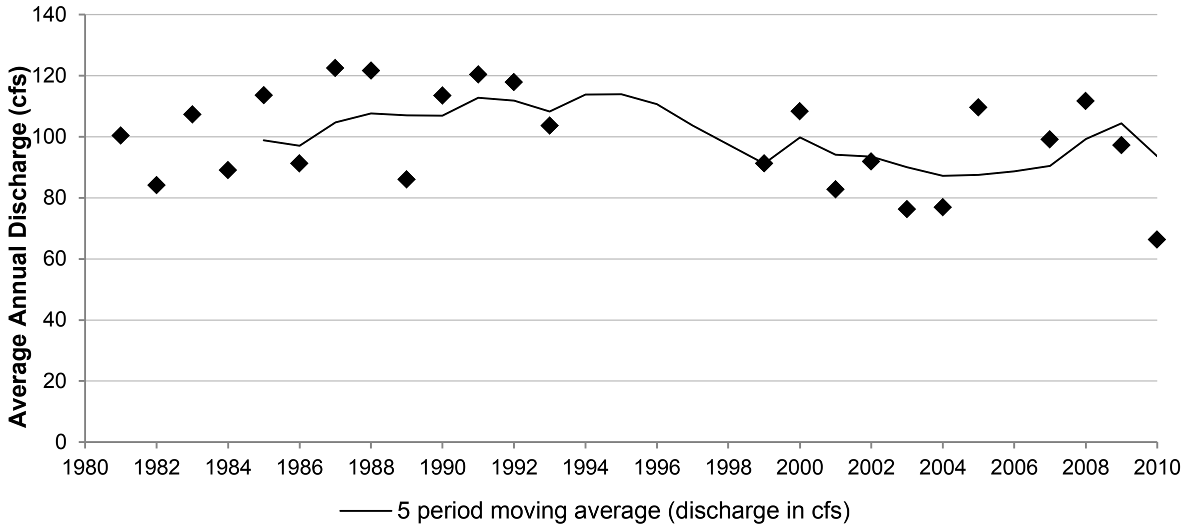


Figure 38. Average annual discharge (cfs) of gage 15087690 (upstream) from 1981-1993 and 1999-2005. No data are available for 1994 to 1998, and 2006. Shown with a five-year moving average trendline. Data obtained from the USGS database on the USGS 15087690 Indian River near Sitka gage. Data obtained from Craig Smith for 2007-2010, and annual averages were calculated from daily readings.

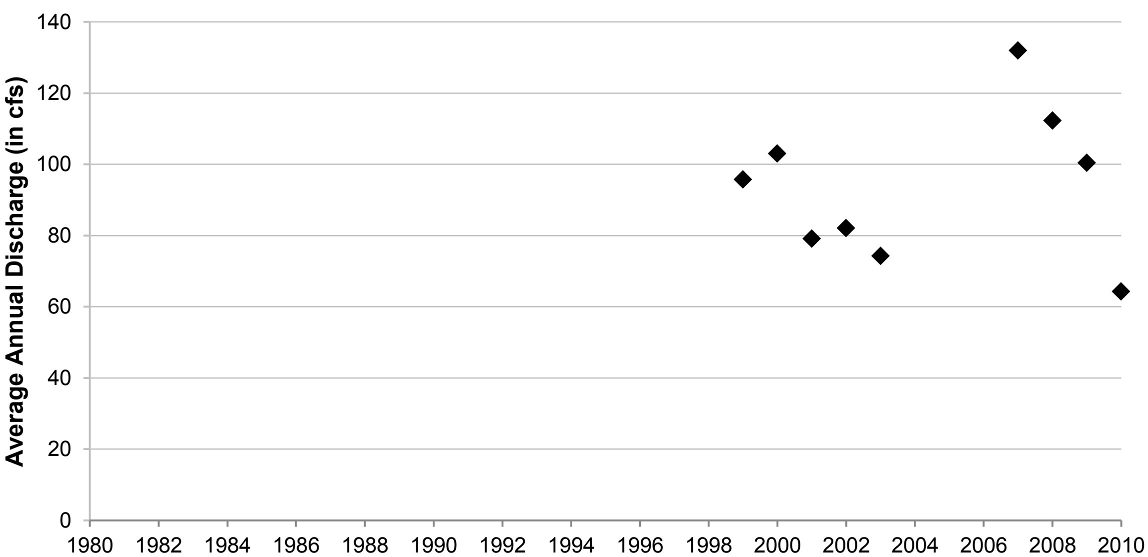


Figure 39. Average annual discharge of gage 15087700 (at Sitka) in cfs from 1999-2003. No data are available for 2004 to 2006. Data obtained from the USGS database on USGS 15087700 Indian River at Sitka gage. Data obtained from Craig Smith for 2007-2010, and annual averages were calculated from daily readings.

<u>Minimum Discharge of the Indian River During Salmon Spawning and Rearing</u>

Currently, data only exist for the ―natural" discharge (without human water diversions) of the river at gage 1587690 (Figure 40). The corresponding graph for gage15087700 mirrors the gage 15087690 graph (Figure 41). The lower gage 15087700 cannot precisely measure the amount of water that would naturally flow through the park, because water naturally flows in and out of the stream between the two gages (NPS 2011). In addition to this, water is diverted before it can be measured at the lower gage 15087700, and some volume water is returned to the river after the lower gage 15087700; therefore exact amounts of flow reduction cannot be measure using only the existing two existing gages (1587680 and 15087700) (NPS 2011).

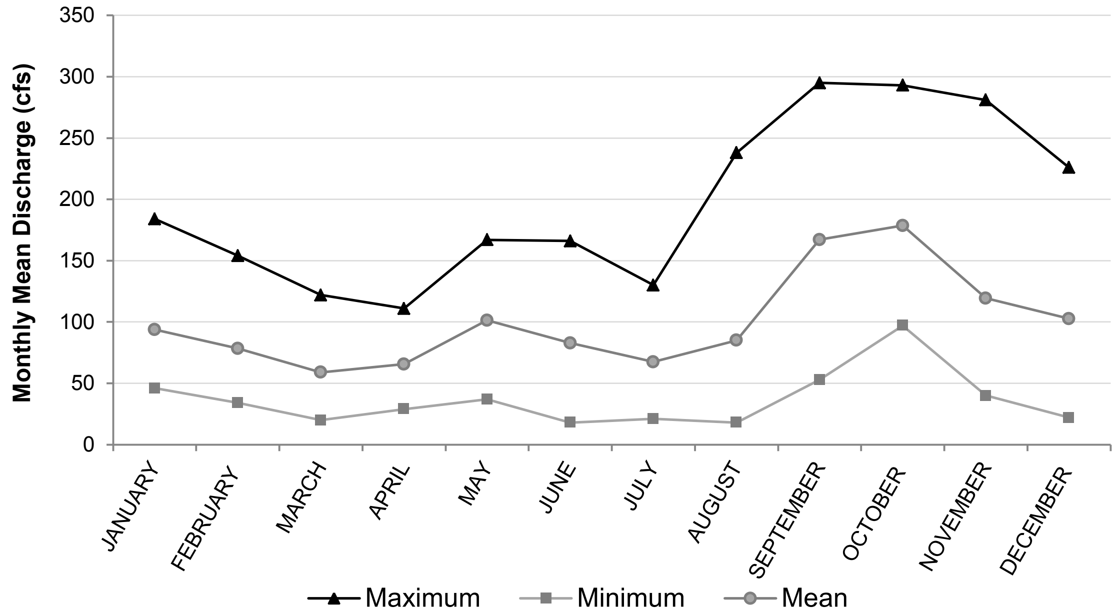


Figure 40. Monthly maximum, minimum, and mean discharges for gage 15087690, for the period of record from August 1980 to September 1993, October 1998 to September 2002, 2003 to 2005, and 2007 to 2010 (Graph from Neal et al. 2004, updated through September 2010).

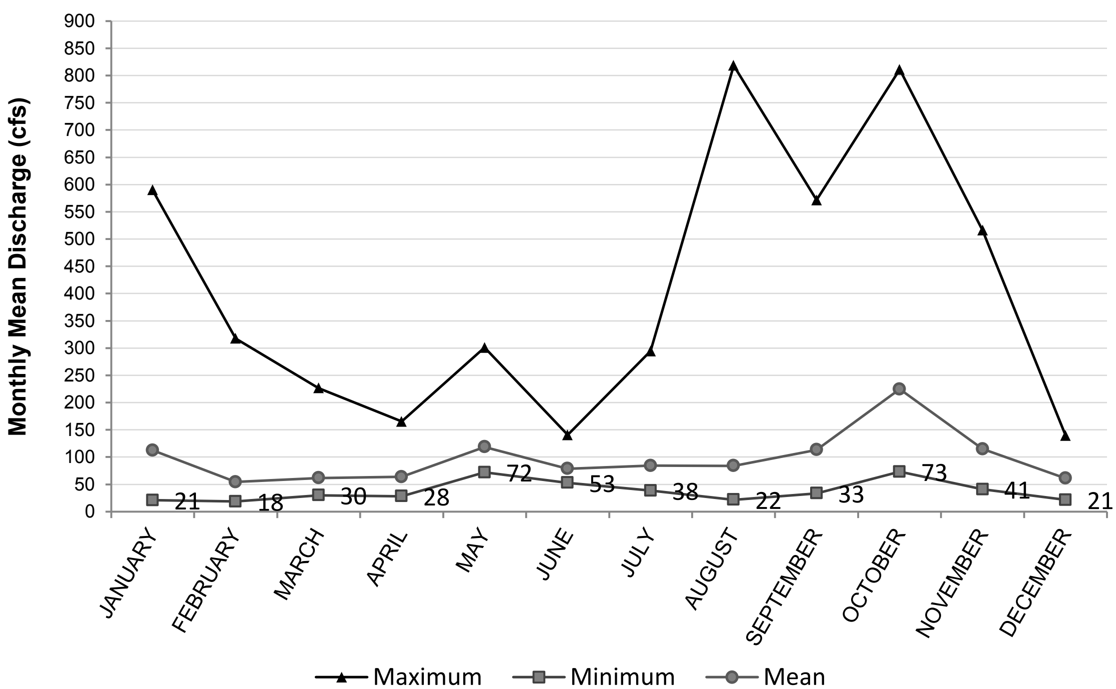


Figure 41. Monthly maximum, minimum, and mean discharges for gage 15087700, for the period of record October 2007 to September 2010 (Data received from Craig Smith).

Four species of Pacific salmon use the Indian River in SITK for spawning habitat, or as a primary route to reach spawning areas farther up-river or in tributaries (NPS 2011). Salmon species use the river from July through November (NPS 2011). According to NPS (2011), it is important to maintain stream discharges in SITK for the incubation of salmon eggs, the support of alevins (hatched salmon with egg sac attached) in the winter season, and the rearing of juvenile coho salmon before they migrate to the sea. The Indian River in SITK is suited for pink and chum salmon spawning, but the lack of deep pools and large woody debris habitat creates poor rearing habitat for juvenile and fingerling salmon (Paustian and Hardy 1995). Table 18 depicts anadromous species that use the Indian River with corresponding seasonal spawning periods.

Table 18. Spawning periods for various salmonid species that utilize the Indian River for reproduction (ADF&G 2010, as cited in NPS 2011).

Salmonids	Spawning Period
Chinook salmon (*Oncorhynchus tshawytscha*)	May to July
Chum salmon (*O. keta*)	Not listed
Coho salmon (*O. kisutch*)	July to November
Dolly Varden (char) (*Salvelinus malma*)	September to November
Pink salmon (*O. kisutch*)	Late June to mid-October
Steelhead trout (*O. mykiss*)	Mid-April to early June
Rainbow trout (*O. mykiss*)	Late March to early July, dependent on location severity of weather

The diversions created by CBS and SSSC conflicted with the ADF&G's goal to protect salmon spawning and rearing habitat by limiting the water flow (Neal et al. 2004). These diversions may increase the severity of low flows (NPS 2011). The SSSC hatchery diverts an annual average of 11 cfs of water (NPS 2011). SSSC has proposed diversions from 15 June to 30 November at 15.4 cfs to 16.3 cfs of water, and an additional 10 cfs for another portion of the facility (NPS 2011). ADF&G regulates the last 4-km (2.5-mi) stretch of the river just before it reaches the ocean, reserving a minimum amount of water that should be flowing through the river each month to maintain its biological integrity (Table 19).

Table 19. ADF&G flow reservations on Indian River from the mouth upstream to river mile 2.5 (Neal et al. 2004).

Date Range	ADF&G Flow Reservations (cfs)
October 1 - October 31	101
November 1 - November 30	40
December 1 - April 15	35
April 16 - April 30	40
May 1 - June 30	51
July 1 - July 15	43
July 16 - July 31	51
August 1 - September 30	61

Neal et al. (2004) found that, out of 236 days of their two-year study, the river did not meet required minimum flows set by the ADF&G (Figure 42). This indicates that the river is experiencing many periods of low flow and that flow reservations are not being met.

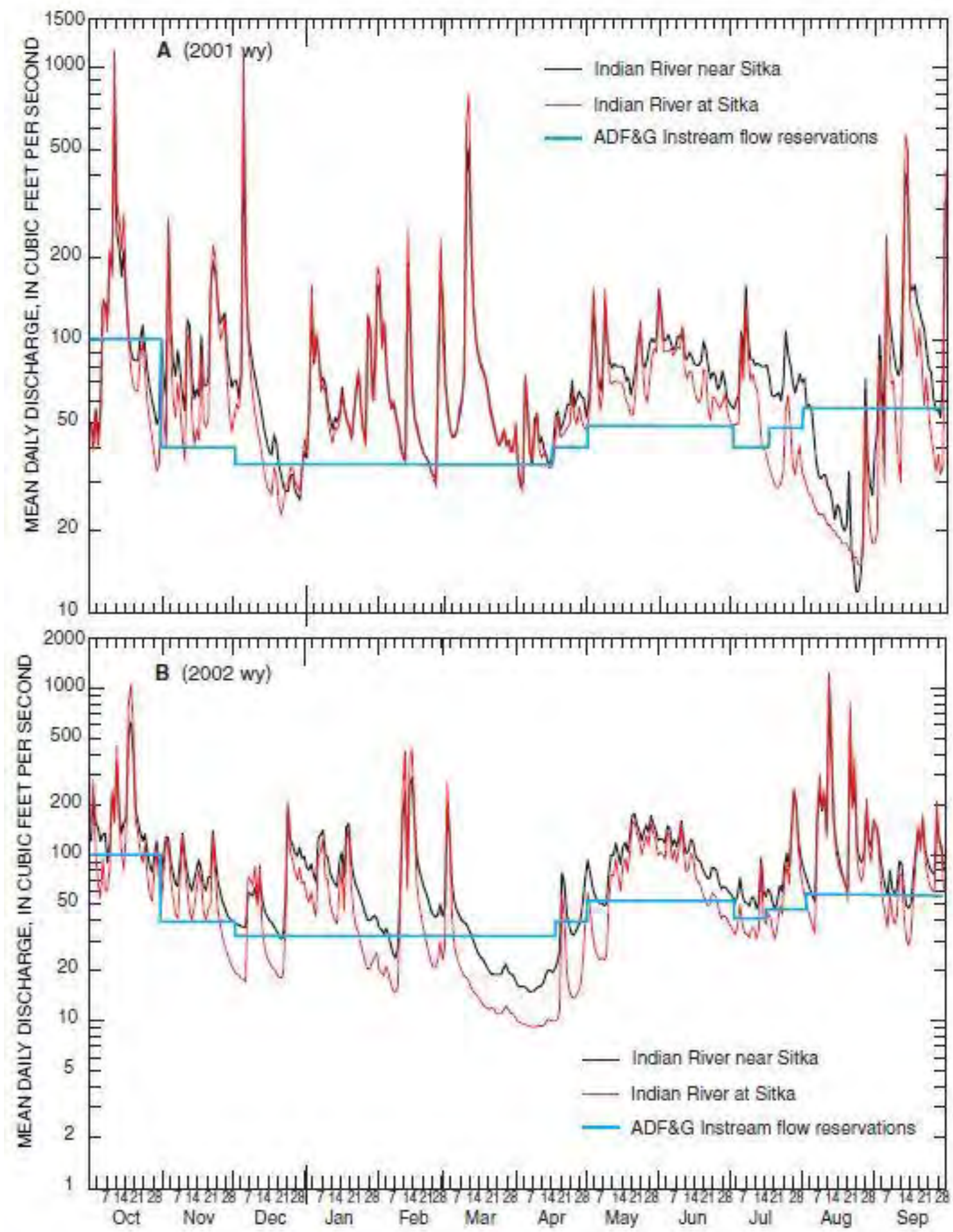


Figure 42. Daily mean discharge for the gages 15087690 and 15087700, and the Alaska Department of Fish and Game flow reservations for the lower 4 km (2.5 mi) of Indian River, water years 2001 and 2002 (Neal et al. 2004).

According to NPS (2011), the discharge records are rated by the ability to accurately predict the actual discharge of the river for each gage station. The rating given to each station can either be poor, fair, good, or excellent, and data from a gage is considered not acceptable with a poor rating. Gage 15087690 and gage 15087700 were each given a rating of fair (Table 20).

Table 20. Indian River gage information including gage elevation, drainage, and level of accuracy at measuring discharge (NPS 2011).

Station Name (abbreviation in this report)	Elevation above sea level, m (ft)	Drainage area, km^2 (mi^2)	Accuracy of discharge record
15087690 Indian River near Sitka AK (upper gage)	38.1 (125)	26.2 (10.1)	Fair
15087700 Indian River at Sitka AK (lower gage)	9.1 (30)	31.1 (12)	Fair
15089930 Indian R Div to SJC at Sawmill C Rd at Sitka AK (diversion)	21.3 (70)	---	Good to Fair
15087735 Indian R Div Return Flow from SJC at Sitka AK (return flow)	18.3 (60)	---	Good to Fair
508494 Sitka Japonski FAA Airport (precipitation)	3.0- 21.3 (10-70)	---	---

In 2007, none of the days in August reached the ADF&G‘s recommended in-stream flow for spawning salmon in the Indian River (Smith 2010). In August of 2008 the river volume dropped below the ADF&G recommended minimum flow of 61 cfs 65% of the time in the first 23 days.

Low flows reduce the amount of water for the active resident and anadromous fish redds (eggs deposited in a depression), which becomes a major limiting factor for fish production, in particular the lowest 7-day average winter low-flow (Nadeau and Lyons 1987). According to Nadeau and Lyons (1987), regular fluctuations in stream discharge are not detrimental to the life of the fish or the spawning period; however, periods of extreme low flow can jeopardize reproductive success during the incubation period, as well as stress the eggs and pre-emergent fry. If redds are in areas of low flow or non-flow, eggs may be exposed to the air and risk drying out (Nadeau and Lyons 1987). Nadeau and Lyons (1987) found the median discharge for the Indian River to be approximately 70 cfs, and natural flows to vary between 35 cfs and 100 cfs during the five-year study.

Diminished levels of streamflow can affect biota other than anadromous salmon including resident fish, macroinvertebrates, and algae. Eckert et al. (2006) reported that periods of low flow and the changes in sediment dynamics could have an eliminating effect on macroinvertebrate and fish spawning habitat.

<u>Threats and Stressor Factors</u>

Periods of very low flow caused by diversions have the potential to interfere with salmon spawning (NPS 2011), and therefore represent a stressor to the hydrologic flow regime and to the biota that depend on the flow. NPS (2011) stated that diverting 10 cfs from the Indian River can deplete in-stream flows in the summer months (between July and September), or in times of drought, to a degree that will affect salmon spawning and movement. Approximately 11 to 28% of the time, the flow of water from the upper gage is insufficient to meet the ADF&G‘s water-right requirements (NPS 2011). Flows measured at the lower gage fail to meet this requirement approximately 19 to 45% of the time (NPS 2011). NPS (2011) provides a set of recommendations including recommended diversion volumes by month and a set of conditions be place on the SSSC water right.

Another threat to hydrology in SITK is the alteration of sediment transport by in-river diversions and dams (Eckert et al. 2006). There are two dams located upstream from SITK. These dams collect sediment, starving the lower portion of the river of naturally transported sediment. Hyra (1987) states that it is crucial for discharge levels to be able to provide for all of the varying life stages of salmon species including up-stream migration, spawning, egg incubation, rearing, and down-stream migration. In addition, sufficient water flow is critical in providing water flowing into the saltwater environment to attract salmon up into the river mouth to spawn (Hyra 1987).

Depriving the stream of sediment also causes problems with scouring and erosion of the riverbank (Eckert et al. 2006). In some sections, the Indian River is lined by rip rap and shot rock, covered with a thin layer of soil and vegetation (SSSC 2010). During a study in 1994, Paustian and Hardy (1995) found the Indian River to have 30-50% of the streambed particles finer than 2.5 inches (64 mm) in diameter, which indicated that streambed armoring and channel degradation occurred (Paustian and Hardy 1995). According to Paustian and Hardy (1995, p. 12), ―alluvial channels tend to seek a dynamic equilibrium between sediment load and stream discharge." Factors that adjust to suit the load of the river include channel shape, sinuosity, gradient, and bed roughness (Paustian and Hardy 1995). The Indian River floodplain and estuary undergoes lateral bank erosion and channel migration, which are considered normal adjustment processes (Paustian and Hardy 1995). Shannon and Wilson Inc. (1995) suggest that the noted increases in the rate of bank failure were likely results of the change in gradient, due to the river being diverted, channelized, dredged, and rip rapped (Shannon and Wilson Inc. 1995). The shoreline in this area erodes about 1 to 2 m per year (Shannon and Wilson Inc. 1995). The authors recommend that riprap dike construction be modified on the lower floodplain to reduce bank erosion at the head of the Indian River estuary. The rip rap present on both banks of the river, described by Neal et al. (2004), is composed of a range of substrates, from coarse gravel to boulders and bedrock.

Armored shoreline is a stressor to the hydrology of the park because it alters or prevents natural flow characteristics of the Indian River. Three major changes have altered the natural flow of the Indian River over the last 70 years (Paustian and Hardy 1995, Eckert et al. 2006). In 1945, a meander in the channel was straightened in order divert the flow to the west bank of the estuary (Paustian and Hardy 1995, Eckert et al. 2006). This, however, was the last phase of a gravel mining operation at the mouth of the Indian River that began in 1939 (Chaney et al. 1995). The gravel mining operations increased the gradient and lowered river levels (Chaney et al. 1995). Then, under park management direction, a riprap wall was installed above a gravel island, significantly constricting the natural head of the estuary (Paustian and Hardy 1995, Eckert et al. 2006). Finally, in 1985, the NPS installed toed-in shot-rock riprap along the west bank of the estuary (Paustian and Hardy 1995, Eckert et al. 2006). This armoring of the river‘s shorelines was done to protect nearby historic and cultural resources from bank erosion. More recently, Shannon and Wilson Inc. (1995) suggested that in order to stabilize the bank and prevent erosion, extensive placement of riprap or the placement of a seawall would be necessary and costly. However, according to Paustian and Hardy (1995), channel and flood plain conditions were stable at the time.

Climate change is a major concern for SITK. The average rate of temperature change is an increase of 0.3°C (0.6°F) per decade (SNAP et al. 2009). By 2040, the average annual temperature is predicted to be 1.7°C (3° F) warmer and by 2080 about 3.3°C (6°F) warmer (SNAP et al. 2009). This change in temperature is likely to cause an 8% increase in precipitation (SNAP et al. 2009). The increase in precipitation is unlikely to cause an increase in flow or runoff, because evapotranspiration caused by warmer temperatures will outweigh increased precipitation (SNAP et al. 2009). Scientists predict that increased temperatures will cause early snowmelt (Stewart et al. 2004). If snowmelt began one month earlier than normal, the length of the summer droughts may be extended in Alaska and would have consequences on the water supply and therefore the entire ecosystem (Stewart et al. 2004).

Fluctuations in the regional climate are of particular concern for hydrology in SITK. In Alaska, the Pacific Decadal Oscillation (PDO) presents some challenges for the region (Keen 2008). 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. Major shifts occurred in 1925 (negative to positive), 1947 (positive to negative), and 1977 (negative to positive) (Mantua et al. 1997). Hartmann and Wendler (2005) suggest that much of the warming that occurred in Alaska during the last half of the twentieth century was influenced by the PDO shift in 1976-77. Hartmann and Wendler (2005) found the total annual precipitation had increased by 7%, and total annual snowfall decreased by 36 % in the southeast Alaska Region. The increase in precipitation in the form of water instead of snow can greatly affect the hydrology of the Indian River by altering flow levels (Hartmann and Wendler 2005).

Data Needs/Gaps

Data that characterizes the natural flow on the Indian River during periods of low flow are lacking. Establishing a monitoring program to capture this will allow a comparison of natural low flows to the volume of water that diversions remove from the Indian River during the low flow periods (C. Smith, pers. comm., 2011).

Overall Condition

SITK staff assigned the total annual discharge measure a *Significance Level* of 1, and the minimum discharge of Indian River during salmon spawning and rearing measure a *Significance Level* of 2.

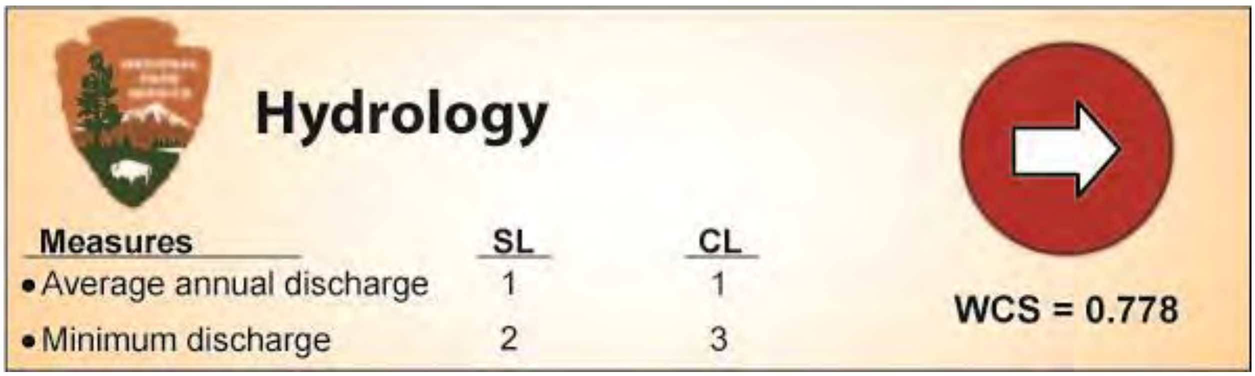
Average Annual Discharge of the Indian River

SITK's hydrology measure, total annual discharge of the Indian River, was assigned a *Condition Level* of 1. Without a clearly defined reference condition (i.e., historic data indicating what natural low flows were in the river before dams and diversions were installed), it is not possible to quantify how river flow has changed. Despite a lack of long term historic flow measurements the present data do not indicate a noticeable trend in the annual discharge; therefore this measure was given a *Condition Level* of 1.

Minimum Discharge of the Indian River During Salmon Spawning and Rearing
The minimum discharge of the Indian River during salmon spawning and rearing measure was assigned a *Condition Level* of 3. Data from NPS (2011) indicated that low flow levels did not meet recommended standards nearly half the time. Poor salmon spawning conditions compromise natural salmon populations. In addition, biota such as resident fish, algae, and macroinvertebrates that are indirectly dependent on the benefits of salmon spawning (e.g., nutrients of fish carcasses) and spawning and rearing habitat may be threatened.

Weighted Condition Score (WCS)
The Weighted Condition Score (WCS) (see Chapter 3 for methodology) for hydrology in SITK was 0.778. A WCS of 0.778 represents an overall condition of high concern (0.666-1.00).

Flows have been low enough during low flow periods to have severe ramifications on salmon spawning in the Indian River. This is a cause for high concern for the condition of the river's flow (hydrology) and the biota that depend on it. The SSSC hatchery is in the process of applying for a permit from the ADF&G to significantly increase the production of coho, chum, and pink salmon. It is unclear as to the portions of the diversion volume being used for current fish production in the hatchery. However, if the permit to produce more fish at the hatchery is granted, the hatchery is more likely to use more of its 30 cfs diversion. The available data indicate that these hydrologic conditions have not improved or worsened over the period of record, therefore while it is presently a significant concern, the trend in condition remains stable.



Sources of Expertise
The primary source of local information and reviews for this section was Craig S. Smith, SITK biologist. Additional information was provided by Geof Smith, former SITK biologist, currently an aquatic ecologist at Voyageurs National Park.

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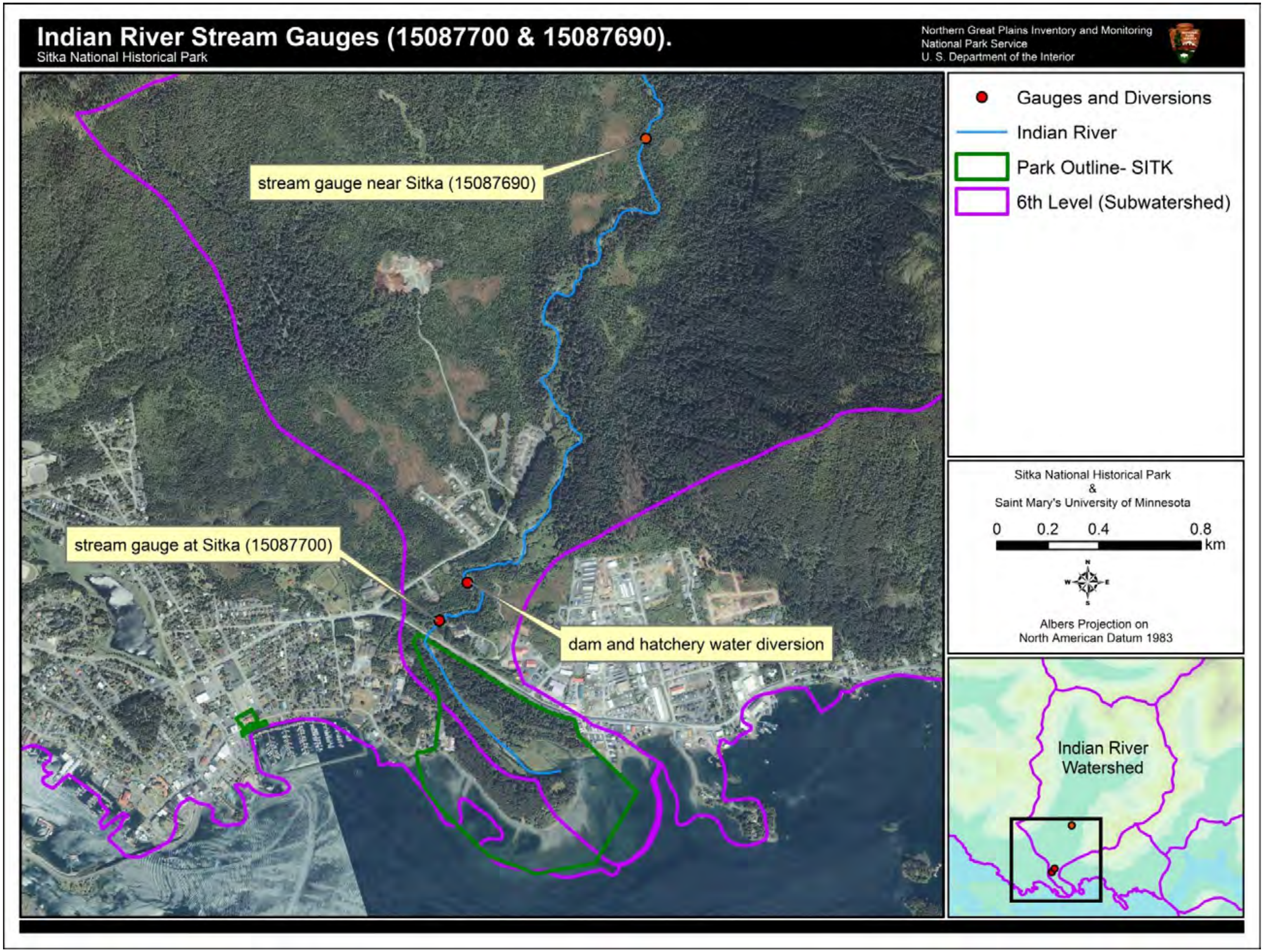


Plate 5. Locations of the Indian River near Sitka (station 15087690) and Indian River at Sitka (station 15087700) in relation to park boundaries (main map) and the Indian River watershed in relation to the park (inset locator map).

Chapter 5 Discussion

5.1 Component Data Gaps

The identification of key data and information gaps is an important objective of the NRCA. Data gaps or needs are those pieces of information that are currently unavailable, but would help to inform the condition status of a key resource component. Data gaps/needs exist for all key resource components assessed in this NRCA (Table 21).

Some data gaps, if addressed, would inform multiple components in the project framework. Data gaps regarding landform/land cover and forests focus primarily on inventory of existing vegetation composition and better characterization of the effects of human disturbance, such as social trail use in the park. Also, a more clearly defined reference condition will help managers put current conditions into a management context. Map information (GIS data) regarding plant community composition and geographic distribution is another data gap that is soon to be addressed by the completion of a land cover mapping project currently underway. Another data gap that relates to multiple components (e.g., fish, hydrology, freshwater water quality) is the potential effects of water diversions from the Indian River, especially during low streamflow periods, and the extent to which salmon populations in the river are affected by straying of hatchery raised fish. Further investigation is necessary to determine normal streamflows in the park without upstream water diversions. Monitoring biomass cover of algal species in the Indian River, particularly didymo, could help create baseline information for comparison if river conditions change in the future or the species expands.

Data gaps for land birds and water birds relate to developing methods for performing more intensive population surveys, or altering existing methods to increase the confidence in estimates and to provide data specific to the park. The NPS views non-native invasive species as stressors to other valued natural resources and processes. Currently, data are lacking or limited on algal blooms and social trail effects on invasive plants in forested areas, respectively. Additional information on effective methods for controlling mountain ash trees in natural areas is necessary if the park chooses to pursue such an effort.

The development of long-term monitoring plans will aid managers in developing consistent data collection and analysis methods, allowing parameters to be tracked and compared over time, which will help in understanding the health of both the freshwater and intertidal environments in the park. For air quality, developing mercury contaminant thresholds in lichens could better enable managers to understand the nature of atmospheric deposition of mercury in the park, particularily its effects on lichen species abundance and diversity. In the freshwater environment of the Indian River, monitoring of potential stressors to the ecosystem such as effects of upstream development activities (i.e., erosion and contaminant sources) is also recommended.

Table 21. Component data gaps/needs list for SITK.

Component	Data Gaps
Landform / Land Cover	-clearly defined reference conditions by park management zone
	-an update to landform change of the park since an early 1990s examination, especially in the intertidal zone (gravel mined area), channel migration of the Indian River, and saw log-affected beach formation
	-map data (GIS data) representing land cover (vegetation) and landforms of the park (a project to address this is currently funded)
Land Birds	-intensive survey during breeding season, repeated surveys to identify possible trends
	-park-specific monitoring efforts to provide insight to species richness, diversity, changes in abundance of species of concern, and the percent of expected species present
Coastal Waterbirds	-formal definition of coastal waterbirds
	-intensive survey during breeding season, repeated surveys to identify possible trends
	-survey specifically designed for species of concern (e.g., yellow-billed loons)
Invasive Species	-park-wide documentation of non-native insects or diseases
	-further study of increasing human disturbance on plant communities
	-continue ongoing mapping of invasive plant species to track changes and success of control methods
Anadromous and Nonanadromous Fish	-sufficient sampling across years, within years, and among populations (species) of anadromous and nonanadromous fish
	-chum and coho data (ADFG estimates) contain several gaps in annual counts
	-Chinook population status year to year is not well understood
	-data are lacking that differentiate between hatchery strays and naturally spawning salmon in the Indian River
	-abundance (population) data are severely lacking for all nonanadromous fish species
Forests	-very limited data for native species regeneration
	-very limited data for understory species diversity; an update to USFS studies conducted in the mid-1990s
	-no park-wide documentation of non-native insects or diseases
Air Quality	-continued sampling and analysis of lichens and concentrations of nitrogen oxides in the air to determine trends
	-information on the effects of mercury on lichens, specifically a threshold level is lacking

Table 21. (continued) Component data gaps/needs list for SITK.

Component	Data Gaps
Intertidal Water/Habitat Quality	-limited baseline data characterizing coastal resources; long term monitoring and evaluation plan is needed to inventory resources and to predict and identify potential stressors
	-information outlining the effects of cruise ships on water quality parameters (e.g., turbidity)
	-monitoring nearby development efforts to determine possible effects on the park*
	-identification of sensitive early warning species (e.g., mussel species)*
	-survey of nearby vessels during high-use periods to identify potential risk areas*
	-development and integration of web-accessible GIS data*
Freshwater Water/Habitat Quality	-monitoring of erosion and stormwater runoff, including mercury and POP levels*
	-more research and management of HABs (e.g., monitoring biomass cover)
Hydrology (Indian River)	-data characterizing natural flow (without upstream diversions), especially during low flow periods, are lacking; monitoring program could be designed to capture this

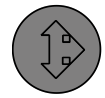
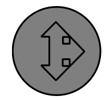
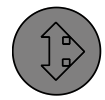
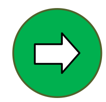
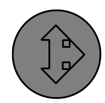
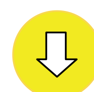
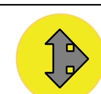
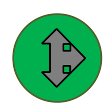
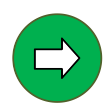
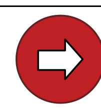
*Recommendations in Eckert et al. (2006).

5.2 Component Condition Designations

Chapter 5 provides an opportunity to bring together and discuss the common threads in findings regarding the featured components. Table 22 displays the condition graphics assigned to each resource component presented in Chapter 4. It is important to remember that the graphics represented are merely symbols for the overall condition and trend assigned to each of the measures. It is necessary to refer to the overall condition section for each component for a more detailed account and explanation of the assigned condition, as the assignment of condition for most components is based on multiple factors. Figure 43 contains the definition of each condition graphic.

Existing literature contains detailed documentation of the historic alterations to the park‘s landscape (both landforms and vegetation). However, it is unclear what human alteration are considered part of the historic significance of the park, and what activities are considered to be negative alterations to the landscape of the park. It is clear that gravel mining, pulp-logs, and intentional alterations to the Indian River in the form of dams, water diversions, and installations of erosion control features have resulted in altered natural communities and processes in the park. While the current conditions are, in part, the result of these human alterations, much of these activities occurred decades ago and the park‘s landforms are stabilizing and vegetation is still responding.

Table 22. Component condition designations.

Component	WCS	Condition
Ecosystem Extent and Pattern		
Landform / Land Cover	N/A	
Biological Composition		
Land Birds (breeding birds)	N/A	
Costal Waterbirds	N/A	
Invasive Non-Native Species	0.250	
Anadromous and Nonanadromous Freshwater Fish	N/A	
Forest	0.500	
Chemical and Physical Characteristics / Environmental Quality		
Chemical/Environmental Quality		
Air Quality	0.424	
Intertidal Water Quality / Habitat Quality	0.176	
Freshwater Water Quality / Habitat Quality	0.143	
Physical Parameters		
Hydrology (Indian River)	0.778	

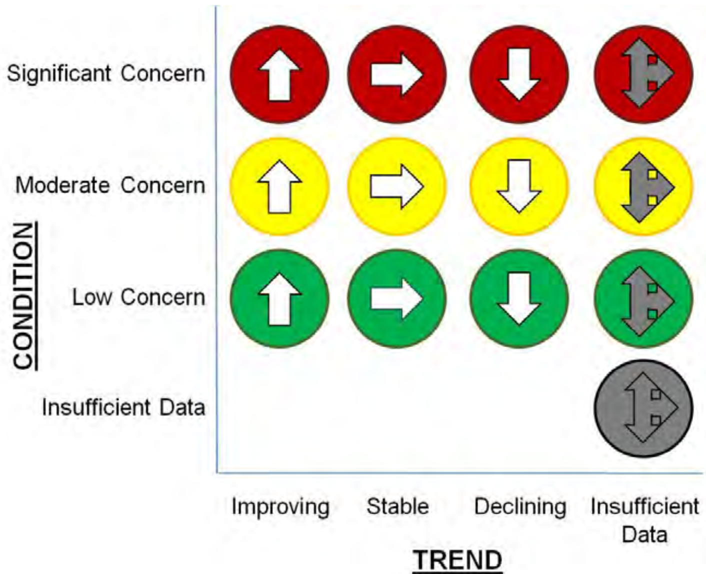


Figure 43. Symbols used for individual component assessments with condition or concern designations along the vertical axis and trend designations along the horizontal.

5.3 Park-wide Condition Observations

Humans have altered landforms and vegetation in what is now SITK for at least 200 years, with some significant 20th century alterations that continue to have lasting effects. In the late 1800s the area was used as a city park. This involved activities which cleared vegetation and caused soil disturbance (e.g., various trail, road, and bridge construction projects). Localized soil disturbances were also caused by activities such as the construction of a power-line, site preparation for the Kiks.ádi fort site, the erection and moving of many totems within the park, and U.S. military constructed gunnery emplacements along the shoreline during World War II. Multiple buildings were constructed, some of which are no longer standing, include historically significant Russian buildings. Other buildings include those constructed by the U.S. military and the NPS (Visitor Center).

Activities such as gravel dredging, installation of erosion control features, road building, asphalt plant operation and decommissioning, and trailer court fill have likely created more lasting effects to landforms, compared with other human activities. Large volumes of gravel were dredged from the intertidal zone near the mouth of the Indian River over a period of several years during the World War II time frame. Additional gravel mining occurred in the late 1950s and sporadically until the late 1970s at the mouth of the Indian River. This altered the intertidal zone and the Indian River sediment budgets through increased gradients. Dam construction, water diversions, river-channel dredging and the installation of erosion control features (e.g., riverbank rip-rap and log cribbing) have also altered the Indian River. An asphalt plant operated near the banks of the Indian River, ending in the burial of excess asphalt and debris. Large pulp-logs from a nearby paper mill continued to wash ashore until the mill closed in 1993 and additions of blasted rock to armor the shore from erosion altered beach formation processes, resulting in the establishment of woody vegetation. All of these human alterations and influences result in landforms and vegetation that are much different than during the historic battle of 1804. While together these represent major alterations to the park, many of the human activities ceased decades ago, and natural forces (e.g., uplift, beach development, river dynamics and delta development, and vegetation succession) continue to drive landform and vegetation dynamics in the park.

A large number of visitors use the relatively small park. While several major trails and historic sites tend to focus the use in certain areas, a continued threat of disturbance exists in the form of social-trail use. These social trails could limit regeneration of some forest species and reduce understory diversity in the park‘s forested areas. The Indian River and its native biota, focal natural resources of the park, are stressed by low flows and threatened by additional hatchery-stray salmon, potential contaminant inputs from upstream activities (e.g., development), asphalt plant contaminants, and possibly expanding algal growth within the river. However, years of macroinvertebrate sampling and the continued presence of native salmon indicate that the Indian River is generally a healthy cold-water stream ecosystem. Continued flow, water quality parameter, and macroinvertebrate sampling and monitoring will allow managers to detect any future changes.

Literature Cited

Eckert, G., E. Hood, C. Talus, and S. Nagorski. 2006. Assessment of coastal water resources and watershed conditions at Sitka National Historical Park, Alaska. Technical Report NPS/NRWRD/NRTR-2006/347. National Park Service, Water Resource Division, Fort Collins, Colorado.

Appendices

Appendix 1. NPS Certified Land Bird Species List, historic SITK checklist (reference condition), and species listed on eight conservation lists.

Scientific Name	Common Name	NPS 2011	Historic Checklist	Kirchhoff and Padula 2010	Stenhouse and Senner 2005	Denlinger 2006	NAS 2007	USFWS 2008	ASG 2008	PIF SRI	IUCN 2010
Calypte anna	Anna's hummingbird	x	x								
Selasphorus rufus	rufous hummingbird	x	x					x		x	
Accipiter gentilis	northern goshawk	x	x	Yellow List	x			x			
Accipiter striatus	sharp-shinned hawk	x	x								
Buteo jamaicensis	red-tailed hawk	x	x								
Haliaeetus leucocephalus	bald eagle	x	x							x	
Pandion haliaetus	osprey	x	A								
Falco columbarius	merlin	x	x								
Falco peregrinus	peregrine falcon	x	x		x			x			
Falco sparverius	American kestrel	x	x								
Columba livia	rock dove	x	x								
Zenaida macroura	mourning dove	x	x								
Ceryle alcyon	belted kingfisher	x	x							x	
Dendragapus fuliginosus	sooty grouse	x									
Dendragapus obscurus	blue grouse		A								
Bombycilla cedrorum	cedar waxwing	x	A								
Bombycilla garrulus	Bohemian waxwing	x	x								
Certhia americana	brown creeper	x	x								
Cinclus mexicanus	American dipper	x	x								
Corvus caurinus	northwestern crow	x	x							x	
Corvus corax	common raven	x	x								
Cyanocitta stelleri	Steller's jay	x	x							x	

Scientific Name	Common Name	NPS 2011	Historic Checklist	Kirchhoff and Padula 2010	Stenhouse and Senner 2005	Denlinger 2006	NAS 2007	USFWS 2008	ASG 2008	PIF SRI	IUCN 2010
Pica hudsonia	black-billed magpie	x	A								
Calcarius lapponicus	Lapland longspur	x	x								
Junco hyemalis	dark-eyed junco	x	x								
Melospiza lincolnii	Lincoln's sparrow	x	x								
Melospiza melodia	song sparrow	x	x								
Passerculus sandwichensis	savannah sparrow	x	x								
Passerella iliaca	fox sparrow	x	x								
Plectrophenax nivalis	snow bunting	x	x								
Spizella arborea	American tree sparrow	x	A								
Zonotrichia atricapilla	golden-crowned sparrow	x	x								
Zonotrichia leucophrys	white-crowned sparrow	x	x								
Zonotrichia querula	Harris' sparrow	x	x								
Carduelis flammea	common redpoll	x	x								
Carduelis pinus	pine siskin	x	x								
Carduelis tristis	American goldfinch	x	A								
Fringilla montifringilla	brambling	x	A								
Leucosticte tephrocotis	gray-crowned rosy-finch	x	A								
Loxia leucoptera	white-winged crossbill	x	x								
Loxia curvirostra	red crossbill	x	x							x	
Pinicola enucleator	pine grosbeak	x	x								
Hirundo rustica	barn swallow	x	x								
Tachycineta bicolor	tree swallow	x	x								
Tachycineta thalassina	violet-green swallow	x	x								
Agelaius phoeniceus	red-winged blackbird	x	x								

Scientific Name	Common Name	NPS 2011	Historic Checklist	Kirchhoff and Padula 2010	Stenhouse and Senner 2005	Denlinger 2006	NAS 2007	USFWS 2008	ASG 2008	PIF SRI	IUCN 2010
Euphagus carolinus	rusty blackbird	x	x	Red List	x		x	x		x	VU
Euphagus cyanocephalus	Brewer's blackbird	x	x								
Molothrus ater	brown-headed cowbird	x	A								
Sturnella neglecta	western meadowlark	x	A								
Lanius excubitor	great gray shrike	x	A								
Mimus polyglottos	northern mockingbird	x	A								
Anthus rubescens	American pipit	x	x								
Poecile gambeli	mountain chickadee	x	x								
Poecile rufescens	chestnut-backed chickadee	x	x							x	
Dendroica coronata	yellow-rumped warbler	x	x								
Dendroica petechia	yellow warbler	x	x								
Dendroica townsendi	Townsend's warbler	x	x							x	
Vermivora celata	orange-crowned warbler	x	x							x	
Wilsonia pusilla	Wilson's warbler	x	x								
Regulus calendula	ruby-crowned kinglet	x	x								
Regulus satrapa	golden-crowned kinglet	x	x							x	
Sturnus vulgaris	European starling	x	x								
Piranga ludoviciana	western tanager	x	A								
Troglodytes troglodytes	winter wren	x	x								
Catharus guttatus	hermit thrush	x	x								
Catharus ustulatus	Swainson's thrush	x	x								
Ixoreus naevius	varied thrush	x	x	Red List			x			x	
Sialia currucoides	mountain bluebird	x	A								

Scientific Name	Common Name	NPS 2011	Historic Checklist	Kirchhoff and Padula 2010	Stenhouse and Senner 2005	Denlinger 2006	NAS 2007	USFWS 2008	ASG 2008	PIF SRI	IUCN 2010
Turdus migratorius	American robin	x	x								
Empidonax difficilis	Pacific slope flycatcher	x	x								
Empidonax oberholseri	dusky flycatcher	x	A							x	
Tyrannus verticalis	western kingbird	x	A								
Sayornis saya	Say's phoebe		x								
Colaptes auratus	northern flicker	x	x								
Picoides dorsalis	American three-toed woodpecker	x	x								
Picoides pubescens	downy woodpecker	x	x								
Picoides villosus	hairy woodpecker	x	x								
Sphyrapicus ruber	red-breasted sapsucker	x	x							x	
Chordeiles minor	common nighthawk		x								
Aegolius acadicus	northern saw-whet owl	x	x							x	
Aegolius funereus	boreal owl	x	A								
Bubo scandiacus	snowy owl	x	x								
Bubo virginianus	great horned owl	x	x								
Glaucidium gnoma	northern pygmy owl	x	x							x	
Megascops kennicottii	western screech-owl	x	x								

A= Accidental Species

CR = Critically Endangered

EN = Endangered

VU = Vulnerable

NT = Near Threatened

Appendix 2. The birds of SITK Checklist. Serves as a reference condition for several measures of the Coastal Waterbirds component. Note that SP = spring (1 April – 15 May), S = summer (16 May – 15 August), F = fall (16 August – 15 November), and W = winter (16 November – 31 March).

Category / species	Sp[1]	S[1]	F[1]	W[1]	R[2]
Swans, Geese, & Ducks					
trumpeter swan	u	r	u	r	m
tundra swan	u		u	r	m
brant	u	r	r	r	m
Canada goose	r	r	r	r	m
greater white-fronted goose	r		r		m
green-winged teal	u	u	u	u	m
mallard	c	c	c	c	r
northern pintail	c	u	c	u	m
blue-winged teal	r	r	r		m
gadwall	o		o		m
northern shoveler	u		u	r	m
American wigeon	c	u	c	u	r
European wigeon	o				m
greater scaup	c	u	c	c	r
lesser scaup	u				m
canvasback			o	o	m
redhead	r		r		m
ring-necked duck	r		r	o	m
Steller's eider		o			m
Harlequin duck	c	r	c	c	r
long-tailed duck	u		u	c	m
black scoter	u		u	u	r
surf scoter	c	c	c	c	r
white-winged scoter	c		u	c	r
common goldeneye	u		u	u	m
Barrow's goldeneye	c	r	c	c	m
bufflehead	c		c	c	m
hooded merganser	u	r	u	u	m
common merganser	c	c	c	c	b
red-breasted merganser	u		u	u	m
Cranes					
sandhill crane	o				m
Plovers					
black-bellied plover	u		u		m
Pacific golden-plover	o		o		m
semipalmated plover	o		o		m
killdeer	o		o		m
Oystercatchers					

Category / species	Sp[1]	S[1]	F[1]	W[1]	R[2]
black oystercatcher	u	u	u		m
Sandpipers, Phalaropes					
greater yellowlegs	u		u		m
lesser yellowlegs	u		u		m
spotted sandpiper	c	c	c	r	b
whimbrel	u		u		m
marbled godwit	u	u			m
ruddy turnstone	u		u		m
black turnstone	c	r	c	r	m
surfbird	u	r	u	r	m
sanderling	u		u		m
semipalmated sandpiper	u		u		m
western sandpiper	c		c		m
least sandpiper	c		c		m
pectoral sandpiper	c		c		m
rock sandpiper	c		c		m
dunlin	c		c		m
short-billed dowitcher	c		r		m
long-billed dowitcher	o		o		m
Wilson's snipe	u	r	u	u	m
red-necked phalarope		r	u		m
red knot	o				m
wandering tattler		o	o		m
Jaegers, Gulls, Terns					
parasitic jaeger	r	r	r		m
Bonaparte's gull	u	u	u		m
mew gull	c	c	c	c	r
California gull		r	r		m
herring gull	c	c	c	c	r
Thayer's gull	c	u	c	c	r
glaucous-winged gull	c	c	c	c	r
arctic tern	r		r		m
black-legged kittiwake	u	u	u	u	m
glaucous gull	r			r	m
Heermann's gull			o		m
Loons					
red-throated loon	u	u	u	u	r, m
common loon	c	u	c	u	r
yellow-billed loon	u	r	r	u	m
Pacific loon	c	u	c	c	r
Grebes					

Category / species	Sp[1]	S[1]	F[1]	W[1]	R[2]
horned grebe	u		u	u	r
red-necked grebe	c	u	c	c	r
western grebe	r		r	r	m
pied-billed grebe			u	u	r
Storm-Petrels					
fork-tailed storm-petrel	r	r	r		m
Cormorants					
double-crested cormorant	c		c	c	r
pelagic cormorant	c	u	c	c	r
Herons					
great blue heron	c	c	c	c	r
Auks & Puffins					
common murre	c	c	c	c	
marbled murrelet	c	c	c	c	
pigeon guillemot	c	c	c	u	
rhinocerous auklet	u	u	u		
tufted puffin	c	c	c	r	

Accidental Species

These species are considered to be accidental occurrence. These birds have been seen or heard one or more times in or near Sitka National Historical Park.

American coot
American golden-plover
Baird's sandpiper
brambling
Caspian tern
cattle egret
cinnamon teal
emperor goose
Franklin's gull
great egret
horned puffin
Hudsonian godwit
Leach's storm-petrel
red-faced cormorant
red-legged kittiwake
ruff
slaty-backed gull
willet

[1] = Symbols used for relative abundance include:
- a - abundant - may be seen daily, in suitable habitat and season, and counted in relatively large numbers
- c – common – may be seen daily, in suitable habitat and season, but not in large numbers
- u – uncommon – likely to be seen monthly in appropriate habitat and season
- r – rare – present, but usually seen only a few times each year
- o – occasional – occurs in the park at least once every few years, but not necessarily every year

[2] = Symbols used for residency include:
- b – breeder – population reproduces in the park
- r – resident – a significant population is maintained in the park for more than two months a year or more, but is not known to breed there
- m – migratory – species that occur in the park approximately two months or less a year and does not breed there.

Appendix 3. Coastal bird species observed in SITK from 2002 to 2010 (NPS 2010).

Scientific Name	Common Name	No. of records*
Aix galericulata	Mandarin duck	1
Anas acuta	northern pintail	34
Anas americana	American wigeon	34
Anas clypeata	northern shoveler	29
Anas crecca	green-winged teal	42
Anas discors	blue-winged teal	4
Anas penelope	Eurasian wigeon	11
Anas platyrhynchos	mallard	17
Anas strepera	gadwall	8
Anser albifrons	greater white-fronted goose	12
Aphriza virgata	surfbird	9
Ardea herodias	great blue heron	18
Arenaria interpres	ruddy turnstone	6
Arenaria melanocephala	black turnstone	41
Aythya collaris	ring-necked duck	5
Aythya marila	greater scaup	6
Aythya valisineria	canvasback	3
Branta bernicla	brant goose	19
Branta canadensis	Canada goose	21
Bucephala albeola	bufflehead	5
Bucephala clangula	common goldeneye	3
Bucephala islandica	Barrow's goldeneye	9
Caldris alpina	dunlin	20
Calidris alba	sanderling	1
Calidris bairdii	Baird's sandpiper	1
Calidris canutus	red knot	3
Calidris mauri	western sandpiper	24
Calidris melanotos	pectoral sandpiper	9
Calidris minutilla	least sandpiper	20
Calidris ptilocnemis	rock sandpiper	2
Calidris pusilla	semipalmated sandpiper	1
Charadrius semipalmatus	semipalmated plover	12
Charadrius vociferus	killdeer	2

Scientific Name	Common Name	No. of records*
Chen caerulescens	snow/blue goose	3
Clangula hyemalis	long-tailed duck	1
Cygnus buccinator	trumpeter swan	2
Fratercula cirrhata	tufted puffin	1
Fuluca americana	American coot	5
Gallinago delicata	Wilson's snipe	3
Gavia adamsii	yellow-billed loon	1
Gavia immer	common loon	5
Grus canadensis	sandhill crane	1
Haematopus bachmani	black oystercatcher	14
Heteroscelus incanus	wandering tattler	6
Histrionicus histrionicus	harlequin duck	20
Larus argentatus	herring gull	2
Larus philadelphia	Bonaparte's gull	8
Larus pipixcan	Franklin's gull	1
Larus schistisagus	slaty-backed gull	4
Larus spp.	mixed gulls	3
Larus thayeri	Thayer's gull	3
Limnodromus griseus	short-billed dowitcher	22
Limnodromus scolopaceus	long-billed dowitcher	3
Limosa fedoa	marbled godwit	24
Limosa haemastica	Hudsonian godwit	3
Lophodytes cucullatus	hooded merganser	1
Melanitta deglandi	white-winged scoter	2
Melanitta nigra	black scoter	1
Melanitta perspicillata	surf scoter	11
Mergus merganser	common merganser	11
Numenius phaeopus	whimbrel	12
Oceanodroma furcata	fork-tailed storm-petrel	3
Phalacrocorax auritus	double-crested cormorant	2
Phalacrocorax pelagicus	pelagic cormorant	3
Phalaropus lobatus	red-necked phalarope	7
Pluvialis fulva	Pacific golden-plover	8
Pluvialis squatarola	black-bellied plover	23

Scientific Name	Common Name	No. of records*
Podiceps auritus	horned grebe	4
Podilymbus podiceps	pied-billed grebe	2
Puffinus sp. *(tenuirostis/griseus)*	short-tailed/sooty shearwater	1
Rissa brevirostris	red-legged kittiwake	1
Rissa tridactyla	black-legged kittiwake	14
Sterna caspia	Caspian tern	8
Tringa flavipes	lesser yellowlegs	4
Tringa melanoleuca	greater yellowlegs	32
Uria aalge	common murre	2
Xema sabini	Sabine's gull	1

This table only contains bird species from the following orders: Ciconiiformes (shorebirds, excluding species formerly of the order Falconiformes), Anseriformes (ducks and allies), and Gruiformes (cranes and allies).

*This column represents the number of unique records (rows). The numbers of individuals observed varies greatly by record, listed only in a comment (text) field of the wildlife observation database.

Appendix 4. Plant species in SITK.

Scientific Name	Common Name	Occurrence	Nativity
Acer glabrum var. *douglasii*	Douglas maple	Present in Park	Native
Achillea millefolium var. *borealis*	boreal yarrow	Present in Park	Native
Agrostis exarata	spike bentgrass	Present in Park	Native
Agrostis stolonifera	carpet bentgrass, creeping bentgrass	Present in Park	Non-Native
Alnus rubra	red alder	Present in Park	Native
Alnus viridis ssp. *crispa*	mountain alder	Probably Present	Native
Alnus viridis ssp. *sinuata*	Sitka alder	Probably Present	Native
Angelica genuflexa	bentleaf angelica	Present in Park	Native
Angelica lucida	seacoast angelica	Present in Park	Native
Arabidopsis lyrata ssp. *kamchatica*	Kamchatka rockcress	Present in Park	Native
Argentina egedii ssp. *egedii*	Pacific silverweed	Probably Present	Native
Aruncus dioicus var. *vulgaris*	bride's feathers	Present in Park	Native
Athyrium filix-femina	lady Fern	Present in Park	Native
Atriplex alaskensis	Alaska orache	Probably Present	Native
Atriplex gmelinii	Gmelin's saltbush	Present in Park	Native
Atriplex patula	spear scale	Probably Present	Non-Native
Barbarea orthoceras	winter cress	Present in Park	Native
Blechnum spicant	deer fern	Probably Present	Native
Boschniakia rossica	northern groundcone	Probably Present	Native
Calamagrostis canadensis var. *langsdorfii*	bluejoint	Present in Park	Native
Campanula rotundifolia	bluebell	Present in Park	Native
Capsella bursa-pastoris	sheperd's purse	Present in Park	Non-Native
Cardamine oligosperma var. *kamtschatica*	umbel bittercress	Probably Present	Native
Carex laeviculmis	smoothstem sedge	Probably Present	Native
Carex lenticularis var. lipocarpa	Kellogg sedge	Present in Park	Native
Carex lyngbyei	Lyngbye's sedge	Present in Park	Native
Carex mertensii	Mertens' sedge	Probably Present	Native
Carex utriculata	Northwest Territory sedge	Probably Present	Native
Castilleja unalaschcensis	yellow Indian paintbrush	Present in Park	Native
Cerastium fontanum	common chickweed, mouse-ear chickweed	Present in Park	Non-Native
Chamerion angustifolium ssp. *angustifolium*	fireweed	Present in Park	Native
Chamerion latifolium	dwarf fireweed	Probably Present	Native
Chenopodium album	lamb's quarters	Present in Park	Non-Native

Scientific Name	Common Name	Occurrence	Nativity
Cicuta douglasii	water hemlock	Probably Present	Native
Circaea alpina	Alpine circaea, small enchanter's nightshade	Probably Present	Native
Cirsium arvense	Canada thistle	Probably Present	Non-Native
Claytonia sibirica	Siberian springbeauty	Present in Park	Native
Cochlearia groenlandica	Danish scurvygrass	Probably Present	Native
Cochlearia officinalis	common scurvygrass	Probably Present	Native
Conioselinum chinense	hemlock parsley	Probably Present	Native
Conioselinum gmelinii	Pacific hemlock parsley	Probably Present	Native
Corallorrhiza maculata	spotted coralroot, summer coralroot	Present in Park	Native
Cornus canadensis	bunchberry	Present in Park	Native
Cystopteris fragilis	brittle bladder fern, fragile fern	Present in Park	Native
Deschampsia beringensis	Bering's tufted hairgrass	Probably Present	Native
Draba hyperborea	north Pacific draba	Probably Present	Native
Dryopteris campyloptera	mountain woodfern	Probably Present	Native
Dryopteris expansa	spreading woodfern	Present in Park	Native
Elymus hirsutus	northern ryegrass	Present in Park	Native
Epilobium ciliatum ssp. *ciliatum*	coast willowweed, fringed willowherb	Probably Present	Native
Epilobium lactiflorum	willow-herb	Present in Park	Native
Equisetum arvense	field horsetail, scouring rush	Present in Park	Native
Erigeron peregrinus	subalpine fleabane, wandering daisy	Present in Park	Native
Eriophorum angustifolium	narrowleaf cottonsedge, tall cottongrass,	Probably Present	Native
Festuca rubra	ravine fescue, red fescue	Present in Park	Native
Fragaria chiloensis	beach strawberry	Present in Park	Native
Fritillaria camschatcensis	chocolate lily	Present in Park	Native
Galeopsis bifida	splitlip hempnettle	Probably Present	Non-Native
Galium aparine	cleavers	Present in Park	Native
Galium triflorum	sweet-scented bedstraw	Present in Park	Native
Gaultheria shallon	salal	Probably Present	Native
Gentiana douglasiana	swamp gentian	Probably Present	Native
Geranium erianthum	woolly geranium	Probably Present	Native
Geum macrophyllum var. *macrophyllum*	largeleaf avens	Present in Park	Native
Gymnocarpium dryopteris	oak fern	Present in Park	Native
Harrimanella stelleriana	Alaska bellheather	Probably Present	Native
Heracleum maximum	common cowparsnip, cow parsnip	Present in Park	Native

Scientific Name	Common Name	Occurrence	Nativity
Hippuris vulgaris	common mare's-tail	Probably Present	Native
Honckenya peploides ssp. *major*	seaside sandplant	Present in Park	Native
Hordeum brachyantherum	meadow barley	Present in Park	Native
Huperzia selago	fir club moss	Probably Present	Native
Impatiens noli-tangere	western touch-me-not	Probably Present	Native
Iris setosa	beachhead iris	Probably Present	Native
Juncus alpinoarticulatus ssp. *nodulosus*	northern green rush	Probably Present	Native
Juncus bufonius	toad rush	Probably Present	Unknown
Lapsana communis	common nipplewort	Probably Present	Non-Native
Lathyrus japonicus var. *maritimus*	beach pea	Probably Present	Native
Leucanthemum vulgare	ox-eye daisy	Probably Present	Non-Native
Leymus mollis ssp. *mollis*	American dunegrass	Present in Park	Native
Ligusticum scoticum ssp. *hultenii*	Hulten beach lovage	Present in Park	Native
Linnaea borealis	American twinflower, northern twinflower	Probably Present	Native
Listera caurina	northwestern twayblade	Present in Park	Native
Listera cordata	twayblade	Probably Present	Native
Lupinus nootkatensis	Nootka lupine	Probably Present	Native
Luzula kobayasii	common woodrush	Probably Present	Native
Luzula multiflora	common wood-rush	Probably Present	Native
Luzula parviflora	millet woodrush, smallflowered woodrush	Probably Present	Native
Luzula wahlenbergii	Wahlenberg wood rush	Present in Park	Native
Lysichiton americanus	American skunkcabbage	Present in Park	Native
Maianthemum dilatatum	false lily of the valley	Present in Park	Native
Matricaria discoidea	disc mayweed, pineappleweed	Present in Park	Non-Native
Menziesia ferruginea	rusty menziesia	Probably Present	Native
Microseris borealis	apargidium	Present in Park	Native
Moehringia lateriflora	blunt-leaf grove-sandwort	Probably Present	Native
Moneses uniflora	single-delight	Probably Present	Native
Monotropa hypopithys	many-flower Indian-pipe, pinesap	Probably Present	Native
Nephrophyllidium crista-galli	deercabbage	Probably Present	Native
Oenanthe sarmentosa	water parsley	Probably Present	Native
Oplopanax horridus	devil’s club	Present in Park	Native
Orthilia secunda	oneside wintergreen, sidebells,	Present in Park	Native
Osmorhiza berteroi	mountain sweetroot, sweet cicely	Present in Park	Native
Osmorhiza purpurea	Sitka sweet cicely	Probably Present	Native
Pedicularis verticillata	whorled lousewort	Probably Present	Native

Scientific Name	Common Name	Occurrence	Nativity
Phegopteris connectilis	long beechfern	Present in Park	Native
Phleum pratense	timothy	Present in Park	Non-Native
Picea sitchensis	Sitka spruce	Present in Park	Native
Pinguicula villosa	hairy butterwort	Probably Present	Native
Pinguicula vulgaris	common butterwort	Probably Present	Native
Plantago major	common plantain	Present in Park	Non-Native
Plantago maritima	goosetongue	Present in Park	Native
Poa alpina	Alpine bluegrass	Probably Present	Unknown
Poa annua	annual bluegrass, walkgrass	Present in Park	Non-Native
Poa palustris	fowl bluegrass	Probably Present	Native
Poa pratensis ssp. *pratensis*	Kentucky bluegrass	Present in Park	Non-Native
Polygonum convolvulus	black bindweed, climbing buckwheat	Present in Park	Non-Native
Polygonum fowleri	Fowler's knotweed	Probably Present	Native
Polygonum viviparum	Alpine bistort, serpent-grass	Probably Present	Native
Polypodium glycyrrhiza	licorice fern	Present in Park	Native
Polypodium virginianum	rock polypody	Present in Park	Native
Potentilla villosa	beach silverweed	Present in Park	Native
Prenanthes alata	rattlesnake root	Present in Park	Native
Puccinellia nutkaensis	Nootka alkaligrass	Probably Present	Native
Ranunculus macounii	Macoun's buttercup	Present in Park	Native
Ranunculus occidentalis var. *occidentalis*	western buttercup	Present in Park	Native
Ranunculus pacificus	Pacific buttercup	Present in Park	Native
Ranunculus repens	creeping buttercup	Present in Park	Non-Native
Rhinanthus minor ssp. *groenlandicus*	Arctic rattlebox	Present in Park	Native
Ribes bracteosum	stink currant	Present in Park	Native
Ribes lacustre	prickly currant	Probably Present	Native
Ribes laxiflorum	trailing black currant	Present in Park	Native
Romanzoffia sitchensis	Sitka mistmaiden	Probably Present	Native
Romanzoffia unalaschcensis	Alaska mistmaiden	Probably Present	Native
Rosa nutkana	Nootka rose	Probably Present	Native
Rubus parviflorus	thimbleberry	Present in Park	Native
Rubus pedatus	five leaf bramble	Present in Park	Native
Rubus spectabilis	salmonberry	Present in Park	Native
Rumex acetosella	sheep sorrel	Present in Park	Non-Native
Sagina maxima ssp. *crassicaulis*	stickystem pearlwort	Present in Park	Native
Sambucus racemosa var. *racemosa*	bunchberry elder, red elderberry	Present in Park	Native

Scientific Name	Common Name	Occurrence	Nativity
Senecio pseudoarnica	seaside ragwort	Probably Present	Native
Senecio triangularis	arrowleaf groundsel, arrowleaf ragwort	Probably Present	Native
Senecio vulgaris	common groundsel, old-man-in-the-spring	Probably Present	Non-Native
Sisyrinchium littorale	Alaska blue-eyed grass	Probably Present	Native
Sorbus aucuparia	mountain ash	Present in Park	Non-Native
Spergularia canadensis var. *canadensis*	Canadian sandspurry	Present in Park	Native
Stellaria calycantha	northern chickweed, northern starwort	Probably Present	Native
Stellaria humifusa	saltmarsh starwort	Probably Present	Native
Stellaria media	chickweed, nodding chickweed	Probably Present	Non-Native
Streptopus amplexifolius	clasping twisted stalk, twisted stalk	Present in Park	Native
Streptopus lanceolatus var. *roseus*	twistedstalk	Present in Park	Native
Symphyotrichum subspicatum var. subspicatum	Douglas aster	Present in Park	Native
Taraxacum officinale	dandelion	Present in Park	Non-Native
Tiarella trifoliata	lace flower	Present in Park	Native
Trifolium pratense	red clover	Present in Park	Non-Native
Trifolium repens	sweet white clover	Present in Park	Non-Native
Triglochin maritimum	arrowgrass, seaside arrow-grass	Present in Park	Native
Trisetum canescens	tall trisetum	Present in Park	Native
Tsuga heterophylla	western hemlock	Present in Park	Native
Vaccinium alaskaense	Alaska bluberry	Probably Present	Native
Vaccinium ovalifolium	oval-leaf blueberry	Present in Park	Native
Vaccinium vitis-idaea	lLingonberry	Probably Present	Native
Veronica americana	American speedwell, brooklime	Present in Park	Native
Vicia gigantea	giant vetch	Present in Park	Native
Viola epipsila	dwarf marsh violet	Probably Present	Native
Viola glabella	yellow stream violet	Present in Park	Native
Zostera marina	seawrack	Present in Park	Native

Appendix 5. Alphabetical list (by scientific name) of present and expected species of marine fishes for SITK. from Litzow et al. (2002), Piazza (2001) and Geof Smith (NPS SITK), personal communication, 2005). Status P = present and E = expected. Adapted from Appendix 1 in Eckert et al. (2006) and adapted (added habitat column).

Common name	Scientific name	Status	Habitat
High cockscomb	*Anoplarchus purpurescens*	P	Marine; demersal; depth 1-30m, Intertidal [1]
Penpoint gunnel	*Apodichthys flavidus*	P	Marine; demersal, Algae and tidepools [1]
Padded sculpin	*Artedius fenestralis*	P	Marine; demersal, depth 1-55m, Rocky [1]
Scalyhead sculpin	*Artedius harringtoni*	E	Intertidal to subtidal rocky [1]
Smoothhead sculpin	*Artedius lateralis*	E	Marine; demersal, depth 0-13m, Common intertidal zone [1]
Rosylip sculpin	*Ascelichthys rhodorus*	E	Marine; demersal, tidepools and rocky, inshore [1]
Tube-snout	*Aulorhynchus flavidus*	P	Marine; benthopelagic; depth 0-30m, Kelp, eelgrass, rocky areas [1]
Crested sculpin	*Blepsias bilobus*	E	Marine: demersal: depth 0-250m [1]
Silverspotted sculpin	*Blepsias cirrhosus*	P	Marine; demersal; depth 0-150m, Algae in subtidal zone [1]
Rockhead	*Bothragonus swanii*	E	Marine; demersl; depth 0-18m; Intertidal zone [1]
*Sharpnose sculpin	*Clinocottus acuticeps*	E	Marine; freshwater; brackish; demersal; common rocky intertidal and subtidal (sand, eelgrass, and algae) [1]
Calico sculpin	*Clinocottus embryum*	E	Marine; demersal; Rocky intertidal [1]
Mosshead sculpin	*Clinocottus globiceps*	E	Marine; demersal; non-migratory; depth 0-30m; Tidepools, shallow rock areas, high surf [1]
*Pacific herring	*Clupea pallasi pallasi*	P	Marine; freshwater; brackish; pelagic-neritic; non-migratory; (depth 0-475 m) [1]
*Shiner perch	*Cymatogaster aggregata*	P	Marine; freshwater; brackish; demersal; non-migratory; depth ?-146m; Shallow marine, piers, bay, and estuary with eelgrass [1]
Buffalo sculpin	*Enophrys bison*	P	Marine; demersal; depth range ?-20m; Common Rocky, Inshore [1]
Pacific cod	*Gadus macrocephalus*	P	Marine; demersal; oceanodromous; (Depths 100-400m) [2]
*Threespine stickleback	*Gasterosteus aculeatus*	E	Marine; freshwater; brackish; benthopelagic; anadromous; (depths 0-100m); spawn in freshwater [2]
Northern clingfish	*Gobiesox maeandricus*	E	Marine; demersal; depth ?-8m; Intertidal, rocky with algae (kelp) [1]

Common name	Scientific name	Status	Habitat
Red Irish lord	*Hemilepidotus hemilepidotus*	P	Marine; demersal; depth 0-450m); Nearshore, rocky [1]
Kelp greenling	*Hexagrammos decagrammus*	P	Marine; demersal; depth ?-46m; Rocky inshore and kelp beds [1]
Rock greenling	*Hexagrammos lagocephalus*	P	Marine; demersal; depth 0-596m; shallow, rocky areas [1]
Masked greenling	*Hexagrammos octogrammus*	P	Marine; demersal; depth 0-200m [1]
Whitespotted greenling	*Hexagrammos stelleri*	P	Marine; demersal; depth range 0-300m; Shallow rocky areas [1]
Surf smelt	*Hypomesus pretiosus pretiosus*	E	Marine; brackish, benthopelagic, inshore, spawns in few cm of water [2]
Pacific staghorn sculpin	*Leptocottus armatus*	P	Marine; brackish; demersal; amphidromous; Nearshore, bays, estuaries, coastal streams [1]
Spotted snailfish	*Liparis callyodon*	E	Marine; demersal; dpth 0-20m; Tidepools and intertidal [1]
Tidepool snailfish	*Liparis florae*	P	Marine; fewshwater; brackish; pelagic-oceanic; andadromous; Inshore, tidepools [1, 4]
Capelin	*Mallotus villosus*	E	Marine, pelagic (from surface to depths over 200m) (Mecklenburg et al. 2002)
Great sculpin	*Myoxocephalus polyacanthocephalus*	P	Marine; demersal; amphidroumous [3];Shallow nearshore environment [1]
Tidepool sculpin	*Oligocottus maculosus*	P	Marine; demersal; non-migratory; depth 0-102m [5]; Tidepools and sheltered intertidal areas [1]
Saddleback sculpin	*Oligocottus rimensis*	E	Marine; demersal, depth 0-?; Lower tidepools rocky and kelp [1]
Fluffy sculpin	*Oligocottus snyderi*	E	Marine; demersal; non-migratory; depth 0-?; Tidepools, Shallow, rocky areas [1]
*Cutthroat trout	*Oncorhynchus clarki clarki*	P	Marine; freshwater; brackish; demersal; anadromous; depth 0-200m [6]; Spawning: cold, clear, gravely streams, Juveniles/Adults: salt water or estuary and near-shore environments (ADF&G 2011)
*Pink salmon	*Oncorhynchus gorbuscha*	P	Marine: freshwater; brackish; demersal; anadromous; depth range 0-250m [2]; Spawning and egg development: lower reaches of freshwater streams or intertidal areas, Juvenile: (StreamNet Project)
*Chum salmon	*Oncorhynchus keta*	P	Marine; freshwater; brackish; benthopelagic; anadromous [2]; Spawning and egg development: lower reaches of stream, Juveniles: estuarine [7]

Common name	Scientific name	Status	Habitat
*Coho/silver salmon	*Oncorhynchus kisutch*	P	Marine; freshwater; brackish; demersal; anadromous [2]; Juvenile: freshwater habitat protected by down trees and other vegetation [7]
*Rainbow trout	*Oncorhynchus mykiss*	P	Marine; freshwater; brackish; benthopelagic; anadromous [2]; Juvenile rearing phase: freshwater protected by down trees and other vegetation [7]
*Chinook/king salmon	*Oncorhynchus tshawytscha*	P	Marine; freshwater; brackish; benthopelagic; anadromous [2]; Juvenile: estuaries and intertidal areas or freshwater streams with diverse habitat including large woody debris, Spawning: mainstream channels [7]
Lingcod	*Ophiodon elongates*	E	Marine; demersal; oceanodromous [2]
*Rainbow smelt	*Osmerus mordax dentex*	E	Marine; freshwater; brackish; pelagic-ceritic; anadromous [2]; Midwaters of lakes, inshore coastal waters, rivers and estuaries (Mecklenburg et al. 2002)
Painted greenling	*Oxylebius pictus*	E	Marine; demersal; depth range ?-49m; Rocky intertidal [1]
Tubenose poacher	*Pallasina barbata*	P	Marine; demersal; depth range 0-105m; Eelgrass and seaweed [1]
Crescent gunnel	*Pholis laeta*	P	Marine; demersal; depth range 0-73m; Tidepools [1]
*Starry flounder	*Platichthys stellatus*	P	Marine; freshwater; brackish; demersal; catadromous; depth range 0-375m [2]; Nearshore and estuary [1]
Atka mackerel	*Pleurogrammus monopterygius*	E	Marine; demersal; depth range 0-575; Primarily pelagic, demersal during spawning (ADF&G 2011b)
Grunt sculpin	*Rhamphocottus richardsonii*	E	Marine; demersal; depth range 0-165m [1]; Tidepool, rocky area [1]
*Dolly Varden	*Salvelinus malma*	P	Marine; freshwater; brackish; benthopelagic; anadromous [2]; Cool clear moving streams (habitat can vary to large deep lakes, or to saltwater habitats from estuaries to marine shorelines environments) (ADF&G 2011)
Cabezon	*Scorpaenichthys marmoratus*	P	Marine; demersal; depth range 0-200m [1]; Hard bottom over reefs [3]
Redstripe rockfish	*Sebastes* sp.	P	Marine; bathydemersal; depth 12-425m (Allen and Smith 1988)
Night smelt	*Spirinchus starksi*	E	Marine; benthopelagic [1]; Spawn in surf at night [1]

Common name	Scientific name	Status	Habitat
Longfin smelt	*Spirinchus thaleichthys*	E	Marine; freshwater; brackish; benthopelagic; anadromous Estuarine [2]
Manacled sculpin	*Synchirus gilli*	P	Marine; demersal; bays, tidepools, and kelp [1]
*Eulachon	*Thaleichthys pacificus*	E	Marine; freshwater; brackish; pelagic-neritic; andromous[2]; Eggs: freshwater, Larvae: Pelagic, river, estuary, marine, Adults and Juveniles: pelagic, marine [1]

Compiled by 2006 from Litzow et al. (2002), Piazza (2001) and Geof Smith (NPS-SITK, pers. comm., 2005). Status P = present and E = expected. Adapted from Eckert et al. (2006).

*Indicates species that may occur in or use the Indian River (freshwater environment) for a portion of their life cycle.

The Habitat column was populated using listings in (Sempeir 2003) and from www.fishbase.us with original citations listed below (citations listed in the component section referring to this appendix):

[1] Eschmeyer et al. 1983
[2] Riede 2004
[3] Saruwatari et al. 1997
[4] McDowall 1997
[5] Parin et al. 2002
[6] Morrow 1980
[7] StreamNet Project 1996.

Appendix 6. Selected locations sampled for mercury (Hg), selected persistent organic pollutants (POPs), and total polycyclic aromatic hydrocarbons (TPAHs) at GLBA and SITK. Hg concentrations are reported as µg/g wet tissue and POP and TPAH concentrations are reported as ng/g in sediment and mussel samples. *indicates control site. <LOQ = below quantifiable limits. N/A = Not analyzed due to high expenses or because POP analyses were restricted to mussel samples. Table modified from Tallmon 2011.

Park	Site Description	Hg	∑CHLD	∑DDT	∑HCH	∑PCB	∑PBDE	TPAH
SITK	**Visitor Center**	0.0073	< LOQ	0.75	< LOQ	7.1	< LOQ	2.7
SITK	**Indian River**	0.0068	< LOQ	0.4	< LOQ	5.1	< LOQ	<LOQ
SITK	**Crescent Harbor***	0.021	< LOQ	1.3	< LOQ	15	3.2	<LOQ
SITK	**Visitor Center**	N/A	N/A	N/A	N/A	N/A	N/A	406.01
SITK	**Visitor Center**	0.0068	< LOQ	0.22	< LOQ	4.1	< LOQ	12.73
SITK	**Crescent Harbor***	0.0031	0.2	0.95	1.5	14	3.5	949.22
GLBA	Berg Bay	N/A	< LOQ	< LOQ	< LOQ	1	< LOQ	N/A
GLBA	Berg Bay	N/A	< LOQ	< LOQ	< LOQ	1.3	< LOQ	N/A
GLBA	Berg Bay	N/A	< LOQ	< LOQ	< LOQ	1.3	< LOQ	N/A
GLBA	Bartlett Cove	0.0093	< LOQ	< LOQ	< LOQ	1.4	< LOQ	<LOQ
GLBA	Bartlett Cove	0.0088	< LOQ	< LOQ	< LOQ	0.62	< LOQ	<LOQ
GLBA	B Boat Ramp*	0.0082	< LOQ	< LOQ	< LOQ	1.2	< LOQ	<LOQ
GLBA	Ripple Cove	0.0086	< LOQ	< LOQ	< LOQ	0.77	< LOQ	<LOQ
GLBA	N Rush Point	0.0091	< LOQ	< LOQ	< LOQ	0.69	< LOQ	<LOQ
GLBA	S Whidbey Psg	0.0071	< LOQ	< LOQ	< LOQ	0.79	< LOQ	<LOQ
GLBA	N Drake Island	0.0063	< LOQ	< LOQ	< LOQ	0.64	< LOQ	<LOQ
GLBA	Geikie Inlet Isl	0.0079	< LOQ	< LOQ	< LOQ	0.65	< LOQ	<LOQ
GLBA	Sebree Island	0.0057	< LOQ	< LOQ	< LOQ	0.7	< LOQ	<LOQ
GLBA	N Caroline Pt	0.0067	< LOQ	< LOQ	< LOQ	0.14	< LOQ	<LOQ
GLBA	Muir Pt	0.0058	< LOQ	< LOQ	< LOQ	< LOQ	< LOQ	<LOQ
GLBA	N Pt George	0.0073	< LOQ	< LOQ	< LOQ	0.72	< LOQ	<LOQ
GLBA	Gateway Knob	0.0066	< LOQ	< LOQ	< LOQ	0.78	< LOQ	<LOQ
GLBA	Hunters Cove	0.0065	< LOQ	< LOQ	< LOQ	0.65	< LOQ	<LOQ
GLBA	Spokane Cove	0.0065	< LOQ	< LOQ	< LOQ	0.67	< LOQ	N/A
GLBA	B Fuel Dock*	0.0094	< LOQ	< LOQ	< LOQ	2.2	< LOQ	1488.27
GLBA	Bartlett R Trib	0.011	< LOQ	< LOQ	< LOQ	1	< LOQ	<LOQ
GLBA	S Stump Cove	0.0065	< LOQ	< LOQ	< LOQ	1.7	< LOQ	<LOQ
GLBA	Westdahl Pt	0.0057	< LOQ	< LOQ	< LOQ	1.5	< LOQ	<LOQ
GLBA	N Nunatak Cr	0.0074	< LOQ	< LOQ	< LOQ	1.1	< LOQ	<LOQ
GLBA	McBride Spit S	0.0074	< LOQ	< LOQ	< LOQ	0.72	< LOQ	<LOQ
GLBA	McBride Spit S	N/A	N/A	N/A	N/A	N/A	N/A	<LOQ
GLBA	Tidal inlet	0.0065	< LOQ	< LOQ	0.18	0.87	< LOQ	<LOQ
GLBA	E Russell Rocks	0.0051	< LOQ	< LOQ	< LOQ	1.2	< LOQ	<LOQ
GLBA	Russell Fan	0.0057	< LOQ	< LOQ	< LOQ	0.78	< LOQ	<LOQ
GLBA	Russell Island	0.007	< LOQ	< LOQ	< LOQ	1	< LOQ	<LOQ
GLBA	N Russell Fan	0.0071	< LOQ	< LOQ	0.21	1.2	< LOQ	<LOQ
GLBA	S Tarr Inlet	0.0053	N/A	N/A	N/A	N/A	N/A	<LOQ

Park	Site Description	Hg	∑CHLD	∑DDT	∑HCH	∑PCB	∑PBDE	TPAH
GLBA	Tarr Inlet	0.0076	< LOQ	< LOQ	< LOQ	0.66	< LOQ	<LOQ
GLBA	W Hazelton Camp	0.0069	< LOQ	< LOQ	< LOQ	0.66	< LOQ	<LOQ
GLBA	Blue Mouse Cove	0.0075	< LOQ	< LOQ	< LOQ	< LOQ	< LOQ	<LOQ
GLBA	Blue Mouse Cove	N/A	N/A	N/A	N/A	N/A	N/A	3.59
GLBA	Upper Excursion	0.0083	< LOQ	< LOQ	< LOQ	0.54	< LOQ	<LOQ
GLBA	Upper Excursion	N/A	N/A	N/A	N/A	N/A	N/A	6.94
GLBA	Excursion Fish Plt*	0.0086	0.45	0.25	< LOQ	1.8	< LOQ	13.55
GLBA	Lower Excursion	0.0046	< LOQ	< LOQ	< LOQ	0.79	< LOQ	<LOQ
GLBA	NE Pleasant Island	0.0046	< LOQ	< LOQ	< LOQ	1.2	< LOQ	<LOQ
GLBA	E Carolus R	0.0081	< LOQ	< LOQ	< LOQ	1	< LOQ	<LOQ
GLBA	E Carolus R	N/A	N/A	N/A	N/A	N/A	N/A	<LOQ
GLBA	W Carolus	0.0067	< LOQ	< LOQ	< LOQ	1.1	< LOQ	<LOQ
GLBA	W Pt Dundas	0.0067	< LOQ	< LOQ	< LOQ	1.1	< LOQ	<LOQ
GLBA	W Pt Dundas	N/A	N/A	N/A	N/A	N/A	N/A	<LOQ
GLBA	W Arm Dundas	0.0068	< LOQ	< LOQ	< LOQ	1.2	< LOQ	<LOQ
GLBA	Outer Elfin Cove*	0.01	< LOQ	0.48	< LOQ	3.7	6.3	69.74
GLBA	Mouth Rush Pt Cr	0.0071	< LOQ	< LOQ	< LOQ	0.77	< LOQ	<LOQ
GLBA	Graves	0.0097	< LOQ	< LOQ	< LOQ	0.65	< LOQ	<LOQ
GLBA	Torch Bay N	0.01	< LOQ	< LOQ	< LOQ	< LOQ	< LOQ	<LOQ
GLBA	Dixon Harbor	0.011	< LOQ	< LOQ	< LOQ	0.84	< LOQ	<LOQ
GLBA	Lituya Bay	0.0057	< LOQ	< LOQ	< LOQ	1.1	< LOQ	N/A
GLBA	Berg Bay	0.0075	N/A	N/A	N/A	N/A	N/A	137.66
GLBA	E Russell Rocks	0.0025	< LOQ	< LOQ	< LOQ	0.36	< LOQ	0.83
GLBA	W Hazelton Camp	0.0022	< LOQ	< LOQ	< LOQ	0.33	< LOQ	1.09
GLBA	Ripple Cove	0.0023	< LOQ	< LOQ	< LOQ	0.35	< LOQ	0.48
GLBA	Bartlett Cove	0.0084	< LOQ	< LOQ	< LOQ	0.36	< LOQ	0.78

Appendix 7. Taxonomic list of macroinvertebrate species sampled at the SITK monitoring site near the mouth of the Indian River, from years 1999, 2002, and 2003. Table modified from Irvine and Madison 2008.

Kingdom	Phylum	Family	Genus	Species
Monera	Cyanophyceae	Rivulariaceae	*Calothrix*	spp.
Plantae	Chlorophyta	Acrosiphoniaceae	*Acrosiphonia*	spp.
		Kornmanniaceae	*Blidingia*	*minima*
		Ulvaceae	*Enteromorpha*	*intestinalis*
			Ulva	*fenestrata*
		Prasiolaceae	*Prasiola*	*meridionalis*
	Phaeophyta	Desmarestiaceae	*Desmarestia*	*aculeata*
				viridis
		Dictyosiphonaceae	*Dictyosiphon*	*foeniculaceus*
		Punctariaceae	*Punctaria*	spp.
			Soranthera	*ulvoidea*
		Chordariaceae	*Chordaria*	*flagelliformis*
			Eudesme	*virescens*
		Corynophlaeaceae	*Leathesia*	*difformis*
		Ectocarpaceae	*Pilayella*	*littoralis*
		Ralfsiaceae	*Ralfsia*	*fungiformis*
		Fucaceae	*Fucus*	*distichus* var. *evanescens*
		Laminariaceae	*Laminaria*	*saccharina*
		Scytosiphonaceae	*Petalonia*	*fascia*
		Sphacelariaceae	*Sphacelaria*	spp.
	Rhodophyta	Hildenbrandiaceae	*Hildenbrandia*	spp.
		Dumontiaceae	*Cryptosiphonia*	*woodii*
			Farlowia	*mollis*
		Endocladiaceae	*Endocladia*	*muricata*
			Gloiopeltis	*furcata*
		Cruoriaceae	*Petrocelis*	spp.
		Gigartinaceae		
		Helminthocladiaceae	*Nemalion*	*helminthoides*
		Phyllophoraceae	*Mastocarpus*	*papillatus*
		Rhodomelaceae	*Osmundea*	*spectabilis*
			Odonthalia	*floccosa*
			Pterosiphonia	spp.
			Polysiphonia	spp.
		Rhodymeniaceae	*Halosaccion*	*glandiforme*
		Corallinaceae	*Corallina*	*frondescens*
	Magnoliophyta	Zosteraceae	*Zostera*	*marina*
		Poaceae	*Puccinellia*	*nutkaensis*
		Plantaginaceae	*Plantago*	*maritima*
		Chenopodiaceae	*Atriplex*	*patula*

Kingdom	Phylum	Family	Genus	Species
	Bacillariophyta			
Fungi	Ascomycota	Verrucariaceae	*Verrucaria*	spp.
Animalia	Porifera	Halichondriidae	*Halichondria*	spp.
		Chalinidae	*Haliclona*	spp.
	Cnidaria	Actiniidae	*Urticina*	*felina*
	Platyhelminthes	Amphiporidae	*Amphiporus*	spp.
		Emplectonematidae	*Emplectonema*	*gracile*
	Mollusca	Lepidochitondidae	*Tonicella*	spp.
		Trochidae	*Margarites*	spp.
		Acmaeidae	*Acmaea*	*mitra*
		Littorinidae	*Littorina*	*scutulata*
				sitkana
			Lacuna	spp.
		Lottiidae	*Lottia*	*pelta*
				strigatella
			Tectura	*persona*
				scutum
		Nucellidae	*Nucella*	*lima*
				lamellosa
		Buccinidae	*Lirabuccinum*	*dirum*
		Mytilidae	*Modiolus*	*modiolus*
			Mytilus	*trossulus*
	Annelida	Nereidae		
		Pectinariidae	*Pectinaria*	*granulata*
		Spirorbidae		
	Arthropoda	Archaeobalanidae	*Semibalanus*	*balanoides*
				cariosus
		Balanidae	*Balanus*	*glandula*
		Chthamalidae	*Chthamalus*	*dalli*
		Sphaeromatidae	*Gnorimosphaeroma*	*oregonense*
		Varunidae	*Hemigrapsus*	spp.
		Paguridae	*Pagurus*	*hirsutiusculus*
		Cancridae	*Cancer*	*productus*
		Bdellidae	*Neomolgus*	*littoralis*
	Echinodermata	Asteropseidae	*Dermasterias*	*imbricata*
		Asteriidae	*Evasterias*	*troschelii*
			Lepasterias	*epichlora*
			Pisaster	*ochraceus*
			Pycnopodia	*helianthoides*
		Strongylocentrotidae	*Strongylocentotus*	*droebachiensis*
				franciscanus
	Chordata	Cottidae	*Oligocottus*	*maculosus*

Appendix 8. Tolerance values for aquatic macroinvertebrates found in the Sitka, Alaska area, Baranof Island SITK.

Family	Genus	Tolerance Score	FFG Primary	FFG Secondary	Habitat Primary	Habitat Secondary
Ephemeroptera			GC			
Heptageniidae		4	SC			
	Epeorus	0	SC		cn	
	Rhithrogena	0	SC		cn	
	Cinygmula	4	SC		cn	
	Cinygma	4	SC		cn	
Baetidae		4	GC			
	Baetis	5	GC		sw	cb
Leptophlebiidae		2	GC			
	Paraleptophlebia	1	GC		sw	cn
Ameletidae						
	Ameletis	0	GC		sw	cb
Ephemerellidae		1	GC			
	Drunella	0	PR		cn	sp
	Serratella	2	GC		cn	
Plecoptera			PR		cn	
Capniidae		1	SH		sp	cn
	Capnia	1	SH			
	Mesocapnia					
Leuctridae		0	SH			
	Paraleuctra	0	SH		sp	cn
	Despaxia	0	SH		cn	
Nemouridae		2	SH			
	Zapada	2	SH			
	Visoka		SC		sp	cn
	Podmosta	2	SH			
Taeniopterygidae		2	SH		sp	cn
	Doddsia					
Chloroperlidae		1	PR		cn	
	Sweltsa	1	PR			
	Suwallia (Neaviperla)	1	PR		cn	
	Kathroperla	0	PR			
Perlodidae		2	PR		cn	sp
	Megarcys	2	PR		cn	
	Kogotus	2	PR		cn	

Family	Genus	Tolerance Score	FFG Primary	FFG Secondary	Habitat Primary	Habitat Secondary
Trichoptera					sp	
Rhyacophilidae		0	PR		cn	
	Rhyacophila	0	PR			
Glossosomatidae		0	SC		cn	
	Glossosoma	0	SC			
Philopotamidae		3	FC		cn	
	Dolophilodes	1	FC	GC		
Hydropsychidae		4	FC			
	Parapsyche	1	PR			
Polycentropodidae			FC		cn	
	Polycentropus	6	PR	FC	cn	
Phryganeidae			SH		cb	
	Ptilostomis		PR	SH	cn	
Limnephilidae		4	SH			
	Chyranda		SH		sp	
	Dicosmoecus	1	SH			
	Ecclisomyia	2	GC			
	Glyphopsyche	1				
	Onocosmoecus	1	SH			
	Lenarchus					
	Limnephilus	5	SH			
	Psychoglypha	1	GC			
Brachycentridae		1	FC		cn	cb
	Micrasema	1	SH			
Lepidostomatidae		3	SH			
	Lepidostoma	1	SH			
Uenoidae		0	SC			
	Neophylax	3	SC			
Diptera		7				
Chironomidae		6	GC		bu	
	Brillia	5	SH	GC		
	Cricotopus	7	SH	GC		
	Corynoneura	7	GC			
	Eukiefferiella	8	GC	SC		
	Micropsectra	7	GC			
	Pagastia	1	GC			
	Paracricoptopus		GC			

Family	Genus	Tolerance Score	FFG Primary	FFG Secondary	Habitat Primary	Habitat Secondary
	Parakiefferiella	6	GC			
	Paramerina	6	PR		sp	
	Parametriocnemus	5	GC		sp	
	Paraphaenocladius	5	GC		sp	
	Polypedilum	6	SH	GC		
	Rheocricotopus	6	GC	SH		
	Stempellinella	4	GC			
	Stilocladius		GC		sp	
	Thienemanniella	6	GC			
	Tvetenia	5	GC			
	Orthcladiinae	5	GC		bu	
	Micropsectra/Tanytarus	6	FC	GC		
	Cricotopus/Orthocladius	7	SH	GC		
Simuliidae		6	FC		cn	
	Prosimulium	3	FC			
Tipulidae		3	SH			
	Antocha	3	GC			
	Hesperoconopa	1	GC		bu	
	Dicranota	3	PR			
Empididae		6	PR		sp	bu
	Clinocera	6	PR			
	Chelifera	6	GC			
	Oreogeton	5	PA			
Ceratopogonidae		6	PR			
Coleoptera			PR			
Amphizoidae						
Empididae		6	PR		sp	bu
	Clinocera	6	PR			
	Chelifera	6	GC			
	Oreogeton	5	PA			
	Amphizoa	1	PR		cn	
Dytiscidae		5	PR			
Collembola		10	GC			
Pelecypoda		8	FC			
Sphaeriidae						
	Pisidium	8	FC			
Nematoda		5	PA			

Family	Genus	Tolerance Score	FFG Primary	FFG Secondary	Habitat Primary	Habitat Secondary
Oligochaeta		5	GC			
Lumbriculidae		8	GC			
Enchytraeidae		10	GC			
Class Turbellaria		4	PR			
Subclass Acari			PR/PA			

Data obtained from G. Smith. Tolorance valued from Barbour et al. (1999), Appendix B representing the Northewest Region.
The abbreviations for the Functional Feeding Designations (FFG) are PA=parasite, PR=predator, OM=omnivore, GC=gatherer/collector, FC=filter/collector, SC= scraper, SH=shredder, and PI=piercer. The abbreviations for Habitat/Behavior Designations are bu=burrower, cb=climber, cn=clinger, dv=diver, sk=skater, sp=sprawler, and sw=swimmer. This list was derived from work in Idaho and represents the Pacific Northwest Region. Tolerance values are on a 0 to 10 scale, 0 representing an extremely sensitive organism and 10 for a tolerant organism. For functional feeding group and habit/behavior assignments, primary and secondary designations are listed (G. Smith, unpublished data).

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