KARLUK LAKE NUTRIENT ENRICHMENT

Final Environmental Assessment and Section 810 Evaluation

Kodiak Island, Kodiak National Wildlife Refuge
Kodiak, Alaska

KARLUK LAKE NUTRIENT ENRICHMENT FINAL ENVIRONMENTAL ASSESSMENT AND ANILCA SECTION 810 EVALUATION

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ACRONYMS

AAC	Alaska Administrative Code
ADCCED	Alaska Department of Commerce, Community, and Economic Development
ADEC	Alaska Department of Environmental Conservation
ADF&G	Alaska Department of Fish and Game
AHRS	Alaska Heritage Resources Survey
ANCSA	Alaska Native Claims Settlement Act
ANILCA	Alaska National Interest Lands Conservation Act
APE	area of potential effects
BEGs	biological escapement goals
BMPs	best management practices
CCP	comprehensive conservation plan
CDP	census-designated place
CEQ	Council on Environmental Quality
CFEC	Commercial Fisheries Entry Commission
CFR	Code of Federal Regulations
CSIS	Community Subsistence Information System
CWA	Clean Water Act
DO	dissolved oxygen
EA	environmental assessment
EPA	Environmental Protection Agency
ESA	Endangered Species Act
FONSI	finding of no significant impact
IC	Interim Conveyance
IDT	interdisciplinary team
Improvement Act	National Wildlife Refuge System Improvement Act
kg	kilograms

km	kilometer
Kodiak Refuge	Kodiak National Wildlife Refuge
Koniag, Inc.	Koniag, Incorporated
KRAA	Kodiak Regional Aquaculture Association
MDN	marine-derived nutrients
mg/m^2	milligrams per square meter
NHPA	National Historic Preservation Act
NLCD	National Land Cover Database
N:P	nitrogen:phosphorus
NEPA	National Environmental Policy Act
NWRS	National Wildlife Refuge System
OEG	optimal escapement goal
PL	Public Law
PP	particulate phosphorus
ppb	parts per billion
RO	responsible official
RPT	Regional Planning Team
SEG	sustainable escapement goal
Service, USFWS	U.S. Fish and Wildlife Service
SET	sustained escapement threshold
SRP	soluble reactive phosphorus
SUP	special use permit
TN:TP	total nitrogen:total phosphorus
TP	total phosphorus
USC	United States Code
USGS	U.S. Geological Survey
µg/L	micrograms per liter

TERMS AND DEFINITIONS

Backstocking: Stocking of a watershed using juvenile salmonids collected from broodstock returning to the same watershed.

Biological Escapement Goal: A biological escapement goal is the number of salmon in a particular stock that ADF&G has determined should be allowed to escape the fishery to spawn to achieve the maximum sustained yield (human use). This determination is based on biological information about the fish stock in question.

Conservation Concern: A conservation concern is “a concern arising from a chronic inability, despite the use of specific management measures, to maintain escapements for a stock above a SET” (5 AAC 39.222(f)(6)).

Direct impacts: Impacts from a proposed project that affect a specific resource and generally occur at the same time and place as the action.

Escapement: The number of fish allowed to “escape” being harvested and return to the Karluk system to spawn. Escapement is managed through a series of monitoring actions and regulations on commercial and subsistence harvest.

Fee Title: Fee title is a real estate term indicating an absolute title to land; it is a type of ownership that gives the land owner the maximum interest in the land and the right to use it in any manner he or she wishes.

Eutrophic and Eutrophication: Eutrophication is an increase in phosphorus, nitrogen, and other nutrients in a lake, resulting in increased biological productivity. A eutrophic lake is one that is rich in mineral and organic nutrients and has a resulting proliferation of plant life, including algae. Algal blooms can reduce the dissolved oxygen level in the lake and may thus cause the extinction of other organisms in a eutrophic lake.

Indirect impacts: Impacts from a project can result from one resource affecting another (e.g., soil erosion and sedimentation affecting water resources) or can occur later in time or be removed in location.

Limnetic zone: The well-lit, open surface waters of a lake.

Management Concern: A management concern is “a concern arising from a chronic inability, despite the use of specific management measures, to maintain escapements for a salmon stock within the bounds of the SEG, BEG, OEG, or other specified management objectives for the fishery” (5 AAC 39.222(f)(21)).

Maximum Sustained Yield: the largest yield (or catch) that can be taken from a species' stock over an indefinite period to allowing the population to continue to be productive indefinitely.

Metalimnion: The metalimnion is a layer of the lake that is created during the summer stratification period and is defined as the layer of water with the greatest change in temperature with respect to depth. The metalimnion separates a warmer, surficial mixed layer from a cooler and denser lower layer.

Metalimnetic Oxygen Depletion (MOD) Rate: The MOD rate is arrived at by calculating the difference in dissolved oxygen concentrations at the top and bottom of the metalimnion over a period of time.

Oligotrophic Lake: An oligotrophic lake is one that has low biological productivity; such lakes are relatively cool and clear, and have low nutrient concentrations.

Outstocking: Stocking of a watershed using juvenile salmonids collected from broodstock returning to a different watershed than the one to be stocked.

Over-escapement: Where the number of fish returning to the stream to spawn exceeds the upper escapement goal set by ADF&G.

Primary Production: The process where energy is converted through photosynthesis to organic substances. For this project, primary production refers to phytoplankton production.

Recruitment: The amount of fish added to a stock each year due to growth and/or migration into the fishing area. For example, the number of fish that grow to become vulnerable to the fishing gear in one year would be the recruitment to the fishable population that year.

Secondary Production: The consumption of primary producers (phytoplankton) by herbivorous consumers (zooplankton).

Tertiary Production: The consumption of herbivorous consumers (zooplankton) by carnivorous consumers (fishes).

Traditional Cultural Properties (TCP): A TCP is "a property that is eligible for inclusion in the National Register of Historic Places based on its associations with the cultural practices, traditions, beliefs, lifeways, arts, crafts, or social institutions of a living community. TCPs are rooted in a traditional community's history and are important in maintaining the continuing cultural identity of the community" (National Park Service 2012).

Yield Concern: A yield concern is "a concern arising from a chronic inability, despite the use of specific management measures, to maintain specific yields, or harvestable surpluses, above a stock's escapement needs" (5 AAC 39.222(f)(42)).

1. PURPOSE AND NEED FOR ACTION

1.1. Introduction

The U.S. Fish and Wildlife Service (Service, USFWS) has prepared this environmental assessment (EA) in response to an application from the Kodiak Regional Aquaculture Association (KRAA) for a special use permit (SUP) to conduct a nutrient enrichment project on Karluk Lake within the Kodiak National Wildlife Refuge (Kodiak Refuge), Alaska (Figure 1). This EA describes the proposed project and the legal and regulatory context; examines alternatives; and analyzes expected direct, indirect, and cumulative impacts on the human and natural environment under the National Environmental Policy Act (NEPA).

The EA has been prepared in accordance with the requirements of NEPA (42 U.S. Code [USC] 4321, et seq.), as implemented by the Council on Environmental Quality (CEQ) regulations in 40 Code of Federal Regulations (CFR) 1500–1508.

1.2. Purpose and Need for Action

The Service's need is to respond to KRAA's application and make a decision regarding whether to issue the SUP in accordance with laws and regulations governing the Proposed Action. The Service reviews and approves or disapproves SUP applications under the terms of the National Wildlife Refuge System Administration Act of 1966 (16 USC 668DD–668EE), as amended, and the regulations found at 50 CFR 29.1, 31.13, and 36.41.

The Service's purpose in considering KRAA's application is to ensure that the Proposed Action (lake nutrient enrichment) is appropriate and compatible with the purposes of Kodiak Refuge and the mission of the National Wildlife Refuge System (NWRS) and furthers the goals and management of Kodiak Refuge.

1.3. Background

The Kodiak Refuge was established on August 19, 1941, by Executive Order 8857 to protect the natural feeding and breeding ranges of the brown bear and other wildlife on Uganik and Kodiak Islands. The Refuge encompasses approximately 1.7 million acres of fee title and conservation easement land on Kodiak, Afognak, and Ban Islands, and some marine waters around Kodiak and Afognak Islands in the Kodiak Archipelago. Refuge lands are intermixed with Alaska Native corporation lands, including those of Koniag, Incorporated (Koniag, Inc.), and other private lands.

1.3.1. Proposed Project History

Karluk Lake has historically been the largest producer of sockeye salmon (*Oncorhynchus nerka*) on Kodiak Island, Alaska (Foster 2014). From 2008 to 2011 the early sockeye salmon runs in Karluk Lake failed to meet the Alaska Department of Fish and Game's (ADF&G's) escapement goals. These escapement goals are established to allow a certain percentage of the total run to "escape" harvest and return to their spawning areas in Karluk Lake and tributaries to reproduce. In response to four years of low runs, KRAA submitted a proposal to the Service to conduct a 9-year nutrient enrichment project on the lake, consisting of 5 years of nutrient application along with 2 years of pre-treatment and 2 years of post-treatment monitoring of the lake.

Lower runs during 2008 (to 2011) are due to many complex and interrelated factors, Foster (2014) lists the relative small size and condition of outmigrating smolt and their potential for reduced marine survival as the most likely direct factor responsible for reduced productivity. But the system is complex. Foster goes on to suggest five factors potentially responsible for smaller smolt, including: poor feeding conditions in Karluk Lake due to declining zooplankton biomass; preferred food (*Bosmina*) below threshold size for feeding; low water temperatures; decreases in the Pacific Decadal Oscillation; and continued overescapement during 1985 to 2005 (Foster 2014). In their proposal, KRAA asserts that "Karluk Lake is currently in a state of reduced productivity" and "it is unlikely that the system will return to previous, naturally high levels of productivity without intervention". To remedy this situation they propose to apply liquid fertilizer to the lake's surface over a 5-year period in an effort to increase plankton productivity and address the poor feeding conditions in Karluk Lake. Further, KRAA's also intends to "provide for higher and sustainable escapement of adult sockeye salmon into Karluk Lake", which would "benefit subsistence, sport and commercial harvesters" (KRAA 2012).

The Proposed Action would seek to maintain an annual mean phosphorus load of 90% of "permissible" levels and nutrient targets, and would adapt to changing conditions. KRAA would work with ADF&G and the Service each spring, prior to the May–August growing season, to develop nutrient concentration and application plans. Upon initiation of aerial application of fertilizer, KRAA would use in-season monitoring data to maintain appropriate nitrogen and phosphorus ratios throughout the growing period. Should the targeted nutrient level be achieved at any time during the proposed project, fertilizer solution application would stop. Monitoring would continue, and if nutrient concentrations were to fall back below desired levels, adaptive application would resume.

To minimize flight time to Karluk Lake during nutrient application, the aqueous solution would be shipped to Larsen Bay, Alaska, and stored near the airport. A fixed-wing aircraft equipped with a sprayer bar would fuel and take on the fertilizer solution at the airport and then fly to the project area. Nutrients would then be sprayed over the lake surface within a prescribed area that includes the lake's Main, Thumb, and O'Malley Basins.

Under the Proposed Action and all other considered alternatives, physical, chemical, and biological parameters for the lake would be monitored to evaluate project effectiveness. KRAA's Proposed Action is further discussed in Chapter 2.

1.3.2. Summary of the Karluk Sockeye Salmon Fishery

Karluk Lake, with a surface area of approximately 9,630 acres, is the largest lake in the Kodiak Archipelago (see Figure 1). Karluk Lake and Karluk River and their associated tributaries (the Karluk System) drain a watershed of 275 square kilometers (km^2; 106 square miles) (Uchimaya and others 2008). The south half of the lake is surrounded by Kodiak Refuge lands administered by the Service; the north half of the lake is surrounded by private lands owned and managed by Koniag, Inc.[1]

Commercial harvest of sockeye salmon in the Karluk system began in the late 1800s, and over one million fish a year were regularly collected (USFWS 1986). Runs began to decline soon after commercial harvest began and continued to trend lower into the 1970s (Loewen 2014; Schmidt and others 1998). Prior to 1971, the salmon fishery on the Westside of Kodiak was allowed to operate during most of the

1 The northern portion of Karluk Lake was conveyed (Interim Conveyance [IC] 117 [August 24, 1978]) to Nu-Nachk Pit, Inc. (village of Larsen Bay) under the Alaska Native Claims Settlement Act (ANCSA). In 1980 Nu-Nachk Pit, Inc. elected to merge into Koniag, Inc., the Kodiak Archipelago's Regional ANCSA Native Corporation.

year with little restriction; in most areas as much as 5 to 7 days a week (1985 Kodiak AMR). As a consequence, the Karluk sockeye salmon runs were struggling and a need to change management was recognized. In 1971 and following years significant management action was taken (see section 3.4.1) to increase escapement including an almost complete closure of the fishery for 15 years and implementation of escapement based management (USFWS 1986). Finally, backstocking efforts were allowed from 1978 to 1986. The result of all the State's actions (1971-1986 excluding fertilization) was that from 1985-2007, escapement of earlyrun Karluk Lake sockeye exceeded or nearly exceed their respective escapement goals (Personal communication, Nick Sagalkin, Alaska Department of Fish and Game).

Active nutrient enrichment of Karluk Lake by ADF&G began in 1986 and continued annually through 1990. Phosphorus and chlorophyll *a* concentrations increased during fertilization but returned to pre-fertilization levels following enrichment. Zooplankton biomass did not follow this pattern and was lower during the 4 years of fertilization (Golder and Associates 2011).

From 1985 to 2013, adult sockeye salmon runs and escapements were cyclical, as is typical for this system. From 1989 to 2007, overescapement occurred regularly. Run size and escapement levels to Karluk Lake between 2008 and 2011 fell to annual averages that were less than half those of 1985 to 2007 (Loewen 2014). Leading up to those years zooplankton biomass was depressed in 2005, 2006, and 2008. Despite this, migrating adult populations have improved in recent years, and total run and escapement increased from 2012 to 2014 to near the averages between 1985 and 2007 (Loewen 2014; Moore 2014).

Additional information on the Karluk Lake aquatic ecosystem and its fishery is provided in Chapter 3.

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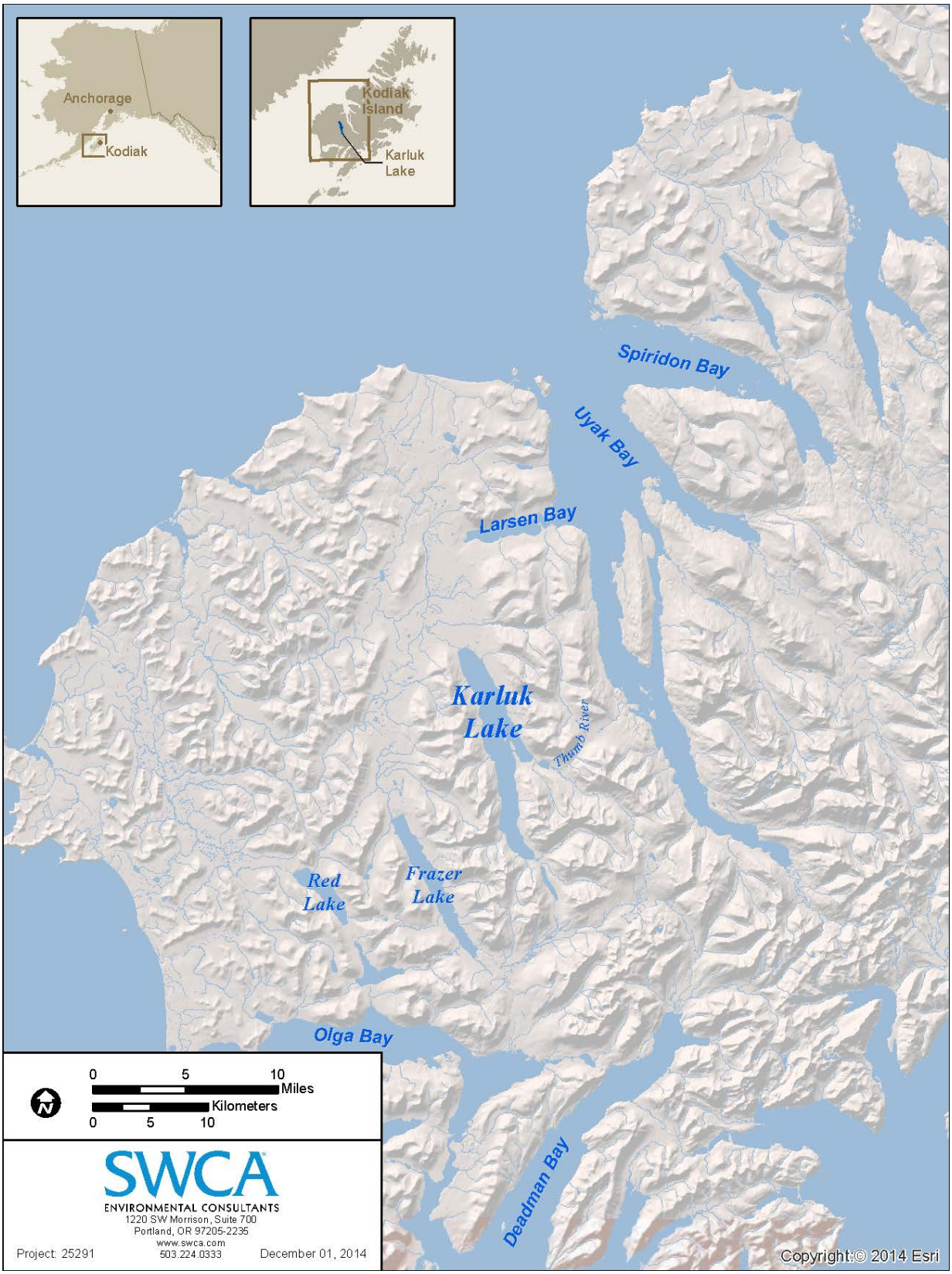

Figure 1. Location of Karluk Lake on Kodiak Island, Alaska.

Document continues on the following page.

1.4. Regulatory Authorities and Responsibilities

This section summarizes the regulatory authority and responsibility of the Service and other state and federal agencies regarding the management and purposes of Kodiak Refuge.

1.4.1. Mission of the Service

The mission of the Service is "… working with others to conserve, protect, and enhance fish, wildlife, plants, and their habitats for the continuing benefit of the American people" (USFWS 2013).

1.4.2. Mission of the National Wildlife Refuge System

The Kodiak Refuge is part of the NWRS. The legally mandated mission of the NWRS is "… to administer a national network of lands and waters for the conservation, management and where appropriate, restoration of the fish, wildlife and plant resources and their habitats within the United States for the benefit of present and future generations of Americans" (NWRS Administration Act of 1966, as amended [16 USC 668dd–668ee]).

1.4.3. Kodiak Refuge Purposes

Kodiak Refuge was specifically established in 1941 "… for the purpose of protecting the natural feeding and breeding ranges of the brown bear and other wildlife …." Forty years later, Alaska National Interest Lands Conservation Act (ANILCA) Section 303 (5)(b) added the following purposes:

i. to conserve fish and wildlife populations (and) habitats in their natural diversity including, but not limited to, Kodiak brown bears, salmonids, sea otters, sea lions and other marine mammals and migratory birds;

ii. to fulfill the international treaty obligations of the United States with respect to fish and wildlife and their habitats;

iii. to provide, in a manner consistent with the purposes set forth in subparagraphs (i) and (ii), the opportunity for continued subsistence uses by local residents; and

iv. to ensure, to the maximum extent practicable and in a manner consistent with the purposes set forth in paragraph (i), water quality and necessary water quantity within the refuge.

1.4.4. Legal Context

Management of Kodiak Refuge lands and waters is also influenced by a number of legal mandates that address protection and management of public lands, fish and wildlife policy, and enforcement. These other mandates are briefly described below.

1.4.4.1. NATIONAL WILDLIFE REFUGE SYSTEM ADMINISTRATION ACT OF 1966, AS AMENDED BY THE NATIONAL WILDLIFE REFUGE SYSTEM IMPROVEMENT ACT OF 1997, 16 USC 668DD–668EE

The NWRS Administration Act of 1966 (16 USC 668dd–668ee, derived from Sections 4 and 5 of Public Law (PL) 89-669 (October 15, 1966; 80 Stat. 927),. as amended by PL 105-57, the National Wildlife

Refuge System Improvement Act (Improvement Act, October 9, 1997), constitutes an "organic act" for the NWRS.

The Improvement Act (111 Stat. 1253) gives guidance to the Secretary of the Interior for the overall management of the NWRS and establishes a unifying mission for the NWRS that, first and foremost, focuses on the conservation of fish, wildlife, plants, and their habitats for the continuing benefit of the American people. The Act's main components include a strong and singular wildlife conservation mission for the NWRS; a requirement that the Secretary of the Interior maintain the biological integrity, diversity, and environmental health of the NWRS; a new process for determining compatible uses of refuges; a recognition that wildlife-dependent recreational uses involving hunting, fishing, wildlife observation and photography, and environmental education and interpretation, when determined to be compatible, are legitimate and appropriate public uses of the NWRS; that these compatible wildlife-dependent recreational uses are the priority general public uses of the NWRS; and a requirement for preparing comprehensive conservation plans (CCPs).

1.4.4.2. ALASKA NATIONAL INTEREST LANDS CONSERVATION ACT, AS AMENDED, 16 USC 140HH-3233, 43 USC 1602–1784

ANILCA (PL 96–487) designated over 100 million acres of federal public lands in Alaska as national parks, national wildlife refuges, Wild and Scenic Rivers, and wilderness. Under ANILCA Section 303(5), Kodiak Refuge was expanded to include selected public lands on Afognak and Ban Islands. This provision also set the purposes that guide management of Kodiak Refuge (see Section 1.4.3, Kodiak Refuge Purposes). Under ANILCA Section 304, the Service is required to develop CCPs for each wildlife refuge in Alaska. CCPs are management plans that guide management of each refuge in a manner consistent with existing laws and regulations. The Service completed the first CCP for Kodiak Refuge in 1987. The Service last completed a revision to the CCP in 2008.

1.4.4.3. ALASKA NATIVE CLAIMS SETTLEMENT ACT OF 1971, AS AMENDED, 43 USC 1601–1624

The Alaska Native Claims Settlement Act (ANCSA) was signed into law to settle all claims by Alaska Natives and Alaska Native groups, based on aboriginal land claims. ANCSA provided for grants of land and money and the establishment of Alaska Native corporations to maintain the economic affairs of Alaska Native organizations. In exchange, all aboriginal titles and claims, including any fishing and hunting rights, were extinguished. Section 12(a) allowed village corporations to select lands, with several stipulations, in national wildlife refuges. Section 22(g), however, stated that these lands were to "… remain subject to the laws and regulations governing use and development of such refuge and this would be done through a compatibility determination

1.4.4.4. NATIONAL ENVIRONMENTAL POLICY ACT OF 1969, AS AMENDED, 42 USC 4321–4347

This act and the implementing regulations developed by the CEQ (40 CFR 1500–1508) require federal agencies to integrate the NEPA process with other planning at the earliest possible time to provide a systematic interdisciplinary approach to decision making; to identify and analyze the environmental effects of their actions; to describe appropriate alternatives to the proposed actions; and to involve the affected state and federal agencies, tribal governments, and public in the planning and decision-making process.

1.4.4.5. NATIONAL HISTORIC PRESERVATION ACT, AS AMENDED, 16 USC 470

Section 106 of the National Historic Preservation Act (NHPA) mandates a review process for all federally funded and permitted projects that may impact sites listed on, or eligible for listing on, the National Register of Historic Places. Section 106 also requires consultation, especially with tribes, and gives oversight of historic properties statewide to each State Historic Preservation Office.

Any federal agency planning a project must identify the area of the project and any listed or eligible historic properties that may be impacted by the work, as well as evaluate these resources' eligibility for the National Register of Historic Places or historical importance. The evaluation is provided to the State Historic Preservation Office, federally recognized Native American tribes, and other interested parties for their consultation. The agency then assesses the impacts of its actions on the historic resource, and returns to the State Historic Preservation Office and interested parties for consultation and concurrence.

1.4.4.6. ENDANGERED SPECIES ACT, AS AMENDED, 16 USC 1531–1544

The Endangered Species Act (ESA) directs all federal agencies to work to conserve endangered and threatened species and to use their authorities to further the purposes of the act. Section 7 of the act, Interagency Cooperation, is the mechanism by which federal agencies ensure the actions they take, including those they fund or authorize, do not jeopardize the existence of any listed species.

Under Section 7, the Service must determine when any action the agency carries out, funds, or authorizes (such as through a permit) may affect a listed endangered or threatened species. If the Service determines that the proposed action is not likely to affect any listed species in the project area, the informal consultation is complete and the proposed project moves ahead. If it appears that the agency's action may affect a listed species, the Service may then prepare a biological assessment to assist in its determination of the project's effect on a species.

1.4.4.7. CLEAN WATER ACT OF 1972, AS AMENDED, 33 USC 1311–1377

The Clean Water Act (CWA) is the primary federal law in the United States governing water pollution. Passed in 1972, the objective of the CWA is to restore and maintain the chemical, physical, and biological integrity of the nation's waters by preventing point and nonpoint pollution sources and maintaining the integrity of wetlands.

For projects on refuge lands, the Service is required to evaluate effects to water quality and wetlands under the CWA. Section 401 of the CWA delegates authority for protection of water quality to the states. In Alaska, the Department of Environmental Conservation sets water quality standards for both point and nonpoint pollution sources under the guidance of the Environmental Protection Agency. Section 404 of the CWA established a program to regulate the discharge of dredged or fill material into waters of the U.S. and authorized the U.S. Army Corps of Engineers to permit any placement of dredged or fill material into waters of the U.S.

1.5. Consistency with Other Plans and Policies

The preparation of this EA is in accordance with NEPA and in compliance with CEQ regulations (40 CFR 1500–1508), Department of Interior requirements (Department Manual 516), and guidelines as listed in the Service NEPA Handbook.

1.5.1. NWRS Biological Integrity Policy

The Service's Biological Integrity policy is a key policy directive from the Improvement Act of 1997. Section 4(a)(4)(B) of the law states that "In administering the System [NWRS], the Secretary shall … ensure that the biological integrity, diversity, and environmental health of the System are maintained for the benefit of present and future generations of Americans….". The policy further clarifies that implicit in these terms are maintenance of biotic composition, structure and functioning of ecosystems resulting from natural processes and abiotic processes. Refuges are managed to fulfill their purpose(s) and the NWRS mission while maintaining and, where appropriate, restoring biological integrity, diversity, and environmental health to lost or severely degraded ecosystems (at the refuge scale).

1.5.2. Refuge Compatibility Policy

The Refuge Compatibility policy, as authorized under the NRWS Administration Act, the Improvement Act, and ANILCA, requires development of compatibility. Compatibility determinations are documents written, signed, and dated by the refuge manager and the regional chief of refuges that signify whether any proposed or existing uses of a national wildlife refuge are compatible with that refuge's establishing purposes and the mission of the NWRS. All recreational activities and economic or other uses of a refuge by the public or other non-Service entity require compatibility determinations. Economic uses must also contribute to achieving refuge purposes and the mission of the NWRS. When completing compatibility determinations, refuge managers use sound professional judgment to ensure that a use will not materially interfere with or detract from the fulfillment of the NWRS mission or the purposes of the refuge before allowing that use. Inherent in fulfilling the NWRS mission is not degrading the ecological integrity of the refuge.

1.5.3. Kodiak Refuge Management Direction

The Kodiak Refuge CCP (USFWS 2008) provides guidance on refuge management through the establishment of a refuge vision statement, the development of refuge goals and objectives, the use of topical management direction, and the designation of management categories for Kodiak Refuge lands.

1.5.3.1. GOALS AND OBJECTIVES

Refuge goals support the purposes of the Kodiak Refuge and reflect its contribution to the NWRS. The following goals and objectives relate most directly to the proposed activity and its possible effects on refuge resources.

> *Goal 2: Ensure that Kodiak brown bears continue to flourish throughout the Refuge and congregate at traditional concentration areas.*
>
> *Goal 7: Conserve the abundance of natural salmonid populations for continued human and wildlife use and to ensure the diversity of species as indicators of the health of the Refuge's ecosystem.* (USFWS 2008:2-19)

Associated with Goal 7 are several Kodiak Refuge objectives relevant to the proposed project (Objectives 7.2, 7.8, 7.11, and 7.12):

> *Objective 7.2: Monitor salmon escapement in streams on the Refuge that are key seasonal feeding areas for brown bears and bald eagles, and work collaboratively with ADF&G to maintain escapement levels that reflect wildlife needs.*

Objective 7.8: Through a collaborative effort with ADF&G, evaluate situations when fish populations are determined not to be meeting escapement goals or management targets. When weak stocks are identified … develop strategies to improve and stabilize runs, which may include implementation of specific management actions and research or rehabilitation projects, while maintaining genetic integrity of those fish populations.

Objective 7.11: Through a coordinated effort with ADF&G, evaluate salmon spawning and rearing habitat to determine productivity of salmon-producing systems within the Refuge.

Goal 8: Provide opportunity for local residents to continue their subsistence uses on the Refuge, consistent with the subsistence priority and with other refuge purposes.

Goal 9: Improve baseline understanding of natural flowing waters on the Refuge and maintain the water quality and quantity necessary to conserve fish and wildlife populations and habitats in their natural diversity.

1.5.3.2. MANAGEMENT POLICIES AND GUIDELINES

Management policies and guidelines work together with laws and regulations and establish standards for resource management or limit the range of potential activities that may be allowed on refuges. The Kodiak Refuge CCP (PG. 2-62) provides following guidance for fishery restoration and enhancement actions:

> Fishery restoration is any management action that increases fishery resources to allow full use of available habitat or to reach a population level based on historical biologic data. Although the goal of restoration is self-sustaining populations, situations may exist in which some form of fishery management or facilities could continue indefinitely.
>
> Where fishery resources have been severely adversely affected, the Refuge will work with the State of Alaska, local tribes and other partners to restore habitats and populations to appropriate, sustainable conditions. Restoration emphasis will focus on strategies that are the least intrusive to the ecosystem and that do not compromise the viability or genetic characteristics of the depleted population. This may include regulatory adjustments and/or evaluations of escapement goals. (USFWS 2008:2-62)
>
> ADF&G, in cooperation with the Kodiak Regional Aquaculture Association and the Refuge, has undertaken several restoration projects on Kodiak Refuge, including temporary actions such as the fertilization of Karluk Lake to restore zooplankton productivity for sockeye salmon and a temporary incubation facility in the upper Thumb River (Karluk drainage) to restore sockeye productivity. The Refuge will continue to support similar restoration actions provided they are compatible with Refuge purposes and the Refuge System mission.
>
> Fishery enhancement is any management action or set of actions that is applied to a fishery stock to supplement numbers of harvestable fish to a level beyond that which could be naturally produced based on a determination or reasonable estimate of historic levels. This could be accomplished by stocking barren lakes, providing access to barren spawning areas (fish passages), constructing hatcheries, outstocking in productive systems, or fertilizing rearing habitat. Refuge management priorities will focus on conserving naturally diverse ecosystems. Fishery enhancement facilities for the purposes of artificially increasing fish populations normally will not occur within any management

category unless stocks have been reduced or are threatened. Proposals for fishery enhancement projects will be subject to the provisions of NEPA regulations, an ANILCA Section 810 determination, and a compatibility determination. Only temporary fisheries enhancement facilities may be authorized in Minimal management areas. (USFWS 2008:2-62)

1.5.3.3. MANAGEMENT CATEGORIES

Management categories define the level of human activity appropriate to a specific area of a refuge. Five management levels exist on national wildlife refuges in Alaska, ranging from intensive management to wilderness. Kodiak Refuge lands are categorized as moderate management or minimal management in most of the Refuge. All of the project area is classified as "minimal management."

Minimal Management

In this zone, the natural landscape is the dominant feature, although some signs of human actions may be visible. *Habitats should be allowed to change and function through natural processes*. *Administration will ensure that the resource values and environmental characteristics identified in the Conservation Plan are conserved. Management actions in this category focus on understanding natural systems and monitoring the health of Refuge resources. No permanent structures are allowed (except cabins). Compatible economic activities may be allowed where the evidence of those activities does not last past the season of use. These are generally described as commercial recreational activities.*

Moderate Management

Moderate management allows compatible management actions, commercial uses, etc. that *may result in changes to the natural environment that are temporary or permanent but small in scale and that do not disrupt natural processes*. *Signs of human activity may be present.* Management actions will focus on *maintaining, restoring or enhancing habitats to maintain healthy populations of plants and animals where natural processes take over*. Compatible economic activities may be allowed where *impacts to natural processes and habitats are temporary* and require a special use permit.

While both fisheries restoration and fisheries enhancement may be allowed or authorized in minimal and moderate management areas of the refuge they must be consistent with the Management Policies and Guidelines for those activities (see Section 1.5.3.2, Management Policies and Guidelines) (USFWS 2008: 2-85, Table 2-2).

1.5.4. Kodiak National Wildlife Refuge Fishery Management Plan

The Fishery Management Plan (USFWS 1990) for Kodiak Refuge was completed in 1990 and provides management direction to support the conservation of the refuge's fisheries resources for the benefit of wildlife and people. Although much new information has been gained since the development of this plan, and more recent laws and policies developed by the Service may alter the plan's perspective, much of the Plan is still relevant. The Plan recognizes that the Karluk-Alitak Unit (B) is the most productive fishery unit on the refuge. The management strategy for this Unit is for ADF&G to continue to collect data and assess fish populations and to operate in-stream fish-counting weirs on the Karluk River to aid in determining in-season escapement. The management direction for aquatic habitat encompasses the premise that "healthy, natural, and diverse fish populations require little habitat manipulation, given adequate escapement levels and favorable environmental conditions". The plan further states that the refuge will protect aquatic habitat and assess any proposed modification (e.g. fish passasge, lake fertilization) that may affect instream or lake habitat either physically or chemically. Finally, the Plan

recognizes that "escapement needs could change to reflect a new or updated data base or management strategy."

1.5.5. State Plans and Policies

The state of Alaska has developed numerous fisheries management plans and policies, which include annual salmon escapement goals established by the Alaska Board of Fisheries and the ADF&G's sustainable salmon fisheries policy. These policies are designed to ensure sustained yield and habitat protection for wild salmon stocks through the establishment of escapement goals and action plans for management, where necessary. Additional discussion of these topics is provided below.

1.5.5.1. KODIAK COMPREHENSIVE SALMON PLAN

Comprehensive salmon planning, authorized under AS 16.10.375-480, is an on-going process for ADF&G and the Regional Aquaculture Associations (in this case Kodiak Regional Aquaculture Association (KRAA) of "identifying enhancement, rehabilitation, research and management priorities for the salmon resources of the Kodiak Region" (Kodiak Regional Planning Team [RPT] 2011). The Kodiak RPT consists of three representatives each from ADF&G and KRAA. The Kodiak Comprehensive Salmon Plan, Phase III, established Kodiak Management Area sockeye salmon harvest objectives of 4.8 million fish for the archipelago, of which 2.3 million are to be from "naturally produced" sockeye, to be achieved by management, enhancement and rehabilitation of lake systems. This target harvest has been achieved in only four years since 1882 – 1901, 1990, 1991, 1996. This harvest objective is significantly higher than average harvest. Average harvest data presented in the plan for sockeye include: an average harvest of: 1.8 million sockeye from 1882 to 2007; an average of 1.65 million between 1948 and 2007; and just over 3 million sockeye from 1998 to 2007. The plan notes that the ability to meet these harvest objectives may depend upon "changes in regulatory policy and fishing practices" and limnology investigations conducted by KRAA, which form the foundation for KRAA in determining a lake's candidacy for nutrient enrichment.. . The larger intent of the Plan is to increase overall salmon harvest by 29% for odd years and 41% increase for even years compared to the average annual harvest between 1999 and 2008. The current plan was approved by the ADF&G commissioner in May of 2011.

1.5.5.2. SUSTAINABLE SALMON FISHERIES POLICY

ADF&G manages salmon stocks throughout the state in accordance with the policy for the management of sustainable salmon fisheries (5 Alaska Administrative Code [AAC] 39.222). For brevity, only the major highlights of the policy are included here. The policy directs the ADF&G to:

(1) Manage fisheries based on the following principles and criteria:

- Wild salmon stocks and the salmon's habitats should be maintained at levels of resource productivity that assure (*sic*) sustained yields;
- Salmon fisheries shall be managed to allow escapements within ranges necessary to conserve and sustain potential salmon production and maintain normal ecosystem functioning;
- Effective management systems should be established and applied to regulate human activities that affect salmon;
- In the face of uncertainty, salmon stocks, fisheries, artificial propagation, and essential habitats shall be managed conservatively;
- At regular meetings of the board, the department will, to the extent practicable, provide the board with reports on the status of salmon stocks within the following levels of concern:

  - Yield concern: "a concern arising from a chronic inability, despite the use of specific management measures, to maintain specific yields, or harvestable surpluses, above a stock's escapement needs; a Yield Concern is less severe than a Management Concern" (5 AAC 39.222(f)(42))
  - Management concern: "a concern arising from a chronic inability, despite the use of specific management measures, to maintain escapements for a salmon stock within the bounds of the SEG [sustainable escapement goal], BEGs [biological escapement goals], OEG [optimal escapement goal], or other specified management objectives for the fishery; a Management Concern is not as severe as a Conservation Concern" (5 AAC 39.222(f)(21))
  - Conservation concern: "a concern arising from a chronic inability, despite the use of specific management measures, to maintain escapements for a stock above a sustained escapement threshold (SET); a Conservation Concern is more severe than a Management Concern" (5 AAC 39.222(f)(6))
- At regular meetings of the board, the department will, to the extent practicable, provide the board with reports on salmon fisheries under consideration for regulatory changes
- In response to the department's salmon stock status reports, reports from other resource agencies, and public input, the board will review the management plan, or consider developing a management plan, for each affected salmon fishery or stock;
- Management plans will be based on the principles and criteria contained in this policy and will
  - contain goals and measurable and implementable objectives that are reviewed on a regular basis and utilize the best available scientific information;
  - minimize the adverse effects on salmon habitat caused by fishing;
  - protect, restore, and promote the long-term health and sustainability of the salmon fishery and habitat;
  - prevent overfishing; and
  - provide conservation and management measures that are necessary and appropriate to promote maximum or optimum sustained yield of the fishery resource;
- In the course of review of the salmon stock status reports and management plans…, the board, in consultation with the department, will determine if any new fisheries or expanding fisheries, stock yield concerns, stock management concerns, or stock conservation concerns exist; if so, the board will, as appropriate, amend or develop salmon fishery management plans to address these concerns; the extent of regulatory action, if any, should be commensurate with the level of concerns and range from milder to stronger as concerns range from new and expanding salmon fisheries through yield concerns, management concerns, and conservation concerns;
- In association with the appropriate management plan, the department and the board will, as appropriate, collaborate in the development and periodic review of an action plan for any new or expanding salmon fisheries, or stocks of concern; action plans should contain goals, measurable and implementable objectives, and provisions;
- Each action plan will include a research plan as necessary to provide information to address concerns; research needs and priorities will be evaluated periodically, based on the effectiveness of the monitoring described in this subsection;
- Where actions [are] needed to regulate human activities that affect salmon and salmon habitat that are outside the authority of the department or the board, the

> department or board shall correspond with the relevant authority, including the governor, relevant boards and commissions, commissioners, and chairs of appropriate legislative committees, to describe the issue and recommend appropriate action.

1.5.5.3. ADF&G ESCAPEMENT MANAGEMENT

An important element of the sustainable salmon fisheries policy is the establishment of escapement goals. The policy for establishing escapement goals is described in 5 AAC 39.223:

> The Department of Fish and Game (department) and the Board of Fisheries (board) are charged with the duty to conserve and develop Alaska's salmon fisheries on the sustained yield principle. Therefore, the establishment of salmon escapement goals is the responsibility of both the board and the department working collaboratively. The purpose of this policy is to establish the concepts, criteria, and procedures for establishing and modifying salmon escapement goals and to establish a process that facilitates public review of allocative issues associated with escapement goals.

ADF&G's responsibility is to

(1) document existing salmon escapement goals for all salmon stocks that are currently managed for an escapement goal;

(2) establish BEG for salmon stocks for which the department can reliably enumerate salmon escapement levels, as well as total annual returns;

(3) prepare a scientific analysis with supporting data whenever a new BEG, SEG, or SET, or a modification to an existing BEG, SEG, or SET is proposed and, in its discretion, to conduct independent peer reviews of its BEG, SEG, and SET analyses;

(4) notify the public whenever a new BEG, SEG, or SET is established or an existing BEG, SEG, or SET is modified;

(5) whenever allocative impacts arise from any management actions necessary to achieve a new or modified BEG, SEG or SET, report to the board on a schedule that conforms, to the extent practicable, to the board's regular cycle of consideration of area regulatory proposals so that it can address allocation issues.

Following the ADF&G's mission and regulatory policies, management of Karluk Lake sockeye salmon is governed by the state-regulated Westside Kodiak Salmon Management Plan (5 AAC 18.362). This plan is discussed in Section 1.5.5.4, below.

Information on how the Karluk watershed escapement goal was established and how ADF&G manages the Karluk system using escapement is discussed in Chapter 2 of the EA.

1.5.5.4. WESTSIDE KODIAK SALMON MANAGEMENT PLAN

The Westside Kodiak Salmon Management Plan directs the ADF&G in decision making for commercial fisheries opening in the Northwest Kodiak District, Southwest Kodiak District, and Southwest Afognak Section (part of the Afognak District) (5 AAC 18.362). The goal of the Westside Kodiak Salmon Management Plan is to achieve escapement and harvest objectives of sockeye salmon returning to the Karluk, Ayakulik, and other west side minor sockeye salmon systems and of pink, chum, and coho

salmon returning to systems in the in the Northwest Kodiak and the Southwest Kodiak Districts and the Southwest Afognak Section of the Afognak District in accordance with the guidelines set out in this plan. All regulations, including management plans, are open for review during the regular Board of Fisheries cycle. Either the public or the ADF&G is able to suggest changes to the management plan to the board.

1.6. Decisions to be Made

Decisions made regarding the Proposed Action and alternatives will be documented in a decision document signed by the appropriate responsible official (RO) for the Service. In the document, the RO will determine the following:

- Whether any of the anticipated impacts of the Proposed Action and other action alternatives are likely to be significant;
- Whether the analysis contained in this EA is adequate for the purposes of reaching an informed decision regarding KRAA's proposal;
- Whether to approve the Proposed Action or deny KRAA's request for a permit;
- Whether the Proposed Action and other action alternatives conform with the purposes of Kodiak Refuge and mission of the NWRS; and
- Appropriate terms and conditions (including mitigation and monitoring requirements), as necessary, if the project is approved.

1.7. Scope of Environmental Assessment

This EA analyzes and discloses the environmental impacts of the Proposed Action, a No Action Alternative, and a reasonable range of other alternatives to the Proposed Action. It does so at a level of detail that allows the Service to make an informed decision regarding implementation of any one of the alternatives. This EA also serves to disclose the potential impacts of these alternatives to the public, other agencies, and interested stakeholders. Accordingly, this EA assesses the direct, indirect, and cumulative impacts of each alternative and identifies mitigation measures necessary to reduce or eliminate impacts.

The scope of this EA is largely characterized by the issues raised during an agency scoping meeting conducted in the spring of 2013. These issues are summarized below.

1.8. Issues

Based on the results of scoping, the Service, and representatives from ADF&G and Koniag, Inc. identified specific areas of concern, referred to as issues, for consideration in this EA. Issues generally require in-depth analysis and disclosure, and are often used to generate alternatives. In some cases, they can be addressed by project design criteria or mitigation measures. The following eight issues, framed below as questions, will be evaluated prior to making a decision with respect to KRAA's proposal:

- **Effects to aquatic productivity:** What is the annual variability of productivity parameters? Does the Karluk watershed have a productivity problem? How will the success of project actions be measured?
- **Effects to fisheries:** Are there any effects to fish species? What are the potential impacts of lake fertilization to lower trophic levels? Are there any effects on other salmon populations from harvest of an enhanced population?
- **Effects to wildlife:** Would fish-eating wildlife be affected by lake fertilization activities?

- **Effects to water quality:** Would fertilization affect Karluk Lake's water quality, such as by increasing potential for eutrophication?
- **Effects to subsistence:** What would be the effect to subsistence resources and users?
- **Effects to recreation:** What are the effects to opportunities for recreational uses, such as bear viewing at Karluk Lake?
- **Effects to socioeconomics:** What would be the socioeconomic effects to local communities and individuals?
- **Effects to cultural resources:** What effects would occur to cultural resources and traditional cultural properties?

A more detailed discussion of each issue is provided below.

1.8.1. Aquatic Productivity

One of the most discussed topics during internal scoping involved whether there is an aquatic productivity issue in the Karluk Lake watershed. Concerns over productivity of this watershed encompass many issues, including whether:

- there is a nutrient deficiency issue;
- the variability of nutrients in recent years is outside of historical ranges;
- there is an adult sockeye salmon productivity issue; and
- the current sockeye salmon run size is adequate to achieve appropriate levels of harvest for sport, commercial, and subsistence fishing.

While Karluk Lake is one of the most studied lakes in Alaska, it remains a complex system with many unknown variables that influence the watershed's productivity. Salmon numbers cycle up and down over time and known drivers include commercial fishing, climate cycles, and lake nutrient levels resulting from carcass deposition (Schmidt and others 1998; Finney and others 2000; Finney and others 2002). Therefore, it is not clear whether recent short-term (2008–2011) reductions in sockeye salmon runs represent a significant downward trend or natural variability in the system. The EA will qualitatively describe changes to aquatic productivity that could occur from implementation of any alternative, including the No Action Alternative, but will also identify areas of scientific uncertainty over system response that could affect project outcomes.

Another related issue discussed during scoping revolved around how to measure success of the project. Although backstocking and fertilization efforts have occurred in the lake in the past (in the 1980s and 1990s), there was insufficient analysis of data at the time to determine effects to the Karluk stocks of sockeye salmon. Subsequent analysis published by Schmidt and others (1989) provided a peer reviewed analysis and conclusions, Salmon numbers cycle up and down over time caused mainly by drivers including commercial fishing, climate cycles, and lake nutrient levels resulting from carcass deposition. There was an increase in run size in 1983 after low total runs in 1980-1982. The increase began prior to and running concurrent with the fertilization project. Some may credit fertilization, but data presented below summarize current information regarding cause and effect relationships. Similar increases in escapement are noted starting in 1956, 1973, and 2011without fertilization, and there are no data that link fertilization as a direct cause to an increase in adult sockeye numbers in the 1980s. We noted there is significant scientific uncertainty regarding the Karluk watershed, which makes identifying a metric of "success" difficult for the previous fertilization project. These concerns are acknowledged in this EA and addressed qualitatively as feasibility and effects are evaluated based on current science and data.

1.8.2. Fisheries

Potential effects to sockeye salmon as well as the other fish species, in particular Chinook salmon (*Oncorhynchus tshawytscha*), were identified as a major concern during scoping. Population fluctuations are a concern and will be examined and placed in the context of long-term data and trends. Additionally, questions were raised on whether project actions could negatively affect lower trophic levels, including phytoplankton and zooplankton population composition and abundance. Again, examining natural variability will be a key method of placing recent data in the context of historical parameter patterns and projected effects of the various alternatives. The EA will identify and discuss potential direct and indirect effects on species' abundance, composition, and habitat including the effects of enhanced populations on other populations in a mixed stock fishery.

1.8.3. Wildlife

The Karluk Lake system supports a variety of fish-eating wildlife species that could be affected by changes to productivity of sockeye salmon and other fish. Potential effects from overflights and other human activity on Kodiak brown bear (*Ursus arctos middendorffi*), red fox (*Vulpes vulpes*), river otter (*Lontra canadensis*), bald eagle (*Haliaeetus leucocephalus*), and a variety of water birds, including locally nesting and migrating ducks (*Anatidae*), grebes (*Podicipedidae*), and loons (*Gavia* spp.), will be addressed in the EA.

1.8.4. Water Quality

Karluk Lake is classified as an oligotrophic lake with low nutrient levels and associated low levels of primary productivity. As such, there are concerns that project actions could result in limnological changes to the watershed, including eutrophication of the lake, and reduced water quality in Karluk Lake. These concerns will be analyzed in this EA.

1.8.5. Subsistence

The opportunity for continued subsistence uses by local residents is one of the purposes of Kodiak Refuge. The EA will describe current subsistence uses in the area and evaluate effects from project actions on subsistence opportunities and the availability of sockeye salmon and other fish, wildlife, and plant species used for subsistence in the Karluk watershed.

1.8.6. Recreation

Concern was expressed that the project could impact recreational opportunities in Kodiak Refuge, including big-game hunting, fishing, duck and ptarmigan hunting, and non-consumptive activities such as hiking and wildlife viewing. These concerns will be analyzed in this EA.

1.8.7. Socioeconomics

Koniag, Inc. has substantial land holdings around Karluk Lake and bordering the Karluk River and has expressed concerns about possible impacts from increased overflights on their commercial bear viewing and other recreational operations. The nearby communities of Larsen Bay and Kodiak also rely on tourism as a source of income and jobs. In addition, residents of communities throughout the Kodiak Archipelago commercially fish for salmon in marine waters adjacent to the Karluk watershed. The EA will address potential socioeconomic impacts to these communities and residents.

1.8.8. Cultural Resources

Karluk Lake has been important to people for millennia. As such, area cultural resources include not only the physical evidence of past use by humans, but also the role that specific properties have in the Alutiiq people's shared cultural heritage, which can include beliefs, customs, and practices (referred to as traditional cultural properties). The EA will describe these existing cultural resources and discuss any potential impacts to them.

1.9. Issues Dismissed from Further Analysis

1.9.1. Impacts to Air Quality

Air quality in the project area is characteristic of remote wilderness locations where limited human activity occurs. Air pollutant sources include limited emissions from existing modes of transportation such as light aircraft and boats with outboard motors and emissions from small, contained fires at campsites and cabins, as well as natural sources. Because of the relatively small amount of emissions or any other point sources of air pollution in the project area, current air quality is considered excellent. KRAA's Proposed Action would introduce intermittent, limited quantities of air pollutants from boating and aircraft activity, but National Ambient Air Quality Standards for all federally listed pollutants would continue to be met. Therefore, this issue is not carried forward for analysis.

1.9.2. Impacts to Threatened and Endangered Species

1.9.2.1. PLANT SPECIES

There are no federally endangered or threatened plant species present within the project area. Therefore, this issue is not carried forward for analysis.

1.9.2.2. MAMMAL SPECIES

There are no federally threatened, endangered, or sensitive mammal species that occur in the project area. Alaskan endangered mammal species such as the blue whale (*Balaenoptera musculus*), humpback whale (*Megaptera novaeangliae*), North Pacific right whale (*Eubalaena japonica*), and the northern sea otter (*Enhydra lutris kenyoni*) periodically occur in marine waters adjacent to Kodiak Island (ADF&G 2013f), but are not found in inland waters. Therefore, this issue is not carried forward for analysis.

1.9.2.3. BIRD SPECIES

Several federally listed or candidate endangered or threatened bird species have been reported from the Refuge, but none are known to occur in the project area. The range of the Steller's albatross (*Phoebastria albatrus*) includes Kodiak Island and the surrounding seas (ADF&G 2013f) but this oceanic species is not likely to occur in inland lakes. Similarly, both the threatened spectacled eider (*Somateria fischeri*) and Steller's eider (*Polysticta stelleri*) have been recorded in Kodiak Refuge but are not likely to occur in inland lakes (ADF&G 2006; USFWS 2008). Three other species are under federal consideration for listing under the ESA: black-footed albatross (*Diomedea nigripes*), Kittlitz's murrelet (*Brachyramphus brevirostris*), and yellow-billed loon (*Gavia adamsii*). All three species have been recorded at Kodiak Refuge but only Kittlitz's murrelet is known to breed there (USFWS 2008). Kittlitz's murrelets nest in recently deglaciated habitat (ADF&G 2006), which does not occur in the project area. Therefore, this issue is not carried forward for analysis.

2. PROPOSED ACTION AND ALTERNATIVES

2.1. Introduction

Alternative analysis is guided by CEQ regulations that implement NEPA (40 CFR 1500–1508), which require the Service to:

- develop and describe the range of alternatives capable of achieving the purpose and need, including the No Action Alternative; and
- rigorously explore and objectively evaluate these alternatives, and provide reasons why the Service eliminated certain alternatives from further study.

This chapter describes how alternatives were developed for this EA, provides a detailed description of analyzed alternatives, and offers justification for alternatives eliminated from further consideration. Readers are also referred to the end of this chapter for a comparison of actions that would be implemented by each alternative.

2.2. Alternatives Development

The Service reviewed KRAA's proposal for nutrient enrichment of Karluk Lake through aerial application of liquid nitrogen and phosphorus fertilizer to Karluk Lake. Following this review, the Service identified four other alternatives for consideration in this EA:

- Continuing the current management strategy for Karluk Lake (i.e., the No Action Alternative required by CEQ);
- Nutrient enrichment of Karluk Lake using other nutrient sources (salmon carcasses or carcass analogs) to add nitrogen, phosphorus, other marine-derived nutrients (MDN), and organic matter to the lake system;
- Nutrient enrichment of Karluk Lake through backstocking fry, smolt, or adult sockeye salmon to increase salmon population or spawning and subsequently increasing carcass volume and nutrient release into the lake; and
- Removing the three-spined stickleback (*Gasterosteus aculeatus*) through seining or electrofishing to reduce competition with sockeye salmon for food.

These alternatives were identified based on the best available scientific information regarding past and present conditions of Karluk Lake. Along with the Proposed Action, these action alternatives represent a range of strategies that could be implemented to improve sockeye salmon productivity.

The Service then conducted a review of the Proposed Action and alternatives to determine what actions would meet the project purpose and need and were technically, economically, and environmentally practical and feasible. This review resulted in the identification of four alternatives for detailed analysis in this EA:

- Alternative A: no action
- Alternative B (Proposed Action): lake nutrient enrichment
- Alternative C: sockeye salmon fry backstocking
- Alternative D: combined lake nutrient enrichment and sockeye salmon fry backstocking

Other alternatives were considered but ultimately eliminated from detailed analysis. These alternatives are described in Section 2.8, along with the rationale for their elimination.

2.3. Actions Common to All Action Alternatives

ADF&G, in collaboration with the Board of Fisheries, currently estimates and manages escapement for multiple salmon species in the Karluk watershed. ADF&G sets BEGs when information is available to assess and quantify the effects of harvest to the run and can count the escapement directly through the use of a counting weir. Chinook and sockeye salmon escapement sizes are estimated and managed at the Karluk weir according to the BEGs (Jackson and Keyse 2013). Pink (*Oncorhynchus gorbuscha*), chum (*O. keta*), and coho (*O. kisutch*) do not have BEGs, and their escapement sizes are primarily estimated through a variety of techniques including aerial, foot, and weir monitoring (Jackson and Keyse 2013).

ADF&G has set a Chinook BEG of between 3,000 and 6,000 fish (Nemeth and others 2010; ADF&G 2014a; Jackson and Keyse 2013); however, escapements have only averaged roughly 3,000 in the past 10 years and have been below the lower bound of the escapement goal in 5 of the past 10 years. Information on the age, sex, and length of Karluk River Chinook salmon is gathered in conjunction with escapement management. Smolt abundance and migration studies have been conducted sporadically (ADF&G 2014a).

Both the early-run and late-run sockeye salmon stocks are currently managed in the Karluk system. Because KRAA's proposal is focused solely on sockeye salmon, discussion of ADF&G escapement management for the Karluk system in the paragraphs below will only focus on management of sockeye salmon and will not include management of other salmonids or any non-salmonid species.

2.3.1. Sockeye Salmon Escapement Management

ADF&G has set a BEG of between 110,000 and 250,000 sockeye salmon for the early-run on the Karluk system and between 170,000 and 380,000 sockeye salmon for the late run. For the Karluk system, most harvest is from commercial fishing, which constitutes over 99% of the total harvest of Karluk sockeye salmon. The BEG was last updated and approved by the Alaska Board of Fisheries for the early sockeye salmon run in 2007 to set the current goals (increase of the lower limit from 100,000 to 110,000 and an increase of the upper limit from 210,000 to 250,000) and for the late run in 2004 (decrease of the lower limit from 400,000 to 170,000 and a decrease of the upper limit from 550,000 to 380,000) (Sagalkin and others 2013). These changes were made as a result of analysis of recent data using spawner-recruit analysis (a statistical analysis using the reproductive productivity of the adult population and the number of offspring after egg stage to estimate future populations), euphotic volume analysis (analysis of available phytoplankton production in the lake), and estimation of smolt biomass as a function of zooplankton biomass. A review of the Karluk sockeye salmon escapement goals last occurred in 2013, when ADF&G recommended no changes to the BEGs and the Alaska Board of Fisheries concurred.

Under all alternatives, ADF&G would continue to manage the number of fish returning to spawn in Karluk Lake and tributaries to the allowable BEGs through the monitoring of lake-outmigrating smolts and of returning adults through the weir, as well as regulation of commercial fisheries in marine waters around the Karluk system.

2.3.2. Monitoring

In addition, all action alternatives would require initial baseline data and subsequent monitoring by which the success of the proposed project would be determined. These data would also be used to determine the appropriate loading for lake nutrient enrichment (Alternative B), sockeye salmon fry backstocking levels (Alternative C), or loading for lake nutrient enrichment and sockeye salmon fry backstocking levels

(Alternative D) if any of these alternatives were to be selected in the finding of no significant impact (FONSI). Monitoring during the 2 years of pre-treatment and 5-year nutrient application phase of the project would follow current ADF&G protocols and Service stipulations and would occur pre-season (April–May), during the summer growth period (typically May–August), and post-season (September–October). No monitoring would occur between November and April, when Karluk Lake may be frozen.

Upon completion of treatment activities, KRAA has proposed that 2 years of follow-up monitoring would be conducted to assess treatment effects. Monitoring would occur as described in Section 2.3.2.1, below.

2.3.2.1. PRE-SEASON MONITORING AND ASSESSMENT

For pre-season monitoring, water samples would be collected from each of the three main basins of Karluk Lake to assess lake physical characteristics, water chemistry and nutrients, and primary (phytoplankton), secondary (zooplankton), and tertiary productivity (sockeye salmon). Sampling protocols would follow those outlined by ADF&G (Ruhl 2013) and are described in the sections below. Approximately one to two personnel would conduct the sampling effort. Personnel would travel to the lake via charter seaplane and would establish an off-site base camp for the duration of the visit, as needed. Staff would travel to established ADF&G limnology stations (Figure 2) via boats. Boat fuel would be stored in proper fuel containers to prevent leaks; any spill would be cleaned up immediately.

Sampling of lake physical characteristics would include measurement of light penetration (photosynthetically active radiation), Secchi disc depth, water temperature, and dissolved oxygen (DO) at multiple depths. The water chemistry parameters of pH and alkalinity would be assessed at each sampling location. Specific conductance would be measured in situ. In addition, 1 to 2 gallons of water would be collected at each sampling location. Upon completion of the trip, these water samples would be sent to a qualified laboratory for analysis of total phosphorus (TP), total ammonia, total Kjeldahl nitrogen, nitrate + nitrite, chlorophyll *a*, and phaeophytin *a*. All laboratory analyses would adhere to the methods of Koenings and others (1987) and Thomsen and others (2002), or as subsequently required by the ADF&G or the Service. Some samples would be sent to different laboratories for processing and comparison of results (blind testing).

Metal samples would be collected at one sampling location. Samples would be delivered to an external laboratory for analysis to determine existing levels of arsenic, cadmium, calcium, cobalt, iron, lead, magnesium, mercury, molybdenum, nickel, selenium, and zinc.

Chlorophyll *a* concentrations would be monitored as an index for the standing crop of phytoplankton in Karluk Lake. Taxonomic composition of the algae community would also be visually monitored and recorded.

Vertical zooplankton tows would be conducted at each sampling location. Each sample would be stored for analysis at a qualified laboratory. Subsamples of zooplankton would be keyed to family or genus and counted. This process would be replicated three times per sample, and then counts would be averaged and extrapolated over the entire sample. For each plankton tow, mean length would be measured for each family or genus with a sample size derived from a student’s t-test to achieve a confidence level of 95%. Biomass would be calculated via species-specific linear regression equations. Zooplankton data would be compared to physical and nutrient data via linear regression and published values of length and biomass. Calculations and analyses of data using other statistical models could also be employed as appropriate.

Data to characterize smolt age, weight, and length would be gathered near the outlet of Karluk Lake and adult sockeye salmon age, sex, and length is collected at the ADF&G weir. All data collection procedures would follow ADF&G protocols.

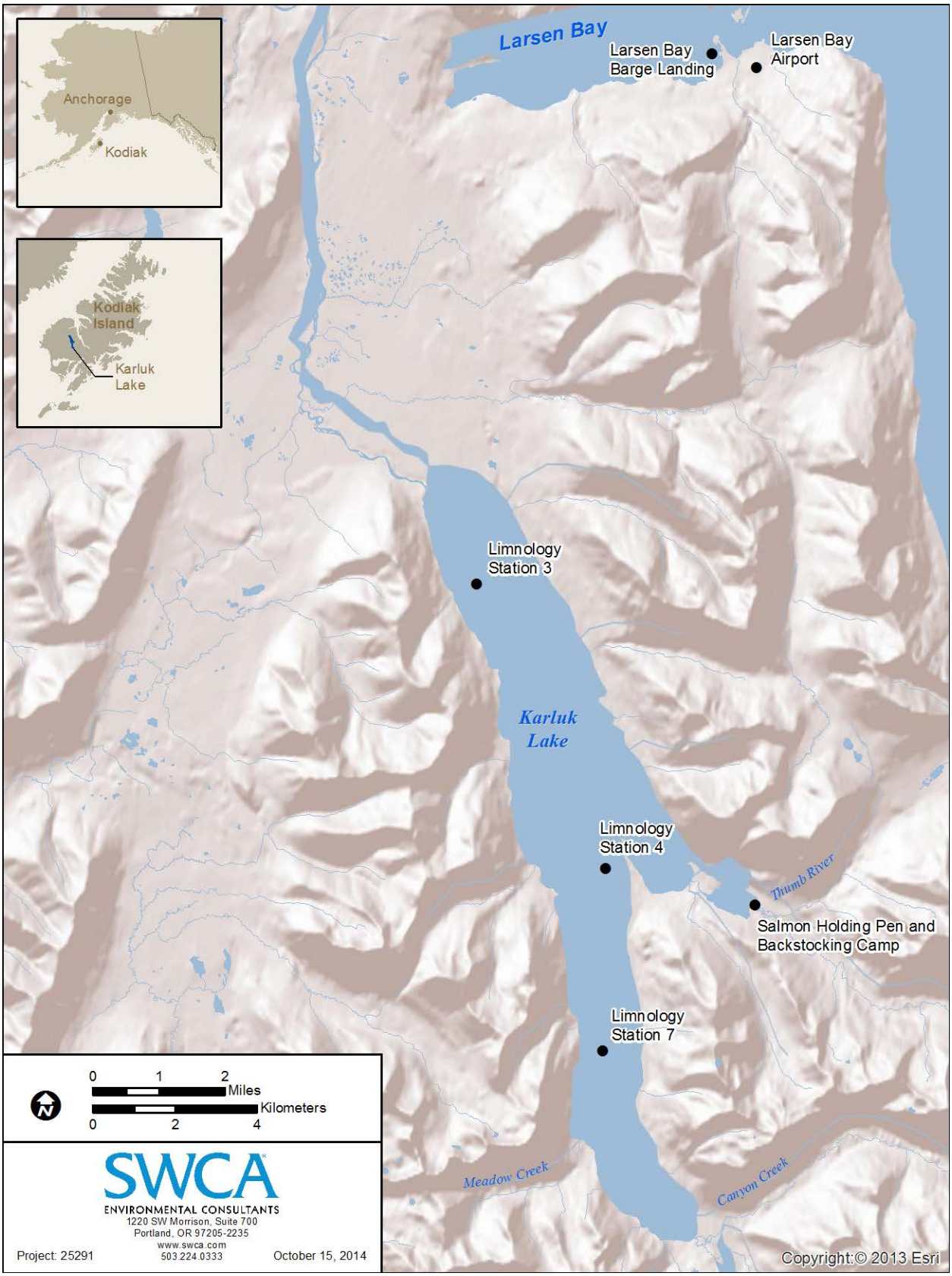

Figure 2. Sampling locations and other key project component locations.

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2.3.2.2. IN-SEASON MONITORING AND ASSESSMENT

During the treatment phase of this project, KRAA would conduct monitoring as described in Section 2.3.2.1. Monitoring would occur once a week or every other week for Alternatives B (Proposed Action: lake nutrient enrichment) and D (lake nutrient enrichment and sockeye salmon fry backstocking). For Alternative C (fry backstocking), monitoring would occur on a monthly basis.

2.3.2.3. POST-SEASON MONITORING AND ASSESSMENT

Post-season sampling activities and timing would remain generally consistent with pre-season and in-season monitoring efforts. As with previously described efforts, monitoring during this phase would require approximately one to two personnel.

KRAA would generate an annual post-season report detailing monitoring outcomes, program actions, objective review, and overall program status. At the conclusion of the post-treatment monitoring (i.e., 7 years following the start of nutrient application), KRAA would consult with ADF&G and the Service and produce a project status report with levels of nutrients added annually and preliminary findings from in-season monitoring. Following the post-treatment monitoring, KRAA would produce an assessment of the project to date. This evaluation would constitute either a project completion report or a decision document outlining the purpose and need for continuing the project for additional years.

2.3.3. Applicant-committed Measures

KRAA would educate its contractors and employees about the relevant federal regulations intended to protect refuge resources, including cultural resources. In the event of an unanticipated cultural resources discovery on refuge land, operations in the immediate area would be suspended until written authorization to proceed is issued by the refuge manager, as appropriate and pursuant to Section 106 of NHPA, to prevent the loss of significant resource values. Appropriate mitigation measures would be determined through consultation with SHPO.

2.4. Alternative A: No Action

Implementing regulations for NEPA require that a No Action Alternative be analyzed in the EA (40 CFR 1502.14[d]). The No Action Alternative also forms the baseline against which the potential impacts of the Proposed Action and the other action alternatives are compared. As such, it includes current actions and activities in the project area.

Under the No Action Alternative, the Service would follow current management plans and continue to cooperate with ADF&G to address sockeye salmon productivity in the Karluk watershed. Ongoing Service and ADF&G management actions and activities would be assumed to continue and are accounted for in the analysis of impacts in Chapter 4. These actions are described by agency below.

2.4.1. Service

Under the No Action Alternative, the Kodiak Refuge would continue to manage fisheries habitat on refuge lands within the Karluk watershed to protect and conserve habitats in their natural biodiversity. The Service’s actions and management goals are outlined in the 2008 Kodiak Refuge CCP, and Service policies are outlined in Section 1.5 of the EA. To promote these polices and accomplish its goals, the refuge currently conducts the following actions in the Karluk Basin.

2.4.1.1. INVASIVE PLANT MANAGEMENT

Since 2003, the Refuge and its conservation partners have actively managed an extensive infestation of orange hawkweed (*Hieracium aurantiacum*), a highly invasive, terrestrial, perennial species in the Camp Island vicinity. The objectives of management are eradication of the infestation and restoration of native plants on previously infested sites.

2.4.1.2. SCIENTIFIC WILDLIFE MONITORING AND RESEARCH

Recent monitoring and research projects have focused on brown bear, sockeye salmon, bald eagle, and Barrow's goldeneye (*Bucephala islandica*). Activities pertaining to each of these species are addressed below.

From July to mid-August, the Refuge counts and classifies (by age/sex) bear groups congregated along selected streams used by spawning sockeye salmon in southwestern Kodiak Island including the Thumb River and O'Malley River tributaries of Karluk Lake. The information is used to evaluate trends in productivity, survival, and bear use of streams.

The refuge and ADF&G periodically conduct aerial surveys of brown bears in different regions of Kodiak Island. Results from these surveys document trends in bear abundance, and are considered a primary tool of bear population management. In the Karluk Lake area, surveys were completed in 1994, 2004, and 2013. The number of bears within the Karluk survey area decreased by 48% from 2004 to 2013 (Van Daele 2013). The Refuge is also conducting research within the southwestern region of Kodiak Island, including the Karluk Lake area, to improve understanding of brown bear response to fluctuations in the abundance and timing of sockeye salmon runs and to investigate factors that may be contributing to the recent documented declines in bear numbers within the Karluk basin.

The refuge has studied and monitored the bald eagle population in the Karluk Lake area since the early 1960s. Aerial surveys estimating occupancy and nest success between 1963 and 2007 documented the recovery of the bald eagle from the bounty years in Alaska prior to the 1960s, with populations appearing to stabilize around 2002. Current monitoring consists of periodic survey (5-year interval) of eagle abundance in selected coastal areas and interior lakes including Karluk Lake. The last survey was conducted in 2013. Since 2011, occupancy, clutch size, and hatching success of Barrow's goldeneye, a species important to subsistence users, have been monitored annually at Karluk Lake.

The ADF&G, in cooperation with KRAA, maintains a comprehensive program of monitoring limnology of Kodiak Archipelago lakes, including Karluk Lake, which provide rearing habitat to the primary stocks of sockeye salmon. In response to concerns about the potential influence of climate change on the quality of salmon lake rearing habitat and to complement ADF&G and KRAA's efforts, the refuge initiated monitoring of water temperature in Karluk Lake and Red Lake in 2011. Monitoring stations at these two lakes record temperature data at hourly intervals on a year-round basis at fixed intervals between the lake surface and bottom. Temperature records are annually downloaded and shared with the ADF&G limnologist.

2.4.1.3. WILDLIFE-ORIENTED PRIORITY PUBLIC USES

The Service also manages wildlife-oriented (priority) public uses. The Service offers two sole-use big-game hunting guide use areas within the Karluk watershed. An SUP has been awarded for each area through a competitive process known as a prospectus. The objective of allowing commercial big-game guiding is to make available a variety of quality services to the public for compatible recreational hunting. These permits are issued for a 5-year period with a possible 5-year extension. The target species for big-

game hunting in the Karluk watershed are brown bear, mountain goat (*Oreamnos americanus*), and Sitka black-tailed deer (*Odocoileus hemionus sitkensis*). The bear hunting seasons and total number of brown bears harvested each year is determined by Alaska's Board of Game and ADF&G, and bear hunting permits are obtained through a drawing system. The harvest numbers of other species are managed by bag limits allowed with an Alaska state hunting license, and the number of hunters using the area fluctuates from year to year. Over the past 5 years, approximately 40 to 50 people visited the area each year for guided or non-guided hunting.

A prospectus offering has also been awarded for the sole-use of O'Malley River, located at the southern end of Karluk Lake, for wildlife viewing. This SUP allows a single commercial operator to provide guided brown bear viewing services within an area of approximately 2,560 acres encompassing the O'Malley River that is seasonally closed to all public access, use, and occupancy. This program was established to provide a structured opportunity for the public to view and enjoy a unique seasonal concentration of Kodiak brown bears in a relatively wild and undisturbed location while protecting and conserving brown bear populations. This permit was also issued for a 5-year period with a possible 5-year extension. To date, the commercial operator selected for O'Malley River has not fully implemented the program as defined in the prospectus, and no clients have visited the area. Instead, the operator has concentrated on developing and refining its bear viewing program on private lands elsewhere on Karluk Lake. When implemented, the O'Malley River bear viewing program will allow approximately 100 clients to visit the area throughout the summer.

The Service also issues SUPs for commercial sport fishing guides (14), wildlife viewing guides (20), videographers (7), and air transporters (9) who use unrestricted areas of the refuge within the Karluk watershed. Approximately 50 permits are applied for and issued on an annual basis. Several operators rely on the recreational and aesthetic values of the Karluk watershed to provide unique opportunities for their clients and video productions. All of the permits issued by the Service require that operators show compliance with the applicable terms and conditions, and a satisfactory record of performance. The Service conducts permit compliance monitoring and operational oversight to ensure that permitted activities are compatible with the purposes of the refuge, and that the quality of refuge natural resources and recreational opportunities are not negatively impacted. The number of visitors accessing the area with a permitted guide has remained steady over the past 5 years, with an average of 46 people per year. Unguided visitors are more difficult to quantify, as they are not required to obtain a permit to visit refuge lands. Using air taxi reports and anecdotal observations from field staff, it is estimated that over the past 5 years, between 50 and 60 unguided visitors used the area each year for fishing, wildlife viewing, boating, or photography.

The Service does not currently have a public use cabin in the Karluk watershed, but it does have its primary backcountry administrative facility on Camp Island in Karluk Lake. The Service annually maintains and upgrades this facility to provide living and working space for carrying out scientific investigations and management projects. Throughout the spring, summer, and fall this facility is regularly filled to capacity with multiple project crews.

2.4.2. ADF&G

ADF&G actively manages Karluk sockeye salmon escapement, defined as the number of fish allowed to "escape" being harvested and return to the Karluk system to spawn, through a series of monitoring actions and regulations on commercial and subsistence harvest. Ongoing monitoring actions include:

- Enumeration of early-run and late-run sockeye salmon passing through the Karluk River weir. The Karluk River weir is approximately 101 meters (m; 330 feet) long and is located about 1.3 km (0.8 mile) upstream of the confluence of the Karluk River and Karluk Lagoon. The weir has

operated at various locations between Karluk Lagoon and Karluk Lake since 1921 and has been at its current location since 1976. The weir allows ADF&G to effectively count the number of sockeye salmon returning to spawn in Karluk Lake and its tributaries, as most harvest of sockeye salmon occurs in marine waters around the west side of Kodiak Island.

- Monitoring of lake-outmigrating smolt through smolt traps. Smolt traps are placed in the lower Karluk River to capture outmigrating sockeye salmon. The smolt traps are estimated to catch between 8.5% and 28.8% of all outmigrating smolt. This catch can then be used to estimate the total outmigration of smolt into marine waters and allows ADF&G to better estimate the total population of returning adults after the smolt spend 2 to 3 years in the ocean. ADF&G has actively monitored smolt outmigration intermittently as funding has been available since 1980. The most recent smolt monitoring began in 2012 and will continue as long as funding is available to collect the data. For more information on smolt data collection see Figure D-1 in Appendix D.

Once ADF&G has an estimate on the anticipated total run in a given year, they develop an annual Commercial Harvest Strategy. As part of the Commercial Harvest Strategy, ADF&G develops charts based on historical averages that estimate run timing relative to the Karluk upper and lower escapement goals for both the early and late sockeye salmon runs. At any given date for the early or late run, ADF&G managers can review the escapement counts from the weir and compare them against the historical average run timing to see how closely they are managing the run to the upper or lower escapement goal.

The Westside Kodiak Salmon Management Plan also plays an integral role in escapement management of the Karluk runs. Like escapement goals, the Westside Kodiak Salmon Management Plan is developed by ADF&G and must be approved by the Board of Fisheries before implementation of the plan. The plan establishes the specific timeframe in which Westside Districts and sections may open to commercial fishing based on the relative abundance of salmon. This framework enables managers to use their Emergency Order (EO) authority to set the dates and times for opening the commercial fishery, and harvest salmon bound to the various management areas that contribute to westside salmon runs, including sockeye salmon returning to the Karluk system. Additional information on the plan is provided in Section 1.5.5.4.

When commercial fishing nets are in operation, fewer sockeye salmon return to the Karluk system, and when commercial fishing is closed, more sockeye salmon return to Karluk spawning grounds. ADF&G actively monitors catch (the number of fish being caught in commercial fishing nets) as well as catch rates (the number of fish caught in commercial nets during a given time). Using these tools, ADF&G can adjust commercial fishing openings to allow more or fewer fish to be caught based on whether the Karluk system is anticipated to meet its escapement goals for the early- and late-run sockeye salmon. Management of the of the West Side mixed stock fishery is complicated and this process can result in overescapement (i.e., exceeding the upper goal set by ADF&G) of fish if either ADF&G or commercial fishermen are unable to respond quickly enough. Currently, ADF&G cannot open commercial salmon fishing periods in the Inner Karluk Section from June 1 through July 15 until it is apparent that the Karluk early-run sockeye salmon upper escapement goal of 250,000 will be exceeded. Despite continuous commercial fishing in the Central and North Cape sections of the Northwest District, the Karluk early-run sockeye salmon upper escapement goal has frequently been exceeded (personal communication, James Jackson, ADF&G, 6/2015).

ADF&G also incorporates estimates of subsistence and sport fishing harvest into their escapement strategy, to allow for continued opportunities for subsistence and sport fishing harvest while still meeting escapement goals.

2.5. Alternative B: Lake Nutrient Enrichment (Proposed Action)

Alternative B is KRAA's Proposed Action. Under this alternative, KRAA (2012) is proposing to "help restore the runs of adult sockeye salmon to the Karluk Lake system to previously high, natural levels of production". They intend to use an adaptive management approach to the enrichment of Karluk Lake through application of aqueous fertilizer to the lake and annual and post-fertilization monitoring. This activity is intended to increase primary productivity (i.e., phytoplankton growth) and ideally improve tertiary productivity (i.e., sockeye salmon productivity).

Under the Proposed Action, KRAA proposes to apply an aqueous nutrient solution to the lake if pre-season monitoring indicates that lake nutrient levels are below target values. The project would also include 2 years each of pre- and post-treatment monitoring as an integral component.

KRAA has established the following lake nutrient level targets for Karluk Lake: a seasonal average nitrogen:phosphorus (N:P) application ratio of 15:1 and a seasonal TP concentration of 9 micrograms per liter (μg/L), with an overall ambient total nitrogen:total phosphorus (TN:TP) molar ratio greater than or equal to 17:1. This alternative is adaptive to changing conditions, and targets may be adjusted by ADF&G or the Service should the best available science indicate that another specific target level is more appropriate.

The aqueous nutrient solution applied to Karluk Lake would consist of phosphorus and nitrogen using two different formulations: 28-0-0 and 10-34-0. These formulations represent, by weight, the percentage of nitrogen, phosphate, and potash present in the fertilizer solution. For example, 10-34-0 would be, by weight, 10% nitrogen in the form of nitrate, 34% phosphorus as phosphate, and 0% potash. Other nutrient formulations (such as 32-0-0 or 10-25-0) could be used in subsequent years based on monitoring outcomes. Product standards would be reviewed closely prior to purchase and application to ensure appropriate nutrient grade and composition.

To minimize flight time to Karluk Lake during nutrient application, the aqueous solution would be shipped to Larsen Bay, Alaska, and stored near the airport. A fixed-wing aircraft equipped with a sprayer bar would fuel and take on the fertilizer solution at the airport and then fly to the project area. Nutrients would then be sprayed over the lake surface within a prescribed area that includes the lake's Main, Thumb, and O'Malley Basins.

At a maximum, the solution would be applied to the surface of the lake on a once-per-week basis over a 14-week period beginning in mid-May and ending in mid-August for 5 years. The nutrient application program is adapted from Ashley and Stockner (2003) and shortened from 16 to 14 weeks in order to account for the shorter summer growing period in Alaska. Peak phosphorus inputs would occur in the late spring to maximize early-season productivity. The nutrient loading pattern would be designed to prevent dissolved nitrogen limitation and decrease the likelihood of colonial cyanobacteria (blue-green algae) blooms that are often associated with nitrogen depletion or low N:P ratios.

The proposed nutrient application schedule and calculations would seek to maintain an annual mean phosphorus load of 90% of "permissible" levels and nutrient targets. For example, based upon 2010 Karluk Lake nutrient loads, an estimated 2,796 gallons (14,871 kilograms [kg]) of 10-34-0 and 9,899 gallons (48,114 kg) of 28-0-0 aqueous nutrients would have been applied over the course of a 14-week enrichment period in 2011 to meet these targets, delivering a total of 2,206 kg phosphorus and 14,968 kg nitrogen to the lake.

KRAA would work with ADF&G and the Service each spring, prior to the May–August growing season, to develop nutrient concentration and application plans. Estimated annual supplemental nutrient loads would be calculated based on the target phosphorus concentration in relation to the system's initial spring TP concentration or the seasonal mean TP concentration of the previous year. Seasonal nutrient applications would be determined based on pre-season monitoring data.

Upon initiation of aerial application of fertilizer, KRAA would use in-season monitoring data to maintain appropriate nitrogen and phosphorus ratios throughout the growing period. This is an adaptive application plan, so the amount of aqueous nutrient solution and number of application flights would vary depending on the most current sampling results and targeted nutrient levels. Should the targeted nutrient level be achieved at any time during the proposed project, fertilizer solution application would stop. Monitoring would continue, and if nutrient concentrations were to fall back below desired levels, adaptive application would resume.

KRAA's proposal also outlines a series of response variable and decision points for inseason, annual, and long-term, multi-year time frames. These variable include various parameters related to zooplankton, fry, and smolt and adult returns (KRAA 2012).

Estimated costs for aqueous nutrient solution, aerial application, and associated monitoring are approximately $250,000, annually; however, actual costs at the time of implementation would depend on the amount of nutrients needed and prices for air charters, fuel, and other supplies.

ADF&G would not examine or re-examine escapement in response to implementation of the Proposed Action. Therefore, if project activities resulted in increased sockeye salmon within the bands of the biological escapement goal (BEG), no additional fish would be escaped to the Karluk system. As is currently the case, if the run is above the BEG, commercial fishermen would be the primary beneficiary and may profit from the harvest of any additional fish. Sport and subsistence users would also have increased opportunity to harvest fish.

2.6. Alternative C: Fry Backstocking

Alternative C proposes to conduct a backstocking program using Karluk sockeye salmon to fertilize eggs, raise them to the fry stage at a hatchery, and return the fry to the Karluk watershed.

Under Alternative C, KRAA could implement a sockeye salmon fry backstocking program at the Upper Thumb River and Thumb River (as necessary in low run years) if sockeye salmon escapement and harvest (commercial) are low but nutrient levels are sufficient to support a higher sockeye salmon run. This alternative would occur in three phases: broodstock collection and ripening; egg collection, incubation, and rearing; and backstocking of salmon fry in the Upper Thumb River. KRAA currently works with ADF&G to determine backstocking levels for all of KRAA's sockeye salmon backstocking programs and anticipates that this relationship would continue for setting the number of fry to be backstocked at Karluk Lake.

As with Alternative B, the project would consist of 5 years of fry backstocking and 2 years each of annual pre- and post-treatment monitoring to assess project effectiveness. Estimated costs for fry backstocking are between $250,000 and $300,000 annually, but these costs could vary depending on the number of eggs taken and the costs for needed personnel, fuel, and other supplies. As part of this alternative, KRAA would apply for a Fish Transport Permit with ADF&G to permit collection of sockeye salmon gametes, transportation of sockeye salmon eggs to a hatchery for incubation, and then release of sockeye fry back to Karluk Lake.

2.6.1. Broodstock Collection and Ripening

During this phase, KRAA staff could propose to collect female and male adult sockeye salmon to harvest salmon eggs and milt. Collection of adults would occur at the confluence of the Upper Thumb River and Thumb Lake. The Thumb River was the location for collecting sockeye salmon broodstock during past backstocking efforts in the late 1970s and 1980s and is one of the many drainages and shoals (23 stocks are genetically distinguished; Personal communication, Birch Foster, ADF&G) where early- and late-runs of Karluk sockeye salmon typically spawn. Sockeye salmon have a high fidelity to their natal stream or shoal spawning area. Early-run sockeye salmon in the area are predominantly stream spawners (personal communication, Nick Sagalkin, Alaska Department of Fish and Game). Releasing fed fry in the same tributary in which broodstock was collected increases the likelihood that they would return to the same area to spawn as adults.

KRAA estimates that collection and holding of broodstock for egg and milt collection would require 2 to 3 weeks of labor. KRAA proposes to establish a camp near a small embayment south of the confluence of Upper Thumb River and Thumb Lake (see Figure 2) to house workers, build temporary holding pens, and collect ripe eggs and milt. An estimated three workers would remain on-site for the duration of this phase. Workers would be housed in an approximately 10 × 16–foot WeatherPort shelter. Fish would be held in approximately 10 × 10 × 10–foot pens (Figure 3). Both the camp and temporary holding structures would be removed when egg collection is complete. KRAA estimates that transport of employees, supplies, and equipment would require a total of four flights from Kodiak to the area for set-up and takedown annually.

KRAA would collect early-run adult sockeye salmon by seining at the mouth of the Upper Thumb River (and Thumb River in years where runs to the Upper Thumb are low) where fish aggregate during the early-season run (typically late July through mid-August). Staff would use a small Achilles raft to help bring in nets by hand, and salmon would be sorted by sex into holding pens. Broodstock holding pens are essentially a floating collar to which a net is attached. The pen has a lid, either zippered or “bed sheet style,” to retain fish in the pen (Figure 3). Pens are tied off to an anchor line, which is typically secured to an anchor and then further secured to shore. The pens would be located near the Upper Thumb River and would be designed to hold adult sockeye salmon until they “ripen” and reach sexual maturity.

Figure 3. Temporary holding pens, consisting of a 10 × 10 × 10–foot cube and fitted lid (photo courtesy of KRAA).

2.6.2. Egg Collection, Incubation, and Rearing

Egg collection would occur approximately 7 to 10 days after seining and would require killing collected adult male and female fish to remove eggs and milt. Approximately two egg collections would be required to achieve desired fry counts. KRAA estimates that each egg collection would produce a minimum of two million eggs, based on collection of approximately 750 to 850 females and 495 to 560 males.

Approximately 10 staff would be required for each egg collection process. Transport of employees, supplies, and equipment would require an average of eight flights from Kodiak to the area per collection, and staff would be housed at a base camp as necessary. All generated waste, trash, and equipment and supplies would be stored using appropriate containers and removed following the completion of egg collection activities.

Eggs would be fertilized on-site and then flown to the Pillar Creek Hatchery in Kodiak, Alaska, which has the capacity to incubate up to 20 million eggs and, in the short term, rear approximately five to seven million sockeye salmon fry. The number of salmon fry reared (and released) would depend on estimated escapement and smolt counts from previous years. During low early-run sockeye salmon escapement years at Karluk Lake, KRAA could incubate up to five million salmon eggs at the facility for release the following spring. During years with higher early-run sockeye salmon, KRAA could incubate approximately two million eggs for release. The annual egg-take goal could be adaptively determined by ADF&G, the Service, and KRAA, based on annual factors such as estimated escapement by run, nutrient levels, zooplankton levels, and smolt count and condition.

Eggs transported to Pillar Creek Hatchery would be placed in incubation tanks to overwinter. In mid-winter of the following year, the eggs would hatch and then emerge as fry that spring.

After the eggs hatch, KRAA would feed and rear the fry for approximately 1 to 2 months. Backstocking fed fry would increase the likelihood of their survival upon release. Studies have shown that the size of salmon fry is directly correlated to increased survival during subsequent life stages (Groot and others 1995). Fed fry generally weigh approximately 0.4 gram at backstocking, whereas fry that hatch in the wild weigh around 0.25 gram at the same life stage. Once the fry reach the appropriate size (0.4 gram), KRAA would then transport the fry back to the Upper Thumb River for backstocking.

2.6.3. Backstocking

KRAA would transport fed fry to Karluk Lake via charter aircraft. Backstocking would occur when reared fry achieved the appropriate size (approximately May to June) and would require approximately 20 flights over 4 to 5 days to transport two million salmon fry and required staff to the lake. Once at the lake, approximately 4 to 5 KRAA employees would transport the fish via foot to the Upper Thumb River by dip netting fish out of transport containers into waterproof containers strapped onto a backpack. Staff would release fry at upstream locations identified during a previous foot survey; locations would be based on suitable stream conditions and available oxygen supply for transported fish.

To evaluate the success of backstocking, KRAA would otolith-mark all fry released to Karluk Lake. Resultant smolt would be sampled throughout the smolt emigration period (May–June/July) for otolith marks. Based on the estimated number of smolt with otolith marks, KRAA can calculate the fry to smolt survival rate and determine the proportion of smolt that originated from the backstocking program. Returning adult salmon would also be sampled for otolith marks to determine survival rates and whether they are hatchery fish.

2.7. ADF&G would not examine or re-examine escapement in response to implementation of the Proposed Action. Therefore, if project activities resulted in increased sockeye salmon within the bands of the biological escapement goal (BEG), no additional fish would be escaped to the Karluk system. As is currently the case, if the run is above the BEG, commercial fishermen would be the primary beneficiary and may profit from the harvest of any additional fish. Sport and subsistence users would also have increased opportunity to harvest fish. Alternative D: Lake Nutrient Enrichment and Fry Backstocking

Alternative D is a combination of Alternatives B and C, in which aqueous nutrients would be applied in combination with backstocking of sockeye salmon fry.

For this alternative, KRAA could choose to apply aqueous nutrients to Karluk Lake if pre-season monitoring were to indicate that lake nutrient levels are below the target values set for Alternative B. In addition, KRAA could implement a sockeye salmon fry backstocking program at the Upper Thumb River and Thumb River (as necessary) if sockeye salmon escapement and harvest (commercial) are low but nutrient levels are sufficiently high to support a higher sockeye salmon run. As with other action

alternatives, the project would consist of 5 years of fry backstocking and nutrient application, as well as 2 years each of annual pre- and post-treatment monitoring to assess project effectiveness.

Water quality sampling and aerial nutrient application would begin in 2015 and would continue through 2021, as described in Sections 2.3 and 2.5. KRAA would conduct water quality sampling during the pre-season (April–May), summer growth period (typically May–August), and post-season (September–October), following the ADF&G sampling schedule. Fertilizer would be purchased and stored at the Larsen Bay airport and applied weekly via fixed-wing aircraft over the surface of Karluk Lake from May to August of each year.

A broodstock collection field camp would be established near the confluence of the Upper Thumb River and Thumb Lake in late July (see Figure 2), and adult sockeye salmon would be captured and held as described in Section 2.6. Egg collection would occur during August to collect a minimum of two million eggs during an estimated two egg takes. Collected eggs would be fertilized and transported to the Pillar Creek Hatchery for incubation and rearing. Salmon fry would be transported to the Upper Thumb River for release the following year; backstocking of salmon fry would continue from 2016 to 2021.

The combined effort of fry backstocking and fertilizer application would be subject to annual review and discussion between KRAA, the Service, and ADF&G personnel regarding the need for fertilization and backstocking due to changes in seasonal limnological data, salmon returns, and other parameters. Because no data exist on the potential synergistic effects of combining the two actions, the USFWS has expressed concern that this lack of data will hinder their ability to evaluate the project.

The cost of implementing Alternative D would be approximately the same as the cost of the fertilization and backstocking alternatives combined.

ADF&G would not examine or re-examine escapement in response to implementation of the Proposed Action. Therefore, if project activities resulted in increased sockeye salmon within the bands of the biological escapement goal (BEG), no additional fish would be escaped to the Karluk system. As is currently the case, if the run is above the BEG, commercial fishermen would be the primary beneficiary and may profit from the harvest of any additional fish. Sport and subsistence users would also have increased opportunity to harvest fish.

2.8. *Alternatives Considered but Eliminated from Detailed* Analysis

Several alternatives were considered during the EA process but eliminated from detailed analysis. In general, the following reasons may be considered grounds for eliminating an alternative.

- It would be ineffective (the alternative would not respond to the purpose and need).
- It would be technically or economically infeasible.
- It would be inconsistent with the basic policy objectives for the management of the area.
- Its prospects for implementation would be remote and/or the results would be speculative.
- It would be substantially similar in design to an alternative that would be analyzed.
- It would have substantially similar effects to an alternative that would be analyzed.

The specific alternatives that were eliminated from detailed analysis are discussed below, along with the rationale for their elimination.

2.8.1. Placement of Salmon Carcasses in Karluk Lake

Placement of salmonid carcasses at Karluk Lake would add nitrogen, phosphorus, other MDN, and organic matter to the lake system and provide food at multiple levels of the terrestrial and aquatic food webs.

Pink salmon are the only salmon species that could effectively be collected in the area because most of them spawn in the river and are washed downstream post-spawning. Other species do not spawn in numbers sufficient for effective collection, do not spawn in the river (i.e., are lake or tributary spawners and thus would not be effectively collected at the weir), or spawn after ADF&G removes the weir for the winter. Transport of fish from outside of the project area could be cost-prohibitive and impractical, given that U.S. fish health standards for fish transport require that fish (dead or alive) transported across watersheds be tested for pathogens prior to release.

Because pink salmon spawn for a limited time, carcass collection and distribution could only occur for 3 weeks in late August and September, which is the end of the growing season in Karluk Lake. Therefore, the time frame for nutrients from pink salmon carcasses to become available to primary producers and ultimately sockeye salmon would be much longer than it would be for an aerial application of nutrients on the lake.

Additionally, during odd-numbered years when pink salmon runs are typically significantly lower, the availability of sufficient numbers of pink salmon carcasses would be limited. Nutrient content calculations done by Laney and Slaney (1997) indicate that to meet the nitrogen and phosphorus nutrient needs identified in KRAA's proposal (KRAA 2012), approximately 347,232 pink salmon carcasses (roughly 500 tons of biomass) per year would be required. In even-numbered years, when runs are typically over one million fish, it is anticipated that biomass needs might be met. However, in odd-numbered years, biomass needs would likely not be met. As such, the Service removed this alternative from further consideration.

2.8.2. Placement of Carcass Analogs

Placement of carcass analogs at Karluk Lake would provide an alternative way to provide nutrients to Karluk Lake. Carcass analogs are briquettes made of fishmeal and other ingredients that provide a pathogen-free source of nutrients and organic material to freshwater systems.

Carcass analogs would introduce key nutrients at lower concentrations than aqueous fertilizer. Carcass analogs contain approximately 8% nitrogen and 1.8% phosphorus (personal communication, Ron Malnor 2013). Almost all identified uses of carcass analogs have occurred in freshwater streams (Kohler and others 2008; Kohler and others 2012; Pearsons and others 2007), so the use of carcass analogs in lacustrine systems such as Karluk Lake would be experimental. There is also uncertainty about the rates at which carcass analogs would dissolve in lakes. As such, the Service removed this alternative from future consideration.

2.8.3. Stock Smolts in Karluk Lake

The Service considered stocking sockeye salmon smolt in Karluk Lake that would outmigrate but be imprinted to return to the Karluk system. Stocking smolt in Karluk Lake would place a lower grazing demand on zooplankton in the lake than would stocking smaller-sized fish, based on a reduced residency time in the lake. Rearing juvenile sockeye salmon to smolt size in a hatchery will produce generally larger fish at age than naturally spawned fish that rear in a lake and they would have higher survival rates. In a hatchery setting, natural selective pressures are reduced and abundant feed is provided to maximize

growth. Neff and others (2011) indicate that, "Artificial breeding programs may have unintended consequences that threaten the persistence of naturally occurring stocks." Listed consequences include reduced foraging efficiency, reduced sensitivity to predation risk, reduced reproductive success when interbreeding with wild fish, and increased aggressiveness. Additionally, rearing salmon to smolt size would require overwintering the fish in raceways at Pillar Creek Hatchery. This facility is currently using all available water and space for other stocking projects that require overwinter rearing. A Karluk early-run sockeye salmon smolt-rearing project would require reallocating raceway space and possible loss of other established stocking projects, or would require significant facility improvements. Alternative C, fry backstocking, reduces the time the juvenile salmon are in the hatchery and maximizes the opportunity for imprinting the fish to the same spawning stream as the parent broodstock. As such, the Service removed this alternative from further consideration.

2.8.4. Move Adult Sockeye Salmon to Karluk Lake

Capturing adult sockeye salmon (and possibly other species) at the mouth of the Karluk River via a fish wheel (or other method) and planting those individuals in Karluk Lake could increase the number of spawners and subsequent carcass mass and nutrient release to the lake. Not all Karluk sockeye salmon, and almost no other anadromous salmonid species, however, travel as far upstream as the lake. Though this method would eliminate the possibility of predation on the captured fish, it would not account for the possibility of capturing stream-spawning sockeye salmon that would leave the lake once placed there.

Handling of adult sockeye salmon has been known to reduce their ability to reach spawning grounds (Donaldson and others 2011) and increases physiological disturbances and mortality (Donaldson and others 2012). Transplanted fish that are not ready to be at the spawning grounds would leave and return when ready, further increasing stress, energy expenditure, and subsequent fish mortality. As such, the Service removed this alternative from further consideration.

2.8.5. Reduce Three-spined Stickleback Population

Three-spined stickleback, which is abundant in Karluk Lake, may compete with juvenile sockeye salmon due to the species filling similar niches. The Service considered the option of removing stickleback through seining or electrofishing to provide sockeye salmon with less competition for food. However, removing a native species, the stickleback, to benefit another species would not meet the Service's policy for maintaining biological integrity and diversity, and populations of native species (601 FW 3.14 B), including managing populations for natural densities and levels of variation (601 FW 3.14 C). As such, the Service removed this alternative from further consideration.

2.9. Alternatives Comparison

Table 1 provides a comparison of alternatives for the Karluk Lake Nutrient Enrichment project.

Table 1. Comparison of Actions Proposed in Alternatives for the Karluk Lake Nutrient Enrichment (Environmental Assessment)

Project Action	No Action Alternative	Alternative B (Proposed Action)	Alternative C	Alternative D
Monitoring before, during, and after action	Monthly (April to October)	April–May and September–October, monthly During active enrichment (May–September), weekly	Monthly (April to October)	April–May and September–October, monthly During active enrichment (May–September), weekly
Management of sockeye salmon escapement using commercial fishing openings and closures	X	X	X	X
Application of aqueous fertilizer using fixed-wing aircraft		X		X
Collection of broodstock for egg fertilization			X	X
Planting of sockeye salmon fry back to the Karluk watershed			X	X
Annual number of on-the-ground personnel required to implement alternative (in person/days)*	14	36	117	153
Annual number of fixed-wing aircraft flights needed*	7	32	47	72

*Because all alternatives incorporate monitoring of lake conditions as part of the alternative, the personnel and aircraft flight totals include the number of personnel and flights needed for monitoring. Since Alternative D is a combination of Alternatives B and C, the monitoring personnel and flights include only the personnel and flights under the more frequent monitoring schedule (Alternative B).

3. AFFECTED ENVIRONMENT

The Karluk River drainage provides for a variety of anadromous and resident fish stocks. Chinook salmon, coho salmon, pink salmon, chum salmon, sockeye salmon, steelhead trout (*Oncorhynchus mykiss*, the anadromous form), and Dolly Varden (*Salvelinus malma*) anadromous stocks are documented in the state of Alaska's anadromous fish catalog from the drainage. The Karluk District (now the SW and NW Kodiak District) is the largest commercial salmon fishery on Kodiak Island and Karluk Lake has historically been the largest producer of sockeye salmon (Foster 2014). Pink salmon and chum salmon runs have decreased slightly in the recent past but have largely remained consistent throughout the Kodiak Management Area (ADF&G 2013e). Chinook salmon (which have no in-river targeted fishery, but are harvested in salt water sport fisheries) have fared less well than other salmonids, under commercial, subsistence, and public recreational fishing, although the causes for this decline have yet to be fully determined. Karluk River Chinook have all but collapsed and have failed to attain the lower bound of the BEG in 5 of the past 10 years (ADF&G 2014a). Karluk Lake is also an important area for the Kodiak Refuge in meeting the refuge purposes as set out in ANILCA (described in Section 1.4.3).

3.1. Introduction

This chapter summarizes the physical, biological, social, and economic environments that could be affected under the No Action Alternative, Proposed Action, and other action alternatives. Only those resources raised as issues of concern by the Service are considered below (see Section 1.8, Issues). For the purposes of this EA, existing conditions are described for a 613-km^2 (237-square-mile) project area, consisting of seven subwatersheds in the Karluk area, unless otherwise noted (Figure 4). The marine environment, beyond Karluk Lagoon, is not part of the project area.

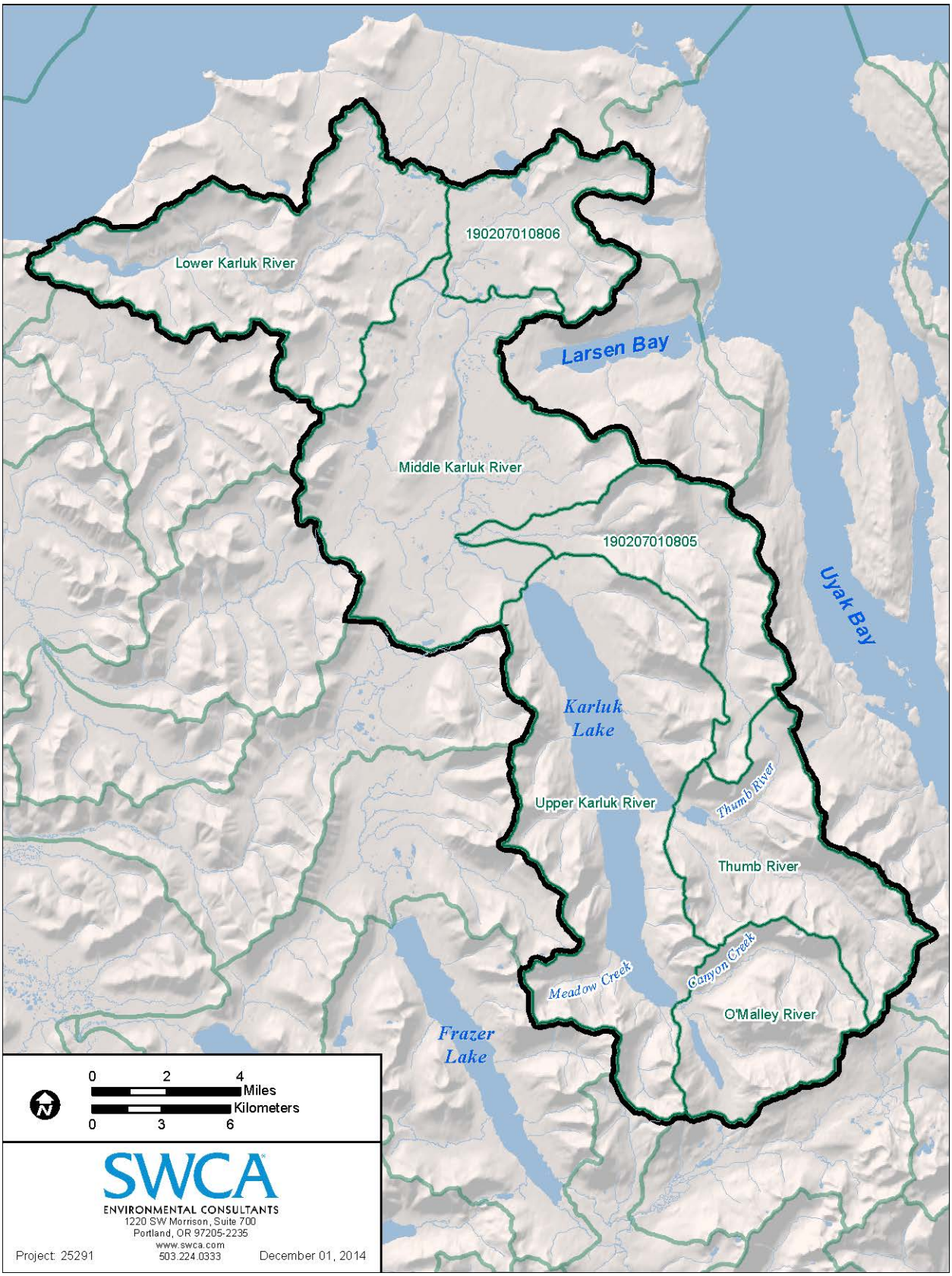

Figure 4. Project area for Karluk Lake Nutrient Enrichment EA.

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3.2. Aquatic Resources

This section describes the aquatic resources present in the project area. Information on aquatic species was obtained from the Kodiak Refuge CCP (USFWS 2008); ADF&G; the Service; and technical and research publications.

Fish species diversity in the project area is relatively high for south-central Alaska and comprises a mixture of anadromous and resident fish species with different life cycles, habitats, and diets (ADF&G 2013b; Gotthardt and Booz 2005; Greenbank and Nelson 1959; McClory and Gotthardt 2005; Morrow 1980). This section provides a description of the various fishes found in the drainage and more specific information on sockeye salmon. Salmon other than sockeye are of interest because some types of enhancement and restoration projects can disproportionately affect anadromous salmon populations that have lower productivity (Collie and others 1990, Nehlsen and others 1991). This can occur in a mixed stock fishery when supplementation raises the proportion of the run available to harvest in the enhanced/restored stock while "un-affected stocks do not share this increased productivity. The result can be harvest rates that push recruitment below the 1:1 ratio required for replacement. The Karluk River drainage may pose such a situation because the fishery is not a terminal fishery and harvest of Chinook and other salmon may occur in the fishery.

3.2.1. Other Fish Species

A variety of fish species inhabit the Karluk drainage. Anadromous species include Chinook salmon, sockeye salmon, coho salmon, pink salmon, chum salmon, steelhead trout, and Dolly Varden. Non-anadromous species include rainbow trout (*O. mykiss*), Arctic char (*S. alpinus*), coastrange sculpin (*Cottus aleuticus*), three-spined stickleback, and nine-spine stickleback (*Pungitius pungitius*) (Hartman and Burgner 1972). Four of the anadromous salmon are target species in the Westside Kodiak Salmon Management Plan—sockeye, coho, pink, and chum—but all five salmon species are subject to harvest in the mixed stock fisheries of the west side fishing districts. Table 2 provides information on salmonid catch other than sockeye during the Westside Kodiak sockeye salmon fishery.

Table 2. Westside Fishery catch of salmonids other than sockeye from 2004 to 2013

Year	Chinook	Coho	Pink	Chum	Totals
2004	4,499	59,677	4,269,754	82,776	4,418,710
2005	4,930	122,527	1,315,616	67,314	1,512,392
2006	7,096	146,036	6,025,474	99,271	6,279,883
2007	3,110	99,609	3,915,006	80,363	4,100,095
2008	6,486	48,480	1,339,060	31,873	1,427,907
2009	273	2,613	324,755	3,846	333,496
2010	784	23,304	714,143	18,940	759,181
2011	1,192	35,035	588,347	29,336	655,921
2012	2,672	87,466	2,834,828	72,307	2,999,285
2013	8,264	60,085	1,429,706	84,066	1,584,134

Sources: Dinnocenzo (2006, 2010); Dinnocenzo and Caldentey (2008); Dinnocenzo and others. (2006); Dinnocenzo and others (2007); Dinnocenzo and others (2010); Jackson and Keyse (2010); Jackson and others (2010); Jackson and others (2012); Spalinger, G. personal communication (2012).

Spawning occurs in a variety of locations in the lower reaches of the Karluk River downstream of Karluk Lake (ADF&G 2014a) (Figure 5). A September 2011 trawl survey in the lake contained only sockeye

salmon and stickleback (Mueller and Degan 2012), however sample sizes are small and sampling may not be reflect the true conditions. Other species can be expected to be found in relatively low abundances in the lake except coho salmon which represent a high percentage of fish captured in outmigration studies in the project area.

In 2010, the Alaska Board of Fisheries designated the Karluk River Chinook salmon as a stock of management concern (Munro and Volk 2013). This is the only stock of concern in the Kodiak Management Area, which consists of the entire Kodiak Archipelago and a portion of the Alaska Peninsula that drains into Shelikof Strait (ADF&G 2013a).

All fish species in Karluk Lake are generalists and use a wide variety of prey, including zooplankton, in their diet (ADF&G 2013b; Gotthardt and Booz 2005; Greenbank and Nelson 1959; McClory and Gotthardt 2005; Morrow 1980). Sculpin do not occupy juvenile sockeye salmon habitat (Morrow 1980) whereas Arctic char, nine-spine stickleback, Dolly Varden, trout, and coho do share similar open surface water habitat. Coho and nine-spine stickleback are known to eat salmon eggs while trout, Dolly Varden, and Arctic char eat both eggs and small fish (ADF&G 2013b; Gotthardt and Booz 2005; Greenbank and Nelson 1959; McClory and Gotthardt 2005).

Three-spined stickleback in Karluk Lake are abundant (Mueller and Degan 2012); they forage on common prey (Greenbank and Nelson 1959), and use similar habitat as juvenile sockeye salmon (Gotthardt and Booz 2005). Midge fly larvae and crustacean zooplankton constitute the majority of the three-spined stickleback diet. These organisms also serve as a similar source of food for juvenile sockeye salmon. A 1951 study that examined the stomach contents of stickleback in Karluk Lake indicated that sticklebacks do not appear to eat sockeye salmon eggs (Greenbank and Nelson 1959).

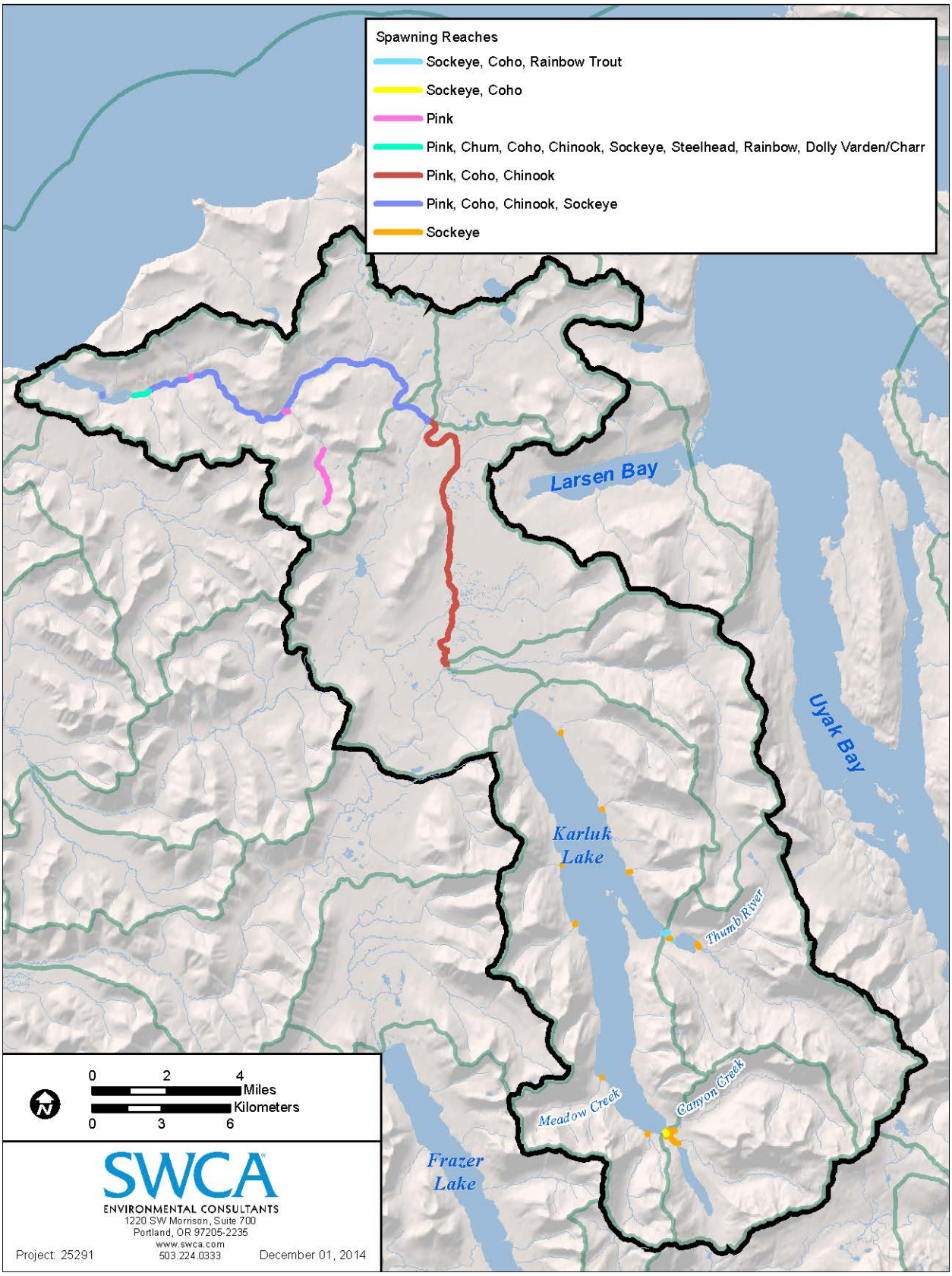

Figure 5. Spawning reaches for salmonids in the Karluk watershed

3.2.2. Sockeye Salmon

The following sections discuss information on the life stages of sockeye salmon in the Karluk drainage.

3.2.2.1. JUVENILE ECOLOGY

Sockeye salmon fry emerge in two groups, early and late imprinting on their location of emergence. These groups focus on separate organisms for food based on their time of peak abundance. Early emerging fry feed primarily on copepods, while late emerging fry focus on cladocerans (Schmidt and others 1998). Sockeye salmon typically rear in Karluk Lake for 2 to 3 years, and their growth (weight and length) is determined by a variety of factors including environmental conditions (e.g., carcasses deposition the previous year), food, and space availability. While in the lake, they spend most of their time in limnetic waters (Burgner 1991). The juveniles then travel downstream to the sea as smolts when they have grown to the appropriate size. Freshwater-age-2 smolt have historically dominated the outmigrating age class (Foster 2014). Age-3 smolts are also common and reflect both a need to grow to an appropriate length prior to migration and a second survival strategy for both the individual smolt and population. This increased time in fresh water for juvenile sockeye salmon, when compared to other lakes in the area, is associated with poor rearing conditions (i.e., low nutrients, primary productivity, and zooplankton population; Koenings and Burkett 1987a).

Juvenile sockeye salmon are tertiary consumers, defined as fish that consume secondary consumers (zooplankton). Up to 96% of their diet may consist of zooplankton depending on the season, habitat use, and development stage of the individual (Groot and Margolis 1991). Juvenile sockeye salmon also eat insects and fish larvae. Juvenile sockeye salmon tend to rear in lakes that are farther upstream than the riverine habitats used by other juvenile salmonids and therefore have little competition with other salmonids for zooplankton. Because juvenile sockeye salmon can occur in large numbers and have a preference for zooplankton, impacts of intense predation on the zooplankton community have been documented (Koenings and Kyle 1997).

In sockeye salmon-rearing lakes, salmon fry will emerge at the same time as peak zooplankton productivity in order to take advantage of the abundant food source. However, past research identified a difference in the timing of peak zooplankton concentration and the forage demand of sockeye salmon fry in Karluk Lake (Koenings and Burkett 1987a, 1987b). More recent conclusions from research indicate that sockeye salmon in Karluk Lake emerge to utilize two primary zoo-planktonic organisms that have peak productivity at different time periods, an early and late zooplankton peak (Schmidt and others 1998). This is a system-specific phenomenon that provides for both early and late emerging fry.

3.2.2.2. ADULT ECOLOGY

Sockeye salmon spend 2 or 3 years in the ocean before mature adults return to spawn. Statewide, sockeye salmon spawn in mainstem rivers, lake shores (shoals), and tributaries above lakes. Karluk Lake supports the largest sockeye salmon run in the Kodiak Management Area (Foster 2014) and consists of early-run and late-run stocks. Most of the early-run stock passes through an ADF&G weir prior to mid-July, and most of the late-run stock passes through the weir after mid-July (Moore 2014). The sockeye salmon then return to the stream system or lake shore location in which they emerged. This includes the Thumb and O'Malley Rivers, which are the two largest tributaries to Karluk Lake and the lake shore. Here, adult salmon spawn and die, carcasses decompose, and nutrients are released into the surrounding ecosystem. Salmon carcasses are a major contributor of phosphorus and other nutrients to these freshwater systems (Barnaby 1944; Koenings and Burkett 1987a; Schmidt and others 1998), and spring nutrient concentrations in lakes containing anadromous species have been positively related to the previous year's adult sockeye salmon return (Kline and others 1993; Koenings and Burkett 1987a; Golder and Associates

2011). Nutrients from adult carcasses have been traced to use and uptake by juvenile salmon, indicating that nutrients from adults can also play a role in the productivity of juveniles (Kline and others 1993). Schmidt and others (1998) credit decomposing carcasses as the predominant sources of phosphorus which is utilized within year and between years.

Karluk Lake and Karluk River are classified by the ADF&G as anadromous water bodies (ADF&G Anadromous Waters Catalog waterbody #s 255-10-10010 and 255-10-10010-0010), meaning that they support at least one life stage of fish species that spawn and rear in fresh water but live as adults in salt water.

3.2.3. Zooplankton and Phytoplankton

Phytoplankton are microscopic, photosynthetic organisms that inhabit the upper layer of most lakes, oceans, and other bodies of water and serve as the base of the aquatic food web. These primary producers are discussed in Section 3.3, Water Quality.

Zooplankton are microscopic- to macroscopic-sized organisms that live in freshwater and saltwater habitats. They are secondary consumers that feed predominantly on primary producers, particularly drifting phytoplankton, and are the primary forage of sockeye salmon fry. As a result, zooplankton populations are impacted by phytoplankton availability as prey, and by predatory pressure from juvenile sockeye salmon. Of particular interest in Karluk Lake are two groups of zooplankton, copepods and cladocerans, both of which graze on phytoplankton and are in turn fed upon by sockeye salmon fry. Early emerging fry feed primarily on copepods while late emerging fry focus on cladocerans, whose biomass peaks later in the summer (Schmidt and others 1998).

Since 1980, Karluk Lake's mean annual total zooplankton biomass has ranged from 228 to 3,215 milligrams per square meter (mg/m^2; Appendix D) and had a mean (average) of 1193 mg/m^2 (n = 31). Biomass has occasionally fallen short of maximum growth potential, or satiation level, for juvenile sockeye salmon (1,000 mg/m^2; Edmundson and Mazumder 2001) during this time but has always supported some level of growth and remained above starvation level (100 mg/m^2; Edmundson and Mazumder 2001). In more recent years (from 2001 to present), for example, zooplankton biomass ranged from 228 to 2848 mg/m^2. Seven of these years were found to be above satiation level while only three years were below the average of 600 mg/m^2 or six times the minimum level.

3.2.4. Fisheries and Climate Change

Regionally, Alaska has reported a 3.1-degree-Fahrenheit rise in annual air temperatures over the past 60 years, "with key effects occurring to permafrost and sea ice, forests and other vegetation, coastline communities and infrastructure, marine ecosystems and fisheries, and subsistence livelihoods" (Alaska Department of Environmental Conservation [ADEC] 2010:7). Climate change and temperature increases are expected to have an effect on aquatic system productivity; however, the nature and the extent of these effects are unknown (Foster 2014) in oligotrophic lakes of Alaska.

3.3. Water Quality

This section describes existing water quality and limnological conditions for the project area. Information on water and lake resources was obtained from the U.S. Geological Survey (USGS), peer-reviewed scientific literature, and ADF&G reports.

3.3.1. Lake Morphometry and Hydrology

Karluk Lake is a deep lake with a mean depth of 134 feet (40.9 m), though depths range from less than 33 feet (10 m) near the banks to 456 feet (139 m) in the center of the lake (Finkle 2013). It is approximately 11.8 miles long (19.6 km) and is 1.2 miles (2 km) wide on average. Lake-bottom slopes are steep, and the littoral zone (the shallow, submerged area close to shore) in the lake is small, resulting in very little visible aquatic vegetation (Juday and others 1932).

The total volume of the lake is 149,400 acre-feet ($1{,}843 \times 10^6$ cubic meters; Finkle 2013), and the average water residence time is approximately 4.6 years (Edmundson and others 1999; Koenings and Burkett 1987a; Uchiyama and others 2008).

3.3.2. Lake Nutrients

Karluk Lake is classified as an oligotrophic lake (Hartman and Burgner 1972; Koenings and Burkett 1987a; Schmidt and others 1998), defined as having low primary productivity (measured by concentrations of the algal pigment, chlorophyll *a*) due to low nutrient levels. This is in contrast to eutrophic lakes, which have high levels of nutrients and high primary productivity, and mesotrophic lakes, which have intermediate levels of nutrients and productivity (Table 3). Eutrophic lakes are often associated with landscapes experiencing higher impacts from human development and activities while oligotrophy is often associated with landscapes with less human impacts and less development in the drainage.

Primary productivity in Karluk Lake is generally regarded as phosphorus limited (Juday and others 1932; Koenings and Burkett 1987a), meaning that increases in algal biomass are limited primarily by the availability of phosphorus in the lake (see Section 3.3.3). At times, however, the lake may be co-limited by both nitrogen and phosphorus (Koenings and Burkett 1987a) and also silica, which is required for diatom (i.e., a form of algae) growth (Finkle 2013).

Table 3. General Trophic Classification of Lakes and Reservoirs Compared to Karluk Lake

Parameter (annual mean)	Oligotrophic	Mesotrophic	Eutrophic	Karluk Lake*
Total phosphorus (ppb)	8.0	26.7	84.4	7.8
Total nitrogen (ppb)	661	753	1,875	189.0
Chlorophyll *a* (ppb)	1.7	4.7	14.3	1.8

Source: Adopted from Wetzel 2001.

Note: Annual means are based on data from an international eutrophication program. Trophic status is based on the opinions of the experienced investigators of each lake.

* Based on available data from 1980–2013.

Phosphorus and other nutrients are delivered to the lake through two main pathways: tributaries, which drain the surrounding landscape, and salmon. After salmon spawn and die in the basins and tributaries of the lake, they decompose and release nutrients into the water column. Decomposing adult salmon carcasses can contribute up to 60% of the phosphorus (Koenings and Burkett 1987a) and up to 60% of the nitrogen (Finney 1998) loads to Karluk Lake.

Because phosphorus is the limiting nutrient in Karluk Lake, it is the primary nutrient of concern for the fertilization study. However, nitrogen must be added in addition to phosphorus in order to prevent blooms of nuisance algae, which tend to occur when nitrogen levels become low with respect to phosphorus

levels (see TN:TP discussion in Section 3.3.3). In addition, when adding nutrients to the lake, care must be taken to prevent shifts between trophic states (i.e., shifting from an oligotrophic lake to a mesotrophic lake) because these shifts are often very difficult to reverse (e.g., Bachmann and others 1999). This is accomplished by setting critical and permissible phosphorus levels for the lake. The critical phosphorus level for Karluk Lake marks its theoretical transition from an oligotrophic lake to a mesotrophic lake, and has been calculated to be approximately 20 parts per billion (ppb) TP (Golder and Associates 2011). The critical phosphorus level was established based on levels in other northern oligotrophic lakes (Vollenweider 1976). The permissible phosphorus level of Karluk Lake is 50% of the critical level, or 10 ppb (Golder and Associates 2011). The goal of the fertilization proposal is to achieve a target phosphorus concentration of 90% of the permissible phosphorus level, or 9 ppb, a concentration substantially lower than the critical, trophic-transition level (Golder and Associates 2011).

3.3.3. Primary Productivity and Water Quality

Primary production, which consists of algae and phytoplankton growth in Karluk Lake, is measured through concentrations of chlorophyll *a*, a green pigment involved in photosynthesis. Seasonal average chlorophyll *a* values from 1980 to 2013 ranged from 0.42 to 3.13 ppb (average = 1.47 ppb, n = 23), and are within the range for oligotrophy as described in Table 3. Primary production is one of the main drivers of lake processes and exerts a great deal of control on both secondary production (i.e., zooplankton, discussed as within the range to support sockeye salmon production) and tertiary production (i.e., salmon). The abundance of phytoplankton within the water column is also directly related to nutrient and DO concentrations (Wetzel 2001).

Primary productivity in Karluk Lake is largely limited by phosphorus. Generally, lakes are phosphorus-limited if their TN:TP ratio is greater than 30 (Wetzel 2001); Karluk Lake consistently has TN:TP values of greater than 40. Therefore, increases in phosphorus concentrations result in increases in phytoplankton and algal biomass. However, at large enough phosphorus loads, nitrogen can become co-limiting and growth of toxic cyanobacteria may result. Toxic cyanobacteria fix nitrogen from the atmosphere to counter nitrogen limitations of the lake, though they generally only occur in lakes that are limited or co-limited by nitrogen, which is rare in oligotrophic waterbodies like Karluk Lake.

When phytoplankton die, they settle to the lake bottom. In this settling process, they are constantly being decomposed and this decomposition exerts an oxygen demand on the water column. This oxygen demand can be measured in several ways, but one common way is through a metalimnetic oxygen depletion (MOD) rate. The metalimnion is a layer of the lake that is created during the summer stratification period and is defined as the layer of water with the greatest change in temperature with respect to depth. The metalimnion separates a warmer, surficial mixed layer from a cooler and denser lower layer (hypolimnion). The MOD rate is arrived at by calculating the difference in DO concentrations at the top and bottom of the metalimnion over a period of time. Generally speaking, MOD rates can range from 8 to 16 ppb DO per day in Karluk Lake.

3.4. History of Karluk Lake Fishery

The following sections discuss changes to aquatic resources over time, including natural variations in aquatic productivity and changes caused by commercial fishing, stocking, and lake fertilization. The sections include changes to sockeye salmon populations, limnological trends, and zooplankton and phytoplankton abundance.

3.4.1. Historical Sockeye Salmon Trends in Karluk Lake

Various studies have examined historical sockeye salmon run sizes in the Karluk system from 2,200 years ago to present. Recent work on variability in nitrogen isotope data from Karluk Lake sediment cores has been used to infer long-term variability in salmon abundance in the lake (Finney 1998; Finney and others 2000; Finney and others 2002). Natural nitrogen consists of two stable isotopes (atoms with the same number of protons, but different numbers of neutrons), ^{14}N and ^{15}N, where ^{14}N makes up the vast majority of naturally occurring nitrogen. Because the ratio of ^{15}N to ^{14}N tends to increase through biological processes, the ratio of the two isotopes in a sample provides information about where the nitrogen in that sample originated (e.g., nitrogen derived from the atmosphere versus nitrogen derived from animal waste). In Karluk Lake, higher ^{15}N to ^{14}N ratios found in soil samples are shown to be representative of greater presence of salmon-derived nutrients in the lake, and thus greater salmon populations (Finney 1998).

Work conducted by Finney and others (Finney 1998; Finney and others 2000; Finney and others 2002; Finney and others 2010; Gregory-Eaves and others 2003) identifies climate-related population fluctuation on millennial, centennial, and decadal time scales. A major decline in salmon populations beginning around 1920 corroborates declines in associated organic phosphorus concentrations in the lake from 1920 to the present (see above). Prior to this, there were approximately 700 years of relatively high ^{15}N to ^{14}N ratios (referred to as $\delta^{15}N$, or “del 15 N”) in Karluk Lake, providing evidence of high salmon escapements (Figures 6 and 7). Strong correlations between nitrogen isotope fractionation, sedimentary diatom assemblages, and salmon escapement data, combined with a comparison to a reference lake (Frazer Lake), indicate that annual escapements of one to three million salmon were common until commercial harvesting became commonplace on Karluk Lake in the late nineteenth and early twentieth centuries (Finney and others 2002; Gregory-Eaves and others 2009). Sedimentary diatom assemblages also showed a striking shift from one dominated by meso- to eutrophic species (TP optimal range between 14.8 and 21.5 ppb) to a nutrient-poor assemblage (TP optimal range between 9.9 and 12.3 ppb) beginning in the 1950s and lasting through the 1980s (Gregory-Eaves and others 2003). Comparisons to a reference lake with no salmon indicated that nearly all of the inter-annual variation in $\delta^{15}N$ in Karluk Lake is due to variation in salmon escapements (Finney and others 2002).

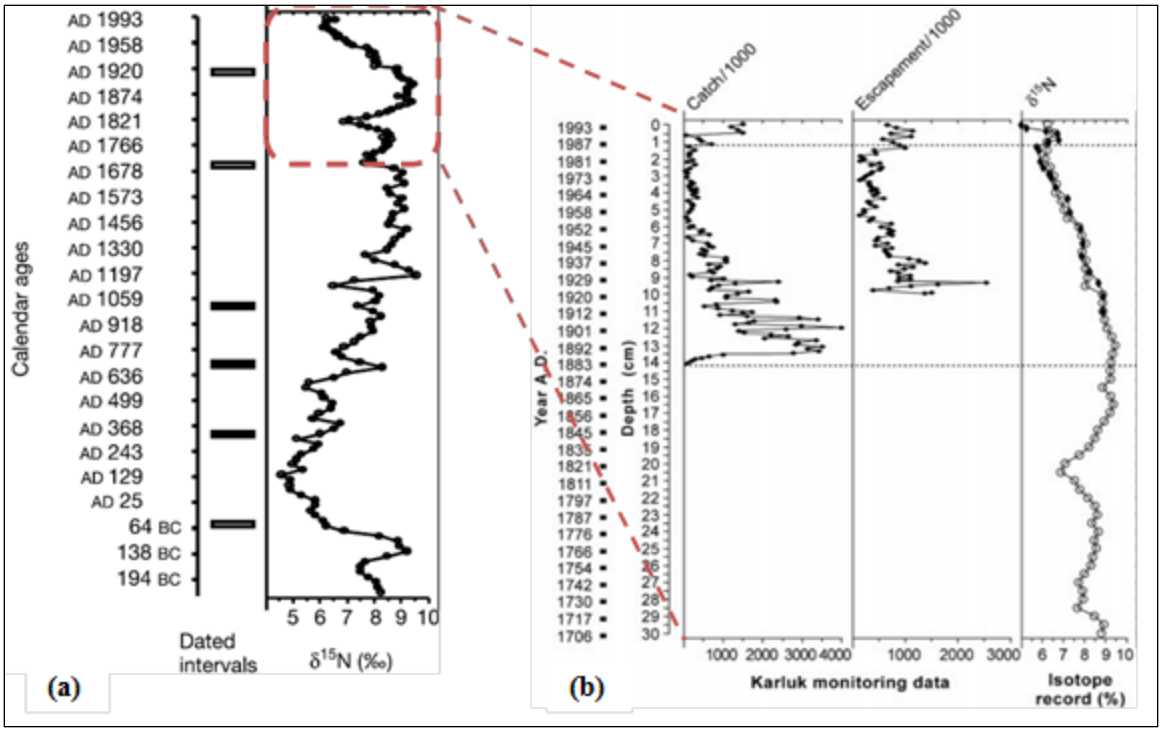

Figure 6. (a) $\delta^{15}N$ for past 2,000 years and reconstructed sockeye salmon escapement data for Karluk Lake (adopted from Finney and others 2002), and (b) sockeye salmon monitoring data and $\delta^{15}N$ records for past 300 years (adopted from Finney and others 2000).

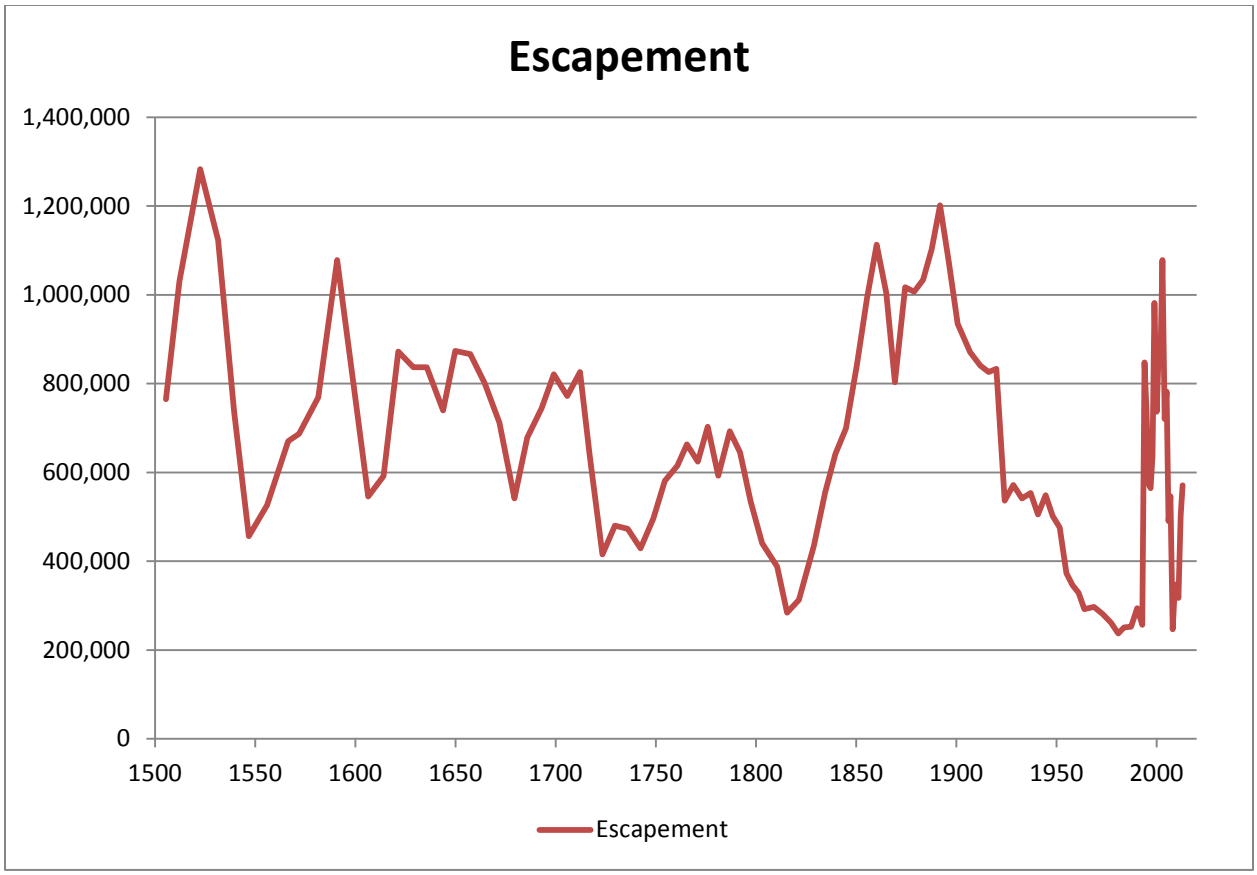

Figure 7. Karluk Lake paleo-reconstruction of sockeye salmon escapement from 1500 to present.

Source: Data from 1500 to 1921 , unpublished data, Schindler, 2014; Data from 1922 to 2013 from ADF&G.

Although commercial harvesting has clearly had an impact on salmon abundance in Karluk Lake, Finney and others (2002) point out that "the two noticeable multi-century shifts in inferred sockeye salmon abundance at ~100 BC and ~AD 800–1200 correspond to periods of major change in ocean–atmosphere circulation in the northeastern Pacific" (see Figures 5 and 6). They further note that "the dramatic decrease in Alaskan salmon abundance at ~100 BC is contemporaneous with warming of marine waters in the Santa Barbara basin, California," implying that shifts in climate are an important driver of salmon abundance, and that greater abundance of sockeye salmon in Alaska is potentially associated with a cooler climate.

Commercial harvest of sockeye salmon in the Karluk system dates back to the late 1800s. Catch records before 1921, when a weir was installed in Karluk River (Loewen 2014; Schmidt and others 1998), are unreliable but estimate harvests of roughly 1.3 to 2.5 million fish. A 5-year cyclical pattern of increased runs had been detected in this time period but disappeared by the late 1920s, likely as a result of the heavy commercial fishing in the area. Harvest did not again exceed one million sockeye salmon between 1938 and 1985 (USFWS 1986). We note here that in general the catch data prior to 1921 are regarded as somewhat unreliable by Barrett and Nelson (1995). Further, data prior to 1985 contain "substantial errors in assignment of Westside catch to the Karluk system." In general substantial caveats must be considered when analyzing the data; however, no better data set has been complied to date.

In 1924, the White Act, which reserved 50% of a run for escapement, was implemented to increase escapement levels throughout Alaska. Regardless of this statewide effort, runs at Karluk Lake trended lower after the 1920s peak. Runs from the 1940s fluctuated and were cycling lower in the early 1970s.

Prior to 1971, the salmon fishery on the Westside of Kodiak was allowed to operate during most of the year with little restriction; in most areas as much as 5 to 7 days a week. As a consequence, the Karluk sockeye salmon runs were severely depressed. Prior to 1975, all fishing in Kodiak was based on a prearranged weekly fishing schedule that could be rescinded by EO (based on perceived inseason run strength). With the beginning of escapement based management, the fishery opened and closed by emergency (EO) order based on the perceived inseason escapement and run strength (Alaska Commercial Fishing regulations; Finfish 1975). With this change, the fall sockeye fishery on the Westside also became very restrictive (1976 Kodiak AMR; see EO's). ADF&G did not expect that a harvestable Karluk sockeye run would return in one or two cycles, but by 1976 and 1979 Karluk early-run escapements looked stronger (1984 AMR). In the early 1980s, a period of particularly low runs, ADF&G and USFWS began research on the low sockeye salmon population and established an escapement goal (USFWS 1986).

By the mid to late 1980's the Karluk sockeye salmon runs began to see the initial benefits of these significant rebuilding efforts. In 1985 and 1986 both Karluk early and late runs either exceeded or nearly exceeded their respective escapement goals. In the late 1980s runs trended briefly above one million returning adult sockeye salmon (Loewen 2014; Schmidt and others 1998) and from 1985 to 2007 the Karluk early-run either exceeded or nearly exceeded its early-runescapement goal.

A summary of the significant management actions put in place during this time period included:

1) Beginning of State Management [beginning of local or decentralized authority];

2) Outlaw of fish traps (1959/1960) (no longer allowing processors to own fishing permits);

3) Fifteen year [1971-1985] June commercial fishery closure to rebuild Kodiak sockeye salmon stocks; the Kodiak Area was completely closed (with some small exceptions);

4) Establishment of the "Fish Ticket" system (1970) to more accurately monitor the commercial salmon fishery harvest;

5) 1975 Abolition of the weekly fishing schedule (that was determined preseason); commercial openings would be prosecuted via Emergency Order and only based on salmon abundance (i.e. escapement based management);

6) 1970-1975 Major salmon counting weirs were moved from lake outlets to the ocean shoreline to better reflect average run timing in order to use numbers for escapement based management;

7) 1975 Creation of the Commercial Fisheries Entry Commission (CFEC) to limit the numbers of individuals able to fish in the Kodiak Commercial Salmon fishery (i.e. limited entry);

8) 1976 Passing of the Magnuson Stevens Act, and enforcement of the 200 mile boundary;

9) 1988, Westside Kodiak Salmon Management Plan codified in regulation;

10) The Sustainable Salmon Fisheries Policy is created, which is a comprehensive policy for the regulation and management of sustainable salmon fisheries;

11) The policy for statewide salmon escapement goals is created; with the purpose of creating scientifically defendable salmon escapement goals.

The State's management actions have had a lasting effect on the Karluk Sockeye salmon runs. From 1985-2007 escapement of early-run Karluk Lake sockeye exceeded or nearly exceed their respective escapement goals (personal communication, Nick Sagalkin, Alaska Department of Fish and Game) and

sockeye spawning stocks in the Karluk drainage have continued to fluctuate, cycling lower from 2008 to 201, and cycling higher more recently.

Both fish backstocking and nutrient enrichment have occurred in the project area with the aim to increase sockeye salmon runs. Past backstocking efforts conducted from 1978 to 1986 released an estimated 1.0 to 8.5 million juveniles annually into the Karluk system, as fish numbers were increasing, however few data were collected to evaluate the trends in adult runs (escapement) as a result of backstocking and fertilization efforts (e.g., no marking, no treatment groups).

Karluk Lake juvenile sockeye salmon biomass varies widely as described by available data. Monitoring of tertiary productivity, specifically juvenile sockeye salmon production, has occurred periodically throughout the years, and findings have been have been highly variable (Schrof and Honnold 2003; Figure D-1 in Appendix D). Counts of outmigrating smolts using a variety of methods have also varied widely over time. As such, few, if any, reasonable inferences can be made on juvenile sockeye salmon data due to incomparable and inconsistent data.

From 1981 to 2014, runs and escapement sizes of sockeye salmon have varied widely (Figures 7 and 8). However, between 1988, when BEGs were first developed, and 2007, the early-run had the most consistent production of any large sockeye salmon run in the Westward Region (Foster 2008) and was regularly over the upper limit of the BEG. In fact, “overescapement ” occurred in 13 years between 1993 and 2007. More recently, 2001 to 2014 Karluk Lake early-run escapements were above the 10-year average (2004–2013; Fuerst 2014) and exceeded the lower BEG in 10 of those years. During that time escapements were below the average and below the BEG in the 4 years from 2008 to 2011. This period of depressed escapements and runs was followed in 2012 by recovery to above the lower range of the BEG and above the 10-year average (see Figure 9), and runs similar to those in the 2000s. This trend continued into2014.

The late-run has been the most abundant Kodiak-area sockeye salmon run since 1985 (Foster 2014). Late-run fish were within or above the BEG range in 13 of 14 years and below the 10-year average in 6 years (2006–2011). The smallest late run since 1985 was also recorded in 2008 and coincided with a lower early-run during that year. This period of below-average escapements and runs was followed in 2012 by recovery to levels above the 10-year average (Fuerst 2014; see Figure 9) and runs similar to those in the early 2000s (personal communication, Amanda Dorner 2014).

The years of below-average early runs between 2008 and 2011 and the below-average late run in 2008 may be a product of overescapement in previous years, specifically of the early run between 1993 and 2007. It may be that the high number of years with overescapement in the early - and late runs between 1985 and 2007 resulted in large numbers of juveniles for many years between 1985 and 2007 (Foster 2014).

In recent years, however, returning adult populations of sockeye salmon have increased. Early-and late-runs and escapement increased in 2012 (Loewen 2014) and further in 2013 (Moore 2014). Both runs in each year met the BEG (see Figure 9). Weir counts for the early-run in 2014 exceeded the upper BEG (253,857), and weir counts of the late run before removal of the weir on September 8 were within the lower and upper BEG (386,669). Overall, the 2012 to 2014 numbers mark a substantial difference from those recorded between 2008 and 2011 (see Figures 7 and 8). Considering the adult and juvenile population patterns since 1985, this recent increase was not attributed to backstocking and fertilization effort but rather to a complex of factors in the lake and ocean environment and ADF&G management (i.e. escapement).

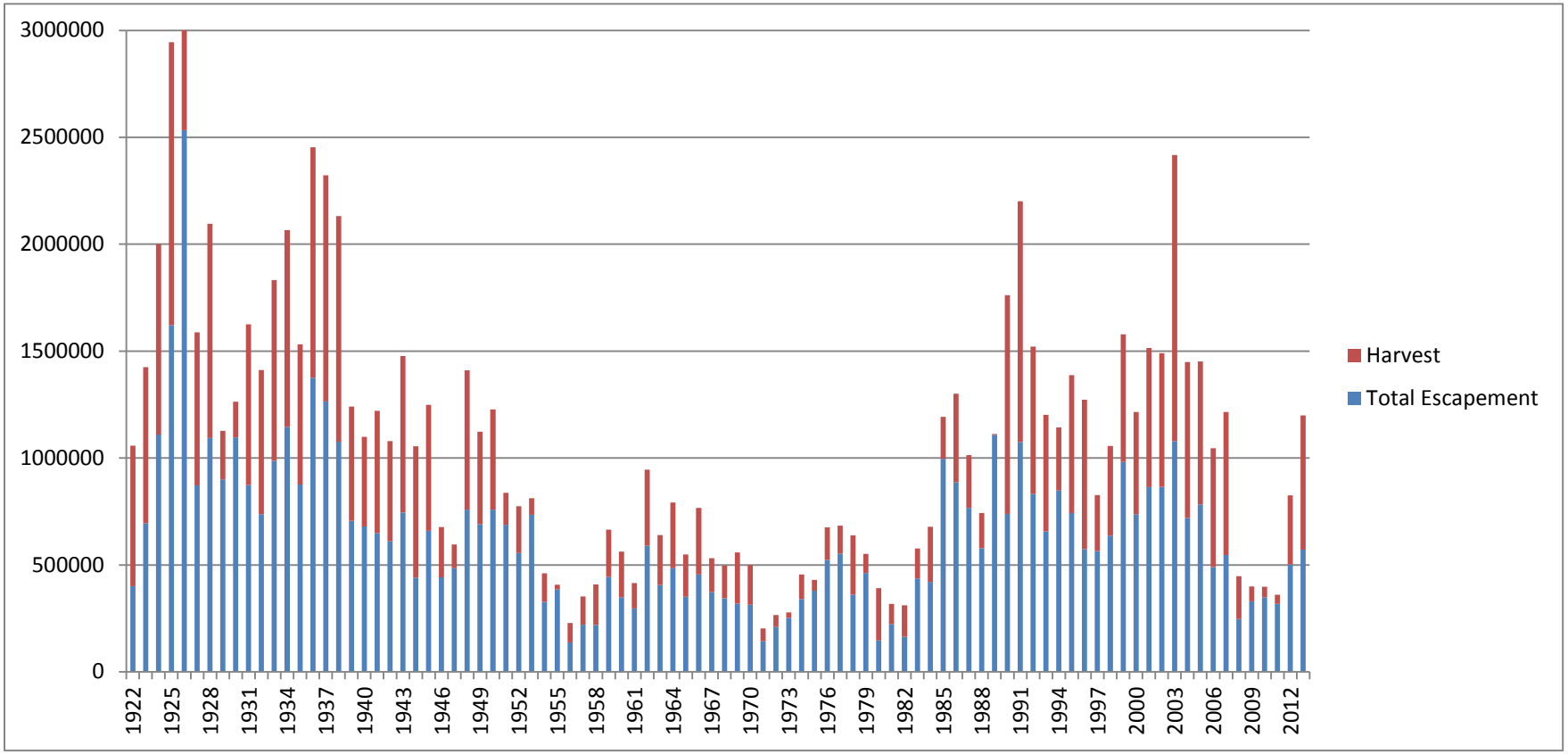

Figure 8. Variability and cyclic nature of sockeye salmon runs in the Karluk Lake basin from 1922 to 2013.

Source: Total escapement data from early- and late runs from 1922 to 1993 are based on lake core data provided by D. Schindler (light blue). Total escapement data after 1993 come from ADF&G management reports. Harvest data from 1922 to 2013 come from Appendix 1 of Schindler and others (1998) and studies cited Barrett and Nelson (1994) and Rounsefell (1958).

Note: Adults in runs have typically spent two to three winters in the ocean, two winters as juveniles in Karluk Lake (three during the early 1990s), and one winter as eggs.

Barrett and Nelson 1994 point to several reasons why caution should be exercised in closely interpreting the harvest data presented.

1926 total escapement and harvest totals 4,919,700 (2,533,400 total escapement and 2,836,300 harvest). 1926 data not fully shown to allow for scale of other years.

The 1989 harvest was curtailed due to the Exxon Valdez oil spill.

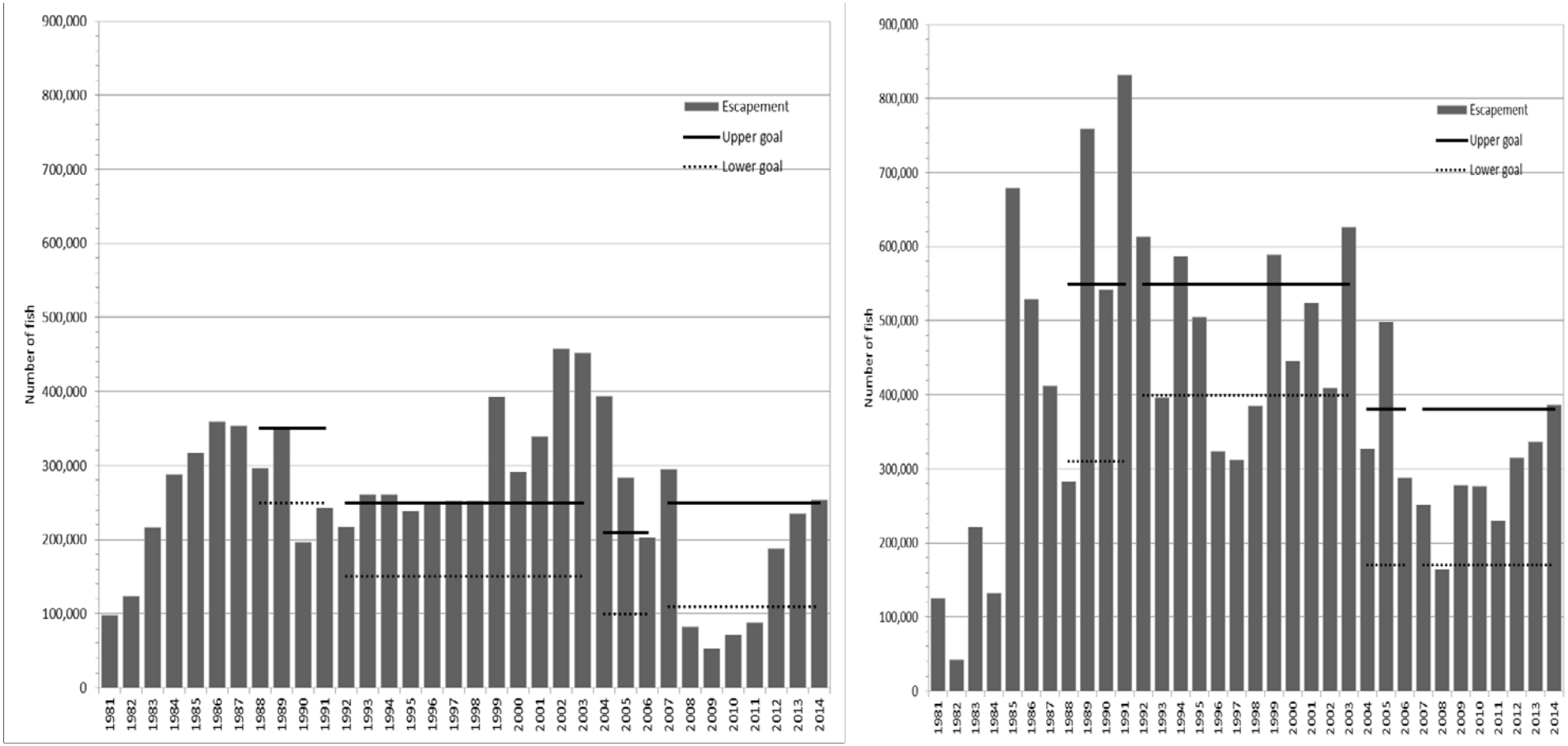

Figure 9. Sockeye salmon historical early (A) and late (B) run escapements and escapement goals in Karluk Lake.

Source: Data through 2012 are from Loewen 2014; 2013 data are from Moore 2014; and 2014 data are preliminary numbers from weir counts.

Notes: Adults in runs have typically spent two to three winters in the ocean, two winters as juveniles in Karluk Lake (three during the early 1990s), and one winter as eggs.

Shift in upper and lower goals reflect changes in goals, which are reviewed triennially by ADF&G.

The 1989 harvest was curtailed due to the Exxon Valdez oil spill.

Sockeye salmon abundance on other river systems throughout the Kodiak Management Area have also fluctuated throughout the years. Comparisons between the systems on the west coast of Kodiak Island (Ayakulik, Frazer, Karluk, Little, Malina, Uganik, and Upper Station) can assist in confirming or rejecting island-wide changes. Unfortunately, run data only exist between 1981 and 2012 for Ayakulik, Frazer, Karluk, and Upper Station and from 1985 onward for Karluk Lake. Runs for all of these systems were highly variable but peaked in 1990 and 1991. Runs then decreased between 1992 and 1994, and the systems all increased again in 1995 or 1996 (Sagalkin and others 2013; Figure 10). The similarities in systems during and immediately after the period of enrichment in Karluk Lake suggest minimal effects from the addition of nutrients. In other words, the Karluk system may have followed the same trends in runs without enrichment. The cause of dissimilarity in systems after 1997 is unknown.

While some argued that the fertilization initiated in 1986 should be credited with the recovery of adult sockeye salmon numbers from low levels in the early 1980s, data from the 1980s are insufficient to conclusively link increased productivity in Karluk Lake, as no summary report was written for the project. Sockeye salmon runs cycled up prior to any possible effect regarding adult returns. In addition, histograms of total run and escapement demonstrate several down and up population cycles unrelated to fertilization through several decades. Finally, other researchers have found strong evidence (strong evidence is defined here as tested hypotheses or conclusions in peer reviewed science journals) credited the population recovery to increased carcass deposition in the 1980s, which was largely driven by the effects of the commercial fishery, and to cyclic climate conditions (Schmidt and others 1998). Finney and others (2000) found strong evidence to suggest that decade-level climate cycles were connected to sockeye salmon productivity. Centennial and millennial time scale climate cycles have become apparent with the analysis of even longer duration data sets (Finney and others 2010).

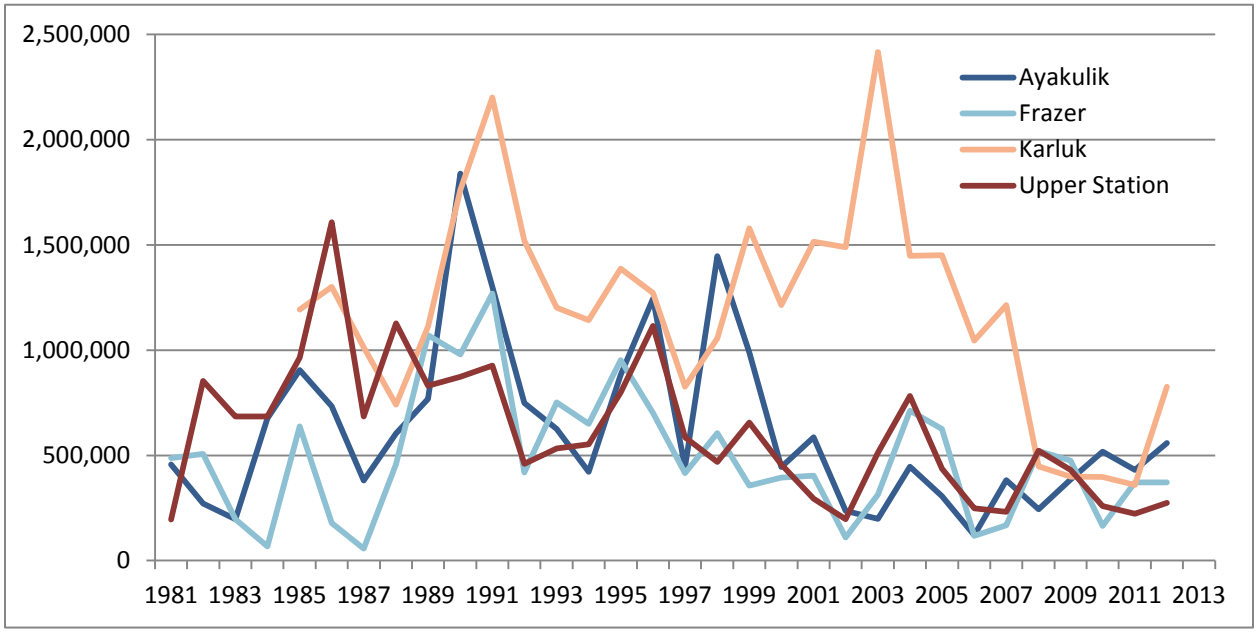

Figure 10. Sockeye salmon historical run sizes for systems on the west coast of Kodiak Island.

Source: Sagalkin and others 2013.

Notes: Adults in runs have typically spent two to three winters in the ocean, two winters as juveniles in Karluk Lake (three during the early 1990s), and one winter as eggs.

3.4.2. Historical Limnology Trends

The first scientific studies on the limnology of Karluk Lake were conducted in the 1920s, after the Karluk River weir was constructed in 1921. These studies were initiated to determine if a reliable correlation between salmon escapement population size and the number of resulting offspring existed. Results from the 1920s work provide the first values of physical, chemical, and biological measurements of Karluk Lake. All values were very similar to the most recent measurements on Karluk Lake, except for TP, which was 2.6 times greater in 1927–1930 than it was in 2013 (Table 4). Given that the soluble reactive phosphorus (i.e., that portion of the TP concentration that is most immediately available for biologic uptake) concentrations are identical for both time periods; this difference in TP is potentially attributable to much lower concentrations of organic phosphorus in 2013 than in 1927–1930. It is possible that the assumed lower organic phosphorus concentrations in 2013 are a result of lower salmon escapements relative to escapements from the 1920s, as salmon are the primary source of organic phosphorus to Karluk Lake (Schmidt and others 1998). Differences in phytoplankton density between the two measurement periods are likely related to changes in methodology and inclusion of additional phytoplankton not considered in the 1927–1930 measurements (e.g., Chrysophyta, Pyrrophyta, and Euglenophyta).

Table 4. Comparison of Karluk Lake Physical, Chemical, and Biological Parameters

Parameter	Value		Units
	1927–1930*	2013	
Secchi depth	7.0	8.2	m
Epilimnion depth	8	8	m
Metalimnion depth	8–15	8–20	m
pH	8.2	7.96	-
Total phosphorus	15.2	5.8	ppb
Soluble reactive phosphorus†	2.1	2.1	ppb
Organic phosphorus	13.0	NA	ppb
Silica	167	135	ppb
Ammonia	7	18.1	ppb
Nitrite	0	NA	ppb
Nitrate	27.3	35.1‡	ppb
Phytoplankton density	15,249,000	86,919,000	$\#/m^3$
Zooplankton density	34,000	34,492	$\#/m^3$

* Source: Juday and others (1932). All chemical values are averaged across depths and stations from July–August 1927. All plankton density values are average across years (1927–1930) and stations. Zooplankton density only includes cladocera and copepoda.

† Note that Juday and others (1932) partitions total phosphorus into soluble reactive phosphorus (SRP) and organic phosphorus (which at the time also included particulate phosphorus [PP]) components. 2013 measurements only include TP and SRP, and the difference between TP and SRP is the sum of soluble unreactive phosphorus (which consists largely of soluble organic phosphorus) and PP (i.e., TP = SRP + soluble unreactive phosphorus + PP), or the equivalent to the "organic phosphorus" form named by Juday and others

‡ Nitrate + nitrite. It is assumed that nitrite concentrations are negligible.

NA = Not applicable. Information is not available.

3.4.3. Zooplankton and Phytoplankton Trends

Evaluation of zooplankton and phytoplankton trends is fairly difficult, as data collection has occurred periodically throughout the years. Findings have been highly variable, and differences in number of years compared should be noted. Figure 11 and Table D-1 in Appendix D provide a summary of all available phosphorus and chlorophyll *a* concentrations at Karluk Lake from 1980 to 2013.

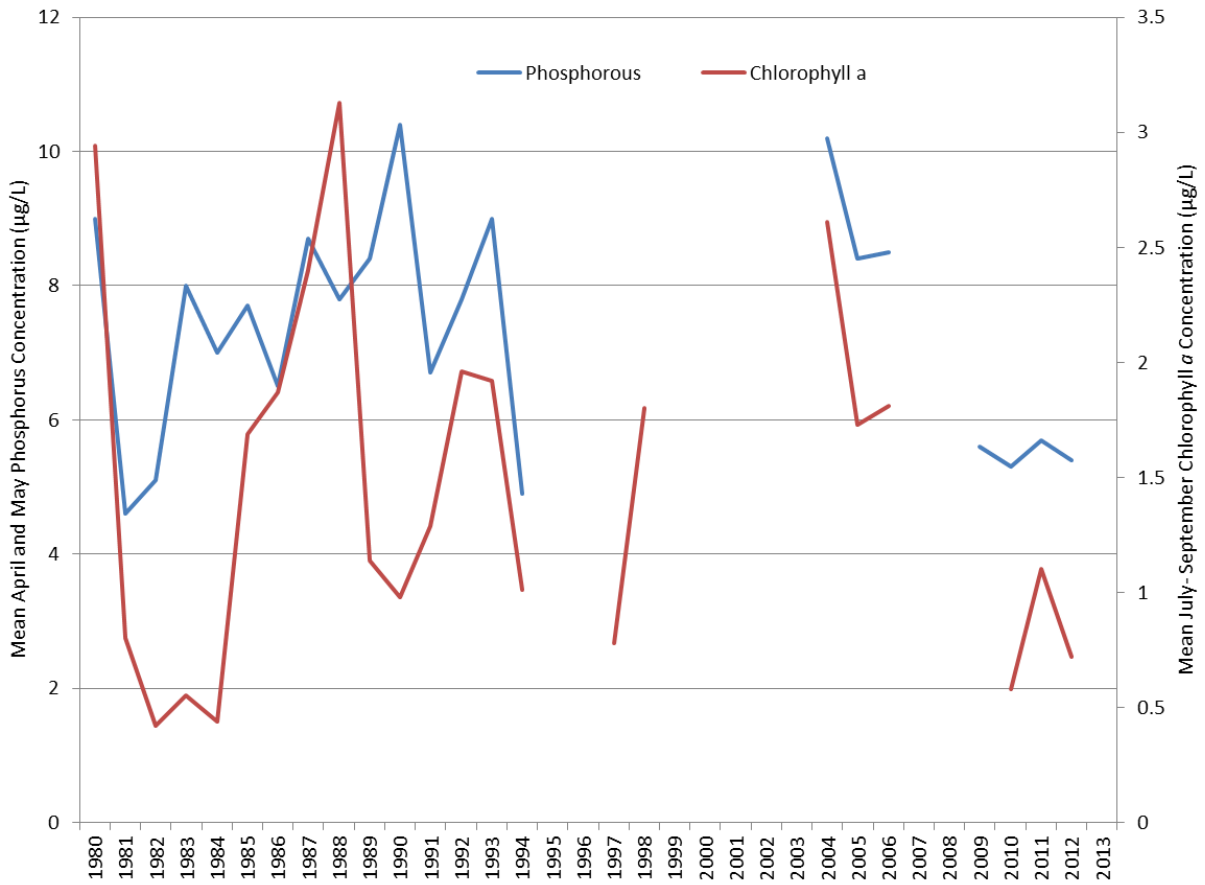

Figure 11. Mean phosphorus and chlorophyll a concentrations from 1980 to 2013.

Source: ADF&G 2013 and Fairbanks 2013.

Figure 12 and Table D-1 in Appendix D provide a summary of all available zooplankton data at Karluk Lake from 1980 to 2013. During this time, outmigrating smolt were predominantly age-3 as opposed to age-2 (Moore 2014). This increased time in fresh water for juvenile sockeye salmon is associated with poor rearing conditions (Koenings and Burkett 1987a).

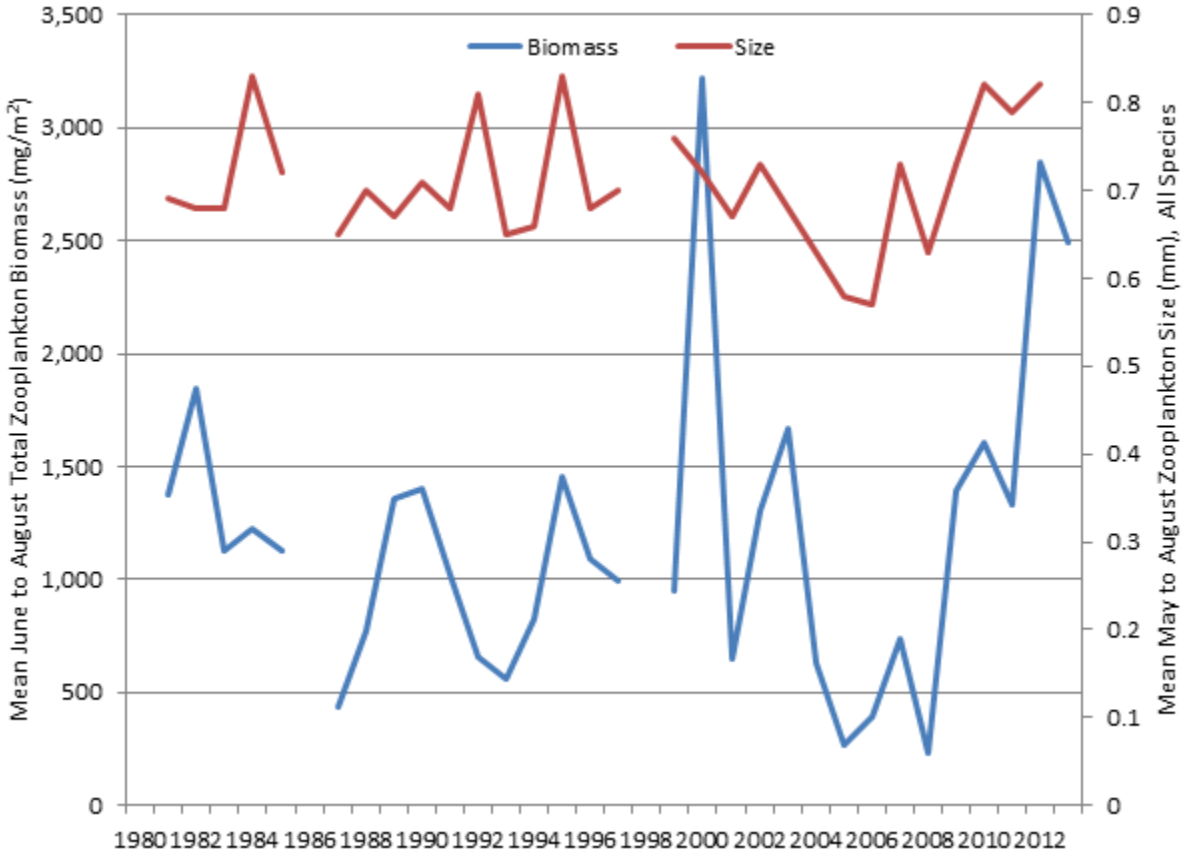

Figure 12. Mean zooplankton biomass and zooplankton size from 1980 to 2013.

Source: ADF&G Limnology Lab data (2013c) and Fairbanks (2013).

Overall, with the available data, the lack of consistent trends (among years and before, during, and after enrichment) among phosphorus concentrations, chlorophyll *a* concentrations, zooplankton biomass, and juvenile estimates (presented in Section 3.4.1) suggests that the trophic web in the lake is not simply controlled by the amount of nutrients present. Gaps and inconsistency in data tables make conclusions regarding the relationship between nutrients, primary producers, and primary consumers difficult; however, researchers have concluded that carcass deposition within the lake is likely the strongest driver of lake productivity after drivers found outside the study areas—most importantly, commercial fish harvest (by changing the MDN returning to the drainage), and second, climate cycles (Finney and others 1998; Rogers and others 2013; Schmidt and others 1998).

3.5. Wildlife and Vegetation

This section describes the botanical and wildlife resources that are present in the project area. Information on plant and wildlife species and vegetation communities was obtained from the Kodiak Refuge CCP (USFWS 2008), the National Land Cover Database (NLCD; Fry and others 2011), publications in peer-reviewed journals, unpublished reports of research conducted by or for the Kodiak Refuge, and Service and ADF&G web pages on federal and Alaska listed and sensitive species.

3.5.1. Mammals

3.5.1.1. BROWN BEAR

Brown bears in the project area are strongly linked with sockeye salmon and other salmon because they feed heavily on salmon when they are seasonally abundant (Barnes 1990; Gard 1971). Bears also enrich riparian and upland zones with MDN when they transport salmon carcasses away from waterbodies (Gende and others 2001; Gende and others 2002; Reimchen 2000). The Refuge and ADF&G periodically conduct aerial surveys of the abundance of brown bear in different regions of Kodiak Island. In the Karluk Lake area, surveys were completed in 1994, 2004, and 2013. Results from these surveys document the trend in bear abundance, and are considered a primary tool of bear population management. Surveys conducted 1994 and 2003 revealed that the Karluk Lake area supported an estimated 1.04-1.25 independent bears (excluding dependent young) per square mile, the highest density documented on Kodiak Island (Van Daele 2003, Barnes and Smith 1998). Results from the 2013 survey revealed that density had declined to 0.64 independent bears per square mile, a 48% decrease since the 2003 survey (Van Daele 2013). It is unknown if this decline is restricted to the Karluk basin or is more widespread (e.g. southwest Kodiak Island).

Refuge biologists suspected the decline may be due to a major reduction in the availability of two primary, seasonal food sources—stream-spawning sockeye salmon (early-run stock) and berries (red elderberry and salmonberry)—during 2008-2011. While the Refuge, ADF&G, Koniag, and some members of the public strongly suspect that bears were adversely affected by the reduction in availability of the early-run stock, it has also been observed that resource selection for food by many bears is complex and not driven exclusively by the presence of sockeye salmon. There are currently few empirical data that quantify the specific relationship between the abundance of sockeye salmon, bear use, and bear nutritional condition. It is also likely that the lack of key seasonal foods in the Karluk Lake area forced bears traditionally reliant on these resources to seek alternative resources, resulting in increased travel and competition at stream sites occupied by other bears. For bears that traditionally relied on food resources in the Karluk Lake area during mid-summer, the consequence was reduced nutritional condition, productivity of maternal females, and survival of cubs. This potential outcome is supported by comparison of bear stream use in southwestern Kodiak Island before and during the period of diminished availability of key foods (Leacock 2014).

Identified areas of seasonal bear concentration include the lower reaches of all lateral tributaries of Karluk Lake, various shoal areas of the Karluk Lake shoreline, and the Karluk Lake outlet and river downstream for approximately 3.1 miles. During early July to mid-August, bears congregate O'Malley River, Thumb River, Canyon Creek, Cascade Creek, Meadow Creek, Moraine Creek, and Cottonwood Creek in large numbers to feed on early-run, stream-spawning sockeye salmon (Fischbach and Reynolds 2005, Barnes 1998, Wilker and Barnes 1998). During late summer and early fall, bear distribution shifts in response to the shift in salmon distribution and availability. During September-November bears commonly forage in lake-shoal areas for late-run sockeye salmon (Fischbach and Reynolds 2005). The largest concentrations of lakeshore foraging bears occur in the largest areas of shoals adjacent to O'Malley River and Thumb River (Refuge files, unpublished data). In addition, the O'Malley-Cascade-Canyon Creek drainage is regarded as a high bear-use area and is closed to visitors from June 25 to September 30, except for a guided bear viewing area on O'Malley Creek (Refuge files, unpublished data, Wilker and Barnes 1998).

3.5.1.2. OTHER MAMMAL SPECIES

A limited number of other native and introduced mammal species are present in the project area. Resident river otter and red fox seasonally use salmon as a food source.

3.5.2. Birds

3.5.2.1. SENSITIVE BIRD SPECIES

Of ADF&G-identified avian sensitive species in Alaska, five are known to occur or be likely to occur in the project area (ADF&G 2006; USFWS 2008). All of these are fish-eating species for which potential nesting habitat is present at Karluk Lake and its tributaries (USFWS 2008): red-throated loon (*Gavia stellata*), red-necked grebe (*Podiceps grisegena*), Arctic tern (*Sterna paradisaea*), Aleutian tern (*S. aleutica*), and possibly marbled murrelet (*Brachyramphus marmoratus*). The harlequin duck (*Histrionicus histrionicus*) is not on the ADF&G (2006) list but is considered sensitive by the Kodiak Refuge. Zweifelhofer (2005a) reported that harlequin ducks appeared to prefer the upper 3 miles of the Karluk River during the nesting and brood-rearing periods, although birds have also been observed on Karluk Lake (Zweifelhofer 2005b).

3.5.2.2. OTHER BIRD SPECIES

The bald eagle is abundant in Kodiak Refuge and is the most common fish-eating bird of prey in the Karluk Lake vicinity. The portions of the project area adjacent to Karluk Lake are have supported very high (mean of ≥4 active nests/plot) or high (mean of 2 to <4 active nests/plot) densities of nesting bald eagles (Zweifelhofer 2002).

A number of other bird species occupy the project area on a seasonal or year-round basis (USFWS 2008). Gulls and terns, loons, northwestern crows (*Corvus caurinus*), common ravens (*C. corax*), black-billed magpies (*Pica pica*), and belted kingfishers (*Ceryl alcyon*) all consume live fish or scavenge carcasses, including juvenile and adult salmon. During waterfowl surveys, Zweifelhofer (2005b) also identified nine nesting duck species in Karluk Lake and Karluk River (in addition to the harlequin duck addressed above): American wigeon (*Anas americana*), green-winged teal (*A. discors*), northern pintail (*A. acuta*), gadwall (*A. strepera*), mallard (*A. platyrhynchos*), Barrow's goldeneye, greater scaup (*Aythya marila*), common merganser (*Mergus merganser*), and red-breasted merganser (*M. serrator*). Of these nine species, the two mergansers regularly consume small fish including young salmon.

3.5.3. Habitat

The project area is a part of the Kodiak Archipelago Ecoregion (Nowacki and others 2000; Nowacki and others 2001). Within the Karluk Lake Basin, landcover is comprised mainly of a mixture of classes, some of which are dominated by herbs and others by shrubs and trees (Table 5). Whereas forest and woodland classes tends to dominate lowlands (below about 1,200 foot elevation), herb-dominated classes tend to occur at higher elevations. Wetland vegetation commonly occur along streams and in sites with perched water tables (National Wetlands Inventory data).

Table 5. Vegetation Classes Present in the Project Area

Vegetation Type	Acreage	Percent of Project Area (%)
Alder	22,862	40
Upland meadow	13,820	24

Alpine tundra	8,097	14
Willow	4,713	8
Birch-cottonwood forest	3,585	6
Fragmented rock	2,484	4
Bedrock	719	1
Mixed shrub	188	<1
Lowland heath	164	<1
Shrub wetland	85	<1
Graminoid wetland	62	<1
Salmonberry	15	<1
Graminoid	12	<1
Aquatics	1	<1

Source: Fleming and Spencer (2007).

No rare plants are known to occur within the project area. Non-native invasive plants are uncommon in the project area; however, on Camp Island, the Service is working on eradicating a population of orange hawkweed (USFWS 2008).

3.6. Subsistence Use and Resources

Information on these issues was obtained using the Kodiak Refuge CCP (USFWS 2008), ADF&G Community Subsistence Information System (CSIS; ADF&G 2013d) and ADF&G reports. For this section, “local users” refer to federally eligible subsistence users for the area, which includes all residents of Kodiak Island. “Non-local users” refers to Alaska residents outside of Kodiak Island and residents of other states and countries.

ADF&G gathers information regarding subsistence use and resources by the community and publishes this information via the ADF&G CSIS. As such, this section introduces the availability and use of subsistence resources for the communities closest to Karluk Lake: Karluk and Larsen Bay. Reported subsistence activity for residents in these communities includes, but does not exclusively occur within, the project area. Residents may also travel to other locations to obtain subsistence resources. Subsistence use and resources for these two communities are summarized below.

According to CSIS data, 100% of Karluk and Larsen Bay households use subsistence resources (ADF&G 2013d). Subsistence resources used by residents consist of fish, land mammals, marine mammals, birds and their eggs, marine invertebrates, and vegetation (Tables 6 and 7).

Table 6. Subsistence Resource Categories Use by Karluk Residents

Resource	Percent Using	Percent Attempting to Harvest	Percent Harvesting	Percent Receiving	Percent Giving	Per Capita Harvest (lbs)
All resources combined	100.0	100.0	100.0	100.0	100.0	268.7
Fish	100.0	100.0	100.0	84.6	100.0	222.2
Salmon	100.0	100.0	100.0	69.2	100.0	192.2
Non-salmon	100.0	76.9	76.9	84.6	69.2	30.0
Land mammals	100.0	69.2	61.5	92.3	76.9	29.8

Large	100.0	69.2	61.5	92.3	76.9	29.7
Small	15.4	23.1	15.4	0.0	15.4	0.03
Marine mammals	38.5	23.1	7.7	30.8	15.4	0.9
Marine invertebrates	84.6	76.9	76.9	76.9	76.9	4.3
Birds and eggs	53.8	38.5	30.8	38.5	38.5	1.1
Vegetation	100	92.3	92.3	69.2	76.9	10.3

Source: ADF&G (2013d).

Note: Information is for the most representative reporting year for Karluk (1991).

Table 7. Subsistence Resource Categories Use by Larsen Bay Residents

Resource	Percent Using	Percent Attempting to Harvest	Percent Harvesting	Percent Receiving	Percent Giving	Per Capita Harvest (lbs)
All resources combined	100.0	96.0	92.0	72.0	92.0	326.4
Fish	96.0	72.0	72.0	60.0	76.0	238.1
Salmon	96.0	56.0	56.0	44.0	56.0	181.0
Non-salmon	80.0	56.0	56.0	44.0	64.0	57.1
Land mammals	84.0	28.0	28.0	32.0	72.0	18.9
Large	84.0	28.0	28.0	32.0	72.0	18.6
Small	12.0	8.0	8.0	0.0	4.0	0.24
Marine mammals	24.0	4.0	4.0	4.0	20.0	2.2
Marine invertebrates	56.0	36.0	36.0	44.0	36.0	50.6
Birds and eggs	20.0	16.0	12.0	12.0	12.0	0.8
Vegetation	72.0	76.0	72.0	52.0	12.0	15.8

Source: ADF&G (2013d).

Note: Information is for the most representative reporting year for Larsen Bay (2003).

3.6.1. Fishes

All salmon species that occur in Alaska are important subsistence resources for rural residents of the Kodiak Archipelago, including those inhabiting the communities of Larsen Bay and Karluk. The most common salmon species harvested by Karluk and Larsen Bay residents are sockeye salmon, followed by coho salmon (ADF&G 2013d). Non-salmonoid fish, such as Dolly Varden, steelhead, and rainbow trout, are also harvested by Karluk and Larsen Bay residents (ADF&G 2013d). Despite fluctuations in sockeye salmon abundance, the supply has usually been sufficient to meet the traditional harvest needs of residents of Karluk and Larsen Bay. Other salmonid populations in the project area have generally increased or remained steady, with the exception of Chinook salmon, which has experienced declines in annual runs all across the state of Alaska since around 2007.

Most subsistence harvest of fish occurs via boat at the Karluk Lagoon by gillnets where the Karluk River enters Shelikof Strait. Table 8 shows subsistence harvest by salmon species for the Karluk Lagoon area from 2000 to 2013. There are very few physical or legal restrictions on local rural residents accessing fish. The subsistence fishery for sockeye salmon has only been closed once, for a period of two days, in 2008, because of early season concerns over meeting escapement goals. Access to fish for subsistence harvest currently is likely most affected by the price of gasoline for running outboard motors. Local and non-local residents may compete for salmon fishing opportunities, as many residents of communities around Kodiak Island travel to the project area to harvest sockeye salmon (ADF&G 2013e). Commercial

fishers can legally retain a portion of their catch for personal use and this practice is common. Though unquantified, it is possible that this type of personal use accounts for much of the non-commercial harvest of Karluk River-bound sockeye salmon, including subsistence.

Table 8. Number of Subsistence Permits Fished and Harvest of Salmon by Species in the Karluk Lagoon Area from 2000–2013

Year	Permits Fished	Chinook Harvest	Sockeye Harvest	Coho Harvest	Pink Harvest	Chum Harvest	Total Harvest
2000	6	22	618	20	20	0	680
2001	16	24	1,157	33	0	28	1,242
2002	14	165	792	50	10	0	1,017
2003	15	6	820	12	10	0	848
2004	12	15	865	8	0	0	888
2005	8	5	744	23	0	0	772
2006	15	17	814	67	5	0	903
2007	11	1	495	25	1	0	522
2008	8	5	768	10	20	5	808
2009	5	0	223	15	0	0	238
2010	6	0	127	15	5	0	147
2011	6	2	276	16	0	0	294
2012	6	0	172	12	0	0	184
2013	10	0	417	0	0	0	417

Source: ADF&G (2014c).

3.6.2. Terrestrial Mammals

Sitka black-tailed deer represent the vast majority of terrestrial mammal harvest by Karluk and Larsen Bay residents. Over 80% of all households in both communities reported using deer for subsistence (ADF&G 2013d). Abundance and availability of deer for subsistence harvest is highly dependent on snow depth and winter conditions. During consecutive mild winters on deer winter range, there is low deer mortality and population increase. However, during years of persistent high snowpack on winter range, deer mortality is extensive and the population declines. These fluctuations in deer populations have affected Karluk and Larsen Bay residents' ability to harvest deer in years following harsh winters and declining deer numbers (ADF&G 2011).

The communities of Karluk and Larsen Bay currently access the project area for deer mainly by all-terrain vehicle and by foot. However, most of the deer harvest occurs near beaches accessed by boat outside the project area. Local subsistence users currently have competition from non-local Alaska residents and from non-residents in the harvest of Sitka black-tailed deer.

3.6.3. Birds and Bird Eggs

Bird harvest primarily consists of ducks and ptarmigan (ADF&G 2013d). The communities of Karluk and Larsen Bay currently access the project area for birds and bird egg harvest, predominantly by boat and by foot. Most subsistence harvest of waterfowl and bird eggs occurs along beaches, riparian areas, or freshwater streams and lakes. Ptarmigan harvest generally occurs in subalpine and alpine habitats. Local

subsistence users currently have competition from non-local Alaska residents and from non-residents in the harvest of waterfowl and ptarmigan. In addition, only Native Alaskans can harvest migratory bird eggs under the Migratory Bird Treaty Act.

3.6.4. Vegetation

Berries and wild greens are widely available throughout the project area during the growing season and are used by Karluk and Larsen Bay residents. Harvest of these resources by subsistence users generally occurs in the lower reaches of the project area only and would likely not be affected by project actions. As such, these subsistence resources are not included for detailed analysis in this EA.

3.6.5. Marine Mammal and Marine Invertebrates

Marine invertebrates and mammals are found in Shelikof Strait and are important subsistence resources for Karluk and Larsen Bay residents. Harvest of these resources by subsistence users may occasionally occur in the lower reaches of the project area if marine invertebrate and marine mammals enter Karluk River in search of food and would not be affected by project actions. As such, these subsistence resources are not included for detailed analysis in this EA,

3.7. Recreation

Existing recreational uses in the project area are consistent with the NWRS Improvement Act's six wildlife-dependent recreational use priorities: hunting, fishing, wildlife observation and photography, and environmental education and interpretation. According to the Kodiak Refuge CCP, the main recreational activities pursued by visitors on the refuge are hunting (bear, deer, goat, and elk) and wildlife viewing. Over half of Kodiak Refuge visitors pursue these recreational activities with the aid of local guides who hold permits issued by Kodiak Refuge. Approximately 100 people recreate in the area annually. Users come from within and outside the local area (Kodiak) for the high-quality recreation opportunity the Karluk area provides.

Tourists are drawn to Karluk Lake for wildlife viewing, especially bear-viewing, and the general allure of recreating in the remote confines of Kodiak Island. The lake tourism industry is supported by businesses in Larsen Bay and Kodiak, which supply transportation and fishing and recreational supplies to Karluk Lake. Recreation and tourism on lands managed by Koniag, Inc. are regulated by the Koniag, Inc. Lands Department. In 2014, Koniag, Inc. implemented a land access permit system for public access to its lands. Public recreation, both guided and unguided, is only allowed on Koniag, Inc. lands with purchase of a land access permit. Furthermore, certain restrictions also apply to public access. These restrictions include designated camping areas and group size limits for camping along the Karluk River, closure of the upper river and lower shores of Karluk Lake to camping and unguided hunting, and closure of all public access on Koniag, Inc. lands along Karluk Lake from the lower shore restriction area up to the Refuge boundary (Koniag, Inc. lands along the middle of Karluk Lake).

To further facilitate tourism at Karluk Lake, Koniag, Inc. constructed lodging facilities on Camp Island in 2012. Visitors to the Kodiak Brown Bear Center, which includes lodging facilities, participate in wildlife viewing with a focus on Kodiak brown bear, fishing, and environmental education. Revenue generated by tourism at Camp Island supports the shareholders of Koniag, Inc.

3.8. Socioeconomics and Land Use

3.8.1. Socioeconomics

No permanent residences exist adjacent to Karluk Lake. Public use of Karluk Lake comes from Kodiak Refuge visitors, Koniag, Inc. (the adjacent land owner) visitors, the nearby local communities of Karluk and Larsen Bay, and lodges in the area that use the lake and surrounding lands for subsistence resource harvesting, recreation, and/or tourism activities that support the local economy and Koniag, Inc. shareholders.

The closest year-round population centers to the project area are in Karluk[2] and Larsen Bay. In 2010, the population of Karluk was 37 people and the population of Larsen Bay was 87 (U.S. Census Bureau 2013a). According to American Community Survey 5-Year Estimates, the median household income in Karluk during 2007–2011 was $37,083, and the percentage of families living below poverty level was 37.5% (U.S. Census Bureau 2013b). For the same time period, in Larsen Bay the median household income was $71,000 (U.S. Census Bureau 2013b). Much of Larsen Bay's economy comes from commercial fishing (ADCCED 2014). Data for families living below poverty level in Larsen Bay are not currently available.

The Karluk stocks of sockeye salmon provide an important component of a diverse Kodiak fishing industry. Total receipts for all seafood harvest in the Kodiak Island Borough were approximately $130 million (CFEC 2014). The total receipts for all commercially harvested salmon in the Kodiak Island Borough in 2013 were $43 million, about one third of the total seafood harvest income (CFEC 2014). Karluk sockeye salmon stocks contribute 49 percent of total sockeye salmon harvest for the Kodiak NW District (Keyse 2014) and 6.4% of all total seafood harvest receipts ($8.3 million).

3.8.2. Service Management and Land Use

Land management for lands under the jurisdiction of the refuge is guided by laws, regulations, and policies and by the *Revised Comprehensive Conservation Plan of Kodiak National Wildlife Refuge*. Management direction and goals of the refuge that are applicable to Karluk Lake and adjacent lands are identified in Chapter 1. Current refuge management activities are listed as part of the No Action Alternative in Chapter 2.

3.8.3. Koniag, Inc. Management and Land Use

As the Kodiak Archipelago's Regional ANCSA Alaska Native Corporation, Koniag is entrusted with making management decisions that are most beneficial to its shareholders and their descendants, while ensuring these management decisions will result in responsible resource development through conservation and stewardship. Use of Koniag, Inc. lands in the Karluk watershed is specifically managed for the following priority activities (personal communication, Matthew Van Daele 2014):

- Protection of subsistence opportunities and archaeological resources
- Tourism and natural resources education through the Kodiak Brown Bear Center
- Hunting, fishing, camping, and other permitted public uses
- Collaboration with State and Federal partners for cooperative resource management and research

[2] The U.S. census referred to the Karluk area as the Karluk census-designated place (CDP).

3.9. Cultural Resources

This section describes cultural resources that are present in the project area. Information on these resources was obtained from the Kodiak Refuge CCP (USFWS 2008), scientific journals and reports, and personal communication with local experts.

3.9.1. Cultural History

The indigenous people of the Kodiak Archipelago are today known as the Alutiiq. Archaeological evidence suggests that their ancestors arrived on the archipelago around 7,300 calibrated years before present (B.P.) (Steffian and others 2002). Their prehistory (the time before written records) on the Kodiak Archipelago has been broken into three cultural phases by archaeologists based on technology, tool types, house structure, and settlement size. These three cultural phases are known as Ocean Bay (7300–3800 B.P.), Kachemak (3800–800 B.P.), and Koniag (800–230 B.P.). Residents of the Ocean Bay Phase likely lived in small groups in tents and shallow semi-subterranean houses, leaving few surface features behind (Steffian and others 2006). During the Kachemak Phase, the Alutiiq built the first true villages and significant semi-subterranean houses and began using nets to capture salmon in large quantities (Steffian and others 2006). In the later Koniag Phase, the Alutiiq congregated into large winter villages while continuing to use smaller camps for seasonal resource gathering. Preserved animal bones in several sites demonstrate that the harvest and storage of anadromous fish became increasingly important throughout the Koniag Phase (Partlow 2000; West 2009).

3.9.2. Cultural Resources Inventory

For the purpose of this analysis, the project area (also referred to as the area of potential effects [APE]) was determined to be 164 feet (50 m) from the shores of Karluk Lake, O'Malley Lake, O'Malley River, Thumb Lake, and Thumb River, based on the likely inland extent of proposed actions. A literature review of the Alaska Heritage Resources Survey (AHRS) and of the Alutiiq Museum's report of their 2008 and 2009 surveys (Saltonstall and Steffian 2010) identified 40 archaeological sites within this APE. Thirty of the sites contain prehistoric deposits (nine of which are encompassed by the Thumb River Archaeological District), and 11 sites contain historic-period remains within the APE (one site contains both historic-period and prehistoric deposits).

The recorded prehistoric sites in the project area consist of surface depressions, buried deposits, and faunal middens spanning the Ocean Bay, Kachemak, and Koniag Phases (Saltonstall and Steffian 2010). Historic-period remains recorded in the project area consist of surface artifacts, depressions, foundations, and structural remains of cabins. The surface features and debris appear to be related to twentieth-century hunting, fishing, and recreation, mid-twentieth-century bear guiding, and possibly World War II Navy activities.

The project area may be considered to be a property with traditional religious and cultural importance (as defined by the NHPA, Section 101(d)(6)(A) (personal communication, Debbie Corbett 2013). At this time, the project area is not designated as such, and this EA only assesses the potential effects of the action alternatives on archaeological sites.

4. ENVIRONMENTAL CONSEQUENCES

4.1. Introduction

The following sections examine the potential impacts associated with the alternatives on aquatic resources; cultural resources; public uses; refuge management direction; terrestrial resources; and water quality. Impacts (or effects) are modifications to the existing environment and on humans brought about by an action. Impacts can be beneficial or adverse; they can result from the action directly or indirectly; and they can be temporary, permanent, or cumulative in nature. Direct impacts from a proposed project affect a specific resource and generally occur at the same time and place as the action. Indirect impacts can result from one resource affecting another (e.g., soil erosion and sedimentation affecting water resources) or can occur later in time or be removed in location. Cumulative effects result from the incremental effects of an action when added to other past, present, and reasonably foreseeable future actions not linked to this project. Direct and indirect effects are described in this chapter. Cumulative effects are discussed in Chapter 5.

4.2. Aquatic Resources

4.2.1. Effects Common to All Alternatives

Escapement goals, set by the Alaska Board of Fish, would remain unchanged at least until the next periodic review in 2016. Escapement goals could be revised by the Alaska Board of Fish as stipulated in their regulations.

Regardless of project actions, global climate change is expected to continue to influence long-term productivity of Pacific salmon populations via shifts in freshwater temperatures (Schindler and others 2008) and ocean temperature regimes (Rogers and others 2013). Previous research has indicated that increased water temperature can affect invertebrate and algae abundance and composition (Piggott and others 2012), which can have a cascading adverse effect through the food web and promote species that are undesirable for salmon production. In addition, increasing lake temperatures have been shown to advance the timing of stratification and phytoplankton blooms. Zooplankton species have variable ability to adapt to these changes, resulting in population and composition change (Winder and Schindler 2004). Within the Karluk watershed, the effects related to global climate have yet to be documented.

4.2.2. Alternative A (No Action)

Under the No Action Alternative, sockeye salmon and their habitat would continue to be evaluated through harvest reporting, lake limnological assessment, and smolt outmigration and escapement monitoring (see Section 2.4). Assuming long-term cyclical trends continue, the early- and late-run sockeye salmon escapement goals would be met in most years, and a sufficient number of spawning adults would escape to spawning grounds to ensure healthy future runs. These goals have been met in the previous 3 years for the early -run and the previous 6 years for the late run. Overall, the early-runs have increased since 2009 and late-runs have increased since 2011. It appears that sockeye runs are trending upward.

Data from Schmidt and others (1998) show that carcasses are an important driver of salmon productivity and run size within a watershed, and sustainable runs appear to be possible given the major drivers, harvest, escapement, and climate cycles. Given recent conclusions by Rogers and others in 2013, models that assume constant productivity or run size cannot reasonably be expected. Wild salmon runs fluctuate.

Thus, in the No Action Alternative we should expect further variation in both productivity and carrying capacity of the ecological systems that support the sockeye salmon runs of Karluk Lake. There would be no change in interspecies competition, predation among salmonoid and non-salmonoid fish, or community ecology in the Karluk system for the No Action Alternative, although these factors would continue to be influenced by fluctuations in forage and population size, as noted above.

The No Action Alternative would retain genetic structure and fitness in Karluk Lake sockeye salmon stocks. In addition, the No Action Alternative would likely lower variability of adult returns and stabilize ecosystem services provide on the Refuge (Schindler and others 2010).

4.2.3. Alternative B (Proposed Action; Lake Nutrient Enrichment)

Under Alternative B, the Proposed Action would add nutrients (phosphorus and nitrogen) to Karluk Lake to stimulate primary production (measured as chlorophyll *a*; see Section 4.3, Water Quality, for more details). Fertilization of the lake would increase phytoplankton in the lake and could result in the following chain of effects:

- An increased zooplankton biomass in Karluk Lake; and
- An increased body size and improved body condition of sockeye salmon smolts;

We evaluated the Proposed Action, in part, by examining the outcomes of the previous nutrient enrichment project conducted in the mid-1980s: (1) in light of other limnological/fisheries literature from Karluk Lake; (2) in comparison with data from other lakes in Southwest Alaska and the Kodiak archipelago; and (3) in consideration of broader long-term climate data provided by proxies for escapement in lake sediment cores.

Examination of published literature regarding the mid-1980s fertilization project is instructive in predicting the potential outcome of the Proposed Action. Schmidt and others (1998) documented a trend of increased phytoplankton with increased phosphorus, and decreased phytoplankton with increased zooplankton. Carcass availability (i.e., carcass deposition via escapement) was the significant factor (when considered along with fertilization) in loading phosphorus into the Karluk system and the retention of phosphorus into the following spring. In that study, fertilization was not similarly credited. These findings highlight that assumptions presented as part of the Proposed Action are not necessarily supported by data. Hypotheses lacking support include the following:

- There is a link between fertilization and the quantity of fry.
- There is a link between fertilization and the production of smolts.

It should be noted that egg deposition, fry quantity, and smolt production have been linked to carcass deposition via escapement not fertilization (Schmidt 1998). While part of the problem in linking fertilization to the other assumptions listed above may be measuring the outcome, ecological efficiency is not necessarily high. According to Hyatt and others (2004) only 1% of the nutrients added are thought to reach sockeye salmon fry through a four-stage ecological process, from TP to algae to zooplankton to sockeye salmon.

The previous fertilization project could also be examined in the context of other drainages in the Kodiak Management Area. However, comparisons from other river systems in the Kodiak Management Area are difficult due to the scarcity of smolt data. Total run estimates and escapement are more consistently collected than smolt numbers (Figure 10), but show that populations from within these areas are not necessarily synchronized, and that the impacts of marine harvest, climate (marine environment),and local drivers make direct comparison difficult.

A third context for examination is through proxy data sets of abundance. Rogers and others (2013) showed decadal, centennial, and millennial climate cycles that were significant drivers of productivity. They concluded that an expectation of static population levels is not reasonable under any management scenario. The 1980s fertilization project at Karluk Lake, when viewed in the context of long-term data and conclusions presented by Finney and others (2000, 2002) and Rogers and others (2013), does not appear to have had any effect on adult run size. On the contrary, it appears that it would be more consistent to interpret the adult run size as resulting from decadal fluctuations unrelated to the project.

Considering the earlier nutrient enrichment project in the different contexts discussed above, one could conclude that, over the long term, the proposed project would likely result in the same effect as the No Action Alternative—that is, that commercial harvest, climatic cycles, and carcass deposition would drive population fluctuations. However, if nutrient enrichment were to increase sockeye salmon populations, and the escapement levels don't change, much of the sockeye salmon population increase would meet escapement and above that level would be harvested by the commercial fishery. There is some risk that, due to the difficulties ADF&G has in managing the Inner Karluk Section of the fishery (Personal Communication, James Jackson, ADF&G[3]) more fish make escapement than intended (i.e. overescapement). In that situation, MDNs could increase. In addition, if sockeye salmon populations increase, other adverse effects to aquatic resources may occur, as described below.

Consequences to other fish species must also be considered. Increases in biomass of sockeye salmon fry from nutrient enrichment could increase interspecies competition among fish that depend on the same prey and habitat. However, all fish species that use Karluk Lake (excluding three-spined stickleback) either do not share juvenile sockeye salmon habitat or do not appear to be present in sufficient numbers to compete with juvenile sockeye salmon (Mueller and Degan 2012). In addition, other fish species are in Karluk Lake are opportunistic generalists that are capable of using a variety of other available prey options (ADF&G 2013b; Gotthardt and Booz 2005; Greenbank and Nelson 1959; McClory and Gotthardt 2005; Morrow 1980) if outcompeted by sockeye salmon for zooplankton. The exception is three-spined stickleback, which does share diet preferences with sockeye salmon and is estimated to be over twice as abundant as juveniles salmon in 2011 (Mueller and Degan 2012). Stickleback populations have not been consistently monitored in Karluk Lake. Stickleback feed on zooplankton, and as discussed in Section 3.4, fertilization has been shown to increase zooplankton biomass. An increase in zooplankton biomass could cause additional growth in stickleback biomass and numbers.

Enrichment-related increases in the biomass of juvenile sockeye salmon could also increase biomass prey availability for piscivorous fish species, such as Arctic char, Dolly Varden, and steelhead or rainbow trout (ADF&G 2013b). However, directed studies on predation from piscivorous fish have not been conducted.

Alternative B would not unnaturally alter genetic fitness in Karluk Lake sockeye salmon stocks, as could occur under a sockeye salmon backstocking program. Selection of brood fish under a backstocking program would alter the natural process and favor gene and genotypes that would not be the "most fit" for survival (Neff and others 2011).

In addition, if the Proposed Action increases sockeye salmon populations, all stocks taken incidental to the commercial fishery for sockeye salmon could be overharvested. Other Pacific salmon species are

3 Currently, the Department (ADFG) cannot open commercial salmon fishing periods in the Inner Karluk Section from June 1 through July 15 until it is apparent that the Karluk early-run sockeye salmon upper escapement goal of 250,000 will be exceeded. Despite continuous commercial fishing in the Central and North Cape sections of the Northwest District, the Karluk early-run sockeye salmon upper escapement goal has frequently been exceeded. *Personal Communication, James Jackson ADFG*.

harvested in significant numbers by commercial fishers during their prosecution of incidental the sockeye salmon fishery (see Table 2 in Chapter 3). Westside commercial, sport, and subsistence users primarily harvest fish in Shelikof Strait and the Karluk Lagoon, where the O'Malley River and Thumb River stocks are mixed and indistinguishable. Of particular concern is the Karluk River population of Chinook salmon that is currently listed as a "stock of management concern" by the state of Alaska. If sockeye salmon populations do not increase under the Proposed Action, there would be no increased potential for overharvest of other salmonids as bycatch in the sockeye salmon commercial fishery.

Nutrient enrichment has the potential to negatively affect the community ecology of Karluk Lake and so, we provide a review here. Piggott and others 2012 indicated that increased nutrients can affect invertebrate and algae abundance and composition, which can have a cascading effect through the food web and promote species that are undesirable for salmon production. Eutrophication is the mechanism in which increased nutrients result in increased plant and algae growth, such as diatoms and toxic cyanobacteria, and can decrease dissolved oxygen levels. Hyatt and others (2004) list three potential detrimental phytoplankton blooms resulting from fertilizations including detrimental blue-green and "ungrazable" diatoms. They conclude that "solutions designed to constrain" these bloom types "remain elusive." They mention two other effects, the overproduction of stickleback which is discussed above, and the production of competitive crustaceans of the order Mysida which are not present in the system and can be eliminated from consideration. Lackey (2003) pointed out that adding nutrients is counter to the general direction in the United States of reducing nutrients in waterbodies, which in eutrophic water bodies are considered pollutants. The eutrophication of lake habitat in those cases is generally not favorable to salmonids that require highly oxygenated water, but Karluk Lake is considered oligotrophic. Anders and Ashley (2007) cites Lackey work, but point to the opposite extreme of "cultural oligotrophication." The point here is that there is a balance to be struck between benefits associated with oligotrophic waters, and benefits derived from increased productivity, a paradox in their terms. The Karluk Lake scenario, the proposed action, seeks to strike a balance as the proponents believe the level of nutrients can be control in the continuum between the oligotrophic and eutrophic conditions; if it is not controlled, it could cause unknown ecological changes. While appropriate to review here for completeness, the Service considers harmful effects as possible, but unlikely.

The Proposed Action would cause intermittent, limited increases in greenhouse gas emissions from transportation of supplies and personnel via chartered seaplane to Karluk Lake, use of small boats with outboard motors to transport personnel and supplies to and from various locations at Karluk Lake, and use of aircraft for aerial application of the aqueous fertilizer on Karluk Lake. Due to the short-term, limited nature of these activities, emissions of greenhouse gases would not be considered a significant contributor to regional or global climate change. Regardless of project actions, however, global climate change is expected to continue to influence long-term stock productivity in Pacific salmon populations. Within the Karluk watershed, system effects related to of global climate have yet to be documented.

4.2.4. Alternative C (Fry Backstocking)

4.2.4.1. BROODSTOCK AND EGG COLLECTION, INCUBATION, AND REARING

An estimated 1,500 to 1,700 female fish would be captured in pens at the confluence of the Thumb River and Thumb Lake for Alternative C and artificially spawned. Selection of brood fish would alter the natural process and could favor gene and genotypes that would not be the "most fit" for survival (Neff and others 2011). Future productivity of progeny could be impaired. If egg take and artificial propagation were to continue for multiple years, any damage to the genetic structure of the sockeye salmon population of Karluk Lake would increase proportionately (Hilborn 1992a).

Egg take operations would reduce the number of eggs naturally deposited in Karluk Lake by roughly 4.0 to 5.2 million. This reduction would reduce the number of eggs available as prey for Arctic char, Dolly Varden, and trout. Considering these species' opportunistic consumption of a wide variety of prey (ADF&G 2013b; Gotthardt and Booz 2005; Greenbank and Nelson 1959; McClory and Gotthardt 2005) and their relatively small population in Karluk Lake (Mueller and Deagan 2012), egg collection would not substantially restrict feeding opportunities or result in adverse effects to these species.

Broodstock collection would not noticeably affect adult escapement in the implementation year. Based on 2013 sockeye salmon escapement data, less than 0.5% of adult sockeye salmon would be killed during the collection period. It is expected that the egg to fry survival rate would be higher in the hatchery than in the wild; this is discussed in more detail below in Section 4.2.4.2, Backstocking.

Other fish species in Karluk Lake could be inadvertently captured in seines; however, the large net mesh size and manual sorting of fish by sex into pens would minimize the risk of physiological disturbance or mortality of other fish species. Carcasses of adult sockeye salmon collected during this stage would also be returned to Karluk Lake. As such, there would be minimal loss of MDN input from this source.

4.2.4.2. BACKSTOCKING

of hatchery-reared sockeye salmon fry would increase the number of juvenile sockeye salmon present in Karluk Lake and the Thumb River. Under Alternative C, it is estimated that approximately 47% of the 4.0 to 5.2 million collected eggs would survive to produce 1.88 to 2.44 million fry. This in-hatchery egg to fry survival rate is substantially greater than the estimated 1.18 to 1.53 that would have been produced naturally (29.4% survival rate; Drucker 1970). A previous survival study on oligotrophic Alaskan nursery lakes, including Karluk Lake, indicated a juvenile to smolt survival rate of approximately 18% (Koenings and Burkett 1987b). Whether this survival rate applies to outplanted fry remains unknown; an 18% survival rate could be reasonably questioned because this would be a large and sudden change to the lake ecology. The proponents of fertilization readily apply the 18%. Hilborn (1992b) provided data demonstrating reduced survival over time resulting from artificial production.

It is difficult to predict whether the increased productivity would lead to increases in adult sockeye salmon runs due to the many unknown variables that affect survival beyond the smolt stage. Because of this uncertainty, it is unknown whether backstocking would increase sockeye salmon runs.

Considering the dependence of juvenile sockeye salmon on zooplankton (Groot and Margolis 1991), the introduction of a large number of hatchery-reared juveniles into the lake could potentially reduce the zooplankton population below levels that would support growth, resulting in an insufficient food supply for wild and hatchery-reared juveniles. If this decrease were to occur after at least one group of hatchery-reared juveniles outmigrated, adults escaping to spawning grounds would provide sufficient nutrients to replenish the zooplankton community. Phytoplankton and zooplankton monitoring would be conducted during project implementation to ensure levels are sufficient to support an increased smolt population. This would minimize, but may not eliminate, adverse effects to the zooplankton population and the aquatic environment.

Marine survival of outplanted fry after migration as smolts is also a matter of conjecture. The literature provides weak support that hatchery reared fry have increased marine survival and much of the support is based on pre-1963 studies (Hyatt and others 2004). Productivity changes cyclically in the marine environment (Rogers and others 2013, and because of this uncertainty, it is difficult to predict whether the increased size would lead to increases in adult sockeye salmon runs. Escapement goals are not expected to change in the short term; so escapement would vary similar to the No Action Alternative.

As discussed in Alternative B, an increase in the growth and density of sockeye salmon could also increase competition for resources between fish species that depend on the same prey and habitat (i.e., stickleback). Piscivorous species do not share juvenile sockeye salmon habitat; have no demonstrated influence on zooplankton abundance; or are not present in Karluk Lake in sufficient numbers to compete with juvenile sockeye salmon—hence, no measurable changes to competition or predation would be anticipated from Alternative C.

Transport of any type of live fish in Alaska requires a fish transport permit from ADF&G, which requires that the fish have been tested for and are free of a whole suite of pathogens. As a consequence, it is unlikely that this alternative would have a discernible adverse effect on either species competition or pathogen presence in the Karluk Lake basin.

If the backstocked hatchery-reared juvenile sockeye salmon increase adult runs to the fishery, an increase in stocked Thumb River fry could also change the proportion of adults harvested, and cause overharvest of wild stocks that have lower egg to fry survival. Since fish imprinted to the O'Malley River area would have lower population numbers compared to fish imprinted to the Thumb River, commercial fishers could unintentionally harvest a higher proportion of O'Malley fish (relative to their overall population size), resulting in both more adult returns to Thumb Lake and fewer returns to O'Malley Lake over time(Collie and others 1990, Nehlsen and others 1991). In addition, all stocks whose productivity did not change taken incidental to the commercial fishery for sockeye salmon could be overharvested. Other Pacific salmon species are harvested in significant numbers by commercial fishers incidental to the take of sockeye salmon (see Table 2 in Chapter 3). Westside commercial, sport, and subsistence users primarily harvest fish in Shelikof Strait and the Karluk Lagoon, where the O'Malley River and Thumb River stocks are mixed and indistinguishable. Of particular concern is the Karluk River population of Chinook salmon that are currently listed as a "stock of management concern" by the state of Alaska.

Post-spawning, adult sockeye salmon die and their carcasses decompose into constituent compounds and elements. This decomposition process can be a major contributor of phosphorus and other nutrients to freshwater systems (Barnaby 1944; Koenings and Burkett 1987a; Schmidt and others 1998). Spring nutrient concentrations in lakes containing anadromous species have been positively related to the previous year's adult sockeye salmon return (Kline and others 1993; Koenings and Burkett 1987a; Golder and Associates 2011). Karluk Lake escapement goals will not be changed, and if additional adults are produced as a result of backstocking, they will be targeted for commercial harvest under the current management regime. Fishery managers have the ability to adjust escapement within the goal range but most surplus adult salmon would be commercially harvested in the ocean. There is some risk that the fleet would not be able to catch a portion of the additional fish and that there would be genetic structural damage to the population. Any short-term increase in lake productivity associated with implementation of this alternative would not transfer to long-term changes because Karluk Lake would receive little or no additional MDN other than the programmed level within the current BEG range.

If productivity cycled high, escapement above the BEG would be possible. While escapement goals have changed multiple times since 1993, they are only reviewed every 3 years, and the fishery managers of the ADF&G use mostly the same tools to suppress escapement now as they did in the early 2000s when the total run fluctuated consistently above those of the previous decade, at least for the early-run. Moreover, additional sockeye salmon harvest restrictions were put in place in 2011 as part of the Chinook Salmon Stock Assessment and Research Plan. The ADF&G's ability to control escapement may be lower than it was between 1993 and 2007 as commercial harvest for all salmon species can be limited under this plan to minimize bycatch of Chinook salmon.

Alternative C would cause intermittent, limited increases in greenhouse gas emissions from transportation of supplies and personnel via chartered seaplane to Karluk Lake and use of small boats with outboard

motors to transport personnel and supplies to and from various locations at Karluk Lake. Due to the short-term, limited nature of these activities, emissions of greenhouse gases would not be considered a significant contributor to regional or global climate change. Regardless of project actions, however, global climate change is expected to continue to influence long-term stock productivity in Pacific salmon populations. Within the Karluk watershed, system effects related to global climate have yet to be documented.

4.2.5. Alternative D (Lake Nutrient Enrichment and Fry Backstocking)

Under Alternative D, both Alternatives B and C would be implemented. All adverse effects to sockeye salmon and the aquatic environment discussed above would apply to this alternative; however, the combination of these alternatives would increase the unknowns affecting each level of the food web and environmental influences. Active management of nutrients and the number of fry outplanted may or may not moderate ecological processes. Change to the genetic structure of the populations present could occur as described above.

As such, the likelihood of increasing the number of outmigrating smolt remains unknown for this alternative. In addition, the number of smolts likely to be produced remains unquantifiable because it is not known how the system would respond to increased primary and secondary productivity. Further, competition between juveniles would increase as density increases and some individuals may not survive. Therefore, sockeye salmon production from backstocking *and* fertilization is uncertain. Marine survival of outplanted fish is equally uncertain as in Alternative C.

In addition, it is still not possible to predict whether the increased phytoplankton and zooplankton would lead to increases in adult sockeye salmon runs. There are too many unknown variables that affect sockeye salmon beyond the smolt stage. Because of this uncertainty, it is, as in Alternatives B and C, not known whether lake fertilization and backstocking would increase sockeye salmon total run size.

4.2.6. Significance Statement for All Alternatives

Karluk Lake is characterized by natural physical and biological variation. Primary drivers of escapement include, in order of effect, commercial harvest, climate cycles and carcass deposition. A current concern is that past high levels of commercial fishing have reduced the level of MDN (Finney 1998, Finney and others 2000). Historic run information suggests to some that productivity is lower than when commercial fishing was initiated in the 1880s. Zooplankton and fish populations have been strong in recent years and are currently trending higher. Fertilization and backstocking may or may not affect this trend, but little evidence in the current scientific literature supports the notion of a positive effect. More evidence indicates that productivity may continue to change and the lake could experience periodic high and low total sockeye populations. As such, the No Action Alternative would then be most consistent with Service policy because it would avoid adverse effects on aquatic resources, biodiversity, and system resilience in the project area by supporting ecological process natural to the lake and avoiding possible negative anthropogenic effects.

All of the action alternatives require significant presumptions that are weakly supported or not supported by the current scientific literature regarding the full life cycle of sockeye salmon and the drivers of aquatic productivity and sockeye salmon population size. While one might assume that Alternative D would likely produce more outmigrating smolt than Alternatives B (Proposed Action) and C individually, and Alternative B would produce more outmigrating smolt than Alternative C, unknowns such as changes in environmental variables, the potential for overgrazing by juvenile salmon, and extent of competition

with three-spined stickleback, make prediction difficult. Increased marine survival related to increased size and biomass of an increased smolt population is only weakly supported. On the other hand, the potential for damage to the populations through changed genetic structure is strongly supported. For populations that are not part of this action (e.g., Chinook and others), classic mix-stock overharvest, a negative consequence, is also strongly supported (Nehlsen and others 1991). Any beneficial effects of the project would be short-lived. The additional smolts would not directly translate to additional spawning adults and increased nutrients in Karluk Lake, except when compared to extreme low returns, because of the narrow range of the biological escapement goals. While fisheries managers have the ability to adjust escapement within the range of the escapement goals, adults produced in excess of the upper range of escapement would be subject to harvest before they reach the project area. In addition, an increase in nutrients or hatchery-reared fry could lead to the same issues that potentially caused the crash from 2008 to 2011, leading to a short-term adverse effect on aquatic resources, biodiversity, and system resilience.

4.3. Water Quality

4.3.1. Modeling Methodology

A model was run to analyze Karluk Lake's response to proposed nutrient enrichment regimes. The BATHTUB reservoir model was chosen as the most appropriate analysis tool because it was developed by the U.S. Army Corps of Engineers as an empirical model for predicting eutrophication responses in reservoirs associated with nutrient loading. BATHTUB performs water and nutrient balance calculations in a steady-state, spatially segmented hydraulic network that accounts for nutrient advective and diffusive transport, and nutrient sedimentation (Walker 1999). Using a series of tested and calibrated empirical algorithms the model can predict relevant water chemistry parameters such as TP and TN, chlorophyll *a*, and MOD rates. Detailed descriptions of modeling methodology are presented in Appendix B.

4.3.2. Alternative A (No Action)

Under the No Action Alternative, in-lake water chemistry parameters would remain consistent with current levels of natural variation and lake trophic state would remain constant. Variability of sockeye salmon escapement would continue to be the main factor (assuming no major changes in watershed land use or land cover) affecting lake nutrients and biology due to influx of MDN.

4.3.3. Alternative B (Proposed Action; Lake Nutrient Enrichment)

Boating, aircraft, and other human activity associated with monitoring and lake fertilization under Alternative B could increase the risk of accidental spills from gasoline, motor oils, or other pollutants in Karluk Lake. Potential adverse effects would be short term and limited, however, as all supplies would be stored in proper storage containers to prevent leaks and any spill would be cleaned up.

The addition of the proposed amounts of nutrients would have relatively minor adverse effects on water chemistry in Karluk Lake (Table 9), and lake trophic state is not predicted to change. Based on model output, TP concentrations would increase by approximately 30% and TN concentrations would increase by approximately 15% from 2011 baseline conditions. Similarly, small increases in chlorophyll concentrations would result in slightly greater MOD rates. Effects of the fertilizer addition in the first year are not predicted to exceed any of the significance thresholds for water quality.

Note that the model was only used to predict concentrations after the first year of fertilization. BATHTUB is not equipped to model water chemistry beyond this time frame due to the inherent complexity of the Karluk Lake system. For instance, MDN, which accounts for a substantial amount of

nutrient loading to the lake, cannot be accurately predicted, nor can it be assumed that a similar amount of fertilizer would be applied in each subsequent year. Furthermore, the complex timing of MDN and salmon spawning and escapement generates substantial water chemistry variability that cannot be accounted for in BATHTUB. However, ongoing lake monitoring and annual coordination among KRAA and ADF&G to develop nutrient concentration and application plans would reduce the likelihood of fertilizer application at loads that would exceed water quality thresholds during subsequent years.

Table 9. Water Chemistry Effects of Fertilizer Application

Parameter	Current Range (2010–2012)	Model Prediction[a]	Significance Threshold
TP (ppb)	4.2–5.6	6.7 ± 1.9[b]	>10[c]
TN (ppb)	103–542	132 ± 28	N/A
TN:TP	47:1–286:1	44:1	<17:1[c]
Chlorophyll *a* (ppb)	0.7–1.5	1.9 ± 0.7	>2.6[d]
MOD (ppb/day)	14.6–15.3	16.0 ± 5.2	>33[e]

Notes: N/A = Not applicable

± numbers indicate standard deviation.

[a] Fertilizer additions were calculated using Vollenweider's (1976) equation for a target TP concentration of 9 ppb, based on a current TP load of 80 kg per square km (KRAA 2012). Furthermore, mean depth (40.9 m [134 feet]) in the Vollenweider equation was replaced by euphotic zone depth (21.5 m [70.5 feet] on average) since it was assumed that the euphotic zone is the zone of active biological growth. Once a TP load was calculated, a 15:1 TN:TP application ratio was used to determine a TN load. These calculations yield a proposed annual fertilizer application of 14,970 kg TN and 2,210 kg TP.

[b] The target TP concentration in the KRAA proposal is 9 ppb. While the spread of the model prediction extends to nearly 9 ppb (6.7 + 1.9 = 8.6 ppb), the average prediction is substantially lower than desired. There are two primary reasons for this result. First, the proposed amount of TP to be added is based on a calculation that only accounts for euphotic zone depth (as opposed to mean lake depth). While this is a reasonable approach, it likely underestimates the amount of TP needed. Second, the starting TP concentration is somewhere in the range of 1–2 ppb lower now than it was just before the 1980s fertilization. This combined with the fact that the proposed load is 20% less than the 1980s fertilization load indicates that resulting TP concentrations from current loads will not be greater than 1980s concentrations (which were between 8 and 9 ppb).

[c] Significant nutrient thresholds for this project were defined in two ways: 1) TP is not to exceed 10 ppb, and 2) the TN:TP ratio is not to be less than 17:1. The TP threshold of 10 ppb is the "permissible" phosphorus concentration for oligotrophic lakes, which is defined as 50% of the "critical" phosphorus concentration (i.e., 20 ppb TP). The critical phosphorus concentration is the theoretical divide between oligotrophic and eutrophic lakes. As a conservative measure, KRAA (2012) has based their proposed fertilizer loading calculations on achieving a targeted TP concentration of 9 ppb, 90% of the permissible concentration.

The significant TN:TP ratio of 17:1 was determined to be the threshold at which lower ratios would result in nitrogen limitation and subsequent cyanobacteria blooms, which are toxic and inedible to zooplankton. Therefore, given a target TP concentration of 9 ppb and a minimum TN:TP ratio of 17:1, the minimum allowable TN concentration (assuming 9 ppb TP) is calculated to be 73 ppb. Generally, TN:TP in Karluk Lake is greater than 50:1.

[d] Literature suggests a significant threshold of 2.6 ppb for chlorophyll *a* in oligotrophic lakes (Carlson and Simpson 1996; U.S. Environmental Protection Agency [EPA] 2010). Lakes with concentrations greater than this tend to be classified as eutrophic, though lakes from 2–7 ppb are classified as mesotrophic.

[e] According to ADEC, for the growth and propagation of aquatic life, DO may not be less than 7 mg/L and may not exceed 17 mg/L in waters used by anadromous fish. BATHTUB does not model DO directly, but instead uses the MOD rate as a proxy. However, given a measured ambient oxygen concentration at the top of the metalimnion (average of 12 mg/L for 2010–2012) and a minimum DO level of 7 mg/L per ADEC regulations, an equivalent significant threshold for MOD is calculated to be 33 ppb/day over the 150-day growing season.

4.3.4. Alternative C (Fry Backstocking)

Effects to water quality from boating, aircraft, and other human activity associated with monitoring and fry backstocking would be the same as described in Section 4.3.3 for Alternative B.

Fry backstocking effects on Karluk Lake water chemistry cannot be accurately quantified using the BATHTUB model due to the lack of direct, measurable attributes presented in this alternative. While this course of action would likely have a series of indirect effects on water chemistry via trophic cascades (e.g., changes in top-down predator-prey relations affecting chlorophyll concentrations and thus uptake of nutrients by food-producing organisms), these effects would be monitored annually and adaptively managed via modifications to the fry backstocking activity. As such, Alternative C is not predicted to exceed any of the significance thresholds for water quality, nor significantly change lake trophic state.

4.3.5. Alternative D (Lake Nutrient Enrichment and Fry Backstocking)

Effects to water quality from boating, aircraft, and other human activity associated with monitoring, fry backstocking, and lake fertilization would be as described in Section 4.3.3 for Alternative B.

The cumulative effect of adding both aqueous nutrients and increasing the number of salmon fry in the lake would influence water chemistry in Karluk Lake through both direct, small increases in TN, TP, chlorophyll *a*, and MOD from fertilizer application, as well as indirect, limited changes to water chemistry through trophic cascades. These water chemistry effects would be monitored annually and adaptively managed via modifications to the fertilizer application schedule or fry backstocking activity, as applicable. As such, Alternative D is not predicted to exceed any of the significance thresholds for water quality, nor significantly change lake trophic state.

4.3.6. Significance Statement for All Alternatives

Significance thresholds as described in Table 9 would not be violated for any of the water chemistry parameters of interest under any of the alternatives. Therefore, they would not adversely affect water resources.

4.4. Wildlife and Vegetation

4.4.1. Alternative A (No Action)

Alternative A (No Action) would continue existing monitoring and management activities and would have no new short- or long-term adverse effects to wildlife. However, the supply of seasonally important food from sockeye salmon carcasses would continue to fluctuate across years due to changes in sockeye salmon escapement and survival in the project area and ocean rearing areas. This means that wildlife species that depend on salmon as part of their food supply could experience population fluctuations in response to this food supply variability. Population size is dependent upon a number of factors, only one of which is food supply, and salmon are one of several important dietary components.

Alternative A (No Action) would continue existing monitoring and management activities and would have no new adverse effects to area vegetation or increase presence of invasive plant species.

4.4.2. Alternative B (Proposed Action; Lake Nutrient Enrichment)

Under Alternative B, KRAA would conduct regular limnology monitoring and weekly aerial flights over Karluk Lake and surrounding lands from mid-May to mid-August for fertilizer application. Bird species, brown bear, and other mammals could be disturbed and temporarily displaced during this period if they are sensitive to aircraft flight or boating noise (Larkin and others 1996). However, because aircraft and boats regularly transport people and supplies to Karluk Lake and Camp Island for the resort and other activities in summer months, we assume that the local wildlife are partly accustomed to air traffic and human activity and that the addition of a weekly project (fertilization) flight and other actions would not result in major adverse effects to local wildlife. One exception is that low-flying aircraft (<100 feet above ground) could result in displacement of brown bear or nesting bald eagle from the shoreline in response to application activity in areas near the shoreline. However, most low-level application flights could occur predominately over the central part of the lake and would mostly exclude shoreline areas, except possibly in the narrow arm near the Thumb River. Therefore, the potential for disturbance and displacement is anticipated to be minor and limited in scope. As a consequence, if located near the central part of the lake,

it is unlikely that this alternative would significantly affect wildlife and the biological diversity of the project area.

This alternative would not influence the food supply of early-run sockeye salmon available to brown bear and other wildlife in the project area as long as ADF&G regulates escapement of adult salmon to the project area within currently prescribed limits. Therefore this alternative would not influence the productivity and size of populations of brown bear and other wildlife partly reliant on the supply of salmon within the project area beyond that already observed under current conditions (No Action).

Alternative B would have a negligible adverse effect on botanical resources. No grading or placement of fill in wetlands would occur. Trampling of native vegetation and soils would occur in the vicinity of project facility support and staging areas, which collectively would occupy a small area (less than 1 acre). Because native vegetation and soils would rapidly recover from the short-term disturbance to these sites, the effect would be negligible. Best management practices (BMPs) would be implemented to minimize the potential for inadvertent transport, establishment, and spread of orange hawkweed, an invasive plant species that occurs in Kodiak and on Camp Island vicinities.

Fertilizer would be applied over Karluk Lake waters by a low-flying aircraft. The fertilizer applied to the lake is anticipated to be consumed entirely by phytoplankton; therefore, shoreline vegetation communities would be unaffected by application-related changes in water or soil chemistry. Direct overspray to plants could occur during application; however, the temporary nature of application and limited nutrient concentration would be unlikely to have a detectable effect on plant growth. To minimize aerial drift, application could be limited to calm conditions.

4.4.3. Alternative C (Fry Backstocking)

As with Alternative B, potential minor, short-term adverse effects to bird species and other mammals, with the exception of brown bear, could result from increased human disturbance during collection and holding of broodstock, egg collection, incubation, and rearing, disposal of carcasses, and fry distribution.

Aviation flights for transport of field crews to the lake and boat trips for monitoring and backstocking activities would occur on a short-term (e.g., 2–3 weeks), limited basis in the project area. Although these actions would represent a negligible increase in noise and human activity on Karluk Lake, they would represent a major short-term increase in human activity on Thumb Lake and in the Thumb River vicinity upstream to a point where a waterfall bars further salmon passage. Because the project activity period would coincide with the peak of seasonal brown bear use of Thumb River, some brown bears would likely be disturbed and displaced by the combination of egg collection and fry planting activities. An outcome of permanent displacement would be likely for bears recurrently disturbed while utilizing the Thumb Lake and River during project field operations.

The magnitude of impact would be moderate, resulting in a persistent and substantial reduction in brown bear use of the Thumb River vicinity during mid-summer. Displaced bears would need to travel outside the Thumb River vicinity to find alternative sites to feed on salmon. Though increased travel may not pose any difficulty for single bears and maternal females with older cubs (>1 year), it may reduce fitness and reproductive success of maternal females with cubs of the year (<1 year old). Additionally, bears displaced from the Thumb River vicinity would face increased competition at alternative stream foraging sites. An increase in competition could decrease foraging efficiency of maternal females and increase the chance of cub depredation or predation by other bears. Consequently, the impacts from fry backstocking would lead to a moderate adverse effect on wildlife.

Alternative C would not decrease the food supply of early-run sockeye salmon available to brown bear and other wildlife in the project area as long as ADF&G regulates escapement of adult salmon to the project area within currently prescribed limits. Consequently, Alternative C would not influence the productivity and size of populations of brown bear and other wildlife partly reliant on the supply of salmon within the project area beyond that already observed based on fish numbers under current conditions (No Action).

Monitoring effects under Alternative C would generally be of the same type and would occur in the same location as described under Section 4.4.2 for Alternative B. Alternative C would require the establishment of a base camp at the confluence of the Upper Thumb River and Thumb Lake, as well as foot traffic transporting fry up the Upper Thumb River drainage for release the following year. These actions would result in additional limited, short-term vegetation trampling, but would not alter existing vegetation communities.

4.4.4. Alternative D (Lake Nutrient Enrichment and Fry Backstocking)

Alternative D would generate the greatest increase in project activity of the three action alternatives because of the combined activities associated with both fry backstocking and lake enrichment. As with Alternative B, potential minor, short-term adverse effects to bird species and other mammals could result from increased human disturbance. However, the effect of project actions on brown bears would be additive and consequently greater in magnitude than either Alternative B or C taken alone. Whereas direct effects would consist of disturbance and displacement, indirect effects would consist of decreases in foraging efficiency, physiological condition, cub survival, and productivity for brown bears. The adverse effect would be moderate and persistent—mainly because of the project activity associated with fry backstocking in the Thumb River vicinity, as described under Alternative C (Section 4.4.3). All other adverse effects would be as described in Sections 4.4.2 and 4.4.3 for Alternatives B and C, respectively.

Lake monitoring and fry backstocking activities could result in short-term, limited vegetation trampling and disturbance, as well as the potential for invasive plant seed dispersal. However, the adverse effects would be negligible due to the small area affected and effective administration of BMPs to minimize potential for inadvertent transport, establishment, and spread of invasive plant species. Fertilization could also result in accidental plant overspray, although adverse effects would likely be negligible because most of the application would occur away from the lakeshore and during conditions when wind drift potential was minimal.

Due to the increased level of on-site activity necessary to implement both fry backstocking and lake fertilization, the magnitude of vegetation disturbance would be greater under Alternative D than under either action individually. However, this disturbance area would be limited to a small area, probably less than 1 acre, collectively associated with project support camps and staging areas.

4.4.5. Significance Statement for All Alternatives

Because current conditions would continue unaltered, no significant adverse effects are expected as a result of Alternative A (No Action). This alternative would not influence the food supply of early-run sockeye salmon available to brown bear and other wildlife in the project area as long as ADF&G regulates escapement of adult salmon to the project area within currently prescribed limits. Thus, no significant adverse effects to brown bear or other wildlife species are considered likely to result from this alternative so long as escapement goals for sockeye salmon are consistently met.

For all action alternatives, disturbance or trampling to shoreline vegetation would be short term and would not be considered significant when compared to the undisturbed acreage of vegetation available

within the project area. Additionally, plant exposure to nutrients would not result in extensive growth or a change in vegetation communities, and invasive plant spread would be controlled through BMPs; therefore, adverse effects to botanical resources would not be significant.

Lake enrichment actions proposed in Alternative B could have a minor effect on brown bear and other wildlife in the project area. In all action alternatives, the productivity and population sizes of wildlife would not be influenced by substantial change in the abundance of sockeye salmon as long as ADF&G maintains escapement within limits currently prescribed for escapement goals. Adverse impacts to wildlife from aerial nutrient applications could be minimized by prohibiting application near shoreline areas inhabited by wildlife.

The combination of egg collection and fry backstocking activities proposed in Alternative C would have locally, persistent moderate adverse effects on wildlife, specifically brown bear. These outcomes would result from reduction in the food supply available to brown bear associated with broodstock collection coupled with displacement from areas where broodstock collection and fry planting in the Thumb River drainage. Specific adverse impacts to nutritional condition, survival, and productivity would result due to costs associated with increased reduction in the salmon food supply and effects associated with travel to, and use of, salmon in other drainages.

Fry backstocking and lake enrichment proposed in Alternative D would have the greatest adverse impact on wildlife specifically brown bear, due to the additive effects of increased intensity and geographic scope of project-related human activity. In particular, broodstock collection and fry backstocking in the Thumb River vicinity would have a moderate adverse effect on brown bears for reasons previously stated under Alternative C. Although lake enrichment, taken alone, may have a minor influence on brown bears, the increase in activity associated with concurrent enrichment and backstocking activities may result in additional disturbance and displacement of bears that seasonally used areas along Karluk Lake.

4.5. Subsistence Resources and Uses

This section discusses effects to subsistence resources and uses as part of project actions under each alternative. The ANILCA Section 810 Evaluation (Appendix A) examines effects to subsistence resources and uses on federal public lands from project actions. For the purposes of evaluation in this section and in the ANILCA Section 810 Evaluation, “local users” refer to federally eligible subsistence users for the area, which includes all residents of the Kodiak Archipelago. “Non-local users” refers to Alaska residents outside of the Kodiak Archipelago and residents of other states and countries.

Salmon from the project area are an important subsistence resource. Fish generally are caught in the lower Karluk River and Karluk Lagoon, and subsistence use of Karluk Lake to catch fish is negligible.

4.5.1. Alternative A (No Action)

Under Alternative A (No Action), the Service and ADF&G would continue existing monitoring and management activities, and the alternative would not affect either subsistence resources or opportunities for subsistence. Sockeye salmon populations would be managed, through management of commercial fishing, within escapement limits prescribed by ADF&G; however, escapements would nonetheless fluctuate annually due to changes in sockeye salmon run size and survival in the lake and ocean rearing areas. In response, supply of sockeye salmon available to subsistence users would also continue to annually fluctuate but not impede accomplishment of subsistence harvest goals based on past harvest patterns. Because there are no changes in physical or legal access to subsistence resources and Alternative A would not increase non-local use of the area, there would be no anticipated adverse effects to access to, or competition for, subsistence resources.

4.5.2. Alternative B (Proposed Action; Lake Nutrient Enrichment)

This alternative would not influence the level of opportunity for subsistence harvest of salmon because the abundance and availability of adult salmon in the subsistence harvest area (primarily Karluk Lagoon) would be managed within ADF&G prescribed escapement limits.

Increased noise and human movement associated with monitoring and aerial spraying activities could temporarily displace terrestrial wildlife and waterfowl during implementation of Alternative B. The adverse effects would be intermittent, short-term, and of a similar nature to current noise sources and activities within the project area. Therefore, adverse effects to the availability and abundance of terrestrial mammals and birds for subsistence harvest would be negligible.

Because other salmon and non-salmon fish use different habitats within the Karluk watershed, this alternative would have a negligible adverse effect on abundance and availability of other salmon and non-salmon fish used for subsistence. However, if the alternative resulted in additional harvestable surplus of sockeye salmon, the potential for additional bycatch of Chinook salmon may negatively affect the abundance and availability of Chinook salmon for harvest.

Under Alternative B, there would be no changes in non-local use of the area and physical or legal access to subsistence resources. Therefore, there are no anticipated adverse effects to access to or competition for subsistence resources from Alternative B.

4.5.3. Alternative C (Fry Backstocking)

Under Alternative C, returning adult sockeye salmon (males and females) would be collected for broodstock at the confluence of the Thumb River and Thumb Lake. Once ripe, the salmon would be killed and the eggs and milt would be collected and flown to the Pillar Creek Hatchery for rearing. Because the broodstock would be collected close to the spawning grounds and most subsistence harvest occurs at the mouth of or in the Karluk River below the lake, there would be minimal loss of sockeye salmon for harvest under this alternative.

Once hatched and reared at a hatchery, approximately 1.88 to 2.44 million additional fry would be introduced into the Karluk system per year with the expectation that they would augment future natural salmon runs. However, as discussed under Alternative B, this alternative would not influence the level of opportunity for subsistence harvest of salmon because the abundance and availability of adult salmon in the subsistence harvest area (primarily lower Karluk River and Karluk Lagoon) would be managed within ADF&G-prescribed escapement limits.

In addition, if an increase does occur, an increase in stocked Thumb River fry could also change the proportion of fish harvested by spawning area. As noted above, commercial, sport, and subsistence users primarily collect fish in Shelikof Strait and the Karluk Lagoon/Karluk River, where the O'Malley River and Thumb River stocks are mixed and indistinguishable. Since O'Malley fish would have lower population numbers relative to the new stocked sockeye salmon that would be imprinted to the Thumb River, fishers could unintentionally harvest a higher proportion of O'Malley fish (relative to their overall population size), resulting in both more adult returns to Thumb Lake and fewer returns to O'Malley Lake over time.

Because other salmon and non-salmon fish use different habitats within the Karluk watershed, this alternative would have a negligible adverse effect on abundance and availability of other salmon and non-salmon fish used for subsistence. However, if the alternative resulted in additional harvestable surplus of

sockeye salmon, the potential for additional bycatch of Chinook salmon may negatively affect the abundance and availability of Chinook salmon for harvest.

Effects to terrestrial wildlife and bird subsistence resource availability and abundance from fry backstocking–related activities would be similar to those described in Alternative B. Under Alternative C, there would be no changes in non-local use of the area and physical or legal access to subsistence resources. Therefore, there are no anticipated adverse effects to access to or competition for subsistence resources under Alternative C.

4.5.4. Alternative D (Lake Nutrient Enrichment and Fry Backstocking)

Alternative D would not influence the level of opportunity for subsistence harvest of salmon because the abundance and availability of adult salmon in the primary subsistence harvest area (primarily Karluk Lagoon) would be managed within agency-prescribed escapement limits, as described in Sections 4.5.2 and 4.5.3.

Because other salmon and non-salmon fish use different habitats within the Karluk watershed, this alternative would have a negligible adverse effect on abundance and availability of other salmon and non-salmon fish used for subsistence. However, if the alternative resulted in additional harvestable surplus of sockeye salmon, the potential for additional bycatch of Chinook salmon may negatively affect the abundance and availability of Chinook salmon for harvest.

Effects to terrestrial wildlife, birds, and vegetation subsistence resource availability and abundance from fry backstocking and lake fertilization–related activities would be as described in Sections 4.5.2 and 4.5.3.

Under Alternative D, there would be no changes in non-local use of the area and physical or legal access to subsistence resources. Therefore, there are no anticipated adverse effects to access to or competition for subsistence resources under Alternative D.

4.5.5. Significance Statement for All Alternatives

None of the action alternatives evaluated in this EA would significantly restrict abundance and availability of subsistence resources or significantly restrict access to or competition for subsistence resources. Therefore, there would be no significant adverse effects to subsistence resources from project implementation.

4.6. Recreation

4.6.1. Alternative A (No Action)

Under Alternative A (No Action), the Service would continue current monitoring and management actions for sockeye salmon in Karluk Lake. Existing public uses would continue to be allowed and permitted at Karluk Lake. These opportunities would not be influenced by variable sockeye salmon population levels as Kodiak Refuge's historical visitation information indicates that few recreational anglers travel to the project area with the exclusive objective of sockeye salmon fishing. In recent years a number of factors, such as travel costs, facilities, and access, have influenced recreational use of the area. At its peak, recreational sport fishing targeted Chinook salmon of the Karluk River. When Chinook salmon numbers declined, visitation declined correspondingly.

Sockeye salmon variability would not affect wildlife viewing, photography, and educational opportunities at the lake. Koniag, Inc. conducts the majority of these uses on the lake and to date have reported general

client satisfaction with the current wildlife viewing opportunities available in the vicinity. Additionally, it has been observed that resource selection for food by bears is complex and not driven exclusively by the presence of sockeye salmon and as long as escapement goals for sockeye salmon are consistently met, bears would continue to use the area, providing wildlife viewing, photography, and educational opportunities for area visitors.

4.6.2. Alternative B (Proposed Action; Lake Nutrient Enrichment)

With the implementation of Alternative B the lake and adjacent lands would remain open to hunting, fishing, wildlife viewing, recreation, tourism, and environmental education during project activities. Recreation has not been directly influenced by variable size of sockeye salmon populations. However, users' recreational experiences during project implementation could be diminished due to increased human presence and aviation noise. As noted above for wildlife resources in Section 4.4.2, project activities could also temporarily displace some species, which could reduce some recreational opportunities such as hunting or wildlife viewing. However, these project activities would be intermittent, short term, and consistent with past and current land use activities in the area.

4.6.3. Alternative C (Fry Backstocking)

As with Alternative B, implementation of Alternative C would not influence the availability of recreational opportunities within the project area or adjacent Karluk River. The amount of recreational fishing is not a function of sockeye salmon numbers and the ADF&G escapement goals would remain the same. However, recreational fishing related to the Chinook salmon population in the Karluk River has already diminished. Increased bycatch because of fry backstocking could prevent or slow recovery of Chinook salmon causing long-term negative effects to recreational opportunities in the area.

However, because of fry backstocking, Alternative C would have a moderate adverse effect locally on the availability of bear-viewing opportunities in the Thumb River area of Karluk Lake. Disturbance effects from aircraft overflights would be similar to those described in Alternative B (fertilization overflights). In addition, project activities associated with backstocking would disturb and displace brown bear that congregated in the Thumb River area to feed on the spawning run of early-run sockeye salmon. Specifically, the relative abundance of bears would decline during the period of project field activity, which would coincide with the time when bear-viewing operations occur. The combined increase in human activity associated with two unrelated projects (fry backstocking and bear viewing) would increase the probability of displacement of brown bear (Wilker and Barnes 1998). The magnitude of adverse effect on bear-viewing opportunities would be moderate during mid-summer for as many years as fry backstocking occurs. Section 4.4.3 contains further analysis of the adverse effects of fry backstocking on brown bear.

4.6.4. Alternative D (Lake Nutrient Enrichment and Fry Backstocking)

As described under the previous action alternatives, implementation of Alternative D would not influence the availability of recreational opportunities within the project area or adjacent Karluk River. The amount of recreational fishing is not a function of sockeye salmon numbers, and ADF&G escapement goals would remain the same. However, recreational fishing related to the Chinook population in the Karluk River has already diminished. Increased bycatch because of fry backstocking could prevent or slow recovery of Chinook salmon causing long term negative effects to recreational opportunities in the area.

Because of fry backstocking, Alternative D would have a moderate adverse effect on the availability of bear-viewing opportunities in the Thumb River area, as described in Section 4.6.3, and disturbance effects

would be similar to those described in Alternatives B (fertilization overflights) and C (human activity in the Thumb River drainage).

4.6.5. Significance Statement for All Alternatives

There would be negligible adverse effects to public uses from implementing the No Action Alternative as sockeye salmon trends have not historically driven visitation for recreational opportunities in the project area. Existing public uses would not be restricted under any action alternative, but visitor experience (both guided and unguided use) could be diminished in the action alternatives (Alternatives B, C, and D) due to increased human presence and aviation noise. In the case of Alternatives C and D, fry backstocking could prevent or slow recovery of Chinook salmon causing long term negative effects to recreational opportunities in the area. In addition, there would also be moderate adverse effects for bear viewing and bear hunting if a significant number of bears were displaced by the project activity.

4.7. Socioeconomics

This section describes effects to socioeconomic patterns from project actions. Because many communities on the Kodiak Archipelago use resources in the Karluk area, effects to socioeconomic conditions are considered to include the entire archipelago.

4.7.1. Effects Common to All Alternatives

The Karluk stocks of sockeye salmon provide an important component of a diverse fishing industry in the Kodiak area. The Karluk fishery is primarily exploited by people who live and work in Kodiak therefore any impacts to it may have a larger impact on the local Kodiak economy than other commercial fishing sectors. Socioeconomic effects from commercial fishing depend on a complex number of factors, including the size of past and present salmon runs, consumer demand, and markets. If sockeye salmon runs increase, businesses that support commercial fishing activities could have a proportionate increase in demand for their services, and if sockeye salmon runs decrease, there would be less demand for goods and services.

4.7.2. Alternative A (No Action)

Under Alternative A (No Action), the ADF&G would continue to manage the fishery to maintain sockeye salmon escapement within the BEG. Commercial fishing opportunities would be adjusted to meet fluctuations caused by major drivers of sockeye salmon productivity. Maintaining current management strategies would not affect tourism (wildlife viewing, photography, and educational) opportunities at the Lake. Effects of fluctuating sockeye salmon populations on the economy in local communities and the archipelago will depend on complex market forces, one aspect of which is salmonsalmon. As noted above in Section 4.6, sockeye provide a source of revenue for several recreation-oriented businesses in the local project area but, overall, are not a major economic driver for recreation and tourism in the Kodiak Archipelago and there is no indication that the demand for recreational fishing is not currently met. Thus, there would be little to no effect to tourism businesses, regardless of whether sockeye salmon populations increase or decrease.

4.7.3. Alternative B (Proposed Action; Lake Nutrient Enrichment)

Implementation of Alternative B is not expected to have an effect beyond the No Action alternative to the local commercial fishing industry (e.g., an increase in the harvestable surplus of fish.). No increase in demand for goods and services would occur and socioeconomic conditions for local communities are not

expected to improve beyond the no action alternative. Similar to the no action alternative, as noted above in Section 4.6, sockeye provide a source of revenue for several recreation-oriented businesses in the project area but are not a major economic driver for recreation and tourism in the Kodiak Archipelago as a whole. Thus, there would no adverse effect to tourism businesses, regardless of whether sockeye salmon populations increase or decrease.

4.7.4. Alternative C (Fry Backstocking)

If Alternative C increases sockeye salmon populations, commercial fishing businesses could experience a slight increase in demand for goods and services, improving socioeconomic conditions for local communities and throughout Kodiak Island. Negative long-term economic effects to the mixed stock fishery could occur with repeated fry backstocking. Tourism and recreation related to the Chinook salmon population in the Karluk River has already diminished. Increased bycatch because of sockeye salmon fry backstocking could prevent or slow recovery of Chinook salmon causing long term negative economic effects to tourism in the area. As noted above (Alt. B) in Section 4.6, sockeye provide a source of revenue for several recreation-oriented businesses in the project area but are not a major economic driver for recreation and tourism in the Kodiak Archipelago as a whole. Increased human activity in the Thumb River drainage would decrease opportunities for bear-viewing, as bears would be displaced from the area during fry backstocking activities. This would reduce and adversely affect bear-viewing tourism in the area.

4.7.5. Alternative D (Lake Nutrient Enrichment and Fry Backstocking)

Project effects to socioeconomic conditions under Alternative D would be similar to those described for Alternative C in Section 4.7.2. If the alternative increases sockeye salmon populations, commercial fishing businesses could experience a slight increase in the short term, along with a demand for goods and services, improving socioeconomic conditions in local communities and throughout Kodiak Island. Negative long-term economic effects to the mixed stock fishery could occur with repeated fry backstocking. Tourism and recreation related to the Chinook salmon population in the Karluk River has already diminished. Increased bycatch because of sockeye salmon fry backstocking could prevent or slow recovery of Chinook salmon causing long term negative economic effects to tourism in the area. As noted above in Section 4.6, sockeye provide a source of revenue for several recreation-oriented businesses in the project area but are not a major economic driver for recreation and tourism in the Kodiak Archipelago as a whole. Increased human activity in the Thumb River drainage would decrease opportunities for bear viewing, as bears would be displaced from the area during fry backstocking activities. This would reduce and adversely affect bear viewing tourism in the area.

4.7.6. Significance Statement for All Alternatives

The significance to socioeconomic conditions of implementing the No Action Alternative would depend on sockeye salmon trends. Sockeye salmon population variability would directly affect commercial fishing opportunities for all alternatives. This variability could have long-term adverse or beneficial effects on local communities and throughout Kodiak Island depending on whether populations declined or increased. If sockeye salmon runs increase and the commercial fishery managers and the commercial fishing industry can respond in a timely fashion, businesses that support commercial fishing activities would have more demand for their services, and if sockeye salmon runs decrease, there would be less demand for goods and services.

Sockeye provide a source of revenue for several recreation-oriented businesses in the project area but are not a major economic driver for recreation and tourism in the Kodiak Archipelago as a whole Thus, there would be a negligible adverse effect to tourism businesses, regardless of whether sockeye salmon

populations increase or decrease. For Alternatives C and D, the potential for increased bycatch of Chinook salmon could prevent or slow recovery of Chinook salmon populations, causing a long-term, negative effect to tourism in the area. In addition, under Alternatives C and D, increased human activities in the Thumb River drainage would decrease opportunities for bear-viewing, as bears would be displaced from the area during fry backstocking activities. This would reduce and adversely affect bear-viewing tourism in the area.

4.8. Land Use

This section describes changes to land use patterns as a result of project actions. Land use effects refer to compliance of project actions with existing land use plans and regulations, including the Kodiak Refuge CCP and Koniag, Inc.'s new land access permit program.

4.8.1. Alternative A (No Action)

Under Alternative A (No Action), the Service and ADF&G would continue to manage sockeye salmon in Karluk Lake through the escapement management strategy outlined in the State's Sustainable Salmon Fisheries policy. If the Karluk Lake sockeye salmon population were to exhibit severe and long-term depletion, the refuge would consider the need for restoration of the habitat or population to maintain a sustainable fishery. Existing public uses would continue at Karluk Lake. These opportunities would be influenced by the naturally cyclic sockeye salmon population levels.

4.8.2. Alternative B (Proposed Action; Lake Nutrient Enrichment)

The Proposed Action, nutrient enrichment to restore productivity to Karluk Lake, would meet the criteria for a fishery restoration under the Kodiak Refuge CCP Management Policies and Guidelines (USFWS 2008: Section 2.2.11.11) if populations are shown to be severely adversely affected and the goal is to restore them to historic levels. All of the proposed project area falls within the *Minimal Management*, where *habitats should be allowed to change and function through natural processes*; nutrient enrichment may be allowed in those areas.

If occurring on Koniag land, Alternative B would be required to conform to existing land management direction for Koniag, Inc.

4.8.3. Alternative C (Fry Backstocking)

The fry backstocking alternative as described, would meet the criteria for a fishery restoration under the Kodiak Refuge CCP Management Policies and Guidelines (USFWS 2008: Section 2.2.11.11) if populations are shown to be severely adversely affected and the goal is to restore them to historic levels. All of the proposed project area falls within the Minimal Management, where habitats should be allowed to change and function through natural processes; fry backstocking may be allowed in those areas.

As with Alternative B, Alternative C would be required to conform to existing land management direction for Koniag, Inc., if activities occurred on Koniag land.

4.8.4. Alternative D (Lake Nutrient Enrichment and Fry Backstocking)

The combination of nutrient enrichment and fry backstocking as described, would meet the criteria for a fishery restoration under the Kodiak Refuge CCP Management Policies and Guidelines (USFWS 2008: Section 2.2.11.11) if populations are shown to be severely adversely affected and the goal is to restore them to historic levels. All of the proposed project area falls within the *Minimal Management*, where

habitats should be allowed to change and function through natural processes; nutrient enrichment and fry backstocking may be allowed in those areas.

Similar to Alternatives B and C, Alternative D would be required to conform to existing land management direction for Koniag, Inc., if it occurred on Koniag land.

4.8.5. Significance Statement for All Alternatives

All action alternatives , as described by KRAA in their proposal (Alternative B) and this EA, fall under the definition of "fishery restoration " if they met the criteria (for a fishery restoration) under the Kodiak Refuge CCP Management Policies and Guidelines (USFWS 2008: Section 2.2.11.11); i.e. if populations are shown to be severely adversely affected and the goal is to restore them to historic levels. All of the proposed project area falls within the *Minimal Management*, where habitats should be allowed to change and function through natural processes; nutrient enrichment and fry backstocking may be allowed in those areas.

All action alternatives conform to existing Koniag, Inc. land management direction.

4.9. Cultural Resources

As an applicant-committed measure, KRAA staff would receive training to identify and avoid archaeological sites and this could minimize damage. In the event of an unanticipated cultural resources discovery, operations in the immediate area would be suspended until the appropriate surface management agency authorizing officer can determine appropriate actions to prevent the loss of significant cultural resource values.

4.9.1. Alternative A (No Action)

Under the No Action Alternative, current management of sockeye salmon would continue. There would be no changes to impacts to cultural resources.

4.9.2. Alternative B (Proposed Action; Lake Nutrient Enrichment)

Under Alternative B (Proposed Action), KRAA proposes to conduct regular monitoring on Karluk Lake. Two prehistoric archaeological sites and one historic-period site are present on Camp. When last visited by professional archaeologists, all were in stable condition (Saltonstall and Steffian 2010:58, 63–64). There are many other sites around the lake. Monitoring staff would receive training to avoid and protect these and any other (newly discovered) archaeological sites.

The enrichment phase for Alternative B would consist of the application of an aqueous nutrient solution to the surface of Karluk Lake by plane on a weekly basis from mid-May to mid-August for a minimum of 5 years. All treatment would occur by plane and would not result in any ground disturbance. Noise from overhead flights would be intermittent, consistent with current noise types and levels present in the project area, and unlikely to affect the features or attributes that contribute to the significance of known cultural sites. Since the two known structural foundations on Camp Island are in stable condition, they are unlikely to be vulnerable to vibration effects from overhead flights. Therefore, Alternative B would have negligible adverse effects on archaeological sites in the project area.

4.9.3. Alternative C (Fry Backstocking)

Under Alternative C, monitoring, noise, and vibration effects to cultural resources would be as described in Section 4.9.2 for Alternative B. The establishment of a base camp and foot traffic along the Upper Thumb River to collect and release fish could exacerbate erosion and result in exposure of previously protected sites. However, as discussed above, KRAA staff would receive training to identify and avoid archaeological sites. As a result, there would be negligible to no adverse effects on archaeological sites in the Thumb River Archaeological District. Because foot traffic is not expected elsewhere at Karluk Lake, this alternative is likely to have negligible adverse effects on archaeological sites in other parts of the project area.

4.9.4. Alternative D (Lake Nutrient Enrichment and Fry Backstocking)

Effects for Alternative D would generally be of the same type and would occur in the same location as described under Sections 4.9.2 and 4.9.3, for Alternatives B and C, respectively. Short-term, limited foot traffic and housing on Camp Island and along the Upper Thumb River could exacerbate erosion and result in exposure of previously protected sites; however, staff would receive training to avoid impacts to archaeological sites during monitoring, broodstock and egg collection, and fry backstocking efforts. This alternative would have the greatest increase in potential noise and vibration, due to overhead flights associated with staff and equipment transportation, as well as aerial spraying, but the Camp Island structural foundations are stable and the generally recognized features that make known cultural sites important would not be altered by an increase in noise frequency. Therefore, Alternative D would have negligible adverse effects on archaeological sites in the project area.

4.9.5. Significance Statement for All Alternatives

The No Action Alternative would not alter the presence or condition of area cultural resources; therefore, adverse effects under this alternative would not be significant. For all action alternatives, the proposed project would result in negligible adverse effects to cultural resources, and staff would complete cultural resource training to identify and avoid archaeological sites. As a result, adverse effects to cultural resources would not be significant.

4.10. Summary of Effects

Table 10 provides a summary of effects by alternatives for the Karluk Lake Nutrient Enrichment project.

Table 10. Summary of Anticipated Effects by Alternative

Resource	No Action Alternative	Alternative B (Proposed Action)	Alternative C	Alternative D
Aquatic Resources	• The lake system would continue as a naturally functioning system. Populations would fluctuate within the range of natural variation. • No effect on escapement levels set by ADF&G • Genetic integrity of the population would be maintained • No new pressures from mixed stock fisheries would be experienced and non-target stocks would fluctuate within levels historically recorded	• Increase in phytoplankton productivity • Likely increase in zooplankton biomass, smolt body size and condition • No effect on escapement levels set by ADF&G • Negligible adverse effect on predation and no adverse effects on interspecies competition • Genetic integrity of the population would likely be maintained • If sockeye salmon populations do not increase above BEG, there would be no new harvest pressures from mixed stock fisheries and non-target stocks would fluctuate within levels historically recorded • Potential change in phytoplankton and zooplankton composition and increased production of three-spined stickleback	• No change in phytoplankton productivity, zooplankton quantity, and smolt body size and condition • No immediate effect on escapement levels and negligible loss of MDN input • Negligible adverse effect on predation and some adverse effects on interspecies competition • Decreased genetic fitness of sockeye salmon stocks • Moderate adverse effects to Chinook and other salmon populations from increased potential for bycatch • Increased risk of overharvest of O'Malley sockeye salmon and underharvest of Thumb River sockeye salmon	• Increase in phytoplankton productivity • Likely increase in zooplankton biomass, smolt body size and condition • No immediate effect on escapement levels and negligible loss of MDN input • Negligible adverse effect on predation and some adverse effects on interspecies competition • Decreased genetic fitness of sockeye salmon stocks • Moderate adverse effects to Chinook and other salmon populations from increased potential for bycatch • Increased risk of overharvest of O'Malley sockeye salmon and underharvest of Thumb River sockeye salmon • Potential change in phytoplankton and zooplankton composition and increased production of three-spined stickleback
Water Quality and Limnology	• No change	• Addition of liquid fertilizer would not exceed any water quality thresholds as planned, but could move lake towards eutrophication • Increased risk of accidental spills of gasoline, motor oils, or other pollutants	• No change • Increased risk of accidental spills of gasoline, motor oils, or other pollutants	• Addition of liquid fertilizer would not exceed any water quality thresholds as planned, but could move lake towards eutrophication • Increased risk of accidental spills of gasoline, motor oils, or other pollutants

Table 10. Summary of Anticipated Effects by Alternative

Resource	No Action Alternative	Alternative B (Proposed Action)	Alternative C	Alternative D
Wildlife and Vegetation	• The lake system would continue as a naturally functioning system. Sockeye salmon populations, and the resulting food supply for wildlife, would fluctuate within the range of historic variation • Bear population numbers could fluctuate with changes in abundance of salmon and other food resources in the area	• Minor short-term displacement of wildlife, particularly brown bears, due to human activity and noise • Limited, short-term vegetation trampling and negligible increased potential for invasive species spread and colonization • Negligible adverse effect to plant growth and communities from potential overspray of fertilizer	• Minor short-term displacement of birds and wildlife, except brown bears, due to human activity and noise • Moderate short-term displacement of brown bears due to human activity and noise • Limited, short-term vegetation trampling and negligible increased potential for invasive species spread and colonization • Potential reduction in major food source for bears within Karluk watershed (fewer sockeye salmon stocks available)	• Minor short-term displacement of birds and wildlife, except brown bears, due to human activity and noise • Moderate short-term displacement of brown bears due to human activity and noise • Limited, short-term vegetation trampling and negligible increased potential for invasive species spread and colonization • Negligible adverse effect to plant growth and communities from potential overspray of fertilizer • Potential reduction in major food source for bears within Karluk watershed (fewer sockeye salmon stocks available)
Subsistence Resources and Uses	• No change in resource abundance and availability • No change in competition for subsistence resources, or physical, legal access to subsistence use areas	• No change in resource abundance and availability, as increase in sockeye salmon runs would be harvested principally by commercial fishermen • No change in competition for subsistence resources, or physical, legal access to subsistence use areas	• Minor effects to subsistence users if Chinook recovery is inhibited further due to increased bycatch • No change in resource abundance and availability of other resources, as increase in sockeye salmon runs would be harvested principally by commercial fishermen • No change in competition for subsistence resources, or physical, legal access to subsistence use areas	• Same as Alternative C
Recreation	• No change in recreation use of the Karluk watershed	• No change in recreation use of the Karluk watershed	• Same as Alternative B except: • Potential for long-term, minor	• Same as Alternative C

Table 10. Summary of Anticipated Effects by Alternative

Resource	No Action Alternative	Alternative B (Proposed Action)	Alternative C	Alternative D
		• Minor decreased in quality of recreational experiences for some users in the project area from increased human presence and airplane traffic	to moderate adverse effects to recreational (fishing) if Chinook recovery is inhibited further due to increased bycatch • Moderate decrease in opportunities for bear viewing tourism from bear displacement during project implementation	
Socioeconomics	• No change in socioeconomic conditions for commercial fishing related businesses • No change in tourism activities	• Minor decrease in opportunities for bear viewing tourism from bear displacement during project implementation	• Slight increase in demand for goods and services supporting the commercial fishing industry. • Moderate decrease in opportunities for bear viewing tourism from bear displacement during project implementation • Potential for long-term, minor to moderate adverse effects to private and commercial recreational (fishing) if Chinook recovery is inhibited further due to increased bycatch	• Same as Alternative C
Land Use	• No change in Service land management category for Karluk area. • No change in Koniag, Inc. land management practices	• Same as Alternative A if done as a Restoration of Karluk fishery • No change in Koniag, Inc. land management practices	• Same as Alternative B	• Same as Alternative B
Cultural Resources	• No change	• Negligible adverse effect to archaeological sites on Camp Island	• Negligible adverse effect to archaeological sites on Camp Island and to potential sites present along the banks of the Upper Thumb River	• Same as effects from both Alternatives B and C

5. CUMULATIVE EFFECTS

5.1. Introduction

This chapter builds on the descriptions of the affected environment and project effects for each resource analyzed in Chapter 3, Affected Environment, and Chapter 4, Environmental Consequences, and describes any additional effects on those resources that could result from the implementation of other actions when combined with the Karluk Lake Nutrient Enrichment project.

The CEQ's regulations for implementing NEPA define cumulative effects as:

> the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes such other actions. (40 CFR 1508.7)

For this EA, reasonably foreseeable future actions are those that have been or will be analyzed in a NEPA document or plan; have a federal, state, local, or tribal government permit application or approval; would occur in the same time frames as the proposed nutrient enrichment action; or have had a funding source identified.

Cumulative actions are defined as past, present, and reasonably foreseeable future actions unrelated to the project but occurring in and around the same area and potentially having combined effects on the same environmental resources.

The intention of a cumulative effects assessment is to determine if the combination of the Karluk Lake Nutrient Enrichment project with other, unrelated actions could cause significant effects even if the nutrient enrichment project alone would not. Simply put, even if the potential effects from the nutrient enrichment project would not be significant, the effects could become significant when combined with other cumulative actions.

5.2. Methods

To determine if the Karluk Lake Nutrient Enrichment project and other actions, combined, would have significant cumulative effects, the Service took these steps:

- Step 1: Identify which of the resources affected by the Karluk Lake Nutrient Enrichment project could also be affected by other actions.
- Step 2: Define the cumulative effects assessment area.
- Step 3: Identify the time frame for the cumulative effects assessment.
- Step 4: Identify other past, ongoing, or reasonably foreseeable future actions that could also affect the environment in the cumulative effects assessment area and in the time frame identified in steps 2 and 3.
- Step 5: Assess how the Karluk Lake Nutrient Enrichment project would affect the resources identified in step 1 when combined with other past, present, or reasonably foreseeable future actions.

5.2.1. Step 1: Identify Resources

Each of the resources analyzed in Chapter 4 has already been or could also be affected by other past, present, or reasonably foreseeable future actions in the project area. Therefore, all the resources analyzed in Chapter 3 and Chapter 4 will be included in the cumulative effects assessment.

5.2.2. Step 2: Define the Assessment Area for Cumulative Effects

For the cumulative effects analysis specific to the Karluk Lake Nutrient Enrichment project, it is sufficient to use the project area (including Upper Karluk Lake, O'Malley River, and Thumb River subwatersheds), as it is large enough to include the effects from other actions.

5.2.3. Step 3: Identify the Assessment Time Frame

To define a time frame for assessing cumulative effects, the Service considered past actions and reasonably foreseeable future actions. The time frame begins with past actions that are still having an effect, as described in Section 5.2.4.2 below. Projects that are reasonably foreseeable within approximately the next 10 years are examined because enough information is available about them to allow for meaningful disclosure of their potential effects.

5.2.4. Step 4: Identify Other Actions

This section identifies the past, present, and reasonably foreseeable future actions occurring in the assessment area with the potential to result in cumulative effects when combined with the Karluk Lake Nutrient Enrichment project.

5.2.4.1. SERVICE DETERMINATION OF OTHER ACTIONS

To determine what other past, present, and reasonably foreseeable future actions have occurred or are occurring in the assessment area, the Service consulted the following sources:

- The *Revised Comprehensive Conservation Plan Kodiak National Wildlife Refuge* (USFWS 2008);
- Kodiak Refuge representatives;
- Koniag, Inc. representatives; and
- ADF&G representatives.

5.2.4.2. PAST ACTIONS THAT HAVE CAUSED OR ARE STILL CAUSING EFFECTS IN THE ASSESSMENT AREA

Past actions in the assessment area have included subsistence; tourism, including fishing, hunting, and wildlife viewing; designation of an area where only guided public bear viewing is allowed; a previous lake fertilization project in the 1980s; ongoing research and monitoring of visitor use, fish, and wildlife; trails (both formal and informal); and tourism-related development (including a lodge on Camp Island). Most of the activity has occurred on and in the vicinity of Camp Island.

5.2.4.3. ACTIONS THAT ARE ONGOING OR REASONABLY FORESEEABLE

From the sources listed in Section 5.2.4.1, the Service identified present, ongoing, and reasonably foreseeable future actions occurring in the assessment area. Table 11 lists and briefly describes these actions. These actions are not to be considered part of the Karluk Lake Nutrient Enrichment project, and their inclusion in this document does not imply a decision on those actions.

Table 11. Present and Reasonably Foreseeable Future Actions

Action	Description
Service refuge research and monitoring of brown bears and sockeye salmon (discussed in detail in Section 2.4.1) (ongoing, present, and future)	Enumerating sockeye salmon escapement in Karluk Lake tributaries through 2015. In 2014, plans include placing radio collars on four brown bears at the south end of Karluk Lake; collars are designed to work for minimum of 2 years and monitoring would continue for at least 2 years. Intensive area surveys for brown bears covering the project area were conducted in 2013 and are to be repeated in 2016. Annual weekly brown bear stream surveys from mid-July through late August or early September would occur.
ADF&G fisheries and limnology research (discussed in detail in Section 2.4.2) (ongoing, present, and future)	Limnological and fish surveys in Karluk, Thumb, and O'Malley Lakes, and outmigrating smolt study near the outlet of the Karluk River.
Bear viewing, hunting, and sport fishing (ongoing)	Both Koniag, Inc. and the Service have issued permits to commercial operations for bear viewing, bear hunting, and sport fishing. The refuge has issued a special use permit for a bear-viewing operation at the O'Malley River on the south side of Karluk Lake. Bear-viewing operations could occur there from June 25 to September 15 each year. Koniag's bear viewing and other recreational tourism in the project area likely to increase in the future with growth of the Kodiak Brown Bear Center

5.2.5. Step 5: Assess Cumulative Effects by Resource

The following sections disclose the cumulative effects to each resource from the Karluk Lake Nutrient Enrichment project when combined with other actions. Each section describes the following:

- The existing condition of the resource, which includes effects from past actions and forms the baseline condition for that resource;
- A discussion of how the present and reasonably foreseeable future actions could also affect the existing condition of that resource;
- A determination of whether those actions, when combined with the Karluk Lake Nutrient Enrichment project, would have a significant cumulative effect; and
- A discussion about possible mitigation measures and responsible parties (if a significant cumulative effect is determined).

5.2.5.1. AQUATIC PRODUCTIVITY

Past, present, and reasonably foreseeable future actions would not affect productivity of phytoplankton, zooplankton, sockeye salmon, or other fish species. The primary driver of productivity in the Karluk watershed is salmon carcasses and those actions would not change the variability of salmon runs or escapement in the watershed. Present and reasonably foreseeable actions could potentially increase fishing activity in the project area. However, any sockeye salmon caught by visitors would be insignificant in relation to the total numbers of sockeye salmon harvested by commercial fishing or that are part of the annual escapement within the watershed. Therefore, present and reasonably foreseeable actions, when combined with the Karluk Lake Nutrient Enrichment project, would not have a significant cumulative adverse effect.

5.2.5.2. WATER QUALITY

Existing water quality is characteristic of an oligotrophic lake with low nutrient levels and consequently low primary (i.e., algal) productivity. None of the present and reasonably foreseeable future actions would

affect water chemistry, eutrophication, or plankton numbers. Therefore, these actions, when combined with the Karluk Lake Nutrient Enrichment project, would not have a significant cumulative adverse effect on water quality.

5.2.5.3. WILDLIFE

The project area contains a diverse population of wildlife species, including brown bears, eagles, and a variety of fish-eating wildlife such as ducks, loons, grebes, gulls, and river otters. Present and reasonably foreseeable actions could increase human activity and noise during critical periods—such as breeding and nesting—resulting in short-term displacement or avoidance by wildlife species.

In addition, visitor levels permitted by Koniag, Inc. and the Service could result in long-term displacement for project-area wildlife species, but this displacement is not expected to affect population viability of wildlife species in the area. Therefore, present and reasonably foreseeable actions, when combined with the Karluk Lake Nutrient Enrichment project, would not have a significant cumulative adverse effect on wildlife resources.

The project area is part of the Kodiak Archipelago Ecoregion and contains seven different plant communities. Implementation of any current and reasonably foreseeable projects could result in vegetation trampling or removal. However, the cumulative amount of disturbance represented by present and reasonably foreseeable actions, when combined with the Karluk Lake Nutrient Enrichment project, would not have a significant adverse effect on botanical resources in the context of the amount of undisturbed acreage of vegetation habitats present.

5.2.5.4. SUBSISTENCE RESOURCES AND USES

Many residents of the Kodiak Archipelago are involved in subsistence activities. Fish are the primary harvested resource, although birds, mammals, and plants are also harvested. Implementation of present and reasonably foreseeable actions could result in non-local competition for subsistence resources, particularly for Sitka black-tailed deer, and potentially cause short-term declines in abundance and availability due to human activity and noise. Given the low number of visitors expected under present and reasonably foreseeable operations, however, these actions, when combined with the Karluk Lake Nutrient Enrichment project, would not have a significant cumulative adverse effect.

5.2.5.5. RECREATION

Karluk Lake and adjacent lands are used for recreational fishing, hunting, and tourism. Present and reasonably foreseeable projects would increase recreational and educational opportunities in the project area, as well as provide a source of tourism and revenue for local communities and Koniag, Inc. Given the low number of visitors permitted under present and reasonably foreseeable operations, however, these actions, when combined with the Karluk Lake Nutrient Enrichment project, would not have a significant cumulative adverse effect.

5.2.5.6. SOCIOECONOMICS

The Karluk Lake watershed is an economic driver for much of western Kodiak Island. Residents of Karluk and Larsen Bay, as well as other communities throughout the Kodiak Archipelago, rely on commercial fishing harvest and tourism in the area. Past, present, and reasonably foreseeable future actions would increase tourism in the area and contribute to better economic conditions for residents. When combined with the Karluk Lake Nutrient Enrichment project, there would be beneficial effects as a result of increased tourism and commercial fishing harvest. As a result, these actions, when combined

with the Karluk Lake Nutrient Enrichment project, would not have a significant cumulative adverse effect.

5.2.5.7. LAND USE

None of the past, present, and reasonably foreseeable future actions would modify land management categories or management direction for Kodiak Refuge or Koniag, Inc.

5.2.5.8. CULTURAL RESOURCES

Cultural resources are present on Camp Island and the Thumb River, among other sites. However, implementation of any present and reasonably foreseeable action is not anticipated to affect any known cultural sites in the project area. Therefore, these actions, when combined with the Karluk Lake Nutrient Enrichment project, would not have a significant cumulative adverse effect.

6. CONSULTATION AND COORDINATION

6.1. Scoping

On March 12, 2013, the Service held an interdisciplinary team (IDT) meeting at their Regional Office in Anchorage to discuss the project purpose and need and to conduct scoping to identify project issues. The IDT consisted of Service Regional Office employees, Kodiak Refuge employees, Service Office of Subsistence Management employees, a Koniag, Inc. employee, and ADF&G employees in Anchorage, Juneau, and Kodiak. A summary of key issues identified during this meeting is provided in Chapter 1.

6.2. Consultation

As part of EA preparation, the Service consulted and coordinated with the following entities:

- ADF&G
- Alaska Department of Natural Resources
- ADEC
- City of Larsen Bay
- Koniag, Inc.
- Kodiak Area Native Association
- Native Village of Karluk
- Native Village of Larsen Bay

An initial project meeting was held on February 20, 2013, and was attended by representatives of the Service, ADF&G, and KRAA. This meeting provided a NEPA overview, discussed the roles of cooperating agencies and IDT members, determined a schedule, and scheduled a kick-off meeting.

7. LIST OF PREPARERS

A list of Service and consultant preparers for this EA is provided below in Tables 12 and 13.

Table 12. Service EA Preparers

Staff	Role
Peter Wikoff	Planning Project Manager
Anne Marie La Rosa	Refuge Manager
Tevis Underwood	Deputy Refuge Manager
Bill Pyle	Supervisory Wildlife Biologist (Refuge)
Kevin Van Hatten	Fisheries Biologist/Pilot (Refuge)
Hansel Klausner	Supervisory Park Ranger (Refuge)

Table 13. Consultant EA Preparers

Staff	Role
George Weekley	Consultant project manager; subsistence, 810 evaluation
Amanda Childs	NEPA lead
Sue Wilmot	NEPA support
Leyla Arsan	Aquatics
Nate Jahns	Aquatics
Molly Odell	Cultural resources
Jonathan Rigg	Public uses
Stacey Benjamin	Botany
Lynn Sharp	Wildlife
Jacob Diamond	Water quality and limnology

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Appendix A

Subsistence Resources and ANILCA 810 Evaluation

810 Evaluation Process

ANILCA Section 810 requires an evaluation of the effects on subsistence uses for any action to withdraw, reserve, lease, or otherwise permit the use, occupancy, or disposition of public lands, including those on National Wildlife Refuges.

The term *subsistence uses* is defined in Section 803 of the Alaska National Interest Lands Conservation Act (ANILCA) of 1980 (Public Law [PL] 96-487) as

> the customary and traditional uses by rural Alaska residents of wild renewable resources for direct personal or family consumption as food, shelter, fuel, clothing, tools, or transportation; for the making and selling of handicraft articles out of non-edible byproducts of fish and wildlife resources taken for personal or family consumption; for barter, or sharing for personal or family consumption; and for customary trade.

The definition of *subsistence resources* is derived from the definition of subsistence uses above as being the plants, fish, and wildlife—in other words, "wild, renewable resources" that are used for subsistence by rural Alaska residents.

This 810 evaluation consists of:

- A finding of whether or not a proposed action would have a significant restriction on subsistence uses,
- A notice and hearing if an action is found to have a significant restriction on subsistence uses, and
- A three-part determination prior to authorization of any action if there is a significant restriction on subsistence uses.

The following serves as the basis for that evaluation.

Subsistence Evaluation Factors

ANILCA requires that a subsistence evaluation under Section 810(a) include findings on three specific issues:

- The effect of use, occupancy, or disposition on subsistence resources and uses;
- The availability of other lands for the purpose sought to be achieved; and
- Other alternatives that would reduce or eliminate the use, occupancy, or disposition of public lands needed for subsistence purposes (16 U.S. Code [U.S.C.] § 3120).

The evaluation and findings required by ANILCA Section 810(a) are set out for each of the alternatives considered in this environmental assessment (EA). If there is a finding that the Proposed Action may significantly restrict subsistence uses, additional requirements are imposed including provisions for notices to the state of Alaska and appropriate regional and local subsistence committees, a hearing in the vicinity of the area involved, and the making of the following determinations, as required by Section 810(a)(3):

- Such a significant restriction of subsistence uses is necessary and consistent with sound management principles for the utilization of the public lands;

- The proposed activity would involve the minimal amount of public lands necessary to accomplish the purposes of use, occupancy, or other disposition; and
- Reasonable steps would be taken to minimize adverse effects upon subsistence uses and resources resulting from such actions.

Effects on subsistence uses are typically discussed by land management agencies in terms of the following types of changes to subsistence resources, as described in the district court's decision of record in *Kunaknana v. Clark*.

- Changes in abundance and availability of subsistence resources: Reductions or increases in the amount of habitat for plants and animals and, by extension, in the numbers of plants and animals that are used for subsistence.
- Changes in access to subsistence resources: Variations in the ability to get to subsistence resource harvesting locations. Access consists of two categories: physical access (can a person reach the locations by walking, driving, boating, or flying?) and legal access (it is illegal to go to the location [regardless of the ease or method of physical access] or to use resources at that location?).
- Changes in competition for subsistence resources: Reductions or increases in the use of subsistence resources harvesting locations by both subsistence and non-subsistence users.

For the purpose of this evaluation, and consistent with the district court's decision in *Kunaknana v. Clark*, the Service considers a restriction on subsistence use to be significant if there are: (1) large reductions in abundance or major redistribution of these resources; (2) substantial interference with harvestable access to active subsistence use sites; or (3) major increases in non-rural use.

For this evaluation, "local users" refer to federally eligible subsistence users for the area, which includes all residents of the Kodiak Archipelago. "Non-local users" refers to Alaska residents outside of the Kodiak Archipelago and residents of other states and countries.

Background Information

Chapter 3 of this EA describes the environment of the Refuge, including subsistence and other human uses. Chapter 4 describes anticipated effects of each alternative on the environment, including subsistence and other uses.

Effects Common to All Alternatives

Evaluation of the Availability of Other Lands for Sockeye Salmon Rehabilitation

All alternatives would use public lands managed by the Service for monitoring and management activities. Other lands around Karluk Lake consist of those owned and/or managed by Koniag Inc. which could be used for monitoring and backstocking of sockeye salmon fry to enhance sockeye salmon productivity in Karluk Lake.

Evaluation of Other Alternatives That Would Reduce or Eliminate the Use, Occupancy, or Disposition of Public Lands Needed for Subsistence Purposes

All alternatives proposed in the EA would use public lands managed by the Kodiak Refuge, but none of the alternatives would remove public lands used for subsistence purposes. Of all the alternatives presented in the EA, Alternative A (No Action) is the only alternative that does not propose additional activities on public lands, therefore it would use the least amount of public lands needed for subsistence purposes. Because Alternative D would use public lands for both lake fertilization and fry backstocking, this alternative would use the most public lands needed for subsistence purposes.

Alternative A (No Action)

Evaluation of the Alternative's Effect on Subsistence Resources and Uses

Under Alternative A (No Action), the Service and ADF&G would continue existing monitoring and management activities, and the alternative would not affect either subsistence resources or opportunities for subsistence. Sockeye salmon populations would be managed through management of commercial fishing, within escapement limits prescribed by ADF&G; however, escapements would nonetheless fluctuate annually due to changes in sockeye salmon run size and survival in the lake and ocean rearing areas. In response, supply of sockeye salmon available to subsistence users would also continue to annually fluctuate but not impede accomplishment of subsistence harvest goals based on past harvest patterns. Because there are no changes in physical or legal access to subsistence resources and Alternative A would not increase non-local use of the area, there would be no anticipated adverse effects to access to, or competition for, subsistence resources.

Alternative B (Proposed Action: Lake Nutrient Enrichment)

Evaluation of the Alternative's Effect on Subsistence Resources and Uses

Because subsistence use of Karluk Lake to catch fish is negligible, this alternative would not influence the level of opportunity for subsistence harvest of salmon because the abundance and availability of adult salmon in the subsistence harvest area (primarily Karluk Lagoon) would be managed within ADF&G prescribed escapement limits.

Increased noise and human movement associated with monitoring and aerial spraying activities could temporarily displace terrestrial wildlife and waterfowl during implementation of Alternative B. The adverse effects would be intermittent, short term, and of a similar nature to current noise sources and activities within the project area. Therefore, adverse effects to the availability and abundance of terrestrial mammals and birds for subsistence harvest would be negligible.

Because other salmon and non-salmon fish use different habitats within the Karluk watershed, this alternative would have a negligible adverse effect on abundance and availability of other salmon and non-salmon fish used for subsistence.

Under Alternative B, there would be no changes in non-local use of the area and physical or legal access to subsistence resources. Therefore, there are no anticipated adverse effects to access to or competition for subsistence resources from Alternative B.

Alternative C (Fry Backstocking)

Evaluation of the Alternative's Effect on Subsistence Resources and Uses

Under Alternative C, broodstock would be collected close to the spawning grounds and most subsistence harvest occurs at the mouth of or in the Karluk River below the lake, therefore there would be minimal direct loss of sockeye salmon for harvest from this action. However, as discussed under Alternative B, this alternative would not influence the level of opportunity for subsistence harvest of salmon because the abundance and availability of adult salmon in the subsistence harvest area (primarily lower Karluk River and Karluk Lagoon) would be managed within ADF&G-prescribed escapement limits.

If an increase were to occur, an increase in stocked Thumb River fry could change the proportion of fish harvested by spawning area. Commercial, sport, and subsistence users primarily collect fish in Shelikof Strait and the Karluk Lagoon, where the O'Malley River and Thumb River stocks are mixed and indistinguishable. Since O'Malley fish would have lower population numbers relative to the new stocked sockeye salmon that would be imprinted to the Thumb River, fishermen could unintentionally harvest a higher proportion of O'Malley fish (relative to their overall population size), resulting in both more adult returns to Thumb Lake and fewer returns to O'Malley Lake over time.

Because other salmon and non-salmon fish use different habitats within the Karluk watershed, this alternative would have a negligible adverse effect on abundance and availability of other salmon and non-salmon fish used for subsistence. However, if the alternative resulted in additional harvestable surplus of sockeye salmon, the potential for additional bycatch of Chinook salmon may negatively affect the abundance and availability of Chinook.

Effects to terrestrial wildlife and bird subsistence resource availability and abundance from fry backstocking–related activities would be similar to those described in Alternative B. Under Alternative C, there would be no changes in non-local use of the area and physical or legal access to subsistence resources. Therefore, there are no anticipated adverse effects to access to or competition for subsistence resources under Alternative C.

Alternative D (Lake Nutrient Enrichment and Fry Backstocking)

Evaluation of the Alternative's Effect on Subsistence Resources and Uses

Alternative D would not influence the level of opportunity for subsistence harvest of salmon because the abundance and availability of adult salmon in the subsistence harvest area (primarily Karluk Lagoon) would be managed within agency-prescribed escapement limits, as described in Sections 4.5.2 and 4.5.3.

Because other salmon and non-salmon fish use different habitats within the Karluk watershed, this alternative would have a negligible adverse effect on abundance and availability of other salmon and non-salmon fish used for subsistence. However, if the alternative resulted in additional harvestable surplus of

sockeye salmon, the potential for additional bycatch of Chinook salmon may negatively affect the abundance and availability of Chinook.

Effects to terrestrial wildlife, birds, and vegetation subsistence resource availability and abundance from fry backstocking and lake fertilization–related activities would be as described in Sections 4.5.2 and 4.5.3.

Under Alternative D, there would be no changes in non-local use of the area and physical or legal access to subsistence resources. Therefore, there are no anticipated adverse effects to access to or competition for subsistence resources under Alternative D.

ANILCA Finding and Significance Statement for All Alternatives

None of the action alternatives evaluated in this EA would significantly restrict abundance and availability of subsistence resources or significantly restrict access to or competition for subsistence resources. As such, there would be no significant adverse effects to subsistence resources from project implementation.

Document continues on the following page.

Appendix B

BATHTUB Model Methodology

NUTRIENT LOAD COMPARISON

As the first methodological step, an analysis of yearly variation in nutrient loading to Karluk Lake was performed to serve as a baseline reference for comparison to modeled outcomes (Table B-1). Karluk Lake was fertilized in its main basin for 5 consecutive years from 1986 to 1990. The combination of complex trophic dynamics, stratification, and lack of tributary flow and concentration data for Karluk Lake allows for only a cursory comparison between treatment years and across past and potential future projects. However, some important results from this analysis can be still be gleaned. One, Alternative B's proposed nutrient application to Karluk Lake of ~15,000 kg TN and ~2,200 kg TP is substantially lower than what was applied in the 1980s (Table B-1). Moreover, the current phosphorus levels in the lake are over 2 ppb lower than they were before nutrients were first applied in 1986 (4.2 ppb in 2012 vs. 6.7 ppb in 1985). The 2012 measurement is likely much more accurate than measurements from prior years since it was performed with an autonomous underwater vehicle, which was able to account for the spatial variation of concentrations that previous stationary measurements likely missed. Regardless, with the combination of lower proposed loads and lower initial nutrient concentrations, it is assumed that the Proposed Action would not result in in-lake concentrations for TP and TN that are any greater than those seen during the 1986–1990 fertilization.

Table B-1. Nutrient Load Comparison

Year	Baseline TN (kg)	TN Added (kg)	Total TN (kg)	Seasonal TN (ppb)	Baseline TP (kg)	TP Added (kg)	Total TP (kg)	Seasonal TP (ppb)
1985	107,000		107,000	149.3	8,200		8,200	6.7
1986	100,000	23,600	123,600	166.3	7,000	2,700	9,700	8.2
1987	92,300	23,600	115,900	193.7	9,300	2,700	12,000	8.4
1988	80,300	23,600	103,900	195.2	8,300	1,500	9,800	8.5
1989	114,300	20,900	135,200	207.6	9,000	1,700	10,700	8.5
1990	90,500	23,300	113,800	178.2	11,100	600	11,700	9.1
1991	112,100		112,100	220.0	7,100		7,100	6.9
2010	65,500		65,500	102.7	5,700		5,700	4.9
2011*	75,300		75,300	240.8	6,100		6,100	5.6
2012*†	75,300		75,300	542.2	5,800		5,800	4.2
Proposed	**75,300**	**15,000**	**90,300**		**6,000**	**2,200**	**8,200**	

Note: Baseline values are estimates. TN and TP concentrations are as-N and as-P, respectively. Concentrations are whole lake averages. Baseline TN is determined from yearly salmon escapements and an assumed constant tributary load of 43,200 kg TN/year (Finney 1998). Baseline TP is determined from Vollenweider's equation (1976) and springtime TP concentrations.

*Salmon escapements for these years were not available, so TN was calculated assuming a 500,000 salmon escapement.

† Water quality data for 2012 from Finkle (2013). Concentrations are average of 1 m and hypolimnion samples.

MODEL DESCRIPTION

Subsequent to the nutrient load comparison, a model was run to analyze Karluk Lake's response to proposed nutrient enrichment regimes. The BATHTUB reservoir model was chosen as an appropriate analysis tool, as it was developed by the U.S. Army Corps of Engineers (USACE) as an empirical model for predicting eutrophication in reservoirs. BATHTUB performs water and nutrient balance calculations in a steady-state, spatially segmented hydraulic network that accounts for nutrient advective and diffuse

transport, and nutrient sedimentation (Walker 1999). Using a series of tested and calibrated empirical algorithms the model is able to predict relevant water chemistry parameters such as TP and TN, chlorophyll *a*, and MOD rates.

Input data requirements for BATHTUB include: physical characteristics of the watershed reservoir morphology (e.g., surface area, mean depth, length, mixed layer depth), inflows and tributary nutrient loading, atmospheric and meteorological parameters (e.g., precipitation, atmospheric loading of nitrogen), and measured lake water quality data. The empirical models implemented in BATHTUB are mathematical generalizations about lake behavior. When applied to data from a particular reservoir, actual observed reservoir water quality data may differ from BATHTUB predictions by a factor of two or more (Walker 1999). Such differences reflect data limitations (e.g., measurement errors, insufficient data), accuracy of applied models, and unique lake features. To account for this, BATHTUB provides users with a "calibration factor" that calibrates the magnitude of predicted reservoir response by a fixed amount in order to match measured data. However, Walker (1999) cautions about the use of calibration factors, and as such they are not used here.

Modeled Conditions

Given a set of initial conditions, BATHTUB predicts lake hydrochemistry averaged over a period of time. One of the most important decisions in the application of BATHTUB is the selection of the "averaging period," or the length of time over which water and mass balance calculations are modeled. Since the growing season is traditionally described as occurring between May and September (KRAA 2012), which is also concurrent with the time frame of the Proposed Action, an averaging period of 0.42 years was used.

Karluk Lake was modeled as a single reservoir with one input tributary and one outflow. This simplified scheme is a reasonable assumption given the constraints on available tributary data and in-lake nutrient processing. This scheme is further validated considering that the model outputs of interest are general, ambient whole-lake water chemistry responses to known cumulative loadings of nutrients (as opposed to segmented lake responses and varied tributary loads).

One of the major missing model parameters for Karluk Lake is flow. An early estimate from Juday and others. (1932) puts inflows to the lake at 247 cubic feet per second (cfs) (7 m^3 s^{-1}). Data from a USGS flow gage (15296600) that was active at the outlet of the lake from 1975 to 1982 yield an average yearly outflow (for years with complete data) of 420 cfs (375,000,000 m^3 yr^{-1}). Assuming the lake is at steady-state (i.e., no net gain or loss of water), Juday and other's (1932) estimate is off by approximately 170 cfs. Using current best estimates for lake volume (1,843,000,000 m^3; Finkle 2013) and average water residence time (4.64 years; Uchiyama 2008), it was calculated that total lake inflow is approximately 400,000,000 m^3 yr^{-1}. Taking into account rainfall and evaporation, the estimated outflow from the lake is approximately 382,000,000 m^3 yr^{-1}, a 2% difference from measured values at the USGS gage. Since BATHTUB calculates mass balances and residence times from lake volume and inflow, this final calculated flow rate (~400,000,000 m^3 yr^{-1}) was the one chosen for modeling in BATHTUB.

Model Inputs

The first required model parameters for BATHTUB are the global variables, which are inputs that impact all model segments. These include the averaging period and atmospheric data. Atmospheric inputs to the BATHTUB model were determined from a mixture of current and historical data sets, and estimation from literature values. Average annual precipitation data was taken from Finney (1998), and evaporation rates were estimated from Western Regional Climate Center (WRCC) pan-evaporation data for several

stations in Alaska (Table B-2; WRCC 2013). Atmospheric nitrogen deposition was averaged from inorganic nitrogen deposition data from the two closest National Atmospheric Deposition Program (NADP) stations to Karluk Lake. Phosphorus deposition was not available in any form and was assumed to be negligible (Table B-2).

Reservoir morphometric inputs were lake surface area, mean lake depth, and depth of stratification layers. The most recent information from Finkle's (2013) high-resolution bathymetry data set was used to populate these values (Table B-3).

BATHTUB also requires both inflow rates and nutrient concentrations associated with those inflows. Data for tributary flow and nutrient concentrations were unavailable for the many (>10) contributing streams to Karluk Lake. Instead, total inflow was assumed to equal the total volume divided by the average residence time of the lake. Influent TP concentrations were calculated by dividing TP loads by the total influent volume. TN concentrations were calculated in an identical manner (Table B-4).

Table B-2. BATHTUB Model Inputs: Global Variables

Input	Units	Value	Rationale
Averaging period	yr	0.42	Length of growing season
Precipitation	m	0.65	Total precipitation during averaging period
Evaporation	m	0.37	Total evaporation during averaging period*
Atmospheric TN load	mg m^{-2} yr^{-1}	48	Estimated from NADP data†
Atmospheric TP load	mg m^{-2} yr^{-1}	0	Assumed to be negligible

*Estimated from pan evaporation from 1949–2005 (WRCC 2013).
†Average of all inorganic nitrogen deposition data for stations AK97 and AK02 (NADP 2013)

Table B-3. BATHTUB Model Inputs: Segment Variables

Input	Units	Value	Rationale
Surface area	km^2	38.5	Measured
Mean depth	m	40.9	Measured
Length	km	19.6	Measured
Mixed layer depth	m	10.9	Difference between mean depth and hypolimnetic depth
Hypolimnetic depth	m	30	Measured

Table B-4. BATHTUB Model Inputs: Tributary Data

Input	Units	Value	Rationale
Flow rate*	hm^3 yr^{-1}	397.2	Total lake volume divided by average residence time

Table B-4. BATHTUB Model Inputs: Tributary Data

Input	Units	Value	Rationale
TP concentration	ppb	variable	Varies by year-to-year changes in loading
TN concentration	ppb	variable	Varies by year-to-year changes in loading

*Units of flow in BATHTUB are cubic hectometers (hm^3) per year. 1 hm^3 = 1,000,000 m^3

Model Calibration

The model was calibrated by comparing known lake hydrochemistry data with modeled hydrochemistry data predicted by BATHTUB and subsequently adjusting the algorithms used within the model. The calibration year was chosen as 1985 in order to capture the conditions present just before fertilization began. Average ambient lake water chemistry data (and associated variance) was calculated from monthly samples taken among three stations at Karluk Lake from May to September for 1985. The relevant program models chosen from the calibration are shown in Table B-5, and calibration results are shown in Table B-6. Only the water chemistry parameters that could be compared to observed values are shown. Values shown are whole-lake mixed-layer seasonal averages. As previously mentioned, the calibration did not use any calibration constants.

Table B-5. BATHTUB model selections

Parameter	Model Chosen	Form	Rationale
TP	Vollenweider	$P = P_i/(1+T^{0.5})$	Valid for oligotrophic northern lakes
TN	Bachman volumetric load	$N = N_i/[1+C\times(TN/V)\times T]$	Valid for oligotrophic northern lakes
Chlorophyll *a*	P, Linear	$B = C\times P$	Valid for phosphorus-limited northern lakes
Transparency	ChlA & Turbidity	$S = 1/(a+b\times B)$	Default Model

P = phosphorus concentration; P_i = initial P concentration; T = hydraulic residence time; N = nitrogen concentration; C = constant; TN = nitrogen mass load; V = lake volume; B = chlorophyll *a* concentration; S = secchi depth; a = non-algal turbidity, b = algal light extinction coefficient

Table B-6. BATHTUB 1985 Calibration

Parameter	Observed Value (ppb)	Predicted Value (ppb)	% Error
TP	6.6 ± 1.9	6.7 ± 1.9	1.5%
TN	149.3 ± 22.1	149.6 ± 34.4	0.0%
Chlorophyll *a*	1.8 ± 0.9	1.9 ± 0.7	5.6%

Model Validation

The BATHTUB model was validated for the years of 1986 and 2011 (Tables B-7 and B-8). These years were chosen because they represent years of active fertilization and current conditions, respectively.

Values are shown only if predicted values could be compared to observed values. Validation for 1986 was performed by assuming the same loads from the calibration year, but also adding fertilizer loads. Validation for 2011 was performed by calculating TP loads from Vollenweider's (1976) equation and TN loads from estimated salmon escapements and assumed river loads.

Validation results indicate that the model is reasonably accurate at predicting TP and TN concentrations, though it generally over-predicts chlorophyll *a* concentrations. This can be attributed to the large amount of uncertainty in timing of trophic cascades in Karluk Lake (Koenings and Burkett 1987a; Schmidt and others 1998; Uchiyama and others 2008). The large error in TN prediction for 2011 can be attributed to the uncertainty in salmon escapements for that year; a 500,000 escapement was assumed. Generally, the greater prediction errors seen in 2011 vs. 1986 may reflect whole lake and watershed changes over the past 30 years, since 1986 was is much closer to the calibration year. However, model outputs for 2011 are still reasonable and fall within observed ranges.

The 2011 validation allowed for a comparison of predicted and observed MOD rates since oxygen profiles were available for that year. The MOD rate is a measure of the amount of oxygen that is depleted in the metalimnion per day. Results show a reasonably close alignment between measured and predicted values (error is −4.2%). This implies that the model should provide accurate predictions for changes in MOD.

Table B-7. BATHTUB 1986 Validation

Parameter	Observed Value (ppb)	Predicted Value (ppb)	% Error
TP	8.6 ± 2.0	8.8 ± 2.5	2.3%
TN	163.1 ± 22.3	173.1 ± 41.5	6.1%
Chlorophyll *a*	1.6 ± 0.4	2.5 ± 0.98	56.3%

Table B-8. BATHTUB 2011 Validation

Parameter	Observed Value (ppb)	Predicted Value (ppb)	% Error
TP	5.6 ± 1.6	4.9 ± 1.4	-12.5%
TN	222.6 ± 71.7	114.6 ± 22.9	-48.5%
Chlorophyll *a*	1.5 ± 0.9	1.3 ± 0.5	-13.3%
MOD rate (ppb d^{-1})	14.3	13.7 ± 4.5	-4.2%

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Appendix C

ADF&G Sustainable Salmon Fisheries Policy

The mission of the Division of Commercial Fisheries is to manage subsistence, commercial, and personal use fisheries in the interest of the general well-being of the people and economy of the state, consistent with the sustained yield principle, and subject to allocations through public regulatory processes.

The department manages salmon stocks throughout the state in accordance with the policy for the management of sustainable salmon fisheries (5 AAC 39.222). This policy is printed below:

> (1) while, in the aggregate, Alaska's salmon fisheries are healthy and sustainable largely because of abundant pristine habitat and the application of sound, precautionary, conservation management practices, there is a need for a comprehensive policy for the regulation and management of sustainable salmon fisheries;
>
> (2) in formulating fishery management plans designed to achieve maximum or optimum salmon production, the board and department must consider factors including environmental change, habitat loss or degradation, data uncertainty, limited funding for research and management programs, existing harvest patterns, and new fisheries or expanding fisheries;
>
> (3) to effectively assure sustained yield and habitat protection for wild salmon stocks, fishery management plans and programs require specific guiding principles and criteria, and the framework for their application contained in this policy.
>
> (b) The goal of the policy under this section is to ensure conservation of salmon and salmon's required marine and aquatic habitats, protection of customary and traditional subsistence uses and other uses, and the sustained economic health of Alaska's fishing communities.
>
> (c) Management of salmon fisheries by the state should be based on the following principles and criteria:
>
> (1) wild salmon stocks and the salmon's habitats should be maintained at levels of resource productivity that assure sustained yields as follows:
>
> (A) salmon spawning, rearing, and migratory habitats should be protected as follows:
>
> (i) salmon habitats should not be perturbed beyond natural boundaries of variation;
>
> (ii) scientific assessments of possible adverse ecological effects of proposed habitat alterations and the impacts of the alterations on salmon populations should be conducted before approval of a proposal;
>
> (iii) adverse environmental impacts on wild salmon stocks and the salmon's habitats should be assessed;
>
> (iv) all essential salmon habitat in marine, estuarine, and freshwater ecosystems and access of salmon to these habitats should be protected; essential habitats include spawning and incubation areas, freshwater rearing areas, estuarine and nearshore rearing areas, offshore rearing areas, and migratory pathways;
>
> (v) salmon habitat in fresh water should be protected on a watershed basis, including appropriate management of riparian zones, water quality, and water quantity;
>
> (B) salmon stocks should be protected within spawning, incubating, rearing, and migratory habitats;
>
> (C) degraded salmon productivity resulting from habitat loss should be assessed, considered, and controlled by affected user groups, regulatory agencies, and boards when making conservation and allocation decisions;

(D) effects and interactions of introduced or enhanced salmon stocks on wild salmon stocks should be assessed; wild salmon stocks and fisheries on those stocks should be protected from adverse impacts from artificial propagation and enhancement efforts;

(E) degraded salmon spawning, incubating, rearing, and migratory habitats should be restored to natural levels of productivity where known and desirable;

(F) ongoing monitoring should be conducted to determine the current status of habitat and the effectiveness of restoration activities;

(G) depleted salmon stocks should be allowed to recover or, where appropriate, should be actively restored; diversity should be maintained to the maximum extent possible, at the genetic, population, species, and ecosystem levels;

(2) salmon fisheries shall be managed to allow escapements within ranges necessary to conserve and sustain potential salmon production and maintain normal ecosystem functioning as follows:

(A) salmon spawning escapements should be assessed both temporally and geographically; escapement monitoring programs should be appropriate to the scale, intensity, and importance of each salmon stock's use;

(B) salmon escapement goals, whether sustainable escapement goals, biological escapement goals, optimal escapement goals, or inriver run goals, should be established in a manner consistent with sustained yield; unless otherwise directed, the department will manage Alaska's salmon fisheries, to the extent possible, for maximum sustained yield;

(C) salmon escapement goal ranges should allow for uncertainty associated with measurement techniques, observed variability in the salmon stock measured, changes in climatic and oceanographic conditions, and varying abundance within related populations of the salmon stock measured;

(D) salmon escapement should be managed in a manner to maintain genetic and phenotypic characteristics of the stock by assuring appropriate geographic and temporal distribution of spawners as well as consideration of size range, sex ratio, and other population attributes;

(E) impacts of fishing, including incidental mortality and other human-induced mortality, should be assessed and considered in harvest management decisions;

(F) salmon escapement and harvest management decisions should be made in a manner that protects nontarget salmon stocks or species;

(G) the role of salmon in ecosystem functioning should be evaluated and considered in harvest management decisions and setting of salmon escapement goals;

(H) salmon abundance trends should be monitored and considered in harvest management decisions;

(3) effective management systems should be established and applied to regulate human activities that affect salmon as follows:

(A) salmon management objectives should be appropriate to the scale and intensity of various uses and the biological capacities of target salmon stocks;

(B) management objectives should be established in harvest management plans, strategies, guiding principles, and policies, such as for mixed stock fishery harvests, fish disease, genetics, and hatchery production, that are subject to periodic review;

(C) when wild salmon stocks are fully allocated, new fisheries or expanding fisheries should be restricted, unless provided for by management plans or by application of the board's allocation criteria;

(D) management agencies should have clear authority in statute and regulation to

(i) control all sources of fishing mortality on salmon;

(ii) protect salmon habitats and control nonfishing sources of mortality;

(E) management programs should be effective in

(i) controlling human-induced sources of fishing mortality and should incorporate procedures to assure effective monitoring, compliance, control, and enforcement;

(ii) protecting salmon habitats and controlling collateral mortality and should incorporate procedures to assure effective monitoring, compliance, control, and enforcement;

(F) fisheries management implementation and outcomes should be consistent with regulations, regulations should be consistent with statutes, and effectively carry out the purpose of this section;

(G) the board will recommend to the commissioner the development of effective joint research, assessment, and management arrangements with appropriate management agencies and bodies for salmon stocks that cross state, federal, or international jurisdictional boundaries; the board will recommend the coordination of appropriate procedures for effective monitoring, compliance, control, and enforcement with those of other agencies, states, or nations;

(H) the board will work, within the limits of its authority, to assure that

(i) management activities are accomplished in a timely and responsive manner to implement objectives, based on the best available scientific information;

(ii) effective mechanisms for the collection and dissemination of information and data necessary to carry out management activities are developed, maintained, and utilized;

(iii) management programs and decision-making procedures are able to clearly distinguish, and effectively deal with, biological and allocation issues;

(I) the board will recommend to the commissioner and legislature that adequate staff and budget for research, management, and enforcement activities be available to fully implement sustainable salmon fisheries principles;

(J) proposals for salmon fisheries development or expansion and artificial propagation and enhancement should include assessments required for sustainable management of existing salmon fisheries and wild salmon stocks;

(K) plans and proposals for development or expansion of salmon fisheries and enhancement programs should effectively document resource assessments, potential impacts, and other information needed to assure sustainable management of wild salmon stocks;

(L) the board will work with the commissioner and other agencies to develop effective processes for controlling excess fishing capacity;

(M) procedures should be implemented to regularly evaluate the effectiveness of fishery management and habitat protection actions in sustaining salmon populations, fisheries, and habitat, and to resolve associated problems or deficiencies;

(N) conservation and management decisions for salmon fisheries should take into account the best available information on biological, environmental, economic, social, and resource use factors;

(O) research and data collection should be undertaken to improve scientific and technical knowledge of salmon fisheries, including ecosystem interactions, status of salmon populations, and the condition of salmon habitats;

(P) the best available scientific information on the status of salmon populations and the condition of the salmon's habitats should be routinely updated and subject to peer review;

(4) public support and involvement for sustained use and protection of salmon resources should be sought and encouraged as follows:

(A) effective mechanisms for dispute resolution should be developed and used;

(B) pertinent information and decisions should be effectively disseminated to all interested parties in a timely manner;

(C) the board's regulatory management and allocation decisions will be made in an open process with public involvement;

(D) an understanding of the proportion of mortality inflicted on each salmon stock by each user group, should be promoted, and the burden of conservation should be allocated across user groups in a manner consistent with applicable state and federal statutes, including AS 16.05.251 (e) and AS 16.05.258; in the absence of a regulatory management plan that otherwise allocates or restricts harvests, and when it is necessary to restrict fisheries on salmon stocks where there are known conservation problems, the burden of conservation shall be shared among all fisheries in close proportion to each fisheries' respective use, consistent with state and federal law;

(E) the board will work with the commissioner and other agencies as necessary to assure that adequately funded public information and education programs provide timely materials on salmon conservation, including habitat requirements, threats to salmon habitat, the value of salmon and habitat to the public and ecosystem (fish and wildlife), natural variability and population dynamics, the status of salmon stocks and fisheries, and the regulatory process;

(5) in the face of uncertainty, salmon stocks, fisheries, artificial propagation, and essential habitats shall be managed conservatively as follows:

(A) a precautionary approach, involving the application of prudent foresight that takes into account the uncertainties in salmon fisheries and habitat management, the biological, social, cultural, and economic risks, and the need to take action with incomplete knowledge, should be applied to the regulation and control of harvest and other human-induced sources of salmon mortality; a precautionary approach requires

(i) consideration of the needs of future generations and avoidance of potentially irreversible changes;

(ii) prior identification of undesirable outcomes and of measures that will avoid undesirable outcomes or correct them promptly;

(iii) initiation of any necessary corrective measure without delay and prompt achievement of the measure's purpose, on a time scale not exceeding five years, which is approximately the generation time of most salmon species;

(iv) that where the impact of resource use is uncertain, but likely presents a measurable risk to sustained yield, priority should be given to conserving the productive capacity of the resource;

(v) appropriate placement of the burden of proof, of adherence to the requirements of this subparagraph, on those plans or ongoing activities that pose a risk or hazard to salmon habitat or production;

(B) a precautionary approach should be applied to the regulation of activities that affect essential salmon habitat.

(d) The principles and criteria for sustainable salmon fisheries shall be applied, by the department and the board using the best available information, as follows:

(1) at regular meetings of the board, the department will, to the extent practicable, provide the board with reports on the status of salmon stocks and salmon fisheries under consideration for regulatory changes, which should include

(A) a stock-by-stock assessment of the extent to which the management of salmon stocks and fisheries is consistent with the principles and criteria contained in the policy under this section;

(B) descriptions of habitat status and any habitat concerns;

(C) identification of healthy salmon stocks and sustainable salmon fisheries;

(D) identification of any existing salmon escapement goals, or management actions needed to achieve these goals, that may have allocative consequences such as the

(i) identification of a new fishery or expanding fishery;

(ii) identification of any salmon stocks, or populations within stocks, that present a concern related to yield, management, or conservation; and

(iii) description of management and research options to address salmon stock or habitat concerns;

(2) in response to the department's salmon stock status reports, reports from other resource agencies, and public input, the board will review the management plan, or consider developing a management plan, for each affected salmon fishery or stock; management plans will be based on the principles and criteria contained in this policy and will

(A) contain goals and measurable and implementable objectives that are reviewed on a regular basis and utilize the best available scientific information;

(B) minimize the adverse effects on salmon habitat caused by fishing;

(C) protect, restore, and promote the long-term health and sustainability of the salmon fishery and habitat;

(D) prevent overfishing; and

(E) provide conservation and management measures that are necessary and appropriate to promote maximum or optimum sustained yield of the fishery resource;

(3) in the course of review of the salmon stock status reports and management plans described in (1) and (2) of this subsection, the board, in consultation with the department, will determine if any new fisheries or expanding fisheries, stock yield concerns, stock management concerns, or stock conservation concerns exist; if so, the board will, as appropriate, amend or develop salmon fishery management plans to address these concerns; the extent of regulatory action, if any, should be commensurate with the level of concerns and range from milder to stronger as concerns range from new and expanding salmon fisheries through yield concerns, management concerns, and conservation concerns;

(4) in association with the appropriate management plan, the department and the board will, as appropriate, collaborate in the development and periodic review of an action plan for any new or expanding salmon fisheries, or stocks of concern; action plans should contain goals, measurable and implementable objectives, and provisions, including

(A) measures required to restore and protect salmon habitat, including necessary coordination with other agencies and organizations;

(B) identification of salmon stock or population rebuilding goals and objectives;

(C) fishery management actions needed to achieve rebuilding goals and objectives, in proportion to each fishery's use of, and hazards posed to, a salmon stock;

(D) descriptions of new or expanding salmon fisheries, management concern, yield concern, or conservation concern; and

(E) performance measures appropriate for monitoring and gauging the effectiveness of the action plan that are derived from the principles and criteria contained in this policy;

(5) each action plan will include a research plan as necessary to provide information to address concerns; research needs and priorities will be evaluated periodically, based on the effectiveness of the monitoring described in (4) of this subsection;

(6) where actions needed to regulate human activities that affect salmon and salmon's habitat that are outside the authority of the department or the board, the department or board shall correspond with the relevant authority, including the governor, relevant boards and commissions, commissioners, and chairs of appropriate legislative committees, to describe the issue and recommend appropriate action.

(e) Nothing in the policy under this section is intended to expand, reduce, or be inconsistent with, the statutory regulatory authority of the board, the department, or other state agencies with regulatory authority that impacts the fishery resources of the state.

[Defined terms of the policy were not duplicated here, but can be found in the regulation]

An important element of the sustainable salmon fisheries policy is the establishment of escapement goals. The policy for establishing escapement goals on systems is described in 5 AAC 39.223:

(a) The Department of Fish and Game (department) and the Board of Fisheries (board) are charged with the duty to conserve and develop Alaska's salmon fisheries on the sustained yield principle. Therefore, the establishment of salmon escapement goals is the responsibility of both the board and the department working collaboratively. The purpose of this policy is to establish the concepts, criteria, and procedures for establishing and modifying salmon escapement goals and to establish a process that facilitates public review of allocative issues associated with escapement goals.

(b) The board recognizes the department's responsibility to

(1) document existing salmon escapement goals for all salmon stocks that are currently managed for an escapement goal;

(2) establish biological escapement goals (BEG) for salmon stocks for which the department can reliably enumerate salmon escapement levels, as well as total annual returns; (3 – 6 omitted);

(7) prepare a scientific analysis with supporting data whenever a new BEG, SEG, or SET, or a modification to an existing BEG, SEG, or SET is proposed and, in its discretion, to conduct independent peer reviews of its BEG, SEG, and SET analyses;

(8) notify the public whenever a new BEG, SEG, or SET is established or an existing BEG, SEG, or SET is modified;

(9) whenever allocative impacts arise from any management actions necessary to achieve a new or modified BEG, SEG or SET, report to the board on a schedule that conforms, to the extent practicable, to the board's regular cycle of consideration of area regulatory proposals so that it can address allocation issues.

(c) In recognition of its joint responsibilities, and in consultation with the department, the board will

(1) take regulatory actions as may be necessary to address allocation issues arising from implementation of a new or modified BEG, SEG, and SET;

(2) during its regulatory process, review a BEG, SEG, or SET determined by the department and, with the assistance of the department, determine the appropriateness of establishing an optimal escapement goal (OEG); the board will provide an explanation of the reasons for establishing an OEG and provide, to the extent practicable, and with the assistance of the department, an estimate of expected differences in yield of any salmon stock, relative to maximum sustained yield, resulting from implementation of an OEG.

To assist fisheries management, ADF&G, defines areas in units. The smallest unit is a statistical area. A group of statistical areas form sections, and sections are grouped into districts. These units of area are important because they are referenced in different management plans. Following the department's mission and regulatory policies, the Karluk Lake escapement goal was last reviewed in 2010 (Sagalkin 2013), and management of Karluk Lake sockeye salmon is governed by a state regulated management plan (5 AAC 18.362), title Westside Kodiak Salmon Management Plan. This management plan directs the department in decision making for commercial fisheries opening in the Northwest Kodiak District, Southwest Kodiak District, and Southwest Afognak Section (part of the Afognak District). There are a number of salmon systems that are managed in this plan. While Karluk Lake sockeye salmon may be caught in many locations, it is presumed that they are most vulnerable to exploitation in the areas described in the Westside Kodiak Salmon Management Plan, and further, this is the best area to manage escapement.

The goal of the Westside Kodiak Management Plan is to achieve escapement and harvest objectives of sockeye salmon returning to the Karluk, Ayakulik, and other Westside minor sockeye salmon systems in the Northwest Kodiak and the Southwest Kodiak Districts and the Southwest Afognak Section in accordance with the guidelines set out in this plan. These guidelines acknowledge that escapements arrive at different systems at different ranges of times. Part of the management is to achieve escapement throughout these time periods, and that stocks will be transiting different areas at different times.

(b) The Central and North Cape Sections must be managed

(1) from June 1 through approximately June 15, as a mixed-stock fishery directed on early-run sockeye salmon returning to Karluk, Ayakulik, and Olga Bay systems; the commissioner shall open, by emergency order, at least two commercial test fishing periods of 33 hours in length;

(2) from approximately June 16 through July 5, based on early-run sockeye salmon returning to the Karluk system;

(3) from approximately July 6 through August 15, based on pink salmon returning to the major pink salmon systems in the Northwest Kodiak District;

(4) from approximately August 16 through August 24, based on pink salmon returning to the Northwest Kodiak District and on late-run sockeye salmon returning to the Karluk system;

(5) from approximately August 25 through September 5, based on late-run sockeye salmon returning to the Karluk system; and

(6) after approximately September 5, based on late-run sockeye salmon returning to the Karluk system and coho salmon returning to the Northwest Kodiak District.

(c) The Anton Larsen Bay, Sheratin Bay, Kizhuyak Bay, Terror Bay, Inner Uganik Bay, Spiridon Bay, Zachar Bay, and Uyak Bay Sections must be managed

(1) from June 1 through approximately June 15, based on local sockeye and early-run chum salmon returning to the major systems in each section; the commissioner shall open, by emergency order, at least two commercial test fishing periods of 33 hours in length to occur at the same time as those in the Central and North Cape Sections;

(2) from approximately June 16 through July 5, based on local sockeye and early-run chum salmon returning to the major systems in each section;

(3) from approximately July 6 through July 31, based on local sockeye, pink, and early-run chum salmon returning to the major systems in each section;

(4) from approximately August 1 through August 24, based on local pink and late-run chum salmon returning to the major systems in each section;

(5) from approximately August 25 through September 5, based on local pink, late-run chum, and coho salmon returning to the major salmon systems in each section; and

(6) after approximately September 5, based on coho salmon returning to the major coho salmon systems in each section.

(d) The Southwest Afognak Section must be managed

(1) from June 1 through approximately June 15, as a mixed-stock fishery directed on early-run sockeye salmon returning to Karluk, Ayakulik, and Olga Bay systems; the commissioner shall open, by emergency order, one commercial test fishing period of 33 hours in length; the department may allow additional fishing time in the Malina Creek Terminal Harvest Area described in 5 AAC 18.378 in order to harvest sockeye salmon bound for Malina Creek;

(2) from approximately June 16 through July 5, based on early-run sockeye salmon returning to the Karluk system; the department may allow additional fishing time in the Malina Creek Terminal Harvest Area described in 5 AAC 18.378 in order to harvest sockeye salmon bound for Malina Creek;

(3) from approximately July 6 through August 15, based on pink salmon returning to the major pink salmon systems in the Southwest Afognak Section and the Northwest Kodiak District; from July 6 through July 25, the section must also be managed according to 5 AAC 18.363(c), the North Shelikof Management Plan;

(4) from approximately August 16 through August 24, based on pink salmon returning to the major pink salmon systems in the Southwest Afognak Section and the Northwest Kodiak District and on the late-run sockeye salmon returning to the Karluk system;

(5) from approximately August 25 through September 5, based on late-run sockeye salmon returning to the Karluk system; and

(6) after approximately September 5, based on coho salmon returning to the major coho salmon systems in the Southwest Afognak District.

(e) The Inner and Outer Karluk Sections must be managed

(1) from June 1 through July 15, based on early-run sockeye salmon returning to the Karluk system; the commissioner may open, by emergency order, fishing periods in the Inner Karluk Section only if the department determines that the desired early-run escapement goal will be exceeded; in the Outer Karluk Section, from June 16 through approximately July 15, the commissioner shall open fishing periods to occur at the same time as open fishing periods in the Central Section;

(2) from July 16 through approximately August 24

(A) on odd-year cycles, based on late-run sockeye salmon returning to the Karluk system;

(B) on even-year cycles, based on late-run sockeye and pink salmon returning to the Karluk system;

(3) from approximately August 25 through September 5, based on late-run sockeye salmon returning to the Karluk system; and

(4) after approximately September 5, based on late-run sockeye salmon and coho salmon returning to the Karluk system.

(f) The Sturgeon and Halibut Bay Sections must be managed

(1) from June 1 through approximately June 22, as mixed-stock fisheries directed on early-run sockeye salmon returning to the Karluk, Ayakulik, and Olga Bay systems; the department shall not open any commercial fishing periods during this time;

(2) from approximately June 23 through July 15, based on early-run sockeye salmon returning to the Ayakulik and Karluk systems, except that the Sturgeon Section must also be managed with consideration for early-run chum salmon returning to the Sturgeon system;

(3) from approximately July 16 through August 24,

(A) in the Sturgeon Section

(i) on odd-year cycles, based on late-run sockeye salmon returning to the Karluk system;

(ii) on even-year cycles, based on late-run sockeye and on pink salmon returning to the Karluk system;

(B) in the Halibut Bay Section

(i) on odd-year cycles, from approximately July 16 through July 31 on late-run sockeye salmon returning to the Ayakulik system, and from approximately August 1 through August 24 on late-run sockeye salmon returning to the Karluk system;

(ii) on even-year cycles, from approximately July 16 through July 31 on late-run sockeye salmon and pink salmon returning to the Ayakulik system, and from approximately August 1 through August 24 on late-run sockeye salmon returning to the Karluk system and on pink salmon returning to the Ayakulik system;

(4) from approximately August 25 through September 5, based on late-run sockeye salmon returning to the Karluk system; and

(5) after approximately September 5, based on coho salmon returning to local coho salmon systems.

(g) The Inner and Outer Ayakulik Sections must be managed

(1) from June 1 through approximately July 15, based on early-run sockeye salmon returning to the Ayakulik system;

(2) from approximately July 16 through August 24,

(A) on odd-year cycles, based on late-run sockeye salmon returning to the Ayakulik system;

(B) on even-year cycles, based on late-run sockeye and pink salmon returning to the Ayakulik system; and

(3) after approximately August 24, based on coho salmon returning to the Ayakulik system.

All regulations, including management plans, are open for review during the regular Board of Fisheries cycle. Either the public or the department is able to suggest changes to the management plan to the board.

Appendix D

Karluk Lake Aquatic Resources Data

Table D-1. Karluk Lake Nutrient Levels, Productivity, and Juvenile Sockeye Salmon Population Estimates

	Nutrients	Primary	Secondary		Tertiary[a]			
Year	**Mean April and May Phosphorus Concentration (µg/L)[1b]**	**Mean July–September Chlorophyll *a* Concentration (µg/L)[1]**	**Mean June to August Total Zooplankton Biomass (mg/m^2)[1]**	**Mean May to August Zooplankton Size (mm), All Species[1]**	**Estimate of Juvenile Sockeye salmon Population in Lake, Summer–Fall[2]**	**Total Outmigrating Smolt[3]**	**Mean Age 2 Smolt Weight (grams)[3c]**	**Mean Age 3 Smolt Weight (grams)[3c]**
1980	9	2.94	NA	NA	NA	1,686,500	9.4	11.7
1981	4.6	0.8	1,374	0.69	NA	2,041,700	13.4	16.2
1982	5.1	0.42	1,848	0.68	NA	821,200	15.1	20.2
1983	8	0.55	1,127	0.68	1,418,000	941,000	14.2	20
1984	7	0.44	1,224	0.83	1,989,000	1,074,000	13.9	19.3
1985	7.7	1.69	1,126	0.72	11,336,000	NA	12.1	16.4
1986	6.5	1.87	NA	NA	6,037,000	NA	13	14.7
1987	8.7	2.4	437	0.65	18,205,000	NA	10.4	15.6
1988	7.8	3.13	770	0.7	10,924,500	NA	9.4	11.9
1989	8.4	1.14	1,361	0.67	3,989,000	NA	9.6	13.4
1990	10.4	0.98	1,403	0.71	48,363,923	NA	8.7	12.2
1991	6.7	1.29	1,021	0.68	7,952,241	4,140,821	11.3	15
1992	7.8	1.96	662	0.81	NA	3,493,996	9.8	13.4
1993	9	1.92	559	0.65	NA	NA	NA	NA
1994	4.9	1.01	825	0.66	1,176,045	NA	11.1	13.4
1995	NA	NA	1,457	0.83	1,443,958	NA	12.3	16.1
1996	NA	NA	1,093	0.68	2,178,586	NA	NA	NA
1997	5.2	0.78	998	0.7	2,057,491	NA	13	13.4
1998	NA	1.80	NA	NA	NA	NA	NA	NA
1999	NA	NA	948	0.76	NA	1,066,534	13.2	16.5
2000	NA	NA	3,215	0.72	NA	1,676,502	15	19.7
2001	NA	NA	653	0.67	NA	3,740,255	14.4	23.4

Table D-1. Karluk Lake Nutrient Levels, Productivity, and Juvenile Sockeye Salmon Population Estimates

	Nutrients	Primary	Secondary		Tertiary[a]			
Year	**Mean April and May Phosphorus Concentration (µg/L)[1b]**	**Mean July–September Chlorophyll *a* Concentration (µg/L)[1]**	**Mean June to August Total Zooplankton Biomass (mg/m^2)[1]**	**Mean May to August Zooplankton Size (mm), All Species[1]**	**Estimate of Juvenile Sockeye salmon Population in Lake, Summer–Fall[2]**	**Total Outmigrating Smolt[3]**	**Mean Age 2 Smolt Weight (grams)[3c]**	**Mean Age 3 Smolt Weight (grams)[3c]**
2002	NA	NA	1,306	0.73	NA	1,281,971	9.6	12.1
2003	NA	NA	1,671	0.68	NA	2,235,435	12.2	14.4
2004	10.2	2.61	627	0.63	NA	2,308,625	13.2	16.4
2005	8.4	1.73	269	0.58	NA	1,494,818	8.7	11.5
2006	8.5	1.81	391	0.57	NA	1,173,252	6.3	7.9
2007	NA	NA	739	0.73	NA	NA	NA	NA
2008	NA	NA	231	0.63	NA	NA	NA	NA
2009	5.6	NA	1,394	0.73	NA	NA	NA	NA
2010	5.3	0.58	1,607	0.82	NA	NA	17.0[e]	23.5[e]
2011	5.7	1.10	1,329	0.79	NA	NA	20.0[e]	24.1[e]
2012	5.4	0.72	2,848	0.82	NA	888,658	20.3	25.6
2013	NA	NA	2,488	NA	NA	269,873[f]	30.1	40.0
Mean	7.21	1.46	1,194	0.71	9,005,442	1,784,420	13.1	17.1

[1] From Golder and Associates 2011 except 2010–2012 data, which were obtained via personal communication from Tina Fairbanks, KRAA, to George Weekley, SWCA Environmental Consultants, 2013.

[2] From Schrof and Honnold 2003 completed by hydroacoustic studies. This number represents fish present in the lake.

[3] From Loewen 2014. The total number of outmigrating smolts is typically lower than the number of juvenile sockeye salmon in the lake since some fish may spend additional years in residence or may not survive to outmigration.

[a] Lake estimates differ from outmigrating estimates because not all smolt survive to migration or they may reside in lake for additional years.

[b] Mean of samples taken in April and May when the lake was assumed to not be satisfied.

[c] Estimates generated from counting growth rigs on fish scales.

[e] Data from “grab sample” studies (Loewen 2014).

[f] Trap avoidance was observed throughout the season and value is considered an underestimate.

NA = data not available

Table D-2. Karluk Lake Adult Sockeye Salmon Run, Escapement

Year	Early-run[a]			Late Run[a]		
	Run Total[1]	Escapement to Spawning Ground[1]	Goal Status[b]	Run Total[1]	Escapement to Spawning Ground [1]	Goal Status[b]
1985	345,014	316,688	NA	847,588	679,260	NA
1986	474,947	358,756	NA	825,457	528,415	NA
1987	431,250	354,094	NA	582,176	412,157	NA
1988	331,746	296,510	Met	410,027	282,306	Under
1989[d]	349,755	349,753	Met	762,369	758,893	Over
1990	228,218	196,197	Under	1,532,551	541,891	Met
1991	271,204	243,069	Under	1,929,800	831,970	Over
1992	462,164	217,152	Met	1,056,954	614,262	Over
1993	569,748	261,169	Over	631,649	396,288	Under
1994	449,223	260,771	Over	693,583	587,258	Over
1995	521,412	238,079	Met	866,512	504,977	Met
1996	760,231	250,357	Over	511,686	323,969	Under
1997	387,339	252,859	Over	439,016	311,902	Under
1998	368,771	252,298	Over	687,014	384,848	Under
1999	574,996	392,419	Over	1,004,004	589,119	Over
2000	557,836	291,351	Over	656,939	445,393	Met
2001	642,463	338,799	Over	872,529	524,739	Met
2002	623,880	456,842	Over	866,019	408,734	Met
2003	824,617	451,856	Over	1,592,338	626,854	Over
2004	789,556	393,468	Over	658,930	326,466	Met
2005	529,660	283,860	Over	921,675	498,102	Over
2006	474,903	202,366	Met	570,448	288,007	Met
2007	493,094	294,740	Over	721,610	251,835	Met

Table D-2. Karluk Lake Adult Sockeye Salmon Run, Escapement

Year	Early-run[a]			Late Run[a]		
	Run Total[1]	Escapement to Spawning Ground[1]	Goal Status[b]	Run Total[1]	Escapement to Spawning Ground [1]	Goal Status[b]
2008	152,942	82,191	Under	294,886	164,299	Under
2009	68,852	52,798	Under	329,783	277,280	Met
2010	81,361	71,453	Under	315,997	276,649	Met
2011	93,854	87,049	Under	265,268	230,273	Met
2012	235,886	188,085	Met	589,797	314,605	Met
2013	445,579	234,880	Met	753,414	336,479	Met
Mean	432,431	254,382	NA	765,173	401,101	NA
2014 prediction	283,000	175,000	NA	669,000	270,000	NA

[1] Data through 2012 are from Loewen 2014, 2013 data are from Moore 2014, and 2014 data are from Munro and Volk 2013.

[2] Sagalkin and others 2013.

[a] Reliable data do not exist before 1985 (Moore 2014).

[b] Reflect changes in goals reviewed triennially by the ADF&G.

[c] Fish were caught 1–9 years after corresponding hatch year and after outmigrating, living in the ocean, and returning as adults to spawn. Ages of fish (plus 1 year for time between spawn and hatch) were subtracted from catch year to determine year of hatch. All individuals per hatch year, regardless of catch year, were added together to generate estimate.

[d] Harvest was curtailed due to the Exxon Valdez oil spill.

[e] Values are underestimated as not all sockeye salmon from brood year have returned as adults.

NA = data not available.

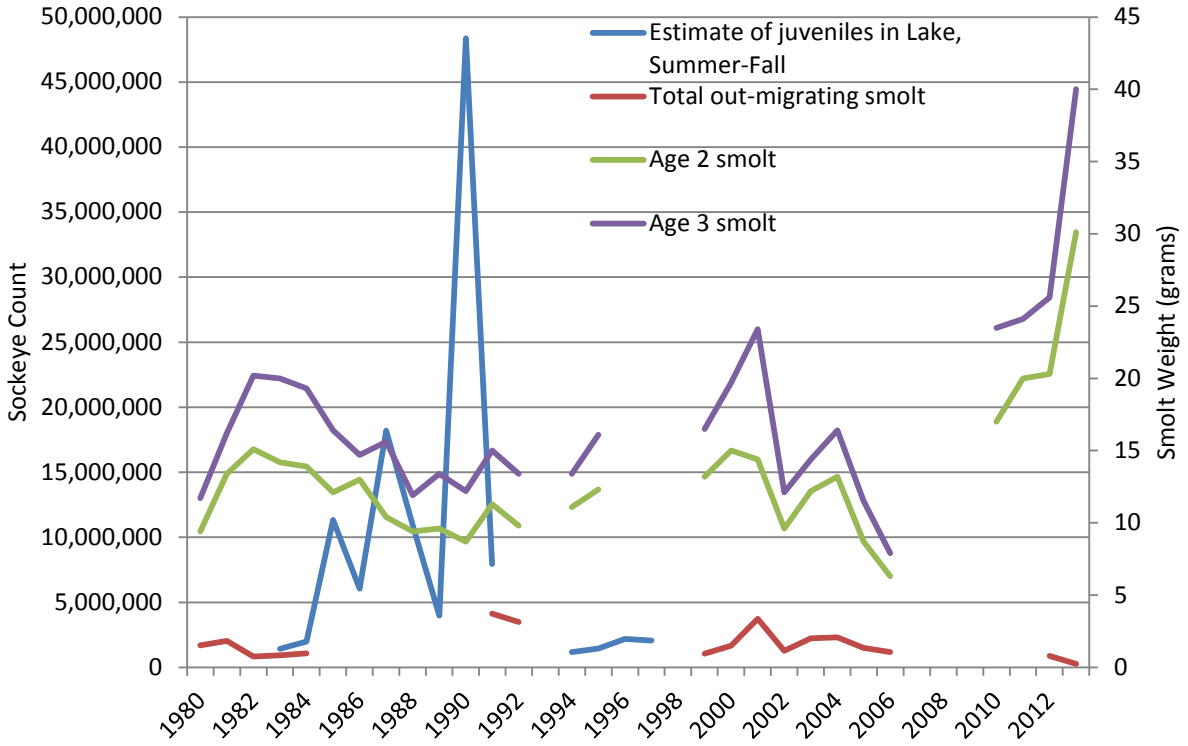

Figure D-1. Historical tertiary productivity measured as in lake and outmigrating juvenile sockeye salmon count and smolt size in Karluk Lake.

[1] *Source*: Schrof and Honnold 2003, completed by hydroacoustic studies. This number represents fish present in the lake.

[2] *Source*: Loewen 2014. The total number of outmigrating smolts is typically lower than the number of juvenile sockeye salmon in the lake since some fish may spend additional years in residence or may not survive to outmigration.

[a] Estimates generated from counting growth rigs on fish scales.

[b] Lake estimates differ from outmigrating estimates because not all smolt survive to migration or they may reside in the lake for additional years.

[c] 2010 and 2011 weight data from "grab sample" studies (Loewen 2014).

[d] Trap avoidance was observed throughout the 2013 season and value is considered an underestimate.