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An Assessment of Potential Mining Impacts on Salmon Ecosystems of Bristol Bay, Alaska

Volume 2 – Appendices A-D

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Volume 2—Appendices A-D

U.S. Environmental Protection Agency

Region 10

Seattle, WA

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Fishery Resources of the Bristol Bay Region

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INTRODUCTION

Millions of Pacific salmon return from feeding in the open ocean each year and swarm through Bristol Bay en route to their natal spawning streams. Nine major river systems comprise the spawning grounds for Bristol Bay salmon (Figure 1), and schools navigate toward the mouths of their respective rivers as they pass through the Bay. Each summer, thousands of commercial fishermen use drift and set gill nets to capture millions of returning fish, making Bristol Bay the largest sockeye salmon fishery in the world. Salmon that escape the fishery distribute throughout the Bay's watersheds and spawn in hundreds of discreet populations. Sport anglers target those salmon, especially sockeye, Chinook and coho, as they migrate through the river systems toward their spawning grounds. Also prized are abundant populations of rainbow trout and other sport fish, including Dolly Varden and Arctic grayling, which attain trophy size by gorging on energy-rich salmon eggs, flesh from salmon carcasses, and invertebrates dislodged by spawning salmon. The abundance of large game fish, along with the wilderness setting, makes the Bristol Bay region a world-class destination for sport anglers. Alongside recreationists, aboriginal people, guided by an age-old culture, harvest their share of migrating salmon and other fish species, which provide a primary source of sustenance.

In this report we reviewed the biology, ecology, and management of the fishes of the Bristol Bay watersheds, emphasizing those species of the greatest cultural and economic importance – sockeye salmon, Chinook salmon, and rainbow trout. Rather than to imply that other fishes are not important, this focus reflected the disproportionate amount of research on these species (especially sockeye salmon) and was necessary to keep the amount of material manageable. In contrast, there is relatively little information available for the region's freshwater species, despite the importance of some in subsistence and sport fisheries. Our objectives were to describe the commercial and sport fishery resources of the region and to discuss the importance of Bristol Bay salmon populations in the context of the greater North Pacific Ocean. The subsistence fisheries and their importance are discussed in the main body of the Assessment (Chapters 5 and 12). The literature reviewed consisted primarily of agency reports and peer-reviewed scientific papers, although unpublished data and personal communications were used where no pertinent published literature existed and popular sources were consulted to characterize the more subjective attributes of the sport fisheries. Our geographic focus was the Kvichak River watershed (including the Alagnak River) and the Nushagak River watershed (including the Wood River). Since the Kvichak and Nushagak sockeye salmon populations are components of the Bristol Bay-wide stock complex, however, we typically discuss their abundance trends at both the Bristol Bay scale and at the scale of the individual river systems. The economics of Bristol Bay's fisheries and the role of fish in the region's aboriginal cultures are each covered in separate sections of the Bristol Bay Watershed Analysis.

Figure 1. Major river systems and fishing districts in Bristol Bay, Alaska.

ECOLOGY AND LIFE HISTORY OF BRISTOL BAY FISHES

General salmon life history

Five species of Pacific salmon are native to North American waters – pink (*Oncorhynchus gorbuscha*), chum (*O. keta*), sockeye (*O. nerka*), coho (*O. kisutch*), and Chinook (*O. tshawytscha*) salmon – and all have spawning populations in the Bristol Bay region. These species share a rare combination of life history traits that contribute to their biological success, as well as their status as cultural icons around the North Pacific rim. These traits – anadromy, homing, and semelparity – are described briefly in the following paragraphs.

All Pacific salmon hatch in fresh water, migrate to sea for a period of relatively rapid growth, and return to fresh water to spawn. This strategy, termed anadromy, allows salmon to capitalize on the resource-rich marine environment, where growth rates are much faster than in fresh water. Thus, anadromy allows salmon to attain larger body size, mature more quickly, and maintain larger spawning populations than would be possible with a non-anadromous life history (McDowall 2001). A prevailing theory is that anadromy evolves where a disparity in productivity exists between adjacent freshwater and marine environments (Gross et al. 1988). Freshwater productivity generally declines with latitude, and in the spawning range of Pacific salmon is half (or less) of that in lower latitudes. Conversely, ocean productivity generally increases with latitude, peaking within the range of Pacific salmon (Gross et al. 1988).

When salmon enter fresh water to spawn, the vast majority return to the location where they were spawned. By this means, termed homing, salmon increase juvenile survival by returning to spawn in an environment with proven suitability (Cury 1994). Another adaptive advantage of homing is that it fosters reproductive isolation that enables populations to adapt to their particular environment (Blair et al. 1993, Dittman and Quinn 1996, Eliason et al. 2011). For instance, populations that travel long distances to reach inland spawning sites develop large lipid reserves to fuel the migration (Quinn 2005, pgs. 77–78 and figures 4-6), since adult salmon generally do not feed after entering fresh water. As another example, sockeye fry from populations that spawn downstream of nursery lakes are genetically programmed to migrate upstream after emergence, while fry from populations that spawn upstream of nursery lakes are programmed to migrate downstream (Burgner 1991, pgs. 33-35). Examples of adaptations are many, and include heritable anatomical, physiological, and behavioral traits. Without homing, gene flow would occur throughout the species, making adaptation to specific freshwater conditions impossible; in this sense, homing counteracts the dispersal effects of anadromy (McDowall 2001). Homing is not absolute, however, and a small amount of straying ensures that amenable habitats are colonized by salmon (e.g., Milner and Bailey 1989).

Pacific salmon, quite famously, die after spawning only once. This trait, termed semelparity, serves to maximize the investment in one reproductive effort at the expense of any future reproductive effort. In salmon, it may have evolved as a response to the high cost of migration to natal streams and the associated reduction in adult survival (Roff 1988). The evolution of semelparity in Pacific salmon was accompanied by increased egg size so, while long migrations may have been a prerequisite, the driving force behind the evolution of semelparity was likely the increase in egg mass and associated increase in juvenile survival (Crespi and Teo 2002).

As salmon approach sexual maturity, the countershading and silvery sheen that hide them at sea give way to characteristic spawning colors, often with hues of red. Males develop hooked snouts (the generic name *Oncorhynchus* refers to this trait) and protruding teeth, and their previously bullet-shaped bodies become laterally flattened. These spawning colors and secondary sexual characteristics, which develop to varying degrees among species and even among populations, probably serve multiple purposes on the spawning grounds, including species recognition, sex recognition, and territorial displays.

With few exceptions, preferred spawning habitat consists of gravel-bedded stream reaches with moderate depth and current (30–60 cm deep and 30–100 cm per second, respectively; Quinn 2005, pg. 108). Females excavate a nest (redd) in the gravel to receive the eggs, which are fertilized by one or more competing males as they are released and subsequently buried by the female. The seasonality of spawning and incubation is roughly the same for all species of Pacific salmon, although the timing can vary somewhat by species, population, and region. In general, salmon spawn during summer or early fall and the fry emerge from the spawning gravel the following spring. While in the gravel, the embryos develop within their eggs and then hatch into fry that continue to subsist on yolk sacs. After emerging from the gravel, basic life history patterns of the five species differ in notable ways.

Species-specific life history and ecology

Sockeye salmon

Sockeye salmon originate from river systems along the North American and Asian shores of the North Pacific and Bering Sea, roughly from the latitude of the Sacramento River to that of Kotzebue Sound. The largest North American populations occur between the Columbia and Kuskokwim rivers (Burgner 1991, pg. 5). Spawning sockeye are readily identified by their striking red bodies with green heads and tails; males additionally develop a large hump in front of the dorsal fin.

Sockeye are unique among salmon in that most stocks rely on lakes as the primary freshwater rearing habitat. Some sockeye spawn within the nursery lake where their young will rear. Others spawn in nearby stream reaches, and their fry migrate to the nursery lake after emerging from spawning redds. Sockeye are by far the most abundant salmon species in the Bristol Bay region (Salomone et al. 2011, pg. 1), undoubtedly due to the abundance of accessible lakes in this landscape (Figure 1; also see discussion of *habitat quantity*). Tributaries to Iliamna Lake, Lake Clark, and the Wood Tikchik Lakes are major spawning areas, and juveniles rear in each of these systems (Figure 2). On average, the Kvichak River, with Iliamna Lake as its primary rearing site, produces more sockeye than any other system in the Bristol Bay region (see Appendix 1). Juveniles in Bristol Bay systems rear for one or two years in their nursery lakes (West et al. 2009, pg. 235), feeding primarily on zooplankton in the limnetic zone (Burgner 1991, pg. 37). Many Nushagak River sockeye populations spawn and rear in riverine habitats throughout the basin and do not use lakes (Figure 2).

Fish then typically spend two or three years at sea (West et al. 2009), returning at an average weight of 5.9 lb (2.7 kg, based on recent commercial catches; Salomone et al. 2011, pg.

105). At sea, sockeye salmon feed on a range of invertebrates, small fish, and squid (Burgner 1991, pg 83).

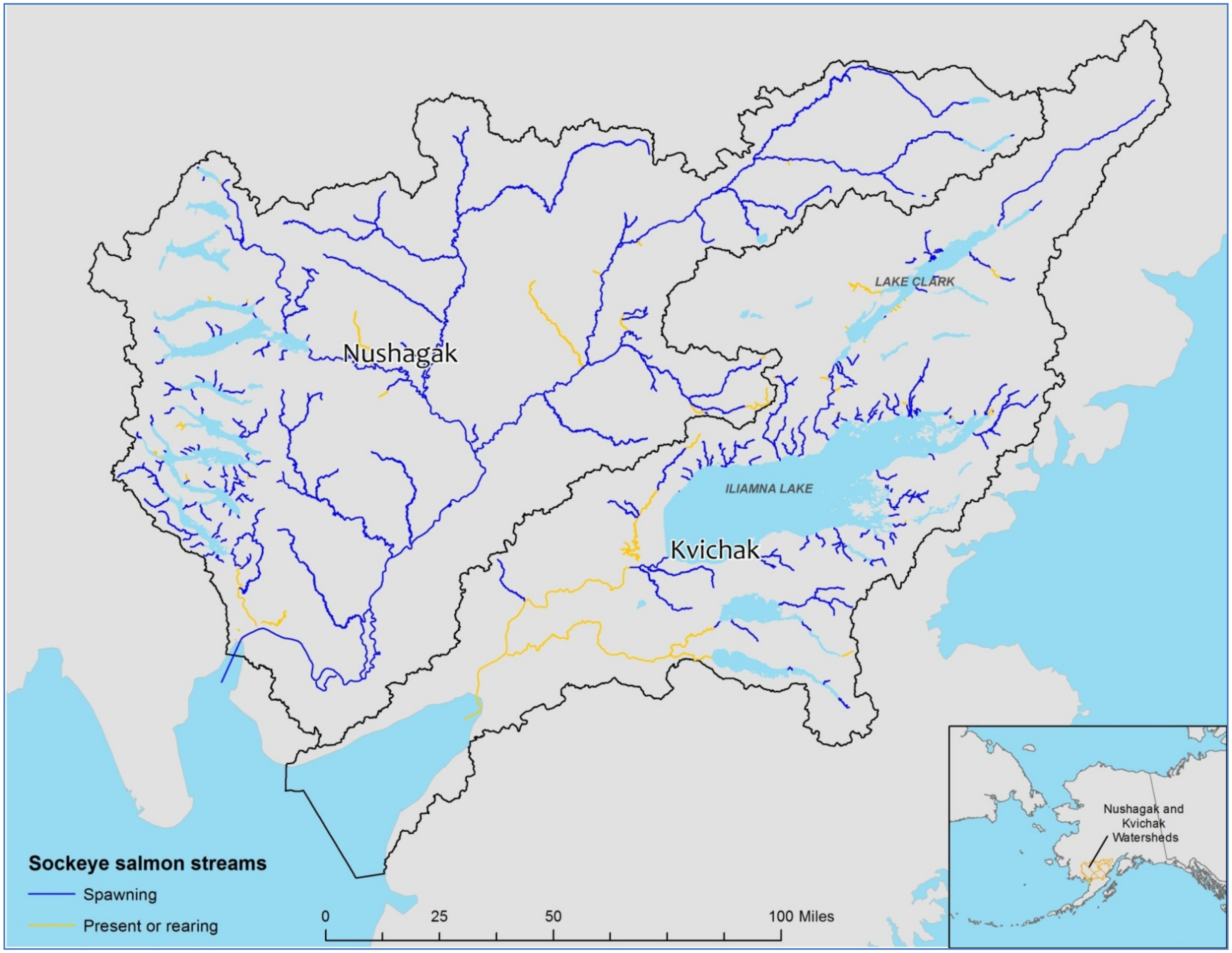


Figure 2. Documented sockeye salmon distribution in the Nushagak and Kvichak watersheds. Data are from the Alaska Department of Fish and Game's Anadromous Waters Catalog (AWC; Johnson and Blanche 2012). See Section 7.2.5 in the main body of the assessment for assumptions and caveats associated with interpreting AWC data.

Chinook salmon

Chinook salmon spawn in streams on both shores of the North Pacific and Bering Sea, roughly from the latitude of central California to that of Point Hope. There are more than a thousand North American spawning populations and a much smaller number in Asia. These populations tend to be relatively small, however, making Chinook the rarest of North America's Pacific salmon species (Healey 1991, pg. 316). They are also the largest of the Pacific salmon; at least one specimen over 60 kg has been reported, but most weigh less than 23 kg (Mecklenburg et al. 2002, pg. 207).

Chinook salmon have two different behavioral forms. The "stream type" form is predominant in Bristol Bay, as well as other areas of northern North America, Asia, and the headwaters of Pacific Northwest rivers (Healey 1991, pg. 314). These fish spend one or more years as juveniles in fresh water, range widely at sea, and return to spawning streams during spring or summer. "Ocean type" Chinook, by contrast, migrate to sea soon after hatching, forage primarily in coastal marine waters, and return to spawning streams in the fall (Healey 1991, pg. 314). In fresh water, juvenile Chinook tend to occupy flowing water and feed on aquatic insects. At sea, Chinook are generally pisciverous (Brodeur 1990) and feed higher on the food chain than other salmon species (Satterfield and Finney 2002).

Chinook spawn and rear throughout the Nushagak River basin and in many tributaries of the Kvichak River (Figure 3). Some life history data are available from adults returning to the Nushagak River, Bristol Bay's largest Chinook salmon run. Essentially all Chinook spend one year rearing in fresh water, and the vast majority (typically >90% of a given brood year) spend two to four years at sea (Gregory Buck, ADF&G, unpublished data). Fish that spend four years at sea are the dominant age class and comprise approximately 43% of the average return, followed by those that spend 3 years (35%) and two years (17%) at sea. Chinook salmon individuals in recent Bristol Bay commercial catches have averaged 16.6 lb (7.5 kg; Salomone et al. 2011, pg. 105).

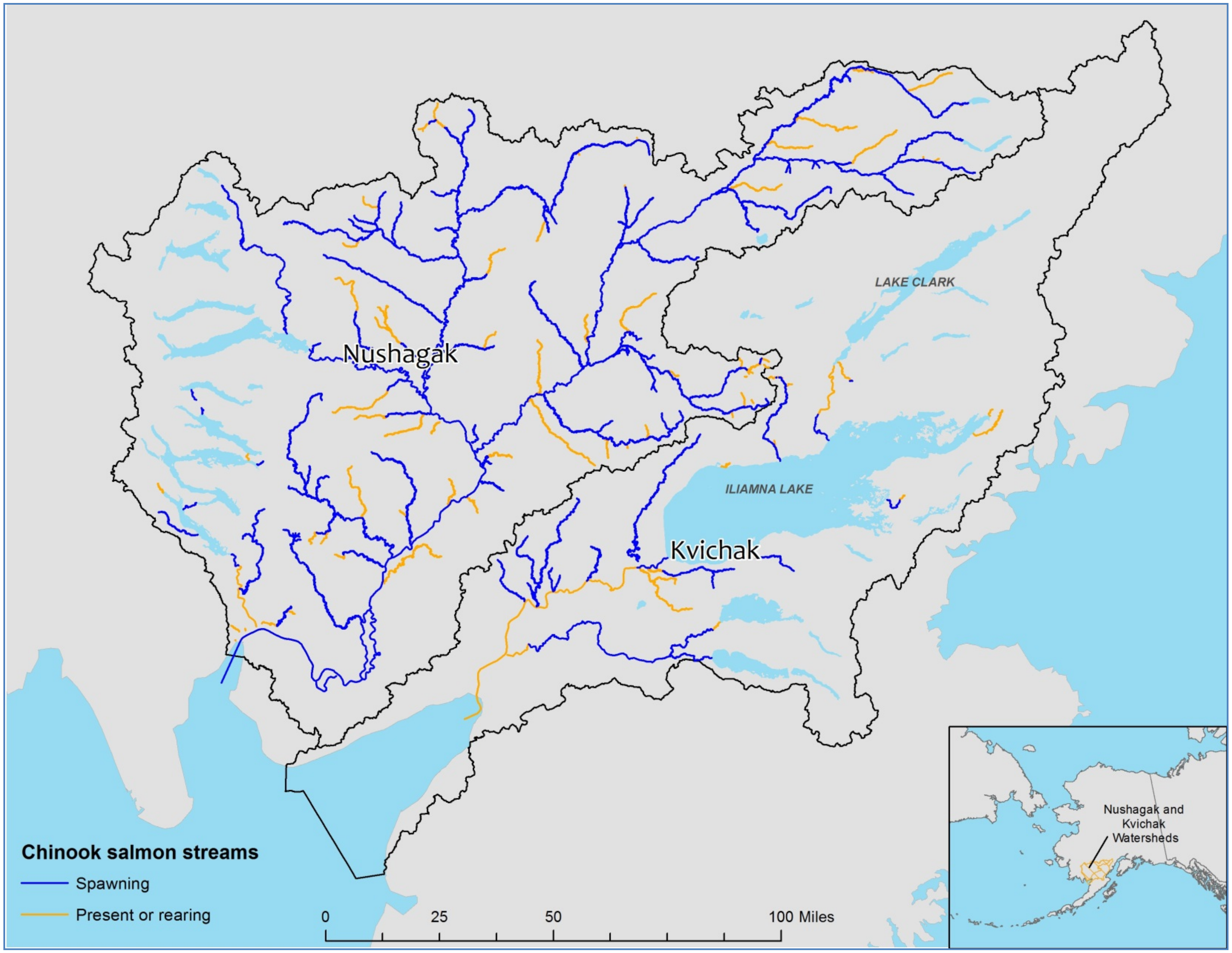


Figure 3. Documented Chinook salmon distribution in the Nushagak and Kvichak watersheds. Data are from the Alaska Department of Fish and Game's Anadromous Waters Catalog (AWC; Johnson and Blanche 2012).

Rainbow trout

Rainbow trout (*Oncorhynchus mykiss*) are native to western North America and the eastern coast of Asia, although their popularity as a sport fish has led to introduced populations around the world. Bristol Bay's rainbow trout are of the coastal variety (sensu Behnke 1992, pg. 193), which ranges from the Kuskokwim River to southern California. While classified in the same genus as the Pacific salmon, there are some key differences. Foremost, rainbow trout are not genetically programmed to die after spawning, making iteroparity (i.e., repeat spawning) a feature of most populations. Also, most coastal drainages support populations of both resident and anadromous (i.e., steelhead) forms, although only the resident form occurs near the northern and southern limits of rainbow trout distribution (Behnke 1992, pg. 197), including the Nushagak and Kvichak drainages. Finally, rainbow trout spawn in the spring, as opposed to summer or early fall, although their spawning habitat and behavior is otherwise generally similar to that of salmon.

Bristol Bay rainbow trout tend to mature slowly and grow to relatively large size. For example, 90% of spawners in Lower Talarik Creek were more than seven years old; the vast majority of these were longer than 500 mm and a few exceeded 800 mm (years 1971-1976; Russell 1977, pgs. 30-31). Growth (mm/year) was fastest for fish between four and six years of age and winter growth appeared to be minimal (Russell 1977, pgs. 44-45).

Bristol Bay trout utilize complex and varying migratory patterns that allow them to capitalize on different stream and lake habitats for feeding, spawning, and wintering. Fish from Lower Talarik Creek migrate downstream to Iliamna Lake after spawning. From there, they appear to utilize a variety of habitats, as some tagged individuals have been recovered in other Iliamna Lake tributaries and in the Newhalen and Kvichak Rivers (Russell 1977, pg. 23). In the Alagnak River watershed, a number of rainbow trout life history types have been identified, each with their own habitat use and seasonal migratory patterns (Meka et al. 2003). These consist of lake, lake-river, and river residents, the latter of which range from non-migratory to highly migratory (Meka et al. 2003). Individuals comprising each of these life history types migrate in order to spend the summer in areas with abundant spawning salmon (Meka et al. 2003).

Eggs from spawning salmon are a major food item for Bristol Bay trout and are likely responsible for much of the growth attained by these fish. Upon the arrival of spawning salmon in the Wood River basin, rainbow trout shifted from consuming aquatic insects to primarily salmon eggs for a 5-fold increase in ration and energy intake (Scheuerell et al. 2007). With this rate of intake, a bioenergetics model predicts a 100-g trout to gain 83 g in 76 days; without the salmon-derived subsidy, the same fish was predicted to lose five g (Scheuerell et al. 2007). Rainbow trout in Lower Talarik Creek were significantly fatter (i.e., higher condition factor) in years with high spawner abundance than in years with low abundance (Russell 1977, pg. 35).

Coho salmon

Coho salmon are native to coastal drainages in western North America and eastern Asia, approximately from the latitude of the Sacramento River to that of Point Hope (Sandercock

1991, pg. 398). Coho salmon occur in relatively small populations, and are second only to Chinook salmon in rarity.

Most Alaskan coho salmon populations tend to spend two years in fresh water and one year at sea (Sandercock 1991, pg. 405). Few age data exist for Bristol Bay, but samples from two years on the Nushagak River indicated that approximately 90% of escaped coho salmon shared this age structure, while the remaining fish had spent either one year or three years in fresh water (West et al. 2009, pg. 84). Coho salmon individuals in recent Bristol Bay commercial catches have averaged 6.7 lb (3.0 kg; Salomone et al. 2011, pg. 105).

At sea, coho salmon consume a mix of fish and invertebrates (Brodeur 1990, pg. 15). Their trophic position is intermediate for Pacific salmon; Chinook salmon consume more fish while sockeye, pink, and chum salmon eat more zooplankton and squid (Satterfield and Finney 2002).

In fresh water, coho salmon feed primarily on aquatic insects, although salmon eggs and flesh can be important nutritional subsidies (Heintz et al. 2010, Rinella et al. 2011). They utilize a wide range of lotic and lentic freshwater habitats, including stream channels, off-channel sloughs and alcoves, beaver ponds, and lakes. Coho spawn in many stream reaches throughout the Nushagak and lower Kvichak watersheds, and juveniles distribute widely into headwater streams (Figure 4), where they are often the only salmon species present (Woody and O'Neal 2010, King et al. 2012, ADF&G Anadromous Waters Catalog). Production of juvenile coho is often limited by the extent and quality of available wintering habitats (Nickelson et al. 1992, Solazzi et al. 2000), and preliminary work in southcentral Alaska suggests that upwelling groundwater is an important feature (D.J. Rinella, unpublished data).

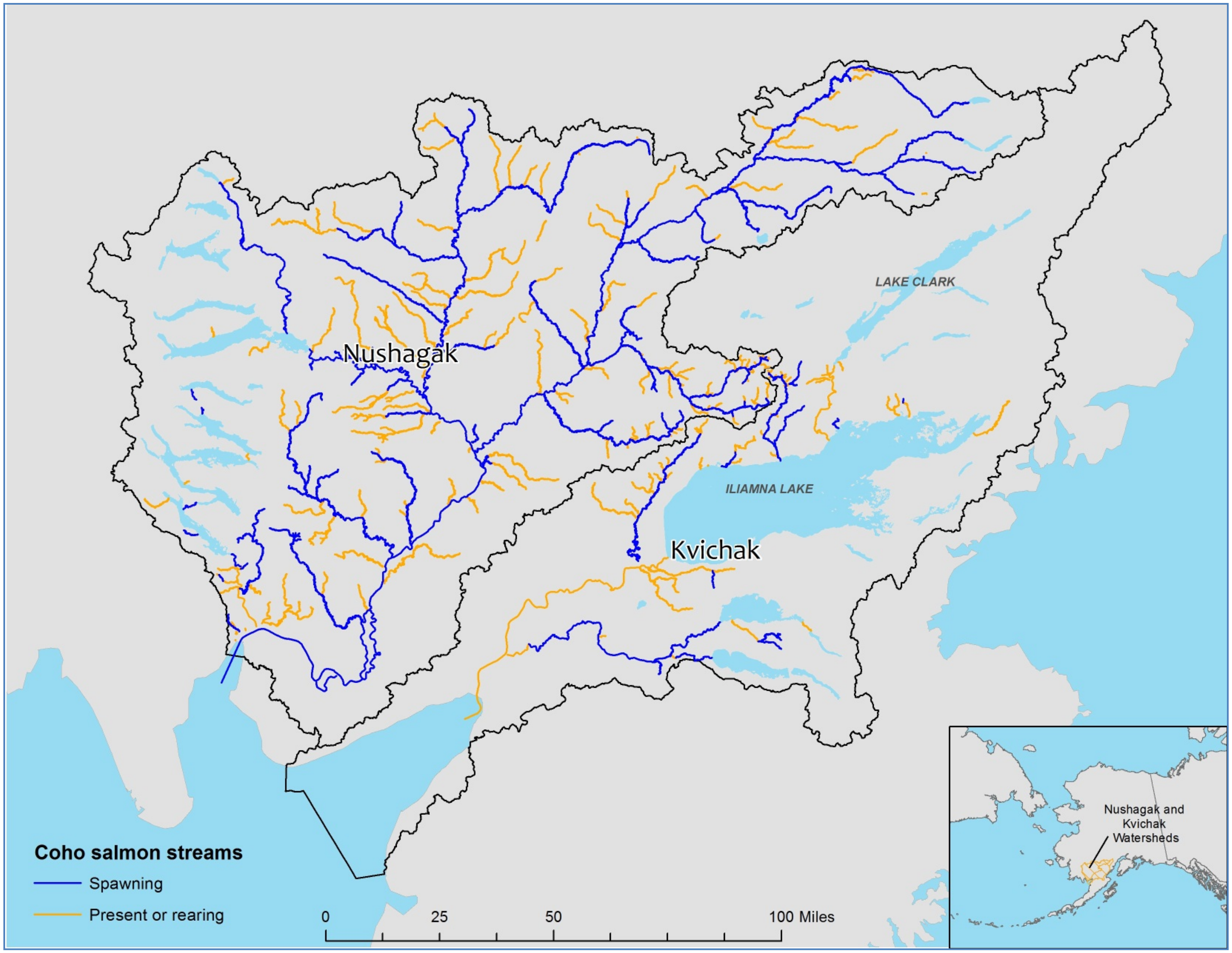


Figure 4. Documented coho salmon distribution in the Nushagak and Kvichak watersheds. Data are from the Alaska Department of Fish and Game's Anadromous Waters Catalog (AWC; Johnson and Blanche 2012).

Pink salmon

Pink salmon spawning populations occur on both sides of the North Pacific and Bering Sea, as far south as the Sacramento River and northern Japan. Northward, small spawning populations are scattered along the North American and Asian shores of the Arctic Ocean. Most pink salmon in the Kvichak and Nushagak watersheds spawn in mainstem habitats, although some tributary spawning occurs (Figure 5). The most abundant Pacific salmon overall (Irvine et al. 2009, pg. 2), pink salmon have a simplified life history that relies little on freshwater rearing habitat, and their young migrate to sea soon after emerging (Heard 1991, pg. 144). Pink salmon typically spawn in shallow, rocky stream reaches relatively low in the watershed, although most Nushagak River pink salmon spawn about 200 km above tidewater in the Nuyakuk River (Heard 1991, pg. 137).

Essentially all pink salmon breed at two years of age, and this strict two-year life cycle results in genetic isolation of odd- and even-year spawning runs, even within the same river system. For reasons not entirely clear, large disparities between odd- and even-year run sizes occur across geographic regions and extend over many generations. An extreme example is the Fraser River, in southern British Columbia, where millions of pink salmon return during odd-numbered years, yet no fish return during even-numbered years (Riddell and Beamish 2003, pg. 4). In Bristol Bay rivers, even-year runs currently dominate the returns (Salomone et al. 2011, pg. 5).

Pink salmon are the smallest of the Pacific salmon species; individuals in recent Bristol Bay commercial catches have averaged 3.6 lb (1.6 kg; Salomone et al. 2011, pg. 105). Sexually mature males become highly laterally compressed and develop a massive dorsal hump, hence the common name "humpy."

Chum salmon

Chum salmon spawn on both shores of the Bering Sea and North Pacific, extending south to the latitude of Japan and California (Salo 1991, pg. 234), with scattered spawning populations also occurring on the Asian and North American shores of the Arctic Ocean. Populations tend to be relatively large, and chum salmon are the third most abundant species, behind pink and sockeye salmon. Chum salmon spawn throughout the Nushagak and lower Kvichak watersheds (Figure 6).

Chum salmon, like pink salmon, migrate to sea soon after emerging from spawning gravel. Across their range, the vast majority spends two to four years at sea (Salo 1991, pg. 272). At sea, chum salmon consume a range of invertebrates and fishes, and gelatinous material is commonly found in stomachs leading to speculation that jellyfish may be a common prey item (Brodeur 1990, pg. 8, Azuma 1992). Individuals in recent Bristol Bay commercial catches have averaged 6.8 lb (3.1 kg, Salomone et al. 2011, pg. 105).

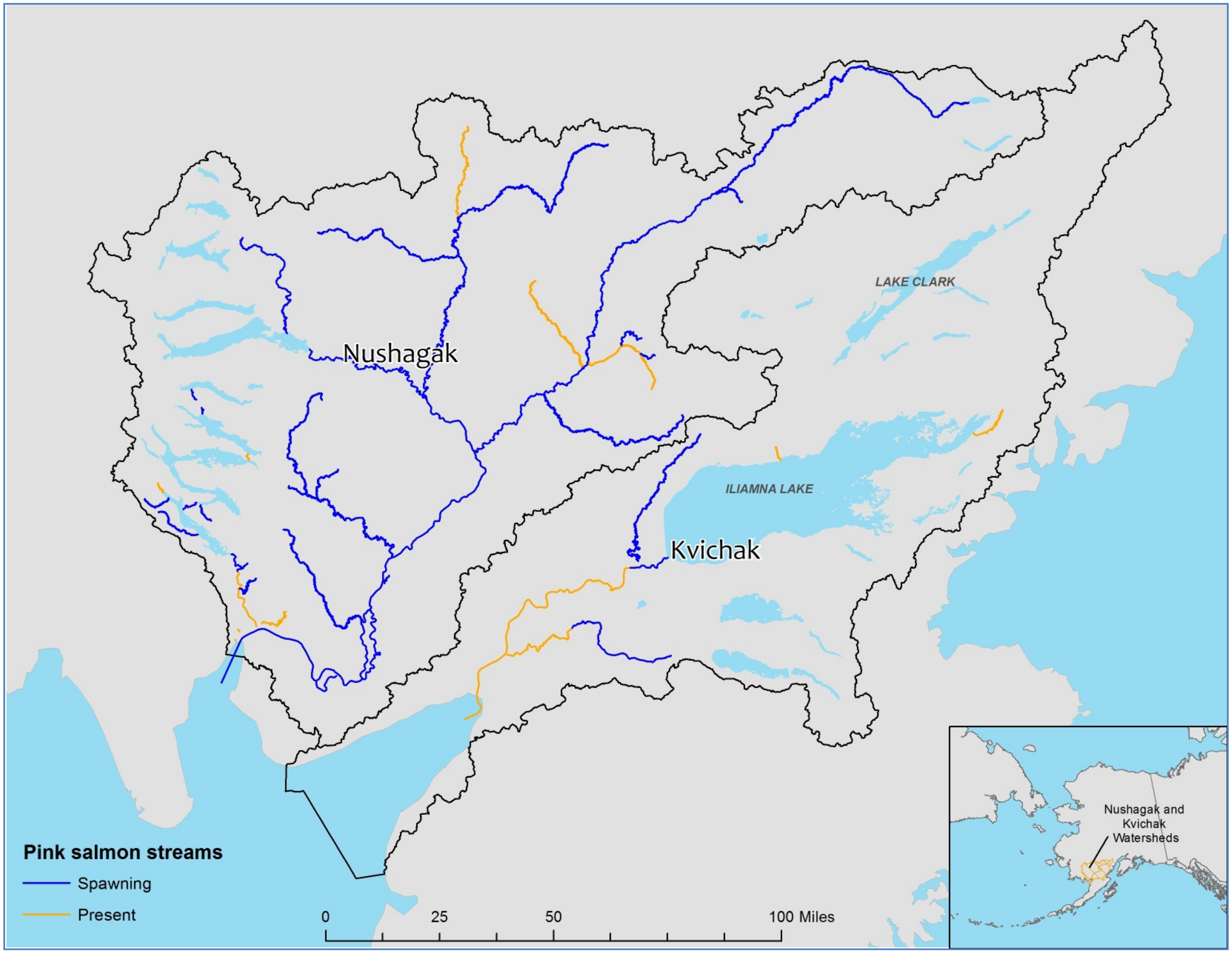


Figure 5. Documented pink salmon distribution in the Nushagak and Kvichak watersheds. Data are from the Alaska Department of Fish and Game's Anadromous Waters Catalog (AWC; Johnson and Blanche 2012).

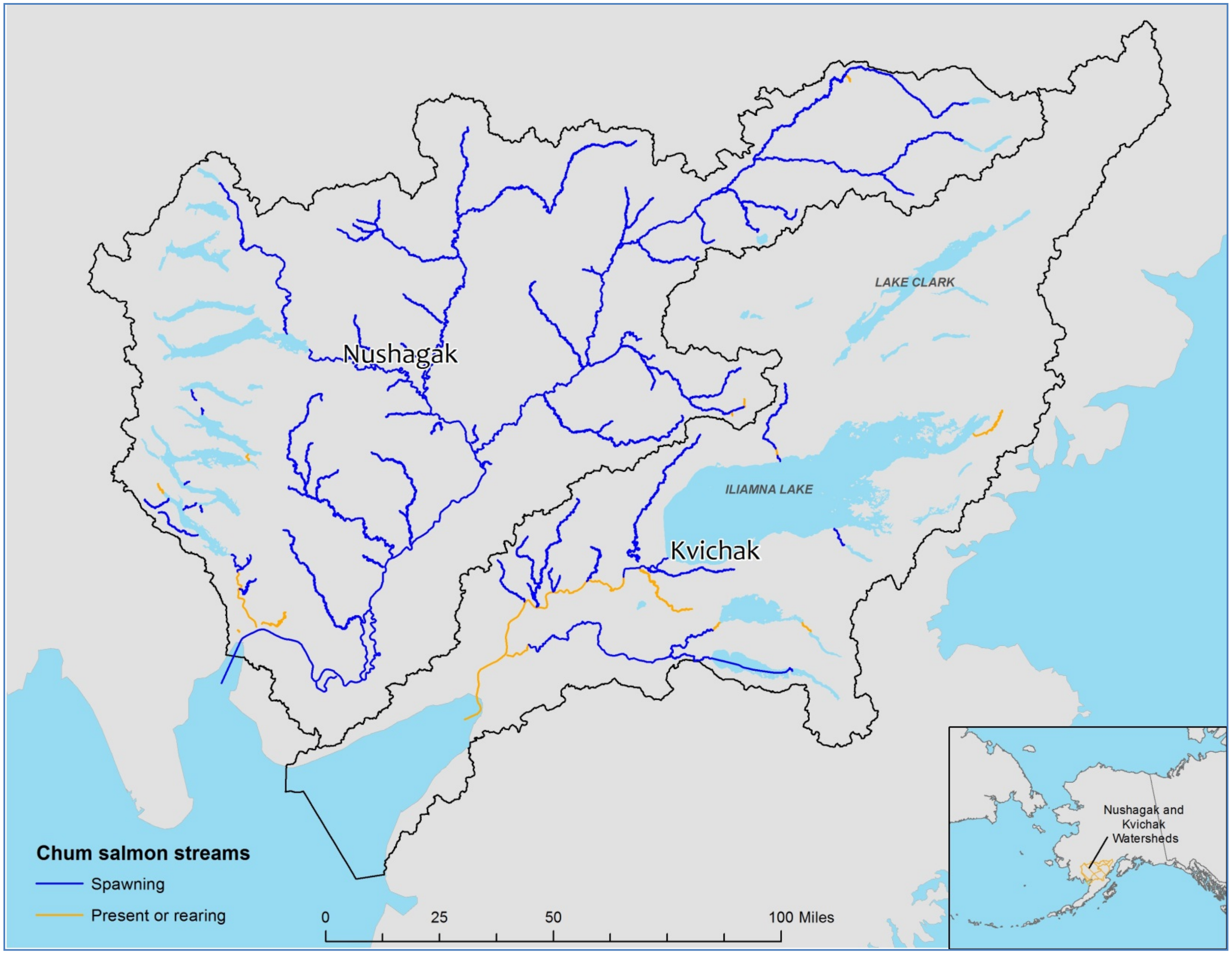


Figure 6. Documented chum salmon distribution in the Nushagak and Kvichak watersheds. Data are from the Alaska Department of Fish and Game's Anadromous Waters Catalog (AWC; Johnson and Blanche 2012).

BRISTOL BAY FISHERIES AND FISHERIES MANAGEMENT

Historical perspective on commercial salmon fisheries

Salmon have long been an important economic driver in Alaska's economy and have played an important role in the state's history. Commercial fishing interests were among the original supporters of the purchase of Alaska from Russia in 1867 (King 2009, pg. 1). The first canneries were established eleven years later, and by the 1920s salmon surpassed mining as Alaska's major industry as Alaska became the world's principal salmon producer (Ringsmuth 2005, pg. 21).

In the early years, fish packing companies essentially had a monopoly on the harvest of salmon. Packers in Bristol Bay and elsewhere built industrial fish traps, constructed of wood pilings and wire fencing with long arms that guided schools of migrating salmon into holding pens (King 2009, pg. 4). In Bristol Bay, packing interests also upheld a federal ban on fishing with power boats until 1951. Ostensibly a conservation measure, this law served to protect obsolete cannery-owned sailboat fleets by excluding independent Alaska-based fishermen who largely used power boats by this time (Troll 2011, pg. 39).

Salmon harvest peaked in 1936 then declined steadily for many years, leading to a federal disaster declaration in the 1950s (King 2009, pg. 1). A lack of scientific management, poor federal oversight, excessive harvest during World War II, and natural changes in ocean conditions contributed to the decline.

Declining salmon runs, along with Alaskans' desire for more control over their fisheries, was a significant factor in the drive toward Statehood (Augerot 2005, King 2009, pg. 2). In 1955, Alaskans began to develop a state constitution that included provisions intended to preserve Alaska's fisheries and, unique among state constitutions, to guarantee equal access to fish and game for all residents. Alaska became a state in 1959, the year that marked the lowest salmon harvest since 1900 (King 2009, pg. 3). Statehood was a turning point for Alaska's salmon fisheries, with the end of federal management, fish traps, and undue control of the resource by the canning industry. With the mandate for equal access came decentralization of the fishing industry, and thousands of individual fishermen began harvesting salmon for market to the canneries (Ringsmuth 2005, pg. 65).

When the Alaska Department of Fish and Game (ADF&G) assumed management of the fisheries in 1960, restoring salmon runs to their former abundance became a primary objective. Inventorying fish stocks, understanding basic ecology, and improving run strength forecasting were central research goals. Of particular importance was the development and application of methods for counting salmon runs in spawning streams, which allowed the establishment of escapement goals and management based on scientific principles of sustained yield. Bristol Bay salmon research has been conducted primarily by ADF&G staff and researchers at the University of Washington's Alaska Salmon Program (see http://fish.washington.edu/research/alaska/). The latter, funded largely by the salmon processing industry, began researching factors controlling sockeye salmon production in 1947. While the scope of their investigations has expanded over the years, sockeye monitoring is still a focus and represents the world's longest-running program for monitoring salmon and their habitats.

Over time, a number of state and federal policy changes have affected Bristol Bay salmon fisheries. A 1972 constitutional amendment set the stage for a bill that limited participation in Alaska commercial salmon fisheries. This legislation, designed to curb the expanding commercial fishery, set an optimum number of permits for each fishery, which were then issued by the State based on an individual's fishing history. Permits are owned by the individual fisherman and are transferable, making them a limited and valuable asset (King 2009, pg. 22). The Fishery Conservation and Management Act of 1976, commonly known as the Magnuson-Stevens Act, was introduced to Congress by the late senator Ted Stevens as a means to curtail high seas salmon fishing. In response to intensive Japanese gill netting in the western Aleutians and Bering Sea since 1952, this legislation extended America's jurisdiction from 12 to 200 miles (19 to 322 km) offshore. This ensured that salmon produced in Alaskan rivers would be harvested and processed locally and gave Alaska's fishery managers much more control in deciding when and where salmon are harvested. Both the Policy for the Management of Sustainable Salmon Fisheries and the Policy for Statewide Salmon Escapement Goals were adopted in the winter of 2000-2001 (Baker et al. 2009, pg. 2). The former established a comprehensive policy for the regulation and management of sustainable fisheries and the latter defined procedures for establishing and updating salmon escapement, including a process for public review of allocation disputes associated with escapement goals

The Alaska Department of Fish and Game is responsible for managing fisheries under the sustained yield principle. Fishing regulations, policies, and management plans are enacted by the Board of Fisheries, which it does in consultation with ADF&G, advisory committees, the public, and other state agencies. The Board of Fisheries consists of seven citizens, appointed by the governor and confirmed by the legislature, that serve three-year terms. Eighty-one advisory committees, whose members are elected in local communities around the state, provide local input. While regulations and management plans provide the framework for fisheries regulation, local fisheries managers are ultimately responsible for their execution. They are delegated authority to make "emergency orders," in-season changes to fishing regulations, which allow rapid adjustments to changing conditions, often with very short notice. Managers use them to provide additional protection to fish stocks when conservation concerns arise and to liberalize harvest when surplus fish are available. Management plans directed at specific fish stocks are often based on anticipated scenarios and give specific directions to managers, making the in-season management process predictable to ADF&G, commercial fishermen, and the public. Alaska's management of its salmon fishery has proven successful; it was the second fishery in the world to be certified as well managed by the Marine Stewardship Council (Hilborn 2006) and is regarded as a model of sustainability (Hilborn et al. 2003a, King 2009).

Current management of commercial salmon fisheries

While all five species of Pacific Salmon are harvested in Bristol Bay, sockeye salmon dominate the runs and harvest by a huge margin (Table 1). Salmon return predominately to nine major river systems, located on the eastern and northern sides of the Bay, and are harvested in five fishing districts in close proximity to the river mouths that allow managers to regulate harvest individually for the various river systems (Figure 1). The Naknek-Kvichak district includes those two rivers as well as the Alagnak. The Nushagak district includes the

Nushagak, Wood, and Igushik Rivers. The Egegik, Ugashik, and Togiak districts include the rivers for which they are named.

Table 1. Mean commercial harvest by species and fishing district, 1990-2009. Unpublished data, Paul Salomone, ADF&G Area Management Biologist.

	Naknek-Kvichak	Egegik	Ugashik	Nushagak	Togiak	Total
Sockeye	8,238,895	8,835,094	2,664,738	5,478,820	514,970	25,732,517
Chinook	2,816	849	1,402	52,624	8,803	66,494
Chum	184,399	78,183	70,240	493,574	158,879	985,275
Pink*	73,661	1,489	138	50,448	43,446	169,182
Coho	4,436	27,433	10,425	27,754	14,234	84,282

*Pink salmon data are from even-numbered years only since harvest is negligible during the smaller odd-year runs.

Fishing is conducted with drift or set gillnets. Drift gillnets have a maximum length of 150 fathoms (274 m) and are fished from boats no longer than of 32 ft. (9.8 m) in length. Set gillnets are fished from beaches, often with the aid of an open skiff, and have a maximum length of 50 fathoms (91 m). There are approximately 1900 drift gillnet permits and 1000 set gillnet permits in the Bristol Bay salmon fishery, of which around 90% are fished on a given year (1990-2010 average; Salomone et al. 2011, pg. 84).

The management of the Bristol Bay sockeye salmon fishery is focused on allowing an adequate number of spawners to reach each river system while maximizing harvest in the commercial fishery (Salomone et al. 2011, pg. 2). This balancing act is achieved through the establishment of escapement goals which represent the optimum range of spawners for a given river system. Escapement goals are established using a time series of spawner counts where a spawning run of a given size (i.e., stock) can be linked to the number of its offspring returning in subsequent years (i.e., recruits). Established stock-recruit models (Ricker 1954, Beverton and Holt 1957) are then used to estimate the stock size that results in the largest number of recruits, or the maximum sustained yield (Baker et al. 2009, pg. 4). In theory, spawning runs that are too small or large can result in reduced recruitment. With the former, too few eggs are deposited. With the latter, superimposition of spawning redds can diminish egg viability and competition in nursery lakes can reduce growth and survival. Once escapement goals are set, the timing and duration of commercial fishery openings are then adjusted during the fishing season (i.e., in-season management) to ensure that escapement goals are met and any additional fish are harvested. Escapement goals are periodically reviewed and updated based on regulatory policies, specifically, the Policy for the Management of Sustainable Salmon Fisheries and the Policy for Statewide Salmon Escapement Goals.

Each of Bristol Bay's nine major river systems has an escapement goal for sockeye salmon (Table 2), and in-season management of the commercial fishery is used to keep escapement in line with the goals. Management responsibility is divided among three managers: one for the Naknek, Kvichak, and Alagnak rivers; one for the Nushagak, Wood, Igushik, and Togiak rivers; and one for the Ugashik and Egegik rivers. Fishery openings are based on information from a number of sources, including preseason forecasts, the test fishery at Port Moller, the early performance of the commercial fishery, and in-river escapement monitoring.

Table 2. Bristol Bay escapement goal ranges for sockeye salmon.

River	Escapement range (thousands)
Kvichak	2,000–10,000
Alagnak	320 minimum
Naknek	800–1,400
Egegik	800–1,400
Ugashik	500–1,200
Wood River	700–1,500
Igushik	150–300
Nushagak-Mulchatna	370–840
Togiak	120–170

Preseason forecasts are the expected returns of the dominant age classes in a given river system, and they are based on the number of spawning adults that produced each age class. In the Port Moller test fishery, gill netting at standardized locations provides a daily index of the overall number of fish entering Bristol Bay (Flynn and Hilborn 2004), with approximately seven days' lead before they enter the commercial fishing districts. Genetic samples from the test fishery are analyzed within four days (Dann et al. 2009, pg. 3) to give managers an advance estimate of run strength for each of the nine major river systems. Test fisheries in selected districts give additional information on run strength and timing. As salmon move into fresh water, escapement is monitored with counting towers on each of the major rivers, except the Nushagak where a sonar system is used. Counting towers are elevated platforms along small to medium-sized (10-130 m wide), clear rivers from which migrating salmon are visually counted (Woody 2007). The Nushagak River's DIDSON sonar uses sound waves to detect and enumerate migrating salmon. Since tower and sonar monitoring occurs well upstream of the commercial fishery, all information regarding the performance of the fishery must be analyzed on a continual basis to ensure escapement levels will be met (Clark 2005, pg. 4, Salomone et al. 2011).

The fishery is typically opened on a schedule during the early part of the season, during which time the frequency and duration of openings are primarily based on preseason forecasts and management is conservative. As the fishing season progresses and more information becomes available, managers make constant adjustments to fishing time and area. If the escapement goal is exceeded at a given monitoring station, the fishery is opened longer and more frequently. If the escapement goal is not reached, the fishery is closed. Fishing time is opened and closed using emergency orders, and fishermen often learn of changes only a few hours before they go into effect. Since the bulk of the sockeye salmon harvest occurs during a short timeframe - from the last week of June until the middle of July - this short warning system is needed to maximize fishing time while ensuring that escapement levels are met. Migrating fish move quickly through the fishing districts, and delaying an opener by one day during the peak of the migration can forego the harvest of a million salmon. This is a significant loss of revenue to individual fishermen, and compounded by the missed revenue of workers, processors, and marketers (Clark 2005, pg. 5). The fishery will periodically close *de facto* during the peak of the season when catch rates exceed processing capacity and processors stop buying fish. This lack of buyers can also curtail salmon harvest early and late in the season when numbers of fish do not warrant keeping processing facilities operational.

In-season management is also used to help meet an escapement goal for Chinook salmon on the Nushagak River (Table 3), where escapement is monitored by sonar. There are also chum, coho, and pink salmon escapement goals on for the Nushagak River and Chinook salmon goals for the Alagnak and Naknek rivers (Table 3), but in-season management is not used to help attain these goals (Baker et al. 2009).

Bristol Bay salmon fisheries are regarded as a management success (Hilborn et al. 2003a, Hilborn 2006), and Hilborn (2006) lists four contributing factors: "(1) a clear objective of maximum sustainable yield, (2) the escapement-goal system, which assures maintenance of the biological productive capacity; (3) management by a single agency with clear objectives and direct line responsibility; and (4) good luck in the form of lack of habitat loss and good ocean conditions since the late 1970s."

Table 3. Bristol Bay escapement goal ranges for Chinook, chum, coho, and pink salmon.

River	Species	Escapement goal
Nushagak	Chinook	55,000–120,000
Nushagak	chum	200,000 minimum
Nushagak	coho	60,000–120,000
Nushagak	pink	165,000 minimum
Alagnak	Chinook	2,700 minimum
Naknek	Chinook	5,000 minimum

Description of sport fisheries

The sport fisheries in Bristol Bay's river systems are regarded as world class. A recent ADF&G report (Dye and Schwanke 2009) notes that "The BBMA [Bristol Bay Management Area] contains some of the most productive Pacific salmon, rainbow trout, Arctic grayling, Arctic char and Dolly Varden waters in the world. The area has been acclaimed for its sport fisheries since the 1930s." Similar views prevail in the popular sport fishing literature, where articles praising Bristol Bay as a destination are common. For example, *Fly Rod and Reel* (Williams 2006) says "No place on earth is wilder or more beautiful or offers finer salmonid fishing." Over the years, many other articles in *Field and Stream*, *Fly Fisherman*, *Fish Alaska*, *Fly Rod and Reel*, *Salmon Trout Steelheader*, *World Angler*, and other magazines have touted the high quality fishing and wilderness ambiance.

Large numbers of salmon and trout are caught in Bristol Bay's sport fisheries each year (see below), but the area is best known for its rainbow trout fishing. ADF&G (1990) notes that "Wild rainbow trout stocks of the region are world famous and are the cornerstone to a multimillion dollar sport fishing industry." Articles in the sport fishing press laud the trout fisheries, especially those of the Kvichak River drainage. *Fish Alaska* magazine calls the Iliamna system “One of the greatest trophy trout fisheries in the world…the crown of Alaska’s sport fishing” (Weiner 2006) and names seven Bristol Bay drainages, five of which are in the Nushagak or Kvichak river basins, in a rundown of Alaska’s top ten spots for trophy rainbow trout (Letherman 2003). Thirty-inch (76 cm) rainbow trout can be caught in many areas of the Kvichak River and other drainages (Randolph 2006) and 43% of clients at remote Bristol Bay sport fishing lodges reported catching a rainbow trout longer than 26 inches (66 cm) on their most recent trip (Duffield et al. 2006, pg. 48).

Unlike commercial fisheries, whose salient features tend to be readily quantifiable (e.g., economics, sustainability), the quality of a sport fishery can hinge on personal and subjective attributes. Despite the potential to catch high numbers of sizeable fish, Bristol Bay anglers rate aesthetic qualities as most important in selecting fishing locations. Of 11 attributes that capture different motivations and aesthetic preferences, including “catching and releasing large numbers of fish” and “chance to catch large or trophy-sized fish,” Alaska resident and nonresident anglers picked the same top five: “natural beauty of the area”, “being in an area with few other anglers”, “being in a wilderness setting”, “chance to catch wild fish”, and “opportunities to view wildlife” (Duffield et al. 2006, pg. 45). The same priorities apply for nonresident anglers across Alaska (Romberg 1999, pg. 85).

The Bristol Bay region is not linked to the State’s highway system and roads connected to the major communities provide very limited access. Small aircraft with floats are the primary source of access followed by boats based out of communities and remote lodges (Dye and Schwanke 2009, pg. 1). A range of services are available for recreational anglers. Anglers willing to pay $7,500 to $9,500 a week can stay in a plush remote lodge and fly to different streams each day with a fishing guide (Purnell 2011). Modest river camps, with cabins or wall tents, are a lower-budget option. Many self-guided expeditions center on multi-day raft trips that use chartered aircraft for transport to and from access points along a river.

Site-specific data regarding participation, effort and harvest have been collected from sport fishing guides and businesses since 2005 (Sigurdsson and Powers 2011). In 2010, the most recent year for which data are available, 72 businesses and 319 guides operated in the Kvichak and Nushagak watersheds (Table 4; Dora Sigurdsson, ADF&G, unpublished data). In addition, Table 4 shows figures for 2005, the first year of data collection, and 2008, a peak year.

Table 4. The number of businesses and guides operating in the Nushagak and Kvichak watersheds in 2005, 2008 and 2010.

Watershed	2005		2008		2010	
	Businesses	Guides	Businesses	Guides	Businesses	Guides
Kvichak River (including Alagnak River)	53	204	59	274	46	211
Nushagak River (including Wood River)	67	199	60	245	47	162
Kvichak and Nushagak combined[1]	91	336	92	426	72	319

[1] Business and guide totals are not additive because a business and/or guide can operate in multiple watersheds.

Management of sport fisheries

The Alaska Department of Fish and Game's Division of Sport Fish manages recreational fisheries in the Bristol Bay Management Area (BBMA), which includes all fresh waters flowing into Bristol Bay between Cape Menshikof, on the Bay's southeast shore, and Cape Newenham in the northwest. Four local management plans guide sport fishing regulations in the Bristol Bay region (in addition to several statewide plans). The Nushagak-Mulchatna King Salmon Management Plan, the Nushagak-Mulchatna Coho Salmon Management Plan and the Kvichak River Drainage Sockeye Salmon Management Plan call for sport fishing bag limit reductions or closures by emergency order during poor runs. The Southwest Alaska Rainbow Trout Management Plan recommended conservative trout management uniformly throughout the region, which replaced the fragmentary restrictions that had been established over the previous decades. Sport fishing regulations are updated annually and can be accessed on ADF&G's website: http://www.adfg.alaska.gov/index.cfm?adfg=fishregulations.sport.

The Division of Sport Fish uses the annual Statewide Harvest Survey, mailed to randomly-selected licensed anglers, to monitor effort, catch, and harvest. Between 1997 and 2008, angler-days of effort within the BBMA ranged from 83,994 to 111,838 (Dye and Schwanke 2009, pg. 4). Total annual sport harvest for the same period ranged from 39,362 to 71,539 fish, of which sockeye, Chinook and coho salmon comprise the majority (Dye and Schwanke 2009, pg. 8). Resident fish species, including rainbow trout, Dolly Varden, Arctic char, Arctic grayling, northern pike and whitefish, are also harvested in the BBMA (Dye and Schwanke 2009, pg. 8). Harvest rates are lower for these species than for salmon, likely due to restrictive bag limits and the popularity of catch-and-release fishing (Dye and Schwanke 2009, pgs. 6 and 8).

Chinook salmon

In the Nushagak drainage, the general season runs from May 1 to July 31 for Chinook salmon, although some areas close on July 24 in order to protect spawners. The daily limit is two per day, only one of which can be over 28 inches (71 cm). The annual limit is four fish. The Nushagak-Mulchatna King Salmon Management Plan calls for an in-river return of 75,000 fish with a spawning escapement of 65,000 fish. The guideline harvest for the sport fishery is 5,000 fish, although restrictions are triggered if the in-river return falls below 55,000 fish. In other Bristol Bay drainages, the daily limit for Chinook salmon is three and the annual limit is five, although there are additional restrictions in the Wood and Naknek river drainages.

The major Chinook salmon sport fisheries in the BBMA include the Nushagak, Naknek, Togiak and Alagnak rivers and the average annual harvest is 11,100 fish for the period from 1997 to 2008. The largest individual fishery takes place in the Nushagak River, where harvest from 2003 to 2007 averaged 7,281, approximately 58% of the total Bristol Bay sport harvest for that period (Dye and Schwanke 2009, pg. 13).

Sockeye salmon

Sockeye salmon fishing is open year round with a daily limit of five fish. Runs enter rivers starting in late June, peak in early July, and continue into late July or early August. The Kvichak River Drainage Sockeye Salmon Management Plan places restrictions on the sport fishery to avoid conflicts with subsistence users when the escapement falls below the minimum sustainable escapement goal of two million fish. Restrictions include actions such as reducing the daily limit for sockeye and closure of areas for sport fishing that are used by both subsistence and recreational anglers.

Sockeye are the most abundant salmon species in the BBMA. Recent annual sport harvest ranged from 8,444 to 23,002 fish (Dye and Schwanke 2009, pg. 22). The two locations that support the largest sport harvest are the Kvichak River, near the outlet of Iliamna Lake, and the Newhalen River, just above Iliamna Lake (Dye and Schwanke 2009, pg. 24). Other drainages that support moderate harvests of sockeye salmon include the Naknek and Alagnak rivers and the Wood River lake system (Dye and Schwanke 2009, pg. 22).

Rainbow trout

Due to their relatively small spawning populations and their popularity as a game fish, fishing regulations for rainbow trout are more restrictive than those for any other species. The Southwest Alaska Rainbow Trout Management Plan (ADF&G 1990) calls for conservative management, allows limited harvest in specific areas, and bans stocking of hatchery trout (although stocking had not been practiced previously). Special management areas were created to preserve a diversity of sport fishing opportunities: eight catch-and-release areas, six fly-fishing catch-and-release areas, and eleven areas where only single-hook artificial lures can be used (Dye and Schwanke 2009, pgs. 34-36).

In flowing waters throughout most of the Kvichak River drainage, only single-hook artificial lures can be used and sport fishing is closed from April 10 through June 7 to provide protection for spawning rainbow trout. From June 8 through October 31 anglers are allowed to keep one trout per day, with the exception of a number of streams where no harvest is allowed. From November 1 through April 9, when anglers are few, the daily limit increases to five fish although only one may be longer than 20 inches (51 cm). Rainbow trout fishing regulations are similarly restrictive in other drainages across the BBMA.

The most popular rainbow trout fisheries are found in the Kvichak drainage, the Naknek drainage, portions of the Nushagak and Mulchatna drainages, and streams of the Wood River Lakes system (Dye and Schwanke 2009, pg. 26). Field surveys and the Statewide Harvest Survey show that harvest has decreased over the past decade but that total catch and effort have remained stable or increased (Dye and Schwanke 2009, pg. 26). The annual BBMA-wide harvest between 1997 and 2008 averaged 1900 fish, but the catch estimate over this period was nearly 100 times greater (183,000 fish; (Dye and Schwanke 2009, pgs. 29 and 31). Although the fishery is widespread, approximately eighty percent of the total catch (144,400 fish) was from the eastern portion of the BBMA, where the Naknek and Kvichak systems are located. Eastern BBMA streams with estimated sport catches greater than 10,000 fish in 2008 included the Naknek, Brooks, Kvichak, Copper, and Alagnak rivers (Dye and Schwanke 2009, pg. 31).

SALMON ABUNDANCE TRENDS AROUND THE NORTH PACIFIC, WITH REFERENCE TO BRISTOL BAY POPULATIONS

Wild Pacific salmon, from most to least abundant, are pink, sockeye, chum, coho, and Chinook (Ruggerone et al. 2010). The relative abundance of Pacific salmon species relates to their life histories, as those species that are not constrained by the availability of stream rearing habitat (i.e., pink, sockeye, and chum salmon) are able to spawn and rear in greater numbers than those that are (i.e. coho and Chinook; Quinn 2005, pg. 319). The highest Pacific-wide salmon harvest occurred in 2007 and totaled 513 million fish, over 300 million of which were pink salmon (Irvine et al. 2009, pg. 2). Approximately five billion juvenile salmon are released annually from hatcheries around the North Pacific (Irvine et al. 2009, pg. 6), although none are reared or released in the Bristol Bay region.

Sockeye salmon

Size of Bristol Bay, Kvichak, and Nushagak sockeye salmon returns

Escapement monitoring within the Bristol Bay watershed has been conducted since the 1950s, when ADF&G established counting towers on the nine major river systems. When combined with commercial, subsistence and sport harvest, data from escapement monitoring allows estimates of total run sizes. A recent synthesis of salmon returns for 12 regions around the North Pacific also extends back to the 1950s, allowing comparisons of wild sockeye salmon returns between Bristol Bay and other regions for the period 1956 to 2005 (Ruggerone et al. 2010). The average global abundance of wild sockeye salmon over that period was 65.3 million (M) fish, and Bristol Bay constituted the largest proportion of that total at 46% (Figure 7). Total returns to Bristol Bay ranged from a low of 3.5 M in 1973 to a high of 67.3 M in 1980 (Figure 8), with an annual average of 29.8 M. The region with the second largest returns is southern British Columbia/Washington, which averaged 14% of the total (Figure 7), or 8.9 M salmon. Other regions that produce high abundances of wild sockeye salmon include the Kamchatka Peninsula, northern British Columbia, Cook Inlet and Kodiak Island (Ruggerone et al. 2010).

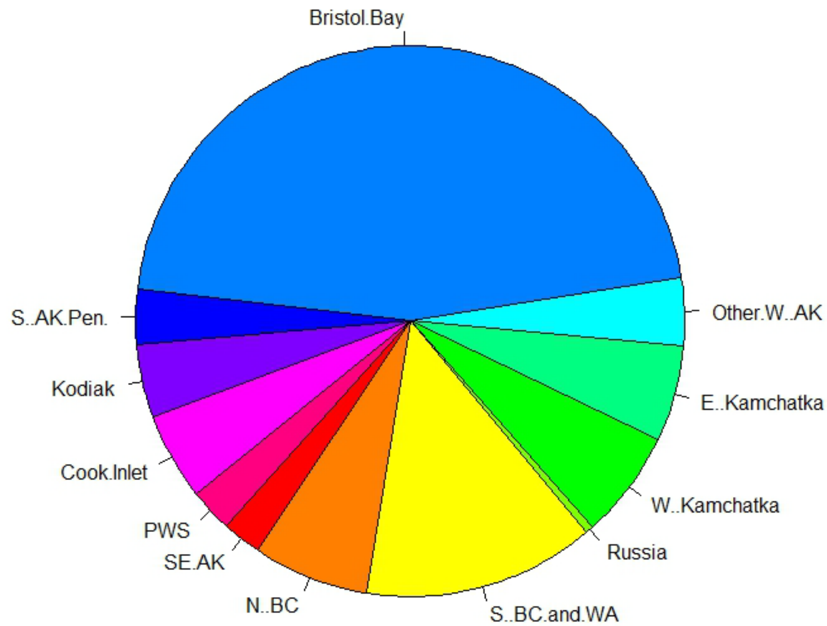


Figure 7. Relative abundance of wild sockeye salmon stocks in the North Pacific, 1956-2005. See Appendix 1 for data and sources. Stocks are ordered from west to east across the North Pacific.

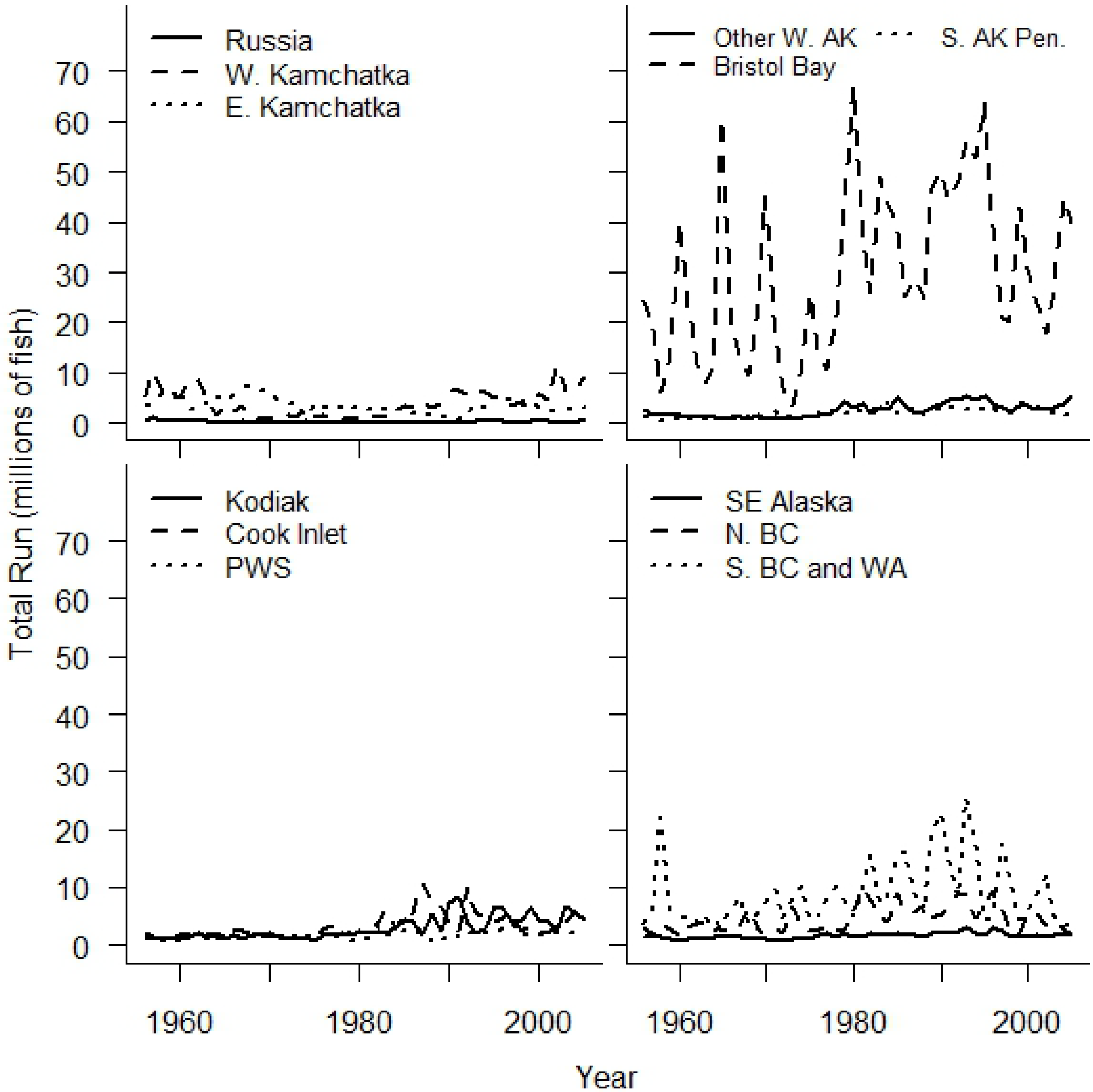


Figure 8. Wild sockeye salmon abundances by region in the North Pacific, 1956-2005. See Appendix 1 for data and sources. Each graph shows three regions organized from west to east across the North Pacific.

Hatchery production of sockeye salmon started in 1977 and accounted for an annual average of 3 M fish, or 4% of the world total, during the 10-year period from 1995 to 2005 (Ruggerone et al. 2010). No hatchery production has occurred in the Bristol Bay region. Regions with major hatchery production include Prince William Sound, Cook Inlet, and Kodiak Island, which produced a respective 1.0, 0.9 and 0.6 M hatchery fish, on average, from 1995-2005 (Ruggerone et al. 2010).

Although the Alagnak River is part of the Kvichak watershed and the Wood River is part of the Nushagak watershed, we report sockeye salmon data separately for these systems (unless noted otherwise) because ADF&G monitors returns on each. On average, the Kvichak River has the largest sockeye salmon run in Bristol Bay, with an average annual return of 10.4 M fish between 1956 and 2010 (Figure 9). Iliamna Lake provides the majority of the rearing habitat for sockeye in the Kvichak watershed, followed by Lake Clark where the estimated proportion of the escapement ranges from 7 to 30% (Young 2005, pg. 2). Runs exceeding 30 M fish have occurred three times in the Kvichak River: 47.7 M, 34.6 M and 37.7 M fish returned in 1965, 1970 and 1980, respectively (Tim Baker, ADF&G, unpublished data). Those runs accounted for 57%, 49% and 40% of world production of sockeye salmon during those years (Ruggerone et al. 2010). The Egegik River supports Bristol Bay's second largest run, with a mean annual return of 6.3 M fish from 1956 to 2010 (Figure 9). The Nushagak and Wood rivers are smaller runs and average returns from 1956 to 2010 were 1.3 and 3.3 M fish, respectively.

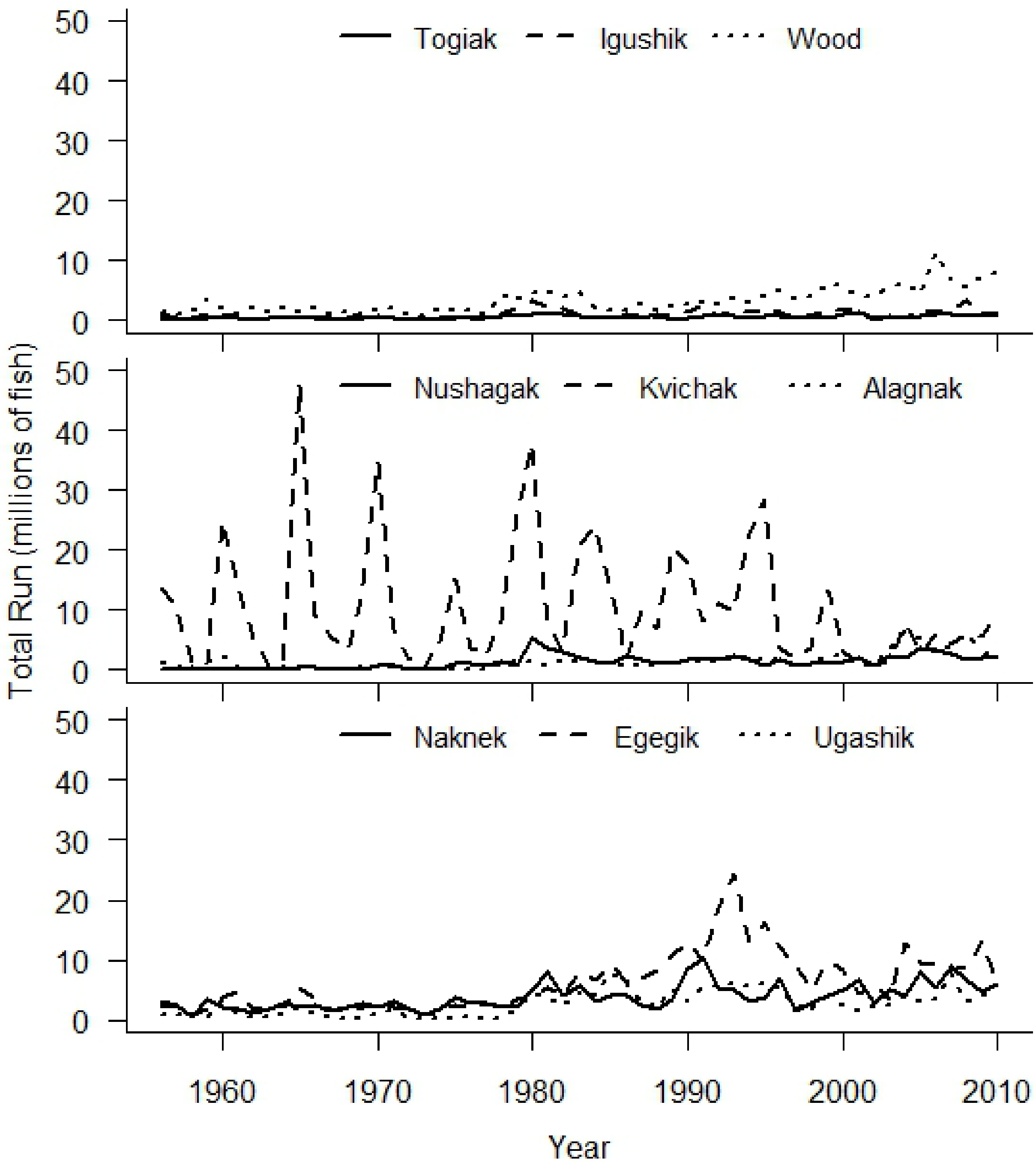


Figure 9. Total sockeye returns by river system in Bristol Bay, 1956-2010. See Appendix 1 for data and sources. Each graph shows three river systems listed from west to east across Bristol Bay.

The Kvichak River sockeye salmon runs are not only the largest in Bristol Bay, but also the largest in the world (Figures 8 through 10). As noted above, returns to the Kvichak River have averaged 10.4 M fish, and this number climbs to 11.9 M fish when returns to the Alagnak River are included (Tim Baker, ADF&G, unpublished data). The Fraser River system supports the world's second largest run, with an average of 8.1 M fish for the same period (Catherine Michielsens, Pacific Salmon Commission, unpublished data). Other major producers outside of Bristol Bay include the Copper, Kenai, Karluk, and Chignik rivers in Alaska and the Skeena River in British Columbia (Figure 10). The Kamchatka Peninsula in Russia also has rivers with large sockeye runs, but abundances for individual rivers were not readily available. The combined runs for the western and eastern Kamchatka Peninsula averaged less than 5 M sockeye during the period from 1952 to 2005 (Ruggerone et al. 2010).

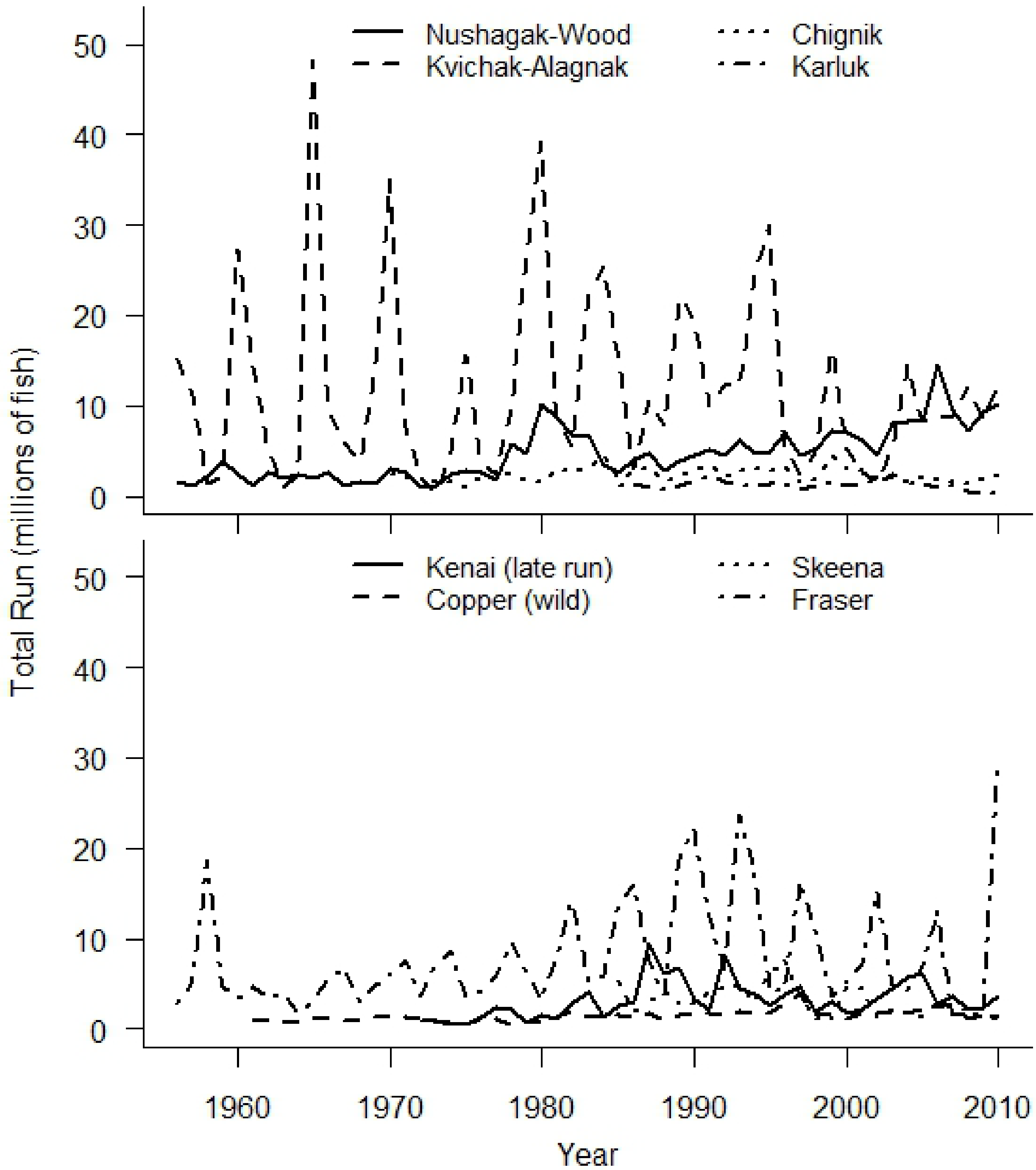


Figure 10. Sockeye salmon abundances for major rivers of the North Pacific, 1956-2010. See Appendix 1 for data and sources. The top graph includes time series for the Nushagak-Wood and Kvichak-Alagnak systems from 1956 to 2010, the Chignik River from 1970 to 2010, and the Karluk River from 1985 to 2010. The bottom graph shows the Kenai River late run from 1972 to 2010, the Copper River wild run from 1961 to 2010, the Skeena River from 1985 to 2010, and the Fraser River from 1956 to 2010. Rivers are listed in the graphs as they occur from west to east across the North Pacific.

Factors affecting Bristol Bay sockeye salmon abundance

Changes in the ocean and freshwater environments that affect sockeye salmon abundances and trends across the North Pacific are many. A major driver is the Pacific decadal oscillation (PDO), an inter-decadal pattern of correlated changes in sea-level pressures and sea-surface temperatures (Mantua et al. 1997). The warm phase of the PDO is characterized by warmer than average winter sea surface temperatures along the western coastline of North America and increased stream flows around the Gulf of Alaska, both of which are linked to increased salmon survival (Mantua et al. 1997, Ruggerone et al. 2007). There are three regime shifts documented in the recent climate record that correlate with salmon productivity: 1947, 1977 and 1989. From 1947 to 1977, the PDO was in a cool phase marked by low productivity for Alaskan and British Columbia sockeye salmon. The PDO shifted to a warm phase in 1977, after which most North American stocks increased (Figure 8). For Bristol Bay stocks, this warm phase corresponded with increased marine growth and, in turn, increased abundances and numbers of recruits (returning adults) generated per spawner (Ruggerone et al. 2007). Bristol Bay stocks more than doubled during this warm phase and remained high until the mid-90s, when declines in the Kvichak and other rivers reduced the overall abundance (Figure 4, Ruggerone et al. 2010). Biological indicators suggest that decreased productivity associated with a cool phase began in 1989, while climate indices point to a short-lived reversal from 1989 to 1991, followed by a return to a warm phase (Hare and Mantua 2000). Late marine growth and adult length-at-age of Bristol Bay sockeye decreased after the 1989 regime shift, potentially reducing stock productivity (Ruggerone et al. 2007).

Another factor affecting sockeye salmon productivity is competition with increasing numbers of hatchery smolts released into the North Pacific. Alaska produces the most hatchery pink salmon in the world, averaging 42 M fish for the period 1995 to 2005, followed next by Russia, with 12.6 M for the same period (Ruggerone et al. 2010). Approximately 75% of the pink salmon hatchery production in Alaska occurs in Prince William Sound, with other facilities located in Kodiak, Cook Inlet, and Southeast Alaska. Japan dominates the production of hatchery chum salmon, with 67.3 M fish returning on average for 1995 to 2005 (Ruggerone et al. 2010). Coming in a distant second behind Japan, Southeast Alaska averaged 9.7 M hatchery chum salmon for the same period (Ruggerone et al. 2010). Bristol Bay sockeye smolts that migrated to sea during even-numbered years and interacted with dominant odd-year Asian pink salmon experienced decreased growth, survival and adult abundance compared to the smolts that migrated during odd-numbered years (Ruggerone et al. 2003). Additionally, Kvichak sockeye salmon productivity was negatively correlated with a running three-year mean of Kamchatka pink salmon abundances (Ruggerone and Link 2006).

In the freshwater environment, spawning and rearing habitats can limit sockeye salmon populations through negative density dependence. The amount of suitable spawning habitat is limited within a given system, so when spawning densities are high and suitable spawning sites are occupied, females will dig nests on top of existing nests, dislodging many of the previously laid eggs, or die without spawning (Semenchenko 1988, Essington et al. 2000). As such, the amount of available spawning habitat can impose an upper limit on potential fry production. In nursery lakes, juvenile growth rates decrease with rearing densities (Kyle et al. 1988, Schindler et al. 2005a), leading to decreased survival for small individuals in the subsequent marine stage (Koenings et al. 1992). Together, these processes limit the number of recruits potentially produced by a large spawning run.

Kvichak sockeye abundances follow five-year cycles that are unique amongst the nine major systems of Bristol Bay. Previous hypotheses for the cycle included natural depensatory mechanisms, such as predation, and fishing-related depensation. Since the first escapement goal was established for the Kvichak River in 1962 until the most recent change in 2010, the escapement goals were managed to match the cycle year. Most recently, off-cycle years had an escapement goal range of 2 to 10 M spawners, while pre-peak and peak cycle years were managed for escapement of 6 to 10 M spawners (Baker et al. 2009, pg. 6). In 2010, the escapement goal was changed to one goal for all years of 2 to 10 M spawners. Ruggerone and Link (2006) recently analyzed the population characteristics of Kvichak sockeye and found that the cycle is likely perpetuated by three factors: density dependence during pre-peak and peak cycle years reducing productivity in off-cycle years, higher percentage interceptions in off-cycle years biasing productivity low, and the dominance of age 2.2 salmon (2 years in fresh water and two years in the ocean), which return after five years. Kvichak salmon were shown to have high interception rates in the Egegik and Ugashik fisheries in years when the Egegik and Ugashik returns were more than double the Kvichak return, which biased the number of returning recruits during off-cycle years. They did not find any evidence of natural depensatory mechanisms, nor did they find reason to believe that the change in the escapement goal in 1984 could have had any effect on the decline in the 1990s.

In recent years, ADF&G has developed genetic stock identification methods, which are being used to reanalyze past interceptions of Kvichak salmon from the mixed stock fisheries on the east side of the Bay (Dann et al. 2009, pg. 37). It is anticipated that current brood tables from which total runs by system are reconstructed will change as this analysis progresses (Tim Baker, ADF&G, personal communication) giving researchers a more accurate understanding of the dynamics of Bristol Bay stock composition and return dynamics.

The decline in Kvichak River sockeye salmon runs

From 1977 through 1995, during the warm PDO phase, Bristol Bay runs averaged almost 41 M fish annually, while runs to the Kvichak River averaged nearly 15 M, comprising about 36% of the entire Bristol Bay run (Table 5). Beginning in 1996, with the spawning return of the 1991 brood year, Kvichak runs dropped to an average of 4.7 M fish, comprising less than 14% of the total Bristol Bay run (Table 5). This decline was accompanied by a decline in stock productivity, as expressed by the number of recruits generated per spawner (R/S). Bristol Bay systems averaged approximately two recruits for every spawner prior to the 1977 regime shift, and R/S increased substantially for many systems, such as the Egegik and Ugashik rivers, during the subsequent warm phase (Hilborn 2006). R/S for the Kvichak averaged 3.2 for the 1972 to 1990 broods, but five of the nine broods from 1991 onward failed to replace themselves (i.e., R/S <1). Productivity also decreased during this time in two other systems on the east side of Bristol Bay, the Egegik and Ugashik rivers (Ruggerone and Link 2006). The decline in the Kvichak River run led ADF&G to classify it as a stock of yield concern in 2001 (Morstad and Baker 2009, pg. 1), indicating an inability to maintain a harvestable surplus. The Kvichak run was further downgraded to a stock of management concern in 2003, based on failure to meet escapement goals.

Table 5. Mean annual returns of sockeye salmon in Bristol Bay, 1956-2010, and percent of total by river system. See Appendix 1 for data and sources. Rivers are listed from east to west across Bristol Bay.

Rivers	1956-1976	%	1977-1995	%	1996-2010	%	1956-2010	%
Ugashik	882,458	4.6	4,123,115	10.1	3,522,697	10.1	2,722,023	8.8
Egegik	2,320,059	12.0	9,100,953	22.2	8,402,365	24.1	6,321,361	20.4
Naknek	2,200,534	11.4	4,454,164	10.9	5,251,810	15.1	3,811,227	12.3
Alagnak	514,544	2.7	1,360,651	3.3	3,008,922	8.6	1,487,121	4.8
Kvichak	10,482,754	54.3	14,784,340	36.1	4,757,008	13.7	10,407,190	33.6
Nushagak	392,574	2.0	1,919,420	4.7	1,933,461	5.6	1,340,272	4.3
Igushik	516,021	2.7	1,349,775	3.3	1,341,581	3.9	1,029,198	3.3
Wood	1,707,120	8.8	3,150,620	7.7	5,834,787	16.8	3,331,511	10.7
Togiak	305,069	1.6	661,011	1.6	742,696	2.1	547,384	1.8
Total	19,321,134		40,904,050		34,795,327		30,997,285	

Ruggerone and Link (2006) analyzed the decline in the Kvichak run starting with the 1991 brood year and identified a number of potential factors. The number of smolts per spawner declined by 48% and smolt-to-adult survival declined by 46%, suggesting that factors in both freshwater and marine habitats were involved. The average number of smolts out-migrating from the Kvichak River during the years 1982 to 1993 was approximately 150 M, which declined to an approximate average of 50 M from 1994 to 2001 (Ruggerone and Link 2006). The declines were accompanied by a shift in the dominant age structure of Kvichak spawners from 2.2 (i.e., two years in fresh water followed by two years at sea), which represented an average of 84% of the return, to 1.3, indicating that salmon were spending less time in fresh water and more time at sea. Across the nine monitored Bristol Bay watersheds, the decrease in the percentage of 2.2 salmon in the total return correlated strongly with decreases in R/S and run size. The decrease in spawner length at age starting in 1991 and higher than normal sea surface temperatures in June from 1990-1998 both may have contributed to lower reproductive potential, since smaller females produce fewer eggs. Competition with Asian pink salmon also may have played a role. Abundances of Asian pink salmon have been linked to decreased size at age of returning Bristol Bay sockeye salmon in addition to decreased abundance during even-year migrations when interactions are highest (Ruggerone et al. 2003). Abundances of Kamchatka pink salmon were high from 1994 to 2000, the beginning of which correlates to age-1 smolts from the 1991 brood year. The three eastern Bristol Bay stocks that experienced the largest declines during the 1990s (Kvichak, Egegik and

Ugashik rivers) have greater overlap with Asian pink salmon stocks in their marine distribution than other stocks that did not decline significantly (Ruggerone and Link 2006, pg. 31).

Ultimately, conditions outside of the freshwater environment likely led to the decline of Kvichak sockeye salmon. Warmer summer temperatures in both fresh water (Schindler et al. 2005a) and the ocean (Hare and Mantua 2000) and interactions with Asian pink salmon affected Kvichak sockeye salmon disproportionately to other systems due to the dominance of ocean-age-two salmon in the Kvichak watershed (Ruggerone and Link 2006, pg. 12). Because ocean-age-two salmon interact with only one Asian pink salmon population at sea, the effects on growth and abundance are greater than for ocean-age-three salmon, which interact with both large (even) and small (odd) Asian pink salmon populations at sea and thus, have the opportunity for higher growth rates during odd years (Ruggerone et al. 2003). The decrease in spawner to smolt survival may also be related to marine conditions causing smaller length at age of returning adults and reduced reproductive success (Ruggerone and Link 2006, pg. 15).

In 2009, following several years of improvement, ADF&G upgraded the Kvichak's classification to a stock of yield concern (Morstad and Baker 2009). Since 2004, Bristol Bay returns have again totaled more than 40 million fish annually and in 2010 the Kvichak run increased to over 9.5 million fish, equating to 23% of the total for the Bay.

Chinook salmon

The total commercial harvest of Chinook salmon in the North Pacific ranged between three and four million fish until the early 90s; recent total catches have decreased to one to two million fish (Eggers et al. 2005). Lacking escapement data for many runs, commercial harvest is a good surrogate for salmon abundance, and suggests a decline in Chinook salmon abundance in recent decades. The U.S. makes over half of the total commercial catch, followed by Canada, Russia, and Japan (Heard et al. 2007). Recreational, subsistence, and aboriginal catch is significant for this salmon species and totaled approximately one million annually in 2003-2004 (Heard et al. 2007). Washington dominates hatchery production of Chinook salmon, with over one billion juveniles released annually from 1993-2001 (Heard et al. 2007).

The Columbia River historically produced the largest Chinook salmon run in the world, with peak runs (spring, summer, and fall combined) estimated at 3.2 M fish during the late 1800s (Chapman 1986). Peak catches for the Columbia River summer-run Chinook salmon occurred at this time, until overfishing decimated the run. Fishing effort then shifted to the fall run, which suffered a similar demise in the early 1900s. There are currently five stocks of Chinook salmon in the Columbia River watershed listed under the Endangered Species Act and the majority of the current returns are hatchery fish (70%, 80% and 50% of the spring, summer and fall runs, respectively; Heard et al. 2007).

Currently, the largest runs of Chinook salmon in the world originate from three of the largest watersheds that drain to the North Pacific: the Yukon, Kuskokwim and Fraser rivers (Table 6). Total Chinook escapements to the Kuskokwim and Yukon rivers have not been quantified directly due to their large watershed area, but recent total run estimates based on mark-recapture studies put them at 217,000 and 265,000 fish, respectively (Molyneaux and Brannian 2006, pg. 102, Spencer et al. 2009, pg. 28). On the Fraser River, the average size of the spring, summer, and fall Chinook runs combined (including the Harrison River) for the most recent ten-year period (2000-2009) was 287,000 fish (PSC 2011, pg. 87).

Table 6. Nushagak River Chinook average run sizes for 2000-2009, in comparison to other rivers across the North Pacific. Other rivers are sorted in order of decreasing run size.

Watershed	Region	Average run size (2000-2009)	Area[15] (km^2)
Nushagak R.	Bristol Bay, Western Alaska	151,348 [1]	31,383
Fraser R., total run	British Columbia, Canada	287,475 [2]	233,156
Kuskokwim R., total run	Western Alaska	284,000 [3]	118,019
Yukon R., total run	Western Alaska	217,405 [4]	857,996
Harrison R. (trib. of Fraser R.)	British Columbia, Canada	98,257 [5]	7,870
Taku R.	Southeast Alaska	78,081 [6]	17,639
Copper R.	Southcentral Alaska	75,081 [7]	64,529
Kenai R. (early and late runs)	Southcentral Alaska	70,976 [8]	5,537
Skeena R.	British Columbia, Canada	63,356 [9]	51,383
Yukon R., Canadian mainstem	Yukon Territory, Canada	59,346 [10]	323,800
Nass R.	British Columbia, Canada	31,738 [11]	20,669
Grays Harbor (Chehalis R. + 5 others)	Washington	23,964 [12]	6,993
Skagit R.	Washington	18,286 [13]	8,234
Nehalem R.	Oregon	12,267 [14]	2,193

[1] Unpublished data, Gregory Buck, ADF&G
[2] Pacific Salmon Commission 2011, pg. 88
[3] Unpublished data, Kevin Schaberg, ADF&G
[4] Average from 2000-2004, Spencer et al. 2009, pg. 28
[5] Pacific Salmon Commission 2011, pg. 88
[6] McPherson et al. 2010, pg. 14
[7] Unpublished data, Steve Moffitt, ADF&G
[8] Begich and Pawluk 2010, pg. 69
[9] Pacific Salmon Commission 2011, pg. 87
[10] Howard et al. 2009, pg. 35
[11] Pacific Salmon Commission 2011, pg. 87
[12] Pacific Salmon Commission 2011, pg. 90
[13] Pacific Salmon Commission 2011, pg. 89
[14] Pacific Salmon Commission 2011, pg. 93
[15] Watershed area from the Riverscape Analysis Project 2010 (http://rap.ntsg.umt.edu).

Chinook sport and commercial harvests in the Nushagak River are larger than all of the other systems in Bristol Bay combined (Dye and Schwanke 2009, pg. 13, Salomone et al. 2011, pg. 86). The Nushagak produces entirely wild runs that are periodically at or near the world's largest (Figure 8), which is remarkable considering its relatively small watershed area (Table 6). Returns consistently number over 100,000 fish, while returns greater than 200,000 fish have occurred eleven times between 1966 and 2010 (Figure 11). An especially productive six-year period from 1978-1983 produced three returns greater than 300,000 fish (Figure 11). Other rivers that produce large returns of Chinook salmon include the Copper, Kenai, and Taku rivers in Alaska and the Skeena and Harrison rivers in British Columbia (Table 6). The Harrison River is the dominant fall run stock for the Fraser River.

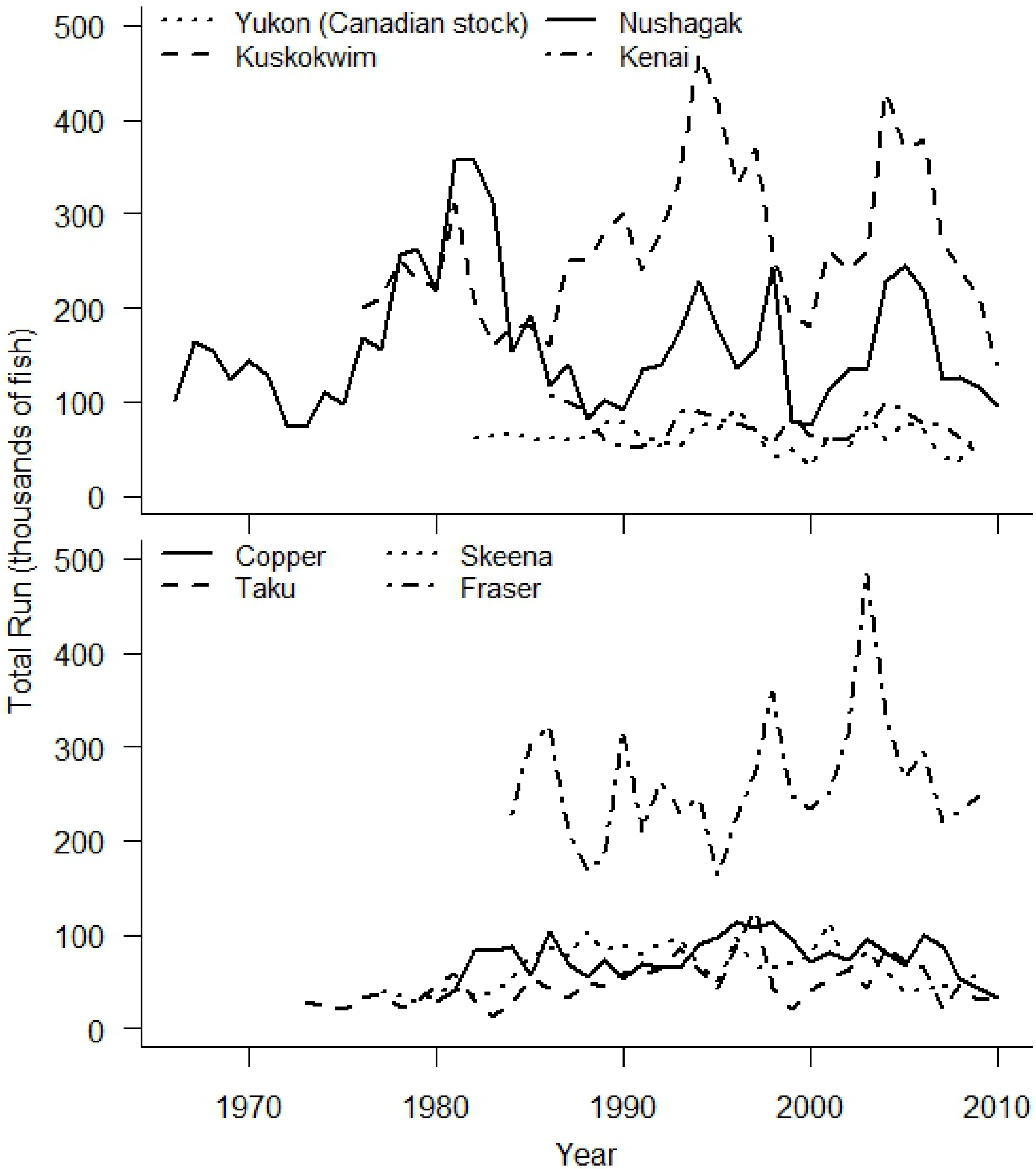


Figure 11. Chinook salmon abundances by river system, 1966-2010. See Appendix 1 for data and sources. The top graph shows total runs for the Yukon River (Canadian stock) from 1982 to 2009, the Kuskokwim River from 1976 to 2010, the Nushagak River from 1966 to 2010, and the Kenai River from 1986 to 2010. The bottom graph shows total runs for the Copper River from 1980 to 2010, the Taku River from 1973 to 2010, the Skeena River from 1977 to 2009, and the Fraser River from 1984 to 2009. Rivers are organized from west to east across the North Pacific.

A sustainable escapement goal (SEG) was implemented for Nushagak Chinook salmon in 2007 with a target of 40,000 to 80,000 fish. Sonar counts used to estimate escapement were initiated in 1989 and since that time, the Nushagak run has consistently met the minimum escapement for the current SEG and was over the SEG 12 times (Gregory Buck, ADF&G, unpublished data). The Nushagak Chinook stock is considered stable (Heard et al. 2007, Dye and Schwanke 2009, pg. 17), in contrast to Chinook stocks on the Kuskokwim and Yukon rivers, which experienced declines starting in the late 1990s. Both the Yukon and Kuskokwim Chinook were listed as stocks of yield concern in 2000 (Estensen et al. 2009, pg. 2, Howard et al. 2009, pg. 1). The Yukon River stock is still listed but the Kuskokwim River Chinook stock was delisted as a stock of concern in 2007, based on higher than normal returns starting in 2004 (Estensen et al. 2009, pg. 2).

The decline in Yukon and Kuskokwim Chinook stocks that began in the late 1990s may have resulted from the 1997-1998 El Nino (Kruse 1998b, Myers et al. 2010 pg. 199). That event was characterized by sea surface temperatures at least 2° C higher than normal in the Bering Sea, along with weak winds and high solar radiation that led to two anomalous phytoplankton blooms, typically associated with nutrient-limited waters (Kruse 1998a). The decline in Chinook stocks that persisted after the 1997-1998 El Nino indicate that multiple ocean age classes were affected by this event (Ruggerone et al. 2009). Alternative hypotheses for these declines have been proposed, including density-dependent effects, freshwater mortality, spawner fitness, and pathogens, leading to calls for additional research (e.g., Schindler et al. 2013).

Chinook salmon hatchery production contributes to harvests in both southeast and southcentral Alaska. The average number of returning hatchery Chinook salmon in Alaska for 2000 to 2009 was 118,000 fish annually and, in 2009, hatchery Chinook salmon contributed 16% of the total commercial harvest for the State (White 2010). There are no salmon hatcheries located in western Alaska and none of the total runs for the Alaskan rivers listed in Figure 11 or Table 6 include contributions from hatcheries (Yukon, Kuskokwim, Nushagak, Kenai, Copper, and Taku rivers). Salmon enhancement programs for Chinook salmon in British Columbia are significant; for the period 1990 to 2000, hatchery releases averaged approximately 50 million fish annually and hatcheries contributed approximately 30% to the total Canadian catch (MacKinlay et al. Undated). The Chehalis River hatchery in the Harrison River watershed and the Chilliwack River, Inch Creek, and Spius Creek hatcheries in the Fraser River watershed all contribute to the Chinook salmon runs on those systems (FOC 2011).

Threatened and endangered salmon and conservation priorities

Although it is difficult to quantify the true number of extinct salmon populations around the North Pacific, estimates for the Western United States (California, Oregon, Washington and Idaho) have ranged from 106 to 406 populations (Nehlsen et al. 1991, Augerot 2005, pg. 65, Gustafson et al. 2007). Chinook had the largest number of extinctions followed by coho and then either chum or sockeye (Nehlsen et al. 1991, Augerot 2005, pg. 67). Many of the patterns of population extinction are related to time spent in fresh water: interior populations have been lost at a higher rate than coastal populations, stream-maturing Chinook and steelhead (which may spend up to nine months in fresh water before spawning) had higher losses than their ocean-maturing counterparts, and species that relied on fresh water for rearing (Chinook, coho, and sockeye) had higher rates of extinction than pink or chum salmon, which go to sea soon after emergence (Gustafson et al. 2007). No populations from Alaska are known to have gone extinct. Salmon populations in the southern extent of their range have suffered higher extinction rates and are considered at higher risk than populations further to the north (Brown et al. 1994, Kope and Wainwright 1998, Rand 2008, Rand et al. 2012).

In addition to the large number of populations now extinct, there are many that are considered at risk due to declining population trends. The Columbia River basin dominated the list of at risk stocks identified by Nehlson et al. (1991), contributing 76 stocks to the total of 214 for California, Oregon, Washington, and Idaho. Approximately half of the 214 stocks evaluated were listed as high risk because they failed to replace themselves (fewer than one recruit per spawner) or had recent escapements below 200 individuals. More recent analyses of the status of salmon populations in the North Pacific continue to highlight the declines in the Pacific Northwest. A detailed assessment of salmon populations in the Columbia River basin from 1980 to 2000 showed that many are declining and this trend is heightened when hatchery fish are excluded (McClure et al. 2003). A comparison between time periods reflecting both good and bad ocean productivity for Columbia River salmon populations further indicates that the declining trends are not due to the regime shift of 1977 (McClure et al. 2003). An analysis of over 7,000 stocks across the North Pacific found that over 30% of sockeye, Chinook, and coho stocks were at moderate or high risk and that the Western U.S. (Washington, Oregon, California, and Idaho) had the highest concentrations of high-risk stocks (Augerot 2005, pgs. 66-67).

A detailed assessment of sockeye salmon populations across the North Pacific highlights threats for this species in British Columbia (Rand 2008, Rand et al. 2012). At the global population level, sockeye salmon are considered a species of least concern. Ninety-eight subpopulations were identified for assessment, five of which are extinct and 31 did not have the necessary data with which to conduct a status assessment. Of the remaining 62 subpopulations, 19 were identified as threatened (critically endangered, endangered, or vulnerable) and two as nearly threatened. British Columbia has 15 threatened (vulnerable, endangered, or critically endangered) subpopulations, 79% of the worldwide total. Three key threats to sockeye salmon were identified: mixed stock fisheries that lead to high harvests of small, less productive populations; poor marine survival rates and high rates of disease in adults due to changing climatic conditions; and negative effects of enhancement activities such as hatcheries and spawning channels (Rand 2012). Twenty six subpopulations were assessed for Alaska: 10 were data deficient, 13 were of least concern (including the one subpopulation identified for Bristol Bay), and two populations were listed as vulnerable; one subpopulation in the eastern Gulf of Alaska and the Lake McDonald population in Southeast Alaska. The Hugh Smith Lakes subpopulation in Southeast Alaska was listed as endangered. Both the Hugh Smith and McDonald Lake populations were listed as stocks of management concern by ADF&G in 2003 and 2009, respectively (Piston 2008, pg. 1, Eggers et al. 2009, pg. 1). Both were de-listed within four years after runs met escapement goals for several consecutive years following implementation of successful fishing restrictions (Piston 2008, pg. 1, Regnart and Swanton 2011).

Government agencies in the United States and Canada are tasked with identifying and protecting salmon populations at risk. In the U.S., the National Marine Fisheries Service (NMFS) manages listings of salmon species under the Endangered Species Act (ESA). Salmon stocks considered for listing under ESA must meet the definition of an Evolutionarily Significant Unit (ESU): it must be substantially reproductively isolated from other nonspecific population units and it must represent an important component of the evolutionary legacy of the species (Federal Register 58612, November 20, 1991). Current determinations for the U.S. include one endangered and one threatened ESU for sockeye; two threatened ESUs for chum; one endangered, three threatened, and one ESU of concern for coho; two endangered, seven threatened, and one ESU of concern for Chinook; and one endangered, ten threatened, and one ESU of concern for steelhead (Table 7, NMFS 2010). All listed ESUs occur in the western contiguous U.S. (California, Oregon, Washington, and Idaho). In Canada, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) conducts status assessments to determine if a species is at risk nationally. The Minister of the Environment and the federal cabinet then decide whether to list the species under the Species at Risk Act (SARA). Currently, COSEWIC status assessments have recommended listing two endangered sockeye salmon populations, one endangered coho salmon population, and one threatened Chinook salmon population, but none of these assessments have resulted in legal listings under SARA (COSEWIC 2009). On the Asian side of the Pacific, no information was found regarding listings of threatened or endangered salmon populations under a legal framework. Other assessments of Asian salmon distribution and status have relied on interviews with fishery biologists due to the scarcity of data and the dominance of hatcheries in Japanese fisheries (Augerot 2005, pg. 66, Rand 2008).

Table 7. Endangered Species Act listings for salmon ESUs in the United States.

Species	ESU Name	ESA Listing Status	Date of Most Recent Review
Chinook	Sacramento River Winter-run	endangered	8/15/2011
Chinook	Upper Columbia River Spring-run	endangered	8/15/2011
Chinook	California Coastal	threatened	8/15/2011
Chinook	Central Valley Spring-run	threatened	8/15/2011
Chinook	Lower Columbia River	threatened	8/15/2011
Chinook	Puget Sound	threatened	8/15/2011
Chinook	Snake River Fall-run	threatened	8/15/2011
Chinook	Snake River Spring/Summer-run	threatened	8/15/2011
Chinook	Upper Willamette River	threatened	8/15/2011
Chinook	Central Valley Fall- and Late Fall-run	species of concern	4/15/2004
chum	Hood Canal Summer-run	threatened	8/15/2011
chum	Columbia River	threatened	8/15/2011
coho	Central California Coast	endangered	8/15/2011
coho	Southern OR/Northern CA Coasts	threatened	8/15/2011
coho	Lower Columbia River	threatened	8/15/2011
coho	Oregon Coast	threatened	8/15/2011
coho	Puget Sound/Strait of Georgia	species of concern	4/15/2004
sockeye	Snake River	endangered	8/15/2011
sockeye	Ozette Lake	threatened	8/15/2011
steelhead	Southern California	endangered	1/5/2006
steelhead	California Central Valley	threatened	8/15/2011
steelhead	Central California Coast	threatened	1/5/2006
steelhead	Lower Columbia River	threatened	8/15/2011
steelhead	Middle Columbia River	threatened	8/15/2011
steelhead	Northern California	threatened	1/5/2006
steelhead	Puget Sound	threatened	8/15/2011
steelhead	Snake River Basin	threatened	8/15/2011
steelhead	Southcentral California Coast	threatened	1/5/2006
steelhead	Upper Columbia River	threatened	8/15/2011
steelhead	Upper Willamette River	threatened	8/15/2011
steelhead	Oregon Coast	species of concern	4/15/2004

The causes leading to extinction and continued population declines are numerous and analyses are confounded by the effects of interacting factors within watersheds. In California, both the building of dams that eliminated access to upstream spawning and rearing areas and destruction of coastal habitat from extensive logging were major contributors to the decline of coho salmon populations in the southern extent of their range (Brown et al. 1994). Heavy fishing pressure at the end of the 19th century followed by extensive impacts to river habitats from agriculture, logging, mining, irrigation and hydroelectric dams all led to the extensive decline of Columbia River salmon by the mid 20th century (Chapman 1986, McConnaha et al. 2006).

Restoration activities to help restore salmon habitat and populations in the Pacific Northwest require huge expenditures with results that are often difficult to measure due to annual variation, the time lapse between restoration action and effect on the population, and changing climate and ocean conditions (GAO 2002, pg. 4). Approximately $1.5 billion was spent on Columbia River salmon and steelhead for the period 1997 through 2001 (GAO 2002, pg. 2). Predicted outcomes from restoration rarely take into account climate change scenarios. Models developed to predict the outcome of restoration on Snohomish basin Chinook salmon habitat showed that increased temperatures resulting from climate change changed snow to rain in high elevation watersheds and affected three hydrologic parameters that decreased fish populations: higher flows during egg incubation, lower flows during spawning, and increased temperatures during pre-spawning (Battin et al. 2007). Often used as mitigation for lost habitat, salmon hatcheries have resulted in decreased survival of the wild populations they are intended to support (NRC 1996, pg. 319, Naish et al. 2008). Impacts of hatchery fish include overfishing of wild populations in mixed-stock fisheries (Hilborn and Eggers 2000), competition with wild salmon in both fresh water and the ocean (Ruggerone and Nielsen 2009), and a reduction in life history diversity making populations more susceptible to climate variability (Moore et al. 2010).

Due to the high costs of restoration and the difficulty in predicting or measuring outcomes, some have argued that the best way to protect salmon for future generations is to create salmon sanctuaries that maintain intact and connected habitats throughout the watershed from headwaters to the ocean (Rahr et al. 1998, Lichatowich et al. 2000, Rahr and Augerot 2006). Protecting entire watersheds is especially important to sockeye, Chinook, and coho salmon, which spend 1-2 years rearing in fresh water prior to entering the ocean. These sanctuaries would provide habitat for salmon populations with heightened resilience to factors outside of management control, such as climate change and changes in the ocean environment. The salmon populations in Bristol Bay meet all the criteria for selecting sanctuaries across the North Pacific by having intact habitats, abundant populations, and a high diversity of life history patterns (Schindler et al. 2010). In addition, several studies have targeted Bristol Bay as a high priority for salmon conservation. The Kvichak, Nushagak, and Wood watersheds were ranked third, 44th, and fourth, respectively, in an analysis of physical complexity of 1574 watersheds from California to the Kamchatka Peninsula (Luck et al. 2010, FLBS 2011). Pinsky et al. (2009) characterized high conservation value salmon catchments across the North Pacific as the top 20% (out of 1046 total) based on abundance and run timing diversity. Bristol Bay, the Kamchatka Peninsula, and coastal British Columbia all had clusters of high conservation value catchments. Fewer than 9% of the high conservation value watersheds had greater than half of their area under protected status.

KEY HABITAT ELEMENTS OF BRISTOL BAY RIVER SYSTEMS (OR *WHY DO BRISTOL BAY WATERSHEDS PRODUCE SO MANY FISH?*)

No published materials specifically address the question "*Why do Bristol Bay watersheds support so many salmon?*" While this isn't particularly surprising given the complexity and scope of the question, it does require us to draw on experts and a diverse body of literature to posit an answer. Obviously, the simplest answer is "*Habitat*." But what is it about the habitat in Bristol Bay watersheds that allows them to sustain such prolific fisheries? Our inquiry led us to the conclusion that interplay between the quantity, quality, and diversity of habitats in these river systems accounts for their productivity. The major habitat attributes discussed here were identified in personal communications with Dr. Tom Quinn (University of Washington) and Dr. Jack Stanford (University of Montana).

Habitat quantity

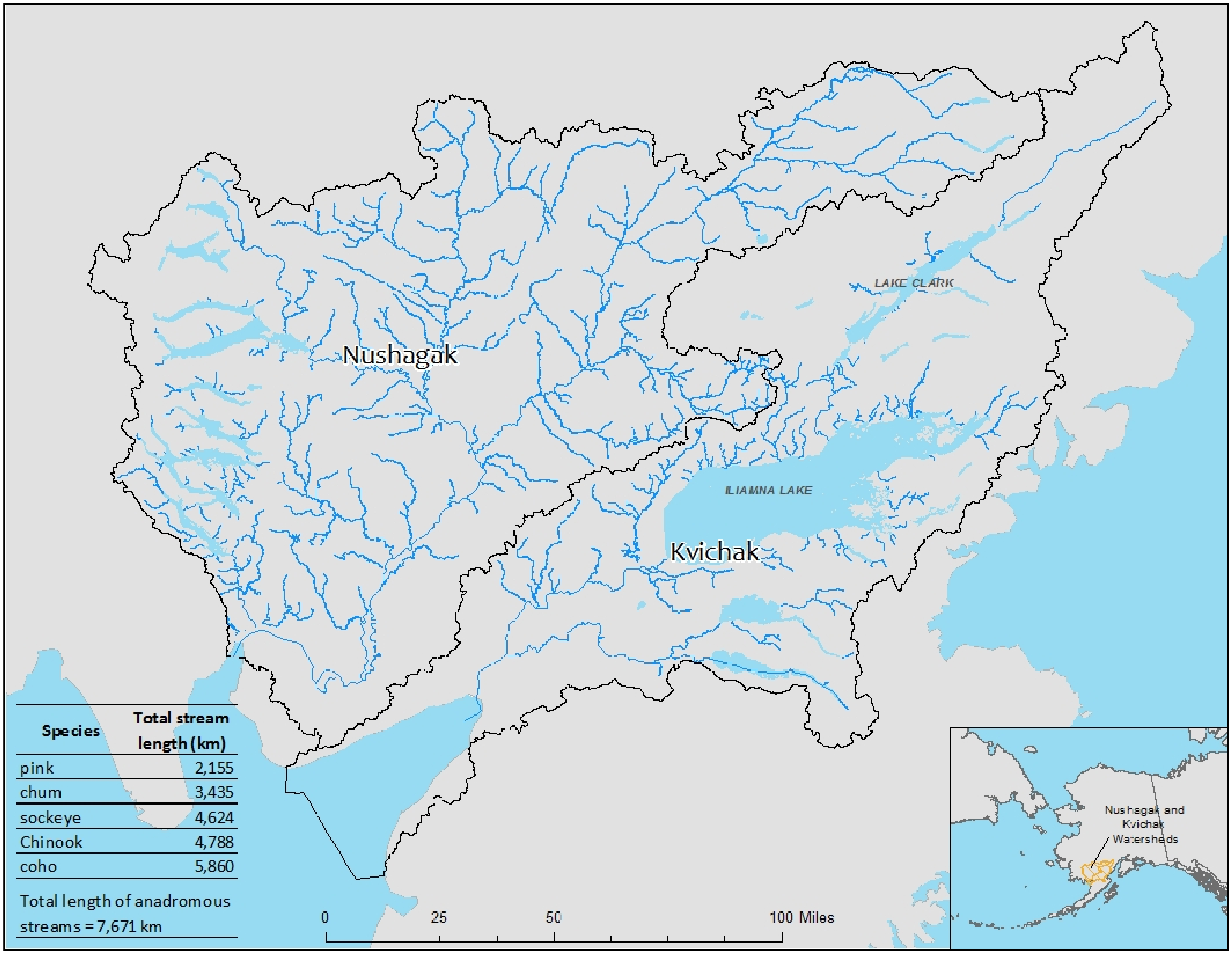
An obvious feature of the Bristol Bay watershed is the abundance of large lakes (Figure 12). The Kvichak River drains Iliamna Lake, Alaska's largest, in addition to Lake Clark, Nonvianuk Lake, Kukaklek Lake, and an array of smaller lakes. The Nuyakuk River, a major tributary to the upper Nushagak River, drains Nuyakuk, Tikchik, Chauekuktuli, Chikuminuk, Upnuk, Nishlik, and a number of smaller lakes. The Wood River, a major tributary to the lower Nushagak River, drains an interconnected chain of four major lakes – lakes Kulik, Beverly, Nerka, and Aleknagik – and several smaller lakes. Lakes cover 7.9% of the Bristol Bay region, which is substantially higher than the other major salmon-producing regions analyzed (Table 8). Lakes cover 13.7% of the Kvichak River basin (Table 8). Within the Nushagak River basin, lakes cover 11.3% of the Wood River drainage and a much smaller percentage of the remainder (1.7%; Table 8).

Since watershed elevations in the Bristol Bay region are relatively low (Table 8), barriers to fish migration are few and a large proportion of the watershed can be accessed by salmon. The Nushagak and Kvichak watersheds have over 58,000 km of streams (National Hydrography Dataset), of which 7,671 km (13%) have been documented as anadromous fish streams (ADF&G 2011 Anadromous Waters Catalog; Figure 12). Since fish use must be documented firsthand by field biologists, a large proportion of anadromous fish habitat undoubtedly remains undocumented. For example, a recent survey targeted 135 undocumented headwater (i.e., 1^{st}- and 2^{nd}-order) stream reaches with low to moderate gradient (i.e., <10% channel slope) north of Iliamna Lake (Woody and O'Neal 2010, pgs. 11-12). Of these stream reaches, 16% were dry or nonexistent, 53% had juvenile salmon, 66% had resident fish, and 3% contained no fish at the time of sampling (Woody and O'Neal 2010, pg. 22).

Table 8. Comparison of landscape features potentially important to sockeye salmon production for watersheds across the North Pacific (top portion of table) and across the Bristol Bay watershed (bottom portion of table). All landscape data are from the Riverscape Analysis Project (Luck et al. 2010).

Watershed	Location	Watershed area (km^2)	Mean watershed elevation (m)	Number of lakes > 1 km^2	Average elevation of lakes (m)	% Lake coverage in watershed	Mean annual sockeye run (millions of fish, 1990-2005)[+]
Kamchatka	Russia	53,598	549	82	15	0.4	3.2
Kenai	Central Alaska	5,537	522	2	97	2.9	5.2
Copper	Prince William Sound	64,529	1,194	9	448	0.5	3.0
Fraser	British Columbia	233,156	1,188	119	763	1.6	10.7
Columbia	Washington	669,608	1,328	68	1,212	0.2	
Bristol Bay	Western Alaska	88,233	269*	69	219*	7.9*	42.8
Togiak	Bristol Bay	4,600	322	6	160	1.4	0.7
Igushik	Bristol Bay	2,126	74	2	15	3.3	1.3
Nushagak (inc. Wood)	Bristol Bay	35,237	250	20	325	2.7	6.0
Kvichak (inc. Alagnak)	Bristol Bay	25,328	340	29	193	13.7	10.9
Naknek	Bristol Bay	9,624	312	8	230	8.3	5.2
Egegik	Bristol Bay	7,117	168	1	4	16.5	11.0
Ugashik	Bristol Bay	4,201	104	3	4	9.9	3.8

[*]Some figures for Bristol Bay represent the weighted average of individual Bristol Bay watersheds.
[+]Salmon abundance sources: Kamchatka, Fraser, and Columbia are from Ruggerone et al. 2010 (Fraser and Columbia rivers were combined into one region "Southern B.C. and Washington."); Kenai is from sockeye brood tables for Kenai River (pers. comm. Pat Shields, 2011); Copper is from sockeye brood tables for Copper River (pers. comm. Jeremy Botz, 2011); Bristol Bay and individual watersheds within Bristol Bay are from sockeye brood tables for Bristol Bay (pers. comm. Tim Baker, 2011).



Species	Total stream length (km)
pink	2,155
chum	3,435
sockeye	4,624
Chinook	4,788
coho	5,860

Total length of anadromous streams = 7,671 km

Figure 12. Map of surveyed anadromous streams in the Nushagak and Kvichak watersheds. Data are from ADF&G 2011 Anadromous Waters Catalog.

Habitat quality

In addition to the overall abundance of salmon habitat, there are a number of habitat attributes that likely contribute to the productivity of Bristol Bay's river systems. First of all, Bristol Bay streambeds tend to have abundant gravel, which is essential substrate for salmon spawning and egg incubation (Bjornn and Reiser 1991, pgs. 95-97 , Quinn 2005, pg. 108). Several Pleistocene glacial advances have left behind a complex landscape of gravel-rich moraines, melt-water deposits, and outwash plains (Stilwell and Kaufman 1996, Hamilton and Kleiforth 2010). As stream channels meander and cut through these deposits, gravel and other sediments are captured and formed into riffles, bars and other habitat features. In a survey of 76 wadeable stream reaches across the Kvichak and Nushagak watersheds, gravel (2-64 mm) was the dominant substrate, covering 56% (±15%) of each streambed (D.J. Rinella, unpublished data).

Groundwater inputs to streams and lakes are also an important feature of salmon habitat in the Kvichak and Nushagak watersheds. Rainwater and melting snow infiltrate the extensive glacial deposits and saturate pore spaces below the water table, thus recharging the groundwater aquifer (Power et al. 1999, pg. 402). Ponds are common on the Bristol Bay landscape and contribute disproportionately to groundwater recharge (Rains 2011). Once in the aquifer, groundwater flows slowly downhill and eventually surfaces in areas of relatively low elevation, like stream channels or lake basins. Areas of groundwater upwelling are heavily used by spawning sockeye salmon because they provide circulation, stable flows, and stable temperatures (Burgner 1991, pgs. 16-19). These habitats include lake beaches and spring-fed ponds, creeks, and side channels (Burgner 1991, pgs. 16-19). Studies in the Wood River system of Bristol Bay demonstrate the importance of groundwater upwelling to spawning sockeye salmon. In lakes, densities of beach spawners were highest at sites with the strongest upwelling, while spawners were absent at beach sites with no upwelling (Burgner 1991, pg. 19). Beach spawners comprise substantial portions of the spawning populations in three of the four main Wood River lakes: 47% in Nerka, 87% in Beverly, 59% in Kulik, but only 3% in Aleknagik (1955-1962; Burgner et al. 1969, pg. 420). In a spring-fed tributary to Lake Nerka, the distribution of sockeye salmon spawners also corresponded with areas of groundwater upwelling (Mathisen 1962, pgs. 145-146). Large numbers of sockeye salmon in the Kvichak River system also spawn in lake beaches, spring-fed ponds, and other groundwater-associated habitats (Morstad 2003, pgs. 2-17). In addition to spawning sockeye, groundwater is an important habitat feature for other salmon species and life history stages. Chum salmon have been shown to preferentially spawn in areas of groundwater upwelling (Salo 1991, pg. 240, Leman 1993). Groundwater also maintains ice-free habitats used extensively by wintering fishes, helps to maintain streamflow during dry weather, and provides thermal refuge during periods of warm water (Reynolds 1997, Power et al. 1999).

Salmon themselves are another important habitat feature of Bristol Bay watersheds. Each year, the region's spawning salmon populations convey massive amounts of energy and nutrients from the North Pacific to fresh waters. These marine-derived nutrients (MDN), released as excreta, carcasses, and energy-rich eggs, greatly enhance the productivity of freshwater ecosystems, making Pacific salmon classic examples of keystone species that have large effects on the ecosystems where they spawn (Willson and Halupka 1995, Power et al. 1996).

Salmon contain limiting nutrients (i.e, nitrogen and phosphorus) and energy (i.e., carbon) in the same relative proportions as needed for growth by rearing fishes, making MDN an ideal fertilizer for salmon ecosystems (Wipfli et al. 2004). Given the high densities of spawning salmon in some streams, MDN subsidies can be large. On average, spawning sockeye salmon import 50,200 kg of phosphorus and 397,000 kg of nitrogen to the Kvichak River system and 12,700 kg of phosphorus and 101,000 kg of nitrogen to the Wood River system each year (Moore and Schindler 2004). In high latitudes, the importance of marine nutrients is magnified by the low ambient nutrient levels in freshwater systems (Gross et al. 1988, Perrin and Richardson 1997). In Iliamna Lake, for example, nitrogen inputs from spawning salmon greatly exceed inputs from the watershed (Kline et al. 1993).

Resident fishes (e.g., rainbow trout, Dolly Varden, Arctic grayling) and juvenile salmon of species that rear for extended periods in streams (i.e., coho and Chinook) derive clear and substantial nutritional benefits through the consumption of salmon eggs and flesh and other food sources related to spawning salmon (Bilby et al. 1996). In streams in the Nushagak River basin, for example, ration size and energy consumption among rainbow trout and Arctic graying increased by 480 to 620% after the arrival of spawning salmon (Scheuerell et al. 2007). The increase in rainbow trout diet was attributable to salmon eggs, salmon flesh, and maggots that colonized salmon carcasses, while the increase in Arctic grayling diet was attributable to consumption of benthic invertebrates dislodged by spawning salmon (Scheuerell et al. 2007). A bioenergetics model suggested that these subsidies were responsible for a large majority of the annual growth of these fish populations (Scheuerell et al. 2007). In a stream in the Kvichak River basin, Dolly Varden moved into ponds where sockeye salmon spawned and fed almost entirely on salmon eggs (Denton et al. 2009). The growth rate of these Dolly Varden increased three-fold while salmon eggs were available (Denton et al. 2009). On the Kenai Peninsula, Alaska, recent work has shown that the number of salmon spawning in a given stream is an important predictor of the growth rate and energy storage among coho salmon and Dolly Varden rearing there (Rinella et al. 2011). These and other studies indicate that the availability of MDN enhances growth rates (Bilby et al. 1996, Wipfli et al. 2003, Giannico and Hinch 2007), body condition (Bilby et al. 1998), and energy storage (Heintz et al. 2004) of stream-dwelling fishes, likely leading to increased chances of survival to adulthood (Gardiner and Geddes 1980, Wipfli et al. 2003, Heintz et al. 2004).

MDN is also linked with bottom-up effects on aquatic food webs. In streams, increased standing stocks of biofilm (Wipfli et al. 1998, Wipfli et al. 1999, Johnston et al. 2004, Mitchell and Lamberti 2005) and macroinvertebrates (Claeson et al. 2006, Lessard and Merritt 2006, Walter et al. 2006) have been associated with MDN inputs. Stream-dwelling fishes likely benefit indirectly through increased macroinvertebrate production, but this has yet to be directly established. Likewise, MDN can comprise a major proportion of the annual nutrient budget in Bristol Bay lakes (Mathisen 1972, Koenings and Burkett 1987, Schmidt et al. 1998) and salmon-derived nitrogen is ultimately taken up by juvenile sockeye salmon (Kline et al. 1993). However, it is not clear if these nitrogen inputs have measurable effects on sockeye salmon populations (Schindler et al. 2005b, Uchiyama et al. 2008).

The importance of MDN to fish populations is perhaps most clearly demonstrated in cases where MDN supplies are disrupted by depletion of salmon populations. The prolonged depression of salmon stocks in the Columbia River basin is a prime example, where a chronic nutrient deficiency hinders the recovery of endangered and threatened Pacific salmon stocks (Gresh et al. 2000, Petrosky et al. 2001, Achord et al. 2003, Peery et al. 2003, Scheuerell et al. 2005, Zabel et al. 2006) and diminishes the potential of expensive habitat improvement projects (Gresh et al. 2000). Density-dependent mortality has been documented among juvenile Chinook, despite the fact that populations have been reduced to a fraction of historic levels, suggesting that nutrient deficits have reduced the carrying capacity of spawning streams in the Columbia River basin (Achord et al. 2003, Scheuerell et al. 2005). A population viability analysis has indicated that declines in MDN have very likely contributed to low productivity of juvenile salmon and that increasing the productivity could lead to large increases in the salmon population (Zabel et al. 2006). Diminished salmon runs, thus, present a negative feedback loop where the decline in spawner abundance reduces the capacity of streams to produce new spawners (Levy 1997). Fisheries managers recognize the importance of MDN in sustaining the productivity of salmon systems and are now attempting to supplement nutrient stores by planting hatchery salmon carcasses and analogous fertilizers in waters throughout the Pacific Northwest (Stockner 2003, Shaff and Compton 2009).

In addition to their inherent natural productivity, Bristol Bay watersheds have not been subjected to anthropogenic watershed disturbances that have contributed to declining salmon populations elsewhere. For example, Nehlsen et al. (1991) reviewed the status of native salmon and steelhead stocks in California, Oregon, Washington, and Idaho. They found that 214 stocks appeared to face a risk of extinction; of these, habitat loss or modification was a contributing factor for 194. These cases were in addition to at least 106 stocks that had already gone extinct (Nehlsen et al. 1991). A National Research Council committee (NRC 1996), convened to review the population status of Pacific Northwest salmon, summarized that:

> *The ecological fabric that once sustained enormous salmon populations has been dramatically modified through heavy human exploitation – trapping, fishing, grazing, logging, mining, damming of rivers, channelization of streams, ditching and draining of wetlands, withdrawals of water for irrigation, conversions of estuaries, modification of riparian systems and instream habitats, alterations to water quality and flow regimes, urbanization, and other effects.*

Thus, it is generally agreed that a complex and poorly understood combination of factors – with direct and indirect effects of habitat degradation at the fore – are responsible for declining Pacific Northwest salmon stocks (NRC 1996, Gregory and Bisson 1997, Lackey 2003).

In watersheds of the Bristol Bay region, including the Nushagak and Kvichak rivers, human habitation is confined to a few small towns and villages, roads are few, and large-scale habitat modifications are absent. The Riverscape Analysis Project, using spatial data from the Socioeconomic Data and Applications Center (Sanderson et al. 2002), ranked 1574 salmon-producing watersheds around the North Pacific based on an index of human footprint (http://rap.ntsg.umt.edu/humanfootprintrank; accessed 9/1/11). Of these, the Kvichak River ranked 197, the Nushagak (exclusive of the Wood River) ranked 131, and the Wood River ranked 332. Additionally, invasive fishes and riparian plants, which can negatively impact native fish populations, have not been introduced to Bristol Bay's watersheds.

Habitat diversity

A diverse assemblage of spawning and rearing habitats is an exceedingly important feature of Bristol Bay's riverine ecosystems. Since salmon adapt in predictable ways to conditions within their specific environments, a high level of habitat diversity fosters a correspondingly high level of population and life history diversity. The utilization of different types of spawning habitat is an easily observable example. Suitable lotic habitats range from small gravel-bed creeks to large cobble-bed rivers (Hilborn et al. 2003b), and even silt-laden glacial streams (Ramstad et al. 2010). Spring-fed ponds are also used, as are areas of groundwater upwelling on mainland lake beaches, and rocky beaches of low-lying islands (Hilborn et al. 2003b). Sockeye salmon have adapted to each of these environments in predictable ways, optimizing behavioral and physiological traits like timing of spawning, egg size, and the size and shape of spawning adults (Table 9; Hilborn et al. 2003b). The result is a stock complex comprised of hundreds of distinct spawning populations, each adapted to its own spawning and rearing environment.

This complexity is compounded by variation within each spawning population, likely in ways that are not yet fully understood (Hilborn et al. 2003b). One clear example is variation in the amount of time spent rearing in fresh water and at sea (Table 10). Within a given cohort, most individuals rear for either one or two years in fresh water, although a small number may spend three years or go to sea shortly after hatching (i.e., zero years in fresh water). The latter life history is relatively common among Nushagak River sockeye, many of which rear in rivers as opposed to lakes. Once at sea, most fish will rear for an additional two or three years, although a few will rear for as little as one year or as many as five years. This life history complexity superimposed on localized adaptations results in a high degree of biological complexity within the stock complex.

Table 9. A summary of life history variation within the Bristol Bay stock complex of sockeye salmon (from Hilborn et al. 2003).

Element of biocomplexity	Range of traits or options found
Watershed location within Bristol Bay complex	Seven different major watersheds, ranging from maritime-influenced systems on the Alaska Peninsula to more continental systems
Time of adult return to fresh water	June – September
Time of spawning	July – November
Spawning habitat	Major rivers, small streams, spring fed ponds, mainland beaches, island beaches
Body size and shape of adults	130 – 190 mm body depth at 450 mm male length: sleek, fusiform to very deep bodied, with exaggerated humps and jaws
Egg size	88 – 166 mg at 450 mm female length
Energetic allocation within spawning period	Time between entry into spawning habitat and death ranges from 1 – 3 days to several weeks
Time spent rearing in fresh water	0 – 3 years
Time spent at sea	1 – 4 years

Table 10. Variation in time spent rearing in fresh water and at sea for Bristol Bay sockeye salmon. Numbers represent percentage of fish returning to the respective river systems after a given combination of freshwater and sea rearing periods. + indicate combinations that were represented in the data but comprised <1% of returns to the respective river system. Data are from ADF&G and cover 1956 to 2005 brood years, except for Nushagak River data which cover 1979 to 2003 brood years.

Number of years spent in fresh water	0				1					2				3		
Number of years spend at sea	2	3	4	5	1	2	3	4	5	1	2	3	4	1	2	3
Kvichak	+	+	+		+	25	10	+		+	58	7	+	+	+	+
Alagnak	+	+	+		+	42	40	+		+	12	5	+			+
Nushagak	2	17	2	+	+	11	60	5	+	+	1	2	+		+	+
Wood	+	+	+		+	48	43	+		+	5	3	+		+	+
Naknek	+	+	+		+	16	44	+	+	+	17	21	+	+	+	+
Egegik	+	+	+		+	9	17	+		+	44	29	+	+	+	+
Ugashik	+	+	+		+	27	28	+	+	+	30	15	+		+	+
Igushik	+	+	+		+	20	68	+		+	5	5	+			
Togiak	+	1	1		+	21	63	+		+	6	7	+		+	

These layers of biocomplexity result in a situation where different stocks within the complex show asynchronous patterns of productivity (Rogers and Schindler 2008). This is because differences in habitat and life history lead to different population responses despite exposure to the same prevailing environmental conditions. For example, a year with low stream flows might negatively impact populations that spawn in small streams but not those that spawn in lakes (Hilborn et al. 2003b). Asynchrony in population dynamics of Bristol Bay sockeye has been demonstrated at both the local scale (i.e., individual tributaries) and the regional scale (i.e., major river systems; Rogers and Schindler 2008). The latter is demonstrated nicely by the relative productivity of Bristol Bay's major rivers during different climatic regimes (Hilborn et al. 2003b), where small runs in the Egegik River were offset by large runs in the Kvichak prior to 1977, but declining runs in the Kvichak River in the 2000s were in turn offset by large runs in the Egegik River (see Figure 9).

Population and life history diversity within Bristol Bay sockeye populations can be equated to spreading risk with a diversified portfolio of financial investments (Schindler et al. 2010). Under any given set of conditions, some assets perform well while others perform poorly, but maintenance of a diversified portfolio stabilizes returns over time. Within the sockeye stock complex, the portfolio of population and life history diversity greatly reduces year-to-year variability in run size, making the commercial salmon fishery much more reliable than it would be otherwise. With the current level of biocomplexity in Bristol Bay sockeye, salmon runs are large enough to meet bay-wide escapement goals of ~10 M fish nearly every year and fishery closures are rare (i.e., less than four closures per 100 years; Schindler et al. 2010). If Bristol Bay sockeye lacked biocomplexity and the associated stabilizing effects, run sizes would fluctuate widely and complete fishery closures would happen every two to three years (Schindler et al. 2010).

While the analyses described here apply to the Bristol Bay commercial sockeye fishery, portfolio effects certainly stabilize populations of other fish species and increase the reliability of sport and subsistence fisheries. In addition, portfolio effects stabilize and extend the availability of salmon to consumers in the watershed food webs. Poor runs in some habitats will be offset by large runs in others, allowing mobile predators and scavengers (e.g., bears, eagles, rainbow trout) to access areas of relatively high spawner density each year (Schindler et al. 2010). Different populations vary in the timing of spawning, which substantially extends the period when salmon are occupying spawning habitats (Schindler et al. 2010).

Since a diversified salmon stock complex is contingent upon a complex suite of habitats, an important question becomes: How does habitat diversity in Bristol Bay watersheds compare to that in other salmon-producing regions? The Riverscape Analysis Project calculated remotely-sensed indices of physical habitat complexity, allowing comparisons among salmon producing watersheds at the North Pacific Rim scale (Luck et al. 2010, Whited et al. 2012). Rankings of overall physical complexity were based on 10 attributes: variation in elevation; floodplain elevation; density of floodplains and stream junctions; human footprint; the proportion of watershed covered by glaciers, floodplains, and lakes; and the elevation and density of lakes. While the characterization of habitat complexity at this broad spatial scale is necessarily imprecise and certainly fails to detect nuanced habitat features, it does seem to quantify attributes that are important to salmon as it explained general patterns in salmon abundance in validation watersheds (Luck et al. 2010). Overall physical complexity was relatively high for the watersheds considered in this assessment; of the 1574 Pacific Rim watersheds characterized, the Kvichak River ranked the 3rd highest, the Nushagak River (exclusive of the Wood River) ranked 44th, and the Wood River ranked 4th (http://rap.ntsg.umt.edu/overallrank; accessed 9/1/11).

The studies reviewed here demonstrate how biocomplexity in salmon populations provides resilience to environmental change. This resilience can break down when habitats are degraded or when the genetic diversity that allows salmon to utilize the full complement of available habitats is diminished. The loss of habitat diversity and associated loss of population diversity has contributed to declines of once prolific salmon fisheries, including those in the Sacramento (Lindley et al. 2009) and Columbia rivers (Bottom et al. 2005, Moore et al. 2010). Lindley et al. (2009), summarizing causes for the recent crash in Sacramento River fall Chinook, highlighted the importance of life history diversity:

> *In conclusion, the development of the Sacramento-San Joaquin watershed has greatly simplified and truncated the once-diverse habitats that historically supported a highly diverse assemblage of populations. The life history diversity of this historical assemblage would have buffered the overall abundance of Chinook salmon in the Central Valley under varying climate conditions.*

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Appendix A. Chinook and sockeye salmon run sizes for Bristol Bay and other regions of the North Pacific

Table A1. Chinook total run sizes (harvest plus escapement) by river system, 1966-2010

Table A2. Sockeye total run sizes (harvest plus escapement) by river system, 1956-2010

Table A3. Sockeye total run sizes (harvest plus escapement) by region, 1956-2005

Table A1. Chinook total run sizes by river system, 1966-2010

Year	Nushagak	Kenai	Yukon, Canadian mainstem	Copper	Taku	Skeena	Nass	Nehalem	Skagit
1966	144,145	NA	NA	NA	NA	NA	NA	NA	NA
1967	234,216	NA	NA	NA	NA	NA	NA	NA	NA
1968	228,551	NA	NA	NA	NA	NA	NA	NA	NA
1969	158,627	NA	NA	NA	NA	NA	NA	NA	NA
1970	196,081	NA	NA	NA	NA	NA	NA	NA	NA
1971	169,206	NA	NA	NA	NA	NA	NA	NA	NA
1972	101,001	NA	NA	NA	NA	NA	NA	NA	NA
1973	107,999	NA	NA	NA	38,307	NA	NA	NA	NA
1974	183,287	NA	NA	NA	35,442	NA	NA	NA	NA
1975	172,144	NA	NA	NA	46,870	NA	17,874	5,060	22,252
1976	273,657	NA	NA	NA	44,555	NA	16,583	9,446	23,939
1977	224,104	NA	NA	NA	41,856	39,606	18,410	11,552	18,514
1978	393,636	NA	NA	NA	56,386	35,055	21,807	11,676	20,962
1979	361,210	NA	NA	NA	60,190	28,166	16,229	12,058	22,261
1980	366,555	NA	NA	29,659	64,247	38,626	18,744	5,645	30,346
1981	513,708	NA	NA	41,047	75,280	42,018	17,606	10,577	20,720
1982	509,867	NA	60,746	84,098	37,042	35,185	13,287	5,111	21,475
1983	482,196	NA	63,427	82,730	19,943	39,510	20,516	4,376	15,225
1984	237,104	NA	66,800	86,373	41,850	53,516	31,408	20,939	15,701
1985	314,434	NA	59,736	55,997	71,814	76,544	24,768	18,845	27,709
1986	165,950	106,917	61,789	103,024	51,190	87,566	47,967	11,570	23,507
1987	231,453	100,123	58,921	69,910	41,474	76,349	26,568	15,268	14,782
1988	141,908	89,462	61,126	55,801	66,601	102,563	21,094	16,684	16,390
1989	187,644	59,409	78,243	73,423	57,086	83,439	36,594	11,650	14,596
1990	156,663	50,751	78,439	52,899	66,517	89,447	33,384	6,617	20,717
1991	246,718	52,810	63,335	68,175	80,066	79,343	13,136	7,498	9,696
1992	232,103	54,302	57,058	64,172	84,882	92,184	25,405	11,558	10,211

Table A1. Chinook total run sizes by river system, 1966-2010

Year	Nushagak	Kenai	Yukon, Canadian mainstem	Copper	Taku	Skeena	Nass	Nehalem	Skagit
1993	283,385	89,748	52,855	65,301	98,073	96,018	36,678	9,137	7,691
1994	334,604	90,552	77,647	90,073	70,253	68,127	32,864	9,194	7,082
1995	271,126	81,563	71,557	96,710	74,564	48,351	16,187	8,671	10,096
1996	193,029	77,228	93,672	113,868	98,184	96,453	30,889	12,975	13,364
1997	247,097	69,773	70,349	107,760	130,091	65,350	27,658	12,732	7,198
1998	370,883	55,540	41,434	112,365	51,706	65,167	34,922	10,591	16,067
1999	148,963	86,553	49,652	95,951	33,500	70,993	22,310	10,361	5,725
2000	137,979	63,373	30,749	70,746	51,055	77,320	31,159	10,817	18,231
2001	213,128	60,320	62,703	81,155	59,449	112,346	44,595	14,293	15,947
2002	228,919	61,878	51,616	72,972	71,902	63,069	21,528	20,552	20,979
2003	224,724	73,210	90,213	94,505	62,436	82,410	36,503	23,569	11,933
2004	351,928	99,765	59,707	80,559	113,923	61,065	25,137	14,456	25,863
2005	307,245	91,309	79,625	66,341	81,173	39,278	24,067	8,222	24,701
2006	218,031	76,186	72,005	99,877	68,842	43,689	37,098	13,129	23,115
2007	125,077	76,472	39,997	87,770	29,766	44,185	34,221	6,648	13,003
2008	128,445	61,152	37,434	53,880	126,700	54,279	26,202	5,651	15,942
2009	117,530	46,095	69,418	43,007	115,559	55,921	36,865	5,332	13,144
2010	93,677	NA	NA	32,999	NA	NA	NA	NA	NA

Table A1. Chinook total run sizes by river system, 1966-2010

Year	Gray's Harbor	Harrison	Fraser	Yukon	Kuskokwim
1966	NA	NA	NA	NA	NA
1967	NA	NA	NA	NA	NA
1968	NA	NA	NA	NA	NA
1969	NA	NA	NA	NA	NA
1970	NA	NA	NA	NA	NA
1971	NA	NA	NA	NA	NA
1972	NA	NA	NA	NA	NA
1973	NA	NA	NA	NA	NA
1974	NA	NA	NA	NA	NA
1975	NA	NA	NA	NA	NA
1976	6,852	NA	NA	NA	200,000
1977	10,086	NA	NA	NA	210,000
1978	7,919	NA	NA	NA	250,000
1979	10,869	NA	NA	NA	230,000
1980	17,067	NA	NA	NA	220,000
1981	10,581	NA	NA	NA	310,000
1982	9,886	NA	NA	NA	210,000
1983	8,473	NA	NA	NA	160,000
1984	23,888	131,740	227,421	NA	180,000
1985	14,225	181,367	303,308	NA	180,000
1986	25,139	177,662	322,279	NA	160,000
1987	35,114	81,799	210,498	NA	250,000
1988	42,811	38,285	167,872	NA	250,000
1989	57,787	76,294	183,137	NA	280,000
1990	40,606	180,837	315,961	NA	300,000
1991	34,569	93,363	209,918	NA	240,000
1992	34,813	132,042	262,291	NA	280,000

Table A1. Chinook total run sizes by river system, 1966-2010

Year	Gray's Harbor	Harrison	Fraser	Yukon	Kuskokwim
1993	31,513	120,600	230,837	NA	340,000
1994	32,468	100,839	246,142	NA	470,000
1995	34,067	29,840	164,318	NA	420,000
1996	39,102	38,568	224,127	NA	330,000
1997	35,927	72,061	274,856	NA	370,000
1998	23,390	189,103	358,436	NA	260,000
1999	14,865	107,884	248,823	NA	190,000
2000	18,595	78,098	233,307	144,173	180,000
2001	22,405	74,419	251,427	392,000	260,000
2002	19,787	91,122	312,142	243,443	240,000
2003	24,945	251,453	483,142	372,697	260,000
2004	48,690	138,890	333,330	311,377	430,000
2005	26,365	92,993	265,274	NA	370,000
2006	27,230	52,798	295,676	NA	380,000
2007	17,976	83,445	220,651	NA	270,000
2008	19,149	43,798	231,389	NA	240,000
2009	14,493	75,550	248,408	NA	210,000
2010	NA	NA	NA	NA	140,000

Data Sources
Nushagak: Buck et al. 2012, pg. 20; Kenai: Begich and Pawluk 2010, pg. 69; Yukon, Canadian mainstem: Howard et al. 2009, pg. 35; Copper: Pers. comm. Steve Moffitt, ADF&G; Taku: McPherson et al. 2010, pg. 14. 2008/2009 data are preliminary pers. comm. Ed Jones, ADF&G; Skeena: PSC 2011, pg. 87; Nass: PSC 2011, pg. 87; Nehalem: PSC 2011, pg. 93; Skagit: PSC 2011, pg. 89; Gray's Harbor: PSC 2011, pg. 90; Harrison: PSC 2011, pg. 88; Fraser: PSC 2011, pg. 88; Yukon: Spencer et al. 2009, pg. 28; Kuskokwim: Pers. comm. Kevin Schaberg, ADF&G

Table A2. Sockeye total run sizes by river system, 1956-2010

Year	Ugashik	Egegik	Naknek	Alagnak	Kvichak	Nushagak	Wood	Igushik
1956	779,000	2,324,000	3,155,000	1,282,000	13,800,000	106,788	1,494,000	903,000
1957	940,000	2,044,000	2,588,000	474,000	10,711,000	262,805	945,000	440,000
1958	776,702	812,799	603,781	206,930	1,180,705	543,003	1,744,000	276,000
1959	678,064	1,827,157	3,403,474	1,295,000	1,004,118	113,107	3,668,000	995,000
1960	3,377,000	3,600,000	2,095,000	2,289,000	24,942,000	237,544	2,124,466	1,177,000
1961	960,000	4,600,000	1,865,815	509,000	14,279,000	185,798	957,144	632,000
1962	559,409	1,878,432	1,277,933	150,000	4,961,330	114,209	2,438,322	107,024
1963	673,000	1,981,649	1,786,728	368,227	657,349	452,272	1,460,090	212,000
1964	1,101,179	2,056,111	2,685,504	554,998	1,801,221	244,344	2,263,164	338,000
1965	2,236,533	5,344,000	2,270,357	506,729	47,657,000	513,460	1,468,609	410,000
1966	1,315,949	3,331,241	2,418,111	354,000	9,064,868	402,292	2,310,435	470,000
1967	449,557	1,908,340	1,372,352	298,956	5,577,403	114,332	1,017,456	563,134
1968	179,413	1,195,917	2,119,324	302,531	3,471,140	290,366	1,357,407	398,190
1969	372,879	2,273,888	2,623,702	329,748	13,472,862	197,135	1,218,238	1,114,000
1970	1,030,000	2,660,244	2,011,095	479,019	34,599,600	885,640	2,169,211	754,083
1971	1,790,000	2,282,819	3,247,238	599,080	6,948,068	662,007	1,912,659	529,000
1972	129,031	1,884,000	1,810,000	235,000	1,763,000	99,603	935,000	161,000
1973	60,108	788,940	724,941	53,833	336,241	428,733	716,226	133,000
1974	65,801	1,530,000	1,728,781	236,681	4,761,892	240,197	2,211,000	471,000
1975	464,000	2,365,792	3,804,529	128,700	15,359,808	1,071,353	1,836,317	365,000
1976	594,000	2,031,920	2,619,548	152,000	3,789,238	1,079,065	1,602,770	388,000
1977	325,175	2,714,435	2,744,790	177,471	2,266,442	946,903	928,878	164,000
1978	95,380	2,230,099	2,005,239	1,178,690	8,266,273	1,482,163	4,294,726	1,145,339
1979	2,158,312	3,385,860	2,292,995	1,562,870	25,297,982	930,285	3,775,140	1,910,000
1980	4,469,800	3,921,579	5,027,516	1,594,128	37,695,437	5,343,159	4,760,312	3,276,190
1981	3,705,000	5,430,399	7,913,237	862,018	7,489,183	3,764,287	4,926,000	2,410,000
1982	2,603,342	3,919,251	4,226,271	2,173,398	3,328,986	2,889,822	3,864,630	2,029,000
1983	4,565,269	8,024,339	5,754,315	1,531,412	20,983,178	2,073,502	4,484,000	853,000

Table A2. Sockeye total run sizes by river system, 1956-2010

Year	Ugashik	Egegik	Naknek	Alagnak	Kvichak	Nushagak	Wood	Igushik
1984	4,093,955	6,623,390	3,056,116	1,522,640	23,907,123	1,421,706	2,076,000	455,000
1985	7,874,523	9,093,576	3,912,742	733,068	14,061,000	963,888	1,693,723	489,000
1986	6,216,732	6,173,448	4,069,000	1,086,130	2,025,616	2,267,373	1,822,225	908,000
1987	2,925,832	6,884,561	2,485,316	811,320	9,839,116	1,794,967	2,917,462	644,000
1988	2,256,139	8,369,057	1,796,819	872,367	6,940,540	1,093,735	1,793,902	414,000
1989	5,049,283	10,983,145	3,303,641	1,456,693	20,548,328	1,260,160	2,601,691	1,253,000
1990	2,982,276	12,931,258	8,678,358	1,517,000	17,988,530	1,797,229	2,687,000	1,317,000
1991	5,628,282	9,938,166	10,285,831	1,652,944	8,329,970	1,800,480	3,424,694	2,515,000
1992	5,831,999	18,614,125	5,327,022	1,349,052	10,969,638	1,898,491	2,570,505	830,000
1993	5,912,214	24,481,560	4,905,051	2,257,321	9,901,170	2,330,448	3,937,623	1,663,194
1994	5,605,405	12,998,886	3,144,067	1,733,796	22,734,248	1,618,150	3,111,885	1,379,000
1995	6,040,271	16,200,980	3,700,788	1,780,054	28,329,704	792,229	4,191,376	1,991,000
1996	5,237,819	12,253,942	7,076,342	1,916,634	3,538,945	1,804,324	5,160,000	1,514,000
1997	2,239,051	9,362,876	1,515,318	680,123	1,826,856	929,880	3,629,898	314,000
1998	1,794,126	5,060,215	2,784,308	1,072,721	3,550,243	1,022,443	4,101,957	602,074
1999	4,058,177	9,407,420	3,970,846	2,841,755	13,309,000	991,826	6,160,000	1,626,000
2000	2,301,000	8,403,612	4,935,000	2,014,897	3,031,000	1,528,923	5,545,000	1,812,000
2001	1,356,716	4,323,287	6,682,794	1,106,728	1,436,000	2,126,175	4,013,792	1,325,000
2002	2,563,977	5,839,236	2,775,032	793,470	727,186	663,000	3,841,698	213,000
2003	2,584,062	3,503,084	5,182,926	3,790,173	1,750,361	2,273,000	5,743,906	1,036,071
2004	4,160,179	12,865,161	3,948,000	6,667,385	7,902,000	2,227,000	5,948,000	523,000
2005	3,093,169	9,553,946	8,059,330	5,436,640	2,924,275	3,567,000	4,607,385	2,089,000
2006	3,507,652	9,066,558	5,503,654	2,866,000	5,882,074	3,308,000	11,304,221	1,466,000
2007	7,897,526	8,209,756	9,047,000	4,430,633	4,381,000	2,670,000	6,755,813	1,826,000
2008	3,053,322	9,027,266	6,518,196	6,157,000	5,869,320	1,713,315	5,456,186	3,433,000
2009	4,033,383	13,039,645	4,870,271	2,699,010	5,723,862	1,983,000	7,402,102	953,000
2010	4,960,291	6,119,472	5,908,135	2,660,659	9,503,000	2,194,032	7,851,845	1,391,576

Table A2. Sockeye total run sizes by river system, 1956-2010

Year	Togiak	Kenai	Copper, wild fish	Fraser
1956	331,000	NA	NA	2,866,977
1957	108,066	NA	NA	5,401,219
1958	118,000	NA	NA	18,778,820
1959	310,000	NA	NA	4,769,576
1960	338,000	NA	NA	3,421,281
1961	421,520	NA	860,258	4,713,837
1962	174,191	NA	1,112,218	3,512,304
1963	352,000	NA	664,596	3,985,486
1964	367,058	NA	949,861	1,824,500
1965	391,000	NA	1,208,709	3,166,871
1966	338,000	NA	1,402,430	5,459,849
1967	171,109	NA	850,993	6,803,585
1968	135,086	NA	829,329	2,955,662
1969	306,027	NA	1,258,136	4,941,025
1970	425,000	NA	1,492,530	6,163,676
1971	484,000	NA	1,250,648	7,696,359
1972	175,000	831,241	1,168,448	3,708,113
1973	270,000	920,826	668,670	6,878,291
1974	238,000	435,344	869,756	8,616,165
1975	407,392	485,352	538,743	3,683,576
1976	546,000	1,374,607	1,161,149	4,340,815
1977	401,000	2,268,568	1,047,326	5,887,114
1978	770,000	2,096,341	502,359	9,420,144
1979	614,000	797,838	618,538	6,358,912
1980	1,173,000	1,495,962	651,014	3,133,187
1981	999,000	1,184,445	1,297,758	7,741,247
1982	972,230	2,766,912	1,883,434	13,985,095
1983	784,000	3,982,112	1,395,556	5,240,936

Table A2. Sockeye total run sizes by river system, 1956-2010

Year	Togiak	Kenai	Copper, wild fish	Fraser
1984	383,000	1,287,187	1,821,370	5,919,324
1985	306,198	2,498,144	1,600,390	13,878,493
1986	405,215	2,955,276	1,329,070	15,927,438
1987	574,000	9,425,518	1,721,153	7,680,095
1988	1,001,000	6,094,157	985,913	3,773,551
1989	178,117	6,662,137	1,435,481	18,594,484
1990	342,000	3,290,388	1,459,380	21,985,937
1991	805,000	2,226,730	1,766,134	12,390,664
1992	863,250	8,273,968	1,537,006	6,442,239
1993	697,000	4,451,954	2,039,851	23,630,664
1994	520,207	3,908,776	1,839,406	17,284,640
1995	771,000	2,658,341	1,778,450	4,020,414
1996	585,349	3,743,751	2,888,442	4,520,445
1997	264,239	4,650,889	3,820,171	16,351,769
1998	312,646	1,953,963	1,661,543	10,873,000
1999	565,258	3,018,164	1,568,335	3,643,000
2000	1,127,000	1,842,904	1,206,275	5,217,000
2001	1,436,000	2,214,605	2,000,609	7,213,000
2002	406,000	3,511,797	1,774,724	15,137,000
2003	897,000	4,447,000	1,839,605	4,873,502
2004	508,000	5,716,924	1,739,197	4,184,200
2005	580,171	6,117,166	2,060,867	7,077,100
2006	905,450	2,835,742	2,305,355	12,981,200
2007	1,066,000	3,592,167	2,828,457	1,510,600
2008	891,541	2,065,205	1,051,154	1,755,355
2009	854,568	2,440,138	1,583,006	1,505,096
2010	741,211	3,595,867	1,248,019	29,005,410

Table A2. Sockeye total run sizes by river system, 1956-2010

Data Sources: Ugashik, Egegik, Naknek, Alagnak, Kvichak, Nushagak, Wood, Igushik, and Togiak rivers, pers. comm. Tim Baker, ADF&G; Kenai River, pers. comm. Pat Shields, ADF&G; Copper River, pers. comm. Jeremy Botz, ADF&G; Fraser River, pers. comm. Catherine Michielsens, PSC.

Table A3. Sockeye total run sizes by region, 1956-2005.

Year	Bristol Bay	Russia Mainland and Islands	West Kamchatka	East Kamchatka	Western Alaska (excluding Bristol Bay)	South Alaska Peninsula	Kodiak	Cook Inlet	Prince William Sound
1956	24,174,788	312,723	5,568,959	3,508,292	2,921,799	1,439,813	1,036,251	2,107,703	1,357,869
1957	18,512,871	1,212,664	10,172,076	4,146,156	1,651,132	823,438	976,164	1,272,942	1,219,564
1958	6,261,920	442,975	6,286,252	6,080,691	1,477,590	654,585	1,064,076	1,026,900	795,032
1959	13,293,920	391,364	5,046,656	5,879,205	1,713,792	837,418	1,134,597	1,227,947	767,304
1960	40,180,010	439,229	5,520,707	6,741,619	1,649,156	1,301,201	1,189,167	1,663,849	921,272
1961	24,410,277	441,422	8,884,293	2,865,949	1,284,695	728,145	1,265,417	1,982,278	1,246,740
1962	11,660,850	402,798	8,304,347	2,940,810	1,236,964	856,552	1,870,103	1,962,984	1,446,375
1963	7,943,315	343,339	5,294,022	4,291,282	1,080,004	936,188	1,263,847	1,690,524	965,103
1964	11,411,579	238,866	1,681,381	5,400,484	1,281,320	918,361	1,415,449	1,727,099	1,413,881
1965	60,797,688	293,827	3,616,954	4,299,788	879,413	1,136,937	1,161,768	2,304,205	1,631,195
1966	20,004,896	279,251	2,496,149	5,651,091	1,100,324	816,878	1,630,675	2,849,643	1,867,747
1967	11,472,639	362,571	3,438,364	7,534,661	1,197,823	1,022,036	1,098,764	2,263,184	1,119,440
1968	9,449,374	297,307	952,912	7,347,250	1,017,865	1,771,470	1,832,648	1,906,856	1,334,651
1969	21,908,479	249,157	705,033	6,672,415	1,459,903	997,774	1,566,384	1,341,961	1,728,312
1970	45,013,892	245,200	1,051,653	6,377,430	1,028,643	2,477,613	2,071,227	1,399,803	2,007,971
1971	18,454,871	221,785	1,908,446	4,283,328	1,224,259	2,224,301	1,382,529	1,262,215	1,362,728
1972	7,191,634	201,509	1,708,238	3,917,303	1,025,402	996,272	957,567	1,604,503	1,671,399
1973	3,512,022	202,599	1,266,604	4,389,459	877,777	1,745,569	880,634	1,310,905	986,426
1974	11,483,352	538,427	2,914,942	1,096,312	1,184,430	1,515,481	1,283,380	1,056,869	1,361,911
1975	25,802,891	185,335	1,315,733	3,858,358	1,171,178	1,048,430	854,537	1,331,877	1,092,387
1976	12,802,541	180,082	1,556,672	3,470,759	1,587,266	2,219,569	1,586,702	2,619,311	1,713,575
1977	10,669,094	177,717	412,752	2,648,024	1,469,757	3,082,269	1,645,986	3,194,737	1,629,798
1978	21,467,909	188,339	936,931	3,596,414	2,695,103	2,547,058	1,925,502	3,250,421	1,026,705
1979	41,927,444	256,120	835,766	3,328,120	4,264,190	1,855,669	1,745,390	1,626,406	798,885
1980	67,261,121	192,795	1,353,186	3,221,802	3,261,091	1,534,564	2,235,004	2,485,427	553,557
1981	37,499,124	175,829	1,641,425	2,910,208	3,764,080	3,009,576	1,977,914	2,266,861	1,396,065

Table A3. Sockeye total run sizes by region, 1956-2005.

Year	Bristol Bay	Russia Mainland and Islands	West Kamchatka	East Kamchatka	Western Alaska (excluding Bristol Bay)	South Alaska Peninsula	Kodiak	Cook Inlet	Prince William Sound
1982	26,006,930	256,135	1,317,999	2,495,343	1,960,326	2,647,192	2,304,607	4,058,186	3,298,288
1983	49,053,015	272,271	1,363,540	3,255,333	2,962,209	3,289,732	1,994,142	5,983,442	1,544,252
1984	43,538,930	188,414	1,853,895	2,869,830	2,854,259	4,463,088	3,164,169	3,023,601	2,058,228
1985	39,127,718	129,556	3,456,410	2,266,824	5,074,028	1,879,199	4,325,529	4,911,883	2,224,415
1986	24,973,739	177,623	2,993,349	2,088,398	3,648,527	2,750,217	4,020,270	5,195,708	1,999,005
1987	28,876,574	173,853	4,388,792	2,244,085	1,881,441	3,234,737	1,573,040	10,612,907	2,503,899
1988	24,537,559	134,865	2,961,712	1,735,950	2,428,248	1,577,614	5,179,735	7,981,926	591,622
1989	46,634,058	162,907	3,929,794	1,614,359	2,984,749	2,239,029	2,465,794	6,653,855	1,196,514
1990	50,240,651	131,959	6,533,656	683,440	4,066,861	3,209,313	7,291,759	3,791,787	672,793
1991	44,380,367	278,341	6,654,665	716,325	4,709,511	3,506,006	8,376,886	2,341,570	1,737,506
1992	48,254,082	290,791	5,946,498	2,171,680	4,550,924	2,376,718	3,727,396	9,803,503	2,109,967
1993	56,085,581	414,830	6,867,277	3,721,809	5,252,589	2,946,843	1,977,835	5,525,342	2,269,986
1994	52,845,644	330,884	6,052,779	3,184,687	4,707,327	3,067,554	2,732,833	4,823,347	1,925,999
1995	63,797,402	547,226	5,142,880	5,342,393	5,231,199	2,921,709	6,683,435	3,916,052	1,917,252
1996	39,087,355	578,622	5,416,529	5,181,509	3,904,663	3,148,403	6,366,442	4,828,498	3,031,366
1997	20,762,241	273,153	3,623,111	4,525,486	3,327,626	1,613,997	4,081,554	5,623,149	3,734,337
1998	20,300,733	186,020	4,216,452	3,350,431	2,342,865	1,928,313	4,297,254	2,240,231	1,653,216
1999	42,930,282	314,421	4,198,803	4,688,991	3,551,763	4,462,260	6,441,216	3,448,544	2,340,818
2000	30,698,432	402,372	5,731,743	3,228,330	3,417,071	3,054,013	4,468,203	2,071,076	1,640,060
2001	23,806,492	458,915	4,698,927	3,295,161	2,741,406	3,234,246	4,042,683	2,035,309	2,118,769
2002	17,822,599	254,755	11,373,958	1,969,758	2,750,691	2,357,095	2,842,606	3,058,610	1,877,644
2003	26,760,583	189,284	6,430,409	3,111,533	2,998,568	2,108,670	6,492,011	4,147,632	2,104,632
2004	44,748,725	92,408	6,655,869	2,370,070	3,968,890	1,724,633	5,735,821	5,507,777	2,039,862
2005	39,910,916	681,161	9,281,680	3,082,258	5,282,123	2,045,602	4,370,163	6,028,983	2,162,713

Table A3. Sockeye total run sizes by region, 1956-2005.

Year	Southeast Alaska	North British Columbia	South British Columbia, Washington, and Oregon
1956	1,223,955	2,874,454	3,724,473
1957	1,433,321	1,785,678	5,923,358
1958	1,348,999	3,563,691	22,137,627
1959	1,191,656	2,827,063	5,976,277
1960	787,118	1,505,791	4,497,613
1961	996,105	3,161,029	5,430,221
1962	1,033,237	3,567,790	4,092,561
1963	907,045	3,841,872	4,991,161
1964	1,236,191	4,200,152	2,315,203
1965	1,452,134	2,214,164	3,698,689
1966	1,410,391	1,954,638	6,316,328
1967	1,299,903	3,624,937	8,400,670
1968	1,111,561	6,486,401	3,609,851
1969	1,085,977	2,737,311	5,809,127
1970	893,721	1,270,879	7,194,502
1971	833,222	2,565,992	9,733,215
1972	714,626	2,187,271	4,565,063
1973	907,999	6,614,542	8,336,516
1974	1,010,069	2,691,442	10,137,727
1975	924,210	2,341,434	4,472,874
1976	1,638,128	2,592,622	5,296,487
1977	2,040,197	3,045,063	8,025,282
1978	1,480,429	2,612,221	10,353,993
1979	1,927,777	2,414,113	8,310,609
1980	1,506,153	5,903,153	5,106,260

Table A3. Sockeye total run sizes by region, 1956-2005.

Year	Southeast Alaska	North British Columbia	South British Columbia, Washington, and Oregon
1981	1,484,281	9,878,197	9,518,792
1982	1,951,773	7,676,011	15,580,715
1983	1,803,879	4,742,841	7,330,812
1984	1,641,315	4,030,945	8,240,361
1985	2,133,525	8,899,568	15,583,867
1986	1,596,155	5,738,111	16,389,443
1987	1,755,611	5,591,872	9,113,405
1988	1,332,203	7,076,794	5,538,086
1989	2,022,589	4,706,414	19,501,105
1990	2,041,318	5,204,017	22,849,561
1991	2,001,214	7,068,326	14,639,516
1992	2,493,953	8,841,375	8,320,825
1993	3,183,080	8,529,952	25,605,669
1994	2,052,188	4,533,119	18,058,968
1995	1,625,062	7,471,188	4,253,526
1996	3,066,710	9,353,278	5,386,660
1997	2,232,489	5,836,899	17,469,309
1998	1,351,217	2,339,626	11,600,660
1999	1,569,562	2,145,620	4,283,929
2000	1,255,042	5,784,376	6,008,081
2001	1,827,078	5,418,729	8,409,348
2002	1,537,801	3,512,452	12,222,016
2003	1,670,133	4,119,532	5,028,196
2004	1,915,752	2,661,373	3,501,674
2005	1,693,703	1,709,492	3,827,344

Table A3. Sockeye total run sizes by region, 1956-2005.

An Assessment of Potential Mining Impacts on Salmon Ecosystems of Bristol Bay, Alaska

Volume 2—Appendices A-D

Appendix B: Non-Salmon Freshwater Fishes of the Nushagak and Kvichak River Drainages

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NON-SALMON FRESHWATER FISHES OF THE NUSHAGAK AND KVICHAK RIVER DRAINAGES

INTRODUCTION

The fresh waters of the Nushagak and Kvichak river drainages in southwest Alaska (Figure 2-3, 2-4 in main assessment report) support diverse fish assemblages that combined total at least 9 families, 17 genera, and 29 species (Table Appendix B-1). An additional six species: Pacific herring *Clupea pallasii*, Pacific cod *Gadus macrocephalus*, saffron cod *Eleginus gracilis,* Pacific staghorn sculpin *Leptocottus armatus*, Arctic flounder *Pleuronectes glacialis,* and starry flounder *Platichthys stellatus* are primarily marine species that venture into the lower reaches of the drainages (Mecklenburg et al. 2002; Morrow 1980b) and are not discussed here. The five species of North American Pacific salmon, keystones of the region's ecological and economic systems, are reviewed in Appendix A of this assessment. Appendix B provides biological, ecological, and human use information for the other 24 species supported by the waters of the Nushagak and Kvichak river drainages.

This appendix is divided in two sections. The *Harvested fish* section describes seven species that are, or have been, targeted by subsistence, sport, and/or commercial fisheries within the fresh waters of the Nushagak and Kvichak river drainages, and that are well distributed across the two drainages. The *Other species* section covers, in less detail, the remaining species that are not major targets of local fisheries or species that are not broadly distributed across the watersheds, but that nonetheless play important ecological roles in the Nushagak and Kvichak river drainages. The relative lack of directed studies limits the information available on the abundance, life history, and ecology of many non-harvested fish species.

HARVESTED FISH

Each of the species described in this section: northern pike, humpback whitefish, rainbow trout, Arctic char, Dolly Varden, lake trout, and Arctic grayling, are distributed across much of both the Nushagak and Kvichak river drainages. Unlike the *obligate anadromous*[1] Pacific salmon populations of the Nushagak and Kvichak river drainages, in which essentially all individuals migrate from natal lakes and streams to the sea to feed and grow, individual fish in these seven species do not need to journey to marine waters to successfully complete their life cycle, although some individuals of certain species (e.g., Dolly Varden and humpback whitefish) may. Also unlike the North American Pacific salmon, individuals in each of these seven species can

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[1] Among migratory fishes, Myers (1949) defined, in part, the following distinct movement patterns:

Diadromous. Fishes which migrate between the sea and fresh water.

Anadromous. Diadromous fishes which spend most of their lives in the sea and migrate to fresh water to breed. [A pattern expressed by many Alaska fishes].

Catadromous. Diadromous fishes which spend most of their lives in fresh water and migrate to the sea to breed. [Not a pattern expressed by Alaska fishes].

Amphidromous. Diadromous fishes whose migration from fresh water to the sea, or vice-versa, is not for the purpose of breeding, but occurs regularly at some other definite stage of the life-cycle. [A pattern expressed by a few primarily marine Alaska fishes (e.g., starry flounder)].

Potamodromous. Fishes whose migrations occur wholly within fresh water. [A pattern expressed by many Alaska fishes].

Table Appendix B-1.Fish species[2,3] reported in the Nushagak and Kvichak river drainages (ADF&G 2012b; Bond and Becker 1963; Burgner et al. 1965; Fall et al. 2006; Krieg et al. 2009; Mecklenburg et al. 2002; Morrow 1980b; Russell 1980).

Scientific/Common Family Name	Common Name	Scientific Name	Principal Migratory Patterns[4]	Relative Abundance	Abundance relative to other Bristol Bay basins
Petromyzontidae/ lampreys	Arctic lamprey	*Lethenteron camtschaticum*[5]	Anadromous	Juveniles common/widespread in sluggish flows where fine sediments accumulate[6]	Unknown, presumably similar
	Alaskan brook lamprey	*L. alaskense*[5]	Nonanadromous		
	Pacific lamprey	*Entosphenus tridentatus*[5]	Anadromous	Rare	Unknown, presumably similar. Not known west of Nushagak drainage
Catostomidae/ suckers	longnose sucker	*Catostomus catostomus*	Nonanadromous	Common in slower flows in larger streams	Unknown, presumably similar
Esocidae/pikes	northern pike	*Esox lucius*	Nonanadromous	Common/widespread in still or sluggish waters	Unknown, presumably similar
Umbridae/ mudminnows	Alaska blackfish	*Dallia pectoralis*	Nonanadromous	Locally common/abundant in still or sluggish waters in flat terrain	Unknown, presumably similar
Osmeridae/smelts	rainbow smelt	*Osmerus mordax*	Anadromous	Seasonally abundant in streams near the coast	Unknown, presumably similar
	pond smelt	*Hypomesus olidus*	Nonanadromous	Locally common in coastal lakes and rivers, Iliamna Lake, inlet spawning streams, and the upper Kvichak River; abundance varies widely interannually	Unknown, presumably similar
	eulachon	*Thaleichthys pacificus*	Anadromous	No or few specific reports; if present, distribution appears limited and abundance low	Unknown, presumably similar
Salmonidae/salmonids	Bering cisco	*Coregonus laurettae*	Nonanadromous and Anadromous[7]	Rare? Very few specific reports	Unknown; perhaps more abundant than elsewhere
	humpback whitefish	*C. pidschian*	Nonanadromous and Anadromous[7]	Common in large upland lakes; locally and seasonally common in large rivers	Unknown; perhaps more abundant than elsewhere
	least cisco	*C. sardinella*	Nonanadromous and Anadromous[7]	Locally common in some lakes (e.g., Lake Clark, morainal lakes near Iliamna Lake); less common in Iliamna Lake and large slow moving rivers such as the Chulitna, Kvichak, and lower Alagnak	Unknown; perhaps more abundant than elsewhere
	pygmy whitefish	*Prosopium coulterii*	Nonanadromous	Locally common in a few upland lakes	Unknown, presumably similar
	round whitefish	*P. cylindraceum*	Nonanadromous	Abundant/widespread throughout larger streams in upland drainages; but not in headwaters or coastal plain	Unknown, presumably similar

-continued-

[2] Does not include primarily marine species that periodically venture into the lower reaches of coastal Bristol Bay streams.

[3] No species listed here has either Federal or State of Alaska special status (e.g., endangered, threatened) except that the State of Alaska has identified Kvichak sockeye salmon as a stock of yield concern (ADF&G 2012c).

[4] **Anadromous**: fishes that spawn in fresh waters and migrate to marine waters to feed; **Nonanadromous**: fishes that spend their entire life in fresh waters, with possible migrations between habitats within a drainage (potamodromous and nonmigratory freshwater fishes); **Nonanadromous and Anadromous**: fish populations in which some individuals have nonanadromous migratory patterns and some have anadromous migratory patterns.

[5] Nomenclature follows Brown et al. (2009).

[6] Juveniles, the most commonly encountered life stage, of Arctic and Alaska brook lamprey are morphologically indistinguishable, so these two species are combined here.

[7] Anadromy known elsewhere in Alaska, but not verified within either the Nushagak or Kvichak river drainages.

Table Appendix B-1.-Page 2 of 2.

Scientific/Common Family Name	Common Name	Scientific Name	Principal Migratory Patterns	Relative Abundance	Abundance relative to other Bristol Bay basins
Salmonidae/salmonids (continued)	coho salmon	*Oncorhynchus kisutch*	Anadromous	Juveniles abundant/widespread in Nushagak drainage upland flowing waters and in some Kvichak R. tributaries downstream of Iliamna Lake; present in some Iliamna Lake tributaries; not recorded in the Lake Clark drainage	More abundant in Nushagak drainage than elsewhere in Bristol Bay, except for the North Alaska Peninsula Basin
	Chinook salmon	*O. tshawytscha*	Anadromous	Juveniles abundant and widespread in upland flowing waters of the Nushagak River watershed and in the Alagnak River; infrequent upstream of Iliamna Lake	More abundant in Nushagak drainage than elsewhere in Bristol Bay
	sockeye salmon	*O. nerka*	Anadromous	Abundant	More abundant than elsewhere, comparable to Egegik basin.
	chum salmon	*O. keta*	Anadromous	Abundant in Nushagak drainage upland flowing waters and in some Kvichak R. tributaries downstream of Iliamna Lake. Infrequent upstream of Iliamna Lake.	More abundant than elsewhere
	pink salmon	*O. gorbuscha*	Anadromous	Abundant, in even years, in Nushagak drainage, with restricted distribution, and in some Kvichak R. tributaries downstream of Iliamna Lake. Rare upstream of Iliamna Lake.	More abundant than elsewhere in even years
	rainbow trout	*O. mykiss*	Nonanadromous[8]	Frequent/common; closely associated during summer with spawning salmon	More abundant/larger body size than much of Bristol Bay
	Arctic char	*Salvelinus alpinus*	Nonanadromous	Locally common in upland lakes	Unknown, presumably similar
	Dolly Varden	*S. malma*	Nonanadromous and Anadromous	Abundant in upland headwaters and selected lakes	Unknown, presumably similar
	lake trout	*S. namaycush*	Nonanadromous	Common in larger upland lakes and seasonally present in lake outlets; absent from the Wood River lakes	Unknown, presumably similar
	Arctic grayling	*Thymallus arcticus*	Nonanadromous	Abundant/widespread	Unknown, presumably similar
Gadidae/cods	burbot	*Lota lota*	Nonanadromous	Infrequent to common in deep, sluggish or still waters	Unknown, presumably similar
Gasterosteidae/ sticklebacks	threespine stickleback	*Gasterosteus aculeatus*	Nonanadromous and Anadromous	Locally abundant in still or sluggish waters; abundant in Iliamna Lake	Unknown, presumably similar
	ninespine stickleback	*Pungitius pungitius*	Nonanadromous	Abundant/widespread in still or sluggish waters	Unknown, presumably similar
Cottidae/sculpins	coastrange sculpin	*Cottus aleuticus*	Nonanadromous	Abundant/widespread[9]	Unknown, presumably similar
	slimy sculpin	*C. cognatus*	Nonanadromous		

[8] In Bristol Bay, anadromous individuals (steelhead) are known to spawn and rear only in the North Alaska Peninsula basin (Figure 2-3).

[9] These two sculpin species are not reliably or frequently distinguished in field collections; slimy sculpin is thought to be the more abundant and widely distributed species (Bond and Becker 1963).

survive to spawn more than once (they are *iteroparous*, Stearns 1992, p. 180) and, compared to salmon, have longer potential life spans (see the following species descriptions).

Northern pike *Esox lucius*

Freshwater distribution and habitats

The Northern pike has a circumpolar distribution across the northern hemisphere and is the only species in the family Esocidae that has colonized arctic waters (Crossman 1978). In North America northern pike inhabit lakes and low gradient rivers from the Arctic Ocean south to the Missouri and Mississippi river drainages, and from the North Atlantic Ocean west to the Rocky Mountains (Scott and Crossman 1998, p. 357). In Alaska, northern pike are native primarily north of the Alaska Range, including waters of the Nushagak and Kvichak river drainages (Mecklenburg et al. 2002, p. 144; Morrow 1980b, p. 168), but were illegally introduced and are now established in several regions south of the Alaska Range, particularly in the Susitna River drainage (Rutz 1999, p. 1). In Bristol Bay, northern pike occur in coastal plain lakes (Hildreth 2008, p. 9), inland lakes (Burgner et al. 1965, p. 4; Dye et al. 2002, p. 1; Russell 1980, p. 87), and river systems (ADF&G 2012) providing suitable habitat. The Nushagak and Nuyakuk river mainstems, Lake Aleknagik, and the Lake Clark drainage (Figure 2-4 in main assessment report) support the largest sport fisheries within the Nushagak and Kvichak river drainages (Jennings et al. 2011, p. 126, 128).

Northern pike primarily spawn in sections of lakes, wetlands, or very low gradient streams providing shallow (less than 1 m), slow or still waters with soft substrates and aquatic vegetation (Cheney 1971d, p. 13; Chihuly 1979, p. 48, 57; Dye et al. 2002, p. 5, 6-7; Russell 1974. p. 42; Rutz 1999, p. 15). Summer habitat is in slightly deeper, but still warm water with dense aquatic vegetation (Chihuly 1979, p. 46, 58; Dye et al. 2002, p. 5; Joy and Burr 2004, p. 22; Roach 1998, p. 3; Rutz 1999, p. 9). In southcentral Alaska’s Susitna River drainage, river-dwelling northern pike are often found in side sloughs where water temperatures are several degrees warmer than the adjacent main channel (Rutz 1999, p. 19). Among the large, deep, cold, glacially-formed lakes of the Nushagak and Kvichak river drainages, shallow, vegetated habitats are scarce, making those found in Lake Clark’s Chulitna Bay and the shallow bays of Lake Aleknagik particularly important northern pike concentration areas (Chihuly 1979, p. 48; Dye et al. 2002, p. 6-7; Russell 1980, p. 91).

Northern pike overwinter in lakes, spring-fed rivers, or larger deep rivers where there is likely to be sufficient water and oxygen to survive until spring (Dye et al. 2002, p. 5; Roach 1998, p. 18-21; Scanlon 2009, p. 17; Taube and Lubinski 1996, p. 5-8). Water depth beneath winter ice may be 0.8 m or less (Taube and Lubinski 1996, p. 8). In winter, local residents ice fish for northern pike along the large rivers of the Nushagak and Kvichak river drainages (Krieg et al. 2009, p. 135, 220, 215, 344).

Life cycle

At spring ice-out in Lake Aleknagik, in the Nushagak River drainage, large fish are in water 1 to 1.5 m deep and within 10 m of shore. In late May to mid-June, as water temperatures rise to about 6 °C, mature fish move inshore to spawn in brush and aquatic vegetation (Dye et al. 2002. p. 5). Female northern pike can produce over 100,000 adhesive 3-mm diameter ova, which they scatter in small batches among aquatic vegetation or rocks, while an attending male fertilizes them. Neither females nor males construct redds (Morrow 1980b, p. 166-167; Scott and Crossman 1998, p. 359). After spawning, as Lake Aleknagik water temperatures rise above 8 °C, fish move slightly offshore, to 1 to 3 m of water, but remain in the bays where they spawned, moving little for the remainder of the summer (Dye et al. 2002, p. 5). As water levels and temperatures drop in mid-September through October, fish move out of shallow bays to depths of 3 to 5 m in the main lake and then move little until the following spring (Dye et al. 2002, p. 5).

Mature northern pike living in Alaska river systems and river-lake complexes ascend tributaries in spring, beneath the ice. Spawning occurs from mid-May to early July as ice melts in side-channel slack waters or lake margins. After spawning, mature pike move to deeper water to feed, where they remain until moving in September and October to lakes, spring-fed streams, and larger, deeper rivers where they overwinter (Cheney 1971d, p. 13-14; Cheney 1972, p. 5; Chythlook and Burr 2002, p. 13; Kepler 1973, p. 75; Russell 1980, p. 91; Taube and Lubinski 1996, p. 6-8).

Northern pike eggs hatch in less than a month. At hatching, fry are 6 to 9 mm long, and have a yolk sac, but no mouth. Before they start actively feeding, fry cling to the substrate, debris, or vegetation for around 10 days, absorbing their yolk sacs while their mouths develop (Morrow 1980b, p. 167; Scott and Crossman 1998, p. 359). In Nushagak and Kvichak river drainage lakes, young-of-the-year northern pike are actively swimming by at least late June to early July and grow rapidly through the summer (Chihuly 1979, p. 32, 34; Russell 1980, p. 91, 93). In river systems, fry remain near or downstream of spawning areas (Cheney 1971d, p. 13). In interior Alaska, age-0 fish reach a mean length of 140 mm by September (Cheney 1972, p. 15). In Lake Aleknagik, northern pike grow rapidly to about age 4 and a total length of around 419 mm, then growth slows to about an average of 25 mm per year (Chihuly 1979, p. 27-28, 33). Some male northern pike in Lake Aleknagik mature at age 3, and by around age 5 and lengths of approximately 438 to 469 mm, all fish are mature (Chihuly 1979, p. 34).

Many mature northern pike do not travel far (Chihuly 1979, p. 64; Dye et al. 2002, p. 5; Joy and Burr 2004, p. 25; Rutz 1999, p. 8), but some river-system individuals make extensive seasonal migrations between spawning, feeding, and overwintering areas (Scanlon 2009, p. 11), sometimes moving at least 290 km per year (180 mi per year, Cheney 1971a, p. 7). Mature northern pike may disperse through the summer and then aggregate prior to moving to overwintering locations and while overwintering (Roach 1998, p. 14). Mature northern pike show high fidelity to spawning (Joy and Burr 2004, p. 29; Roach 1998, p. 13) and winter areas (Scanlon 2009, p. 20; Taube and Lubinski 1996, p. 8) and moderate fidelity to summer feeding areas (Taube and Lubinski 1996, p. 8). Because fish must exceed a minimum size before they can be successfully tracked with standard telemetry methods, most movement studies are limited to bigger individuals and seasonal movements of immature Alaska northern pike are largely unknown.

Mature females often tend to be larger than males of the same age (Clark et al. 1988, p. 22, 25; Pearse 1991, p. 36; Rutz 1999, p. 9), but males appear to have a greater mortality rate (Cheney 1971c, p. 17; Chihuly 1979, p. 26; Pearse 1991, p. 36). In the Nushagak and Kvichak river drainages, northern pike can reach total lengths of at least 1.04 m, weights in excess of 7 kg, and ages of 18 years (Chihuly 1979, p. 33, 37; Dye et al. 2002, p. 6; Russell 1980, p. 92, 93). In the

Yukon River drainage, fish can reach 1.2 m in length (Scanlon 2009, p. 20), and 26 years in age (Cheney 1971c, p. 15).

Predator–prey relationships

Northern pike are highly adaptable predators able to consume a wide range of invertebrates and vertebrates, but they are particularly efficient consumers of fish (Craig 2008). Where they are available, a wide variety of fish dominate the diet of larger Nushagak and Kvichak river drainages northern pike, including Alaska blackfish, round whitefish, least cisco, smaller northern pike, ninespine and threespine stickleback, juvenile sockeye salmon, Arctic char, pygmy whitefish, sculpins, longnose suckers, and lake trout (Chihuly 1979, p. 79-86; Russell 1980, p. 95-97). The diet of larger northern pike illegally introduced into southcentral Alaska's Susitna River drainage was dominated by coho and sockeye salmon, whitefish species, stickleback species, and rainbow trout (Rutz 1999, p. 17). Immediately after hatching, young-of-the-year fry eat zooplankton and immature aquatic insects, but quickly transition to small sticklebacks and other small fish (Chihuly 1979, p. 85-88; Morrow 1980b, p. 167). Northern pike smaller than 200 mm feed substantially on invertebrates; fish over 400 mm eat invertebrates (e.g., crustaceans, leeches, beetle larvae, and mollusks, Russell 1980, p. 95-97) only incidentally (Cheney 1972, p. 29; Chihuly 1979, p. 79-88). Northern pike diets are adaptable and can include a wide variety of foods in the absence of fish prey, although growth rates are then lower (Cheney 1971b, p. 23). Northern pike are keystone predators and often the greatest predator of northern pike are larger northern pike (Cheney 1972, p. 27; Chihuly 1979, p. 82; Craig 2008).

Abundance and harvest

Total abundance of northern pike in the Nushagak and Kvichak river drainages is unknown. Dye et al. (2002, p. 6) estimated that in 1998 and 1999, the abundance of northern pike longer than 299 mm in Lake Aleknagik was more than 11,580. Chulitna Bay on Lake Clark has supported a large subsistence fishery; in June 1978 an estimated 350 to 500 large northern pike were harvested from Turner Bay at the head of Chulitna Bay (Russell 1980, p. 91). In the mid-2000s, residents in ten of the Nushagak and Kvichak river drainage villages annually harvested an estimated 4,385 northern pike (Fall et al. 2006, p. 45, 80, 113, 150, 194; Krieg et al. 2009, p. 40, 78, 118, 162, 202), and they were the most important non-salmon fish in four of those villages (Fall et al. 2006, p. 152; Krieg et al. 2009, p. 46, 124, 171). From the mid-1970s to the mid-2000s, northern pike were estimated to represent between 9.9 and 14.1% of the total weight of the Kvichak River drainage non-salmon freshwater fish subsistence harvest (Krieg et al. 2005, p. 214). In 2009, sport anglers caught an estimated 8,217 northern pike in the Nushagak and Kvichak river drainages and the adjacent Togiak River (Figure 2-3 in main assessment report) drainage (10% of the statewide total) and harvested (kept) an estimated 1,177 (6% of the statewide total; Jennings et al. 2011, p. 75). Annual sport harvests have declined, due at least in part to both lower bag limits and the increasing popularity of catch-and-release fishing (Dye and Schwanke 2009, p. 6). In 1966 and 1967, an experimental freshwater commercial fishery on Tikchik Lake harvested 316 northern pike, the third-most commonly harvested fish (6% of total number of fish harvested; Yanagawa 1967, p. 10).

Stressors

Because northern pike are long-lived, have a piscivorous diet, and prefer relatively warm water, they bioaccumulate and biomagnify atmospherically deposited mercury, and tissue mercury concentrations correlate strongly with length and age (Headlee 1996; Mueller et al. 1996, p. 36). Lindesjöö and Thulin (1992) reported that wild northern pike exposed to pulp mill effluents developed severe jaw deformities. They did not determine if the deformities were directly caused by constituents of the effluents, if the deformities resulted from a secondary reduction of dissolved oxygen (DO) levels, or through some other mechanism. Northern pike are highly tolerant of low DO levels. In laboratory experiments, juvenile northern pike survived DO levels down to at least 0.25 $mg \cdot l^{-1}$ (Petrosky and Magnuson 1973).

Casselman (1978) found that, for a Canadian stock of northern pike, maximum summer growth occurred at 19 °C, growth stopped at 28 °C, and 29.4 °C was the upper incipient lethal temperature. For an Ohio stock, Bevelhimer et al. (1985) reported maximum summer growth occurred at 25 °C and that northern pike continued to grow at 30 °C. Combined, these results suggest a possible latitudinal cline in temperature tolerances and optimal and lethal temperatures for Nushagak and Kvichak river drainages northern pike may be lower than those reported by Casselman (1978).

Humpback whitefish *Coregonus pidschian*

The taxonomic status of humpback whitefish remains unsettled. Some sources (e.g., Mecklenburg et al. 2002, p. 180; Morrow 1980b, p. 24) distinguish three separate Alaska whitefish species (lake *C. clupeaformis,* Alaska *C. nelsonii, and* humpback *C. pidschian*) based on gill raker counts; other authors (e.g., Alt 1979; Brown 2006, p. 2; McDermid et al. 2007) consider them a single variable species (the *C. clupeaformis* complex). This appendix treats the three forms synonymously. In addition, Bernatchez and Dodson (1994) suggest that this species should be considered synonymous with the European whitefish *C. lavaretus*.

Freshwater distribution and habitats

In combination with the European whitefish, the humpback whitefish has a circumpolar distribution across the northern hemisphere (Bernatchez and Dodson 1994). In North America, the humpback whitefish freshwater range extends from the Arctic Ocean coastal plain south to near Canada's southern border, and from the Atlantic seaboard to the Bering Strait (Scott and Crossman 1998, p. 271). Humpback whitefish are found in lakes, streams, and brackish water across much of Alaska, primarily north of the Alaska Range (Alt 1979; Mecklenburg et al. 2002, p. 186-188). In the Nushagak and Kvichak river drainages, humpback whitefish are reported in deeper lakes, mainstem rivers, and slow-flowing tributaries (ADF&G 2012; Burgner et al. 1965, p. 4, 5; Fall et al. 2006, p. 321, 337, 354, 381; Krieg et al. 2009, p. 301, 318, 339, 365, 370; Metsker 1967, p. 6; Russell 1980, p. 72-76; Woody and Young 2007, p. 8; Yanagawa 1967, p. 12).

In northwest Ontario, lake spawning sites were found in nearshore areas at average depths of 2.7 to 3.5 m; primarily over boulders, cobbles, and detritus (Anras et al. 1999). In western and interior Alaska, stream spawning sites are in spatially discrete reaches, often glacially-fed, with moderate to high gradients, moderate to swift currents, and gravel substrates (Alt 1979; Brown 2006, p. 25-26; Harper et al. 2009, p. 17; Kepler 1973, p. 71). In interior Alaska's Chatanika River, fish spawn in water 1.3 to 2.6 m deep, flowing at approximately 0.5 $m \cdot s^{-1}$ (Kepler 1973, p. 71).

After spawning, adults migrate downstream to more slowly flowing waters with fine substrates (Brown 2006, p. 26). In Canada's Mackenzie River system, overwintering locations are in deep mainstem channels or delta areas (Reist and Bond 1988). Lakes and sloughs supporting summer feeding aggregations in southcentral and interior Alaska are well connected to mainstem channels, ensuring that feeding fish can reliably enter in spring and exit in late summer during migrations from and to spawning and overwintering areas (ADF&G 1983b, p. G-15; ADF&G 2006, p. 31).

In early August, apparently mature fish were collected in the lower Swan River), about 2 km upstream of the confluence with the Koktuli River (ADF&G 2012, sites FSN0604A02, FSN0604A04), and mature fish were collected at the mouth of Koggiling Creek, at its confluence with the lower Nushagak River (ADF&G 2012, sites FSN0607C08, FSN0607C10). The stomachs of most of the Koggiling Creek fish were empty (Wiedmer *unpublished*). These fish may have recently left summer feeding lakes in the Swan River and Koggiling Creek drainages and were staging before beginning their upstream spawning migration (see Life cycle and Predator-prey discussions below).

In late August, apparently mature and perhaps larger immature fish were collected in small upland lakes draining to the upper North Fork Koktuli River (ADF&G 2012, sites PEB91NK011, PEB91NK019). Whether humpback whitefish overwinter in these lakes is not known. In fall, residents of the Nushagak and Kvichak river drainages harvest humpback whitefish in mainstem rivers, as the whitefish move upstream to spawn. In winter, residents also harvest humpback whitefish in Sixmile and Iliamna lakes, Lake Clark (Figure 2-4 in main assessment report), and mainstem rivers (Fall et al. 2006, p. 39, 200, 289, 321, 337, 354, 381; Krieg et al. 2009, p. 55, 135, 159, 178, 220, 301, 339, 365).

In Alaska, the habitat preferences of juvenile humpback whitefish have been particularly difficult to define (Brown 2004, p. 19; Brown 2006, p. 25, 30; Brown et al. 2002, p. 18). In the lower Mackenzie River, nursery habitats and foraging areas for young-of-the-year are in delta lakes and main delta channels (Chang-Kue and Jessop 1992, p. 27). No young-of-the-year were found in main-channel rivers and streams in the Nushagak River drainage in August 2006 (ADF&G 2012), suggesting either a year-class failure (Bogdanov et al. 1992) or that they were occupying off-channel habitats. In Lake Clark and adjacent lakes, juveniles were captured mostly in shallow (less than 3 m) nearshore areas, while larger fish were more broadly distributed (Woody and Young 2007, p. 8).

Life cycle

North of the Nushagak and Kvichak river drainages, some humpback whitefish populations include anadromous individuals, but the proportion of anadromous individuals within populations appears to decrease with increasing distance from marine waters (Brown 2004, p. 17; Brown 2006, p. 14; Harper et al. 2007, p. 11; Sundet and Pechek 1985, p. 34). Within the Nushagak and Kvichak river drainages, limited otolith isotope analyses have yet to reveal evidence for anadromy in fish collected in Lake Clark or the lower Nushagak River (Randy Brown, U. S. Fish and Wildlife Service, Fairbanks, personal communication; Woody and Young 2007, p. 12).

In interior Alaska, large fish feed in lakes until late summer. They then move into mainstem rivers and stay near lake outlets for up to 3 weeks before beginning to migrate upstream to spawning areas in late August to early September. Most adults arrive in the spawning areas by mid-September, and spawning extends from late September to mid-October (Brown 2006, p. 26). Russell (1980, p. 72) reported spawning in late September in Nushagak and Kvichak river drainage lakes. Lake spawning in northwest Ontario occurs at temperatures between 2 and 6 °C, shortly before lake surfaces begin to freeze (Anras et al. 1999). Kepler (1973, p. 71) reported spawning in an interior Alaska stream from mid-September to early October, at temperatures ranging from 0 to 3 °C.

In interior Alaska, males mature at ages 4 to 6; females at ages 5 to 7 (Alt 1979; Brown 2006, p. 28). Fish are reported to mature at lengths of about 310 to 380 mm (FL; Alt 1979; Brown 2004, p. 19; Brown 2006, p. 23; Chang-Kue and Jessop 1992, p. 17; Kepler 1973, p. 71), and age and length at maturity may vary among locations (Alt 1979; Brown 2004, p. 19; Chang-Kue and Jessop 1992, p. 17). Three females from the lower Nushagak River (ADF&G 2012, sites FSN0607C08, FSN0607C10) with fork lengths ranging from 435 to 460 mm were mature, while one 370-mm female was not (Wiedmer *unpublished*). In interior Alaska, females apparently spawn every year (Brown 2006, p. 29). Farther north, at least some females do not spawn every year, although males may (Brown 2004, p. 16, 17).

Humpback whitefish broadcast spawn instead of digging redds; after fertilization their 2- to 3-mm diameter eggs sink and lodge in the interstitial spaces of the substrate (Anras et al. 1999; Morrow 1980b, p. 36, 38; Scott and Crossman 1998, p. 271). Fecundity of interior Alaska humpback whitefish ranges from 8,400 to 65,400 ova for females ranging in length from 320 to 520 mm (Clark and Bernard 1992). The estimated fecundity of three mature females collected in August in the mouth of Koggiling Creek in the Nushagak River drainage (ADF&G 2012, Site FSN0607C10) fell within this range (Wiedmer *unpublished*).

In Siberian rivers, the time from spawning to hatching is about 185 to 190 days and survival from egg to fry appears to vary greatly from year to year (Bogdanov et al. 1992). Larval fish, weighing 4.9 to 6.3 mg, with lengths of 9 to 13 mm, drift downstream immediately after hatching (Bogdanov et al. 1992; Shestakov 1991). Studies in both Norway and Siberia found that these fry still have yolk sacs and do not begin feeding for the first several days of their downstream drift (Næsje et al. 1986; Shestakov 1991). In Siberia's Anadyr River, larvae drift downstream for two to three weeks, from late May to early June (Shestakov 1991; Shestakov 1992). The scale and speed of downstream migrations correlate with increases in river discharge (Bogdanov et al. 1992; Næsje et al. 1986; Shestakov 1991). Russell (1980, p. 72) observed fry in the shallows of Kvichak River drainage lakes by mid-June.

In interior Alaska and northern Canada, immature fish, from age 0 to about age 4, appear to rear far downstream of spawning areas in off-channel sites such as deltas, lakes, and sloughs, or in mainstem eddies (Brown 2006, p. 31; Reist and Bond 1988). Age-0 juveniles in the Anadyr River primarily inhabit lakes that connect to the mainstem during spring high flows (Shestakov 1992). By mid-July, age-0 fish reach 43 mm, with growth faster in floodplain lakes than in streams (Shestakov 1992).

In the Nushagak and Kvichak river drainages, humpback whitefish reach at least age 27 and lengths to 584 mm (Woody and Young 2007, p. 8). Elsewhere, maximum age can be up to 57 years (Power 1978). In interior Alaska, maturing and mature fish show fidelity to both summer feeding (Brown 2006, p. 21; Brown et al. 2002, p. 16; Harper et al. 2007, p. 14; Harper et al. 2009, p. 11, 17), and fall spawning areas, which can be more than 600 km apart (Harper et al. 2007, p. 15; Harper et al. 2009, p, 30).

Predator–prey relationships

Large humpback whitefish from Nushagak and Kvichak river drainage lakes feed predominantly on benthic invertebrates, particularly mollusks, chironomids (non-biting midges), planktonic crustaceans, and caddis fly larvae (Metsker 1967, p. 29; Russell 1980, p. 76), but will apparently feed on salmon eggs and small fry when available (Van Whye and Peck 1968, p. 37; Woody and Young 2007, p. 13). Adults preparing to spawn stop eating earlier than mature non-spawners, and large humpback whitefish feed little during the spawning migration and while overwintering (Brown 2004, p. 21; Brown et al. 2002, p. 16). In lakes, young-of-the-year fry initially feed primarily on planktonic crustaceans (Claramunt et al. 2010; Hoyle et al. 2011). After they reach lengths greater than 40 mm, their diet transitions to benthic macroinvertebrates, particularly chironomids (Claramunt et al. 2010).

Round whitefish and Arctic grayling feed on humpback whitefish eggs (Brown 2006, p. 23; Kepler 1973, p. 71), and other species likely do as well. Humpback whitefish are vulnerable to predation by piscivorous fish, such as lake trout (Van Whye and Peck 1968, p. 37) and in the Nushagak and Kvichak river drainages, northern pike may be important predators (Russell 1980, p. 95).

Abundance and harvest

The total abundance of humpback whitefish in the Nushagak and Kvichak river drainages is not known. The estimated mid-2000s annual subsistence harvests in nine of the villages within the Nushagak and Kvichak river drainages totaled over 4,000 fish (Fall et al. 2006, p. 45, 80, 113, 150, 194; Krieg et al. 2009, p. 40, 78, 118, 162, 202). From the mid-1970s to the mid-2000s, whitefish, the majority of which were humpback whitefish, were estimated to represent between 8.3 to 26.8% of the total weight of the Kvichak River drainage non-salmon freshwater fish subsistence harvest (Krieg et al. 2005, p. 214).

The 2009 estimated sport catch of all whitefish species in the Nushagak and Kvichak river drainages plus the Togiak River drainage was 1,118 fish (11% of the total statewide catch of all whitefish species excluding sheefish *Stenodus leucichthys*), and the estimated harvest was 520 (18% of the total statewide harvest of all whitefish species, excluding sheefish; Jennings et al. 2011, p. 76). In the mid-1960s, Iliamna Lake and Lake Clark supported a commercial humpback whitefish fishery (Metsker 1967, p. 8, 10). In 1966 and 1967, humpback whitefish comprised 62% of the total number of fish harvested in a freshwater commercial fishery on Tikchik Lake (Yanagawa 1967, p. 12).

Stressors

Mature humpback whitefish aggregate in discrete spawning habitats, leaving them at risk to both acute events during fall spawning and chronic changes to spawning habitat (Brown 2006, p. 32).

Extreme high water events shortly before fall spawning may cause adult whitefish to leave spawning areas and delay spawning to another year (Underwood et al. 1998, p. 13). The spawning success of lake-dwelling whitefish is vulnerable to lake level manipulation during the winter incubating period (Anras et al. 1999) and to elevated substrate sedimentation (Fudge and Bodaly 1984). Age-0 fish are vulnerable to low flows in spring, which can prevent access to preferred floodplain lake habitats (Shestakov 1992).

Mature humpback whitefish appear not to feed during spawning migrations or during the winter (Brown 2004, p. 21; Brown et al. 2002, p. 16). Almost all annual feeding occurs in summer, often in off-channel lakes and sloughs. Mature whitefish must have access to and from these off-channel habitats, both in spring to immigrate and in late summer to emigrate (Brown 2006, p. 26; Harper et al. 2007, p. 16).

Fertilized eggs need cold water (optimally around 0.5 °C; Morrow 1980b) during development; eggs incubating in 10 °C waters suffer 99% mortality rates (Scott and Crossman 1998, p. 272). In an experiment mimicking Great Lakes summer conditions, Edsall (1999) found juvenile survival peaked at water temperatures of 10 to 15 °C and declined at lower and warmer temperatures and that juvenile growth peaked at 18.5 °C. For Great Lakes young-of-the-year acclimated to warmer waters, the upper lethal temperature was 26.6 °C (Edsall and Rottiers 1976). Metabolically, whitefish do not swim as efficiently as other salmonids (Bernatchez and Dodson 1985). Swimming performance peaks at around 12 °C and declines at lower temperatures. Bernatchez and Dodson (1985) speculate that the timing of seasonal migrations may be a function of the combined influence of seasonal stream velocities and temperatures. Optimal and lethal temperatures may be lower for Alaska populations.

Rainbow trout *Oncorhynchus mykiss*

Rainbow trout and steelhead are two forms of one species and belong to the same genus (*Oncorhynchus*) as the Pacific salmon. Rainbow trout is the common name for individuals with nonanadromous life histories and steelhead is the common name for individuals with anadromous life histories. Unlike the region's Pacific salmon, southwest Alaska rainbow trout/steelhead are mostly nonanadromous. In Bristol Bay, the Alaska Department of Fish and Game (ADF&G) documents steelhead only in a few spawning streams near Port Moller, in the southwestern portion of the basin, outside the Nushagak and Kvichak river drainages (Johnson and Blanche 2012, Chignik and Port Moller 1:250,000 quadrangles). As no steelhead are known to occur in the fresh waters of the Nushagak and Kvichak river drainages (e.g., Russell 1977, p. 44), they are not discussed further here.

Freshwater distribution and habitats

The native freshwater range of rainbow trout is largely restricted to Pacific Ocean drainages: in North America from Alaska's Kuskokwim River system south to mountain drainages of central Mexico (MacCrimmon 1971, p. 664), and in Asia in the Kamchatka region (Froese and Pauly 2012). Native rainbow trout in Alaska fresh waters are restricted to southwest, southcentral, and southeast Alaska, from the Holitna River region south to Dixon Entrance (Morrow 1980b, p. 78). Rainbow trout have been extensively and successfully transplanted outside their native range, including sites in interior Alaska (MacCrimmon 1971; Morrow 1980b, p. 51). While rainbow trout of the Nushagak and Kvichak river drainages are near the northern limit of their global native range, they are broadly distributed across the Nushagak and Kvichak river drainages, except in Lake Clark and its tributaries (Minard and Dunaway 1991, p. 2; Minard et al. 1998, p. 32), and the Tikchik Lakes system, except for Tikchik Lake itself (Burgner et al. 1965, p. 11; Yanagawa 1967, p. 16-17). They are found in small streams to mainstem rivers and in lakes (ADF&G 2012; Meka et al. 2003).

Rainbow trout typically spawn in flowing water, but can spawn along lake shores, near groundwater upwellings (Northcote and Bull 2007). Rainbow trout in the Naknek River (Figure 2-3 in main assessment report), downstream of several large lakes, spawn in fast water of the mainstem, with much of the spawning occurring in the transition between the upstream confined reach and the downstream unconfined reach (Gwartney 1982, p. 9; Gwartney 1985, p. 47). Females deposit eggs, which are immediately fertilized by males, into excavated redds (Morrow 1980b, p. 51). In Lower Talarik Creek, Russell (1977, p. 9) reported that redds were dug in the gravel of side channels, near the upstream ends of islands, and in pool tails above riffles. Typical water depths at Lower Talarik Creek redd locations were less than 0.6 m and current velocities were 0.3 to 0.6 $m \cdot s^{-1}$. The most suitable sites for rainbow trout spawning in southcentral Alaska's Copper River system had water temperatures ranging from 2 to 9 °C, average depths ranging from 0.3 to 0.4 m, average current velocities of 0.5 to 0.7 $m \cdot s^{-1}$, and substrate diameters ranging from 20 to 60 mm (Brink 1995, p.71-75). In northern Idaho, rainbow trout spawned after the peak of spring snowmelt, and redds had a mean area of 1.19 m^2 (standard deviation (SD) = 0.62; range = 0.27 to 2.40 m^2), a mean water depth at the pit head of 0.18 m (SD = 0.08; range = 0.05 to 0.38 m), and a mean water velocity at the pit head of 0.39 $m \cdot s^{-1}$ (SD = 0.15; range = 0.08 to 0.67 $m \cdot s^{-1}$) (Holecek and Walters 2007). Steelhead in Alaska's Copper River, the size of large Nushagak and Kvichak river drainages rainbow trout, dug redds averaging 3.4 m^2 in area (Brink 1995, p. 125).

As the only spring-spawning member of its genus in the Nushagak and Kvichak river drainages, with eggs hatching later in the summer than other Bristol Bay freshwater fish, young-of-the-year rainbow trout have a very short time to complete incubation and initial growth before the onset of winter. Therefore, spawning and early rearing habitats may be limited to locations with warmer summer temperatures and abundant food, as fry size in late fall is positively related to winter survival (Smith and Griffith 1994). Spawning areas in southcentral Alaska's Susitna and Copper river tributaries are often near lake outlets, presumably because of warmer water there (Brink 1995, p. 16-18, 99; Sundet and Pechek 1985, p. 37). Spawning begins in spring when Lower Talarik Creek water temperatures reach 2 to 3 °C, peaks at 4 to 7 °C, and stops at temperatures greater than 16 °C (Russell 1977, p. 12).

In streams, rainbow trout summer rearing density increases with pool depth and overhead cover (Bryant and Woodsmith 2009; Nakano and Kaeiryama 1995). Winter rearing density increases with increasing availability of multiple cover types (Bjornn and Reiser 1991, p. 135). In summer in southeast Alaska, rearing juveniles leave small tributaries and are relatively more abundant in larger streams ($\geq 3^{rd}$ order; *sensu* Strahler 1952, p. 1120). In spring and fall, juveniles are equally distributed in both headwater tributaries and larger streams (Bramblett et al. 2002). However, beginning in September, juvenile rainbow in Idaho move downstream from summer rearing to winter overwintering areas (Chapman and Bjornn 1968, p. 165). Given the very low winter flows and water temperatures in southwest Alaska low-order streams (e.g., USGS 2012), Nushagak and Kvichak river drainages juvenile rainbow trout may follow the movement pattern of Idaho fish.

In southeast Alaska, juvenile rainbow trout rear in streams with gradients up to at least 16% (Bryant et al. 2004), but there are no reports of trout in such steep streams within the Nushagak and Kvichak river drainages (ADF&G 2012). In streams of southwestern Alaska, in spring and early summer before the arrival of adult salmon, large rainbow trout are lower in drainages, in slower velocity currents, often in sloughs (Alt 1986). Later in the summer the distribution of age-1 and older Alaska rainbow trout is closely tied to the distribution of spawning salmon (Alt 1986; Brink 1995, p. 102, 104; Meka et al. 2003; Sundet and Pechek 1985, p. 39-40). In fall, after salmon spawning (except for coho) is complete, large southwestern Alaska rainbow trout occupy stream reaches with moderate currents and gravel substrates, often near grassy banks (Alt 1986). Stream fish may congregate in discrete overwintering habitats with moderate currents, often in areas of groundwater upwelling (Sundet and Pechek 1985, p. 40), and in late winter rainbow trout appear to select areas with ice cover (Sundet 1986, p. 39). In general, groundwater influence may be an important habitat characteristic because in regions where they are non-native, rainbow trout invasions can be limited to only groundwater-fed streams with stable flows (Inoue et al. 2009).

Radio telemetry, tagging, and genetic studies indicate the presence of multiple rainbow trout populations, including resident and adfluvial forms, within Bristol Bay watersheds (Burger and Gwartney 1986, p. 22, 26; Gwartney 1985, p. 70-71; Krueger et al. 1999; Meka et al. 2003; Minard et al. 1992, p. 34; PLP 2011, p. 15.1-85).

Life cycle

Rainbow trout spawning in the Bristol Bay region is associated with spring ice-out and occurs from late March through mid-June (Burger and Gwartney 1986, p. 22; Dye 2008, p. 21; Gwartney 1985, p. 45-46, 51; Minard et al. 1992, p. 2; PLP 2011, p. 15.1-85; Russell 1977, p. 41). Pre-spawner movements to spawning tributaries begins prior to ice-out, in early March (Dye 2008, p. 13). Within a given drainage, the timing of spawning can vary by several weeks depending on spatial and interannual stream temperature patterns (Burger and Gwartney 1986, p. 22; Hartman et al. 1962, p. 195; Russell 1977, p. 12). While post-spawners are often in poor physical condition (Russell 1977, p. 15), rainbow trout in the Nushagak and Kvichak river drainages can spawn in consecutive years and some spawn at least three years in a row (Minard et al. 1992, p. 17, 22; Russell 1977, p. 15).

In small lakes in southcentral Alaska, males matured at a smaller size than females and approximately one-third of males smaller than 178 mm (SL, standard length; 7 in) were mature. In this population most females did not mature until about 300 mm (SL; 12 in), while all males matured at about 250 mm (SL; 10 in) (Allin 1954, p. 36). In Moose Creek, in the Wood River lake system (Figure 2-4 in main assessment report), half of the fish over 376 mm (FL) were sexually mature (Dye 2008, p. 22). In Lower Talarik Creek, most spawners were ages 7 to 9 (Russell 1977, p. 17); in the upper Kvichak River, from 1989 to 1991, spawners were primarily ages 5 to 7 (Minard et al. 1992, p. 15). Fecundity of Lower Talarik Creek females (lengths ranging from 533 to 692 mm FL) averaged 3,431 (n = 16, SD = 1,053) and ova diameter averaged 5.5 mm (n = 25, SD = 0.6, Russell 1977, p. 18). In the Nushagak and Kvichak river drainages rainbow trout can reach at least age 14 (Minard and Dunaway 1991, p. 111, 189; determined by scale pattern analysis, a conservative measure; e.g., Sharp and Bernard 1988), with lengths to at least 814 mm (FL; Russell 1977, p. 30).

Post-spawning adults exhibit multiple movement patterns (Gwartney 1985, p. 68, 70; Meka et al. 2003). In Bristol Bay watersheds, many adults migrate shortly after spawning in the inlet or outlet streams of large lakes to feeding areas in large lakes (Burger and Gwartney 1986, p. 20; Meka et al. 2003; Minard et al. 1992, p. 2; Russell 1977, p. 44). After a summer of feeding in lakes, from September through November these mature rainbow trout move back to, or near, lake inlets and outlets to overwinter (Burger and Gwartney 1986, p. 20; Meka et al. 2003; Minard et al. 1992, p. 2; Russell 1977, p. 32). In late summer, some large adults move from Iliamna Lake into tributaries to forage amongst the spawning sockeye salmon, and then return to Iliamna Lake (PLP 2011, p. 15.1-85). In the Wood River lakes system, mature rainbow trout from many spawning streams aggregate to feed in the inter-lake rivers and remain there, or nearby in the adjacent lakes, through the following winter (Dye 2008, p. 13). After spawning in tributaries to southcentral Alaska's Susitna River, some mature rainbow trout remained near spawning areas, some moved downstream, some moved into other tributaries, and some moved upstream (Sundet and Pechek 1985, p. 39). Even in watersheds with large lakes, some fish may remain in outlet rivers year-round (Meka et al. 2003). Fish grow little in winter (Russell 1977, p. 32).

While some mature fish may not undergo large seasonal migrations, others move considerable distances (Dye 2008, p. 15; Meka et al. 2003; Minard et al. 1992, p. 33; Russell 1977, p. 23), to at least 200 km (122 mi) or more (Burger and Gwartney 1986, p. 16). Meka et al. (2003) speculated that seasonal migrations may be longer in watersheds with large lakes than in watersheds without large lakes. In southwest Alaska's Goodnews River, most adult fish moved less than 10 km throughout the year, and the movement that does occur is primarily upstream to spring spawning locations, and downstream to overwintering locations (Faustini 1996. p. 19-20).

Incubating rainbow trout eggs develop much more rapidly than do those of salmon, and juveniles emerge from spawning gravels between mid-July and mid-August at about 28 mm long (ADF&G 2012, e.g., site FSN0616E01; Johnson et al. 1994; Russell 1977, p. 30). Juveniles grow quickly during late summer and early fall, nearly doubling their length by late September (Russell 1977, p. 30). Immature fish may remain in their natal stream for several years before moving to other habitats (Russell 1977, p.18, 22).

In the Alagnak River (Figure 2-4 in main assessment report), within the Kvichak River drainage, Meka et al. (2003) distinguished three unique adult migratory patterns: lake-resident, lake-river, and river-resident. Each of these populations migrates seasonally, and Meka et al. (2003) suggested that Alagnak rainbow trout evolved these movements to take advantage of seasonal food sources (salmon eggs and carcasses) and warmer winter water temperatures. A similar pattern was observed in Upper Talarik Creek (PLP 2011, p. 15.1-85). Russell (1977, p. 37) noted that Lower Talarik Creek trout were in better condition following large Kvichak drainage sockeye salmon escapements than after small escapements.

Predator–prey relationships

The diet of rearing rainbow trout includes a broad range of aquatic and terrestrial invertebrates (Nakano and Kaeiryama 1995). When available, sockeye salmon eggs dominate rainbow trout diet in Lower Talarik Creek. While their diet is highly varied, other important Lower Talarik Creek rainbow trout food items includes aquatic dipterans (chironomids) and caddis fly larvae (Russell 1977, p. 36). Many larger Lower Talarik Creek rainbow trout appear to feed primarily in Iliamna Lake and not in the stream (Russell 1977, p. 35). In streams of the Nushagak and

Kvichak river drainages, Russell (1980, p. 103) reported that aquatic insects, salmon eggs, shrews and voles, unidentified fish and Chinook salmon fry, and salmon carcasses made up the bulk of the summer and fall diet of rainbow trout.

In studies within the Nushagak and Kvichak river drainages, Scheuerell et al. (2007) reported that before the seasonal arrival of adult salmon, rainbow trout primarily feed on dipterans (39%), stoneflies (18%), mayflies (12%), and caddis flies (11%). When spawning sockeye salmon arrive, rainbow trout diet shifts to salmon eggs (64%), larval blowflies (which feed on salmon carcasses; (11%)), and salmon carcasses (9%). This diet shift in conjunction with seasonal salmon spawning activity increases rainbow trout energy intake more than five-fold (Scheuerell et al. 2007).

In the laboratory, slimy sculpin, a ubiquitous species throughout the lakes and streams of the Nushagak and Kvichak river drainages, consume rainbow trout eggs (Fitzsimons et al. 2006). While Nushagak and Kvichak river drainages rainbow trout are certainly consumed by predators, they are not specifically identified in the diet of regional predatory fish (Metsker 1967, p. 26, 29; Russell 1980, p. 55-56, 62-63, 67, 73, 76, 81-83, 95-97, 103, 108), perhaps due in part to their comparatively low abundance relative to other available prey species.

Abundance and harvest

In the Nushagak and Kvichak river drainages total rainbow trout abundance is unknown, but there have been population estimates of larger (those targeted by anglers) fish in selected streams. From 2,000 to 4,500 fish available to hook and line angling gather in the upper Kvichak River in spring (Minard et al. 1992, p. 30); an average of 950 fish spawn in Lower Talarik Creek (Russell 1977, p. 9); and 950 fish larger than 199 mm occur in the Tazimina River, north of Iliamna Lake (Schwanke and Evans 2005, p. 9). In the Wood River lakes system, counts have been as high as 13,700 rainbow trout larger than 250 mm in the Agulowak River and 2,400 larger than 340 mm in the Agulukpak River (Dunaway 1993, p. 10, 24).

In the Nushagak and Kvichak river drainages and the adjacent Togiak River drainage, sport anglers caught more rainbow trout in 2009 (an estimated 159,685, or 22% of the statewide total) than all other non-salmon fish species combined (Jennings et al. 2011, p. 69). In 2009 sport anglers harvested 225 rainbow trout within the Nushagak and Kvichak river drainages and adjacent Togiak River drainage (Jennings et al. 2011, p. 69). Annual sport harvests have declined, due at least in part to the increasing popularity of catch-and-release fishing (Dye and Schwanke 2009, p. 6). The State of Alaska's Southwest Alaska Rainbow Trout Management Plan includes policies to manage Nushagak and Kvichak river drainages rainbow trout populations to maintain historic size and age composition without relying on hatcheries, to provide a range of harvest opportunities, and to economically develop the sport fishing industry while acknowledging the intrinsic value of the resource to Alaskans (Dye and Schwanke 2009, p. 32).

From the mid-1970s to the mid-2000s, rainbow trout were estimated to represent between 19 and 30.9% of the total weight of the Kvichak River drainage non-salmon freshwater fish subsistence harvest (Krieg et al. 2005, p. 214). In the mid-2000s, villagers from nine of the Nushagak and Kvichak river drainage communities annually harvested, as part of their subsistence activities, an estimated 3,740 rainbow trout (Fall et al. 2006, p. 45, 80, 113, 150, 194; Krieg et al. 2009, p. 40, 78, 118, 162, 202).

Stressors

Low pH (less than or equal to pH 5.5) impairs adult egg and sperm development and reduces early embryonic survival (Weiner et al. 1986). Pre-emergent embryo survival depends strongly on elevated DO concentrations and movement of groundwater through redds. Embryo survival is minimal where mean DO is less than 5.2 $mg \cdot l^{-1}$; at higher DO levels, embryo survival increases in relation to the velocity of intergravel flows greater than 5 $cm \cdot h^{-1}$ (Sowden and Power 1985). Bjornn and Reiser (1991, p. 84, 85) concluded that upstream migrating large trout need stream depths no less than 0.18 m, velocities no more than 2.44 $m \cdot s^{-1}$, and DO levels at least 80% of saturation and never less than 5.0 $mg \cdot l^{-1}$. For spawning rainbow trout in the central part of their North American range, Bell (1986, p. 96) recommended water temperatures between 2.2 and 20 °C (36 to 68 °F), and optimally 10 °C (49.5 °F). Russell (1977, p. 12) observed that Lower Talarik Creek rainbows stopped spawning at stream temperatures above 16 °C. In the laboratory, at temperatures below 2.8 °C, age-0 fry become inactive and seek refuge within the stream substrate. At temperatures below 5.5 °C, fry stop feeding (Chapman and Bjornn 1968, p. 168).

The survival of incubating embryos rapidly declines as the proportion of fines (sediments less than 6.35 mm in diameter) increases in spawning gravels, probably because the fines reduce intragravel flow (Bjornn and Reiser 1991, p. 99, 100). The success rate of fry emergence from spawning gravels and juvenile rearing density also declines with increasing proportion of fines in the substrate (Bjornn and Reiser 1991, p. 103, 132). Rainbow trout populations are particularly vulnerable when adult fish aggregate in spring spawning grounds and overwintering locations.

Ten steelhead population segments in California, Oregon, and Washington are currently listed as threatened or endangered primarily due to the lack of access to their historic range that has resulted from constructed barriers to migration and to stream dewatering. Nonanadromous rainbow trout populations are not listed (NMFS 2006).

Char

The Nushagak and Kvichak river drainages are home to three species of char: Arctic char, Dolly Varden, and lake trout. These char all spawn in fall. Bristol Bay Dolly Varden are often anadromous; Arctic char and lake trout are typically nonanadromous. The habitats of Dolly Varden and Arctic char occasionally overlap within the Nushagak and Kvichak river drainages, and when they do these species may hybridize (Taylor et al. 2008).

Taxonomic distinctions between Arctic char and Dolly Varden historically have been inconsistent. Some earlier authors (e.g., Craig 1978; Craig and Poulin 1975; Yoshihara 1973) called riverine and anadromous Alaska char “Arctic char” *Salvelinus alpinus*. More recent assessments suggest these fish are Dolly Varden (Behnke 1980, p. 454; Cavender 1980, p. 319-320; Taylor et al. 2008). In general, researchers currently believe that the North American char west of Canada’s Mackenzie River living primarily in flowing water are Dolly Varden, and Arctic char (and lake trout) are largely limited to lakes and adjacent reaches of their inlet and outlet streams (Reist et al. 1996).

The State of Alaska's 2012 edition of the *Catalog of Waters Important for the Spawning, Rearing or Migration of Anadromous Fishes*, or "Anadromous Waters Catalog" (AWC; e.g., Johnson and Blanche 2012) identifies Dolly Varden as the anadromous char across most of the state. However, in Bristol Bay the AWC identifies some streams as anadromous Dolly Varden habitat and some as anadromous Arctic char habitat. The AWC lists both anadromous Dolly Varden and anadromous Arctic char in the Kvichak River drainage, but only anadromous Arctic char in the Nushagak River drainage. These distinctions result from the history of regional variations in species naming and do not accurately reflect the ranges of different species and life histories. Current terminology labels the river-dwelling char of the Nushagak and Kvichak river drainages Dolly Varden. That is, the rivers and streams in the AWC currently designated as Arctic char habitat should, in almost all cases, be interpreted as Dolly Varden habitat. As a result of recent field work, ADF&G concluded that the Nushagak River, and the Koktuli River in particular, likely supported anadromous Dolly Varden (Schwanke 2007, p. 14).

Arctic char *Salvelinus alpinus*

Freshwater distribution and habitats

The Arctic char is a circumpolar species, distributed at high latitudes across the northern hemisphere (Brunner et al. 2001). In fresh water, Arctic char range closer to the North Pole than any other fish species (Johnson 1980, p. 16). In the fresh waters of North America, Arctic char are not typically far from the ocean. They range from Maine and New Hampshire north to the Canadian mainland Arctic Coast and through the Canadian Arctic archipelago (Scott and Crossman 1998, p. 203). The Alaska Arctic char distribution is disjunct. They occur in the Brooks Range, on the North Slope and the Seward Peninsula, in Bristol Bay, and a few other isolated locations in southcentral and interior Alaska (Mecklenburg et al. 2002, p. 199). Multiple distinct Arctic char races, differing in growth rate and migratory strategies, can occupy a single lake (Baroudy and Elliott 1994; Sandlund et al. 1992).

Alaska Arctic char appear primarily restricted to lakes and adjacent reaches of their inlet and outlet streams in well-drained areas (Morrow 1980b, p. 58; Scanlon 2000, p. 56, 58; Taylor et al. 2008, Wiedmer *unpublished*) and do not appear to undertake extensive seasonal migrations outside their home lakes (McBride 1980, p. 17). However, some Alaska Arctic char are known to move 15 to 20 km upstream and downstream between connected lakes (Troyer and Johnson 1994, p. 49) and Scanlon (2000, p. 43-48) suggested some move seasonally to estuarine or marine areas. Within the Nushagak and Kvichak river drainages, they are reported in the Tikchik and Wood River lakes, Iliamna Lake, and other upland lakes (Bond and Becker 1963; Burgner et al. 1965; Russell 1980, p. 49; Taylor et al. 2008), but they are apparently absent from Bristol Bay's coastal tundra lakes (Hildreth 2008, p. 9). Metsker (1967, p. 23) believed that Intricate Bay in Iliamna Lake is a particularly important spawning area. Adults and juveniles are common in the east end of Iliamna Lake, but not in tributaries (Bond and Becker 1963).

The depth of Arctic char lake spawning habitat can vary from 1 to 100 m (reviewed in Johnson 1980, p. 44), but is often in gravel shoals less than 5 m deep (Klemetsen et al. 2003, p. 31). McBride (1980, p. 6) found Wood River lakes spawners concentrated in the mouths of small tributary streams. DeLacy and Morton (1943) concluded that Kodiak Island's Karluk Lake Arctic char spawn in the lake and not in the tributary streams.

During the spring and early summer, McBride (1980, p. 20) estimated that approximately 40% (approximately 65,000) of the Wood River lakes Arctic char population greater than 300 mm long congregated in the inlets and outlets of the inter-lake rivers to feed on the sockeye salmon smolt outmigration. In Bristol Bay's Ugashik lakes (Figure 2-3 in main assessment report), Plumb (2006, p. 14-15) found Arctic char at depths greater than 75 m; but 90% of her catch was in waters less than 10 m deep. Fish sizes were not segregated by depth (Plumb 2006, p. 19-20). Similar to Dolly Varden (discussed below), Arctic char often occupy different habitats depending on the presence or absence of competitors (reviewed in Klemetsen et al. 2003, p. 29-30).

Life cycle

Arctic char in Bristol Bay are thought to be primarily nonanadromous (e.g., Reynolds 2000, p. 16), but Scanlon (2000, p. 43-48) suggested that some Becharof Lake Arctic char were anadromous. In Nushagak and Kvichak river drainage lakes, maturity is reached at around ages 3 to 6, at a length of approximately 330 mm (FL; 13 in.) (Metsker 1967, p. 23; Russell 1980, p. 48, 54). Metsker (1967, p. 23, 26) concluded that individual Iliamna Lake Arctic char spawned in alternating years, but McBride (1980, p. 16) provided evidence that at least some Lake Aleknagik Arctic char return annually to spawning locations. Wood River lakes Arctic char demonstrated high level of interannual fidelity to both spawning and feeding sites (McBride 1980, p. 6, 8, 19). Lake Aleknagik Arctic char periodically provide eggs for Alaska's sport fish hatcheries (Dunaway and Sonnichsen 2001, p. 138).

In the Nushagak and Kvichak river drainages Russell (1980, p. 48) found individuals ready to spawn in mid-September and McBride (1980, p. 6) collected Wood River lakes spawning fish between mid-September and mid-October. Ripening females in Brooks Range lakes have ova diameters ranging from 1.6 to 4.7 mm and fecundity ranges from 3,200 to 4,000 ova (Troyer and Johnson 1994, p. 41). If the substrate is not too coarse (approximately 10 cm or more, Sigurjónsdóttir and Gunnarsson 1989) females excavate redds into which they deposit their ova, which males immediately fertilize (Johnson 1980, p. 45). The incubating eggs and alevins remain in spawning gravels until the following spring (summarized in Johnson 1980, p. 47-48). Bristol Bay Arctic char live at least 15 years (Plumb 2006, p. 19), are particularly slow growing (Russell 1980, p. 48), reach fork lengths to at least 684 mm, and weights to at least 3.8 kg (Scanlon 2000, Appendix Table A). As with Dolly Varden, multiple migratory patterns and morphologies (Klemetsen et al. 2003, p. 36) occur with the basin (Russell 1980, p. 48; Scanlon 2000, p. 63-64). Tagging studies indicated that the Wood River lakes supported at least 20 discrete stocks (McBride 1980, p. 20).

Predator–prey relationships

The diet of young-of-the-year is poorly understood, but is thought in general to be dominated by small benthic and planktonic invertebrates (reviewed in Klemetsen et al. 2003, p. 32). In larger Brooks Range fish, planktonic crustaceans, insects, and snails were the most frequently occurring food items and fish were not an important part of the diet (Troyer and Johnson 1994, p. 44). In Iliamna Lake, summer diet was dominated by snails (Bond and Becker 1963) and winter diet was dominated by threespine stickleback (Metsker 1967, p. 26, 28). In other Nushagak and Kvichak river drainage lakes, mollusks and caddis fly larvae were the dominant benthic organisms consumed (Russell 1980, p. 55-56). In summer, freshwater crustaceans dominated the diet of Ugashik Lakes Arctic char (Plumb 2006, p. 27) and crustaceans, sticklebacks, insects, pygmy whitefish, sculpins, and juvenile sockeye salmon dominated the diet of Becharof Lake Arctic char (Scanlon 2000, p. 51, 53-54).

In the Nushagak and Kvichak river drainages, larger Arctic char eat outmigrating sockeye salmon smolt, often in spring and early summer at lake outlets (McBride 1980, p. 1; Metsker 1967, p. 29). Karluk Lake Arctic char eat mostly insects until the arrival of spawning sockeye, when their diet shifts to drifting salmon eggs, benthic invertebrates dislodged by salmon redd excavation, and adult salmon carcasses (DeLacy and Morton 1943).

Arctic char are eaten by other predatory fish, including lake trout (Troyer and Johnson 1994, p. 42) and larger Arctic char (Klemetsen et al. 2003, p. 33). Mink *Mustela vison* eat mature Wood River lakes Arctic char when they have the opportunity (Dunaway and Sonnichsen 2001, p. 138).

Abundance and harvest

In the Nushagak and Kvichak river drainages total Arctic char abundance is unknown. Meacham (reported in McBride 1980, p. 20) estimated that in the 1970s the Wood River lakes supported between 135,000 and 210,000 (presumably larger) Arctic char. Russell (1980, p. 48, 49) considered them common in some lakes in the Lake Clark area, but absent or rare in lakes of the upper Mulchatna River watershed and Lake Clark itself. In the mid-1960s, Iliamna Lake supported a commercial fishery and char made up 84% (2,979 kg, 6,553 lb) of the total dressed weight harvest (Metsker 1967, p. 9). These fish are thought to be mostly Arctic char (Bond and Becker 1963; Taylor et al. 2008).

Between 1971 and 1980, the annual estimated abundance of Arctic char larger than 249 mm ranged from 8,000 to 12,000 fish at the mouth of the Agulowak River and 4,300 to 7,800 fish at the mouth of the Agulukpak River (Minard et al. 1998, p. 131). By 1993 the estimated abundance of the Agulowak River population declined to only 5,400 fish, prompting a substantial reduction in bag limits and harvest means (Minard and Hasbrouck 1994, p. 13, 22). While excessive sport harvests were thought to be responsible for the decline (Minard et al. 1998, p. 16), anecdotal reports suggested that the more conservative sport harvest regulations were leading to the recovery of the stock (Dunaway and Sonnichsen 2001, p. 131). Minard et al. (1998, p. 16) also reported a similar apparently significant decline in Iliamna River stocks, both in overall abundance and in larger, older age classes. These observations prompted adoption of a catch-and-release fishing regulation.

The State of Alaska's sport and subsistence fisheries statistics do not distinguish between Arctic char and Dolly Varden. Sport anglers caught an estimated 48,438 Arctic char/Dolly Varden in the Nushagak and Kvichak river drainages and the adjacent Togiak River system in 2009 (8% of the statewide total) and harvested (kept) an estimated 2,159 (5% of the statewide total; Jennings et al. 2011, p. 73). Arctic char/Dolly Varden consistently support the greatest sport harvest of any non-salmon freshwater fish in Bristol Bay (Dye and Schwanke 2009, p. 8). Sport harvests have declined, due at least in part to both lower bag limits and the increasing popularity of catch-and-release fishing (Dye and Schwanke 2009, p. 6).

In the mid-2000s, villagers from ten of the Nushagak and Kvichak river drainage communities annually harvested, as part of their subsistence activities, an estimated 3,450 Arctic char and

Dolly Varden combined (Fall et al. 2006, p. 45, 80, 113, 150, 194; Krieg et al. 2009, p. 40, 78, 118, 162, 202). Arctic char and Dolly Varden combined were the most important non-salmon fish harvested in the villages of Iliamna, Newhalen, and Pedro Bay (Fall et al. 2006, p. 49, 84, 117). From the mid-1970s to the mid-2000s, Arctic char/Dolly Varden were estimated to represent between 16.2 and 26.9% of the total weight of the Kvichak River drainage non-salmon freshwater fish subsistence harvest (Krieg et al. 2005, p. 214).

Stressors

Arctic char are not tolerant of warm water. In tests of European Arctic char, egg mortality was 100% at temperatures at or above 12 to 13 °C (Jungwirth and Winkler 1984). Even when acclimated to water temperatures between 15 and 20 °C, pre-emergent fry could not survive exposures to temperatures above 26.6 °C for more than 10 minutes and could not survive temperatures over 21° C for more than a week (Elliott and Klemetsen 2002). Apparent over-harvests have been implicated for historic population declines within the Nushagak and Kvichak river drainages (Minard et al. 1998, p. 16).

Dolly Varden *Salvelinus malma*

Dolly Varden is a highly plastic species: multiple genetically, morphologically, and ecologically distinct morphs (e.g., benthic specialist, riverine specialist, lacustrine generalist, specialized piscivore) can exist in the same water body (Ostberg et al. 2009). Researchers currently recognize two geographically distinct forms of Dolly Varden: northern and southern, based on differences in life history (Armstrong and Morrow 1980, p. 107-130), phenotype (Behnke 1980, 465-466; Cavender 1980, p. 299-318), and genotype (Taylor et al. 2008). Dolly Varden in the Nushagak and Kvichak river drainages are of the northern form (Behnke 1980, p. 465).

Freshwater distribution and habitats

The global native freshwater range of Dolly Varden is restricted to waters draining to the Beaufort, Chukchi, and Bering seas and the North Pacific. The North American range extends from the Arctic coast of Alaska and Canada west of the Mackenzie River south to northern Washington. The Asian range stretches from the Chukotka Peninsula south to Japan and Korea (Mecklenburg et al. 2002, p. 200). In Alaska, Dolly Varden are found in waters draining to all coasts (Mecklenburg et al. 2002, p. 200) and the Alaska Peninsula (Figure 2-3 in main assessment report) divides the northern and southern forms (Behnke 1980, p. 453). Dolly Varden are known to occur widely in Bristol Bay, but their true distribution across the waters of the Nushagak and Kvichak river drainages is underreported. Within the Nushagak and Kvichak river drainages, popular sport fishing areas include the Alagnak, Newhalen, Nushagak, Mulchatna, and the Wood River–Tikchik Lakes systems (Minard et al. 1998, p. 188).

As in southeast Alaska (Bryant et al. 2004), Nushagak and Kvichak river drainage Dolly Varden occur farther upstream in high-gradient headwater streams than other fish species (ADF&G 2012, e.g., Site FSN0604E01). In both southeast Alaska (Bramblett et al. 2002; Wissmar et al. 2010) and the Nushagak and Kvichak river drainages (ADF&G 2012, e.g., Site FSN0616E01; e.g., Tazimina Lakes, Russell 1980, p. 31-32, 73), nonanadromous Dolly Varden occur above migratory barriers that currently prevent access to anadromous salmon populations.

Spawning occurs well upstream from areas used for overwintering (DeCicco 1992). Northern-form anadromous Dolly Varden overwinter primarily in lakes and in lower mainstem rivers where sufficient groundwater provides suitable volumes of free-flowing water (DeCicco 1997; Lisac 2009, p. 13, 15-16). In stream systems, spawning occurs in fast-flowing channels, primarily in upper reaches (Bramblett et al. 2002; Fausch et al. 1994; Hagen and Taylor 2001; Kishi and Maekawa 2009; Koizumi et al. 2006) and small, spring-fed tributaries (Hagen and Taylor 2001). Stream-resident Dolly Varden are reported to spawn in channels that are 1 to 3 m wide and 10 to 35 cm deep (Hino et al. 1990; Maekawa et al. 1993), with a mean depth of 9 cm, mean velocity of 21 $cm \cdot s^{-1}$, and median substrate diameter of 1.6 cm (Hagen and Taylor 2001). Stream-resident females select spawning sites where gravel is prevalent (Kitano and Shimazaki 1995). Spawning site substrate and current velocity do not correlate significantly with female size, but redd depth does (Kitano and Shimazaki 1995). Anadromous individuals spawn in deeper water than nonanadromous fish, ranging from 20 to 60 cm (Blackett 1968). They construct redds approximately 30 cm long, 15 to 25 cm wide, and 15 cm deep (Blackett 1968); composite redds, potentially containing several individual nests can be up to 3.5 m long and 1.2 m wide (Yoshihara 1973, p. 47).

In Kamchatka, Eberle and Stanford (2010) found rearing Dolly Varden in floodplain springbrooks and 7th-order mainstem channels. Within the Nushagak and Kvichak river drainages, juveniles appear to be limited primarily to low-order headwaters (ADF&G 2012), and infrequently to side channels and the main channel of larger rivers downstream to the confluence of 5th-order streams (ADF&G 2012, e.g., Site FSN0609A02). In southeast Alaska Dolly Varden rear in channels with gradients steeper than 20% (Wissmar et al. 2010), but in the Nushagak and Kvichak river drainages, Dolly Varden have been reported only in gradients of 12% or less (ADF&G 2012, e.g., Site FSM0503A07). Rearing Dolly Varden normally stay close to the stream bottom over gravels and cobbles (Dolloff and Reeves 1990; Hagen and Taylor 2001; Nakano and Kaeiryama 1995). Fry density is inversely related to stream depth (Bryant et al. 2004) and use of shallows increases if cover is available (Bugert et al. 1991). Different juvenile age classes can segregate in different micro- (Bugert et al. 1991; Dolloff and Reeves 1990) and macro- (ADF&G 2012; Denton et al. 2009) habitats. Affinity for cover, including cobbles and boulders, increases with age and tolerance for other Dolly Varden declines (Dolloff and Reeves 1990). Gregory (1988, p. 49-53) found stream-resident juvenile Dolly Varden in beaver ponds, where they grow faster than fish in adjacent streams, because of relatively warmer water temperatures and increased productivity.

Dolly Varden occur in upland Bristol Bay lakes, often in large numbers, feeding both at the surface and on the lake bottom, but they are uncommon or absent in lakes supporting Arctic char populations (Russell 1980, p. 49, 69-72; Scanlon 2000, p. 56). Dolly Varden will use all lake habitats in the absence of competitors (other salmonids), but concentrate in offshore and near-bottom habitats where competitors occupy nearshore and near-surface habitats (Andrew et al. 1992; Jonsson et al. 2008; Schutz and Northcote 1972). In the absence of competitors, lake-dwelling Dolly Varden move from deeper offshore waters, where they spend the day, perhaps in loose aggregations, to spend the night in onshore waters, near the surface (Andrusak and Northcote 1971). Dolly Varden vision is more sensitive to low light than competing salmonids (Henderson and Northcote 1985; Henderson and Northcote 1988; Schutz and Northcote 1972), allowing them to feed in deeper water and at night.

Life cycle

Northern-form Dolly Varden express several migratory patterns, including anadromous, nonanadromous stream-resident, nonanadromous spring-resident, nonanadromous lake-resident, nonanadromous lake-river-resident, and nonanadromous residuals (nonanadromous male offspring of anadromous parents; (Armstrong and Morrow 1980, p. 107-130; Behnke 1980, p. 466). Bristol Bay supports Dolly Varden with both anadromous (Reynolds 2000, p. 16-17; Scanlon 2000, p. 48-51) and nonanadromous (Denton et al. 2009; Scanlon 2000, p. 48-51) life histories.

Anadromous Dolly Varden exhibit very complex migratory patterns (Armstrong and Morrow 1980, p. 108-109), frequently leaving one drainage, traveling through marine waters, and reentering distant drainages, including those on separate continents (DeCicco 1992; DeCicco 1997; Lisac 2009, p. 14; Morrow 1980a). Even apparently nonanadromous fish can seasonally move more than 200 km within complex Bristol Bay watersheds (Scanlon 2000, p. 60).

Anadromous Dolly Varden of the Togiak River system, just west of the Nushagak and Kvichak river drainages, spawn from approximately mid-September to mid-October, overwinter downstream from spawning locations, and migrate annually to sea, where they spend approximately six weeks feeding (Lisac and Nelle 2000, p. 31-34). The timing of adult seaward migration generally corresponds with spring ice-out and high water, with adults migrating to sea in May and June. Their return to fresh water appears to relate to decreased stream discharge (Lisac and Nelle 2000, p. 33-34, 35). Anadromous Dolly Varden migrate upstream from the ocean to spawning areas in July and August (Lisac 2011). Russell (1980, p. 72) observed Dolly Varden spawning in the upper Mulchatna River system in mid-September.

Anadromous Dolly Varden home to spawn (Crane et al. 2003; Lisac and Nelle 2000, p. 31), but stocks can mix at sea and in overwintering areas (DeCicco 1992). In northwest Alaska anadromous Dolly Varden usually undertake three to five ocean migrations before reaching sexual maturity (DeCicco 1992). In the Togiak River, some anadromous fish mature at age 2 and most mature at age 4 (Lisac and Nelle 2000, p. 31; Reynolds 2000). Bristol Bay Dolly Varden can live at least 14 years (Plumb 2006, p. 19; Scanlon 2000, Appendix Table B) and reach lengths of 740 mm or more (Faustini 1996, p. 16). The minimum length of anadromous spawners in southwest Alaska's Goodnews River is about 330 to 360 mm (Lisac 2010, p. 4).

Stream-residents mature from age 2 to 5 (Blackett 1973; Craig and Poulin 1975; Maekawa and Hino 1986; Russell 1980, p. 72) and live at least to age 7 (Blackett 1973). They are smaller than their anadromous counterparts, ranging at maturity from 113 mm (Hagen and Taylor 2001) to 520 mm (Gregory 1988, p. 29) in length, with most less than 200 mm (Gregory 1988, p. 21-25). Like anadromous individuals, after spawning stream-resident adults move quickly to downstream overwinter areas (Maekawa and Hino 1986).

Although anadromous Dolly Varden in northern Alaska tend to spawn only every second year (DeCicco 1997), Lisac and Nelle (2000, p. 31) speculated that most anadromous Dolly Varden in the Togiak River near the Nushagak and Kvichak river drainages can spawn in consecutive years. Female fecundity is a function of size (Jonsson et al. 1984), and anadromous females can produce up to 7,000 ova (Armstrong and Morrow 1980, p. 102), a productivity more than 50 times that of nonanadromous females (Blackett 1973). Ripe ova of anadromous females are 3.5

to 6 mm in diameter; ripe ova of nonanadromous females can be as small as 2.8 mm (Armstrong and Morrow 1980, p. 101, 102).

In most cases, a spawning group consists of one female and several males, one of which is a dominant male that actively courts the female (Hino et al. 1990; Maekawa et al. 1993). Females excavate redds in stream gravels, and then deposit their eggs while a male fertilizes them. Chars show little evidence of nest-guarding behavior (Kitano and Shimazaki 1995). Males appear to suffer a much higher post-spawning mortality than do females (Armstrong 1974).

In streams on both sides of the Bering Strait, egg hatching peaks from the end of April to mid-May (Radtke et al. 1996). Embryos are 15 to 20 mm long at hatching and remain in the spawning substrate while they absorb their yolk sac. Alevins emerge from the nest around the time of ice break-up (April to June), at a length of about 25 mm (Armstrong and Morrow 1980, p. 108). Radtke et al. (1996) found that fry begin actively feeding in June to early July, 42 to 52 days after hatching. Newly emerged alevins tend to stay on the bottom of pools and are relatively inactive except when feeding (Armstrong and Morrow 1980, p. 108). Growth greatly increases through the summer as water becomes warmer; by September, age-0 fish average about 60 mm long (Armstrong and Morrow 1980, p. 108). Young anadromous Togiak River Dolly Varden make their first seaward migration between their first summer and age 3 (Reynolds 2000, p. 15). Size, rather than age, appears to govern the timing of initial smolt out-migration (Armstrong 1970).

Predator–prey relationships

Dolly Varden primarily target benthic invertebrates in streams (Eberle and Stanford 2010; Russell 1980, p. 73; Stevens and Deschermeier 1986) and lakes (Scanlon 2000, p. 53-55; Schutz and Northcote 1972). During the day, foraging from stream drift (food drifting in the current) is more important than benthic foraging, but the relative importance of benthic foraging increases at night; surface feeding is not important (Hagen and Taylor 2001). Dolly Varden also switch to benthic feeding when drift availability is limited (Fausch et al. 1997; Nakano et al. 1999; Nakano and Kaeiryama 1995).

Dolly Varden eat juvenile salmon (Armstrong 1970; Bond and Becker 1963), but they have been largely exonerated (Armstrong and Morrow 1980, p. 133; DeLacy and Morton 1943; Morton 1982) from earlier accusations that they were salmon run destroyers. From 1921 to 1939, Alaska Dolly Varden were the target of a bounty program designed to increase salmon abundance. Now it is believed that Dolly Varden were not responsible for the declines in salmon abundance (Harding and Coyle 2011, p. 19). When spawning salmon are present, salmon eggs–probably those flushed by high flows and superposed redd construction–can be important food (Armstrong 1970, p. 53-54; Scanlon 2000). Denton et al. (2009) reported that nonanadromous age-1 and older Dolly Varden in certain ponds near Iliamna Lake feed on sockeye salmon fry for a brief time in late June to mid-July, then migrate to sockeye spawning areas and feed almost exclusively on eggs from late July to mid-September. From late August through September they also eat blowfly larvae that had fed on adult sockeye salmon carcasses. Salmon eggs are too big for age-0 fry to consume, but blowfly maggots, when available, dominate their diet. Some nonanadromous Dolly Varden actively follow adult sockeye salmon to spawning areas and grow significantly faster after the arrival of spawning salmon (Denton et al. 2009; Wipfli et al. 2003). In May in Iliamna Lake tributaries such as the Copper River, Dolly Varden feed heavily on the spawning run of mature pond smelt (Richard Russell, Alaska Department of Fish and Game (retired), King Salmon, AK, personal communication).

The summer diet of stream-resident Dolly Varden in northcentral British Columbia is primarily adult dipterans (true flies; 33.6%) and hymenopterans (wasps, bees, and ants; 7.5%), with other aquatic insects comprising the remainder (Hagen and Taylor 2001). In southeast Alaska Dolly Varden also feed on terrestrial insects, but do so less than other salmonids occupying the same habitat (Wipfli 1997). Juvenile stream-rearing Dolly Varden consume a wide variety of predominantly aquatic invertebrates (Eberle and Stanford 2010), preferentially selecting immature blackflies, non-biting midges (chironomids), and mayflies (Milner 1994; Nakano and Kaeiryama 1995), but also feed on terrestrial invertebrates (Baxter et al. 2007; Nakano et al. 1999), particularly in the absence of competing salmonids (Baxter et al. 2004; Baxter et al. 2007). Some juvenile Dolly Varden eat age-0 Arctic grayling (Stevens and Deschermeier 1986).

In the absence of competitors, lake-dwelling Dolly Varden feed heavily in summer on terrestrial insects and during fall on zooplankton. In the presence of competition, they feed heavily on chironomids (both pupae and larvae) and trichopterans (caddis flies; Andrusak and Northcote 1971; Hindar et al. 1988).

River otters *Lutra canadensis* can extensively prey on rearing Dolly Varden (Dolloff 1993). Armstrong and Morrow (1980, p. 110) noted that bears and wolves take some mature fish from spawning areas (also observed by Wiedmer; ADF&G 2012, Site FSS0424A07) and speculated that fish-eating birds also take a few. Fish-eating birds such as harlequin ducks *Histrionicus histrionicus*, common *Mergus merganser* and red-breasted *M. serrator* mergansers, and bald eagles *Haliaeetus leucocephalus* are common in southwest Alaska throughout the year and ospreys (*Pandion haliaetus*, a fish-eating raptor) are more abundant along the waters of Bristol Bay than elsewhere in Alaska (Armstrong 1980, p. 69, 80, 81, 89, 92). Russell (1980, p. 81) reported that Lake Clark National Park and Preserve (Figure 2-3 in main assessment report) lake trout feed on Dolly Varden. Perhaps the greatest predators on smaller Dolly Varden are larger Dolly Varden (Armstrong and Morrow 1980, p. 110; Russell 1980, p. 73). Wiedmer (ADF&G 2012, Site FSS0406A01) collected a 195-mm (FL) northern-form Dolly Varden that had partially swallowed a 98-mm Dolly Varden.

Abundance and harvest

In the Nushagak and Kvichak river drainages total Dolly Varden abundance is unknown. Between 2002 and 2010 (excluding 2006), annual runs of anadromous Dolly Varden to southwest Alaska's Kanektok River averaged 13,115 (range: 8,140 to 43,292, Lisac 2011). The State of Alaska's sport and subsistence fisheries statistics do not distinguish between Arctic char and Dolly Varden. Sport anglers caught an estimated 48,438 Arctic char/Dolly Varden in the Nushagak and Kvichak river drainages and the adjacent Togiak River system in 2009 (8% of the statewide total) and harvested (kept) an estimated 2,159 (5% of the statewide total; Jennings et al. 2011, p. 73). In combination, Arctic char and Dolly Varden consistently support the greatest harvest of any non-salmon freshwater fish in Bristol Bay (Dye and Schwanke 2009, p. 8). Sport harvests have declined, due at least in part to both lower bag limits and the increasing popularity of catch-and-release fishing (Dye and Schwanke 2009, p. 6).

In the mid-2000s, villagers from ten of the Nushagak and Kvichak river drainage communities annually harvested, as part of their subsistence activities, an estimated 3,450 Dolly Varden and Arctic char combined (Fall et al. 2006, p. 45, 80, 113, 150, 194; Krieg et al. 2009, p. 40, 78, 118, 162, 202). Dolly Varden and Arctic char combined were the most important non-salmon fish harvested in the villages of Iliamna, Newhalen, and Pedro Bay (Fall et al. 2006, p. 49, 84, 117). From the mid-1970s to the mid-2000s, Dolly Varden/Arctic char were estimated to represent between 16.2 and 26.9% of the total weight of the Kvichak River drainage non-salmon freshwater fish subsistence harvest (Krieg et al. 2005, p. 214).

Stressors

Dolly Varden are not tolerant of warm water (Fausch et al. 1994; Kishi et al. 2004; Nakano et al. 1996). Feeding activity declines to low levels at water temperatures above 16 °C and their upper lethal limit is 24 °C (Takami et al. 1997). As a result, activities that increase water temperatures beyond tolerance levels will reduce available habitat (Kishi et al. 2004; Nakano et al. 1996), including the refuge from potential competitors that cold stream temperatures provide (Fausch et al. 2010).

Total dissolved solids (TDS) do not have a significant impact on Dolly Varden fertilization, up to the highest concentrations evaluated (1,817 $mg \cdot l^{-1}$); however, elevated TDS did significantly affect embryo water absorption at concentrations as low as 964 $mg \cdot l^{-1}$ (Brix et al. 2010). Brix et al. (2010) concluded that the water-hardening phase immediately following fertilization was the most sensitive life stage to elevated TDS.

McDonald et al. (2010) reported that Dolly Varden are relatively insensitive to selenium exposure (perhaps due to low rearing temperatures) and estimated that concentrations of 44 and 49 $mg \cdot kg^{-1}$, dry weight affected 10 and 20% of the study population, respectively. Dolly Varden in fresh water metabolize naphthalene much more rapidly than seawater, which may explain the greater toxicity of naphthalene to fish when in seawater (Thomas and Rice 1980). Whether in fresh water or sea water, toluene is more readily metabolized by Dolly Varden than is naphthalene (Thomas and Rice 1986b), and toluene is more rapidly metabolized in warmer water (Thomas and Rice 1986a).

In southeast Alaska Dolly Varden are typically the first salmonid colonizers of new streams formed by glacial retreat, suggesting they have lower requirements for microhabitat features (e.g., pools) that are a function of stream age (Milner 1994). Because they often use small isolated stream habitats and spawning populations can be small, both anadromous and nonanadromous Dolly Varden are particularly vulnerable to barriers to migration (Dunham et al. 2008; Fausch et al. 2010; Kishi and Maekawa 2009; Koizumi 2011; Koizumi and Maekawa 2004) and to alterations of the small headwater streams in which they spawn and rear (Armstrong and Morrow 1980, p. 133). The closely related bull trout *S. confluentus* is listed as threatened in the contiguous United States (USFWS 1999), due in large part to habitat fragmentation and warming stream temperatures.

Lake trout *Salvelinus namaycush*

Freshwater distribution and habitats

The global native distribution of lake trout is limited almost entirely to Canada and Alaska, from the just south of Canada's southern border north to the Canadian Arctic archipelago and from Canada's eastern maritime provinces west to near the Bering Sea coast (Martin and Olver 1980, p. 209-210). This native range is almost entirely restricted to the limits of North American late-Pleistocene glaciations (Lindsey 1964). In Alaska lake trout occur in suitable habitats across most of the state except for southern southeast Alaska, much of western Alaska, and maritime islands (Mecklenburg et al. 2002, p. 198), but within that broad range, there are great discontinuities between occupied habitats (Lindsey 1964). Bristol Bay marks the westernmost limit of the lake trout's native range (Mecklenburg et al. 2002, p. 198). Bristol Bay lake trout appear to be restricted to upland lakes and their inlet and outlet streams (ADF&G 2012, Site FSN0616C03; Burgner et al. 1965; Metsker 1967, p. 9, 11; Russell 1980, p. 47, 78, 79; Yanagawa 1967, p. 10). They are common in the Tikchik Lake system but absent from the main Wood River lakes (Burgner et al. 1965). Russell (1980, p. 77) considered them widely distributed in the Lake Clark area and their diet indicated they fed at lake surfaces and bottoms, and throughout water columns. Anglers target lake trout in many Nushagak and Kvichak river drainage upland lakes, particularly Lake Clark, Iliamna Lake, and the Tikchik Lakes (Minard et al. 1998, p. 152-155).

Almost all spawning occurs along lake shorelines or shoals, above coarse, often angular substrate (Martin and Olver 1980, p. 218; Scott and Crossman 1998, p. 222; Viavant 1997, p. 6-7). Lake trout typically spawn along exposed shorelines off points or islands or in mid-lake shoals (Martin and Olver 1980, p. 218). Russell (1980, p. 77) reported apparent spawning habitats on shoals around islands in Lake Clark. Spawning can occur in very spatially discrete locations (Viavant 1997, p. 6-7). Spawning areas appear to be kept clean of fine sediments by wind-driven or deep-water currents and not by springs or seeps. The maximum depth of spawning may be positively related to lake size, particularly fetch length, but is often less than 6 m (Martin and Olver 1980, p. 218; Royce 1951). In lakes that thermally stratify, lake trout may migrate seasonally from warming surface waters to cool deep waters (Martin and Olver 1980, p. 228-230).

Life cycle

Compared to many other salmonids, lake trout exhibit little tendency toward anadromy (Rounsefell 1958), but some individuals in far northern areas do migrate seasonally to marine waters (Swanson et al. 2010). Like other char, lake trout is a highly variable species and multiple forms, differing in diet, growth, and life span can occupy a single lake (Martin 1966). Adults can live to at least 51 years (Keyse et al. 2007); in the Nushagak and Kvichak river drainages, lake trout are known to live at least 29 years, begin to reach maturity at about 6 years (Russell 1980, p. 77), reach lengths of at least 910 mm (FL; Wiedmer *unpublished*), and weights of at least 14.5 kg (Richard Russell, Alaska Department of Fish and Game (retired), King Salmon, AK, personal communication). In some southcentral Alaska lakes, lake trout mature at ages 7 to 10 at lengths of 450 to 550 mm (FL; Van Whye and Peck 1968, p. 35). In the Nushagak and Kvichak river drainages and lakes in southcentral and interior Alaska, lake trout spawn in mid- to late September and perhaps later (Russell 1980, p. 77; Van Whye and Peck 1968, p. 35; Viavant 1997, p. 6). Mature lake trout, particularly those in more northern habitats, may not spawn annually, but will skip one or two years between spawning events (Martin and Olver 1980, p. 215). Most lake trout appear to home each year to specific spawning sites, but not all do (Martin and Olver 1980, p. 218).

The number of ova produced by mature females is a function of size and perhaps stock; reported average fecundities range from 996 to 15,842, and the diameter of ripe ova range from 3.7 to 6.8 mm (Martin and Olver 1980, p. 211, 213, 214). Lake trout may clean fine debris from the general area of spawning locations, but they do not construct redds, nor cover or guard their fertilized eggs (Royce 1951). Eggs and alevins incubate in spawning substrates until the following spring (Martin and Olver 1980, p. 224). The movements of young-of-the-year fry are poorly understood, but they are suspected to move to deeper water, often using the cover of coarse substrates (Martin 1966, p. 224, 226; Royce 1951). Larger fish can be nomadic within their home lake (Martin and Olver 1980, p. 226-227), and may move short distances between lakes (Scanlon 2010, p. 22). A probably mature, and apparently healthy 565 mm (FL) lake trout was captured in mid-August in the Tikchik River approximately 14 km from the nearest large lake (ADF&G 2012, site FSN0616C03), and sub-adult and adult lake trout are regularly encountered by summer anglers in the Alagnak River, downstream of Kukaklek and Nonvianuk lakes (Charles Summerville, Alaska Trophy Adventures, King Salmon, AK, personal communication). As a result of spawning stress, some adults move from lakes downstream into outlet rivers, and many likely do not survive to return to their natal waters (Richard Russell, Alaska Department of Fish and Game (retired), King Salmon, AK, personal communication).

Predator–prey relationships

In Lake Clark, growth remains fairly constant up to lengths of about 560 mm (FL), after which the relationship between weight and length significantly increases. Metsker (1967) attributed this to a transition, occurring at a length of about 480 mm (FL), from a diet of invertebrates to a diet of fish, primarily least cisco. A similar diet transition from insects and mollusks to fish, coupled with a potential influence on growth rate, was observed in lake trout from lakes in southcentral Alaska (Van Whye and Peck 1968, p. 30, 37).

Aquatic and terrestrial insects and small crustaceans are important foods for young-of-the-year fry (Martin and Olver 1980, p. 234). In Alaska, Arctic grayling, sculpins, humpback, round, and pygmy whitefish, least cisco, sockeye salmon fry, salmon eggs, ninespine stickleback, longnose suckers, Dolly Varden, Arctic char, rodents, shrews, and smaller lake trout are all prey items for large lake trout (Plumb 2006, p. 29; Russell 1980, p. 81-83; Troyer and Johnson 1994, p. 42; Van Whye and Peck 1968, p. 37). Lake trout observed in August in the Tikchik and Alagnak rivers likely were attracted to high densities of spawning salmon. In the absence of fish prey, large lake trout in arctic Alaska lakes are generalist feeders and feed primarily on benthic invertebrates (Keyse et al. 2007). In the presence of large lake trout, small lake trout limit their use of available habitats to avoid predation (Hanson et al. 1992; Keyse et al. 2007; McDonald and Hershey 1992).

In the laboratory, slimy sculpin consume lake trout eggs (Fitzsimons et al. 2006). In the wild, small lake trout (Royce 1951) are known to feed on lake trout eggs, as are round whitefish (Loftus 1958), which are found throughout the Nushagak and Kvichak river drainages (ADF&G 2012). Royce (1951) suspected that humpback whitefish, which are found in many of the same Nushagak and Kvichak river drainage lakes as lake trout, also feed on lake trout eggs. Burbot and large lake trout in the Nushagak and Kvichak river drainages feed on small lake trout (Russell 1980, p. 67, 82-83). Power and Gregoire (1978) concluded that, of the all the members of the fish community in Lower Seal Lake, Quebec, lake trout were the species most affected by freshwater seal *Phoca vitulina* predation. In 1998, Small (2001) reported that Iliamna Lake in the Kvichak River drainage supported a minimum harbor seal population of 321.

Abundance and harvest

In Bristol Bay total lake trout abundance is unknown, but in 2009 the Nushagak and Kvichak river drainages and the adjacent Togiak River system supported an estimated sport catch of 3,651 (12% of the statewide total) and harvest of 588 (11% of the statewide total; Jennings et al. 2011, p. 72). Dye and Schwanke (2009, p. 6) speculated that the trend of decreasing sport harvests are due in part to increasing catch-and-release practices.

In the mid-1960s, Iliamna Lake and Lake Clark supported a commercial winter lake trout fishery (Metsker 1967, p. 8, 10). In 1966 and 1967 Tikchik Lake also supported an experimental commercial freshwater fishery (Yanagawa 1967). Lake trout were the second-most commonly harvested species in that fishery, representing 30% of the overall harvest. The Tikchik Lake fishery harvested 1,502 lake trout, which averaged 2.2 kg in weight, and ranged in length from 500 to 575 mm and in age to more than 15 years (Yanagawa 1967).

In the mid-2000s, villagers from ten of the Nushagak and Kvichak river drainage communities annually harvested, as part of their subsistence activities, about an estimated 1,030 lake trout (Fall et al. 2006, p. 45, 80, 113, 150, 194; Krieg et al. 2009, p. 40, 78, 118, 162, 202). From the mid-1970s to the mid-2000s, lake trout were estimated to represent between 4.6 and 11.8% of the total weight of the Kvichak River drainage non-salmon freshwater fish subsistence harvest (Krieg et al. 2005, p. 214).

Stressors

As with lake-spawning humpback whitefish, excessive variation in lake level is suspected to reduce egg and alevin survival (Martin and Olver 1980, p. 223). Sedimentation of lake spawning areas has resulted in declines or elimination of successful reproduction (reviewed in Martin and Olver 1980, p. 223-224). In nature, lake trout are reported in water temperatures ranging from -0.8 to 18 °C, appear to prefer summer temperatures around 6 to 13 °C (Martin and Olver 1980. p. 230-231), and to have an upper lethal temperature of approximately 23.5 °C (Gibson and Fry 1954). Martin and Olver (1980, p. 231) concluded that a DO level of approximately 4 $mg \cdot l^{-1}$ is the minimum tolerated by lake trout. Late maturity, long life, and slow growth make lake trout particularly vulnerable to over-harvest (Martin and Olver 1980, p. 259). Like the similarly long-lived piscivore, northern pike, lake trout bioaccumulate and biomagnify atmospherically deposited mercury (Swanson et al. 2011). Lake acidification has extirpated lake trout from some Canadian lakes (Matuszek et al. 1992).

Arctic grayling *Thymallus arcticus*

Freshwater distribution and habitats

Arctic grayling are found in fresh waters at higher latitudes in the Northern Hemisphere, from Hudson Bay west across the Bering Strait to the Ob and Kara river drainages east of Asia’s Ural Mountains. In North America, the current native distribution of Arctic grayling is almost entirely restricted to northwestern Canada and Alaska (Scott and Crossman 1998, p. 301, 302). Arctic grayling native to northern Michigan were extirpated by around 1936 (Scott and Crossman 1998, p. 301), and by the 1990s their former broad distribution in streams of the Upper Missouri River were limited to the Big Hole River in southwestern Montana (Lohr et al. 1996). In Alaska, the Arctic grayling native range stretches across the entire mainland, but they are absent from most islands, except those formerly part of the Bering land bridge (Morrow 1980b, p. 145-146). Throughout their range, Arctic grayling are primarily restricted to fresh waters. Along the Arctic Ocean coast, they will descend downstream to feed in nearshore marine waters, but they appear to remain in the low salinity plume at the mouths of rivers or in lagoons (Furniss 1975; Tack 1980, p. 26).

Arctic grayling are widely distributed in Bristol Bay lakes (Burgner et al. 1965; Russell 1980, p. 49, 57; Yanagawa 1967, p. 12) and streams (Coggins 1992). They can occur in slow-flowing lowland streams where salmon, rainbow trout, and Dolly Varden are absent (ADF&G 2012), but they do not occur in many of the small shallow ponds on the coastal plain (Hildreth 2008, p. 9). In the absence of headwater lakes, their range often does not extend quite as far up the higher gradient headwater streams of the Nushagak and Kvichak river drainages as do Dolly Varden and rearing coho salmon, but they are found, at some time of the year, in most tributaries and downstream to the lower Nushagak and Kvichak rivers (ADF&G 2012; Krieg et al. 2009, p.365, 383). Sport anglers catch Arctic grayling across most of the Nushagak and Kvichak river drainages, with a particular focus on the Kvichak, Alagnak, Newhalen, Tazimina, Nushagak, Mulchatna, and Koktuli rivers, Lake Clark, and the Wood River and Tikchik lake systems (Minard et al. 1998, p. 189).

Nushagak and Kvichak river drainages stream spawning locations may represent sites that provide both warm spring and summer temperatures and suitable hydrology (Tack 1980, p. 3-4, 14-16, 27; Warner 1957). Some spawning may occur in lakes, at stream outlets (Warner 1957). Arctic grayling and rainbow trout are the only spring-spawning salmonids in the Nushagak and Kvichak river drainages, and both likely seek spawning sites that enhance incubation rates and early fry growth. Tack (1980, p. 14) reported that most interior Alaska spawning occurred in riffles with sand and gravel substrates and minimal silt, in currents ranging from 0.25 to 1 $m \cdot s^{-1}$. Reed (1964, p. 14) concluded that Alaska Arctic grayling did not target specific spawning substrates.

Best egg survival in the closely-related European grayling *T. thymallus* was 6 to 13.5 °C (Jungwirth and Winkler 1984). For much of the summer, age-0 fish tend to remain near the sites where they emerged from the spawning substrate (Craig and Poulin 1975; MacPhee and Watt 1973, p. 14, 15; Tack 1980, p. 27; Tripp and McCart 1974, p. 56). Given the August distribution of age-0 fry in the Nushagak–Mulchatna drainage (ADF&G 2012), it appears that most Arctic grayling spawning in this system occurs in tributaries.

When food is not limiting, optimal growth for age-0 juveniles in interior Alaska is at about 17 °C (Dion and Hughes 2004; Mallet et al. 1999). Older age classes may segregate to different habitats (Craig and Poulin 1975; Tack 1980, p. 29; Vincent-Lang and Alexandersdottir 1990, p. 50), but the details of that segregation may depend on the drainage-specific patterns of water temperature and food availability (Hughes 1998).

After spawning, adults may migrate further upstream (Hughes and Reynolds 1994; Vascotto 1970, p. 77; Wojcik 1954), or descend back to the mainstem (Craig and Poulin 1975; MacPhee and Watt 1973, p. 14; Tripp and McCart 1974, p. 49-51; Warner 1957), often using the same summer feeding areas annually (Ridder 1998, p. 17; Tack 1980, p. 21). Juveniles age 1 and older often follow adults, perhaps to imprint the complex migratory routes (Tack 1980, p. 20). In interior and southcentral Alaska, adult Arctic grayling overwinter in deep lakes and large rivers (Reed 1964, p. 13; Ridder 1998, p. 10-15; Sundet and Pechek 1985, p. 44; Tack 1980, p. 8, 28). Available evidence suggests the same pattern applies in the Nushagak River drainage. In August, Arctic grayling are absent or uncommon in the lower mainstem of the Nushagak River (ADF&G 2012). However, in this same area, local residents harvest large numbers of Arctic grayling through the ice during winter (Krieg et al. 2009, p. 220, 383).

Life cycle

Arctic grayling are nonanadromous, but often do undertake extensive seasonal migrations. Prior to spring breakup, large fish concentrate in mainstem rivers, at the mouths of tributaries. During and immediately after breakup, fish begin entering tributaries, even below ice cover and through channels on the ice surface (Reed 1964, p. 12-13; Warner 1957). In at least parts of Alaska, the upstream migration correlates with the peak of the spring freshet (Tack 1980, p. 13) and adults appear to show some fidelity to spawning areas (Craig and Poulin 1975; Tack 1980, p. 27). Nushagak and Kvichak river drainages Arctic grayling spawn in May through early June, shortly after breakup (Dye 2008, p. 26; Russell 1980, p. 57).

Mature female fecundity probably averages between about 4,000 and 7,000 ova, with some large fish producing much more (Scott and Crossman 1998, p. 303). Water-hardened eggs have an average diameter of around 3 mm and are non-adhesive (Reed 1964, p 14). Spawning adults do not actively construct redds (Craig and Poulin 1975), but their actions may create slight depressions in the stream substrate (Reed 1964, p. 13-14). Fertilized eggs fall into interstitial spaces, hatch in 2 to 3 weeks at lengths of about 8 mm (Scott and Crossman 1998, p. 303), and fry start feeding a few days later (Morrow 1980b, p. 146). Some age-0 fish in the Nushagak and Kvichak river drainages are free-swimming in early June, and perhaps even earlier in certain locations (Russell 1980, p. 57). Early growth rates appear related to temperature and benthic invertebrate densities (Tripp and McCart 1974, p. 21); on Alaska’s North Slope, growth rates of age-0 Arctic grayling correlate positively to stream temperature (Luecke and MacKinnon 2008).

In the Nushagak and Kvichak river drainages, age-0 fish reach a mean fork length of about 69 mm (n = 700, SD = 13.6 mm) by August (calculated from data provided by ADF&G 2012). After age 0, Arctic grayling in the Nushagak and Kvichak river drainages grow about 47 $mm \cdot y^{-1}$ until age 5 when growth begins to slow (Russell 1980, p. 60). Fish begin maturing at lengths of about 300 mm (FL), and once mature, grayling appear to spawn every year (Craig and Poulin 1975; Engel 1973, p. 8; Tripp and McCart 1974, p. 34). Bristol Bay Arctic grayling mature around age 5 (Russell 1980, p. 57), can live at least 13 years (Plumb 2006, p. 56), reach lengths of at least 650 mm (FL; MacDonald 1995, Table 7) and weights at least 0.9 kg (Russell 1980, p. 57). Alaska Arctic grayling may travel over 320 km between spawning, summer feeding, and overwintering locations (Reed 1964, p. 13; Ridder 1998, p. 10; Tripp and McCart 1974, p. 53).

Predator–prey relationships

Arctic grayling appear to feed on whatever is available to them, primarily aquatic and terrestrial insects, sequentially taking advantage of temporary peaks of abundance of different invertebrate populations (Plumb 2006, p. 62; Reed 1964, p. 20; Scheuerell et al. 2007; Tripp and McCart 1974, p. 60-61). Arctic grayling typically feed at the surface and mid-depth in the water column (Vascotto 1970), but food items include benthic slimy sculpin and slimy sculpin eggs (Bond and Becker 1963) and humpback whitefish eggs (Kepler 1973, p. 71). Scheuerell et al. (2007) discovered that in the Nushagak River drainage, after the arrival of spawning sockeye salmon, the energy intake of Arctic grayling increases more than five-fold, due primarily to the increased availability of benthic invertebrates. As spawning salmon construct redds and bury fertilized eggs, they disturb the substrate, displacing benthic macroinvertebrates, thus making them more available to Arctic grayling predation. In addition, Arctic grayling feed on salmon eggs and the larval blowflies that colonize salmon carcasses. These salmon-derived resources contribute a large majority of the energy necessary for the annual growth of nonanadromous Arctic grayling (Scheuerell et al. 2007). In lakes, Arctic grayling can be the most important prey species of lake trout (Troyer and Johnson 1994, p. 42). In Alaska Arctic streams, Stevens and Deschermeier (1986) found that some juvenile Dolly Varden eat age-0 Arctic grayling fry .

Abundance and harvest

In Bristol Bay total Arctic grayling abundance is unknown, but in 2009 the Nushagak and Kvichak river drainages and the adjacent Togiak River drainage supported an estimated sport fish catch of 44,762 fish (11% of the statewide total) and a harvest of 1,094 (4% of the statewide total; Jennings et al. 2011, p. 74). Dye and Schwanke (2009, p. 6) speculated that the ongoing trend of decreasing sport harvests are due in part to increasing catch-and-release practices.

In the mid-2000s, villagers from nine of the Nushagak and Kvichak river drainage communities annually harvested, as part of their subsistence activities, about an estimated 7,790 Arctic grayling (Fall et al. 2006, p. 45, 80, 113, 150, 194; Krieg et al. 2009, p. 40, 78, 118, 162, 202). From the mid-1970s to the mid-2000s, Arctic grayling were estimated to represent between 6.9 and 9.7% of the total weight of the Kvichak River drainage non-salmon freshwater fish subsistence harvest (Krieg et al. 2005, p. 214).

Stressors

Total dissolved solids up to 2,782 $mg{\cdot}l^{-1}$ do not have a significant impact on Arctic grayling egg fertilization; however, concentrations as low as 1,402 $mg{\cdot}l^{-1}$ do significantly affect water absorption during the water-hardening phase immediately following fertilization, when embryos gain resistance to mechanical damage (Brix et al. 2010). As a result, Brix et al. (2010) identified that period as the most sensitive early developmental stage.

Egg mortality in the closely-related European grayling *T. thymallus* was 100% at temperatures over 16 °C or under 4 °C (Jungwirth and Winkler 1984). In interior Alaska, the minimum and maximum temperatures at which growth occurs are 4.5 °C and 21 °C (Dion and Hughes 2004; Mallet et al. 1999). In interior Alaska, age-0 fish are more tolerant of high water temperatures than alevins and older juveniles, with a median tolerance limit in excess of 24.5 °C, compared to 20 to 24.5 °C for the other life stages (LaPerrier and Carlson 1973, p. 29).

In North Slope streams, the growth of age-0 fry is positively correlated with temperature, while adult growth has no temperature correlation (Deegan et al. 1999; Luecke and MacKinnon 2008). Adult and age-0 juveniles may also respond differently to stream discharge. Adult growth in North Slope streams is positively correlated with discharge, while age-0 growth is negatively correlated with it (Deegan et al. 1999; Luecke and MacKinnon 2008). Wojick (1954, p. 67) speculated that elevated stream discharges during the incubation and early fry rearing stage would harm Arctic grayling stocks.

Although reasons for the dramatic contraction in the native range of stream-resident Upper Missouri River Arctic grayling is not well understood, constructed barriers to fish migration and stream dewatering appear to be major contributing factors (Barndt and Kaya 2000).

OTHER SPECIES

Lampreys (Family Petromyzontidae)

Lamprey taxonomy is unsettled (e.g., Renaud et al. 2009), with particular confusion regarding the relationship between, and the taxonomic status of, nonparasitic nonanadromous forms and parasitic anadromous forms. Currently, the Nushagak and Kvichak river drainages are thought by some (ADF&G 2012; Docker 2009; Lang et al. 2009; Mecklenburg et al. 2002; Renaud et al. 2009) to be home to three lamprey species: Arctic lamprey *Lethenteron camtschaticum*, Alaskan brook lamprey *L. alaskense*, and Pacific lamprey *Entosphenus tridentatus* (nomenclature follows Brown et al. 2009). Arctic and Alaskan brook lamprey are closely allied, but are thought, at least by some, to be distinct, valid species (Vladykov and Kott 1978). The Arctic lamprey is believed to be the ancestral form, from which the species Alaskan brook lamprey is derived (a *satellite species*) (Renaud et al. 2009; Vladykov and Kott 1979). Summer field surveys typically capture juvenile lampreys (called *ammocoetes*) and there is no simple morphological method to distinguish juvenile Arctic lamprey from juvenile Alaskan brook lamprey, so some sources (e.g., ADF&G 2012) record the observations of juveniles that may represent either of the species collectively as "*Arctic-Alaskan brook lamprey paired species*". The spawning run of Arctic lamprey is targeted by subsistence fishers in the Yukon River (Brown et al. 2005; Osgood 1958, p. 48), but lamprey in the Nushagak and Kvichak river drainage are not targeted by subsistence (Fall et al. 2006; Krieg et al. 2009) or sport (Jennings et al. 2011) fisheries.

Freshwater distribution and habitats

The distribution of Arctic lamprey is almost circumpolar; in Alaska it is found in fresh waters in coastal drainages from the Kenai Peninsula west along the Alaska Peninsula and Aleutian Islands, and north to the Arctic coastal plain, as well as in the Yukon River system upstream to Canada (Mecklenburg et al. 2002, p. 62). The reported distribution of Alaskan brook lamprey is much more limited and disjunct, with isolated observations in Bristol Bay, the Kuskokwim, the lower and central Yukon River drainage (but see Sutton et al. 2011), and the Mackenzie River system (ADF&G 2012; Vladykov and Kott 1978). This reported limited and disjunct distribution is likely due in large part to limited appropriate field sampling efforts and ongoing taxonomic uncertainty. The same, or a very closely related species is reported in fresh waters of eastern Russia (Shmidt 1965, p. 16). Juveniles of the species combination "Arctic-Alaskan brook lamprey paired species", as well as individuals recorded as metamorphosed Alaskan brook lamprey have been observed widely across the Nushagak River drainage (there has been less basin-scale survey work conducted in the Kvichak River drainage) from mainstem habitats to smaller streams, but they appear absent from high gradient headwaters, as was reported for central Yukon River tributaries (Sutton et al. 2011). Most observations of adult Arctic lamprey in Bristol Bay are from near the coast (Heard 1966). Heard (1966) found that Alaskan brook lamprey were more common than Arctic lamprey in the Naknek River system.

Pacific lamprey are known to range in North American fresh waters from the Nushagak River drainage south to northern Baja California and in Asia from Bering Sea drainages south to Hokkaido, northern Japan (Froese and Pauly 2012). Pacific lamprey are rarely reported in Bristol Bay drainages (Heard 1966; Russell 2010).

Adults of all three Bristol Bay-area lamprey species spawn in gravel-bedded streams (Heard 1966; Russell 2010). Alaskan brook lamprey excavate small redds and spawn in streams ranging in width from 1.5 to more than 30 m wide, out of the main current in water depths ranging from 0.08 to 0.20 m deep, with velocities of 0.14 to 0.3 $m \cdot s^{-1}$ (Heard 1966). Juvenile lamprey select low velocity sites with fine sediments, into which they burrow (Sutton et al. 2011). While these sites have slow local currents, they are well oxygenated (Potter 1980). In Bristol Bay, juvenile Arctic-Alaskan brook lamprey are found in lakes as well as streams (ADF&G 2012; Heard 1966). Both Arctic and Alaskan brook lamprey were reported spawning in tributaries (Lower Talarik Creek and Copper River) to Iliamna Lake (Richard Russell, Alaska Department of Fish and Game (retired), King Salmon, AK, personal communication).

Life cycle

In the Naknek River system, adult Arctic lamprey range in length from 219 to 311 mm (Heard 1966), while adult Alaskan brook lamprey reach lengths of only 150 and 168 mm and females produce 2,200 to 3,500 ova, each averaging 0.9 mm in diameter (Vladykov and Kott 1978). Mature Pacific lamprey have a mean total length of around 537 mm (Docker 2009). Russell (2010) estimated the lengths of three Pacific lamprey spawning in a Naknek River tributary at between 406 and 574 mm.

In Alaska, including the Nushagak and Kvichak river drainages, anadromous adult Arctic lamprey migrate upstream from marine waters during fall and winter and overwinter in fresh water before spawning in tributary streams in May to early July (Richard Russell, Alaska Department of Fish and Game (retired), King Salmon, AK, personal communication; Bradford et al. 2008; Brown et al. 2005). Heard (1966) reported that Alaskan brook lamprey in Bristol Bay's Naknek River system also spawned from late May through early July and Russell (1974, p. 42) observed spawning in mid-May in Lower Talarik Creek. Pacific lamprey in the Naknek River system were observed spawning in late June (Russell 2010). All three Bristol Bay-area species excavate redds, often communally, in gravel and cobble substrates, into which they deposit their eggs (Heard 1966; Russell 2010). Lamprey are semelparous; all spawners die soon after breeding once.

Lamprey eggs hatch after incubating ~2 weeks and following an additional 1 to 3 weeks of development, larval fish emerge from redds and move downstream to slow-velocity sites where they burrow into fine sediments (Potter 1980). Larval Arctic lamprey leave the spawning redd at lengths of ~8 mm (Kucheryavyi et al. 2007). Juvenile movements tend to be downstream, but they may move short distances upstream or remain in one location for multiple years (Potter 1980). Lampreys have an extended larval stage lasting several years followed by a relatively brief adult stage. The larval form is referred to as an ammocoete, and its appearance and behavior contrasts markedly from the adult form. During a transformative period (metamorphosis) of a few months, ammocoetes develop eyes, fins, and a tooth-bearing oral disk and then usually live less than a year for nonanadromous forms to one or two years for anadromous forms before spawning once, then dying (Docker 2009; Hardisty 2006, p. 181; Lang et al. 2009).

Arctic and Alaskan brook lamprey transform at lengths of around 125 to 210 mm (ADF&G 2012; Docker 2009; Vladykov and Kott 1978). In the Naknek River system this transformation begins in early summer and is completed by August (Heard 1966).

Age at metamorphosis depends on growth rates, which are positively related to stream size and water temperature, and may take as long as 18 years (Potter 1980). Alaska Arctic lamprey can remain in their larval form for at least 8 years (Sutton et al. 2011). After metamorphosis, anadromous species migrate to marine waters to feed on the body fluids of fish and marine mammals (Scott and Crossman 1998, p. 44-45). Nonanadromous Alaskan brook lamprey feed little or not at all after transformation, and their lengths often shrink prior to spawning (ADF&G 2012; Vladykov and Kott 1978). Larval lamprey appear to produce pheromones which migrating adults use as cues to find spawning streams and other larval lamprey may use to find suitable rearing habitats (Fine and Sorensen 2010; Fine et al. 2004; Wagner et al. 2009).

Predator–prey relationships

Juvenile lamprey typically filter feed on organic detritus (Sutton et al. 2011), but will seasonally consume decaying carcasses of adult Pacific salmon (Kucheryavyi et al. 2007). Kucheryavyi et al. (2007) speculate that those larval lamprey with access to salmon carcasses grow more rapidly and accumulate enough energy stores so that they forego the parasitic, anadromous life stage, and transform to adults directly.

Whether Alaskan brook lamprey parasitize freshwater fish remains unsettled; but if they do, they do not seem detrimental to Bristol Bay fish populations (Greenbank 1954; Heard 1966; Vladykov and Kott 1978). Heard (1966) reported that adult Alaskan brook lamprey have been seen attached to, or are suspected of attaching to, Bristol Bay adult and juvenile sockeye salmon, rainbow trout, pygmy whitefish, and threespine sticklebacks.

Rainbow trout, among other fish, are known to eat lamprey eggs and larvae (Manion 1968). In Bristol Bay, a wide variety of birds and mammals feed on lamprey ammoecoetes, including Arctic terns *Sterna paradisaea*, mew, Bonaparte's, and herring gulls *Larus canus, L. philadelphia, and L. argentatus*, common goldeneye *Bucephala clangula*, greater yellowlegs *Tringa melanoleuca*, black-bellied plovers *Pluvialis squatarola*, American golden-plovers *P. dominica*, Hudonian godwits *Limosa haemastica*, common and red-breasted mergansers *Mergus merganser* and *M. serrator*, common loons *Gavia immer*, black-billed magpies *Pica hudsonia*, and river otters *Lutra canadensis* (Russell 2010; Richard Russell, Alaska Department of Fish and Game (retired), King Salmon, AK, personal communication).

Suckers (Family Catostomidae)

Alaska is home to one member of the sucker family, the longnose sucker *Catostomus catostomus*. In recent years, an estimated 2,800 longnose suckers were harvested annually in

Nushagak and Kvichak river drainage subsistence fisheries (Fall et al. 2006, p. 45, 80, 113, 150, 194; Krieg et al. 2009, p. 40, 78, 118, 126, 162, 202, 231), both for human consumption and for sled-dog food. Often longnose suckers were harvested incidentally in subsistence fisheries targeting other species (Krieg et al. 2009, p. 206). They are not a target of sport fisheries (Jennings et al. 2011).

Freshwater distribution and habitats

Longnose suckers range across Canada and northern United States from the Atlantic to the Pacific and north to Arctic Ocean drainages and west to far northeastern Asia (Scott and Crossman 1998). In Alaska, longnose suckers are widely distributed throughout the mainland (Morrow 1980b). Sundet and Pechek (1985) considered longnose suckers to be the most abundant large nonanadromous species in the lower mainstem of southcentral Alaska's Susitna River and they are common in the mainstem of the Yukon River and its major tributaries (Andersen 1983; Bradford et al. 2008). Longnose suckers are widely distributed and often abundant in the lakes, rivers, and larger streams of Bristol Bay, but they are largely absent from headwater areas (ADF&G 2012; Greenbank 1954; Russell 1980).

During summer in the Susitna River system, longnose suckers are found in a variety of habitats, including tributaries, side and upland sloughs, and the mainstem and do not appear to be very particular about water velocities or hydraulic conditions. They are found most frequently in the mainstem during spring and fall (and likely winter), and seem to move into off-channel and tributary habitats in mid-summer (ADF&G 1983b). Spawning has been observed in water depths of 15–30 cm deep, velocities of 0.3–0.45 $m \cdot s^{-1}$, over gravels and small cobbles (Geen et al. 1966).

Longnose suckers often are relatively sedentary or move randomly in summer, but may seasonally migrate hundreds of kilometers per year, and can move at least 60 km per day (Geen et al. 1966; Pierce 1977; Sundet and Pechek 1985; Tripp and McCart 1974).

Life cycle

Mature longnose suckers likely home to spawn in natal streams. In northern Canada, southcentral Alaska, and the Nushagak and Kvichak river drainages, they migrate upstream shortly after ice-out in the second half of May to spawn in mainstems and tributaries in late May to early June (Pierce 1977; Russell 1974, p. 42; Sundet and Pechek 1985; Tripp and McCart 1974). Spawning appears to occur in specific areas (Tripp and McCart 1974).

In Canada's Mackenzie River system, mean female fecundity (mean length 471 mm, range 425 to 525 mm) was 49,278 ova (range 23,935 to 107,988; Tripp and McCart 1974). In a small southcentral Alaska stream, mean fecundity was 26,248, with a range of 8,325 to 55,500 ova (Pierce 1977). Mature ova are 1.5–2 mm in diameter (Pierce 1977; Tripp and McCart 1974). Longnose suckers do not excavate redds and fertilized eggs fall into the interstitial spaces of the stream substrate (Geen et al. 1966).

In central British Columbia, eggs incubate for about 2 weeks at a temperature of 10° C before hatching. Larval fish emerge from the spawning gravel another 1 to 2 weeks later (Tripp and McCart 1974). Around one month after spawning, fry emerge from spawning gravels at a length of approximately 22 mm and begin migrating downstream to rearing areas, primarily at night, when stream levels are high and turbid, or on dark nights (Geen et al. 1966; Tripp and McCart 1974). Russell (1980) reported age-0 fry in Lake Clark's Chulitna Bay as early as June 20. Age-0 fish emigrate from southcentral Alaska spawning streams gradually from mid-July through mid-October (Pierce 1977).

Growth can be slow and fish can live at least 22 years; in some northern populations males may not begin to mature until age 9 and females until age 12 (Tripp and McCart 1974). In southcentral Alaska, males begin to mature at age 5 at lengths of around 208 mm, and most are mature at age 6; females mature begin to mature at age 7 at lengths of around 250 mm and most are mature at age 8 (Pierce 1977). Once longnose suckers mature, they probably spawn every year and can reach lengths of 575 mm (Tripp and McCart 1974).

Predator–prey relationships

Longnose suckers consume a wide range of benthic invertebrates and plants (Beamish et al. 1998; Scott and Crossman 1998). Longnose suckers are a favorite food of river otters (Crait and Ben-David 2006; Wengeler et al. 2010) and are known to be eaten by lake trout, northern pike, and burbot (Beamish et al. 1998; Russell 1980, p. 81, 96).

Mudminnows (Family Umbridae)

The taxonomy of the genus *Dallia* remains unsettled (Crossman and Ráb 1996), but currently most authors report a single species of mudminnow in Alaska—the Alaska blackfish *Dallia pectoralis*. Alaska blackfish were once harvested in large quantities in western Alaska subsistence fisheries (Brown et al. 2005; Osgood 1958, p. 241-242). In recent years, however, only an estimated 100 Alaska blackfish are harvested annually in Nushagak and Kvichak river drainage subsistence fisheries. (Fall et al. 2006, p. 45, 80, 113, 150, 194; Krieg et al. 2009, p. 39, 77, 117, 161, 201). They are not a target of Nushagak and Kvichak river drainage sport fisheries (Jennings et al. 2011).

Freshwater distribution and habitats

Alaska blackfish are native only to the western half of Alaska and the tip of Chukotka Peninsula at the extreme northeastern limit of Asia. This species is found only in and near the limits of Pleistocene Beringian refugia, and with the exception of Chukotkan populations, is endemic to Alaska (Scott and Crossman 1998, p. 339). In Alaska they range from the central North Slope west and south along the Bering Sea coast to Bristol Bay and up the Yukon drainage to the Fairbanks area. They also have been accidentally introduced to the Anchorage area (Morrow 1980b, p. 162). In Bristol Bay, Alaska blackfish are locally common or abundant in ponds, large lakes, and slow-moving or stagnant, small- to large-sized streams draining large flat expanses, particularly on the coastal plain. While they are present in the Wood River lakes near the coast, they seem absent or rare in the Tikchik lakes and Lake Clark and adjacent lakes further from the coast, and in higher gradient headwater streams (ADF&G 2012; Burgner et al. 1965; Hildreth 2008, p. 9; Payne and Moore 2006; Rogers et al. 1963; Russell 1980).

On Alaska's North Slope, Alaska blackfish were found among aquatic vegetation in slow-flowing channels and adjacent shallow lakes (Ostdiek 1956). Alaska blackfish typically occur on substrates composed of silt, mud, or decaying vegetation (Blackett 1962).

Life cycle

In the Nushagak River drainage's Lake Aleknagik, spawning occurs in the second half of July (Aspinwall 1965). Water-hardened eggs are about 2 mm in diameter, are very adhesive, and sink to the bottom or adhere to vegetation. About 10 days after spawning, fry hatch at a length of about 6 mm and reach 20 mm six weeks later (Aspinwall 1965).

In Bristol Bay, most females reach maturity at age 3 at lengths ≥49 mm and individuals reach at least age 8 and lengths of 220 mm (Aspinwall 1965; Hildreth 2008, p. 9). Most females appear to spawn annually, but some may spawn in alternate years (Aspinwall 1965). Individual lake-dwelling Alaska blackfish are not thought to make broad-scale movements, but remain relatively sedentary (Payne and Moore 2006); however Blackett (1962), in an interior Alaska stream, identified an apparent upstream migration after the mid-May ice break-up.

The esophagus is modified as an accessory respiratory organ, and Alaska blackfish can tolerated summer dissolved oxygen levels down to 2.30 ppm (Crawford 1974; Ostdiek 1956).

Predator–prey relationships

Alaska blackfish diet is dominated by benthic invertebrates including cladocerans, copepods, ostracods, larval dipterans, larval caddisflies, snails, and algae (Ostdiek 1956; Ostdiek and Nardone 1959; Payne and Moore 2006). In the Nushagak River drainage, northern pike are known to feed on Alaska blackfish (Chihuly 1979, p. 79-86), but because they are often the only fish species present in their preferred habitats (Scott and Crossman 1998, p. 340), perhaps the most important predators on small Alaska blackfish are larger Alaska blackfish.

Smelts (Family Osmeridae)

The smelt family has a circumpolar distribution across the northern hemisphere and is comprised of approximately 10 marine, anadromous, and freshwater species. As with many fish families, smelt taxonomy is unsettled (Scott and Crossman 1998, p. 311-312). Three smelt species have been reported in Bristol Bay fresh waters: rainbow smelt *Osmerus mordax*, pond smelt *Hypomesus olidus*, and eulachon *Thaleichthys pacificus* (Mecklenburg et al. 2002; Morrow 1980b; Nelle 2003).

In recent years, an estimated 3,200 pounds of smelt (likely a mix of rainbow and pond smelt; Richard Russell, Alaska Department of Fish and Game (retired), King Salmon, AK, personal communication) were harvested annually in Nushagak and Kvichak river drainage subsistence fisheries (Fall et al. 2006, p. 44, 79, 112, 149, 193; Krieg et al. 2009, p. 38, 76, 116, 160, 200). In 2009 an estimated 10,000 smelt (likely rainbow smelt) were harvested in the Kvichak, Nushagak, and Togiak drainage sport fisheries (Jennings et al. 2011, p. 79).

Freshwater distribution and habitats

rainbow smelt

In North America, the native freshwater range of rainbow smelt extends along the east coast from New Jersey to Labrador; and along the west coast from Vancouver Island through the Gulf of Alaska, and along the Bering Sea and Arctic Ocean coasts to the Mackenzie River delta area. In Asia, rainbow smelt range from Hokkaido to Arctic Ocean drainages west to the North

Atlantic. They have been introduced to the Great Lakes, where they are now abundant (Scott and Crossman 1998, p. 312-313).

Russell (2010) reported that rainbow smelt were abundant in winter, often under ice, in the lower and intertidal reaches of Bristol Bay mainstems and tributaries. They apparently begin moving from marine waters into the lower reaches of mainstem rivers in mid- to late September, where they remain until spawning in coarse substrates of mainstems and tributaries the following spring (Nelle 2003; Richard Russell, Alaska Department of Fish and Game (retired), King Salmon, AK, personal communication). They do not appear to range far inland from the Bristol Bay coast (Burgner et al. 1965; Greenbank 1954; Nelle 2003; Russell 1980).

pond smelt

Pond smelt have a very disjunct global distribution. In Asia they range from Korea to the Alazeya River, and after a gap of over 2700 km, occur again near the Kara Sea in the west-central Russian arctic. In North America they are restricted to Alaska and northwestern Canada, where they range from southcentral Alaska's Copper River delta westward to the Bering Sea coast and northward to the Kobuk River drainage, and after a gap of over 1000 km, in the lower Mackenzie River system (Scott and Crossman 1998, p. 308-309).

In Bristol Bay, pond smelt are reported only in low-elevation ponds and lakes near the coast, their tributaries and outlets, and mainstem estuaries (Burgner 1962; Froese and Pauly 2012; Hartman and Burgner 1972; Heard and Hartman 1966; Hildreth 2008, p. 9). They are known in Iliamna Lake, some of its tributaries, and the Kvichak River (Hartman and Burgner 1972; Siedelman et al. 1973, p. 22; Wiedmer *unpublished*), but they have not been reported in the lakes or streams of the upper Nushagak or Kvichak river drainages (ADF&G 2012; Burgner et al. 1965; Russell 1980). Age-1 and older pond smelt in lakes and ponds primarily feed in off-shore, open water habitats, except when mature adults move inshore to spawn in shallow, nearshore areas (Narver 1966).

eulachon

The global freshwater range of eulachon is limited to North America's Pacific coast from northern California to southwestern Alaska, and Bristol Bay is at the northwest limit of this distribution (Willson et al. 2006, p. 3). Eulachon appear to occur in Bristol Bay fresh waters in very low numbers (Nelle 2003) and because of the lack of specific observations within the Nushagak and Kvichak river drainages, eulachon are not examined further here.

Life cycle

rainbow smelt

Most or all Bristol Bay rainbow smelt populations appear to be anadromous (Mecklenburg et al. 2002, p. 174), and mature individuals have fork lengths from around 163 mm to 298 mm (Dion and Bromaghin 2008; Nelle 2003; Russell 2010). Across various river systems in Bristol Bay, rainbow smelt migrate upstream to spawning areas and spawn from mid-April to the second half of June (Dion and Bromaghin 2008; Nelle 2003; Russell 2010; Wiedmer *unpublished*). Estimated fecundity of Bristol Bay's Togiak River females range from 17,000 to 90,000 and average 52,000 (Dion and Bromaghin 2008). By late June, some rainbow smelt fry are free swimming, schooling, and migrating downstream to marine waters (Russell 2010).

In the Togiak River, both males and females begin to mature at age 2, and males live to at least age 8; females to at least age 6 (Dion and Bromaghin 2008). More northerly Alaska populations mature later and live to at least age 15 (Haldorson and Craig 1984).

pond smelt

Alaska pond smelt appear to be nonanadromous (Harvey et al. 1997). Pond smelt are capable of repeat spawning (Degraaf 1986), but in southwest Alaska, most pond smelt spawn only once, then die (Narver 1966). Adult pond smelt in southwest Alaska, including the Nushagak and Kvichak river drainages, migrate upstream in May and spawn from late May to late June in both shallow open nearshore lake habitats with organic sediments and in lake tributaries (Harvey et al. 1997; Narver 1966; Russell 1974, p. 42). Eggs are adhesive and 6-mm-long fry hatch in about 18 days (Scott and Crossman 1998, p. 309) and are free swimming by the end of July (Narver 1966). In late August and September, young-of-the-year fry, 20–30 mm long, migrate downstream to overwintering areas (Harvey et al. 1997).

By August of the following year, pond smelt reach ~58 mm, and the year after they are ~82 mm long (Narver 1966). In southwest Alaska, most pond smelt live until age 2, or at most age 3 (Narver 1966), but in more slowly growing arctic populations age of maturity is 3 and fish may live to at least age 9 (Degraaf 1986). In southwest Alaska lakes where population estimates were made across multiple years, pond smelt abundance varies widely from year to year (Narver 1966).

Predator–prey relationships

rainbow smelt

Rainbow smelt are known to prey on both invertebrates and fish, including young-of-the-year slimy sculpin (Brandt and Madon 1986; Dion and Bromaghin 2008; Haldorson and Craig 1984), but the feeding of anadromous individuals may be largely limited to marine and estuarine areas (Dion and Bromaghin 2008; Haldorson and Craig 1984). In Bristol Bay, during their spawning migrations, high densities of rainbow smelt attract an abundant and diverse assemblage of predators, including mergansers, osprey, bald eagles, mew and glaucous-winged gulls, rainbow trout, and river otters (Russell 2010; Wiedmer *unpublished*).

pond smelt

Pond smelt feed primarily on zooplankton (Degraaf 1986; Hartman and Burgner 1972). While pond smelt may compete with young sockeye salmon for food, no population-level impacts have been demonstrated in Bristol Bay. Pond smelt may provide sockeye salmon fry a buffer from the predations of Arctic char and lake trout (Burgner et al. 1969; Hartman and Burgner 1972).

Salmonids (Family Salmonidae)

In abundance, diversity, ecosystem function, and human use and interest, the 15 extant salmonid species dominate most Nushagak and Kvichak river drainage freshwater fish communities. The Nushagak and Kvichak river drainages annually produce many hundreds of millions of juvenile salmonids, yielding tens of millions of adults (Eggers and Yuen 1984; West et al. 2012). The salmonid family is comprised of three subfamilies, each with representatives in Bristol Bay: salmon, trout, and char (Subfamily Salmoninae); grayling (Subfamily Thymallinae); and whitefish (Subfamily Coregoninae) (Mecklenburg et al. 2002, p. 178-209). The Nushagak and

Kvichak river drainages are home to five species of Pacific salmon, one trout, and three char. The five salmon species: coho salmon *Oncorhynchus kisutch*, Chinook salmon *O. tshawytscha*, sockeye salmon *O. nerka*, chum salmon *O. keta*, and pink salmon *O. gorbuscha* are grouped taxonomically in the same genus with rainbow trout/steelhead *O. mykiss*. Appendix A of this report details the life history traits of the five native Pacific salmon species and rainbow trout are covered in the *Harvested Fish* section of Appendix B. The three char species are members of the genus *Salvelinus*: Dolly Varden *S. malma*, Arctic char *S. alpinus*, and lake trout *S. namaycush* and each are discussed earlier in this appendix, as is Arctic grayling *Thymallus arcticus*. Five species in two whitefish genera are also reported in the Nushagak and Kvichak river drainages: Bering cisco *Coregonus laurettae*, least cisco *C. sardinella*, humpback whitefish *C. pidschian*, pygmy whitefish *Prosopium coulterii*, and round whitefish *P. cylindraceum.* The taxonomic status of members of the genus *Coregonus* is particularly unsettled (e.g., Scott and Crossman 1998, p. 230). Humpback whitefish are described earlier in this appendix. Specific observations of Bering cisco in the Nushagak and Kvichak river drainages are absent or rare, and this species may be largely limited to the area's estuaries (Froese and Pauly 2012), so they will not be discussed further in this report. The remaining three species are outlined below.

In recent years, an estimated 600 round whitefish and less than 50 least cisco were harvested annually in Nushagak and Kvichak river drainage subsistence fisheries (Fall et al. 2006, p. 45, 80, 113, 150, 194; Krieg et al. 2009, p. 40, 78, 118, 162, 202), and neither species is targeted by sport fisheries (Jennings et al. 2011). Pygmy whitefish are not targeted by subsistence or sport fisheries in the Nushagak and Kvichak river drainages (Fall et al. 2006; Jennings et al. 2011; Krieg et al. 2009).

Freshwater distribution and habitats

least cisco

The least cisco is nearly circumpolar in its range, which extends in Arctic Ocean drainages from the central Canadian arctic to northern Europe, and in Bering Sea drainages in both Asia and North America (Scott and Crossman 1998, p. 263-264). In Alaska it is widely distributed in lakes and rivers across the mainland north of the Alaska Range (Mecklenburg et al. 2002, p. 182). In the Nushagak and Kvichak river drainages, the reported distribution of least cisco is centered in and around Lake Clark, including Hoknede and Lower Pickeral lakes and the Chulitna River (Russell 1980, p. 77). While abundant in Lake Clark's offshore, open-water zone (Schlenger 1996, p. 78, 88), it is appears to be less so in Iliamna Lake (Kerns 1968) and low velocity sites in the Kvichak and Alagnak rivers (Wiedmer *unpublished*). Least cisco occur in the Nushagak River's Tikchik lakes, but not in the Wood River lakes (Burgner et al. 1965, p. 4), nor in Bristol Bay tundra ponds near the coast (Hildreth 2008, p. 9). Haas (2004; identification corroborated by Dan Young NPS, Port Alsworth, AK, personal communication) tentatively identified least cisco in morainal lakes west of Iliamna Lake. In Lake Clark, least ciscos are much more abundant in the northern, glacially turbid waters, perhaps in response to predation risk (Schlenger 1996, p. 78, 88).

The Chulitna River system may provide spawning and/or juvenile rearing habitat for Lake Clark least cisco, as local residents reported that in late June juvenile least ciscos migrate out of the Chulitna River to Lake Clark (Russell 1980, p. 77).

pygmy whitefish

The pygmy whitefish is a nonanadromous species with a strikingly disjunct global distribution in north-central and northwestern North America and far northeastern Asia (Eschmeyer and Bailey 1955; Wiedmer et al. 2010). Pygmy whitefish typically inhabit cold, deep lakes and glacially fed rivers, most within the footprint of the Laurentide and Cordilleran ice sheets (Weisel et al. 1973). Even where they occur regionally, researchers have noted the apparent absence of pygmy whitefish from seemingly suitable habitats, perhaps because they are particularly vulnerable to predation or competition (Bird and Roberson 1979; Chereshnev and Skopets 1992). Their extirpation from an estimated 40% of their historic habitats in Washington State, at the southern limit of their range, was attributed to piscicides, introduction of exotic fish species, and/or declining water quality (Hallock and Mongillo 1998, p. 9).

In the Nushagak and Kvichak river drainages, pygmy whitefish have been reported in Iliamna, Kontrashibuna, Tikchik, Nuyakuk, and Little Togiak lakes; Twin Lakes; lakes Clark, Beverley, Nerka, and Aleknagik; southern tributaries to the Chulitna River near Nikabuna Lakes (mapped by Wiedmer et al. 2010); Caribou Lakes (local name for lakes in the headwaters of the Koksetna River, Woods and Young 2010), and Summit Lakes (Dan Young, NPS, Port Alsworth, AK, personal communication). They are not known to occur in Bristol Bay tundra ponds (Haas 2004; Hildreth 2008, p. 9), and their distribution in rivers and streams appears to be very limited (ADF&G 2012).

Where they do occur, pygmy whitefish occupy a wide variety of ecological habitats in Bristol Bay lake systems; from shallow nearshore areas less than 1 m deep to offshore zones at depths of at least 168 m, and from near the bottom to the surface over deep water and in some adjacent streams. (ADF&G 2012, sites PEB91CH001 and PEB91CH007; Heard and Hartman 1966; Russell 1980, p. 98). In the absence of competitors or predators, pygmy whitefish will feed during the day in shallow, nearshore areas (Zemlak and McPhail 2006). However, in low turbidity lakes with competitors and/or predators, pygmy whitefish are often found only at depth, particularly during the day (Eschmeyer and Bailey 1955; McCart 1965; Plumb 2006; Rankin 2004, p. 95). Pygmy whitefish may segregate by age, with younger fish in shallower nearshore areas, and older fish in offshore benthic habitats (Eschmeyer and Bailey 1955, p. 179; Heard and Hartman 1966). Pygmy whitefish often spawn in lake inlet or outlet streams (Heard and Hartman 1966; Weisel et al. 1973), but will spawn in lakes (Hallock and Mongillo 1998, p. 4).

Pygmy whitefish are typically found in water temperatures below 10° C (Hallock and Mongillo 1998, p. 6), but they can tolerate dissolved oxygen levels less than 1.0 $mg{\cdot}l^{-1}$ (Zemlak and McPhail 2006). Because they tend to aggregate in large, mobile schools (Zemlak and McPhail 2006), the abundance of pygmy whitefish in particular locations may appear to vary dramatically.

round whitefish

In North America, round whitefish range from Connecticut north along the North Atlantic coast, including the St. Lawrence River/Great Lakes system, and west across Canada’s and Alaska’s Arctic Ocean and Bering Sea drainages, and south to the Gulf of Alaska. In Asia it is distributed from the Kamachatka Peninsula north and west to the Yenisei River in the central Russian arctic (Scott and Crossman 1998, p. 287-289). Round whitefish are distributed across all of mainland Alaska except for southern Southeast (Mecklenburg et al. 2002, p. 189; Morrow 1980b, p. 41).

Round whitefish are broadly distributed and abundant in many of the streams and lakes of the Nushagak and Kvichak river drainages, but they are absent or uncommon in headwater streams or coastal tundra streams or lakes (ADF&G 2012; Burgner et al. 1965; Hildreth 2008, p. 9; Russell 1980, p. 104).

In southcentral Alaska's Susitna River, round whitefish are more likely to be found feeding in tributaries and off-channel habitats in summer, and migrating in the mainstem in spring and fall from and to mainstem overwintering habitats (ADF&G 1983b, p. G-20 - G-21; Sundet and Pechek 1985, p. 44-45). During summer, they do not demonstrate a preference for water velocity (ADF&G 1983b, p. F-28). While they prefer Susitna River tributaries, they are commonly encountered during the summer in the mainstem Yukon (Andersen 1983, p. 15, 18, 21; Bradford et al. 2008) and Nushagak and Kvichak rivers (ADF&G 2012).

Spawning areas include mainstem rivers, tributary mouths, and inshore areas of lakes (Morrow 1980b, p. 33; Sundet and Pechek 1985, p. 45). Juvenile round whitefish in the Susitna River system were found more often in the turbid mainstem and in off-channel sites than in tributaries, presumably using higher turbidity water as cover from predation (Sundet and Pechek 1985, p. 44-45).

Life cycle

least cisco

The life history patterns of least cisco are broadly similar to those of the humpback whitefish discussed earlier in this appendix. Both species have populations that migrate seasonally between lakes and rivers and populations that are nonmigratory lake residents (Morrow 1980b, p. 29). The least cisco of the Nushagak and Kvichak river drainages may not undertake large migrations, and some may spend their entire lives in single lakes. At least some of the putative least cisco found by Haas (2004) live in lakes with no apparent inlets or outlets, suggesting that these fish remain in their natal lake for life.

Unlike least ciscos in the lower Kuskokwim River drainage (Harper et al. 2007, p. 13) to the north, populations in the Nushagak and Kvichak river drainages appear to be nonanadromous (Mecklenburg et al. 2002, p. 182). While anadromous lower Kuskokwim River drainage individuals do not mature until they reach lengths of 300 mm and age 3, and can grow to at least 450 mm and live to at least age 14 (Harper et al. 2007, p. 13); Lake Clark area least cisco also mature at age 3, but at lengths of only ~145–180 mm, and reach a maximum length of ~276 mm and a reported maximum age of 9 (Russell 1980, p. 77, 85; Schlenger 1996, p. 42).

Mature least cisco in the Kuskokwim River drainage may not spawn every year (Harper et al. 2007, p. 13, 21), but the frequency of spawning in Bristol Bay waters is unknown. The fecundity of sampled large (280 to 420 mm FL) migratory female least cisco in interior Alaska ranges from 11,500 to 111,600 ≤1-mm diameter ova, but the fecundity of the much smaller Nushagak and Kvichak river drainage fish is not reported, and presumably averages less than 11,000 (Clark and Bernard 1992; Morrow 1980b, p. 28).

pygmy whitefish

Pygmy whitefish grow slowly, have low fecundity, and most live short lives (Eschmeyer and Bailey 1955; Heard and Hartman 1966), although some individuals can live to at least age 16 (Rankin 2004, p. 90-92). Maximum total length for individuals in many populations is around 120–140 mm (Chereshnev and Skopets 1992; Eschmeyer and Bailey 1955; Plumb 2006, p. 14; Russell 1980, p. 91). In Bristol Bay, the longest reported length was 163 mm for an age-5 female (Heard and Hartman 1966), and the greatest age was 7 years (Plumb 2006, p. 19). In some Bristol Bay lakes, the maximum age of sampled fish was only 3, and the maximum length was only 83 mm (Heard and Hartman 1966). Across their global range, males and females mature at ages 1 to 4 and lengths as small as 53 to 56 mm (Bird and Roberson 1979; Chereshnev and Skopets 1992; Eschmeyer and Bailey 1955; Heard and Hartman 1966; McCart 1965; Weisel et al. 1973). Heard and Hartman (1966) reported that mature female pygmy whitefish in the lakes of Bristol Bay's Naknek River system produced from 103 to 1,153 ova per year, each measuring an average of 2.4 mm in diameter. Once mature, pygmy whitefish appear to spawn annually (Chereshnev and Skopets 1992; Weisel et al. 1973). Heard and Hartman (1966) concluded that pygmy whitefish in the Naknek River system spawn at night from mid-November to mid-December.

round whitefish

Round whitefish are nonanadromous freshwater residents (Mecklenburg et al. 2002, p. 189) and many do not appear to undertake lengthy migrations (Morrow 1980b, p. 33). In interior Alaska lakes and in the Nushagak and Kvichak river drainages, round whitefish mature at lengths between 220 mm and 290 mm (TL), at ages between 4 and 8 years, and once mature, most spawn annually (Russell 1980, p. 104; Van Whye and Peck 1968, p. 36). In southwest Alaska round whitefish live to at least age 14 and reach lengths of around 420 mm (Russell 1980, p. 104). Furniss (1974, p. 11) reported that the fecundity of northern Alaska round whitefish (mean length = 409 mm) was around 5,300 ova.

Sundet and Pechek (1985, p. 45) concluded that the peak of spawning in the Susitna River system was from mid- to late October. Round whitefish deposit their eggs on the substrate, but do not excavate redds (Morrow 1980b, p. 33). Eggs incubate through the winter and after the young hatch, they remain in the redd absorbing their yolk sac for several more weeks before emerging in late winter to early spring (Scott and Crossman 1998, p. 288).

Predator–prey relationships

least cisco

The diet of Lake Clark-area least cisco includes a wide range of invertebrates including plecoptera nymphs, chironomid nymphs and adults, trichoptera adults, and copepods (Russell 1980, p. 87, 88; Schlenger 1996, p. 57). Because of their diet overlap, Kerns (1968) considered least cisco the most important competitor of juvenile Lake Clark sockeye salmon. Lake Clark lake trout and northern pike are known to feed on least cisco (Metsker 1967, p. 29; Russell 1980, p. 83, 96), and burbot and predatory birds are reported to feed on them in other parts of Alaska (Morrow 1980b, p. 29).

pygmy whitefish

Multiple morphological and ecological pygmy whitefish morphs can occur in individual Bristol Bay lakes (McCart 1970), but invertebrates dominate the diet of all morphs. Pelagic morphs feed primarily on plankton while benthic morphs feed primarily on larval insects (particularly chironomids) and mollusks (Chereshnev and Skopets 1992; Heard and Hartman 1966; McCart 1970). Pygmy whitefish are flexible in their diet (Heard and Hartman 1966; Plumb 2006, p. 46, 51-52; Weisel et al. 1973), and will eat the eggs of whitefish when they are available (Eschmeyer and Bailey 1955). Terns, Dolly Varden, lake trout, and Arctic char are all known to feed on pygmy whitefish (Hallock and Mongillo 1998; Russell 1980, p. 98; Scanlon 2000, p. 51, 53-54; Snyder 1917).

round whitefish

In the Nushagak and Kvichak river drainages, adjacent areas, and elsewhere in Alaska, round whitefish eat primarily benthic invertebrates, including trichopteran and chironomid larvae and snails (Furniss 1974, p. 11, 22, 36; Russell 1980, p. 108; Van Whye and Peck 1968, p. 37). Round whitefish will feed on salmon and other whitefish eggs when they are available (Brown 2006, p. 23; Van Whye and Peck 1968, p. 37). In the Nushagak and Kvichak river drainages and adjacent areas, burbot, lake trout, and northern pike are known to prey on round whitefish (Russell 1980, p. 67, 81-82, 95-96).

Cods (Family Gadidae)

Almost all of the approximately 30 to 60 cod species worldwide are found in cool marine waters, mostly in the northern hemisphere. Like many orders of fish, taxonomy, in this case at the family level, remains unsettled (Froese and Pauly 2012; Mecklenburg et al. 2002, p. 269; Scott and Crossman 1998, p. 640), explaining in part the broad range of species reported in the cod family. Two of the primarily marine cods, Pacific cod *Gadus macrocephalus*, and saffron cod *Eleginus gracilis*, may periodically enter the lower reaches of the Nushagak and Kvichak rivers, but their freshwater distribution appears very limited (Mecklenburg et al. 2002, p. 293, 296; Morrow 1980b, p. 185-188), and they are not discussed further here. Only one of the cods, the burbot *Lota lota*, is exclusively a freshwater resident everywhere it occurs and it is discussed below.

Less than an estimated ~400 burbot are harvested annually in Nushagak and Kvichak river drainage subsistence fisheries (Fall et al. 2006, p. 45, 80, 113, 150, 194; Krieg et al. 2009, p. 39, 76, 117, 161, 201) and they are not a target of the regional sport fishery (Jennings et al. 2011, p. 77).

Freshwater distribution and habitats

Burbot range broadly across the mainland fresh waters of both North America and Eurasia, north of about 40° N (Scott and Crossman 1998, p. 642). Burbot are found throughout mainland Alaska, except for southern Southeast (Mecklenburg et al. 2002, p. 289; Morrow 1980b, p. 187). Burbot are reported in many lakes and streams across the Nushagak and Kvichak river drainages, but they are uncommon or absent in small headwater streams or the lakes and streams of the coastal tundra plain (ADF&G 2012; Burgner et al. 1965, p. 4; Hildreth 2008, p. 9; Russell 1980, p. 64-65; Yanagawa 1967, p. 10).

Burbot live in Alaska lakes (e.g., Schwanke and McCormick 2010), and in large river systems like the Yukon River drainage (Andersen 1983, p. 18, 21; Evenson 1998). In southcentral Alaska's Susitna River, burbot reside mostly in highly turbid waters, both in the mainstem and in off-channel habitats (ADF&G 1983a, p. F-26; ADF&G 1983b, p. F-21, G-20; Sundet 1986, p. 33; Sundet and Pechek 1985, p. 32). In the Susitna River system they spawn both in the mainstem and in low-gradient tributaries at sites with water velocities of 0–0.6 $m \cdot s^{-1}$ (0.0-2.1 $ft \cdot s^{-1}$), depths of 0.6–2.7 m (0.2–9.0 ft), over sand to cobble substrates, possibly in conjunction with upwelling and in areas where anchor ice does not form (Sundet 1986, p. 36-37) (Sundet 1986; Sundet and Pechek 1985, p. 33, 42). In Lake Michigan, their preferred summer water temperature range is 8–13° C (Edsall et al. 1993). Large Alaska river systems may support multiple discrete burbot stocks (Evenson 1988).

Life cycle

Burbot are nonanadromous, freshwater residents, although they may venture into brackish or marine waters (Chen 1969, p. 1). Size at maturity appears to vary across Alaska, and burbot may mature at lengths from 310 to 500 mm, at ages of around 4 to 7 (Chen 1969, p. 36; Evenson 1990; Sundet and Pechek 1985, p. 33). After they mature, most, but not all, individuals spawn each year (Chen 1969, p. 35; Clark et al. 1991, p. 5; Evenson 1990; Sundet and Pechek 1985, p. 33).

In the Susitna River system, mature burbot begin migrating from mainstem summer feeding areas to spawning areas in mid-September to mid-October. While most individuals may move little, some fish will seasonally migrate several hundred kilometers (Evenson 1988, p. 14, 30; Sundet 1986, p. 37; Sundet and Pechek 1985, p. 33). In southcentral and interior Alaska, burbot spawn from mid-January to early February (Chen 1969, p. 20; Sundet 1986. p. 37; Sundet and Pechek 1985. p. 33).

Interior Alaska female burbot (lengths ranging from 504 to 1,040 mm) have estimated fecundities ranging from 184,000 to 2,910,000 ova (Clark et al. 1991, p. 6-8). Eggs are demersal, nonadhesive, and 0.4 to 0.7 mm in diameter (Clark et al. 1991, p. 5). Because it occurs under the ice, details are limited, but Alaska burbot are thought to communally spawn and scatter their eggs near the substrate, where they fall into interstitial spaces. In the Tanana River drainage, eggs are thought to hatch in late April, young-of-the-year fry reach 20 mm long in June, and grow rapidly to lengths of at least 108 mm by early October (Chen 1969, p. 20, 29).

In Alaska, burbot can reach an age of at least 24 years, but most do not appear to live longer than 15 years (Chen 1969, p. 27, 28). In interior Alaska, burbot can reach lengths of at least 1,135 mm (TL; Hallberg 1986), but the largest reported by Russell (1980, p. 64) in the lakes and rivers of the Nushagak and Kvichak river drainages was only 597 mm TL and the oldest was only 11. Burbot of the Nushagak and Kvichak river drainages may mature at a smaller size and younger age and be less fecund than those of the Yukon and Tanana river drainages.

Predator–prey relationships

The diet of young-of-the-year burbot is primarily aquatic insects (Plecoptera, Ephemeroptera, Diptera, and Trichoptera), but as they grow, fish become an increasingly important part of their diet (Chen 1969, p. 42, 43). In the Nushagak and Kvichak river drainages, burbot feed primarily on least cisco, lake trout, round whitefish, sculpin, and larval and adult insects (Russell 1980, p.

67). In other areas, burbot are also known to eat large quantities of whitefish eggs (Bailey 1972), which are available late in the year in the Nushagak and Kvichak river drainages, and lamprey, longnose suckers, and northern pike. Large burbot also prey on small burbot (Chen 1969, p. 42).

Sticklebacks (Family Gasterosteidae)

Members of the stickleback family occur in fresh and nearshore marine waters throughout much of the northern hemisphere north of about 30° N (Scott and Crossman 1998, p. 656). Two, the threespine stickleback *Gasterosteus aculeatus*, and the ninespine stickleback *Pungitius pungitius* are found in the waters of the Nushagak and Kvichak river drainages (Scott and Crossman 1998, p. 656). Across their global ranges, both threespine and ninespine sticklebacks exhibit extensive morphological variations, and some authors (e.g., Nelson 1971) refer to them as species complexes. Here we refer collectively to all members of each species complex by their common names. While sticklebacks may once have been the target of directed harvests by Nushagak and Kvichak river drainage residents (e.g., Krieg et al. 2009, p. 190), they are currently caught only in small numbers in a few locations, principally through the ice in subsistence fisheries (Fall et al. 2006, p. 69, 80, 335), and are not harvested in sport fisheries (Jennings et al. 2011).

Freshwater distribution and habitats

threespine stickleback

This species is nearly circumpolar in distribution, although that distribution has considerable discontinuities (Scott and Crossman 1998, p. 666). In Alaska, where up to four distinct phenotypes have been reported (Narver 1969; Willacker et al. 2010), threespine sticklebacks are reported near the coast from southern Southeast to the Bering Strait, but records west and north of Bristol Bay are uncommon (ADF&G 2012; Mecklenburg et al. 2002, p. 333; Morrow 1980b, p. 333). In and near the Nushagak and Kvichak river drainages, threespine stickleback are reported both in lowland and upland lakes and in river systems from estuaries to medium-sized streams, where they are primarily associated with sites with low current velocity (ADF&G 2012; Burgner et al. 1965; Haas 2004; Hildreth 2008, p. 9; Kerns 1968; Russell 1980, p. 111). They are common in the Kvichak River and in the lower reaches of some Iliamna Lake tributaries. Many of the large individuals encountered during the late summer in the Kvichak River appear to be moribund post-spawners (Wiedmer *unpublished*), a pattern observed elsewhere in southwest Alaska (Harvey et al. 1997). They can occur in swifter streams (Bond and Becker 1963), but appear largely absent from headwaters (ADF&G 2012).

In streams, they have a significant preference for low velocity, deeper (>0.2 m) habitats with extensive aquatic vegetation and high oxygen concentrations. They prefer to be away from stream banks and riparian cover, perhaps to avoid the fish predators that dwell there (Copp and Kováč 2003). In some Nushagak and Kvichak river drainage lakes, such as Iliamna Lake, they are abundant in offshore open waters (Hartman and Burgner 1972; Kerns 1968). Stickleback have an affinity for their native habitat type (lake or stream), and that affinity parallels morphological and genetic divergence (Bolnick et al. 2009), leading to genetically distinct populations, even in a given drainage (Reusch et al. 2001). In lakes of southwest Alaska, spawning and early development is in shallow, nearshore areas; as fish mature they may remain nearshore or move to open, offshore waters (Hartman and Burgner 1972; Narver 1966).

ninespine stickleback

The ninespine stickleback has a circumpolar distribution across the northern hemisphere (Scott and Crossman 1998, p. 672, 673). In Alaska it is found from the Kenai Peninsula west and north to waters draining to the Arctic Ocean. While Mecklenburg et al. (2002, p. 334) map its range across most of mainland Alaska, it appears to be absent or infrequent away from coastal areas (ADF&G 2012; Morrow 1980b, p. 194). In the Nushagak and Kvichak river drainages, ninespine stickleback are more widespread than threespine stickleback. Ninespine sticklebacks can tolerate low dissolved oxygen concentrations and are reported both in lowland and upland ponds and lakes (Burgner et al. 1965; Hartman and Burgner 1972; Hildreth 2008, p. 9; Morrow 1980b, p. 192; Russell 1980, p. 87). They occur from the lower mainstem rivers to headwaters (ADF&G 2012), but are primarily associated with shallow, low velocity sites with emergent vegetation (Russell 1980, p. 87). In southwest Alaska lakes, spawning occurs in shallow, nearshore areas with organic substrates and rooted aquatic plants (Narver 1966). In Iliamna Lake and Lake Clark, they are largely absent from offshore areas (Kerns 1968).

Life cycle

threespine stickleback

Threespine sticklebacks can have either anadromous or nonanadromous life histories, and anadromous individuals migrate in May (Harvey et al. 1997; Sundet and Pechek 1985) from the sea to spawning areas at least 60 km up major North American Pacific coast river systems (Virgl and McPhail 1994). The distribution of anadromous individuals in the Nushagak and Kvichak river drainages is unknown. In southwest Alaska, including the Nushagak and Kvichak river drainages, most spawners are age 2 or 3, most spawning occurs in June and early July, and often occurs in beds of aquatic plants (Bond and Becker 1963; Narver 1966; Russell 1974, p. 42). Males establish and defend territories, and construct, with vegetation and sand, barrel-shaped nests into which females deposit eggs (Morrow 1980b, p. 190). Total fecundity varies considerably depending on food availability during the mating season (Wootton and Evans 1976) and can range from 80 to 1,300 ova (Morrow 1980b, p. 190). Young-of-the-year fry emerge from their nests at lengths of around 7 mm in late July to early August, and by the end of August reach lengths of around 27 mm (Dunn 1962; Harvey et al. 1997; Morrow 1980b, p. 190; Narver 1966). In southwest Alaska, most individuals do not live beyond two or three years, reach lengths to around 80 mm, and probably only spawn once (Dunn 1962; Narver 1966; Russell 1980, p. 111).

ninespine stickleback

Alaska ninespine sticklebacks are primarily nonanadromous (Morrow 1980b, p. 192-193). In some southwest Alaska lakes, ninespine sticklebacks mature at ages 1 to 2 and migrate upstream in May to spawn (Harvey et al. 1997; Narver 1966). Spawning occurs from late June through at least mid-July and, like threespine sticklebacks, males construct nests in which multiple females lay batches of eggs, perhaps 50 to 80 at a time. Total female fecundity reportedly ranges up to 1,000 ova (Froese and Pauly 2012). Eggs hatch in about a week to ten days and the male parent guards and fans the nest while the eggs incubate and the larval fish develop (Morrow 1980b, p. 193; Narver 1966). By late July young-of-the-year fry are free-swimming and some may migrate to downstream feeding and overwintering habitats (Harvey et al. 1997). Egg development and early growth is very rapid; by the end of August fry reach lengths of around 36 mm (Narver

1966). In southwest Alaska, ninespine stickleback reach lengths of around 60 mm and most spawn only once (ADF&G 2012, e.g., Site FSB0318A06; Harvey et al. 1997; Narver 1966).

Predator–prey relationships

threespine stickleback

Copp and Kováč (2003) reported that the diet of threespine sticklebacks was dominated by cladocerans, copepods, amphipods, chrinomids, and ostracods. Considerable competition between age-0 sockeye and similarly sized age-1 threespine stickleback may occur in lakes of the Nushagak and Kvichak river drainages, and dense populations of sockeye fry may displace threespine sticklebacks from open water habitats (Hartman and Burgner 1972; Kerns 1968).

A wide variety of birds and fish in the Nushagak and Kvichak river drainages feed on threespine sticklebacks, including adult Arctic char, northern pike, and rainbow trout (Bond and Becker 1963; Hartman and Burgner 1972; Metsker 1967). Threespine sticklebacks are also preyed on by large aquatic macroinvertebrates such as immature dragonflies (Lescak et al. 2012) and are particularly vulnerable to a host of parasites (Scott and Crossman 1998, p. 667-668; Wiedmer unpublished).

ninespine stickleback

The diet of ninespine sticklebacks is dominated by small aquatic invertebrates, similar to the diet of threespine sticklebacks (Morrow 1980b, p. 194). In the Nushagak and Kvichak river drainages, ninespine sticklebacks are preyed on by a wide variety of birds and fish, including lake trout, northern pike, and rainbow trout (Bond and Becker 1963; Russell 1980, p. 67, 96).

Sculpins (Family Cottidae)

Most of the approximately 70 genera and 300 species of sculpins making up the Family Cottidae live near the bottom of northern marine waters. While only a few species are primarily freshwater residents (Mecklenburg et al. 2002, p. 398), they can be important parts of salmonid stream ecosystems (Petrosky and Waters 1975). Two nonanadromous freshwater sculpin species occur in the Nushagak and Kvichak river drainages: coastrange sculpin *Cottus aleuticus*, and slimy sculpin *C. cognatus*. Because of their very similar appearance, many field surveys do not distinguish between these two species, so the relative distribution of each species within the Nushagak and Kvichak river drainages is uncertain. Sculpins are not a target of Nushagak and Kvichak river drainage subsistence (Fall et al. 2006; Krieg et al. 2009) or sport fisheries (Jennings et al. 2011).

Freshwater distribution and habitats

coastrange sculpin

Coastrange sculpin occupy a narrow (≤200 km wide) fringe along North America's Pacific Ocean coast from southern California to the Aleutian Islands (Scott and Crossman 1998, p. 820-821). Morrow (1980b) reported an isolated population in the Kobuk River draining to Kotzebue Sound. Because this species is readily confused with slimy sculpin, its distribution in the Nushagak and Kvichak river drainages is uncertain, but appears more restricted than slimy sculpin (Bond and Becker 1963). In Bristol Bay they are found in both lakes and in streams; in streams they seem to prefer swift open riffles with coarse substrates (Heard 1965).

Coastrange sculpin often spawn in steep gradients with coarse substrates (McLarney 1968). In July and August, during the first weeks after hatching, coastrange sculpin fry are planktonic near the water surface as they drift downstream to lakes or quiet stream backwaters (Heard 1965; McLarney 1968). In stream-dwelling populations, after the post-hatching fry drift downstream, they migrate back upstream later in the summer after adopting a benthic life-style (McLarney 1968). At least in some lakes, larger coastrange sculpin have a pronounced daily vertical migration: from the bottom during the day to near the surface at night (Ikusemiju 1975).

slimy sculpin

Slimy sculpin range across northern North America from Virginia on the Atlantic Ocean coast, north into Canada's arctic mainland, and west to Alaska and across the Bering Sea to Asia's Chukotka Peninsula. In North America, slimy sculpin is the most widespread member of its genus (Scott and Crossman 1998, p. 832). In Alaska, they range across all of the mainland and the island remnants of the currently submerged Beringia, from headwaters to lower mainstems (Craig and Wells 1976; Morrow 1980b, p. 210).

In southcentral Alaska's Susitna River, slimy sculpin are found in diverse habitats and do not exhibit strong preferences for particular hydraulic conditions, water sources, or velocities (ADF&G 1983b, p. F-28). Because of their tolerance for a wide range of stream conditions, both Bond (1963) and Russell (1980, p. 104) considered them the most widespread of the nonanadromous fishes in the lakes and streams of the Nushagak and Kvichak river drainages. They occur throughout these two drainages, in upland lakes (Burgner et al. 1965) and from small headwater streams to the intertidal zone, but they are uncommon in very low gradient streams with fine sediments (ADF&G 2012) or in shallow coastal tundra ponds (Hildreth 2008, p. 9).

Across their global range, slimy sculpin are found in cool streams and lakes (Craig and Wells 1976; DiLauro and Bennett 2001; Halliwell et al. 2001). They are thought to exhibit site fidelity and do not appear to undertake long-distance seasonal spawning migrations (Cunjak et al. 2005; Galloway et al. 2003; Gray et al. 2004; Morgan and Ringler 1992), but will migrate in lakes in response to seasonal food availability (e.g., sockeye salmon eggs, Foote and Brown 1998).

In streams, slimy sculpins, particularly age-0 juveniles, tend to use shallower habitats with faster velocities, often under the cover of coarse substrates (van Snik Gray and Stauffer 1999). In Bristol Bay they occur at all depths in lakes (Heard 1965). In Lake Ontario, slimy sculpins were found to more than 150 m deep, with younger, smaller individuals typically in shallower waters (Brandt 1986). However, they may not occur in isolated shallow lakes subject to extensive winter freezing (Hershey et al. 2006). Slimy sculpin spawn in streams in areas with shallow water (~0.16 m) and coarse substrates (Keeler and Cunjak 2007) and in lakes (Bond and Becker 1963).

In streams, they prefer cool, stable riffles and are strongly affected by flood, drought, and elevated turbidity (Danehy et al. 1998; Edwards and Cunjak 2007; Keeler et al. 2007; Langdon 2001; Petrosky and Waters 1975). Their preferred temperature is reported to be 11.5-13.5° C (Symons et al. 1976). Young-of-the-year juveniles appear to have the greatest intolerance for warmer water and completely avoid water ≥25° C (Gray et al. 2005).

Life cycle

coastrange sculpin

Coastrange sculpins appear to be nonanadromous freshwater residents (Scott and Crossman 1998, p. 821-822). Individuals mature at lengths of around 40 to 50 mm (Ikusemiju 1975), at ages of 2 or 3, and female fecundity ranges from 100-1764 ova (Patten 1971). In coastal streams in southcentral and southeast Alaska, in May to early June females deposit adhesive eggs (<1.5 mm diameter; Scott and Crossman 1998) on the underside of large, stable rocks. Males fertilize, then guard the eggs, which hatch from late May to early July (McLarney 1968). Newly hatched larvae are ~7 mm (Ikusemiju 1975) and by late July to mid-August fry reach lengths of 20 to 30 mm (Brown et al. 1995; Ikusemiju 1975; McLarney 1968). In the central part of their range, coastrange sculpin reach lengths of at least 101 mm and may not live much beyond age 4 (Patten 1971).

slimy sculpin

Slimy sculpin are nonanadromous freshwater residents (Mecklenburg et al. 2002, p. 468). In arctic Alaska, fish mature between the ages of 3 and 5, at lengths of around 70 mm, and spawn in late May, a week or so after breakup (Craig and Wells 1976). About a week before the onset of spawning, males select and defend nest sites (the undersides of stable rocks or submerged debris) in areas with shallow water (~0.16 m deep) and coarse substrates (Keeler and Cunjak 2007). Males can court multiple females and will guard nests with multiple egg clutches (Majeski and Cochran 2009). Females deposit adhesive eggs 2.5 to 3 mm in diameter (Morrow 1980b) and interior Alaska females have a mean fecundity of around 200 ova (Craig and Wells 1976). Young-of-the-year fry are 11 to 13 mm long at the beginning of August and reach 19 to 24 mm by late September (Craig and Wells 1976). Once mature, they spawn annually (Craig and Wells 1976), can reach age 8 in arctic waters (Hanson et al. 1992; McDonald et al. 1982), and lengths of at least 117 mm in waters of the Nushagak and Kvichak river drainages (Russell 1980, p. 104).

Predator–prey relationships

coastrange sculpin

In California, the diet for coastrange sculpin stream populations is dominated by immature aquatic insects and other aquatic arthropods (Brown et al. 1995). In the Nushagak and Kvichak river drainages, coastrange sculpin prey on sockeye salmon eggs, alevins, and emerging fry (Bond and Becker 1963), particularly on the eggs of Iliamna Lake island beach sockeye salmon spawners (Foote and Brown 1998). In turn, during the summer, age-0 planktonic coastrange sculpin are preyed on by age-1 sockeye salmon fry (Heard 1965) and Nushagak and Kvichak river drainage area sculpin of all sizes (both species combined) are eaten by burbot, humpback whitefish, lake trout, northern pike, rainbow trout, and round whitefish (Russell 1980, p. 67, 76, 81, 82, 83, 96, 97, 103, 108).

slimy sculpin

The diet of slimy sculpins typically is dominated by aquatic invertebrates such as benthic arthropods and small mollusks (Craig and Wells 1976; Hershey and McDonald 1985; Hudson et al. 1995; Petrosky and Waters 1975), but where and when available, they will feed on sockeye salmon eggs, alevins, and emerging fry (Bond and Becker 1963; Foote and Brown 1998), and lake trout eggs and alevins (Fitzsimons et al. 2006; Fitzsimons et al. 2007; Fitzsimons et al. 2002; Savino and Henry 1991). They are more successful feeding on salmonid eggs deposited in coarser substrates, such as those selected by lake trout and island beach-spawning sockeye salmon (Biga et al. 1998). Slimy sculpin predation of successfully buried salmonid eggs and alevins in typical stream substrates may be limited (Moyle 1977).

A wide variety of larger fish eat slimy sculpin; including Arctic grayling, burbot, rainbow smelt, humpback whitefish, lake trout, Arctic char, northern pike, rainbow trout, and round whitefish (Bond and Becker 1963; Brandt and Madon 1986; Elrod and Ogorman 1991; Hudson et al. 1995; Owens and Bergstedt 1994; Russell 1980, p. 67, 76, 81, 82, 83, 96, 97, 103, 108; Scanlon 2000, p. 51, 53-54).

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AN ASSESSMENT OF POTENTIAL MINING IMPACTS ON SALMON ECOSYSTEMS OF BRISTOL BAY, ALASKA

VOLUME 2—APPENDICES A-D

Appendix C: Wildlife Resources of the Nushagak and Kvichak River Watersheds, Alaska

Since the release of the May 2012 draft of this assessment, Appendix C has been published as a U.S. Fish and Wildlife Service report:

Brna, P. J. and L. A. Verbrugge (eds). 2013. Wildlife resources of the Nushagak and Kvichak River watersheds, Alaska. Final Report. Anchorage Fish and Wildlife Field Office, U.S. Fish and Wildlife Service, Anchorage, AK. 177 pp.
Available: http://alaska.fws.gov/fisheries/fieldoffice/anchorage/environmental.htm

An Assessment of Potential Mining Impacts on Salmon Ecosystems of Bristol Bay, Alaska

Volume 2—Appendices A-D

Appendix D: Traditional Ecological Knowledge and Characterization of the Indigenous Cultures of the Nushagak and Kvichak Watersheds, Alaska

TRADITIONAL ECOLOGICAL KNOWLEDGE AND CHARACTERIZATION OF THE INDIGENOUS CULTURES OF THE NUSHAGAK AND KVICHAK WATERSHEDS, ALASKA

Submitted to the Bristol Bay Assessment: Environmental Protection Agency

Nushagak River at Koliganek, September 19, 2011

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Figure 1. Salmon Art, Wall of Sam Fox Museum, Dillingham. September 11, 2011. Photo by Alan Boraas

EXECUTIVE SUMMARY

1. Voices of the People

…Salmon more or less defines this area. It defines who we are. When you look at our art, you will see salmon….It is who we are. When you listen to the stories and take a steam, even in the middle of winter, people talk about salmon. It is in our stories; it is in our art. It is who we are; it defines us. M-61, 9/16/11

…we are relying on EPA to give us a fair shake out here. If EPA is going to crap all over our people, then take out the checkbook, federal government, and start writing million dollar checks for these people to move to Anchorage because you are going to kill us culturally, economically and every other way. M-60, 9/16/11

But I wouldn't trade this place for anything. This is home; this is where I find clean water to drink. M-51, 8/20/11

We love the place; its home. Moving is not an option to me. M-29, 8/17/11

…basically one of the main purposes of the Blessing of the Water is to make that Holy water…. When the Father blesses that particular river, that particular river becomes Holy. M-61, 9/16/11

I think with us, during potlatch times, during hard times, or Russian Christmas, or if we gather together, everybody brings out their dry fish or their jarred fish or their salt fish. Nobody goes hungry, there's always sharing. F-32, 8/18/11

We share with our families, or if anybody does not have fish, we give them fish also. F-27, 8/17/11

2. The Condition of the Indigenous Cultures of the Bristol Bay Region

This section of the Environmental Protection Agency's Bristol Bay characterization studies is based on 53 interviews in seven villages and an overview of previous research in the study area. The condition of the ecosystems, both riverine and lacustrine, on which the Yup'ik and Dena'ina depend for wild fish, mammals, and plants including the keystone species salmon, is nearly pristine. The cultures have proved to be sustainable in this region for thousands of years. Alaska Department of Fish and Game statistics indicate wild subsistence resources including salmon provide the Yup'ik and Dena'ina of the study area with the bulk of their food resources. Wild foods provide critical nutritional elements in both quantity and quality in the diet, but subsistence also forms the core of the culture itself, including knowledge, attitudes, identity, and beliefs important to the Yup'ik and Dena'ina people in their daily lives.

The villages of the study area are predominantly Alaska Native and the population remains stable (United States Census, Alaska). The culture has a very high degree of homogeneity in relation to salmon and water quality as represented by interviewees' responses to questions about the importance of salmon and streams in their lives. Interviews conducted in this project relating to the importance and significance of salmon and clean water resulted in 97% concurrence among Elders and culture bearers—individuals who have an honored place in the culture of the villages. The Yup'ik people of the region retain their language, and more than 40% of the population continues to speak it. The Dena'ina are undergoing a cultural renaissance through language revitalization programs and the emergence of culture camps. Both languages have a large number of words related to salmon and stream resources reflecting nuanced understanding developed over time and represent frames reflecting basic cultural schema.

Elders and culture bearers continue to instruct young people particularly at fish camps where not only fishing and processing techniques are taught, but also cultural values. The social system which forms the backbone of the culture, nurturing the young, supporting the producers, and caring for the Elders, is based upon the virtue of sharing the wild foods harvested from the land and waters. Sharing networks of wild foods, particularly wild salmon, define community membership. Sharing networks also extend to family members living far from home.

The Yup'ik and Dena'ina consider the land and waters to be their sacred homeland. They have traditionally considered the salmon as kin in the sacred web of life. The populations of both Yup'ik and Dena'ina have shown themselves to be spiritually tenacious, combining elements of traditional practices with those of Russian Orthodox and other Christian churches to create a rich syncretic religious heritage for their families providing mechanisms to contextualize modern subsistence life. They continue to practice a first salmon ceremony paying homage to the first salmon caught in the spring and the renewal of their cycle of life. The rivers are blessed by priests annually in the Great Blessing of the Water at Theophany, celebrating the baptism of Christ and symbolically purifying the water of contamination preparing it for the return of the salmon. This ceremony, for Orthodox Yup'ik and Dena'ina, is the pure element of God expressed as sanctified nature. The holy water of the rivers derived from this ceremony is used to bless the homes, churches, and people and is believed to have curative powers.

3. The Status of the Resource Relative to other Salmon Culture Ecosystems Internationally

The Human Relations Area Files on-line cultural database (Human Relations Area Files, World Cultures Data Base. http://www.yale.edu/hraf/collections.htm) identifies 23 world cultures in which anadromous salmon are, or were, a chief component of subsistence. However, today only in Alaska are wild, non-farmed, non-hatchery spawned, non-bioengineered salmon both abundant and reliably accessible to indigenous people. The Yup'ik and Dena'ina of the study area are among the few remaining cultures to still rely on wild salmon as a chief source of nutrients and have an intact relationship with the landscape that supports them and the food that has shaped their cultural traditions.

4. The Causes of the Unique Status of the Resource and the Vulnerability of the Resource

This area is among the last remaining truly viable cultural and ecologically interdependent human/salmon ecosystem in the world because it is an intact ecosystem largely due to the fact that it is remote, roadless, and until recently in the 1980s, not thought to contain sizeable extractive natural resources of value other than fish and game. In addition the unique Alaska State and United States Federal subsistence laws including the Alaska Native Claims Settlement Act (ANCSA, Public Law 92-203 with amendments), Alaska National Interest Lands Conservation Act (Public Law 96-487 with amendments), and the State of Alaska Subsistence Act 1978 (with amendments; encoded within AS 16-05) protect rural and indigenous people's right to harvest wild resources and in some cases provide a priority to those resources over commercial and sport interests.

5. Vulnerabilities

The existing culture of the indigenous people of the study area is vulnerable to Negative changes in the quantity or quality of wild salmon resources or the quantity or quality of water in the Nushagak or Kvichak watersheds. Negative impacts to salmon would leave the existing culture susceptible to destabilization and affect its present sustainability, ability to cope with natural disasters, and promote assimilation and relocation to urban cultural centers. If significant negative impacts to salmon or streams occur, the cultural stability will be vulnerable to change in the following ways:

- Since the diet is heavily dependent on wild foods, particularly salmon, the diet would be changed from a highly nutritious diet to one based on store-bought processed foods.
- Since the social networks are highly dependent on procuring salmon (fish camps) but also sharing salmon and wild food resources, the current social support system would be appreciably degraded
- Since meaningful family-based multi-generational work takes place in fish camp or similar subsistence settings, transmission of cultural values and language learning would be impacted and family cohesion impacted.
- Since values and the belief system are represented by interaction with the natural world through salmon practices, clean water practices, and symbolic rituals, core beliefs would

be challenged potentially resulting in a breakdown of cultural values, mental health degradation and behavioral disorders.

- Since a yearly subsistence round rests on having time to harvest and process wild foods, a shift from part-time wage employment supporting subsistence to full-time wage employment would impact subsistence-gathering capabilities by restricting the time necessary to harvest subsistence resources.
- Since the area exhibits a high degree of cultural uniformity tied to shared subsistence practices, substantial change could provoke increased tension and discord both between villages and among village residents.

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I. INTRODUCTION

A. Overview and Question

The purpose of this Bristol Bay Cultural Assessment is to provide information to the Environmental Protection Agency on the status of the indigenous cultures of the Nushagak and Kvichak River watersheds and their dependence on and relationship to salmon and other stream-based natural resources of the region. The focus of the Bristol Bay Assessment is salmon and water and this part of the overall assessment portrays the human dimension of modern indigenous "salmon-cultures" of the region. The Human Relations Area Files on-line cultural database (http://www.yale.edu/hraf/collections.htm) identifies 23 cultures in which anadromous salmon are or were a chief component of subsistence. Wild Atlantic salmon populations have been decimated by high-seas fishing and habitat degradation such as dam building (Montgomery 2003:111-118). Consequently indigenous cultures such as the Sami of Fennoscandia, Micmac and Abenaki of northeastern North America and other cultures once dependent on Atlantic salmon have been forced to choose non-traditional options (cf. Lehtola 2004: 72-84). In the Asian Far East wild salmon have likewise been decimated in Japan and Russia through overfishing and habitat destruction and legal restrictions to indigenous fishing, and cultures like the Ainu of Hokkaido and Nvkh of Sakhalin Island can no longer depend on wild salmon and diet and cultural institutions based on salmon have been severely affected (cf. Iwasaki-Goodman and Nomoto 1998: 27-46). In the Pacific Northwest of North America hydroelectric dam building, overfishing, and habitat degradation have decimated wild salmon runs and the Northwest Coast cultures from California to British Columbia can no longer subsist on wild salmon as they once did (cf. Johnsen 2009).

The Yup'ik of the Nushagak, Kvichak and Wood River watersheds and the Dena'ina of the Lake Iliamna, Newhalen River and Lake Clark (also the Kvichak River watershed) are among the few remaining cultures still relying on wild salmon as a chief source of nutrients. This reliance on salmon has lasted unbroken for at least 4000 years and salmon subsistence has shaped cultural patterning in multiple ways. Today modern technology is used but many beliefs, social practices and components of spirituality are part of this long history and form both Yup'ik and Dena'ina essential identity and provide the cultural basis for sustainability. To say they are the last wild salmon cultures is an overstatement, but they are certainly among the last. Part of the reason they remain is that Alaska in general, and Bristol Bay in particular, has become the world's last bastion of wild, non-farmed, non-hatchery raised, non-bioengineered wild salmon.

This document is not an exhaustive study of all aspect of all cultural research in the study area; rather, it is a characterization of the village cultures of the Nushagak, Kvichak and Wood River drainages focusing on the relationships of the people to salmon. This document contains five parts. First, this introduction contains information about the project and its methodology. Second, it consists of contextualization of relevant prehistoric, historic, linguistic, and cultural information obtained from anthropological, historical, and other publications and data bases. Third, this document describes the modern culture of the drainages and includes the product of interviews in villages of the Nushagak and Kvichak River watersheds conducted in 2011, which constitutes original research on the peoples of the area as well as drawing from relevant recent anthropological research. Fourth, this document contains conclusions about the vulnerability of the culture to loss of clean water and salmon resources in the Bristol Bay area. Between us (Boraas and Knott) we have 48 years of research, teaching, and collaboration with Alaskan tribes, and that experience is reflected in this study.

B. Methodology

Section 3, Modern Culture, of this study represents original qualitative, interview-based research which asks the question, "How are salmon and other stream-based resources and water important in your lives?" The interview questions involved the topics (domains) of nutrition, subsistence, social relations, spirituality and beliefs. In addition a final question was asked: "is there anything you would like to add, or is there anything you would like the Environmental Protection Agency to know about the situation in your villages." The interview questions are listed in Section III.A.

We recognize and respect that some cultural information may constitute intellectual property rights and is not to be shared with the broader public. As a guide we followed the principles of the United Nations Declaration on the Rights of Indigenous Peoples, particularly Article 31, Section 1 (UNDRIP 2007):

> *Article 31*
> Section 1. Indigenous peoples have the right to maintain, control, protect and develop their cultural heritage, traditional knowledge and traditional cultural expressions, as well as the manifestations of their sciences, technologies and cultures, including human and genetic resources, seeds, medicines, knowledge of the properties of fauna and flora, oral traditions, literatures, designs, sports and traditional games and visual and performing arts. They also have the right to maintain, control, protect and develop their intellectual property over such cultural heritage, traditional knowledge, and traditional cultural expressions.

The study area was defined by the Environmental Protection Agency's assessment team to include the villages of Aleknagik, Port Alsworth, Igiugig, Levelock, Ekwok, Kokhanok, New Stuyahok, Koliganek, Curyung (Dillingham), Nondalton, Pedro Bay, Newhalen, and Iliamna. All are within the Nushagak or Kvichak watersheds except Aleknagik which is in the Wood River watershed near the Nushagak River. As a foundation for this research, all of the federally recognized tribes in the watersheds were contacted through the Environmental Protection Agency's Tribal Trust and Assistance Unit in Anchorage following government to government protocols requesting permission to conduct interviews. Since one of us, Alan Boraas, is an Honorary Member of the Kenaitze Indian Tribe, a letter of introduction from the Kenaitze Tribe to village councils was included in the government to government packet following village conventions (See Appendix 1 which also includes the initial statement of methodology). We selected seven villages in which to conduct interviews: New Stuyahok, Koliganek, Curyung (Dillingham), Nondalton, Pedro Bay, Newhalen, and Iliamna. Four are primarily Yup'ik villages and three are primarily Dena'ina villages.

Table 1. Number of Interviews per Village

Village	Males	Females	Total
Curyung (Dillingham)	7	0	7
Iliamna	1	3	4
Koliganek	5	5	10
Newhalen	5	6	11
New Stuyahok	5	2	7
Nondalton	4	6	10
Pedro Bay	2	2	4
Total	29	24	53

We interviewed 53 Elders and culture bearers, people whom the various village councils or their designates (often the village environmental officer) identified as authoritative sources of information about subsistence, traditional ecological knowledge, nutrition, social relations and spiritual aspects of their culture. The village-selected interviewees consisted of 24 females and 29 males (see Table 1) and ranged in age from mid-twenties to a man reportedly in his nineties. Most, however, were in their forties or older due to the intentional weighting toward village-selected Elders and culture bearers. We were not consulted in the selection of specific interviewees and were assisted by a tribal employee or a village council member who arranged the time and place of the interview. The interviews took place in the villages at a tribal or community center or at private homes because, from the standpoint of the interviewees, they are safe, non-threatening places in which to discuss important cultural matters. The consent form is in Appendix 1 and signed forms are currently under the authors' control. We normally interviewed two to four individuals at any one time but some sessions included as many as six and one was a single interviewee. The interview sessions lasted about two hours with a short break. Interviews followed a standard semi-structured interview process in which a set of questions guided the interview but interviewees were free to add additional information or perspective, in some cases delving into topics not covered by the original question. The questions were specifically designed not to be answered briefly but to probe the subject and allow interviewees to describe cultural structures which for the most part were familiar and obvious to local villagers, but not commonly understood to others, particularly those outside the region. If a response was brief we would respectfully clarify or amplify upon the question to generate a more complete narrative. Interviewees were told they did not have to respond to a question if they chose not to, although none did so verbally. If an interview session exceeded two hours we occasionally eliminated some questions to shorten the time commitment; nevertheless, some interviews exceeded two hours. If the topic of a question had already been covered in a previous discussion during a session we eliminated the question. Consequently, not all interviewees responded to every question. Regularly one person would respond and others would nod agreement or disagreement and we did not request them to repeat the response already given by a speaker out of respect for cultural protocols. Since the questions dealt with a cultural standard (domains), there were few alternative or divergent points of view. We encouraged respondents to use their Native language and some of the interviewees chose to speak in Yup'ik, in which case an interpreter was present to translate the question into Yup'ik and the response into English.

None chose to speak in Dena'ina. Many Elders think and respond in their Native language which generated more accurate, empowered, and nuanced responses to questions about culture.

Figure 2. Nondalton, August 17, 2011. Photo by Alan Boraas

We digitally recorded the interviews and, in the Kenai Peninsula College Anthropology Lab, transcribed the recordings including both responses to our questions and additional perspective provided by the Elders or culture bearers.

The transcribed interviews were lumped into a single Microsoft Word document and the lumped document was searched for key words related to the sub-headings of this report using the powerful search feature of Microsoft Word 2010. In this way we were able to capture responses both to the theme of the question we asked and to that theme that might have been discussed by interviewees in the context of a question related to a different topic.

In this document responses of Elders and culture bearers appear in italics titled "Voices of the People" preceding the anthropological discussion of each section. These direct quotations reflect both the consensus among those interviewed and the rare deviations from consensus. By the standards of highly pluralistic modern America, the Yup'ik and Dena'ina villages of Southwest Alaska are culturally much more homogenous; consequently, the narratives reflect that homogeneity as indicated by the summary of responses described in Section III, A. These responses represent an emic view[1] and are intentionally placed at the beginning of each section as the core of the section or sub-section. They are meant to be read and not to serve as mere illustration. "Voices of the people" statements were selected through the search process

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[1] An "emic" perspective is that of a participant in the culture whereas an "etic" perspective is that of a non-member describing or analyzing a culture such as an anthropologist or journalist.

described above because they were concise, clear, and reflected the intent of the speaker in the context of their broader narrative. Not all responses are included in this document. The entirety of the transcribed interviews are over 500 pages in length; all were carefully read and helped shape the writers' understanding of modern village culture. The English response or translation is transcribed "as is" with little grammatical modification; readers must understand that for some, English is a second language and imperfect English grammar is not to be construed as imperfect or naive thinking. Following University of Alaska Institutional Review Board Standards to protect individual identity of the interviewees, each Elder or culture bearer has been designated by a code, using an "M" or "F" for "male" or "female" and a number, along with the date of the interview.[2] Only we, the interviewers, know the names of the interviewees.

All deviations from consensus have been included in the qualitative "Voices of the people" responses. In addition, the entire 500 page typed narrative was assessed from a favorable/unfavorable or agree/disagree standpoint to give a sense of the degree of conformity to a response. These results, along with the interview questions, are portrayed in Section III.A. and referenced throughout this document to give a more numerical sense of the culture standards of the Nushagak and Kvichak drainages.

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[2] Funding for this project was administered as a contract through the University of Alaska Anchorage/Kenai Peninsula College and came under Institutional Review Board (I.R.B.) auspices since it involved human subjects. See (http://www.uaa.alaska.edu/research/ric/irb/training.cfm), The UAA I.R.B. reviewed and approved the methodology and consent forms of this project (see Appendix 1). I.R.B. stipulates protection of the identity of human subjects, consequently the names of the participants of this study and not revealed (see http://www.uaa.alaska.edu/research/ric/irb/policies.cfm, click on UAA Faculty Handbook). Signed consent forms are held by the researchers.

C. Villages, Population, and Ethnicity

In the 2010 United States Census, the 13 communities of the study area had a total population of 4337. Table 2 describes the population characteristics of the 13 villages and towns located in the Nushagak, Wood, and Kvichak River drainages.

Table 2. Census of the Towns and Villages of the Nushagak and Kvichak River Drainages, 1980 to 2010. Data from U.S. Census, Alaska; Alaska Community Database; Native Names from Indigenous Peoples and Languages of Alaska, Gary Holton Alaska Native Language Center, 2011.

Watershed	Community	Native Name	1980 Pop.	1990 Pop.	2000 Pop.	2010 Pop.	% Alaska Native, 2010	Ethnic Majority
Nushagak River	Dillingham	Curyung	1563	2017	2466	2378	55.9	Yup’ik
	Ekwok	Iquaq	77	77	130	115	90.4	Yup’ik
	Koliganek	Qalirneq	117	181	182	209	95.7	Yup’ik
	New Stuyahok	Cetuyaraq	331	391	471	510	93.5	Yup’ik
	Portage Creek	N/A	48	5	36	2	50.0	Yup’ik
Kvichak River	Igiugig	Igyaraq	33	33	53	50	40.0	Yup’ik, Alutiiq/ Caucasian
	Iliamna	Iliamna	94	94	102	109	54.1	Dena’ina, Caucasian
	Kokhanok	Qarr’unaq	83	152	174	170	80.0	Yup’ik/Dena’ina/ Alutiiq
	Levelock	Liivlek	79	105	122	69	84.1	Yup’ik
	Newhalen	Nuuriileng	87	160	160	190	80.0	Yup’ik
	Nondalton	Nundaltin	173	178	221	164	63.4	Dena’ina
	Pedro Bay	N/A	33	42	50	42	66.7	Dena’ina
	Port Alsworth	N/A	22	55	104	159	21.4	Caucasian
Wood River	Aleknagik	Alaqnaqiq	154	185	221	219	81.9	Yup’ik
						4337 Total 2010 Population		

Since no borough or other census area is specifically limited to the watersheds in question, this village by village enumeration is the most accurate reflection of population characteristics and dynamics.

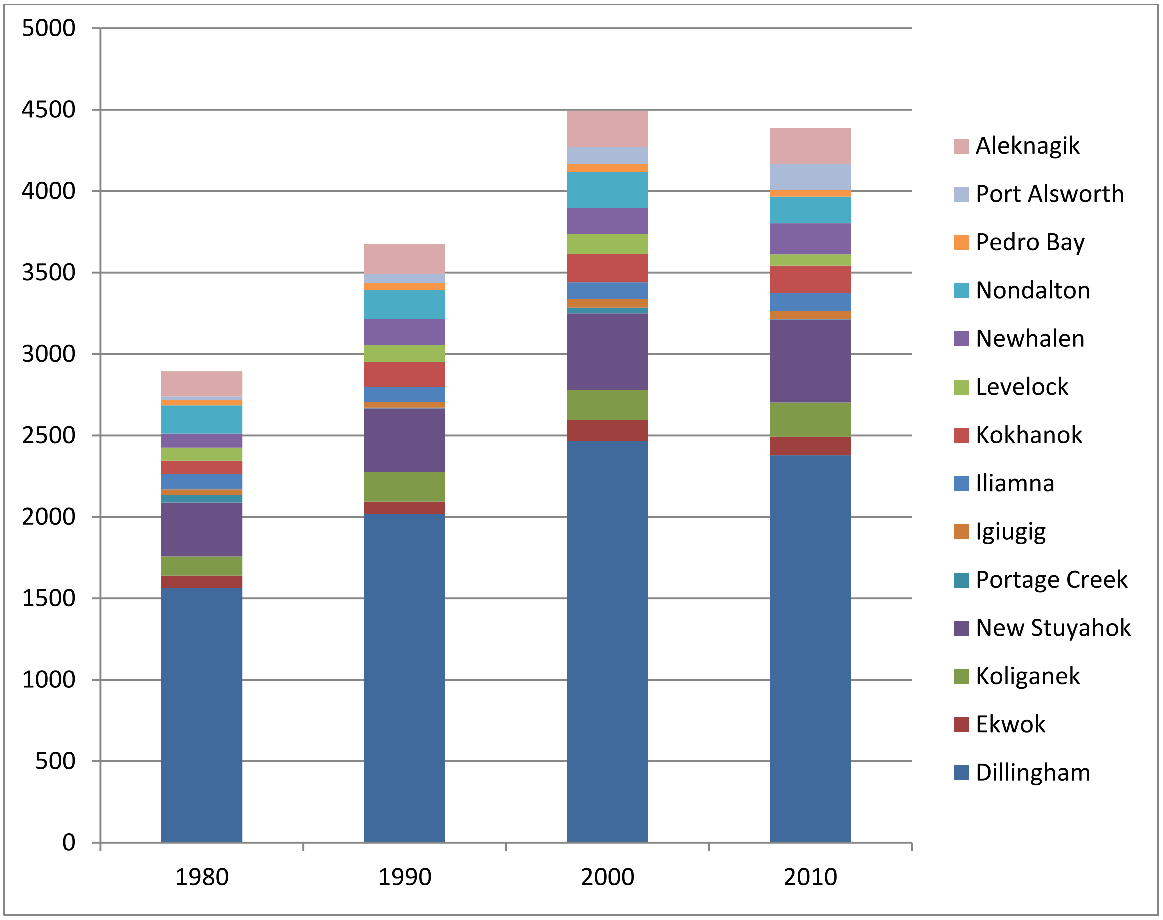

Figure 3. Population Change for the Study Area: 1980 to 2010. Data from U.S. Census.

Table 2 indicates the population of the study area grew substantially from 1980 to 2000 and remained stable between 2000 and 2010. The 1980 to 2000 village population growth is probably due to post-ANCSA changes in land-ownership and is related to a similar phenomenon throughout Southwest Alaska (Fienup-Riordan 1994:39). The population of individual communities can vary considerably; in small populations only a few large families moving in or out can change the overall population considerably. Of the 14 communities identified in Tables 1 & 2, five are anomalous for different reasons: Dillingham, Port Alsworth, Igiugig, Iliamna, and Aleknagik. Dillingham has, by far, the largest population in the area (2,378 in 2010) and is a regional center with an economy based on the Bristol Bay commercial fishing industry, as well as government services, transportation, and professional and business services (Alaska Community Database). Dillingham has a small branch of the University of Alaska, a museum, and Alaska Department of Fish and Game (ADFG) offices, as well as several stores, churches, hotels, and other institutions typical of mid-sized Alaskan towns. Dillingham, however, is 55.9% Alaska Native—mainly Yup'ik—and the Curyung Tribe and Bristol Bay Native Association and associated agencies are a significant presence (Alaska Community Database).

Figure 4. Curyung Tribal Offices, Dillingham, September 16, 2011. Photo by Alan Boraas

Aleknagik is anomalous because it is the only village not in the Nushagak or Kvichak drainages and it is connected by 25 miles of road to Dillingham where institutional services, grocery stores and so on are located. Other than that it shares the characteristics of the Yup'ik and Dena'ina villages in the Nushagak and Kvichak drainages. It is located on Lake Aleknagik where the Wood River drains south to Bristol Bay and is It is primarily Yup'ik (81.9%). Unlike most other villages, Aleknagik has been influenced by Seventh-Day Adventists and Moravian as well as Russian Orthodox churches. The people of Aleknagik can access resources to the lake system to the north as well as the Nushagak and Kvichak Rivers and coastal areas via large skiffs and maintain close cultural ties to those areas.

Port Alsworth is only 21.4% Alaska Native and thus does not have the majority or near-majority Alaska Native population that other villages in the study area have. The population is primarily associated with two institutions. First, Lake Clark National Park and Preserve, which surrounds Lake Clark, has its regional headquarters in Port Alsworth. Because of the park, a number of eco-tourism guides unaffiliated with the park but using its resources are headquartered at Port Alsworth. Second, The Tanalian Bible Camp and associated ministries, loosely connected to Samaritan's Purse, a national fundamentalist Christian ministry directed by Rev. Franklin Graham, is also located at Port Alsworth. Yup'iks who relocated to the area in 1944 (Gaul, 2007:60-61) account for most of the town's Alaska Native population (Port Alsworth is well within traditional Dena'ina territory). Port Alsworth is not a federally recognized tribal entity but is included in this report because it is within the Kvichak watershed.

Igiugig, located where the Kvichak River drains Lake Iliamna, has a substantial number of guided sport fishing and sport hunting operations that have recently moved into or near the village which accounts for the relatively large non-Alaska Native percentage of the population. The same is true for Iliamna, a traditional Dena'ina village located on Iliamna Lake. It has also become a staging area for exploration and other activities associated with proposed copper/gold porphyry mines in the area. Consequently, Iliamna has a proportionately larger non-Alaska Native population than most other villages in the area, although the Alaska Native population (54.1%; Alaska Community Database) outnumbers other ethnic groups, and is still the dominant ethnic group.

The remaining study area communities are Yup'ik or Dena'ina villages with close connections to traditional practices. They are relatively small, with populations ranging from 510 (New Stuyahok) to 42 (Pedro Bay) (Portage Creek, population 2, is seasonally occupied as of 2011, according to interviewee M-26), and from 93.5% Alaska Native (New Stuyahok) to 67% Alaska Native (Pedro Bay). Most have a single church (Russian Orthodox), a public school, a health clinic, an airstrip, a small general merchandise store, a post office, a tribal center, city and/or village corporation offices, a landfill, cemetery, and fuel storage tanks (Alaska Community Database and observations). There are community health aides in the villages of Koliganek, New Stuyahok, Ekwok, Igiugig, Levelock, Kokhanok, Nondalton, and Pedro Bay (Bristol Bay Area Health Consortium, BAHC 2006) and some also have dental aides. The clinics are connected via internet to consulting physicians and the Alaska Native Hospital in Anchorage. Many of the villages are being connected to high-speed fiber-optic internet. Drinking water in the study area villages is derived from multiple sources depending on the village including municipal treated water, piped but untreated water, individual wells, or hauled directly from rivers or lakes[3] (from the Alaska Division of Community and Regional Affairs. http://www.commerce.state.ak.us/dca/commdb/CF_COMDB.htm). Table 3 summarizes the sources of drinking water by village.

[3] According to the State of Alaska definition of a "served" community, there must be at least 60% of the households served with a municipal water system, and therefore some households will have a different water source, whether it be an individual well or they haul water.

Table 3 Village Water Sources. Data from the Alaska Division of Community and Regional Affairs. http://www.commerce.state.ak.us/dca/commdb/CF_COMDB.htm

Community	Municipal/Piped Water	Individual Wells	Haul Water
Dillingham	x		
Ekwok	x	x	
Koliganek	x	x	x
New Stuyahok	x	x	x
Igiugig	x		x
Iliamna		x	
Kokhanok	x	x	
Levelock		x	
Newhalen	x	x	
Nondalton	x		
Pedro Bay		x	x
Port Alsworth		x	x
Aleknagik		x	x

Figure 5. New Stuyahok, January 17, 2012. Photo by Alan Boraas

II. CULTURAL AND HISTORICAL BACKGROUND

A. Pre-Contact Bristol Bay

1. Voices of the People

Salmon and fresh water has been the lifeline of the people here for thousands of years. If you look at the water, that is why fish and game has survived so well here, because we have such clean water. M-62, 9/16/11

[If the salmon were to be impacted**],** *it would stop 10,000 years' plus tradition, culturally and spiritually for my people; not only my people, all the other communities and villages in this region will go away. We would cease to exist. We can't go anywhere. Where are we going to go?* M-33, 8/18/11

Freeze drying is not a new thing. That's been going on with my people for over 10,000 years, eating freeze dried food. M-33, 8/18/11

There's 10,000 cache pits [at the Kijik archaeological site on Lake Clark] *and they are still counting; over 200 houses, which are huge. So it was pretty big.* M-29, 8/17/11

My father, he usually keeps fresh salmon. He would dig a pit and take the topsoil off; dig it out lay some grass on the bottom and on the side. Then take the salmon, lay them in the pit until he filled it up. Then he would put grass on top of it. Then he would lay gravel right on top of it, and he would mark each corner for winter time. Put poles on each corner so he could find where he buried his salmon. And in the winter time, if he wanted salmon, he would take his axe and cut out a piece of the soil and dig from there. That was his freezer. That is how my dad would keep salmon. M-54, 8/20/11

2. Introduction

The pre-contact history (prehistory) of the Bristol Bay drainage is not as well documented as in other parts of Alaska but sufficient data exists to provide a preliminary outline of the study area prehistory. Within the study area there are a total of 228 historic and prehistoric sites listed on the Alaska Heritage Resources Survey (A.H.R.S.), the state's database for officially designated sites kept by the State of Alaska, Office of History and Archaeology. To better understand the patterns of culture change and establish the time-depth of salmon use in the Nushagak and Kvichak River drainages one of us (Alan Boraas) generated a database of the 228 sites and from that developed a preliminary prehistoric cultural chronology depicted in Figure 4.

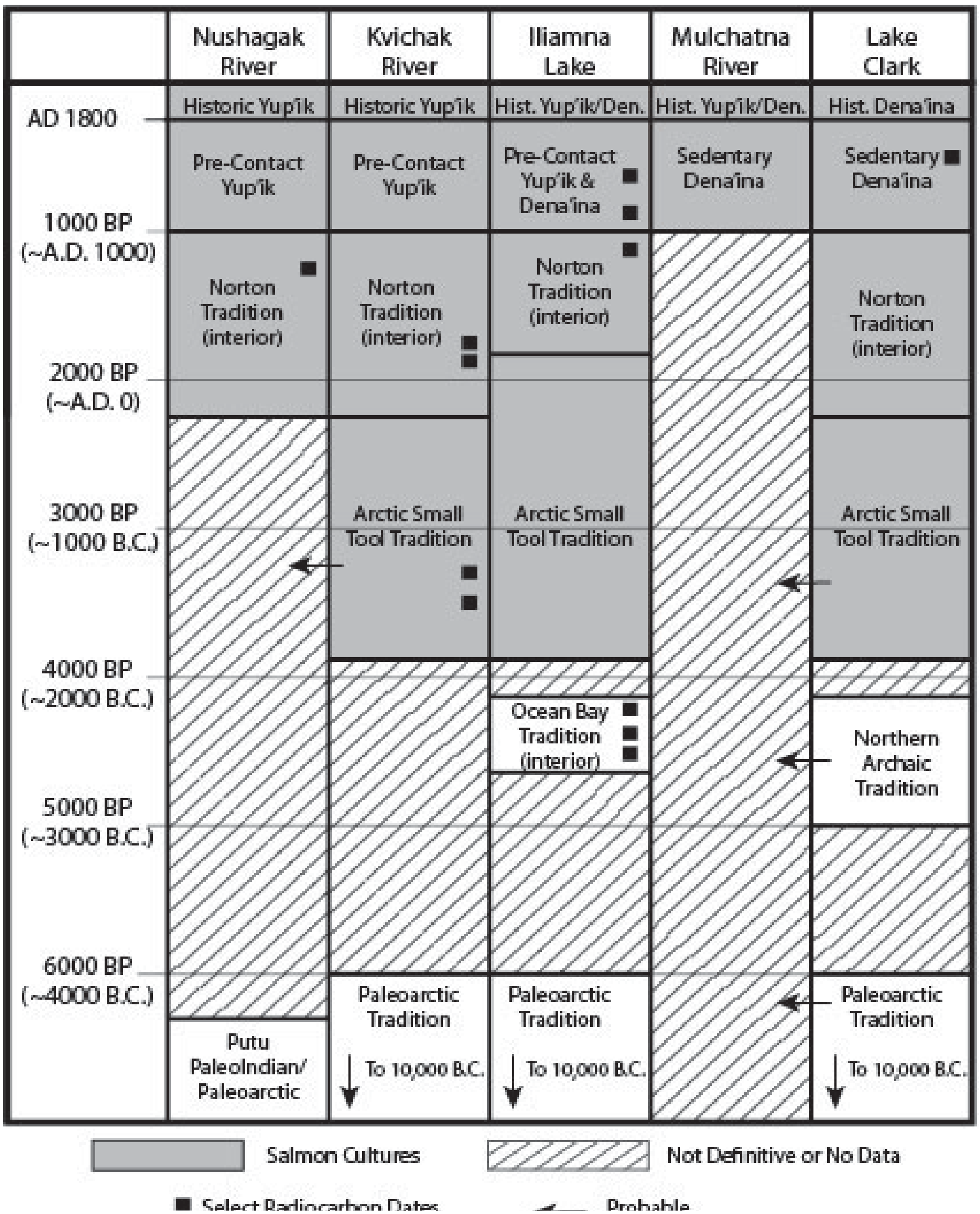

Figure 6. Cultural Chronology of Nushagak and Kvichak River Drainage Salmon-Based Cultures. Compiled from the Alaska Heritage Resource Survey database by Alan Boraas

The "BP" (Before Present) of the y-axis of Figure 4 is in uncalibrated radiocarbon years and an approximate B.C./A.D. date is indicated.[4] AHRS site data was assembled for five regions (Figure 3) within the Nushagak and Kvichak River drainages, including:

- The Nushagak River from its mouth to headwaters.
- The Kvichak River, including nearby archaeological sites in the Alagnak River drainage.
- Iliamna Lake and the lower Newhalen River
- The Mulchatna River.
- Lake Clark, Sixmile Lake, and the Upper Newhalen River

3. Pre-Contact Salmon Fishing Cultures

The study area was occupied as early as 10,000 BP by core and microblade makers of the Paleoarctic tradition. Included in the AHRS database is a single site with two Putu-like points (XHP-00430) normally found only on Alaska's North Slope but found here with Paleoarctic microblades. Subsequently, archaeological cultures of the Northern Archaic and Ocean Bay traditions occupied the area. None involved intensive salmon fishing as indicated by AHRS records. The Paleoarctic and Northern Archaic sites are associated with Athabascans (Boraas 2007: 34-7) and establish a time-depth for the Dena'ina or proto-Dena'ina in the study area.

As described below, archaeological records indicate Yup'ik or proto-Yup'ik people have been fishing for salmon for at least 4,000 years (Figure 4) and may be genetically related to earlier Siberian salmon fishers. Salmon fishing first appears with the Arctic Small Tool tradition (ASTt) (see Figure 4) and Table 4 is a list of ASTt sites in the study area. ASTt cultures are widespread in western and northern Alaska where the site data indicates the existence of interior nomadic hunters (primarily caribou) or coastal sea mammal hunters. In the Bristol Bay drainage, however, three village sites evidenced by ASTt-style houses and artifacts are found on the Kvichak River and five alpine sites (artifacts only) indicate hunting above tree line (see Table 4). The houses are permanent structures, generally measuring four meters on a side, indicative of sedentary or semi-sedentary people and are located adjacent to salmon spawning streams. The ASTt site at Igiugig (ILI-00002), where the Kvichak River flows out of Iliamna Lake, is an example of such a site (Holmes and McMahan, 1996).

[4] The deviation between calibrated calendar years and uncalibrated radiocarbon years becomes significant before 1500 B.C. By 2000 B.C. uncalibrated radiocarbon years are ~ 400 hundred years old (http://www.radiocarbon.com/calendar-calibration-carbon-dating.htm).

Table 4. Arctic Small Tool Tradition Sites in the Study Area. Compiled From Alaska Historic Resources Survey.

ARCTIC SMALL TOOL TRADITION AD 200 to 1800 BC			
Area	**AHRS Site**	**Characteristics**	**Houses**
Nushagak R.	NAK-00018, B	cores and microblades	
Iliamna Lake	ILI=00035	Lithic tools	
Iliamna Lake	ILI-00201	Microblade core	
Iliamna Lake	ILI-00205	Microblade core	
Iliamna Lake	ILI-00193	Lithic camp: microblades, side blades, end scrapers, knives.	
Iliamna Lake	ILI-00219	Microblade core	
Iliamna Lake	ILI-00218	Microblade core	
Kvichak	DIL-00088	Village, sedentary houses; C14 Date, 3580+/-150;	19
Kvichak	DIL-00170	Village; Brooks River Gravel Phase	2
Kvichak	ILI-00002	Cores, microblades, burins, notched stones, 4000 artifacts; Brooks River Gravel phase, ca. 1800 BC to 1100 BC 3350+/-60 BP radiocarbon date, possible Norton component	
Kvichak	ILI-00072	Microblades and other lithics	
Kvichak	ILI-00206	Village site	1

Anadromous salmon remains, while not common, occur in ASTt sites (Dumond, 1984), suggesting salmon were a significant subsistence human resource in riverine and lacustrine areas of southwest Alaska. The lack of abundant salmon bones in ASTt sites may be due to small populations of salmon, decomposition of the relatively delicate bones, or the practice of returning salmon bones to the water—similar to ethnohistoric Yup'ik and Dena'ina—thereby contributing to marine-derived nutrients important in salmon habitats. Further research is necessary to clarify this point. The fact that one site (DIL-00088) contains 19 sedentary houses and is located along a salmon stream indicates salmon were likely a primary resource (Holmes and McMahan, 1996).

Analysis of human hair from a 4,000-year old ASTt site in Greenland places the mitochondrial DNA (mtDNA) in the D2c haplogroup[5] reflecting Siberian origins (Gilbert et al., 2008). Today, haplogroup D2c is present, but haplogroup A is dominant among Yup'iks; haplogroup A also has Siberian origins where researchers place its origin as early as 7,000 years before present (Rubicz et al., 2003). Both haplogroups indicate that the time-depth of Yup'ik people in southwest Alaska is at least 4,000 years and that they derive from Siberian origins, where their ancestors were also potentially salmon fishers. As described in the section on

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[5] For a discussion on haplogroups see the National Geographic Human Genographic Project, https://genographic.nationalgeographic.com/

nutrition (III.C.3.), evidence is building that Yup'iks are biologically adapted to salmon and 4000 years is the temporal context in which that evolution took place.

In all but the Mulchatna River where evidence has yet to be found, the Arctic Small Tool tradition is followed by a well-developed salmon culture, the Norton tradition, dating from ~300 B.C. to A.D. 1000 (see Figure 4; Table 5). Like ethnographic Yup'ik, the Norton tradition has both a coastal and interior subsistence orientation. The coastal Norton tradition is found in sites as far north as Cape Denbeigh and relied primarily on marine mammals (Dumond 1984: 99-101). The interior Norton tradition sites, such as those in the study area on the Nushagak and Kvichak Rivers and Lakes Iliamna and Clark, had a salmon-oriented subsistence culture based on the following evidence: archaeological features, (mainly house styles similar to those at ethnographic Yup'ik salmon fishing sites) large sedentary villages (villages located adjacent to salmon fishing locations) and net fishing artifacts. Riverine Norton tradition sites are similar to ASTt sites in that they consist of large, permanent houses located on salmon streams. One large Norton tradition site on the Kvichak River (DIL-00161) consists of 34 to 45 houses representing a population sustainable only through the availability of abundant resources such as anadromous salmon. In addition, the artifact inventory for the eight Norton village sites in the study area (see Table 5) contains notched stones that were used as net weights (Dumond, 1987:11), similar to the lead line of a modern net. In addition to dwelling houses, Norton sites in southwest Alaska contain large structures indicating a *qasgiq* (*kashgee*, *kasheem*, *kazigi*,; local pronunciations and Euroamerican spellings vary), a men's house also found among pre-contact and early historic Yup'ik villages. These finds indicate that the Bristol Bay drainage Norton culture were Yup'ik or proto-Yup'ik speakers and relied on salmon as their primary subsistence food.

Figure 7. Lake Iliamna. Photo by Alan Boraas

Table 5. Norton tradition sites in the study area. Compiled from Alaska Heritage Resources Survey.

NORTON TRADITION AD 1000 TO 300 BC			
Area	**AHRS Site**	**Characteristics**	**Houses**
Kvichak	DIL-00161	Prehistoric village (6100 artifacts) 1760+/-40 BP	34-45
Kvichak	DIL-00174	Two large house depressions; Smelt Creek Phase 1920+/-40	2
Kvichak	DIL-00175	Village site, artifacts, pottery; Norton Brooks River Weir and Brooks River Falls phases, 1830+/-40 BP	8
Kvichak	DIL-00229	Prehistoric Village	1
Kvichak	ILI-00073	Village site, Pottery,	4
Kvichak	DIL-00207	Village, 43 house depressions; lithics and ceramics	43
Iliamna Lake	ILI-00056	Village, C14 date 860+/-60	12-15
Iliamna Lake	ILI-00127	Pottery and stone beads	
Iliamna Lake	ILI-00128	Weir, Early Norton	
Iliamna Lake	ILI-00098	Village, cache pits no houses apparent on surface, fiber pottery	
Lake Clark	ILI-00012	Village	12
Lake Clark	XLC-00086	Bifaces, scrapers, sideblades, fiber pottery.	

The Norton tradition in the study area is succeeded in Yup'ik territory by a number of pre-contact Yup'ik sites listed in Table 6. Almost all of the sites include semi-subterranean house pits indicating sedentary or semi-sedentary occupation.

Table 6. Pre-Contact and Early Contact Period Yup'ik Sites, A.D. 1000 to A.D. 1800. Compiled from Alaska Heritage Resources Survey.

PRE-CONTACT YUP'IK AD 1000 TO AD 1800			
Area	**AHRS Site**	**Characteristics**	**Houses**
Kvichak	DIL-00168	Prehistoric Village	3
Iliamna Lake	ILI-00034	Village	10
Iliamna Lake	ILI-00032	Village	5
Kvichak	DIL-00033	Lithic remains, ceramics; surface finds in Levelock	
Kvichak	DIL-00226	Village Prehistoric and/or Early Historic Village	7
Kvichak	DIL-00227	Prehistoric and/or Early Historic Village	1
Kvichak	ILI-00053	Village (10 houses with 2 Kashgee) Possible historic component	10
Kvichak	ILI-00074	Village	N/A
Nushagak R. Mouth	DIl-00057	Village, slate blades, pottery	6
Nushagak River	Dil-00047	Yup'ik Village	4
Nushagak River	DIL-00155	Village, House	3
Nushagak River	DIL-00052	Yup'ik Village, Nautauagavik	4
Nushagak River	DIl-00040	Yup'ik Village, Old Kokwok	6
Nushagak River	DIL-00002 A	Yup'ik village, Akulivikchuk	8-88
Nushagak River	DIL-00048 A	Yup'ik village, Agivavik	11
Nushagak River	DIL-00196	House pits, New Stuyahok airport road	N/A
Nushagak River	XNB-00029	Yup'ik Village	3
Nushagak River	NAK-00143	Yup'ik Village	9
Nushagak River	NAK-00001	Yup'ik Village	8
Nushagak River	DIL-00148	Yup'ik Village; C14 dates: BP 60+/-90 BP 50+/-70 BP 1330+/-90	8
Nushagak River	NAK-00144	Yup'ik Village	3
Nushagak River	TAY-00003	Yup'ik Village	2
Mulchatna River	DIL-00177	House, prehistoric	
Iliamna Lake	ILI-00123	Village	2
Mulchatna River	DIL-00194	Prehistoric Village	3

It is not clear how long the Dena'ina have been salmon fishers, but about A.D. 1000, the Dena'ina of the Mulchatna River and Lake Clark areas developed a method to catch salmon using weirs and began storing salmon in underground cold storage pits called *ełnen tugh* (Kenai dialect) that appear in the archaeological record (Boraas 2007). Salmon storage technology spread to Iliamna Lake, Cook Inlet, and the Susitna and middle Copper River areas (Boraas, 2007). A proliferation of Dena'ina sites—65 have been found to date, far more than any other pre-contact period—occurs in the study area, dating to just after A.D. 1000 (Table 7 and Lynch, 1982). Forty-one sites are village sites (not necessarily occupied simultaneously) and the Kijik

Site, XLC-00084 and associated sites, are among the largest in Alaska for the prehistoric period. We can conclude that weir fishing and the underground cold storage technology described in the pre-contact culture section (II.C.2.) below was an extremely successful adaptation and shaped the Dena'ina as "salmon people."

Table 7. Pre-Contact or Early Contact Period Dena'ina Sites in the Study Area. Compiled from Alaska Heritage Resources Survey.

SEDENTARY DENA'INA AD 1000 TO AD 1800			
Area	**AHRS Site**	**Characteristics**	**Houses**
Mulchatna River	XLC-00072	Village	1
Mulchatna River	XLC-00076	Village	2
Mulchatna River	XLC-00078	Cache pits	
Mulchatna River	XLC-00074	Village, Dena'ina	1
Mulchatna River	XLC-00075	Village, Dena'ina	1
Mulchatna River	TAY-00046	Cache pits	
Mulchatna River	TAY-00026	Cache pits	
Mulchatna River	TAY-00030	Cache pits	
Mulchatna River	TAY-00027	Cache pits	
Mulchatna River	TAY-00031	Cache pits	
Mulchatna River	DIL-00200	Cache pit	
Mulchatna River	DIL-00201	Cache pit	
Iliamna Lake	ILI-00029	Fish camp	
Iliamna Lake	ILI-00046 B	Village Complex	
Iliamna Lake	ILI-00019	Village site	3
Iliamna Lake	ILI-00135	Cache pit	
Iliamna Lake	ILI-00021	Village	nd
Iliamna Lake	ILI-00020	Village, houses undetermined	nd
Iliamna Lake	ILI-00001 A	Village	5
Iliamna Lake	ILI-00047	Cache pits	
Iliamna Lake	ILI-00049	Village	4
Iliamna Lake	ILI-00018 B	Village 560+/-60 BP	nd
Lake Clark	XLC-00048	Cache pits	
Lake Clark	XLC-00057 A	Prehistoric Village	30
Lake Clark	XLC-00102	Village	10
Lake Clark	XLC-00167	Village	5
Lake Clark	XLC-00166	Village	2
Lake Clark	XLC-00094	Village	19
Lake Clark	XLC-00165	Village	2
Lake Clark	XLC-00164	Village	2
Lake Clark	XLC-00155	Village	5
Lake Clark	XLC-00163	Village	1
Lake Clark	XLC-00162	Village	2
Lake Clark	XLC-00101	Village	11
Lake Clark	XLC-00100	Village	14
Lake Clark	XLC-00099	Village	2
Lake Clark	XLC-00084	Village (possibly two sites)	95
Lake Clark	XLC-00092	Village	13
Lake Clark	XLC-00090	Village; C14 BP 300+/-60	10
Lake Clark	XLC-00091	Village	4
Lake Clark	XLC-00093	Village	1

Lake Clark	XLC-00021	Cache pits	
Lake Clark	XLC-00020	Village	2
Lake Clark	XLC-00012	Village	2
Lake Clark	XLC-00013	Trapper cabin	
Lake Clark	XLC-00159	Village	3
Lake Clark	XLC-00158	Village	2
Lake Clark	XLC-00104	Village	1
Lake Clark	XLC-00157	Village	3
Lake Clark	XLC-00156	Village	12
Lake Clark	XLC-00105	Village	10
Lake Clark	XLC-00088	Cache pits	
Lake Clark	XLC-00083	Village	6
Lake Clark	XLC-00097	Village, 1 house	
Lake Clark	XLC-00098	Village	5
Lake Clark	XLC-00003	Cache pits	
Lake Clark	XLC-00004	Cache pits	
Lake Clark	XLC-00008	Village	4
Lake Clark	XLC-00250	Cache pit	
Lake Clark	XLC-00133	Village	3
Lake Clark	XLC-00134	Village	1
Lake Clark	ILI-00087	Cache pits	
Lake Clark	XLC-00096	Village	1
Lake Clark	XLC-00249	Cache pits	
Lake Clark	XLC-00107	Village	1
Mulchatna River	DIL-00150	Cache pits	
Iliamna Lake	ILI-00031	Village	5

B. History and Culture of the Yup'ik Area

1. Voices of the People

We want to give to our children the fish, and we want to keep *the water clean for them….It was a gift to us from our ancestors, which will then be given to our children.* F-69, 9/18/11

When I was a little girl they had no Snowgo's [snowmachines], *they had no Hondas* [Four-wheel all-terrain vehicles]. *We live up river and they fished all the time. In wintertime they fished under the ice. They travel with dog teams. My Dad would take me out ice fishing. I used to be scared of those pikes. I don't know how old I was. That's the only thing they do is try to catch fish, summer time nets, and winter time they do ice fishing. That's how they pass it on down. They subsistence fish, usually they travel with dog teams, that's what they did, and that's how come those people were healthy. They walked, and walked, they worked from morning until they go to bed. That's how come they were healthy. They eat their fish, they go get wood with the dog team, they hunt with their dog teams, and they travel to village with their dog team. People walk and they eat that fish. That's what makes them live long and healthy, I noticed that.* F-23, 5/18/11

All we have is use the salmon, salmon all the time. The old people tell us you guys have only one salmon season you guys got to catch it. If you don't catch it you won't have much in the winter, long winter. F-41, 8/19/11

*When you look at the map and where the old villages were they were there because of the salmon. You go to Igiugig and ?, and Port (?), Levelock, South Levelock and Dillingham… all those villages. Site selection of those communities was very important and it was because of the production of subsistence foods at each of those sites processed. Most of those produced salmon in addition to [*other foods*], for example you go to the village of Manokotuk, and it is rich in berries. If you go to the upriver villages they are rich in caribou and moose and other resources. Each village was selected by the folks…because of their subsistence resources.* M-61, 9/16/11

My father along with other people was very active in fisheries politics. Bristol Bay used to be controlled by Brindle which was a big cannery superintendent and what he said was law of the land. Fish and game used to listen to those big processors. One time my dad was talking to a group Truman Amberg, Joe McGill, Joe Clark from Clark's Point, saying we got to go on strike this year. I think it was Joe McGill said we're not going to get any more money [father's name]. Why are we going on strike? You know we are just going to end up sitting on the beach. Dad says we got to let the fish pass. What that meant was we needed more fish up the river spawning so we would have better seasons later. Then a group of locals said okay we're going to strike but know they're not going to give it but we will get more fish up the river because the Japanese decimated our runs in Bristol Bay in the '60's and 70's. We had to build our runs back up, M-60, 9/16/11

Like before, you know a lot of people used to put up a lot of fish 3000, 4000, 5000 fish. They used to have a lot of dogs while they were living that is how they try the tradition they have. They used to hook up their dogs and go wherever they wanted to go. They used to put up a lot of fish to eat. When they get moldy they just wipe it off and eat them. That is the way it was in my living days. Nowadays people when it is moldy they throw them away, that is the way of life now. You can't do that anymore. M-49, 8/20/11

2. Introduction

Perhaps as a result of the relatively recent occurrence of contact with non-Natives, the Yup'ik of the Nushagak and Kvichak watersheds have retained their traditional culture and language, ecological knowledge and practices, social systems, and spirituality, to as great or a greater degree than any other Alaska Native populations. Where they have adopted non-Yup'ik traditions, such as Russian Orthodoxy, they have blended their own practices and beliefs with the introduced practices to create a new belief system that retains the Yup'ik culture as a whole.

3. Pre-Contact Culture

An Eskimo-speaking people have been living in the region for at least 4,000 years as a recognizable salmon culture, at least as far back as the Norton tradition and Arctic Small Tool tradition.

The Yup'ik of the Nushagak, Kvichak and lower Mulchatna Rivers historically were organized in bilateral extended families of up to about thirty people settled in permanent and semi-permanent villages. Many of the villages contain a *qasgiq* (*kashgee* and other dialect variations) or men's house, and are relatively small, averaging five to six houses per village in the 12 pre-contact villages for which there is house data (see Table 6). Historic Yup'ik village sites, of which 21 are currently documented, average between 8- 9 houses per village. Today there are only four modern Yup'ik villages along the Nushagak River (Dillingham, Ekwok, Koliganek, New Stuyahok, (and possibly Portage Creek); see also Table 1) and, except for seasonally occupied Portage Creek, they are larger in population than their historic or pre-contact counterparts.

The wetland landscape is not easy to traverse, except by river, or in the depths of winter when all is frozen. The abundance of fish and game in the Bristol Bay region allowed the Yup'ik to stay within a relatively fixed range, although they moved throughout their range seasonally from a base village, to hunt, gather, and participate in summer fish camps. The extended families practiced food sharing and generalized reciprocity, both within and between families. Most larger villages functioned as independent and self-sufficient social units, and people married within the village or nearby villages. Sometimes fluctuations in game or fish availability caused groups or individuals to travel from one region to another. Large disruptions to the population occurred when epidemic diseases arrived with European explorers. These diseases devastated whole populations, decimated villages, undercut social distinctions (Fienup-Riordan, 1994).

Historically, including after contact, in the winter villages the men and boys older than seven or eight lived in the *qasgiq*, the large communal men's houses, while women and girls lived in a smaller house called an *ena*, both built from sod and wood. During the winter, the community came together for dances and storytelling, but otherwise, men and women kept in their separate groups and worked to do gender-specific chores. Men, for example, repaired the tools for hunting, while women sewed clothes as well as waterproof raingear to protect everyone from harsh weather.

In the summer, everyone participated in harvesting salmon, whether net fishing, or processing the fish in fish camps. Women dominated the work of processing in the fish camps. Family groups might put up as much as 5,000 fish (personal communication to Catherine Knott, Lena Andree, Yup'ik Elder, Dillingham; July, 2011), including fish for their dogs.

The Yup'ik traveled to different subsistence sites either overland, by foot or dogsled, or on the water, in vessels that ranged from small kayaks to larger wooden boats. Traditional festivals during the year included the Bladder Festival, *nakaciuryaraq*, the Messenger Feast, *kevgiryaraq*, and the Seal Party, *uqiquryaraq*. Food exchanges played an important part in these festivals described below.

4. Post-Contact Yup'ik History and Culture (A.D. 1791 to 1935)

At the turn of the 19th century, the bilateral extended family, stretching over several generations, still formed the basis of Yup'ik villages (Fienup-Riordan 1994). Winter villages could be just one family, but ranged up to 150 to 300 people in some places. Families did not all live together in one house; the winter villages had one or more *qasgiq*, where men and boys over age 6 or 7 lived and worked together, telling stories, making tools, and preparing for subsistence activities. In the *ena*, women, girls, and the youngest boys lived in groups of up to a dozen, and the women taught the girls how to sew and cook. They cooked the meals there, either in the entryway, or in a central fireplace. Each winter, for three to six weeks, boys and girls would switch homes, and the men would teach girls survival and hunting skills, while the women would teach the boys how to sew and cook (Fienup-Riordan, 1990).

The *qasgiq* also functioned as the communal sweat bath for the men. They would open the central smoke hole, feed the fire until the heat was intense (possibly up to 300 degrees), then bathe. Men sat in the sweat house in the order of their social status. The *nukalpiaq*, or good provider, held a high social position and contributed wood for the communal sweat bath, as well as oil to keep the lamps lit; he also played an important role in midwinter ceremonial distributions of food (Fienup-Riordan, 1994). There was competition between families to be the best providers.

Contact between the Yup'ik of the Bristol Bay area and Russians or Americans was later and more limited than in most of the rest of Alaska. The region was perceived to have few resources worth exploiting, and the marshlands were difficult to traverse. While some Russian explorers, traders, and missionaries persisted and made repeated contact with the Yup'ik throughout the nineteenth century, they did not settle in the area in any numbers until the twentieth century (VanStone 1967). As a result, the Yup'ik of this region, perhaps more than any other indigenous peoples in Alaska, have retained much of their language and cultural traditions to the present time.

When the Europeans came, they brought diseases, to which the Yup'ik and other Alaska Native populations had no immunity. The first epidemic known to have occurred in the Nushagak River region was before 1832, but there are no records of the number of dead. The 1838-1839 smallpox epidemic caused several hundred deaths in the Nushagak region and also occurred in the Dena’ina territory. Vaccines were introduced in 1838, and some Yup’ik received them, probably reducing the scope of the epidemic and subsequent outbreaks of smallpox. But each year, while not necessarily counted as an epidemic period, brought more death and illness to the region. Survivors were often weakened and succumbed later to other illnesses. VanStone states that during this period “The specter of ill health and death was continually present among the Eskimo population of all southwestern Alaska” (VanStone, 1967:100). VanStone (1967:100) goes on to state that the loss of population (especially Elders), the disruption of families, the plethora of orphans, and subsequent rearrangements of the social order created a social and cultural upheaval that the Yup’ik struggled to overcome. The European visitors and settlers may not have understood that what they observed was not the way the Yup’ik had lived even a few short years before.

It is not certain when the first Russian visit to the Nushagak and Kvichak region occurred, but in the early 1790s Aleksey Ivanov of the Lebedev-Lastochkin Company made an overland journey to Iliamna Lake from Cook Inlet and then west into the Mulchatna and Nushagak drainage. His guide was apparently Dena’ina because the place names, including *Dudna* (spelled Tutna) the Dena’ina name for Yup’ik’s (Downriver People), are Dena’ina, (Chernenko 1967:9-10). The Russian-American company sent an expedition in 1818 to explore the territory north of Bristol Bay. In the same year, the company established a post at the mouth of the Nushagak River, the Alexandrovski Redoubt. Feodor Kolmakov, of mixed Russian and Native American ancestry, was in charge; he established trade relations with the Yup’ik and baptized some of them, spreading the influence of the Russian-American Company (VanStone, 1967:9).

In the summer of 1829, two minor Russian visits had major consequences for the Yup’ik. Ivan Filippovich Vasiliev led an overland expedition to ascend the Nushagak River, and the priest, Ivan Veniaminov, visited the redoubt. Veniaminov took away a permanent interest in the Bristol Bay region and in the Nushagak station which carried over even into his later position as Bishop. Vasiliev’s exploration, in turn, established travel routes that were used by subsequent fur traders (VanStone, 1967:11).

Christianity was introduced in 1818, at the time that Alexandrovski Redoubt was built, but it was not until Veniaminov’s arrival in 1829 that extensive missionary activity took off. Veniaminov was flexible in his approach to the Yup’ik and their traditional religion and numerous conversions were registered in church documents. Veniaminov noted that “the Nushagak River was for them [Yup’ik] the River Jordan” (cited in Barsukov, 1887-1888, vol. 2:37). In 1832 Veniaminov visited again and had a small chapel built. By 1842 there were about 200 converts at Nushagak, and in 1844 Bishop Veniaminov had a new church built. The church, by 1879, was close to 2,400 members. Its success among the Yup’ik may have had much to do with the flexibility of Veniaminov’s approach toward them. Yup’ik people were not required to fast and many indigenous customs were tolerated (VanStone, 1967:31).

Fur trading accompanied exploration, and sometimes incited it. By the 1840’s contacts between the Kolmakovski Redoubt, on the Kuskokwim, and Alexandrovski at Bristol Bay were frequent. The company managers of the fur trade created *toyons,* designated local community leaders, and rewarded them with silver “United Russia” medals and incentive gifts. These *toyons*, motivated by their new prestige and the material rewards offered, then encouraged the members of their social networks to trap more furs for the Russians (Van Stone, 1967:56). The process of using village providers to convert the population into loyal company men and women to recruit fellow villagers into exploiting and extracting the resources of their own region for external benefit in a colonialist economic system has not changed in over a hundred years.

Trade items included wool blankets, tobacco, beads, tent cloth, cast iron kettles, knives, iron spears, steel for striking a fire, needles, combs, pipes, etc. (VanStone, 1967:56). While these items did not immediately alter the deeper structures of the culture, the desire for them acted as a change agent among the population. Where before, access to status had been open to all, through skills and responsible sharing with others, access to the time and materials for trapping, open to fewer individuals, had the potential to change the social dynamics of the Yup'ik. The companies allowed the Alaska Natives to purchase some items on credit; as debt mounted, some would be unable to repay for years. After the Alaska purchase, the powerful Alaska Commercial Company post at Nushagak maintained a trading post through the remainder of the nineteenth century engaging in about $10,000 in fur trades annually (VanStone, 1967:56),

In the nineteenth century gold mining occurred but was economically unimportant compared to other activities. In 1887-1888 the prospectors Percy Walker, Henry Melish, and Al King placer-mined for gold in the Koktuli and Nushagak Rivers, and there was also placer mining along the Mulchatna. In 1909 a group organized the Mulchatna mining district and formed the Mulchatna Development Company in Seattle (VanStone, 1967:83). Their activities were confined to the upper Mulchatna River in Dena'ina territory, and there was only a very temporary influence of miners on the local Alaska Native population. One Elder (New Stuyahok Interviewee in a non-recorded interview situation) told the story of his grandfather, who showed him gold and told him that if he found rocks with gold in them to throw them away, because they were bad. The grandson thought it was because it would cause social disruption by bringing strangers to the area who would disrupt the land and the culture of the people. The Elder said he had thrown a big chunk of gold away once, but he thinks he still knows where it is. The experience of the Yup'ik people with larger mining corporations has been minimal. Fish have been far more important both to subsistence and cash-based economies.

By the end of the nineteenth century, Bristol Bay had become an important commercial salmon fishing zone. The first salmon cannery, The Arctic Packing Company, began operation in 1884 at the village of Kanulik at the mouth of the Nushagak River (Troll, 2011:3). The fourth cannery, built at Clark's Point in 1888, is now the oldest surviving cannery in the region (Troll, 2011:4). The commercial fishermen in Bristol Bay used wooden sailboats for drift gillnet fishing for sockeye salmon and were mostly Italians, Scandinavians, and Finns, hired at Seattle and San Francisco (Troll, 2011:10), although some Yup'ik also fished commercially including Lena Andree, now an Elder from Dillingham who fished on one of the wooden sailboats with her father in the mid-1930s. When World War II began and kept many of the European fishermen from coming to Alaska to fish, the canneries "discovered that the Native Aleuts and Eskimos were marvelous boatmen and seemed to have been born to sail," according to Al Andree (cited in Troll, 2011:35).

The U.S. Bureau of Fisheries visited the Wood River lakes and Nushagak and Nuyakuk Rivers, and, in 1935, the U.S. Geological Survey conducted the first survey of the region and produced what would become, for decades, the standard reference for people not from the region. For the Yup'ik, the Elders continued to convey their traditional knowledge of their homeland, as they had for thousands of years (Van Stone, 1967). A crevasse of deepening proportions opened between two contrasting interpretations of the landscape, that of the outsiders, who saw the region as a land of resources to be exploited, and that of the indigenous peoples, who saw the region as the sacred landscape of home, and whose culture and way of life depended upon it.

Figure 8. Koliganek Tribal Offices. September 19, 2011. Photo by Alan Boraas

C. History and Culture of the Dena'ina

1. Voices of the People

We harvest [subsistence foods] *three times for that one person: day of the burial, forty days later, and then one year later. It is really significant, just for that one person who passed away; we harvest from the land three times to honor and to pay our respects to ones who lost their family member. That has been going on for over 10,000 years*. M-33, 8-18-11

…from our ancestors, that is how we get all of our information to have fish. The way we put it; the way we store it for us to eat. That is where we learned it. It is passed on from generation to generation to have fresh fish. F-48, 8/20/11

I always think that we are very, very, very lucky people. I know where I came from. I know who I am. I know where I belong in this world. I know where my ancestors come from. I know the trips; the walking, the hiking, I know the history of where they were. Every time I come into this part of the country or fly over it, when I first see the Lake Clark area or coming from the south and see Sixmile Lake, I know I'm home! F-32, 8/18/11

*So the importance of this resource, specifically salmon, has a major impact on my people here. That's the reason why we live here. We have sockeye salmon until March, when everyplace else has no more. That's why my ancestors fought over this region… The reason why they've been here for so long is it's a healthy environment, and we have been kind of watching over it all these years. My ancestors fought over it, and they won every battle. We beat the Russians two times. It was musket against bow and arrow. So, you see, the importance of it has a really long history of why it is like it is now. We took care of it. Not only that, we have shared with everybody in the whole world.[*in reference to commercially caught salmon] M-33, 8/18/11

My Auntie [name] *would say, "Don't forget how to live off the land" and I'd think, "Oh, we could just go to the store and have microwave stuff." She said, "One day in this world something's going to happen where you guys are going to rely on living off the land, trapping off the land." Like we take things for granted now; we can go on an airplane and shoot a moose or trap beaver or trap squirrels up on the mountain. We have to. We can't just forget our ways; how to live off the land, because one day there's going to be something that happens in the world, where we are going to have to learn to survive out here.* F-32, 8/18/11

But what the spiritual aspect of what they believed was strong…they had energy. Energy from what they worshipped; everything living. M-33, 8/18/11

That is spring water [at Kijik]. *It does not freeze. That is why you can go over there and get a sockeye salmon in March; it might have a green head, and it's red, but it's still a sockeye salmon. You can go over there on New Year's Day and get a fresh sockeye salmon.* F-33, 8/18/11

Figure 9. Kijik River, called, *Ch'ak'dłatnu* 'Animals Walk Out Stream' in the foreground; *Yuyan Ach'edeł t* 'Where We Walk into the Sky' is the snow-covered pass in the distance. Photo by Alan Boraas

2. Pre-Contact Culture

Dena'ina origins are described in the section on Prehistory (II.C.2) and indicate the Dena'ina have been operating as a culture for whom salmon is the primary resource since A.D. 1000. Much can be inferred about the pre-contact Dena'ina culture because of Cornelius Osgood's (1976, originally published in 1937) comprehensive *Ethnography of the Tanaina* [sic]. Like the pre-contact Yup'ik culture, the Dena'ina pre-contact culture was sustainable and egalitarian in terms of equitable access to resources. The fundamental food source was salmon, but also included caribou, moose, bear, beaver, and other mammals and birds (Osgood, 1976:26) and about 150 edible plants (P. Kari, 1987:60-188). For the pre-contact Dena'ina salmon were caught in a number of ways, but primarily in weirs made of poles sunk into the bottom of a stream and strung with a lattice-like thatch, allowing water to pass through, but trapping migrating fish (Osgood, 1976:28). When they weren't fishing they simply opened a gate, and the fish swam through to spawn upstream. To solve the problem of storing this food resource for later use, the Dena'ina devised a simple but effective underground cold storage pit (Osgood, 1976:42). Two layers of birch bark, with moss in between, lined the pit, which was filled with dried fish, layered with grass, during fall freeze-up. The frozen fish were eaten throughout the winter and spring, until the next summer's salmon run. Like modern fish camps, traditional Dena'ina fishing was an extended family operation. Everyone worked for, and received the benefits of, the clan-based family group.

Because of the stable salmon food resource and a means to preserve it, the Dena'ina lived in sedentary or semi-sedentary villages of substantial log houses, usually spread out along a ridge above a lake, a river side channel or a tributary to one of the major rivers (Osgood, 1976:55-62). The married men of a village were members of the same matrilineal clan and their wives and children were members of a different clan (Osgood, 1976:128-131). Within this family group, connected by blood and marriage, and allied for economic purposes, various individuals performed different assigned tasks. The Dena'ina called this group the *nakilaqa* (*ukilqa* in Osgood) (Osgood, 1976:134) or clan helpers. The clan helpers recognized a chief, called a *qeshqa;* in the Iliamna area the position was related to being a family head (Osgood, 1976:131-3; Fall 1987:6-8). The *qeshqa* had numerous characteristics, among them wisdom, experience, and generosity. He or she had three primary duties: first, to arbitrate and resolve disputes; second, to care for the elderly and orphaned; and third, to assure the survival of the clan helpers through the equitable distribution of food. Regarding the latter, the *qeshqa* controlled the foods gathered, processed, and stored by the clan helpers and had authority to redistribute the food (mainly salmon) back to people throughout the winter on an as-needed basis.

This system provided a safety net. Each *qeshqa* had a partner in a distant village, called a *slocin*. If one village ran low of food, the *qeshqa* could request aid from his partner, who would divert some of his village's food resources to the needy village. The second *qeshqa* would be willing to do this because, at some point, his village might be short of food, and the partner he helped would return the favor.

3. Post-contact History and Culture

In the study area Dena'ina territory includes the Kvichak drainage of Lake Clark, the Newhalen River and the west half of Lake Iliamna. Today, the Dena'ina villages in the Kvichak/Iliamna drainage are Nondalton, Iliamna, and Pedro Bay; Kokhanok is mixed Dena'ina Alutiiq, and Yup'ik. This brief history is germane to the project because it establishes: 1) the Dena'ina repelled Russian colonization maintaining population superiority in their homeland to this day: 2) they adopted Russian Orthodoxy which ritually incorporated traditional viewpoints of a symbolic relationship of people to the land, and, 3) they began to have economic ties to the Bristol Bay salmon canning industry. Through it all the people retained a strong subsistence lifestyle.

During the late eighteenth century, two Russian trading companies, the Shelikhov Company and the Lebedev Company, occupied Dena'ina territory, focusing primarily on the Cook Inlet region but extending into Iliamna Lake. The Lebedev established a post at Pedro Bay, on Iliamna Lake, in the 1790s (Ellana and Balluta, 1992:61). About 200 Russians occupied Cook Inlet and the Iliamna Lake area during the late eighteenth century; by the turn of the century, their presence had shrunk to a small handful through a complex series of events involving attacks and counter-attacks as outlined by Boraas and Leggett (in press, 2013). As a result of hostilities the Russian Lebedev Company left Alaska in the spring of 1798, and subsequent Russian presence in Dena'ina territory was minimal.

Figure 10. Pedro Bay, General Location of the 18th Century Lebedev Company Post. August 19, 2011. Photo by Alan Boraas

In 1838 a terrible smallpox epidemic decimated the Dena'ina (and most other Pacific coastal Alaska Natives). Where there are statistics, such as for the Kenai River drainage, about half the overall population died in two years (Fedorova 1973:164) and, although there are no specific statistics for the Lake Clark and Iliamna, it is likely the situation was tragically similar in the study area. Traditional shamanic practices were ineffective against smallpox and, after 1840, many Dena'ina were baptized as Russian Orthodox, (Townsend 1981:634-6), accepting the church's explanation for the epidemic as "God's will" (Boraas and Leggett in press, 2013). In 1853 the Orthodox Church undertook an inoculation program, vaccinating baptized Dena'ina against smallpox, and an Orthodox Church was built at Kijik in 1884 (Ellana and Balluta, 1992:63). It is probable that by the early twentieth century, most Dena'ina in the Iliamna/Lake Clark area were baptized as Orthodox.

Well into the twentieth century Dena'ina practiced a ritual that involved sending the spirit of the animal to the "reincarnation place." Land animal bones were burned in the fire and water animal bones, like salmon, were returned to the water. These practices ritualized ecology and were said to bring the animal back to be hunted or fished again (Boraas and Peter 1996:188-190).

Archaeological evidence indicates the Dena'ina were burning bones in their fire hearths (Boraas and Peter 2008:220-222)

As summarized by Karen Gaul (2007:48) salmon canning in Bristol Bay emerged as a major industry in the late 1800s. Unregulated Bristol Bay canneries regularly blocked the mouth of the Kvichak and Nushagak Rivers to harvest salmon; consequently, there were years when there was little escapement into the rivers, creating extreme hardship for the upriver Dena'ina and Yup'ik subsistence communities. Starting in the early 1900s, men from the inland villages traveled to the coast to work seasonally in the commercial fishery, as many still do today. The fur trade was a second non-subsistence occupation, providing cash for food, guns and ammunition, traps, cloth, and other items, but commercial salmon fishing remained the primary source of money for most indigenous families and supplemented subsistence activities (Gaul 2007:48).

Small scale gold mining in the upper Mulchatna was mentioned in the previous section. In 1902 a copper mine in Dena'ina territory was staked about nine and a half miles from Cottonwood Bay on Cook Inlet toward Lake Iliamna (DeArmond nd:30). Development, including 14 miles of trail, was carried out by the Dutton Mining & Development Company headed by George W. Dutton. Dutton was established as a small settlement on Cottonwood Bay where a post office was started in 1905. The deposit proved unprofitable and by 1909 the post office was closed and the mine abandoned.

D. Traditional Yup'ik and Dena'ina Spirituality and Cosmology

Many modern practices of Yup'ik and Dena'ina have their basis in traditional spiritual and cosmological beliefs, though they are sometimes re-contextualized in Christianity. This section discusses the traditional spiritual and cosmologic beliefs and practices of both peoples.

Figure 11. Nushagak River, January 18, 2012. Photo by Alan Boraas

1. Traditional Yup'ik Spirituality

Traditional Yup'ik values revolved around not only their extended families, but also their relationships with the wild animals and other components of the natural landscape. Within this belief system, the *Ellam yua*, or creative force, was a universal cosmic presence who coordinated existence and established a basic ordering framework; *tunghit* were powerful spiritual beings who controlled the recycling of different animals, fish, and bird forms (Langdon, 2002).

The Yup'ik have traditionally regarded animals as other peoples, or categories of kinsmen, with whom they have fluid relations that often cross species and interpersonal boundaries. There are numerous stories of half-animal, half-human beings who live in the villages or of people turning into seals, birds, fish, or other animals, and then turning back into humans, as well as stories of people who seem to be human, but turn out to be seals or other animals in a temporary human form. Several major traditional festivals and ceremonies, described below, honored this relationship. The spiritual values associated with each of these festivals emphasized sharing between humans and respect and care for animals. Traditional stories and advice speak of the animals giving themselves to the humans when the humans need them for food. The good practices of sharing, care, and respect (e.g., being careful with the animal's body and soul, and not wasting the food) ensured the animals' continued willingness to give themselves to the hunters and fishermen in the future. Sharing of the products of subsistence with their human kin and other relations also strengthened the bonds of family and community. A version of The First Salmon celebration in the river communities is still celebrated today, when those who have caught the first king salmon in the spring share them with Elders and all those in need, as well as with friends and family, emphasizes these values.

The Yup'ik relations with the wild animals and fish of their landscape were primary, and in many ways still are. The Yup'ik related to the fish, the bear, the caribou, the moose, the ravens as relations, others equally inhabiting the landscape with them as interrelated peoples. During spring, summer, and fall the Yup'ik hunt and fish the animals as food, but when processing the animals as food they treat them with respect and care, and enable their return through rituals and ceremonies. In winter, a period of rest and renewal for the human population, in the past the Yup'ik attended to the renewal of life through the rebirth of the animals they had hunted, and fished, in, according to Fienup-Riordan five ceremonies, "three of which focused on the creative reformation of the relationship between the human community and the spirit world on which they relied." (Fienup-Riordan 1994:267). Today, many of the Russian Orthodox ceremonies continue to be based on this ancient calendar of propitiation of the world of the spirit, in all seasons. During the winter ceremonial season, the men beat the circular drum—traditionally made from stretching seal gut on a wooden frame—for songs and dances. The drum beats represented the heartbeat of *Ellam yua.* Thus, the celebrations were spiritual in the deepest sense. They were also material, involving the exchange and sharing of wild subsistence foods from both animals who had given themselves willingly to the hunters and plants gathered from the landscape, considered to be spiritually alive.

During the Bladder Festival, at or around the Winter Solstice, the women brought out the bladders of seals, which they had been saving since their husbands brought the seals to them to prepare, because the Yup'ik believed that the souls or essence of animals are located or retreat to their bladders when they are killed. By saving the seal bladders and returning them to the sea, the Yup'ik enable the seals to be reborn, and present themselves again as food for the Yup'ik when needed. The women take the seal bladders to the *qasgiq* where the men inflate them and keep them for about ten days, while they go through a series of rituals to honor the seals and share food in the community, before returning the bladders under the ice, to the sea, enabling the seals to be reborn and to present themselves to the Yup'ik when needed again as food. The men would compose new songs for the Bladder Festival, including songs about salmon, and sing continuously in the *qasgiq*; people believed that light from the lamp and the songs drew the attention of animal spirits (Fienup-Riordan, 1994:284).

At *Qaariitaaq*, at the beginning of the Bladder Festival, the young boys were painted to represent the spirits of the dead, and went visiting, going around to the different houses to collect special food treats. Every house was brightly lit, and the hostesses wore their best clothes. The boys held out their hand-carved bowls, and the women handed out the special snacks. On the fifth night of these celebrations, the boys, and men, came to fully embody the spirits of the dead, and the fifth night was considered the arrival of the spirits. (Fienup-Riordan 1994:271). At *Aaniq*, held directly after *Qaariitaaq*, two men dressed in gut skin parkas, are referred to as mothers, the "*aanak,"* and they are taken around to collect newly made bowls filled with *akuutaq*, traditionally a mixture of fat and berries. Small girls and boys referred to as their "dogs" would accompany them.

The way that people do things
And the way of helping others
And the way of creating friendship
The Bladder Festival is like an opening for these things to occur
And through those events
The people being scattered
Through that too they are gathered
(Toksook Bay Eders, November 3, 1983 NI57 in Fienup-Riordan, 1994: 267).

Today, starting during the Russian Christmas season the modern ritual of "Starring" follows this familiar pattern – groups go visiting from house to house, and receive special foods.

Other important ceremonies include the Great Feast for the Dead, *Elriq*, held every ten years, as well as the annual feast for the dead, and *Kelek*, a festival that included both serious and comic masked dances, when "animal spirits and shamanic spirit helpers made themselves visible in the human world in dramatic form" (Fienup Riordan, 1994:316). *Kelek* was performed to influence the animal spirits and elicit successful hunting and fishing through the return of the animals the following year.

Two other winter festivals underscored the redistribution of goods, including subsistence foods. The first, *Kevgiq*, the Messenger Feast, was a celebration and display of the bounty of the harvest, in which villages challenged each other to exchanges of wealth, with demands for specific items that were difficult to provide, such as certain game meat in a year when that game animal was scarce. *Kevgiq* served to reduce tensions between villages through sharing and friendly competition. It also provided food security by strengthening ties between villages and encouraging exchange relationships that could help people in times of food shortages. Sharing was considered to be a behavior that would be rewarded by the return of the animals to those hunters and fishers the following year. *Petugtaq*, the Asking Festival, was a challenge to exchange gifts of value between cross-cousins and others, where the person whose gifts were the most valuable gained the highest prestige. Cross-cousins were in "joking cousin" relations with each other, and were able to call each other out on bad behavior, embarrassing each other without repercussions, since they were not permitted to get angry with each other (Fienup-Riordan, 1994:330). The behaviors were thus made public and frequently resolved through this tension-reducing mechanism. Both festivals involved teasing, dancing and singing as part of the ritual celebration of the exchanges. All of the traditional festivals required subsistence foods, not only for sustenance, but also for the meaningful symbolic and material exchanges.

During their ceremonies, the Yup'ik wore masks they had carved, often representing animals or those in transition between the animal world and the human world, the half–animal, half-human. These masks symbolized both the high regard of the Yup'ik for the animals and the importance of their roles Yup'ik culture. For the Yup'ik, the masks were *agayuliyararput*, or "our way of making prayer" (Fienup-Riordan, 1996:xviii).

Dances, including *ingulag*—the women's loon courtship dance—and other bird dances, filled the evenings and contributed to the festivities. Each dance told a story and many featured the animals with whom the Yup'ik partnered in their negotiation for existence in the challenging landscape. Dances were traditionally an essential part of the culture and celebrations and have returned in force as part of cultural revitalization along the Nushagak and elsewhere. Fienup-Riordan (1994:288) quotes Billy Lincoln:

> And at night, every night, they have what is called *nayangaq*. They dance. These young people who are sitting against the far wall go down in front of them and dance, sitting down pretending to be some animal, so thus, the *nayangaq***.** They imitate a certain animal. When the time came whatever animal he is pretending to be he imitates its noise. They imitate all kinds of animals – loon, hawk, raven, arctic fox. They make noise accordingly. They dance pretending to be some animal (July 10, 1985).

Then as now the dancers represent the many ways the stories and lives of the animals are woven into their own, in the richness of shared existence in the watersheds of southwest Alaska. Lincoln continues:

> These dance motions were more than the mere imitation of the motions of the animals. When the performers danced during *Kelek*, they actually performed the animals' dances. Just as married women danced the loon's mating dance during *Ingulaq*, so the performers during *Kelek* danced the dances of the animals whose presence they hoped to elicit in the year to come. . .

In 1913 Hawkes quoted a Unalakleet chief in an eloquent estimation of the value of these dances within Yup'ik culture: "To stop the Eskimo singing and dancing," he said, "was like cutting the tongue out of a bird" (Hawkes cited in Fienup-Riordan, 1994:320-321).

Fienup-Riordan (1994:355; see also Fienup-Riordan 2010) summarizes how the Yup'ik traditionally saw themselves in relation to the universe: "Yup'ik cosmology is a perpetual cycling between birth and rebirth, humans and animals, and the living and the dead. Their relationship between humans and animals reflects a cycle of reciprocity in which animals give their bodies in exchange for careful treatment and respect."

Figure 12. Iliamna Village. August 20, 2011. Photo by Alan Boraas

2. Traditional Dena'ina Spirituality

The traditional Dena'ina spiritual world revolved around a quest for *k'ech eltani*, or "true belief," as a way to understand and interact with the natural world (Boraas and Peter, 1996:183-4). The Dena'ina believed that social and ecological harmony was affected by an individual's attitudes, actions, and even thoughts toward other Dena'ina and toward nature. To maintain harmony, the Dena'ina sought true belief, a kind of mind-set expressed through hunting practices, cooking rituals, communication with animals and plants (prayer), and other practices that demonstrated having a "good attitude" toward the forces of nature. Kalifornsky (1991:13) writes that, "Whatever is on earth is a person [has a spirit] they used to say. And they said they prayed to everything. That is the way they lived." Achieving *k'ech eltani* involved a spiritually torturous and mentally rigorous quest for understanding (Boraas and Peter, 1996:187).

Many of the Dena'ina traditional stories (*sukdu*) describe the dire consequences of having a bad attitude by not practicing the prescribed rituals such as burning the bones of consumed animals or distributing fish bones in the water as means to symbolically assure the animals would come back (Boraas and Peter, 2008:222-223). In these stories, a bad attitude would have the consequence of the animals, believed to be both sensate and willful, withdrawing and not offering themselves to be taken for food. The result would be starvation. A bad attitude could result in social turmoil or mental illness. There was immense pressure to behave and think respectfully toward the natural world including salmon.

In a forthcoming chapter on Dena'ina world view, Boraas (in press 2013) writes the following about traditional attitudes toward animals:

> Attitudes toward bears typify attitudes toward animals. In "Three People in Search of Truth," (Kalifornsky 1991:164-167) three brothers hunt a brown bear, the most feared and respected animal. The first fails because he is poorly skilled; the second fails because he is impetuous, and the third succeeds because he is skilled, controlled and speaks the correct words to the bear, which then respects him and does not resist being killed. In Kenai a successful hunter used the phrase *Chadaka, k'usht'a nhu'izdeyeshdle*, which translates as "Great Old Man, I am not equal to you," to communicate humility toward the bear he was hunting (Kalifornsky 1991:167). In 1966 Mrs. Mike Delkettie, a Nondalton Dena'ina, reported that a similar saying was used in that area; moreover, the eyes of the bear were buried near the spot where it was killed as an offering showing proper respect (Rooth 1971:62). Francis Wilson, also from Nondalton, told Rooth (1971:50) that, after a bear was killed, they had to follow prescribed procedures, particularly in the treatment of the head, lest they never kill another bear, because "the bear still knows what is happening, so they have to be very careful with what they are doing." Hunting rituals and prayers were meant to thank an animal for allowing itself to be killed and sometimes it also involved giving an offering as a measure of the importance of proper attitude (Rooth 1971:50).

The First Salmon Ceremony (Osgood, 1976:148; Kari and Fall 2003:184-190) expresses the intimate relationship of Dena'ina and salmon. The First Salmon Ceremony was based on a traditional story. As the Osgood's retelling goes, a *qeshqa's* (chief's) daughter was admonished not to go near the fish weir. The determined girl went anyway to find out what was in the trap, promising to return later. At the fish trap she saw a king salmon, began talking to him, and gradually transformed into a salmon and disappeared with him. The desperate *qeshqa* looked for his daughter to no avail. Years later, the *qeshqa* was collecting fish from the weir. He put them on the grass and took them to be cleaned, but forgot one little one. He returned to find a little boy sitting there. He walked around the boy three times and realized it was his grandson. The boy then told his grandfather the things that should be done to ensure the salmon return each year, and those things became the First Salmon Ceremony, a world renewal ceremony[6] which ritually recognized the salmon's return and the Dena'ina as salmon people whose spirit is merged with the fish.

In 1862 Hegumen Nikolai, the first missionary priest stationed in Dena'ina territory wrote in his travel journal, "In the middle of May the king salmon reached our area [writing from Kenai]. This is the best red fish we have here, and the Kenaitze celebrated the fish run with some sort of festivities, during which they treated each other with food" (Znamenski 2003: 91). Fr. Nikolai was clearly referring to the First Salmon Ceremony.

Water was particularly important in Dena'ina spirituality in the act of moving into a spiritually liminal state. One kneeled beside a river or lake and took three sips of water (Boraas in press 2013). This was practiced well into historic times and also occurs in mythological stories (*sukdu*). For example in "The Woman Who Was Fasting" (Kalifornsky 1991:168-9) a young

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[6] World renewal ceremonies are important identity-building ceremonies that recognize the beginning or end of a year's subsistence activity and social cohesion. In American culture Thanksgiving is a world renewal ceremony.

woman was ritually fasting and spoke these words "People will learn something from our beliefs" as she took three sips of water. She was then able to perform a spiritually power act upon which she said, "When we pray and we fast there is another dimension."

Some places took on special importance. The Giants Rock, *Dzełggezh*, was along an old Dena'ina trail that became the Pile Bay Road between Old Iliamna and Kamishak Bay on Cook Inlet, one of the major trails connecting eastern and western Dena'ina territory. The rock was the site of a mythological story and was a spiritual place (Johnson, 2004:49-54). The rock was dynamited in 1955 as part of road building activities by the Territory of Alaska; Dena'ina still regularly leave votive gifts at the site in homage to the place and the mythological event that happened there. Other sacred rocks and sacred locations exist in Dena'ina territory, but for most their locations are privileged cultural information (Boraas 2009:10-20).

Not only are there sacred sites but the Dena'ina believed the landscape retained a sense of events that happened there: events which could be good or bad. For example, *Qil'ihtnu* is located near the historic village of Kijik on Lake Clark and the place name means "Evil Creek" (Kari et al. 1986:7-42) or "bad creek" (Kari and Balluta 1985:A-36). According to Albert Wassilie (Lynch 1982), in the 19th century an Orthodox priest violated taboos concerning the creek (which he later rectified) but to traditional Dena'ina the place retains a sense of its bad history. Spiritually powerful people and animals could detect information about these events and, thus, to travel was to encounter morally good and morally bad events encoded into the landscape (Boraas 2009:8-10).

Figure 13. Evil Creek *Qil'ihtnu* near Lake Clark. Photo by Alan Boraas

E. The Yup'ik and Dena'ina Languages: Salmon and Streams

1. Voices of the People

Talk Native, no English….They talk Native [Yup'ik] better [than English]. [in reference to Elder interviews in Yup'ik] M-25, 5/18/11

That's why we quit using our Native tongue [Dena'ina] because we get our…ears pulled. I don't know how many times I sit in the corner because I use my Native tongue. We couldn't speak our own language in school because we get abused. F-46, 8/20/11
When we first went to school they took our dialect away from us and told us to speak English only. If we spoke our Native tongue we would get hit by the teacher which isn't right. Now they call it abuse. Anyways none of us speak our Native tongue [Dena'ina] because of that. My mom didn't speak English…. F-48, 8/20/11

2. Introduction

Language is intimately tied to cultural identity and Yup'ik and Dena'ina have evolved as languages of place for their respective areas over thousands of years. Landscape, subsistence, social relations, and spirituality are reflected in both languages. The variety of words a language has for a given topic generally reflects the importance of that topic, or cultural domain, to the people who speak it. Given their cultural importance, it is not surprising that both Dena'ina and Yup'ik have numerous, highly detailed terms involving salmon, other fish, and fishing. Streams are also intimately tied to Dena'ina and Yup'ik psyche and their languages reflect that fact.

One Yup'ik interviewee (M-25; 5-18-11) spoke about helping set up a 2011 Elders Conference which occurred a few days before our interviews in New Stuyahok in which the entire discussion was in Yup'ik. He said, "I set up that meeting [Elders Conference], I try to do it for a long time…yes, talk Native [Yup'ik], no English. Get somebody else to translate…they talk Native better [than English]."The speaker was expressing a version of linguistic relativity, the idea that the structure of language predisposed certain thought patterns that are not easily translated into another language and that, in turn, express deeply held cultural ideas (Mihalicek and Wilson 2011:461-467). In a similar way Boraas (2007) has described the way Dena'ina grammar influences Dena'ina thought processes.

3. The Central Yup'ik Language

The Yup'ik people of the Nushagak and Kvichak River watersheds are part of the Central Yup'ik group, of whom there is a population of about 25,000 in an area that also includes coastal communities and the lower and middle Kuskokwim River drainage (Krauss, 2007:408) (See Table 8). Ten thousand four hundred of this population, or 42%, speak Central Yup'ik of which the 7,000 mostly Yup'ik of the Nushagak and Kvichak River drainages are a part. Central Yup'ik has one of the highest percentages of speakers among indigenous languages in the U.S and is an indicator of strong cultural heritage. Yup'ik is the first language for many residents in the study area and the language in which many feel most comfortable expressing complex or heartfelt ideas, which is why, for this project, we encouraged interviewees to respond in Yup'ik if they so chose. Eight of fifty-five interviewees spoke in Yup'ik.

Table 8 Estimated Number of Central Yup'ik and Dena'ina Speakers. Data from Krauss (2007:408)

Language Family	Language	Population Estimate	Speakers	Percent Speakers
Eskimo-Aleut	Central Yup'ik	25,000	10,400	42%
Athabascan-Eyak-Tlingit	Dena'ina	1,000	50	5%

Table 9 presents Yup'ik terms for salmon, related fish, and fishing activities. In many cases there are multiple words and/or dialect differences. As indicated the sheer number of words are indicative of a long history with salmon and fishing activities. Moreover, the nuanced meaning of some words is indicative of a deep knowledge of salmon and related activities. For example the word *kiarneq*' means "unsalted strip or fillet of fish flesh without skin, cut from along the backbone and hung to dry"

Table 9. Yup'ik Words for Salmon and Other Fish and Related Fishing Terms. From Jacobson (1984)

English Term	Yup'ik Word	Literal Translation
		X indicated the literal translation is the same as the English term
salmon (generic) *(Oncorhynchus spp.)*	*neqaraq*	any species of salmon
dog *salmon,* chum *salmon*	*aluyak* *iqalluk* *kangitneq* *mac'utaq* *teggmaarrluk*	**x** 'fish' 'old dog salmon after spawning' **x** boiled half-dried salmon
humpback *salmon,* pink *salmon*	*amaqaayak* *amaqsus* *cuqpeq* *terteq* *amaqatak* *sayalleraam amaqatii* *neqnirquq*	**x** **x** **x** **x** 'back of fish, hump on back' 'back of spawning red salmon is tasty'
silver *salmon,* coho *salmon*	*caayuryaq* *qakiiyaq* *qavlunaq* *uqurliq*	**x** **x** 'streak or wake made on surface by fish'
red *salmon,* sockeye *salmon*	*cayak* *sayak* *sayalleq* *sayagcurtuq* *imarnikaralegmun*	**x** **x** 'he is fishing for red salmon at a deep calm place'
spawning *salmon*	*masseq* *masruuq una neqa* *nalayaq* *nalayarrsuun* *talayaq* *talmag (NUN)* *talmagtut*	'old salmon near spawning' 'this fish is a spawning salmon' **x** 'fish spear to catch spawning salmon' 'calico salmon' 'to spawn (of fish)' 'they are spawning'
king running under smelt	*aciirturtet*	'the first group of king salmon running under the smelt'
salmon egg	*cilluvak*	'salmon egg, especially aged salmon egg'
salmon strip	*culunallraq* *taryitaq*	'salted and dried salmon strip'
salted fish or meat	*culunaq* *culunanek ajurciuq*	'salted fish or meat that is eaten after it is cut up and soaked to remove excess salt' 'she is soaking some salted fish' see culunaq 'my wife cut up the salted fish'

	sulunaq *sulunanek ingqillruuq* *taryitaq, taryiraq* *taryirki sulunarkat*	'salted salmon strip' 'put salt on the pieces of fish to be preserved'
scale (fish)	*kapciq* *qelta* *akakiik qeltairru suu pirniaraqa*	**x** 'fish scale', 'take the scales off the whitefish so that I can make soup with it!'
rolled oats	*qeltengalnguut*	'things like fish scales'
smelt	*cemerliq* *cimigliq*	**x** **x**
stick(*n*) fish-spreading	*ayagta* *ayagtekartellruunga*	'prop, support, *especially* a small stick used to keep a cut fish open as it dries' 'I gathered material to use as spreaders for drying fish'
stickleback	*cukilek* *angun cukilegnek qaluuq* *ilaqcungaq* *quarruuk*	'one with quills' 'the man is dipnetting for sticklebacks' **x** 'needlefish'
supper	*atakutaq*	'supper, evening meal'
tail, fish	*papsalqitaq* *papsalquq*	'dried fish tail' 'tail or caudal fin of fish'
preopercle	*ulluvalqin*	'gill cover of a fish, preopercle'
fish cheek	*ulluvalquq*	'cut from the fish'
trap, fish	*taluyaq*	'fish tray'
whitefish with pointed head	*cingikeggliq*	**x**
young whitefish	*esevsiar(aq)* *iituliar(aq)*	**x** 'whitefish fry'
frozen raw whitefish	*qassayaaq* *akakiigem meluanek qassallruunga*	'frozen whitefish aged before freezing and served frozen' 'I ate the whitefish eggs raw'
To fish (v)	*neqsur*	?
Fish	*iqalluk* *ilaqcuugaq* *neqa* *neqet amllertut maani* *qimugtet neqait nangyarpiartut* *neqtulnguunga* *neqa unguvangraan uklia* *neqngurtuq* *nereneqaiq, neqiaq*	'dog, chum salmon, fish' 'small fish found in lakes' 'food;fish' 'the fish are plentiful here' 'the dogs' food is almost gone' 'i'm tired of eating fish' 'even though the fish is still alive he is cutting it up' 'there was food everywhere',*lit. 'it became food'* 'food-stealing bird'
Boiled fish	*egaaq*	'any cooked fish or other food'

Bundled fish	*inartaq*	**x**
Canned fish	*paankaraq* *qakiiyak paankarak uksuqu nernalukek*	**x** 'he is canning two silver salmon so that he can eat them in winter'
Cut fish	*cegesseg-* *cegtuq* *cegaa, ceggaa* *ceg'aq, cegg'aq* *seg-* *ulligte-* *ulligtuq* *ulligtaaa* *ulligciuq* *ulligtaq* *ingqii-* *inguqin, inguqitaq* *neq'liur-* *neq'liurtuq*	'to cut fish for drying' 'she is cutting fish' 'she is cutting it' 'a fish cut for drying' (see ceg-) 'to cut fish for drying, in the traditional manner, making cuts so that air can reach all parts of the flesh; (NUN) to turn over' 'it is cut for drying' 'she cut it for drying' 'she is cutting it for drying' 'fish cut for drying' 'to make the horizontal cuts in fish flesh while preparing it for drying' 'board on which one prepares meat or fish' 'to work on fish (cleaning it, etc.)' 'he is working on fish'
Fish cut in half	*qup'ayagaq(NUN)*	'fish cut in half to hang and dry'
Dried fish	*neqaluk (NUN)* *neqerrluk* *palircima*	**x** **x** 'to be burnt by the sun (of dried fish)
Dried small fish	*nevkuq* *ulligtaruaq*	**x** 'split and dried small fish, such as whitefish, pike or trout'
Dried fish heads	*nasqurrluk* *qamiqurrluk* *irniani nerevkaraa tepnek*	'cut and dried fish-head' (see above) 'she let her child eat some aged fish heads'
Dried frozen fish	*yay'ussaq*	'dried tomcod or whitefish that has been frozen all winter'
Air dried fish	*tamuaneq*	**x**
Fish dried in a basket	*tut'at (plural)*	'fish packed down and dried in a basket'
Fish partially dried and boiled	*egamaarrluk teggmaarrluk*	**x** 'boiled, half-dried salmon; dog salmon, chum salmon'
Frozen fish	*cetegtaq* *kumlaneq* *nutaqaq* *qercuqaq*	
Poke fish	*uqumaarrluk*	'fish slightly aged and stored in seal oil'

Fish partly smoked and stored in seal oil	*arumaarluk*	**x**
Fish in strips	*kiarneq* *palak'aaq (BB)*	'unsalted strip or fillet of fish flesh without skin, cut from along the backbone and hung to dry' 'strip of dried flesh'
Dried Fish tails	*parmesqatak papsalqitaq*	**x** **?**
Fish strung to dry	*piirrarrluk (Y, HBC)*	'small fish, such as tomcod strung up for drying'
Fish hung to dry	*kanartaq*	**x**
Raw fish	*qassaq, qassaulria* *qassar-* *qassartuq* *qassaraa*	'raw fish or meat' 'to eat raw fish or meat' 'he is eating raw fish' 'he is eating it raw'
Raw frozen fish	*quaq*	'fish to be eaten raw and frozen'
Cooked piece of fish	*ukliaq*	**x**
Fish bin	*qikutaq*	'bin used for temporary storage of fish before they are cut up for drying'
Fish trap	*taluyaq*	**x**
Fish rack	*initaq* *ker'aq* *qer'aq*	'part of a fish rack on which the fish is directly hung'
Fish wheel	*akalria*	**x**
Fish fence	*capon* *angutet capcirtut uqvianek manignarrnaluteng taluyakun* *kalgun*	'weir, fish fence; wall' 'the men set a weir of willows to catch loche with a fishtrap' 'weir, fish fence extending from the bottom of the river and leading fish to a place where one can catch them with a dipnet'
Fish spear	*aggsuun* *ag'ssuun*	**x** **x**
Fishing line	*ipiutaq (NSU)*	**x**
Fish camp	*kiagvik* *neqlilleq*	'summer fish camp' (see above)
Fish Village	*neqlercurvik*	'fish village, site on the lower Yukon'
Fisherman	*neqsurta* *neqsurtuq* *neqsurvik* *neqsurtuq tuniarkaminek* *aataka neqsurtenġuuq*	**x** 'he is fishing' 'fishing place' 'he is fishing commercially' 'my father is a fisherman'
Fish hook	*iqsak*	**x**

	iqsag/manaqutaq *iqsagtuq/manartuq* *iqsagaa/manaraa* *manaq* *manar* *manaryartuq* *qerrlurcaq*	'to fish with a hook and line, to jig for fish' 'he is hooking for fish' 'he hooked it' 'fishing lure with hook' 'to fish with a hook, lure, and line, usually (though not necessarily) through a hole in the ice in winter' 'he went to fish with a hook and line' 'fishhook which is baited and set below the ice, held in place with a stick across the hole, and left unattended to be checked periodically'
Fish net	*kuvyaq, kuvya, kuvsaq* *kuvya* *kuvyauq* *kuvyaq cangliqellruuq* *nutaranek* *qemiraa kuvyaq* *qilagcuutmek aturluni* *kuvyaq civtaa* *kuvyaq takuua* *kuvyarkaq* *qelcaq (Y)*	**x** 'to fish by drift-netting or purse-seining' 'he is drift-netting' 'the net caught lots of fresh fish' ' he is stringing the net using a net shuttle' 'he set the net' 'he checked the nets' 'twine for making nets' 'net into which fish are driven by peopoole who walk in and thrash the water'
Set net	*petugaq*	**x**
Fine mesh net	*caqutaugaq(NUN)*	'fine mesh net for dog salmon, worked by hand by men standing in the water, not left unattended'
Net shuttle	*imgutaq* *qilagcuun*	**x** **x**
Net setting line	*amun* *atlirneq* *nuvun* *qemiq* *qemirtuq* *qemiraa*	'line used to set and reset a net under the ice' 'lead line of fish net' 'threading device (such as the line used to set a net under the ice, or a needle threader)' 'lead line or float line of a net' 'he is stringing (a net)' 'he is stringing it'
Net sinker	*kic'aqutaq*	**x**
Fishing rod	*manaq* *piqrutaq*	'fishing lure with hook'

Roe	*cin'aq* *cilluvak* *imlauk* *meluk* *melug*	'salmon egg, especially aged salmon egg' 'fish egg,roe' 'fish eggs, roe; fish eggs prepared by allowing them to age and become a sticky mass' 'to suck; to eat roe directly from the fish'
aged roe	*cuak*	**x**
herring roe	*imlauk (NUN)* *qaarsaq* *qiaryaq (NUN)*	'dried herring egg' **x** 'herring eggs, so called because they crackle when eaten'
fish rack	*ker'aq (NSU)* *qer'aq*	**x** **x**
trout	*anerrluaq (BB)* *anyuk (BB)*	'type of fish, salt-water trout' **x**
lake trout	*cikignaq*	**x**
steelhead trout	*irunaq*	**x**
rainbow trout	*talaariq*	**x**
dolly varden (char)	*iqallugpik*	**x**
herring	*iqalluarpak, iqallugpak*	**x**
Arctic cod	*iqalluaq*	'boreal smelt'
Pike	*uksumi-llu iqsagnaurtut cuukvagnek*	'and in the winter they would hook for pike'
Wolf Fish	*qugautnaq (NI, NUN)*	**x**
Smokehouse	*elagyaq* *puyurcivik* *talicivik* *neqnek aruvarqiyartua talicivigmi*	'partially underground cache; pit for cleaning fish; smokehouse' **x** 'shelter for smoking fish, smokehouse' 'go smoke the fish in the smokehouse'
Smoked Fish	*aruvarqi-* *aruvir-* *puyurqe* *puyurte-*	'to smoke fish' 'to be smoky; to smoke (fish)' 'to be smoked; to feed the fire when smoking fish' 'to smoke (fish)'
Subsistence	*angussaag-* *yuungnaqe-*	'to hunt, to try to catch game' **?**

4. The Dena'ina Language

There is a dramatic difference in language retention between the Yup'ik of the Nushagak and Kvichak River watersheds and the Dena'ina of the Iliamna Lake and Lake Clark area. In contrast to the Yup'ik, the Dena'ina population is much smaller, estimated by Krauss (2007:408) at 1,000 for the Iliamna/Lake Clark and Cook Inlet Basin areas. Krauss estimates that within this population there are only 50 Dena'ina speakers remaining (see Table 8), most of whom live in the vicinity of Nondalton or Lime Village (the latter outside the study area in the Kuskokwim River drainage). The youngest active Dena'ina speaker is 64 years old. Dena'ina is, thus, one of the world's most endangered indigenous languages (Boraas 2010:2). The reason for the disparity between Dena'ina and Yup'ik language usage is complex but a significant reason for Dena'ina language extinction was the Alaska Territorial School's federally mandated policy of punishment for children speaking their indigenous language in school. This forced assimilation policy occurred to various degrees throughout Alaska but its application seems to have been particularly harsh in Dena'ina territory (Boraas 2010:2).

Given the importance of language to cultural identity, the Dena'ina have begun to revitalize their language and significant efforts are underway to avoid its extinction both in spoken and written form (cf. Boraas and Christian 2010). There is a history of Dena'ina Elders working with linguists dating back to Anna Brigitta Rooth's (1971) work in 1966 in Nondalton followed by dozens of bilingual publications by James Kari working in collaboration with Dena'ina speakers starting in the 1970s and the bilingual publication of Joan Tenenbaum (1984). More recently a number of speakers from Nondalton and Lime Village have participated in Dena'ina Language Institutes, sponsored by a consortium of institutions including the Alaska Native Language Center, Alaska Native Heritage Center, the Sovereign Nation of the Kenaitze, and Kenai Peninsula College. The one to three-week institutes have been held at various locations including Nondalton and include workshops on Dena'ina language learning and teaching. Recently, two speakers from the study area, Andrew Balluta of Nondalton/Newhalen and Walter Johnson of Pedro Bay, now of Homer, have collaborated with linguist James Kari on important bilingual publications: *Shtutda'ina Da'a Sheł Qudeł: My Forefathers are Still Walking with Me* (Balluta 2008) and *Sukdu Neł Nuhtghelnek: I'll Tell You a Story: Stories I Recall from Growing Up on Iliamna Lake* (Johnson 2004). Finally, numerous speakers living and deceased (through archived recordings) contributed to *Dena'ina Ełnena [Dena'ina Territory]: A Celebration* edited by Karen Evanoff (2010). This book is summarized in the Traditional Ecological Knowledge section (Section D).

The language is indicative of the importance of water and salmon and other fish to the Dena'ina. Streams are intimately tied to the Dena'ina psyche through language. The Dena'ina words for directions are not based on the cardinal directions, but on the concept of upstream or downstream. A Dena'ina description of direction results from combining one of five stems, indicating upstream, downstream, and related terms; one of six prefixes, indicating proximity; and a suffix indicating general direction or location (Kari, 2007:336). For example, the word "*yunit*" combines the stem "*ni*" (upstream) with the prefix "*yu*" (distant) and the suffix "*t*" (at a specific place) and means "at a specific place a long way up upstream." If one were using that phrase at Iliamna, *yunit* would mean the direction toward Nondalton, which is a specific place far upstream; in this case, the direction would be north, because from Iliamna the Newhalen River flows south.

Because streams, to Athabascans, are a fundamental cultural construct implicated in a wide range of cultural activities (subsistence, diet, travel, directions, spirituality etc.), Kari (1996) has used stream stem morpheme variations to understand pre-contact movements among Northern Athabascans.

The spirituality of water is also embedded in the language. The Dena'ina have 36 terms for streams (Kari 2007:123-4), among those the primary word for 'water' is of special note. The Dena'ina word for "water" *viniłni* (in the Inland dialect, *miłni* in the Outer dialect) is unique among other Athabascan/Dene languages and Dena'ina linguist James Kari considers it to be esoterogenic meaning a special word reflecting special importance or sacredness (personal communication, Dr. James Kari, UAF Professor Emeritus, December 6, 2011). Dena'ina Elders Clare Swan and Alexandra Lindgren (2011) state "the Dena'ina word for water was held sacred" and by implication the water was sacred. The word *viniłni* and its sacred connotations is reflected today in the Orthodox Great Blessing of the Water ceremony described in section III.F.3 in which river water is annually baptized and made holy.

The Dena'ina named a general category of animal or plant by the name of its most important representative. For example, the name for animal is *ggagga*, for brown bear, and the name for tree is *ch'wala*, for white spruce. Not surprisingly, the name for fish is the name for salmon, *łiq'a*. Table 10 is a compilation of Dena'ina terms for salmon, freshwater fish, and fishing technology which, like the Yup'ik counterparts, shows an intimate connection with salmon, fish, and fishing.

Table 10. Dena'ina Words for Fish and Streams. Data from Kari (2007).

Dialect notations: I = Inland, U=Upper Inlet, O=Outer Inlet, L=Lime Village, Il=Iliamna, S=Seldovia, Lk-i=Kuskokwim Deg H'tan, Su=Susitna Station, E=Eklutna, Ty Tyonek, T=Talkeetna, Kn=Knik

English Term	Dena'ina Word	Literal Meaning
		x means literal translation same as English term.
salmon (generic) *(Oncorhynchus spp.)*	*łiq'a (IU)* *łuq'a (OSl)*	x x
Male fish	*Hest'a, qest'a (IO)* *Tl'ech'I (U)*	
Female fish	*Q'in'i* *Q'inch'eya (IO)* *Q'inch'ey (U)*	'roe one'
Small fish	*Chagela gga (U)* *Shagela gguya (I)* *Shagela ggwa (O)*	
Fry, baby fish	*Lch'eli, dghelch'eli*	'shiny one'
Bottom fish	*Tahliq'a (IU)* *Tahluq'a (O)*	'underwater fish'
Spring fish run	*Łitl'eni (UI)*	x
Spring fish caught under ice	*Ten t'uhdi (U)*	x
king salmon, Chinook salmon *(O. tschawytscha)*	*łiq'aka'a (IU)* *łuq'aka'a (O)* *chavicha, tsavija (O)*	"big salmon' <Rus.
king; *salmon sizes*: smallest	*łiq'agga (U)* *ggas ten'a (L)*	'small salmon' 'king salmon's handle'
two-foot king salmon	*q'inagheltin (U)*	'?'
largest king salmon	*łiq'aka (U)* *vigit'in (L)*	'big salmon' x

middle-sized king salmon	*tl'istqeyi (U)*	x
humpback salmon, pink salmon *(O, gorbuscha)*	*qughuna (OUSl)*	'humped'
red salmon, sockeye salmon *(O. nerka)*	*łiq'a (I)* *t'q'uya (LNOSl)* *k'q'uya ON)* *q'uya (U)*	**x** 'ridged'
nickname	*veghutna qilin (I)*	'it exists for people'
old fall sockeye	*bendashtggeya (U)* *dghelbek'i (UO)*	'partially white' *a rare verb stem*
dog salmon, chum salmon *(O. keta)*, (I) early summer chum salmon	*alima (OIl)* *seyi (U)* *nulay (NL)*	< Esk.. **x** 'runs again'
August run dog salmon	*shighat'iy (Lk-i)*	"?"
silver salmon, coho salmon *(O. kisutch)*	*nusdlaghi (I)* *nudlaghi (O)* *nudlegha, nudleghi (U)*	'one that swims back'
steelhead trout *(Salmo gairdneri)*	*usdlaghi (O)* *telaghi (Il)* *tuni, tuni denłkughi (N)* *shagela (U)*	? 'one that swims past' 'one that runs' 'water one' 'fish'
running salmon	*tuzdlaghi (OI)* *tuydlaghi (U)*	'one swimming in water'
fish laying eggs	*taq'innelyaxi (I)* *taq'innelyashi (UO)*	x
spawned-out salmon	*nudujuzhi, dujuzhi (I)* *dujuyi (U)* *itak'i (O)*	x x x
dead salmon	*tiłani*	X
fall salmon, esp. sockeye	*hey łuq'a (O)* *hey łiq'a (IU)*	'winter salmon'
fingerling, baby salmon, alevin	*tuyiga (OI)* *łiq'agga (U)* *łiq'a gguya*	'water spirit' 'little salmon'
first fish run	*qtsa ghelehi*	x
last fish run	*q'ech'en ghelehi (I)* *unhtl'uh ghelehi (UO)* *unhtl'uyeh (I)*	x
old female salmon	*q'in ch'ezhi (I)* *q'in ch'eya (U)*	'infested roe'
red-colored salmon	*nuditq'azhi (I)* *nishtudghiłtani (U)*	'one that is red' 'that which floats in midstream'
spring (early) salmon run	*ts'iluq'a (O)* *łitl'eni (UI)*	'straight salmon' 'spring one'
summer salmon run, sockeye season	*chiluq'a (O)* *hchiliq'a (UI)* *shanlaghi (UI)*	x 'summer run'
fall-winter running salmon	*tuleha (OU)* *tulehi (I)*	'one running in water'
dead salmon that drift ashore	*niqatayilaxi (I)*	x
salmon captured in weir	*q'anughedełi*	'those swimming back'
Non-salmon fish	*Shagela (IO)* *Chagela (UIl)*	'fish'

	Chebay (U)	
Alaska blackfish	*Huzheghi, huzhehi (L,N)*	'gaping thing pointing up'
Freshwater sculpin	*Ch'qenłt'emich'a* *Ch'qenłt'emch'a (NL)* *Ch'qełdemich'a (Il)* *Ts'est'ugh'I, ts'est'uhdi (U)*	? 'the one beneath rocks'
Burbot, lingcod	*Ch'unya (I)* *Ch'anya (U)* *K'ezex (Lk-i)*	
Burbot's chin barbell	*Veyada k'ich'aynanik'et'i*	'one that hands out from chin'
Arctic char	*Vat (NL)*	
Eel, lamprey	*Suy łiq'a* *Łiq'a q'ints'a* *Łiził (O)* *Tl'eghesh (I)*	'sand fish' ? 'salmon roe female' 'dog windpipe'
Large lamprey	*Ts'iłten hutsesa (U)*	'arrow nock'
grayling	*Ch'dat'an (I)* *Ch'dat'ana (U)*	'one with a blanket'
Grayling's dorsal fin	*Vech'eda*	'It's blanket'
Freshwater herring, least cisco	*Ghelguts'I k'una (N)*	'pike's food'
Three-spined stickleback	*Dghezhi, dghezha (O)* *Dgheyay (U)* *Dghezhay (I)* *Vek'eha qilani (NL)* *Tuyiga (Il)*	'thorny one' 'one with quills' 'water spirit'
Spawning stickleback	*Bente qiyuya (U)*	'one going in lakes'
Northern pike	*Ghelguts'I (I)*	'swift swimmer'
Small pike	*Tl'egh tuzhizha*	'grass water beak'
sheefish	*Shish (L)* *Zdlaghi (L)*	 'one that runs'
sucker	*Duch'ehdi (IU)* *Dehch'udya €* *Łih (O)*	'open mouth one'
Brook trout, Landlocked Dolly Varden char	*Dghili juna (NL)* *Dghili chuna (Il)* *Dghelay tsebaya (T)*	'mountain dark one' 'mountain fish'
Lake trout	*Zhuk'udghuzha (I)* *Bat (Su)*	'spiny mouth'
Rainbow trout	*Tuni (I)* *Telaghi (U)* *Shagela (Il)*	'water one' 'one that swims, runs' 'fish'
Dolly Varden trout	*Qak'elay (I)* *Qak'elvaya (Il)* *Telch'eli (O)* *Chebay (U)* *Łiq'a k'qen (I)*	? ? 'shiny one' 'fish' 'salmon's husband'
Whitefish (any)	*Łih (UI)*	
Alaska whitefish	*Hulehga (I)* *Q'untuq' (Lk-i)*	'runs up' 'ridge on top'
Broad whitefish	*Telay (L)*	'swimmer'
Broad whitefish stomach	*K'jida (I)* *K'eghezh (Lk-i)*	'oval'

Round whitefish, pin-nose whitefish	*Hasten (IT)*	'pus handle'
Fish guts (all)	*K'inazdliy, vinazdliy*	'inner objects'
Fish bones	*K'iztin (IO)* *K'iytin (U)*	'inner long object'
Fish backbone	*K'eyena*	x
Fish belly	*K'eveda*	x
Dark fish blood along backbone	*K'tl'ech' (I)* *K'kuhchashga (I)* *K'kukelashch'a (L)* *K'chashga (U)* *K'kuhchash'a (O)*	x
Dark salmon meat near skin	*Beyes tut' tsen (UO)*	
Fins (any)	*K'ts'elghuk'a (I)* *K'ch'elna (OU)* *K'tay'a (U)*	x 'wings' 'paddle'
Pectoral fin	*K'ch'enla (U)* *K'ts'elghuk'a (I)*	'wing'
Dorsal fin	*K'iniq' ts'elghuk'a* *Ghuk'a (I)* *Biniq' ch'elna (U)* *K'inhdegga (O)*	'back fin' 'back swimmer' 'back wing' 'back collarbone'
Pelvic fin	*K't'egha (U)* *niłk'degga (O)* *k'eveda degga (I)* *nich' k'eltin'a (O)*	'paddle' 'paddles together' 'belly fin' 'one in the middle'
Anal fin and cartilage	*K'tselts'ena (U)* *K'tseldegga (IO)*	'anal bone' 'anal collarbone'
Adipose fin	*K'tagh'a (IO)* *K'tach'ełvasha (N)* *Tak'ełbasha, k'tach'ebasha (OU)*	'paddle' 'submerger'
Tail fin	*K'kalt'a degga (O)* *K'kalt'a ts'elghuk'a (I)*	x
Fresh air sack	*K'kuhlet'*	x
Fish collarbone, pectoral girdle	*K'degga*	x
Fish head gristle	*K'enchigija*	'head cartilage'
Fish meat	*K'enut'* *Duni (Il)*	x 'food'
Fish tail	*K'kalt'a*	x
Meat next to fish tail	*K'kalt'a veghun*	'body of fish tail'
gills	*K'q'eshch'a*	x
Gut with stringy end (pyloric caecum)	*K'delchezha (OIl)* *K'delcheya (U)* *K'jida*	'rattle'
Fish heart	*K'ggałggama (I)* *K'ggałggamam'a (IlOL)* *K'ghałggamama (U)* *K'qałdema (T)*	x
Hump on salmon's back	*K'eyenghezha (OI)*	x
Male sperm sac	*Hest'a vekuhlashga (I)*	x
Sperm, milt	*K'tl'ech'*	x
Nose cartilage	*K'ingija, k'engija (IOU)* *K'ingeja (Il)*	x

Oily strip of meat in front of dorsal fin of salmon	*K'ints'isq'a (U)* *K'yin tseq'a (I)* *K'intsiq'a (OI)*	'back strip'
Roe, fish eggs	*Q'in*	x
Roe sac	*K'q'in yes*	x
scales	*K'gguts'a (O)* *K'ggisga (IU)*	x
Fish slime	*K'eshtl'a (OIl)* *K'tl'eshch'a (IU)*	x
net-making tool, net stringer	*tahvił veł k'etl'iyi,* *tahvił qeyłtl'ixi* *tahvił dugula (I)*	'with it he weaves net'
net rack	*veq' k'etl'iyi* *veq' nuk'detggeni*	'on it he weaves something.' 'on it, it is dried'
net mesh measure	*ve» k'ettl'iyi*	'with it, it is woven'
fishing clothes	*va łiq'a ch'el'ihi*	x
awl for stabbing salmon	*ts'entseł (U)*	
bale of fish	*vava hał*	'dry fish pack'
cutting board	*veq' huts'k'det'esi*	x
dipnet, long-handled dipnet	*tach'enił'iyi (UO)* *nch'equyi (LN)*	x
short-handled dipnet	*tach'enił'i (I)*	x
salmon dipnet (longer handle)	*shanlaghi tach'nił'iy (I)*	'summer run dipnet'
trout dipnet	*taztin (I)*	x
dipnet frame	*taztin duves (I)*	x
fish bait (on hook)	*k'enełneha (O)* *k'inłneha (I)* *k'indneha (U)* *k'egh dghichedi* *beł ch'k'nułneq'i (O)*	x
rabbit or ptarmigan guts used for tomcod bait	*k'entleh, k'entleq' (U)*	x
natural rock hole fish bin	*tsaq'a (I)*	x
rock fish bin, fish cutting hole	*k'usq'a (NL)* *k'esq'a (OIl)* *k't'usq'a (U)*	'cutting cavity'
fish box	*shagela yashiga*	x
fish club, seal club	*tsik'nigheli (IO)*	x
angled fish fence, dipnetting dock	*tanatl'ini*	'woven into water'
fish fermenting hole	*chuqilin q'a (O)* *chaqilin q'a (IU)*	x
gaff hook, branch hook, leister	*qishehi (IU)* *k'isheq'i (Il)* *sheh (L)* *shehi (O)*	'hooker'
fish hook	*ihshak, iqshak (OI)* *k'inaq'i, k'eninaq'i (U)*	Eskimo origin
Note: eleven separate types of named fish hooks		
fishing hole, fish trap location	*k'enq'a (OU)* *k'inq'a, -k'inq'a'a (I)*	x

fish trap location	*tach'k'eł'unt*	'where we set object'
fish jigging hole in ice	*tasaq'a* *tatsiq'a (Il)* *ges aq'a (L)*	'water head hole'
fishing line	*shehi tl'ila (O)* *k'inaq'i tl'ila (U)* *iqshak tl'ila (I)*	'hook line'
fishing pole	*iqshak ten (IO)* *shehi ten (O)* *k'inaq'i ten, k'inaq'i nikena, k'niten, k'neten (U)*	x
fishing reel	*shehi tl'ila telcheshi (UO)*	
fishnet	*tahvił*	'underwater snare'
net-like fish drag	*nich' nuk'tasdun (SlTy*	'in back is hole'
Russian-era fishnet	*sétga (O)* *satga (U)*	Russian origin
drift net	*te»edi (I)*	'one that floats'
gunny sack net	*chida yiztl'ini tahvi» (I)*	
seine net	*veł niqak'idzehi* *nébod (O)*	'with it one scrapes in circle' Russian origin
sinew net	*ts'ah tahvił*	x
twisted willow bark fiber net	*ch'eq' tahvił (IU)*	x
small hole, net mesh,	*k'eniq' (IO)* *k'eneq' (OU)*	x
net drying rack	*tahvił denluh*	x
lead line	*duyeh vetsik'teh'i* *duyeh vetsittehi (I)*	x
corks, floats	*tahvił ts'esa (IO)* *tahbił jija (U)*	x
cork line	*vetsik'teh'i*	x
fish pew, pike	*łiq'a eł dalyashi (OU)* *łiq'a veł telyayi (I)*	x
fish scaler, ulu knife	*vashla* *beł k'elggits'i (U)*	'little stone'
fish spreader stick	*k'enun'i* *nuk'ilqeyi*	x
hoop fish spreader	*dnalch'ehi (I)*	x
small fish spreader	*t'utseyŷi (O)*	x
hand-held fish snare with handle	*k'entsa quggił (I)*	x
spruce root fish snare	*qunqelashi quggił (OU)*	x
fish stringer	*k'e'esh tl'ił (OU)*	x
willow fish stringer	*q'eyk'eda (IU)*	'tough willow'
fishtrap, woven basket style trap	*taz'in (IO)* *tay'in (U)*	'object that is in water'
Note: Seventeen types of fishtraps for different species and conditions		
fishtrap funnel	*k'eshjaya (I)*	x
inner basket	*k'jaya (OU)*	'heart'
angled leads to trap	*taztin (I)*	'long object that is set'
long stick ribbing on fishtrap	*talyagi (IO)* *talyashi (U)*	x
spiral sticks on fishtrap	*k'etnalvesi (L)*	x

branch drag material put in weir	*k'tʼun dighali (U)* *k'tʼun dalghali (I)*	x
inner spruce bark reflectors pinned to bottom of weir	*tah'iggeyi (U)* *vejink'ehi (I)*	'under water turns white' 'stg. swims over it'
vertical stakes for weir	*dik'ali*	x
fish wheel	*niqak'uqułi (I)* *niqaghetesi (U)* *naqak'ułqu»i taz'in (O)*	'scoop that turns'
lead line	*duyeh vetsik'teh'i* *duyeh vetsittehi (I)*	x
net-making tool	*tahvił veł k'etl'iyi* *tahvił dugula (IL)*	x
net rack	*veq' k'etl'iyi* *veq' nuk'detggeni*	x

III. MODERN CULTURE

A. Interview Synopsis

Table 11 is a synopsis of respondents to the semi-structured interviews. The interview process is described in the Introduction and readers should refer to that section (I.B) and note the questions were not designed to elicit a simple yes/no-type response (nominal data) but rather to elicit a narrative of how the interviewee felt about or understood the topic in order to give a richer and more nuanced understanding of cultural patterns and values. The "Voices of the People" in the following sections are a reflection of those deeper understandings. However, Table 11 has been derived from the interviews in order to give the reader a sense of the overall consensus or variation from consensus of the respondents. To accurately depict cultural practices, we read the interviews and characterized the response as Agree, or Disagree/Neutral for each interview question, generating nominal data. This data includes 53 interviews. Sometimes respondents in a group took up a topic at a later time during the interview in which case we included that response as it applied to a previous question. As discussed in Section I.B. Methodology, not everyone responded to every question. In a small-group setting often one person would respond and others would nod or otherwise express agreement with the speaker. We only recorded the verbal response, not non-verbal indications of concurrence in formulating the data in Table 11. A second reason not every responded to every question concerned the well-being of Elders. If Elders were tiring in the course of the two-hour sessions, or if the session went long, we often skipped questions to shorten the interview time.

The responses represent consensus or near consensus: 694 responses were positive and 18 were negative or neutral. The data indicate Elders and culture bearers reflect indigenous cultural standards that have a very high degree of homogeneity as represented by this set of questions revolving around the importance of salmon and streams in their lives. Responses to interview questions are used in the Modern Culture sections (III) that follow with statements like: "interviewees universally felt…," "interviewees predominantly stated…," or "interviewees indicated…."

While everyone who responded indicated that salmon were important in their lives (Question 1), four individuals out of 53 interviewees indicated they thought a subsistence lifestyle was no longer possible (see Section III.B.1 and 2).

Table 11. Nominal Evaluation of Responses to Semi-Structured Interview Questions.

Question	Agree	Disagree or Neutral
1. Are salmon critically important in your lives? Note: often asked: "If the salmon were to disappear for whatever reason, how would it affect your lives?" *Agree means people perceive salmon to be critically important in their lives. Disagree means salmon are not perceived to be critically important.*	40	0
2. How many times in a week or a month do you eat salmon or other fish? Is it different during different seasons? *Agree means three or more times a week or "all the time." Disagree is less than three times a week or "seldom."*	35	0
3. Do people in your village need to eat salmon to be healthy? How does salmon maintain or improve physical or emotional health? *Agree means people perceive they need salmon and other wild foods to be healthy. Disagree means they do not perceive salmon to be necessary for health and wellbeing.*	37	0
4. Which foods are important to give to a child so that he or she will grow up to be smart or strong? *Agree means salmon and other wild foods are perceived to be necessary for children's health. Disagree means salmon and wild foods are not necessary and children can eat commercially purchased food and be healthy.*	30	2
5. Does it matter to you if the salmon you eat is wild salmon? Does it matter to you if the salmon comes from the streams and rivers in your area? *Agree means people perceive that the salmon they harvest and consume must be wild salmon from local streams. Disagree means it doesn't matter where the salmon comes from.*	40	1
6. Does it matter to you that the salmon are connected to the salmon your ancestors ate? *Agree means salmon genetically connected to fish their ancestor's ate is perceived to be important. Disagree means there it is not important that the salmon are genetically connected to ancestral harvests.*	27	0
7. If the fishing practices and care for the streams and rivers are good (what the ancestors call, 'without' impurity, Dena'ina *beggesh quistlagh*), does it result in salmon coming back? *Agree means proper practices are perceived to result in the salmon's return. Disagree means practices have no effect on the salmon's return.*	37	0
8. Have you observed changes in the numbers of salmon that come back each year? Is there a big difference some years? If there is, what do you think causes these differences?	31	0

Agree means people have observed changes in the number of returning salmon. Disagree means people have not observed changes in number of returning salmon.		
9. Are salmon important for the lives of other animals or birds that are important to the Yup'ik or Dena'ina ? What would happen to these animals or birds it they can't eat the salmon? *Agree means salmon are important to other animals. Disagree means salmon are unimportant to other animals.*	35	0
10. Who do you share food with? Perhaps relatives in Anchorage or Dillingham? Elders? Who decides how to share the salmon, and who to give salmon to? *Agree means wild food is shared with family and/or friends living outside of the area. Disagree means wild food is not shared outside the area.*	31	1
11. Do you share salmon with people who don't do subsistence and what type of things to you get in return? *Agree means salmon are shared with people who don't do subsistence. Disagree means salmon are not shared with people who don't do subsistence.*	14	0
12. What does it mean for families to go fishing together? Do young people learn a lot at fish camp? How do you teach the young people to catch salmon? Do you teach young people to respect the salmon? *Agree means it is important for families to fish together. Disagree means it is not important for families to fish together.*	41	0
13. How do you feel when you give salmon? How do you feel when you are given salmon? *Agree means people feel good when they give or receive salmon. Disagree means people have no particular emotion when they give or receive salmon.*	33	0
14. Do you feel an obligation to return the favor when someone gives you salmon? *Agree means people feel no obligation to return the favor of a salmon gift. Disagree means people feel an obligation to return the favor of a salmon gift.*	5	0
15. Are salmon and other wild foods eaten in community celebrations? Is this important? *Agree means it is important to include salmon and wild foods in community celebrations. Disagree means it is not important that salmon and wild foods are included in community celebrations.*	27	1
16. It has been said that most Yup'ik/Dena'ina believe that a wealthy person is one with a large family. Do you think that family is more important that material wealth? *Agree means the person believes family is more important than material wealth. Disagree means material wealth is more important than family.*	36	1
17. Do you do anything to make sure the salmon will return? *Agree means people do specific practices or rituals to assure the*	37	2

salmon return. Disagree means people do not do any specific practices or rituals to assure the salmon return.		
18. What would it mean to treat salmon badly? Why is this bad? *Agree means there are specific things that are identified as bad practices with disagree consequences. Disagree means there are no specific things identified as bad practices with disagree consequences.*	9	3
19. Did the old people tell of a time when there would be a disaster and the fish would disappear? *Agree means people heard elders tell prophetic stories of the disappearance of salmon. Disagree means people never heard Elders tell prophetic stories of the disappearance of salmon.*	15	2
20. Do you ever thank the salmon for offering itself to you? Do you ever pray when you catch salmon? Do you make an offering when you catch the first salmon? *Agree means individuals give thanks through a prayer and give an offering when the first salmon is caught. Disagree means no prayer, offering or other recognition is given with the first salmon catch.*	37	0
21. Do you ever hear the Elders talk about the salmon having a spirit? *Agree means people perceive salmon to have a willful spirit. Disagree means people do not perceive salmon to have a willful spirit.*	19	3
22. Did you ever hear Elders talk about a stream having a spirit or being like it was alive? Do some people still think that way? *Agree means people perceive of a stream as having a spirit and being alive. Disagree means people do not perceive of a stream as having a spirit and being alive.*	7	0
23. Do rivers or streams have events – or stories - associated with them that are good or bad? Is it appropriate to tell any of them now? *Agree means there are stories associated with streams that have a moral implication. Disagree means there are no stories associated with streams that have a moral implication.*	8	0
24. How do people get money to buy boats and motors for subsistence fishing? *Agree means people commercially fish in Bristol Bay or engage in other part time employment. Disagree means people do not engage in Bristol Bay commercial fishery or other part-time employment.*	16	0
25. Do you feel a connection between the way you fish today and the ancestors' way of fishing? *Agree means people feel an emotional connection between subsistence fishing today and the subsistence fishing of their ancestors. Disagree means people feel no such connection.*	8	0
26. Why do you live in your village? *Agree means people desired to live in their village and felt an emotional attachment to their lifestyle. Disagree means people*	39	2

were ambivalent or disliked living in their village or felt they had no future there.		
27. Is there anything else you'd like to say? Is there any message you'd like to convey to Washington D.C./EPA (Environmental Protection Agency)	N.A.	N.A.
Total	**694**	**18**

B. Subsistence

1. Voices of the People

It's free, it's free and peaceful here, and we can get fish… F-27, 8/17/11
It may be different, the way we gather it nowadays, but it's the same end product. It's the same. F-69, 9/18/11

If you get out in these outlying villages, about 80-90% of what they eat is what they gather from their front yards. I was in Igiugig this spring. A can of SPAM… Do you know how much a can of SPAM is in Igiugig? Eight dollars for a can of SPAM! …There are fewer jobs, so subsistence is one of the main cultures and the driving force of the economy within a community. M-60, 9/16/11

Our fish is more important for them. I tell my kids and grandkids with fish they are very rich; without fish you are hungry. This is the important thing all over in Alaska for us. It is very hard out here in the bush. We have to pay double for every food we get, double to get our heating fuel, double for gas, and without gas, we cannot travel. It is very hard in a rural area. In a big city it is easy; you just grab everything from the store, department store. Out here we don't have grocery stores; our grocery store is very expensive. They give us prices that, if you buy one item, you pay for four. So it is very hard for us, but we grow our kids, and you ask us if it is important for us to have fish. We have to have fish every day because the fish is most important. F-48, 8/20/11

For two families we put up in jars 32 cases [of salmon]*….that doesn't include frozen stuff*. M-60, 9/16/11

We get them [smelt] *until freeze-up here. Then, when the river freezes up, people go up and fish through the ice for them with hooks. They seine them up in the lake, too, but you have to catch them at the right time.* M-62, 9/16/11

When that first salmon is caught, it is in the news. KDLG [Dillingham radio station]. *Everybody knows about it*. M-61, 9/16/11

And he still, to this day, goes to fish camp. He gets all excited about fish camp. He's down there getting his net ready, and he still, at 89 years old, still go out and sets his own net, picks his own net, and work on his own fish, because he knows, and he always tells us how important it is to save our fish and salmon for the winter months. F-32, 8/18/11

We would starve if we don't have fish or salmon. In this area we have lived with fish all our lives, from generation to generation. The people that stayed before us and kids that are behind us *will be living on fish. Salmon is very important; all kind of.... Without fish we are very poor; we have no food to eat. With fish we are very rich; our stomach is full. That's the way I look at it.* F-48, 8/20/11

Salmon is one thing. They make you feel rich because you have something to eat all winter. Smoked salmon, sun-dried spawned-out fish; all of those make you feel good, because you grew up with it, it is in your body. Any subsistence food; what you eat, like him and I [gestures]; *we ate it for a long time.* M-53, 8/20/11

Salmon is very important to us. I don't think we could live without fish…. I'm seventy-six years old, and I have never been without fish, since I was small. I don't know how I would feel without it. I think I used fish more than meat when I was growing up, because my Grandma raised me, and that's all she could get, was fish, because it's easier to get. She used to help people put up fish for us to have her share in the wintertime. Then she would put up salt fish for us to have in the winter, so we use it year round. F-27, 8/17/11

<u>Minority View Subsistence</u>

We couldn't live like our parents lived, because it doesn't exist anymore. I mean, we could fish and catch fish and stuff like that. You know, nowadays, you can't live on fish like you used to. You can't even get meat like you used to; you can't even go out hunting for moose or caribou. Nothing is here anymore; everything is disappearing. I know, you know [name] *could verify too. There used to be so much caribou, we would see them all over the road, all over the lake, everything.* F-44, 8/19/11

Like she was saying right now, even with subsistence, we can't live on that. We have to have money to pay for our bills, telephone, our lights, our heat and trash, our toys, water, and sewer. You have to pay so much a month for that. I myself will support any kind of entity that comes and bills for jobs. I don't think subsistence; we love subsistence, but I don't think it is going to last forever….We need money to pay our bills. That is why a lot of people are moving to Anchorage. M-44, 8/19/11

We can't just go out there and get money from nowhere. You know, subsistence is gone in this village [Newhalen] *and in Iliamna. Subsistence, we can't live on subsistence anymore. We have car payments to pay, we have Honda payments to pay, and we have our snowmobile payments to pay. How on subsistence; how are you going to pay all of those bills? Some pay $500 a month for car payments. How are you going to pay $500 a month on subsistence? You can't do that anymore; you have to live to make money nowadays for those young kids.* M-49, 8/20/11

Figure 14. Newhalen. August 20, 2011. Photo by Alan Boraas

2. Introduction

In 1983 the Inuit circumpolar Conference and the World Council of Indigenous Peoples sponsored the Alaska Native Review Commission to conduct hearings in rural Alaska aimed, in part, to help the non-Native community understand the importance of subsistence to Alaskan Natives. In the commission's final report, Thomas Berger (1983:51) summarized rural subsistence as follows:

> The traditional economy is based on subsistence activities that require special skills and a complex understanding of the local environment that enables the people to live directly from the land. It also involves cultural values and attitudes: mutual respect, sharing, resourcefulness, and an understanding that is both conscious and mystical of the intricate interrelationships that link humans, animals, and the environment. To this array of activities and deeply embedded values, we attach the word "subsistence," recognizing that no one word can adequately encompass all these related concepts.

In southwest Alaska subsistence is a fundamental non-monetized economic activity of the region and forms the basis of cultural life. Though the economy involves both cash and subsistence sectors, most of the protein comes from subsistence activity as indicated in the ADF&G Division of Subsistence data reproduced below. Moreover, cultural and personal identity largely revolves around subsistence. Echoing Berger's description cited above, this concept is expressed in a 1988 film by Brink and Brink where Dena'ina leader Fred Bismark highlighted the importance of subsistence when he said, "If they take subsistence away from us, they're taking our life away from us." Two decades later that remains true; Fall et al.(2009:2) wrote of the Nushagak and Kvichak drainages, "At the beginning of the 21st century, subsistence activities and values remain a cornerstone of area residents' way of life, a link to the traditions of the past, and one of their bases for survival and prosperity." Berger's summary, Bismark's statement and Fall's analysis as well as interview generated "Voices of the People" at the beginning of this section illustrate the idea that subsistence is "life" and the foundation of culture for the Nushagak and Kvichak watershed villages. Everyone who responded to Question 1, Table 11 felt the loss of salmon would impact them negatively and subsistence based on salmon and other wild foods is the cultural foundation for the region. Four of the 53 interviewees felt subsistence was no longer tenable.

Subsistence is not a return to practices of earlier centuries but employs modern technology. Nylon nets have replaced spruce-root or sinew nets; aluminum skiffs and four-stroke motors have replaced kayaks or canoes; metal pots have replaced birch-bark or willow baskets; modern clothing has replaced sewn hides and skins; and freezers have replaced underground cold storage pits. Moreover, subsistence activities follow management practices formulated by the ADF&G, dictating bag limits and seasons. However, the results of these interviews and ADF&G research cited below confirm that the diet is still largely based on wild foods caught and processed by the people who live in the area. Values, such as respecting the salmon and not taking more than you need, among others, are still honored; and the identity of the people is shaped by the subsistence process, just as it was in the past.

As described in the Pre-Contact and History sections (II A & B).), indigenous people in the study area have been harvesting wild resources for at least 12,000 years and have intensively caught salmon for at least 4,000 years. This immense time depth has shaped all aspects of the culture, including social structure, political structure, and religion. Because Dena'ina and Yup'ik are the dominant populations in the study area, and because healthy wild salmon stocks and many other components of their traditional way of life still persist such as language, sharing wild foods and sharing beliefs related to nature, the area has a cultural continuum with the past that is rare in North America. In few places in the world do the same wild foods as their ancestors ate dominate the diet and shape the culture as they do today in the Nushagak and Kvichak watersheds

3. Subsistence in Alaska

The importance of salmon and other wild food resources in the study area is tied to federal and state subsistence legislation. No other state in the United States so broadly grants a subsistence priority to wild foods to indigenous people's as does Alaska. Both federal and state subsistence legislation apply to Alaska but they differ, and have resulted in two sets of regulations because of an inherent conflict between federal and state legislation over indigenous rights vs. inherent rights.

Federal subsistence legislation began with the 1971 Alaska Native Claims Settlement Act (ANCSA, Public Law 92-203 with amendments), which extinguished aboriginal hunting and fishing rights and, in return, charged the Secretary of Interior and State of Alaska to "take any action necessary to protect the subsistence needs of Natives" (La Vine 2010:30-34). The federal subsistence intent of the 1971 ANCSA legislation was clarified in Title VIII of the 1980 Alaska National Interest Lands Conservation Act, (ANILCA, Public Law 96-487 with amendments). ANILCA recognized the cultural aspect of indigenous subsistence stating: "the opportunity for subsistence uses by rural residents of Alaska...is essential to Native physical, economic, traditional, *and cultural* existence and to non-Native physical, economic, traditional, and social existence (emphasis added)" (La Vine 2010:32). The language describing the importance of subsistence to Alaska Native and non-Native rural communities is the same with the only difference that "cultural" importance is included in Alaska Native subsistence users' list of essential rights while that term is not included in the non-Native list of essential rights. That language became the basis for federally recognized indigenous subsistence rights.

Federal ANCSA and ANILCA legislation set up a legal conflict between indigenous rights and state law. The "Inherent Rights" clause in Article 1, Section 1 of the Alaska Constitution specifies equal treatment under the law for all Alaskans and makes no provision for indigenous rights. Consequently, subsistence became an important political issue in the early 1970s and remains so today (cf. AFN Federal Priorities, 2011, pp. 1-9).

The State has developed subsistence legislation within the context of the "Inherent Rights" clause cited above. As depicted in the 1988 documentary *Tubughna: The Beach People* by Brink and Brink, in 1973 Governor William Eagan made a promise to Alaska Native people. Speaking at a meeting in Anchorage, Governor Eagan said:

> Let me assure you that the state's commitment to preserving subsistence capability in our fish and game resources is of the first priority and will continue to be. Continuing attention to the Native for maintaining subsistence capability is an integral part of the state's overall fish and game management program. It always has been, is now, and will be so in the future (Brink and Brink 1988).

That promise was partially realized as law in the 1978 *State of Alaska Subsistence Act*, (with amendments; encoded within AS 16-05) which provided for a Division of Subsistence within the ADF&G and defined subsistence as "customary and traditional use." The act also specified a subsistence priority in wild resource allocation over commercial or sport caught resources. The act did not limit subsistence to rural (largely Alaska Native) residents and did not recognize indigenous rights; to do so would have been unconstitutional in state law. The act also directed establishment of a Division of Subsistence within the Alaska Department of Fish and Game to "quantify the amount, nutritional value, and extent of dependence on food acquired through subsistence hunting and fishing" (AS 16-05.094) and has resulted in three decades of the most detailed subsistence data collected anywhere in the world, some of which is used in this report.

As a result of over forty years of legislation and adjudication revolving around the "Inherent Rights" issue among stakeholders, a dual management system has emerged. As summarized by La Vine (2010:34) the state now manages fish and game for subsistence purposes on state and private land including regional and village corporation land, while the federal government, through the U.S. Fish and Wildlife Service or cooperative agencies, manages fish and game in federally designated subsistence areas as determined by criteria applied and regularly reviewed by the Federal Subsistence Board. On state lands all citizens are eligible to harvest fish and game for subsistence purposes but are bound by the customary and traditional use criteria. On rural federal lands only rural residents are eligible to practice subsistence. On non-rural lands subsistence is prohibited. Alaska Natives and non-Natives of the communities of the Kvichak and Nushagak drainage fit both the "customary and traditional" and "rural' criteria and have engaged in subsistence fishing and hunting throughout this time period and will continue to do so as long as they remain rural. Significant population increases constituting a shift from rural to urban would potentially change subsistence access as has happened, for example, on the Kenai Peninsula where the Dena'ina do not have full subsistence rights because the area is largely determined to be urban.

4. Scope of Subsistence

Table 12 is an indication of the importance of subsistence activities and salmon to the people of the Nushagak and Kvichak River systems[7]. Essentially everyone in every village and town (98% or more of the households) uses wild food subsistence resources, and most (88% to 100% of households) use salmon.

Table 12. Use and Reciprocity of Subsistence Resources. Data from Holen et al. 2012, Fall et al. 2009, Krieg et al. 2009, Fall et al. 2005

Community	Year	All Wild Resources; % Households that:			Salmon % Households that:		
		Used	Gave	Received	Used	Gave	Received
Aleknagik	2008	100	84.4	96.9	100	59.4	59.4
Dillingham	1984	98	62.7	88.2	88.2	34.6	43.8
Ekwok	1987	100	86.2	82.8	89.7	48.3	51.7
Igiugig	2005	100	100	100	100	83.3	83.3
Iliamna	2004	100	53.8	76.9	100	30.8	38.5
Kokhanok	2005	100	82.9	94.3	97.1	62.9	60
Koliganek	2005	100	92.9	89.3	100	60.7	53.6
Levelock	2005	100	85.7	92.9	92.9	35.7	78.6
Newhalen	2004	100	80	96	100	64	32
New Stuyahok	2005	100	73.5	98	89.8	55.1	63.3
Nondalton	2004	100	92.1	97.4	92.1	55.3	63.2
Pedro Bay	2004	100	88.9	100	100	72.2	77.8
Port Alsworth	2004	100	72.7	90.9	100	45.5	54.5

[7] ADF&G subsistence data in Section III.B. was assembled by Dave Athons, ADF&G (retired).

The data of Table 12 also indicates reciprocal sharing of wild foods is a fundamental aspect of subsistence culture in the study area. In most villages almost 100% use wild food resources and more than 80% of households receive shared subsistence food resources of some kind. Sharing of salmon is lower than for all resources probably because, typically, extended family units work together at subsistence fish camps (Fall et al. 2010) and the fish they collectively harvest is not considered to be "shared" as much as "earned" among contributing extended family members. Further research by ADF&G or a similar entity could clarify the matter. Sharing is further discussed in Social Relations section (III. E.3).

Table 13. Per-Capita Harvest of Subsistence Resources. Data from Holen et al. 2012, Fall et al. 2009, Krieg et al. 2009, Fall et al. 2005.

Community	Year	Total Harvest Pounds	Estimated Per-Capita Harvest in Pounds						
			All Resources	Salmon	Non-salmon Fish	Land Mammals	Marine Mammals	Freshwater Seals	Beluga
Aleknagik	2008	51,738	296	143.4	25.6	66.1	9.5	0	4.8
Dillingham	1984	494,486	242	141.4	17.5	65.9	2.97	1.7	0
Ekwok	1987	85,260	797	456.2	68.6	249.2	0	0	0
Igiugig	2005	22,310	542	205.2	59.4	207.8	29.2	7.4	21.9
Iliamna	2004	34,160	469	370.1	34.1	32.7	6.5	6.5	0
Kokhanok	2005	107,645	680	512.8	36.3	95.9	1.7	1.7	0
Koliganek	2005	134,779	899	564.7	90.4	186.2	0	0	0
Levelock	2005	17,871	527	151.8	39.9	257.4	37.7	4.5	33.2
Newhalen	2004	86,607	692	502.2	31.8	104.5	4.4	4.4	0
New Stuyahok	2005	163,927	389	188.3	28.0	143.4	0	0	0
Nondalton	2004	58,686	358	219.4	33.9	81.8	0	0	0
Pedro Bay	2004	21,026	306	250.3	15.3	30	0	0	0
Port Alsworth	2004	14,489	133	89.0	12.0	24.7	0	0	0

Table 13 presents the range of some of the important subsistence resources used in the region and their relative importance to each village on a per-capita basis. This data does not include vegetation foods, birds/eggs, and marine invertebrates which are seasonally important, nor does it include salmon retained from commercial fishing. While all subsistence foods are important— particularly for the physical and emotional benefits derived from a varied diet— salmon is, by far, the most important subsistence food ranging up to 82% of the subsistence diet. Land mammals, including moose and caribou among other species, are the second most important form of subsistence food for most villages. Many villagers but particularly Iliamna, Newhalen and Nondalton interviewees indicated that in recent years they are experiencing reduced subsistence returns of caribou. They feel the Mulchatna herd is declining or moving out, possibly due to overhunting from guided trips, fly-in hunters from Anchorage or Kenai, or seismic blasting and helicopter traffic from mining exploration.

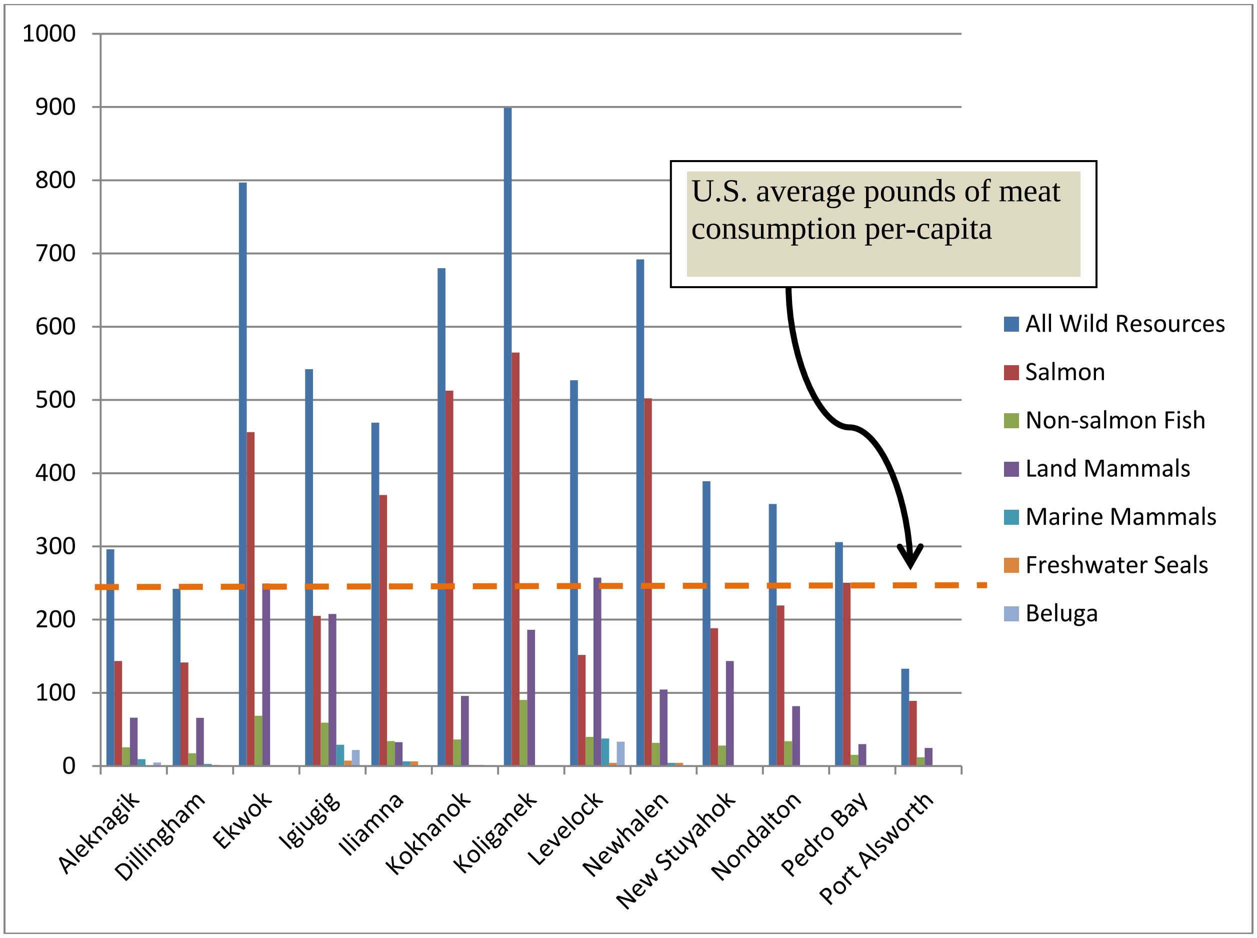

Figure 15. Per Capita Wild food harvest in pounds and selected meat sources. From Table 13 compared to U.S. Average Per Capita Meat Consumption. Data from Holen et al. 2012, Fall et al. 2009, Krieg et al. 2009, Fall et al. 2005, U.S.D.A Factbook.

Non-salmon fish (northern pike, Dolly Varden/char, various whitefish, trout, etc.) constitute a third important type of subsistence resource. Subsistence use of marine mammals includes beluga whales, which regularly move up the Kvichak River, and freshwater harbor seals, a unique freshwater population that lives year-round in Iliamna Lake. These are significant subsistence resources for the Kvichak River villages of Igiugig and Levelock.

The data indicates as much as 899 pounds of dressed meat is harvested per-capita (Koliganek) and an average of 503 pounds of meat per-capita is harvested per village. According to the U.S. Department of Agriculture's "Agriculture Factbook," in 2000 Americans consumed an average of 277 pounds of meat per year per-capita (USDA Factbook). The difference, of course, is the subsistence data presented here is pounds per-capita harvested, not pounds per-capita consumed. A substantial amount of subsistence-harvested food is shared which partially accounts for such high numbers of per-capita harvest. The numbers are high, however, because the people eat a lot of wild food and subsistence foods are the staple of the culture.

Table 14. Per-Capita Harvest of Salmon Resources. Data from Data from Holen et al. 2012, Fall et al. 2009, Krieg et al. 2009, Fall et al. 2005

Community	Year	Total Harvest, Pounds	Per-Capita Subsistence Harvest in Pounds				
			All Wild Resources	All Salmon	King (Chinook)	Red (Sockeye)	Non-Salmon
Aleknagik	2008	51,738	296.0	143.4	72.3	40.3	25.6
Dillingham	1984	494,486	242.2	141.4	52.8	38.5	17.5
Ekwok	1987	85,260	796.6	456.2	178.2	160.3	68.6
Igiugig	2005	22,310	542	205.2	5.4	168.0	59.4
Iliamna	2004	34,160	469.4	370.1	0	369.8	34.1
Kokhanok	2005	107,645	679.6	512.8	3.2	480.4	36.3
Koliganek	2005	134,779	898.5	564.7	193.9	192.5	90.4
Levelock	2005	17,871	526.7	151.8	43.1	85.9	39.9
Newhalen	2004	86,607	691.5	502.2	10.1	487.6	31.8
New Stuyahok	2005	163,927	389.2	188.3	112.6	36.3	28.0
Nondalton	2004	58,686	357.7	219.4	0.4	218.9	33.9
Pedro Bay	2004	21,026	305.5	250.3	0	250.2	15.3
Port Alsworth	2004	14,489	132.8	89.0	0.7	87.6	12.0

Table 14 breaks down the subsistence harvest of salmon by species. King or Chinook salmon spawn in the Nushagak River but not normally in the Kvichak River and consequently are not harvested in the Newhalen River system. Today, interviewees report most king salmon are fished in camps on the Nushagak River located at Lewis Point (*Nunaurluq)* near the mouth of the river. Salmon are also taken near the villages (see Section II.B.3). Sockeye, or red, salmon constitute the most important subsistence salmon species in the villages of the Kvichak and

Newhalen River drainages and are also taken in significant numbers in the Nushagak River drainage.

5. The Seasonal Subsistence Round

As illustrated in Figure 5, the villages in the Nushagak and Kvichak River drainages have a seasonal subsistence round that involves harvesting wild resources at an optimal time throughout the year. Evanoff (2010:66) and Fall et al. (2010) have described the seasonal round for the Kvichak drainage Dena'ina and it is summarized as follows. In the spring, with the return of ducks, geese, and other waterfowl, small groups travel to hunting or egg gathering areas. In addition, villagers also gather early spring plants, such as fiddlehead ferns. In late May and early June, villagers begin harvesting salmon returning to spawn. Some families net salmon near their villages while others travel to fish camp. Subsistence salmon activities occur throughout the summer although many also engage in commercial fishing in Bristol Bay, depleting the fish camp personnel but providing cash to support subsistence activities. Late summer and fall subsistence activities involve berry and plant gathering. In late fall or early winter villagers engage in caribou and/or moose hunting depending on the ADF&G-determined hunting seasons for the specific area. Winter subsistence activities revolve around ice fishing for whitefish and other freshwater species, ptarmigan hunting, wood harvesting to supplement home heating and for steam baths, and trapping of furbearers.

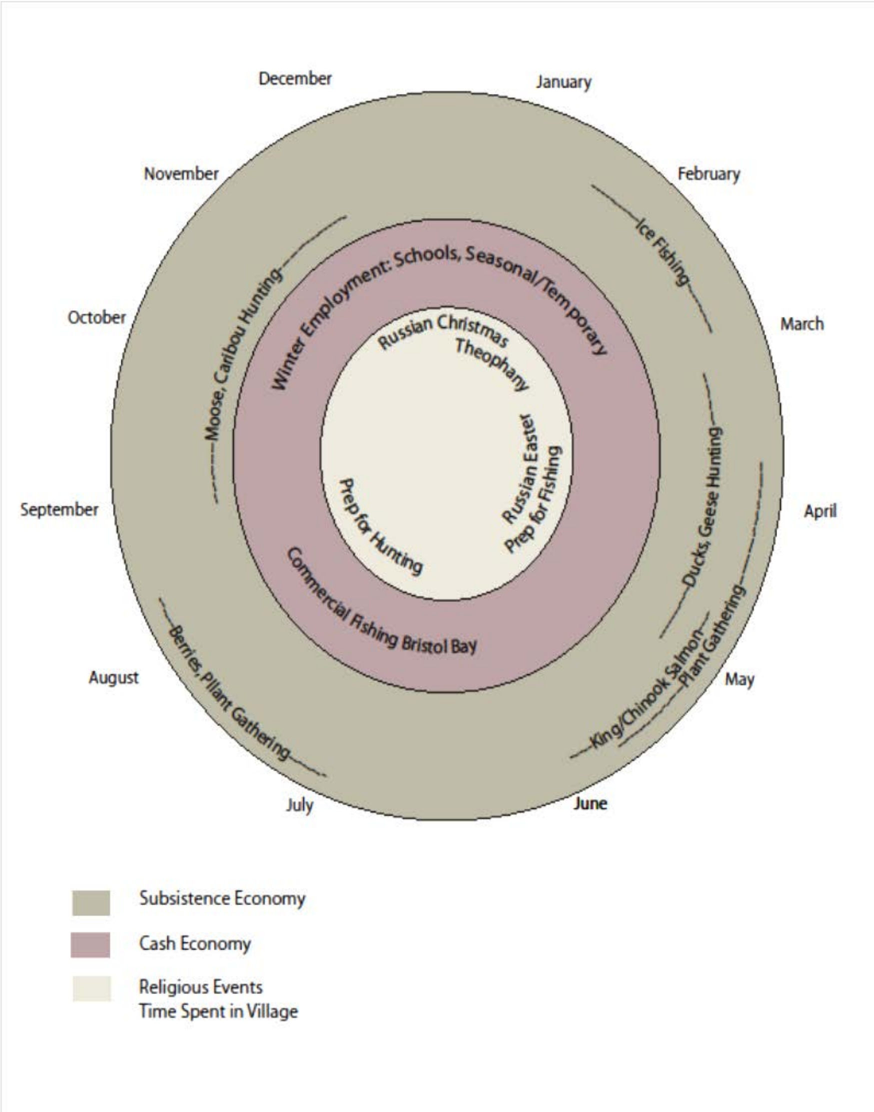

Figure 16. Significant Aspects of the Subsistence Seasonal Round.
Modified from Evanoff (2010:66).

6. The Interplay of Subsistence and Wage Income

Berger noted that subsistence is an interplay of the time, effort, and skill needed to catch, process, and store subsistence foods and part-time wage employment necessary to support the means of subsistence: boats, motors, fuel etc. (Berger 1985: 58) Moreover, Berger (1985:58) notes, "Most villagers do not distinguish conceptually between subsistence and cash elements of the same activity." Today, interviewees reiterate this finding and indicate that, for those fully engaged in it, subsistence is a full-time job, but it is necessary to supplement subsistence with cash from part-time wage labor or commercial fishing, to defray the costs of subsistence activities. With gasoline costs presently in the $6 per gallon range (summer 2011), trips to fish camps and other subsistence areas are expensive. Guns, ammunition, fishing gear, and modern winter clothing, among other expenses, also add to the subsistence investment. While conducting village interviews, researchers observed that besides having a skiff and motor powerful enough to navigate rivers like the Nushagak, Mulchatna, Newhalen, and Kvichak, most families must also rely on one or more all-terrain vehicles (ATVs) and snowmachines for subsistence, all of which require considerable initial investment and maintenance costs. Rather than being recreational vehicles, these means of transport have become necessary for the longer travel distances required for modern subsistence. During the nineteenth century, dog teams, canoes, kayaks, and foot power via snowshoes or hiking were the primary means of transportation, and people, by necessity, lived in small villages located close to subsistence resources. In contrast, the twentieth-century establishment of trading posts/stores, schools, churches, and health services led to residents consolidating in fewer, larger villages. For example, today, there are only three interior villages on the Nushagak River whereas, in the mid- to late nineteenth century, there were eight (VanStone, 1967:114-115). The result of the consolidation is that village residents must now travel farther to obtain subsistence resources, requiring mechanized transportation to do so, and there is overlap among the range of village subsistence activities.

Interviewees indicate that to deal with these costs, many families report holding commercial fishing permits and fish the sockeye run in Bristol Bay during late June and into mid-July or engage in other forms of part time employment. Besides providing needed cash, these forms of employment, with their short duration and/or seasonal nature, are ideally suited to provide another ingredient critical to a subsistence lifestyle, time to engage in subsistence activities. Thomas Lonner indicates that in Bristol Bay villages cash is obtained from wage employment such as working in the commercial fishery (also corporate dividends from membership in Alaska Native Corporations and social welfare payments) and states "wage employment is intended to underwrite subsistence equipment; the time, energy, and opportunity cost in wage employment may be seen as an investment in subsistence" (Lonner cited in Lowe 2007:40). Table 15 is the number of 2010 Bristol Bay Fishing permit holders and crew member licenses for the study area villages reflecting the major source of cash to support subsistence activity.

Table 15. Commercial Fishing Permit Holders and Crew Licenses

	Commercial Permit Holders, 2010	Commercial Crew Member Licenses, 2010	Subsistence Permits, 2007
Aleknagik	n.d.	n.d.	n.d.
Dillingham	227	272	n.d
Ekwok	3	5	n.d
Igiugig	4	4	6
Iliamna	15	26	54*
Kokhanok	9	19	29
Koliganek	18	25	n.d
Levelock	6	10	1
Newhalen	11	1	n.d
New Stuyahok	24	43	n.d
Nondalton	6	6	29
Pedro Bay	3	0	19
Port Alsworth	2	4	30

2010 Data from ADF&G Commercial Fisheries Entry Commission.
http://www.adfg.alaska.gov/index.cfm?adfg=fishingcommercial.main
2007 Data from Fall et al. , 2009, page 19
http://www.adfg.alaska.gov/specialpubs/SP2_SP2009-007.pdf
* Combined data for Iliamna and Newhalen

Figure 17. Subsistence Skiffs, Nushagak River, New Stuyahok. May, 2011. Photo by Alan Boraas

7. Subsistence as an Economic Sector

Labor statistics do not identify subsistence as an employment category because it is not based on wage-labor or a salary and, hence, people engaged in subsistence are considered "unemployed." However, those who choose the subsistence lifestyle work long hours, utilizing considerable skill to provide food for themselves and their families and in interviews described subsistence as a full-time occupation.

The unemployment rate in the study area for 2012 ranges from 14% in Igiugig to 37% in Newhalen (computed from Alaska Division of Regional Affairs Community Database of actual number unemployed per village http://www.dced.state.ak.us/cra/DCRAExternal/community). This compares to the 2012 Alaska unemployment rate of 6.9% (computed from Alaska State Department of Labor and Workforce Development (http://live.laborstats.alaska.gov/labforce/labdata.cfm?s=2&a=1) and the United States 2012 unemployment rate of 8.1% (United States Bureau of Labor Statistics http://data.bls.gov/timeseries/LNU04000000).

The unemployment rate includes only people actively seeking wage-based employment and does not include villagers for whom subsistence is their non-wage employment. The percentage of working-age population "not in labor force" (http://www.bls.gov/cps/cps_htgm.htm#nilf) are high for the villages in the study area and may reflect that fact that subsistence is not a recognized category of employment. Table 16 presents data for the 2010 census of those "not in the labor force" for study area villages compared to Anchorage (28.4 percent is the Alaskan average). Most villages, with the exception of Dillingham and Pedro Bay, had substantially higher percentages of individuals "not in the labor force." It is extremely likely, given the high amount of wild foods that are harvested, that many are not individuals who have given up looking for work, but who work at subsistence and consider themselves "employed" in the sense of providing for themselves and their families. In Alaska commercial fishing is an employment category though for many it is part-time so those who engage in the Bristol Bay commercial fishery do not show up as "not in labor force."

Table 16. Percent Not in the Labor Force, 2010.

	2010 U.S. Census	Percent Not in Labor Force
Anchorage	216,404	26.5
Aleknagik	221	38.5
Dillingham	2378	27.6
Ekwok	115	44.4
Igiugig	50	nd
Iliamna	109	48.5
Kokhanok	170	nd
Koliganek	209	nd
Levelock	163	53.4
Newhalen	190	nd
New Stuyahok	510	46.1
Nondalton	164	50.0
Pedro Bay	42	20.6
Port Alsworth	159	35.4
From http://zipatlas.com/us/ak/city-comparison/percentage-not-in-labor-force.htm		

Based on 2010 U.S. Census Data, 4.0% (Port Alsworth) to 44.5% (Nondalton) of the residents in the study area communities have wage incomes below the poverty level. The weighted average for all communities (excluding Pedro Bay) is 17.1%. These rates compare to a 9.1% rate for Alaska and a 15.1% for the U.S. (DeNavas-Walt et al. 2011:14). These numbers are high but do not reflect the role of wages in a subsistence economy: wage income which for many is not considered the primary source of sustenance but functions to support non-wage subsistence activities. Neither do the statistics consider the non-monetized value of subsistence foods to the economies of the villages.

Subsistence is dictated by the seasons, is time-consuming and must be understood differently from recreational fishing or hunting. It is not critical if a recreational fisher or hunter misses a season due to work obligations or other demands, but, for many Bristol Bay village residents, subsistence is one's work obligation and employment in the cash economy impinges on the time that is necessary to obtain and process food for a family for a year.

Thornton (1998) writing in the on-line edition of *Cultural Survival Quarterly*, considered Alaska subsistence to be the leading employment sector of rural Alaska because of the number of people engaged in subsistence and the economic benefits derived from harvesting one's own food Several attempts have been made to measure subsistence economically by monetizing wild food resources. Fall et al. (2009:3) measured the economic importance of subsistence by calculating the cost of replacing wild foods obtained from hunting, fishing, and gathering with similar foods obtained in a market. Their published data indicates the average annual per-capita harvest of wild foods in the villages of the Nushagak and Kvichak River drainages is 304 pounds of salmon, 123 pounds of land mammals (mostly moose and caribou), 39 pounds of other fish, 23 pounds of plants and fungi (mostly berries), 9 pounds of marine mammals (freshwater seals and beluga whales), 8 pounds of birds and eggs, and one pound of marine invertebrates (mostly clams). To supplement their subsistence harvest, households in the Nushagak and Kvichak River drainages spend 15 to 26% of their annual cash income on store-bought food (Fall et al., 2009:3). In the ten villages for which there is recent data (i.e., excluding Dillingham and Ekwok), the annual per-capita cost of purchasing food ranged from $1,467 to $2,622. At 2004 prices (when the initial analysis was done), the annual replacement cost for the average subsistence harvest described above would be an additional $7,000 per capita, which would increase the demands on the annual cash income an average of nearly 80% ranging from 23% for Port Alsworth to 157% for Koliganek. As high as they are, the estimate may be an under-representation of the estimated worth of subsistence resources. With rising food prices, the replacement value would be significantly higher today. King salmon fillets, for example were $17/pound on December 30, 2010 at 10th and M Seafood's, Anchorage, Alaska. The replacement value of 193 pounds of king salmon alone for Koliganek, for example, would be $3281 per-capita. This value does not reflect the intricate, time consuming care and skill given to smoking and processing salmon that Dena'ina and Yup'ik give to their food (cf. Felton 2005)

While monetizing subsistence gives a measure of its importance to the economy, these values do not reflect the fact that the people of the region unanimously reject replacing their traditional subsistence foods with farmed fish or other imported products, should deterioration of wild salmon runs occur (Interviews). This is based on the belief that such products are of inferior quality and that doing so would result in cultural degradation. See Section III.C.6 for a discussion of the importance of wild salmon from one's home river.

Figure 18. Salmon Drying. Koliganek. September 17, 2011. Photo by Alan Boraas

8. Subsistence and "Wealth"

In Alaska many non-Native people perceive subsistence as an activity for impoverished, unemployed rural people who live in employment-poor communities and cannot afford to buy food so they have to hunt and fish for it. Thornton (1998) asserts that this perception relates to the "minimum food and shelter necessary to support life" dictionary definition of subsistence and has given rise to the "subsistence-as-welfare" concept and associated negative implications. The Yup'ik and Dena'ina perceive subsistence quite differently. Interviewees spoke of the cultural value of subsistence as a chosen lifestyle. (See also the comments by Berger in Section B.2. at the beginning of this section.) As indicated in the 2011 interviews, subsistence is a lifestyle chosen by both old and young. Subsistence is a job, in which the wages are healthy wild foods and the benefits include not only vigorous outdoor activity shared with friends and family, but also a large measure of self-determination supported by a community of like-minded people. Subsistence is coterminous with culture, and the entire range of social and spiritual activities that "culture" implies. Consistently, the Yup'ik and Dena'ina communities of the Nushagak and Kvichak River drainages define a "wealthy person" as one with food in the freezer, a large extended family, and the freedom to pursue a subsistence way of life in the manner of their ancestors (see Social Relations, Section E). Their ability to continue their reliance on subsistence and their concept of wealth has contributed to the maintenance of vital and viable cultures for the last 4000 years.

Interviewees did not talk about materialism either as actual or a symbol indicator of wealth. Typical signs of wealth in urban Alaska such as a large bank account, investment, an elegant home in a high status neighborhood, an expensive automobile, nice clothes or other indicators of wealth were never mentioned in the interviews. Fish, family, and freedom are the indicators of wealth in the Yup'ik and Dena'ina communities of the Nushagak and Kvichak watersheds. In expressing these concepts the interviewees were expressing a local interpretation of the United Nations Declaration on the Rights of Indigenous Peoples, particularly Articles 3 and 26 (UNDRIP 2007) :

> *Article 3*
> Indigenous peoples have the right to self-determination. By virtue of that right they freely determine their political status and freely pursue their economic, social and cultural development.
>
> *Article 26*
> 1. Indigenous peoples have the right to the lands, territories and resources which they have traditionally owned, occupied or otherwise used or acquired.

Figure 19. Talarik Creek, Newhalen River, and Lake Iliamna. January 17, 2012. Photo by Alan Boraas

C. Physical Well-being: the Role of Subsistence

1. Voices of the People

We crave it [salmon] *when we don't have it. We just need it.* F-30, 8/17/11

You know, it's got that one oil in it that is a cancer-fighting oil, and it's really good. F-38, 8/18/11

I think it [salmon] *is healthier than probably beef or pork or something like that.* M-68, 9/18/11

Yes, to be healthy, like I say, if we don't eat fish we won't have anything to eat. That is our health. F-48, 8/20/11

When you are eating fish…you get a drink of water to flush yourself out. If you don't eat fish, you will starve. You got to flush yourself out with water every day; that is what your health is about. God put us on this earth to eat fish every day. That's what it is. Without fish, like I said, we are hungry; with fish we are full. F-48, 8/20/11

We have…to live healthy to be free from diseases if we eat healthy food. Not breathe air that's no good or drink water that is no good; it will affect your whole body. So, on the subsistence, I say let's protect Mother Earth; I demand it. If we don't protect Mother Earth, we are gone. M-51, 8/20/11

We don't buy meat very much. Salmon is our most important dish. F-27, 8/17/11

Salmon is a really an important part of our diet. I think it has things that meat [domestic beef for example] does not have. You are always hearing things about fish oils and how healthy [they are], *but we already have that, so we must be healthy*. F-34, 8/18/11

We can't live without salmon. We'll be missing something. F-27, 8/17/11

Well, we grew up with it. We need it. If we don't have it, we miss it. I can't see anybody that lives around here without it. F-30, 8/17/11c.

I've seen kids teethe on smoked salmon strips. They're hard. They get all fishy and smelly, but man, they just chew. It's better than the rubber toy. F-38, 8/18/11

…[salmon] *is one of our healthiest foods we can give to our child…. It is really healthy*. F-69, 9/18/11

To me, I think eating salmon has sustained our ways of life. I think by eating a lot of salmon, we are a healthy, healthy Dena'ina. I always tell children there at potlaches or wherever; I say that, "If you eat this piece of fish you're going to be a smart Dena'ina woman, you might be able to *be a lawyer or a doctor." It's surprising that, just by telling them that, they…eat it, and they will say, "Oh, taste good."* F-32, 8/18/11

When my kids grew up, I mostly gave them fish and moose meat. F-44, 8/19/11

I definitely limit my child; you know, the fast foods, we eat it once a week, sometimes more… [They eat] *moose meat, the fish…berries, and wild plants as well… We want to give to our children the fish and we want to keep the water clean for them. It was a gift to us from our ancestors, which will then be given to our children*. F-69, 9/18/11

The school system here does get volunteers who donate fish to the schools. Prior to that they used to order cod fish and other fish from out of the area. The kids didn't like it. Not from here. They finally started the donation program, and the fishermen stepped up to the plate and said, "Yes, definitely." The crew members didn't balk. There were no qualms whatsoever about donating fish to the schools. M-61-9/16/11

It is the best hot lunch program we have; the kids just love it when they have salmon day. M-60, 9/16/11

Yes, and that it is healthy [wild salmon]*…and something they* [Yup'ik] *wouldn't have without …. But if we ever lose it, then we won't have anything at all.* M-68, 9/18/11

I think it would matter [that the salmon be wild]*; that would be our concern. We like to take our wild natural renewable resource salmon rather than farmed salmon because you never know what they've* [farmed salmon] *been eating.* M-26, 5/19/11

Wild salmon is more important for us, or wild fish. I don't believe in farmed fish, because wild fish is better for all our health. It has all natural oil, and we don't paint it with artificial paint like the farmed fish you get. You can sell your farmed fish all you want, but wild salmon is more important to us. F-48, 8/20/11

…people from Kenai or Anchorage, they can go to Kenai and get their salmon, but they always say there's nothing like the lake salmon. There's nothing like salmon that comes from Sixmile Lake. We hear that all over…. I always try other people's fish, but there's nothing like salmon from our own stream, salmon from the lake that comes up. Well, I guess we're spoiled having our own. F-32, 8/18/11

There is nothing better than wild salmon…I have talked to many people all over the state, and the best salmon comes from this area, Bristol Bay. M-29, 8/17/11

One year we got a farmed salmon…. What a difference! It came in with the usual run, and it was salmon that was raised in the University of Washington [salmon farm]. *They have a big place out there in Seattle. We went in there, and they had a lot of fish. The meat was soft, and the skin was not firm and scaly. I remember, my daughter was cleaning salmon that year, and she said,* *"Where'd this fish come from? It looks like a salmon, but it's terrible." It was soft. It wasn't like a wild salmon.* F-38, 8/18/11

Matter of fact…I had [salmon] for breakfast this morning before I come over. They stay inside all day. M-53-8/20/11

In the summertime it is every day [we eat fish], as long as the fish are running. We eat fish every way we could: boiled, baked, fried. Every way we could, we eat fish. In the wintertime, what we preserve in the summertime is what we eat in the wintertime, like the dried fish, the canned fish. The fresh canned is something we eat a lot, because you can do so many different things with it. F-35, 8/18/2011

2. Introduction

As described in Section II.A.3., archaeological evidence indicates that salmon were an important component of the diet of the genetic ancestors of the Yup'ik and Dena'ina, as early as 4,000 years ago (see Section II.B.3). The Dena'ina track back to the Paleo-Arctic tradition, as old as 10,000 years ago, although evidence for intensive salmon utilization in Dena'ina territory does not occur until A.D. 1000.

Based on studies of other Yup'ik populations in the nearby Kuskokwim River villages, there is a strong possibility that, within their long history, the Yup'ik may have become genetically adapted to eating salmon. Several recent studies have shown that physical adaptation and evolution based on dietary factors (e.g., lactose intolerance) can occur in 3,000 years or less (Tishkoff, et al., 2007; Bersaglieri et al., 2004: Hollox et al., 2001). Other studies are demonstrating genetic changes at the population level in humans in a similarly short time frame based on adaptation to environmental stressors such as living at high altitudes in Tibet (Peng et al., 2010 :1075-1081; Xin et al., 2010: 75; Simonsen et al., 2010: 72-74).

Research is being done on the health benefits of omega-3 fatty acids, a significant component of wild salmon. One source, the DHA-EPA Omega-3 institute tracks the number of research reports on omega-3 fatty acids and provides this summary reproduced in Table 17 for 2012 alone (DHA-EPA Omega 3 Institute, nd, accessed January 7, 2013).

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Table 17 Scholarly Articles on the Health Benefits of Omega-3 Fatty Acids, 2012

Subject	Number of Articles
Cancer Prevention and Management	10
Cardiovascular Health	49
Cognitive Performance	29
Eye and Visual Health	8
Fitness and Body	4
Inflammatory Diseases	4
Mental Health	19
Nervous System	5
Other Health conditions	29

Significant research is being done on Yup'ik and other populations vulnerability to coronary disease, stroke and diabetes particularly in relation to high consumption of salmon. The National Science Foundation recently funded a University of Alaska study to assess the differences between Yup'ik and other populations in drug metabolism, as well as in vulnerability to metabolic syndrome (development of risk factors for coronary disease, stroke, and diabetes). This study will consider the relevance of dietary differences and resulting long-term physical adaptation, including genetic adaptation (O'Brien et al., 2011). In a separate study researchers from the Center for Alaska Native Health Research (CANHR) are assessing how a subsistence diet affects the vulnerability of Yup'ik people to disease (O'Brien et al., 2011). In a 2009 study whose results strongly support the validity of red blood cell deltaN as a biomarker of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA); the researchers state, "the omega-3 (n-3) fatty acids derived from fish, eicosapentaenoic acid (EPA; 20:5n-3) and docosahexaenoic acid (DHA; 22:6n-3) are associated with a reduced risk of cardiovascular disease and other chronic diseases (O'Brien et al, 2009:913).

While the amounts of salmon and other fish consumed varies from village to village, and from one season to the next, the demonstrated importance of these foods in the diet is consistent with the traditional knowledge shared by Yup'ik Elders and culture bearers, as presented above (Section C.1.) that salmon is critical to their diet. As discussed below, the salmon-dependent diet of the Yup'ik and Dena'ina benefits their physical and mental well-being in multiple ways, as well as encouraging high levels of fitness based on practices involved in subsistence activities.

Figure 20. Ekwok. September 11, 2011. Photo by Alan Boraas

3. Nutrition

The dietary habits of Yup'ik and Dena'ina living in the villages of the Bristol Bay region show regular dependence on several species of wild salmon which they sometimes consume several times a day as the interviews attest. Yup'ik and Dena'ina primarily prepare and eat two species of Pacific wild salmon, Coho (red) and Chinook (king) in different ways, including fresh, salted, pickled, canned, dried, and smoked. Salmon and other traditional wild foods comprise a large part of the villagers' daily diet throughout their lives, beginning as soon as they are old enough to eat solid food (Interviews, 2011).

In addition to salmon, villagers also regularly consume other wild fish species, such as humpback whitefish, Arctic char/Dolly Varden, Arctic grayling, rainbow trout, and northern pike, the wild ungulates caribou and moose, and, to a smaller extent other mammals, birds, and bird eggs. Wild plants, including blueberries, crowberries, salmonberries, ferns, and other species, add fiber, vitamins, and minerals (Interviews).The Yup'ik and Dena'ina continue to harvest certain plants with medicinal values (cf. P. Kari 1995). It is important to recognize that in addition to providing a wide range of valuable nutrients and protein sources, the subsistence diet provides a year round workable harvest schedule with adequate time for preparation and storage.

While subsistence technologies have changed and are now supported in part by the cash economy that commercial fishing provides, enabling purchases of snow machines, rifles and other equipment, the basic subsistence seasonal schedule has been approximately the same for hundreds and probably thousands of years. The implications for population sustainability within the environment, and co-evolution of the human population with environmental food availability mean that hypotheses about the risks of significant changes to the salmon population are important, and change in dependence on local wild salmon could have far-reaching impacts on Yup'ik and Dena'ina physical and psychological health, including at the genetic level.

Interviewees in the study area also eat store-bought foods, but do not prefer them (Interviews 2011). Like other northern subsistence cultures, the Yup'ik and Dena'ina consider their traditional foods to be healthful and satisfying in addition to providing strength, warmth, and energy in ways that processed store-bought food does not (Hopkins, 2007:42-50). Hopkins' study on health and aging also provides an insight into women's views of the importance of the subsistence diet. Eating subsistence foods was an overwhelming theme among all participants.. They generally viewed market or *kass'aq* (white person) food as unhealthful (Hopkins, 2007:46). Hopkins quotes one of the participants, describing the importance of the subsistence diet for Elders: "In years back, before I was born, I know there were elders that were very healthy and strong because they have their food, their native food, not mixed up with the *kass'aq* food. Although they have a hard life, they were healthy, strong, because of their native food. Seal oil, dried fish" (Hopkins 2007:46-50). This statement is consistent with the interviews.

In some parts of Yup'ik territory outside the study area traditional food consumption has decreased as described in a study done in three villages in the Yukon-Kuskokwim delta to the north of the study area (Bersamin et al. 2006). The reason for decreased traditional food consumption is not clear but is partly due to the drastic decline of king (Chinook) salmon, a decline that has not been as drastic for the Nushagak River. The number of Chinook salmon entering the Yukon-Kuskokwim systems, for example, has gone from 45,829 in 2006 to 9719 in 2011 according to Alaska Governor Sean Parnell's (2012) federal disaster request to the U.S. Department of Commerce. Chinook returns to the Nushagak River, however, were 101,572 down from the 15 year average of 170,186 (Fair et al. 2012:35) but not as drastic a decline as the Yukon-Kuskokwim decline. Fluctuating Chinook returns are, nevertheless, a significant concern to Villagers whose primary subsistence fish on the Nushagak are Chinook salmon and any substantial decrease would impact health and nutrition (interviews) as has happened in parts of the Yukon-Kuskokwim Yup'ik area. Bersamin et al. (2006) found that a decline in traditional food consumption in three Yukon-Kuskokwim communities resulted in diets where 63% of the population had diets classified as "poor" and the remaining 37% were classified as "needing improvement" according to Healthy Eating Index (HEI) indicators (Bersamin et al. 2006:1060). These HEI indices are far below United States averages. Moreover, the authors acknowledge that HEI may underestimate dietary health concerning traditional foods which are generally considerably higher in nutrient value than processed "store-bought" foods (Bersamin et al. 2006:1061). In the case of the Yukon-Kuskokwim delta villages the authors conclude: "Traditional foods are excellent sources of numerous essential nutrients but may not be consumed in quantities sufficient to meet recommendations. An even higher intake of traditional foods should be encouraged" (Berasmin et al. 2006:1062). Subsistence data presented in Section III.B. indicate wild traditional foods, particularly salmon, are consumed in sufficient quantities in the study area.

4. Fitness

Yup'ik and Dena'ina dependence on subsistence foods has the additional health benefit of providing opportunities and incentive for physical fitness, since engaging in subsistence harvesting improves fitness and fitness, in turn, enhances the efficiency of subsistence harvesting. Subsistence hunting, fishing, and gathering demands stamina to endure long periods of physical activity and strength to handle meat, large quantities of fish and heavy fishing gear. Hopkins (2007:45-46) quotes from the response of one study participant, over sixty years of age: "I think today most of the women are healthy for activity, physical activities. When they go berry picking, they're working using their bodies everything. When we are cutting fish, we are using everything, our muscles, lifting things."

The fitness needed for, and resulting from, subsistence is part of other aspects of village life, as well. Throughout the winter the Yup'ik villagers, from youth to middle-aged, play basketball and other sports regularly competing in vigorous games. Researchers watched in New Stuyahok as a team of middle-aged men defeated a younger team in an intense, hour-and-a-half game, then went to church services for an hour and returned to play another game of equal length. In several Yup'ik villages, including New Stuyahok, the physical activity of traditional dancing, is making a comeback. As described in Section III.E., this cultural activity is based on dance as story-telling, which both values and elaborates on traditional cultural practices, such as fishing.

While in New Stuyahok, researchers observed that Elders, including the oldest present, at around age 86, frequently walked to locations within the village. According to Hopkins, walking was the primary physical exercise identified in that study's interviews. "The participants referred to walking as an important component of health, both physical health and mental well-being. Walking is believed to keep the body strong, promote energy, and is a basic physical activity in gathering subsistence foods" (Hopkins 2007:46).

The apparent overall fitness of the village population in New Stuyahok gave researchers present at the Elders' Conference the impression of frequent exercise, and led to the hypothesis that the practices of subsistence food gathering, in addition to the food itself, create higher levels of fitness, and act to prevent and reduce health risks from more sedentary lifestyles. For Alaska Natives, as for other Native Americans, the high risk of diabetes and subsequent health consequences is serious enough to make the hypothesis an important one to test.

5. Disease Prevention

Beyond the Yup'iks' own personal conceptions and cultural knowledge about the importance of wild foods in their diets, many studies also confirm the remarkable health benefits of omega-3 fatty acids and the other nutrients found in high percentages in subsistence foods such as wild salmon, and the combination of salmon, wild greens, blueberries and other berries for preventive health among the Yup'ik. These studies particularly underscore the importance of salmon-rich diets for the prevention of maladies, including cardiovascular diseases and type 2 diabetes. O'Brian et al. (2009:913; see also O'Brian et al 2011; O'Harra 2011), for example, concluded that "the omega-3… fatty acids derived from fish…are associated with a reduced risk of cardiovascular disease and other chronic diseases."

In a cohort study of Yup'ik from the Yukon-Kuskokwim area (Boyer et al., 2007:2535-2540), the Center for Alaska Native Health Research (CANHR) found that metabolic syndrome is uncommon in salmon-consuming populations relative to others, occurring at a prevalence of 14.7% in the study population, compared to 23.9% in the general U.S. adult population. The study population also had significantly higher high-density lipoprotein (HDL) cholesterol levels and lower triglyceride levels than the general U.S. adult population.

In a related study, the Fred Hutchinson Cancer Research Center, in collaboration with the CANHR, found that Yup'ik Eskimos consume 20 times more omega-3 fatty acids from fish than the average American and display a much lower risk of obesity-related disease despite having similar rates of being overweight and obesity (Makhoul et al., 2010; Fred Hutchinson Cancer Research Center, 2011). Lead author, Zeina Makhoul, said:

> Because Yup'ik Eskimos have a traditional diet that includes large amounts of fatty fish and have a prevalence of overweight or obesity that is similar to that of the general U.S. population, this offered a unique opportunity to study whether omega-3 fats change the association between obesity and chronic disease risk…. It appeared that high intakes of omega-3-rich seafood protected Yup'ik Eskimos from some of the harmful effects of obesity…. While genetic, lifestyle, and dietary factors may account for this difference, it is reasonable to ask, based on our findings, whether the lower prevalence of diabetes in this population might be attributed, at least in part, to their high consumption of omega 3-rich fish (Makhoul quoted in Woodward 2011).

Compounds derived from their subsistence diet, including omega-3 fats from wild salmon consumption, may also benefit mental health in Yup'ik populations. Lesperance et al. (2010), for instance, report that omega-3 fats can help prevent depression. Another study showed greater improvement in symptoms for patients with chronic depression who consumed omega-3 fats with their medication compared to those receiving only a placebo with their medication. After four weeks significantly reduced symptoms of depression occurred in six of ten patients receiving E-EPA while reduced symptoms only occurred in one of ten receiving a placebo (Nemets et al. 2006). See Section E.7., Behavioral and Mental Health for additional discussion of the behavioral and mental aspects of a subsistence lifestyle.

Other subsistence foods, such as wild greens have nutritional elements associated with better mental health, including folic acid and Vitamins A and C. Other factors associated with a subsistence lifestyle, including time spent outdoors and the physical fitness resulting from subsistence activities, may also benefit mental health. It is interesting to note that several Elder interviewees (Interviews 2011) said that, 20 years ago, no one in their villages knew anything about Alzheimer's disease; it was not an illness they had seen before, but it is appearing now and she attributed it to not eating enough Native foods.

Figure 21. Nushagak and Wood Rivers. September 11, 2011. Photo by Alan Boraas

6. Local Wild Fish

The Yup'ik and Dena'ina populations of the Nushagak and Kvichak watersheds have an interdependent relationship ecologically, nutritionally, socially, spiritually, and possibly evolutionarily, with the local wild salmon populations. It is clear that the benefits, and particularly the long term fit between the human and fish populations, depends upon maintaining the local wild salmon for subsistence fishing. While it would be easy to assume that any salmon would provide a similar quantity and quality of omega-3 fats, a Norwegian study showed that farmed salmon, fed a typical farmed salmon diet, did not have the omega-3 fats in beneficial quantities, in contrast to the wild salmon which did (Sincan, 2011).

It is important to underline that if a human population has adapted to particular environmental dietary elements with a genetic modification in their population, that modification is based on a relationship to the genetics of specific regional species, and subspecies. The fit between environment and population may not be transferable to other places.

Thus the elements of the subsistence diet, in particular wild salmon, provide several substantial health and fitness benefits to the Yup'ik and Dena'ina of the Bristol Bay region. According to recent studies at CANHR led by Andrea Bersamin, "Diets emphasizing traditional Alaskan Native foods were associated with a fatty acid profile promoting greater cardiovascular health than diets emphasizing Western foods" (Bersamin et al., 2007: 266; see also Bersamin et al. 2008). A study by Adler et al. (1994) regarding the benefit of salmon and seal oil consumption concluded these wild foods played a significant role in combating diabetes among Yup'ik and Athabascan Native Alaskans. Adler et al. (1994:1499) state, "Age-, sex-, BMI, and ethnicity adjusted analysis of daily salmon consumption also suggested protection against glucose intolerance….Compared with daily salmon consumers, those participants who ate salmon on a less than daily, but more than weekly, basis were twice as likely to have developed glucose intolerance.” In the present interviews, when asked how many times you eat salmon respondents frequently said “all the time” (see question 2, p. 79) and when asked if you need salmon to be healthy all who responded said “yes” (see question 3, p. 80).

The loss of the local wild salmon as a large component of the Yup’ik and Dena’ina diet would result in risks to the physical and psychological health of the population, including greater risks of cardiovascular disease, type II diabetes, and depression.

D. Traditional Ecological Knowledge

1. Voices of the People

But, I think, when they're spawning, that's where they hit the spring waters, where it doesn't freeze. It's always open, even in the dead of the winter. It's always open; you got to be careful there. Especially up in Lake Clark, around Kijik. It's, man, 30 below zero, and it's still open water. M-29, 8/17/11

Our societies are not different than other societies we have special people that know fishing inside and out, we have people in our society that know weather inside out, that know plants inside out, and that know animals inside out. M-61, 9/16/11

…they drop last year's fish in the middle of the river and we do the same thing here. We put king salmon remains on a string tied to a rock and go out with a boat to the middle of the river and let it sink. That makes king salmon go on both sides [near the banks where they can be netted with set nets.] M-26, 5/19/11

When the fish first come up here we don't put our nets out here before a bunch of them go by for the people who live at the end of the river up in Nondalton and all those guys. They start calling up then maybe middle of July [to tell us they have fish, and then] we start putting our nets out. We just kind of watch the salmon go by for the people who live upstream from us. M-54, 8/20/11
They [the fish] are like us, when we want to know something we ask. The fish are the same way. As we were talking about earlier he mentioned that the fish have souls. Every living creature has a soul. All the animals have souls. They are sensitive, very sensitive. If you put something bad in the water the fish will sense it. They will probably not go up the river, they will go somewhere else. If they spawn here and they notice something different they will move to another spot. The fish are very sensitive. M-20, 5/18/11

What they used to say, was the first time, when they first moved down to fish camps, then this wild celery, I don't know if you know what that is, but we eat those. They go up on the mountainside and pick lots of that, and then they peel it, they peel the peelings off and we eat the inside part. So we have big parties with that. We just really enjoyed the fresh salads that we just had. it was already tall enough to eat. So when we get done with that, then the Elders would tell us, take all the leaves and the skin and everything off of this plant, take it out in the river and throw it in, and they would do that. Then we started asking why we were doing this. This fresh salad plant and the skin will meet with the salmon, and let the salmon know that they are already good to eat, and they need to hurry up and come up because we are hungry. F-28, 8/17/2011
In the winter not only salmon, we do a lot of ice fishing, and my uncle you met this morning [a man in his 90s], *he has a trout net he puts out.* F-35, 8/18/2011

2. Introduction

Anthropologists and other scientists have used different terms to describe the knowledge of indigenous peoples, including "cultural knowledge," "indigenous knowledge," "traditional knowledge," and "local knowledge" (Berkes 1999:8). Fikret Berkes and others working in this area of ethnoscience use the term, "traditional ecological knowledge" or TEK. Berkes defines TEK as "a cumulative body of knowledge, practice and belief evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment" (Berkes 1999:8). TEK, as Berkes describes it, includes spirituality and social relations, as well as a wide range of cultural beliefs and behaviors related to surviving in a particular landscape, because of the holistic nature of culture itself. Berkes' broad approach to TEK is the one used in this study.

Early studies of TEK depended on comparisons between taxonomies and species lists drawn up by Western scientists and those created by indigenous peoples (Knott, 1998). More recently, however, it has become clear to anthropologists, geographers, biologists, and others working with indigenous peoples that their knowledge is far more ecological in scope and requires more than species lists to document. Therefore, a number of scientists working with indigenous peoples have come up with a diverse range of tools to collect and document indigenous knowledge. These research tools include, but are not limited to:

- Maps of local hunting, fishing, and gathering areas
- Maps of sacred sites and other special use areas
- Traditional Place Names mapping
- Species lists
- Collection of stories, songs, and dances of interactions between animals, humans and other species, humans and the natural environment, or allegorical animal stories
- Studies of subsistence technologies
- Animal life histories and their interactions with other plant and animal species including humans, told as information by locals
- Plant life histories and their interactions with other plant and animal species, including humans, told as information
- Stories of human mistakes made, and lessons learned, about interactions with nature and the environment, including storms, earthquakes, floods, ice, glaciers, changes in nature
- Advice in the form of rules, proscriptions against certain behaviors, prescriptions for other behaviors, and guidelines for management of animal and plant harvests
- Uses for animal and plant species, including recipes for foods and medicines
- Observations shared, often about the complex interactions and ecological relationships in the landscape where the people live, hunt, fish, and gather.
- Local descriptions of long term trends for species numbers and migration patterns, weather patterns, climate, and other natural events
- Linguistic, biological, and archaeological evidence.
- And finally, at a broader level, the values, beliefs, social systems and spiritual practices that have developed over thousands of years through the cumulative application of TEK.

A number of important TEK studies have been done in both in the Nushagak and Kvichak River watersheds, and in the Lake Clark and Iliamna Lake area, that cover TEK in detail. Among the Nushagak studies is one by the Nushagak-Mulchatna Watershed Council (NMWC) (2007) and among the Kvichak studies are those by Stickman et al. (2003) Evanoff (2010) P. Kari (1995) and Fall et al. (2010). In addition the Alaska Department of Fish and Game, Subsistence Division has a searchable database titled "From *Neqa to Tepa, Łuq'a to Chuqilin"* which includes maps, place names, interviews, ADF&G technical papers and related TEK information from the Bristol Bay and Alaska Peninsula including extensive information from communities in the study area (ADF&G 2005). These long-term studies have focused on the Yup'ik and Dena'ina TEK in the Bristol Bay region and have provided a wealth of information some of which we summarize in Sections a through c below.

To supplement those long-term studies, we focused interview sessions on the broader levels of TEK, including the values, beliefs, social systems, and spiritual practices of the Yup'ik and Dena'ina that have developed over thousands of years through their cumulative application of TEK. During those sessions we learned much from the Elders and culture bearers about TEK and the cultures as a whole. We also heard some specific examples of ecological insights, prescriptions and proscriptions, and management guidelines for several species.

3. Summaries of Important TEK Studies

Nushagak-Mulchatna Watershed Conservation Plan

Over a two-year period [dates unspecified], the Nushagak-Mulchatna Watershed Council (NMWC) conducted interviews with Elders, residents, and others who use the watershed to create a database of the TEK of the Nushagak and Mulchatna drainages (NMWC 2007:3). The NMWC used the data to create an overall plan for protecting the waters and natural resources of the watershed. The interviews helped with the development of maps to identify areas critical to protection of subsistence resources and habitat. The plan identified 12 fish, 6 mammal, and 12 bird species important for subsistence and mapped 125 traditional use areas and 153 traditional area names. The flora and fauna considered most integral to traditional subsistence use were all five species of Pacific salmon, whitefish, winter freshwater fish, moose, caribou, waterfowl, and edible and medicinal plants (NMWC, 2007:19).

The study also identified probable threats to the watershed in the next fifty years, and, based on the TEK information collected, developed four strategic actions (Nushagak-Mulchatna Watershed Council, 2007:3):

1. Reserve adequate water flow for the Nushagak River and tributaries under existing laws for in-stream flow reservation.
2. Maintain the vegetative complex that supports moose, fish and other species within and adjacent to the floodplain.
3. Maintain water quality standards that protect wild salmon and other fish.
4. Prevent habitat damage that could result from mining.

What is at stake includes habitat, and wildlife including terrestrial mammals, birds, fish, and the subsistence way of life, along with the unique cultures it supports. The report states:

> The Nushagak River system is the fifth largest river in Alaska by volume of water discharged. The drainage supports at least 13 anadromous species, 16 resident species, and four species of fish restricted to estuaries. The Nushagak River and its tributaries host five species of Pacific salmon and provide significant habitat

for Bristol Bay sockeye salmon – the largest runs in the world. The Nushagak River hosts the largest sport fishery for Chinook salmon in the United States, with the third-largest Chinook run in the country. In addition there are significant numbers of rainbow trout, grayling, Arctic char, Dolly Varden, northern pike, lake trout, and non-game species (NMWC, 2007:8).

The flora and fauna considered most integral to traditional subsistence use includes the following. Fish: 1. Sockeye, Chinook, and Coho salmon; 2. Pink and Chum Salmon; 3. Whitefish; 4. Winter Freshwater Fish. Mammals: 5. Moose; 6. Caribou. Other: 7. Waterfowl; and 8. Edible and Medicinal plants. The Elders and other knowledgeable individuals also identified critical habitat for the species of concern and their harvest locations. The conservation plan used this information to delineate the watershed into conservation target areas, in terms of habitat types important for traditional use species (NMWC, 2007:20). Salmon are the keystone species in the region, and provide enormous amounts of marine derived nutrients to the ecosystems described above.

In the present study interviewees identified potential threats to the area including recreation, recreational subdivisions, commercial lodge development, community development, mining, roads, high seas salmon fishing, ocean acidification, oil and gas development, and habitat shifting and alteration. Interviewees in Pedro Bay during the fall of 2011, for example, confirmed the high earthquake activity and expressed concerns about new road construction and its potential impacts on their streams and community, based on their long-term ecological knowledge.

The following tables list the primary and secondary subsistence species identified by the Nushagak River Watershed Traditional Use Area Conservation Plan (2007) and represents the breadth of wild food use and, indirectly, the knowledge of how to harvest, process, and prepare those foods.

Table 18 Subsistence Fish, Terrestrial Mammals, Birds and Plants (Nushagak-Mulchatna Traditional Use Conservation Plan, 2007).

Subsistence Fish Species

Yup’ik	English	Scientific
Taryaqvak	Chinook (King) salmon	*Onchorhynchus tshawytscha*
Sayak	Sockeye salmon (Red)	*Onchorhynchus nerka*
Caayuryaq	Coho salmon (Silver)	*Onchorhynchus kisutch*
Amaqaayak	Pink salmon (Humpy)	*Onchorhynchus gorbuscha*
Kangitneq	Chum salmon (Dog)	*Onchorhynchus keta*
Talaariq	Rainbow trout	*Onchorhynchus mykiss*
Iqalluaq	Rainbow smelt	*Osmerus mordax*
Yugyak	Arctic char,	*Salvelinus alpinus*
Iqallugpik	Dolly Varden,	*Salvelinus malma*
Culugpauk/Nakrullug pak	Arctic grayling	*Thymallus arcticus*
Cuukvak	Northern pike,	*Esox lucius*
Can’giiq	Alaska blackfish,	*Dallia pectoralis*

Additional fish sometimes used

White fish, *Coregonus spp.*
Halibut, *Hippoglossus stenolupsis*
Flounder, *Plutichthys stellatus*
Sheefish, *Stenodus leuichthys*
Burbot, *Lota lota*
Sticklebacks, *Pungitius pungitius*
Tomcod *Eleginus gracilis*
Sculpin, *Cottus spp.*
Herring, *Clupea pallasii*

Subsistence Terrestrial Mammals

Yup'ik	English	Scientific
Tuntuvak	Moose	*Alces alces*
Paluqtaq	American Beaver	*Castor Canadensis*
Cuignilnguq	River Otter	*Luntra Canadensis*
Issaluuq	Porcupine	*Erethizon dorsatum*
Tuntu	Caribou	*Rangifer tarandus*
Taqukaq/Carayak	Brown Bear	*Ursus arctos*

Additional mammals sometimes trapped for furs

Mink *Mustela vision*
Muskrat *Ondata zibethica*
Red Fox *Vulpes vulpes*
Arctic Fox *Alopex lagopus*
Snowshoe hare *Lepus americanus*

Subsistence Bird Species

Yup'ik	English	Scientific
Lagilugpiaq	Canadian goose	*Branta Canadensis*
Kep'alek	Greater scaup	*Aythya marila*
Nacaullek	Emperor goose	*Caidris alpine*
Uqsuqaq	Pintail duck	*Clangula hyemalis*
Cetuskar	Harlequin duck	*Histrionicus histrionicus*
Qucillgaq	Sandhill crane	*Grus Canadensis*
Qugyuk	White swan	*Olor columbianus*
Tungunqeggiq	Black scoter	*Melanitta nigra*
Qengallek	King eider	*Somateria spectabilis*
Curcurliq	Mallard	*Anas platyrhynchos*
Aqesgiq/Kangqiiq	Willow Ptarmigan	*Lagopus lagopus*

Additional Birds

Godwits
Dunlins
Golden Plover
Western sandpiper
Black turnstone
Red-throated loons
Arctic tern
Jager,
Marsh hawk

Kingfisher
Rock Ptarmigan, *Lagopus muticus*

Plants
Salmonberries, *Rubus chamaemorus*
Crowberries, *Empretum nigrum*
Blueberries, *vaccinium uliginosum*
Marsh marigold, *Caltha palustris*
Wild celery, *Angelica lucida*
Willow leaves, *Salix glauca*
Pond greens, sourdock, *Rumex artica*
Caiggluk, *Artemisia tilesii*

K'ezghlegh: Nondalton Traditional Ecological Knowledge of Freshwater Fish

K'ezghlegh: Nondalton Traditional Ecological Knowledge of Freshwater Fish is based on interviews with 18 Nondalton residents in 2001 and focused on their current and past subsistence use of sockeye salmon and other fish in the Lake Clark/Newhalen River drainage (Stickman et al. 2003: 8). Interview questions related to fishing practices, geographic locations, and Dena'ina place names. The questions were presented in semi-directed interviews, with USGS quadrangle maps of the Lake Clark Newhalen River area used to plot information. Answers revealed that the summer months, from mid-June through August, are traditionally devoted to harvesting sockeye salmon that are returning to Sixmile Lake and Lake Clark. Fish camps used to be set up around the outlet of Kijik Lake, but now are primarily at the outlet of Sixmile Lake but also along the shores of the Newhalen River, Sixmile Lake and Lake Clark (Stickman et al., 2003:11).

The interviewees listed nearly a dozen places as the most important locations for sockeye fishing and eighteen as primary locations for harvesting spawned-out sockeye or "redfish." Residents described in detail how and where they get salmon, listed 36 separate places where sockeye spawn, and gave descriptions of several areas where they have noticed reduced spawning activity, particularly Kijik Lake, which is well known as a very productive area. This area in particular has recently had reduced spawning activity due to beaver dams that seem to be blocking the entry of the salmon into the Kijik River, and preventing fish from moving upstream to spawning grounds in and around Kijik Lake. The study also asked about harvest methods and detailed the use of seines, spears, and fish traps. Seining is no longer allowed under State of Alaska fishing regulations and fish traps were banned in 1959. People do use commercially manufactured gill nets.

It was important to the residents that they were respectful of the fish and cared for them. "Everyone interviewed reported that they generally stop fishing once they have caught the number of fish they need" (Stickman et al., 2003:23). Residents also disapproved of people leaving their nets out too long unattended. Andrew Balluta, one of the residents interviewed, said, "They used to say if you don't use what you are catching in your net, don't leave your net out there" (Stickman et al., 2003:24). The study also elicited descriptions of putting up fish. The remaining sections of this report document residents' comments about change: observed change in salmon over time, observed environment changes, human-induced change; and finally the importance of salmon to the population as documented in the observance of the fish camps and the First Salmon Ceremony. A separate section documents the use of other freshwater fish, including rainbow trout, Dolly Varden, whitefish, grayling, northern pike, burbot, candlefish, sucker, and lake trout, and their relative abundance. Residents also noted significant changes in the number of fish returning in the five to ten years prior to the 2003 report. "Each person interviewed reported fewer fish than in the past, and all indicated that they first noticed the change in abundance between five and ten years ago." (Stickman, 2003:26). While Stickman et al. describe numerous possible reasons for the reductions in numbers, as well as changes in timing of the runs, the report also noted that flows in the Newhalen River in 2001 exceeded the level observed to prevent or delay sockeye migration into the lower river (Stickman et al., 2003:27-28 citing C. Woody).

Dena'ina Ełnena: A Celebration

Lake Clark National Park in a project organized by Karen Evanoff produced *Dena'ina Ełnena* (Dena'ina Land) (Evanoff 2010) as a compilation of place name maps and traditional knowledge stories told by Dena'ina Elders for the Inland Dena'ina. The elegant maps describe the scope of knowledge of the landscape as reflected in language, and the eleven maps and data include many of the 1400 place names known in the study area (Evanoff 2010:91). Before "paper" maps and GPS, the place names became a "cognitive" map through which people were able to discuss subsistence events or to know where they were when traveling. Kari (2003:157) describes the complexity of The Dena'ina place name system:

> This is a memorized, verbally transmitted geographic system that is congruent across language and dialect boundaries. We can marvel at the strict purity, orderliness, symmetry, functionality, and the memorizability of the geography. This system is elegantly simple and flexible and has facilitated Athabascan travel and land use since antiquity.

Most (75%) of the Dena'ina place names are for hydrology, landforms, specific rocks, or flora and fauna. About 15% are for human activities such as subsistence places. There are very few personal names, Yup'ik loan word place names, or mythic names although notable exceptions to the latter are *Ch'iduchuq'a*: 'Game Enters Mountain' by Ruth Koktelash, an important Dena'ina origin story (Evanoff 2010:18-19), and *Kuzhaghaten Qatnik'a*: 'The Giant's Rock' told by Walter Johnson (Evanoff 2010:37-8) also described in section D-2, Traditional Dena'ina Culture.

The maps of traditional trails (Evanoff 2010:44-45) document an extensive system to access subsistence territories, travel between villages, or meet with Yup'ik coming up the Nushagak and Mulchatna to trade such as *Yusdi Ghuyiq'*: Long Point, Dena'ina and Yupik at *Yusdi Ghuyiq*, by Albert Wassilie, (Evanoff 2010:16). Thirteen stories describe traveling including "*Qeghnilen* Area: Traveling to Fish and Hunt" by Pete Bobby (Evanoff 2010:43) about subsistence activities.

The Dena'ina seasonal round is described in a set of 15 stories about activities at different times of year and is the core of traditional ecological knowledge. For example one of the stories by Ruth and Pete Koktelash describes the underground cold storage pit for storing salmon for winter (Evanoff 2010: 77-78).

Many of the stories are about subsistence practices such as "*Eseni Dghitnu*: Cottonwood Extends: Respecting Trapping and Hunting Grounds" by Nicholai Balluta (Evanoff 2010:35, 41-42). Balluta describes the area west of Six Mile Lake and the Newhalen River and north of Lake Iliamna, the area of the proposed Pebble Mine development, as a traditional trapping ground divided between the people of Nondalton, Iliamna, and Newhalen. The trapping territories were divided by village and Balluta states, “They used to respect one another’s trapping ground…Yeah, that’s our way, that’s our history” (Evanoff 2010:42).

<u>Nature Conservancy Place Name Project</u>

Place name mapping research is not nearly as far along in the Yup’ik areas of the Nushagak, and Kvichak watersheds. In 2005 The Nature Conservancy conducted research with the assistance of Yup’ik culture bearers on Nushagak River Yup’ik place names (Tim Troll, personal communication, November 15, 2011). Thirty-two traditional place names have been identified in the Ekwok area, eighty in the New Stuyahok area, and eighty-nine in the Koliganek area. Research is on-going but indicates, like the Dena’ina place name data, that the people have an intimate knowledge of their areas through traditional names.

<u>Plant Lore and Bird Traditions</u>

Priscilla Russell Kari conducted two important TEK studies in Dena’ina territory. The first, a study of Dena’ina (Tanaina) plant lore, describes the seasonal cycle in the Dena’ina use of plants, as well as detailing the gathering, processing, and preserving of the most important plants (P. Kari, 1987 (1995)). She also covers Dena’ina beliefs concerning plants and the Dena’ina plant classification system. Her study, based on long-term work in several Dena’ina communities, with a wide range of Dena’ina women, documents more than 150 plants that the Dena’ina depend on for foods, medicines, and other uses (P. Kari, 1987 (1995)). The second was done by Priscilla Russell with George West (Russell and West 2003) and details Dena’ina use of birds. Like the plant lore book, the bird book identifies each species, the native name, and use, often including how it was prepared. The ethno-botanical and ethno-ornithological knowledge portrayed in both of these books is highly detailed and an invaluable contribution preserving Dena’ina ecological knowledge.

E. Social Relations

1. Voices of the People

I feel good, proud [to share]. *And when our friends give us back, way proud*. M-60, 9/16/11

We share with the Elders first, then with family. Usually how I do it, if someone goes with me we go 50-50 and he can decide who to share his fish with, and we do the same. It's not decided by one person, usually me and my wife decide. M-26, 5/19/11

It makes me feel good when I give salmon to somebody. F-47, 8/20/11

It makes you feel good inside because you are sharing. M-53, 8/20/11
It's a good feeling, because we know other people want it. It's a good thing to give away, it's healthy. F-30, 8/17/11

Oh, it makes you really feel good [to give salmon], *because I know we enjoy it, and people that can't get it that were almost raised on it…. That's just the way the whole village is; they share.* F-38, 8/18/11

In our culture here you share with everybody. When I got my first moose, I had to give it to people; when my grandson got his first moose, you give it to people. You share it. That is one thing good about the community of Bristol Bay; we still hold on to our cultural values really strong. Sharing is a very important component to our culture. If somebody is handicapped and unable to provide for themselves, you find some Young Turk or young family to go help them out. You don't expect pay. M-60, 9/16/11

You know, I was having a hard time, and her husband [gestures] *brought me a whole truckload of food, and I damn near cried…. Now, when somebody needs help, we do the same thing. If someone needs help, I try to help as much as I can; we always share. When we give something, it feels good, and when we are having hard times and get something, it feels good*. M-43,8/19/11

[Reference to a woman's] *mom was blind, and she couldn't do certain things, so my mom always made sure she shared with her. That is one of the things she told me about sharing. She thought it was good to share with people who couldn't do things for themselves. But, she was always doing nice things for us, too. She* [the blind woman] *made us string to hang fish and things like that. She was really a nice person, her mom.* F-44, 8/19/11

Yeah, we always share. Holidays, we share, and if somebody passes away, after burial we have a potlatch; we share. We share with people; that is the way we are brought up. F-41, 8/19/11

We share with people here and in Anchorage…. I like to go fishing, so if we run out of freezer space, I will ask people [who can't fish in the village, e.g. Elders] *if they want fish, then I'll go out and catch some fish if they want*. M-70, 9/18/11

Me, I share it with my younger sisters who never do subsistence. Like, some can't work anymore. They [gesture] *share it with their parents. Me, I share it with my younger sisters or my son, my kin*. F-23, 5/18/11

Me and my daughter always share after we fish for all summer, but she always tries to give me lots more, but I say, "No, you've got more kids." Sometimes we give [fish to] our daughter-in-law. F-22, 5/18/11

I think, with us, during potlatch times, during hard times or Russian Christmas, or, if we gather together, everybody brings out their dry fish or their jarred fish or their salt fish. Nobody goes hungry; there's always sharing. We would be greedy if we kept it all to ourselves, but there's always a sense of sharing with the community or sharing with relatives. F-32, 8/18/11

The people up there [Kvichak River villages in the 1990s] *were not meeting their subsistence needs [*allegedly due to ADF&G management decisions*]. They weren't screaming about the cost of gas or the price of lights. They were screaming that they didn't have fish. There were people from over here that were shipping fish over there for people to meet their subsistence needs.* M-60, 9/16/11

You are a very rich person if you share. If you don't share, you are nobody…. I have to go share food with my grandkids, great grandkids; it doesn't matter. I don't care if someone comes in and eats with us; I like to share. That's the way we were brought up. Anybody that is in the house, come and eat with us; you are welcome. F-46, 8/20/11

You know, when I was working down in Seattle, my mom used to send me pieces of dried fish all the time. You know, that mail was slow back then. When I would get it, man, it was just like candy. No, but one time she sent me mixed berries. You make it with lard; we call it "agutak." She sent me those, and by the time it got there, it wasn't good. Salmon doesn't spoil when it is dried. M-53, 8/20/11

We catch moose and caribou and give it away; it ensures good luck back. Even beaver, you give the whole beaver away after you skin it. After you skin the beaver, you give it away; give the whole beaver away. That animal that you give away…give[s] *you back in return good luck.* M-54, 8/20/11

[My wife] *and I have been doing it for thirty some years, doing the fish camp, and putting up fish for the winter. When the kids were small, we were down there for them too, and hopefully, they will have a family, too, and carry on the tradition.* M-33, 8/18/11

Some of the salmon we put up at my fish camp even goes all the way down [to] *the states. My friend* [name] *comes in here, and she puts up fish, and she cans salmon….* [My daughter] *and her friend…they also can fish and dry fish….* [My grandson] *was here all summer*. F-27, 8/17/11

The parents, their sisters, their aunties, their grandparents, their great grandparents. Everybody is there [at fish camp], *you know, telling them* [the children] *how to do this….Everybody does it at their own camps, fish camps…. Everybody is living in different fish camps, so all these families that are together, that's how they taught the younger kids.* F-28, 8/17/11

He [five-year-old grandson] *went fishing with us once; now, he went and seined with us. That's …how we learn, that's how we teach our kids [fish camp]. I mean, it's togetherness.* F-30, 8/17/11

One of the things we were taught and we are teaching our kids and grandkids are that you do not waste. Boy if they let the fish get rotten boy they would be disappointed in us really bad. So we teach and pass that on, don't waste nothing. M-29, 8/17/11

We usually get our subsistence foods, salmon, and a wealthy person, years ago, was when he had a lot of dry fish for his dogs, salt fish, smoke fish. The women had their wooden kegs full of berries for their Eskimo ice cream. Maybe the father was fishing commercially and made enough to buy a few groceries form the store, enough [rifle] *shells. That was a wealthy person. I think today a lot of people still think the same way.* M-62, 9/16/11

Yeah, I think growing up in a small village wealth was defined by what you provided for your family. If you were a highline fisher, you were very wealthy, both physically, as well as mentally. If you were a good hunter, that in itself was very wealthy. Or a good trapper, good provider. M-61, 9/16/11

Salmon is one thing. They make you feel rich, because you have something to eat all winter. Smoked salmon, sun-dried spawned-out fish, all of those make you feel good, because you grew up with it; it is in your body. M-53, 8/20/11

As long as we have a lot of fish and meat and stuff, they are wealthy. We don't believe in… having lots of money. The wealth to us is having more fish put away for the winter, and meat; that's our wealth. F-27, 8/17/11

In this Western society of living in the city, everybody is for themselves. Everybody is worried about "Joe Blow" next door, who has a bigger TV or a bigger car; they are worrying about money, money, money! It just brings on the sickness of worrying. Here, we run a healthy life, because we have everything we need here; everything we could possibly want is right here. F-32, 8/18/11

They don't learn that at school [proper attitudes toward salmon]. [Laughter]. Elders teach them, Elders are teachers and pass it down to younger generations. They learn it and pass it down to their children. Right down to grandchildren, great grandchildren. M-53, 8/20/11

Figure 22. Pedro Bay. August 18, 2011. Photo by Alan Boraas

2. Introduction

Though each has a different cultural social organization going back to pre-contact times, today there are many similarities between the Dena'ina and Yup'ik of the Nushagak and Kvichak River watersheds. Among them are the importance of sharing subsistence foods, fish camp as a social and educational as well as economic institution, gender and age equity, and the concept of wealth.

3. Sharing and Generalized Reciprocity

The Yup'ik and Dena'ina cultures center on belonging to community and on sharing food as a means of creating and maintaining the living bonds of relationship. The focus on sharing functions as the elemental ordering factor in sustaining the culture and the long-term health of the communities. The practice of sharing is elemental in both indigenous and other cultures both from a material and a social standpoint (Counihan 1999:13). Interviewees indicated that the sharing, preparation, and consumption of food together has created opportunities for efficient and sometimes ritualized teamwork, as well as social bonding and building of networks. The Yup'ik and Dena'ina of the Nushagak and Kvichak River watershed villages, as traditional cultures, continue these practices through harvesting, preserving, and preparing food together and sharing food through traditional practices and ritual celebrations. They continue to experience the social, spiritual, and nutritional benefits from sharing food, especially salmon, the staple food, up to the present.

Sharing remains a fundamental institution within Yup'ik and Dena'ina cultures today, according to interviewees, and the importance of sharing food, especially salmon, cannot be overemphasized. Among the Yup'ik, for example, *elaqyaq* means "those of the same stomach" and refers both to sharing food and being biologically related. Oscar Kawagley noted a similar linguistic reference: "The Yupiaq [Yup'ik] term for relatives is associated with the word for viscera, with connotations of deeply interconnected feelings" (Kawagley 2006:11). As Langdon indicates, the time people spent together in subsistence activities is extensive: "The Yupiit [Yup'ik] enjoyed the bounty of some of the world's richest salmon fisheries. Large quantities of fish were harvested and processed through relentless hours of work in order to sustain families and their dogs throughout the long winters" (Langdon, 2002:41).

Figure 23. Jarred Salmon Being Prepared at Fish Camp. July, 2012. Photo courtesy of Karina Chambers.

Yup'ik and Dena'ina sharing is "generalized reciprocity," because the time and place of a return gift is not specified. In general, interviewees indicated that people do not expect a return gift when they share salmon or other subsistence foods with someone else, particularly an Elder, but a return gift of food always seems to appear, whether that month, that year or sometime in the future. The altruism is part of social solidarity. Villagers do not consider sharing to be an obligation, but a way of life, as the Voices of the People at the beginning of this section indicate. Interviewees universally indicated that giving or receiving salmon or other subsistence foods makes them feel good. The altruism of sharing food expresses social solidarity between the participants. Almost universally, Dena'ina and Yup'ik seem to have small jars of salmon available for favored visitors to take with them.

Villagers particularly recognize some Elders who cannot participate in the rigors of subsistence harvesting as people with whom to share salmon and other subsistence foods. The informal first salmon sharing, for instance, always includes Elders (see Section III.F.5). Sharing salmon and other subsistence foods with family living in Anchorage or even farther away is an important bond to home, family, and place. Interviewees consistently talked about how much they appreciated a gift of canned or jarred salmon from home when they were away from the village. They also talked about how important it is for them to send a part of the place to family and friends living away from Bristol Bay.

The Dena'ina believe that tangible items can take on aspects of the owner. This personification is called *beggesha* if the aspects are positive and *beggesh* if negative (Boraas and Peter 2008: 215-9). Artifacts or places can have *beggesha* or *beggesh* depending on events associated with them. A place, something someone made, such as a birch bark basket, or salmon someone prepared take on *beggesha.* The term does not easily translate into English, so today people talk about giving "love" when giving a gift of something they made or prepared. Conversely, one receives "love" when receiving a similar gift. This perspective is one of the reasons that Alaska Native foods, especially salmon, are served at all gatherings such as potlucks and potlatches. Preparing and giving food is a tangible act of love. Recipients appreciate non-Native foods, but they are not from the place, were not made by the giver and, consequently, are not an expression of love when gifted.

Athabascan Elder, the late Reverend Peter John 1996:60) expresses love this way, "True love is something that you never see….By gathering to share food, songs, and speeches, love grows among the people."

4. Fish Camp

Writing of subsistence in general, including fish camp, Yup'ik Elder and scholar Mary C. Pete (1993:10) wrote:

> For many Yup'iks, subsistence activities teach children much more than hunting and fishing: they convey respect and proper conduct toward the land and water and animals and other humans; they promote satisfaction from hard work and contribution to the kin group. For many Yup'iks, subsistence goes beyond mere economy—it is a vital way of live and a source of pride and identity.

Both the Dena'ina and Yup'ik have a long tradition of going to fish camp to harvest salmon. As interviewees indicate, the villages of the Nushagak and Kvichak River drainages harvest salmon either at or very near town, and fish camp may be only a short boat ride or four-wheeler trip to a traditional fishing locality where they may or may not camp out (cf. Fall et al.

2010). Many villagers, however, still travel to a traditional place, set up camp, and live for several weeks catching and putting up salmon. Villagers from Kokhanok, for example, travel to fish camp on Gibraltar Lake, while residents of New Stuyahok, Ekwok, and Koliganek stay at various camps on the Nushagak River, downstream of the villages primarily at Lewis Point (*Nunaurluq*), and villagers from Nondalton go to camps on Sixmile Lake and Lake Clark. Generally, the interviewees indicate the fish camp consists of an extended family, with three or more generations, but close friends may also participate (Fall et al. 2010).

Figure 24 Young Boy Helping at a Nondalton Area Fish Camp. Photo courtesy of Karina Chambers

Families typically view fish camp as a good time when they can renew bonds of togetherness by engaging in the physical work of catching and processing salmon. Family members who don't live in the villages often schedule vacation time to return home to fish camp, not just for the salmon, but for family. The importance of sharing in vigorous, meaningful work cannot be overestimated. It creates cross-generational bonds between children, their parents, aunts, uncles, and/or grandparents that, today, are rare in Western culture because there are so few instances in which meaningful, multi-generational work occurs (Interviews, 2011).

Figure 25. Smoking Salmon at a Nondalton Area Fish Camp, July, 2012. Photo courtesy of Karina Chambers

Fish camp is a time when children and teens learn not only the practice of how to properly catch, clean, and process fish, but the values that are an integral part of harvesting salmon and interacting with nature. As such, it is a primary educational institution (Fall et al. 2010). Young people learn from their parental generation and, particularly, from their grandparents, their Elders, about the Yup'ik or Dena'ina way (cf. Ellana and Balluta 1992:208). Interviewees stressed that the primary value passed on at fish camp is respect for nature and, particularly, respect for salmon. As discussed in Section III.F.4., showing this respect involves using everything and disposing of what little is left over in a respectful manner. Fish are not disparaged, bragged about or made fun of. Catching salmon with a good attitude is the first step in imbuing it with the *beggesha* or love discussed in the previous section.

Fishing and fish camp also play a significant role in maintaining emotional and spiritual health because the meaningful group activity has a significant therapeutic affect (Capers 2003:1,8-10; Mills 2003:85-88). See Section 7, Behavioral and Mental Health Treatment below for further discussion on this matter.

5. Gender and Age Equity

Gender equity among subsistence families is balanced and has many of the characteristics of a traditional family farm or family-run business. Both men's roles and women's roles are equally valued, and it is common that men can do most "women's" activities (cook, clean fish, etc.), while women can do most "men's" activities (shoot a moose, run a boat, etc.) (Interviews 2011).

Traditionally, Elders are important members of village society, seen both as sources of values and storehouses of traditional knowledge, and they are valued in child-rearing, village decision-making, and life guidance. A common saying in the villages is: "When an Elder dies, we lose an encyclopedia."

6. Wealth

When asked their perception of wealth, only 3 of 53 interviewees, all from the same village, indicated that they measure at least part of their wealth in terms of money, material items, and potentially high-paying jobs (see Section III.B.8.). The remaining interviewees who commented responded that wealth is measured in terms of one, or more, of three themes: food in the freezer, family, and/or freedom.

To the majority of interviewees, stored subsistence food means a family is wealthy or rich as noted in Section III, B. Various entities attempt to monetize this value, but to the people, subsistence is priceless. It means you won't starve; it means you will have among the healthiest diets in the world; it means you will be able to actively engage in the sharing networks described above; and it means shared, activity that enhances family and/or village togetherness. A full freezer (or freezers, as is often the case), a well-stocked pantry and a full wood bin are primary symbols of wealth in the Nushagak and Kvichak River villages. Most villagers, of course, recognize that money is a necessity, but money is not the singular measure of wealth. Money is necessary for the tools for subsistence, gas and oil for boat and house, and occasional travel, and locals generally acquire it through part-time jobs or commercial fishing that still allows time for subsistence activities. By Western materialist standards most of the villages are poor; by their own standards Nushagak and Kvichak River villagers are rich, and it is the people who live a non-subsistence lifestyle who are poor (summarized from interviews, 2011).

Interviewees indicate that wealth also derives from having a large, extended family, particularly one that is closely knit by subsistence activities. Nuclear families are not necessarily large, but having an extended family means having people you can count on if need be, and it means having people to whom you can give your love and assistance. This tradition of alliance through marriage has its origin in pre-contact Yup’ik and Dena’ina culture (see Sections II.B.3 and II.C.2).

Few interviewees spoke with fondness of living in Anchorage or other urban places they have lived or visited. Though hunting and fishing require abiding with ADF&G regulations, most villagers see those activities as involving a degree of freedom that does not often occur in non-subsistence work settings. As described in many interviews, with subsistence as your job, you don’t have to punch a clock, you only follow nature’s clock; you don’t have a boss, you are your own boss, and you either suffer the consequences if you do not perform well or reap the benefits if you do. During our May visit to one village on the Nushagak River, two young men in their early twenties left on a 17-day subsistence trip upriver into the Mulchatna area, one of the most remote places in North America at any time of year, but virtually deserted in spring, when snow was still present. They were on their own, and apparently all who were connected to the endeavor embraced that freedom. As they left, for example, the mother of one of the boys simply said, “Be careful,” just as a parent living on Alaska’s road system might say to a son embarking on a trip to Anchorage. This view comes from villagers having knowledge of and ranging over a vast territory, almost all of which is in a natural state. Consistently, people are thankful to live in a place where they can live off the land in the manner of their ancestors, and don’t want to live anywhere else (Interviews, 2011).

7. Behavioral and Mental Health

There is increasing recognition by Western behavioral and mental health practitioners of the role of traditional cultural practices in maintaining and treating behavioral and emotional health. In subsistence cultures, such as the Yup’ik and Dena’ina villages of the study area, Capers (2003:1) states that culturally-based behavioral assessments have a higher probability of providing useful information than Western based assessments. Capers (2003:1) points out that an assessment of healthy homes in Yup’ik territory can be measured of the size of the woodpile and the amount of fish put up for winter. Capers cites Kenneth Robertson of the Substance Abuse and Mental Health Services Administration (SAMHSA) as stating, “substance abuse renders individuals incapable of taking care of themselves or their families—which in turn affects the well-being of the entire community” (Capers 2003:1). From a behavioral health perspective, if one is abusing drugs or alcohol that individual will not be able to adequately engage in the demanding tasks of subsistence.

In a study done in Yup’ik territory (the Yukon-Kuskokwim delta) Hazel and Mohatt (2001) point out the importance of Native-based spirituality in substance abuse treatment rather than zealous application of Western-based treatment programs which may or may not work well. Hazel and Mohatt (2001:544) state:

> Spirituality is central to the worldviews of Native people…a paradigmatic shift is necessary, one which moves away from a deficit and disease theory to an examination of the problem of alcohol addiction from an indigenous perspective. The new paradigm would focus on the revitalization of cultural pride, work within communities rather than just on individuals, see both abstinence and temperance as worthy goals, and acknowledge Natives' search for personal competence and spiritual power.

Hazel and Mohatt conducted focus group sessions with Yup'ik leaders in which they identified the therapeutic value of traditional activities in dealing with substance abuse including: use of Native healers; eating traditional foods; cleansing and purifying rituals; participating in Native dancing; singing and drumming; subsistence activities such as berry picking, hunting, and fishing; involvement in traditional art and crafts; attending spirit camps, and other worthwhile and meaningful activities that challenge the individual to remain connected to *Ellam-iinga*[8] (Hazel and Mohatt 2001:547). It follows that such activities are important if not critical to the maintenance of emotional stability for healthy individuals.

Mills (2003:85-88) describes a behavioral treatment program that successfully utilized traditional practices in the Yukon-Kuskokwim part of Yup'ik territory. Table 20 describes the "categories" of traditional culture that were recognized as having therapeutic value not just in treating individuals with problems, but in maintaining day-to-day emotional balance. While Western culture usually does not recognize activities like fishing, berry picking, gathering and chopping firewood, walks, and steambaths as having treatment value, they proved to be of such significance in Southwest Alaska that they were recognized by Medicaid for the purpose of billing and reimbursement (See Table 20).

[8] *Ellam-iinga* is a dialect variation of *Ellam Yua* a universal creative, cosmic force described in Section D-1 "Traditional Yup'ik and Dena'ina Spirituality and Cosmology."

Figure 26. Hot Room of a *Maqi* or Steambath. New Stuyahok. January 16, 2012. Photo by Alan Boraas

Table 19. Traditional Yup'ik and Cup'ik Cultural Practices Correlated with Medicaid Billing Categories. Modified from Mills (2003:87).

Traditional Practice	Medicaid Billing Category					
	Rehabilitation Treatment Services	Intensive Outpatient Services	Care Coordination	Individual Counseling	Family Counseling	Group Counseling
Pissuryaq (hunting)	X	X		X		
Aqevylguq/Ar'sasuq (berry picking)			X		X	
Neeqsq-Kuvyiliuuni (fishing)	X	X		X		
Kaluukaq (to hold a feast, potlatch, ceremony					X	X
Quqtaq (gathering wood)	X	X		X		
Eqiurtauq (chopping wood)	X	X		X		
Cuilqeriuni (tundra walk)						
Makiiraq (gathering edible and medicinal plants)			X		X	
Maqi (steam bath)	X	X	X	X		
Caliinguaq (traditional arts and crafts)	X	X				X

8. Steam Baths

In many villages, informal gender-specific groups meet several times a week for steam baths in small wooden buildings heated with wood-fired barrel stoves and share stories, the advice and wisdom of the Elders, and cultural connections. In some ways, these steam baths, or *maqi* as the Yup'ik call them, have taken the place of the men's traditional house, *qasgiq*, and the women's house, *ena*, where the transmission of cultural values and knowledge traditionally occurred, as well as much entertaining talk. As described in Section 7 they are a significant integrative factor in individual emotional stability. Among Dena'ina the traditional word for steambath is *neli* which traditionally was a spiritually powerful place as well as a place for healing (Kalifornsky 1991:48-50; 218). Today the Dena'ina *neli* has many of the social aspects of the Yup'ik *maqi*.

Modern *maqi* consist of three rooms, an outer changing room, a warm room and an inner hot room where the wood stove surrounded by rocks burns heats the inner room to over 200 degrees F. and as hot as 300 degree F (see Figure 25 and 26). Men generally take a "steam" earlier in the evening, and women later. The age range is from children about four to the eldest in the village. Bathers move in and out between the hot and warm room and finish by soaping and rinsing with buckets of fresh water. Young men sometimes engage in competitions to determine who can stand the hottest temperature. Steambaths are taken several times a week, for some each evening, and collecting firewood for the steambath is a regular activity. Kizzia (1991:129) describes the Nushagak River village *maqi* experience as a chance to "slow down and put the world in perspective." The steambath is an institution of sharing community news and obtaining advice from Elders as well as a vehicle to maintain emotional and community stability.

Figure 27. Firewood sled (foreground) and *Maqi* or Steam Bath (background). New Stuyahok, January, 18, 2012. Photo by Alan Boraas

9. Suicide in the Study Area

Tragically, suicide is one of the primary indicators of individual loss of identity and breakdown of society (anomie). Alaska has one of the highest suicide rates in the nation and that, sadly, is due in part to very high rates in rural Alaska. However, as indicated by data from the Alaska Bureau of Vital Statistics (see Table 21), those high rates are not spread equally throughout rural Alaska. In the Northwest Arctic census area the age adjusted suicide rates per

100,000 are four times the Alaska rate (22.7 in 2009) and six times the national rate (11.5 in 2011). Suicide rates for the Bethel area north of the study area indicate a similarly grim picture.

The suicide rates for the study area including the Dillingham census area which includes the Nushagak drainage villages of Dillingham, Ekwok, Koliganek, and New Stuyahok as well as five other villages outside the study area are comparatively much lower. In only one two-year period was the age-adjusted rate per 100,000 even calculable at the 95% confidence level because the number of suicides was so low (see Table 21). Suicides were even lower for the Lake and Peninsula Census area which includes the study area villages of Igiugig, Iliamna, Kokhanok, Levelock, Newhalen, Nondalton, and Pedro Bay in the Kvichak drainage and 10 other villages outside the study area. While any suicide is a horrible loss for family and community, especially in small rural villages, statistics indicate suicide is not of the epidemic proportions in the study area that it is in other parts of Alaska.

Table 20. Suicide Rates in the Study Area (in gray) compared to Alaska and Other Selected Areas.

	Alaska	**Dillingham Census Area**		**Lake and Peninsula Census Area**		**Bethel Census Area**		**Northwest Arctic Census Area**	
2010 Population	698,473	4,933		1,488		17,236		7,208	
	*per 100,000	*per 100,000	Actual Number	*per 100,000	Actual Number	*per 100,000	Actual Number	* per 100,000	Actual Number
2007-2009	22.7	42.4	6	--	0	61.6	30	67.5	15
2006-2008	22.6	--	2	--	0	50.1	25	93.0	21
2005-2007	20.9	--	2	--	0	38.3	19	81.9	18
2004-2006	21.0	--	2	--	0	48.1	24	79.4	18
2003-2005	21.0	--	4	--	0	56.9	29	66.1	15
2002-2004	21.5	--	4	--	1	50.8	26	74.8	17
2001-2003	19.4	--	3	--	1	32.7	17	78.4	17
2000-2002	19.6	--	1	--	3	27.6	13	74.5	16
1999-2001	18.3	--	2	--	2	23.8	11	62.2	13

* Rate is Age-Adjusted per 100,000 calculated at the 95% confidence interval
-- Rate per 100,000 not calculated because the incidence is too low to be within the 95% confidence interval
Data from "Alaska Bureau of Vital Statistics, Detailed causes of Death in Alaska.
http://www.hss.state.ak.us/dph/bvs/death_statistics/Detailed_Causes_Census/frame.htm

While suicide is complex, one of the chief reasons is a debilitating feeling of hopelessness. The 2011 Alaska Federation of Natives panel on suicide identified specific causal factors including historical trauma, substance abuse, sexual abuse, and family violence (DeMarban 2011). It is also not easy to determine why suicide rates are much lower in some parts of rural Alaska such as the Nushagak and Kvichak drainage. One reason is that Orthodoxy is generally strong in these villages and Orthodoxy considers suicide to be a sin and a violation of the fifth commandment “Thou shall not kill” (Morelli n.d.). Resident indigenous priests with close ties to the village no doubt provide preventative spiritual counseling to those in despair who might be contemplating suicide. Second, the cultural strength of a subsistence lifestyle cannot be discounted as a second effective defensive measure against suicide in places like the Nushagak and Kvichak villages where subsistence is very strong. Eating a healthy, natural diet; engaged in vigorous, meaningful outdoor activity with family and friends and the village support of those friends and family; and having a significant degree of independence and therefore feelings of control of one’s destiny; and living in a cultural continuum that goes back thousands of years on the landscape of one’s ancestors in all probability remediates the despair that can lead to suicide before it ever gets to a critical state.

F. Spirituality and Beliefs Concerning Water and Salmon

1. Voices of the People

Respect and Thanks

Yes, they do [streams have a spirit], *like everything else, all living things. Before Russian Orthodox came here, that is what we worshipped. We worshipped all the living things, even the air, the sky, the moon, the sun, snow, rain. It is in every aspect of our lives, how we are made up, what we believe in, why are we still here?* M-33, 8/18/11

They say everything on Earth has a spirit, like we have a spirit. So everything has spirits, the streams, the waters, the lakes, the mountains, trees, birds; everything has a spirit. To me, I think, that's why we have to pray, and you have to keep the streams clean, not pollute it. F-27, 8/17/11

I think that, if you treat animals disrespectful, that they are not going to show up again. F-32, 8/18/11

That is why we are so clean around here…they [outsiders] don't know if we camped around here or not, because we clean up our garbage, and we hardly leave any evidence that we were there. M-36, 8-18-2011
Yes, like all other things you are granted [by God], *you give thanks for* [salmon]. F-69, 9/18/11b.

First Salmon Ceremony

The first salmon, it's still tradition to share with everybody. You do say a prayer. F-47, 8/20/11

When we catch the first king salmon, about this month [May], *maybe next week, we share that king salmon, cut in little pieces, to give to them to cook, especially to the Elders, because they always want fresh fish.* F-22, 5/18/11

First catch is shared with all of the Elders. Elders first, always the priority, Elder, because they cut it in pieces, you know, if you catch a king, you share, instead of eating the whole fish by yourself. The first catch. M-20, 5/18/11

Tradition--first salmon, the very first salmon you catch you boil everything, everything. You don't waste anything then you eat it too. I mean, even the liver, if it's a male the sperm sac, everything. M-29, 8/17/11
Every year, when I first catch a king salmon, I usually pray to God and thank Him for it. A lot of people do the same thing, because he is the one giving us these wild foods. M-63, 9-18-11

Figure 28. St. Michael the Archangel Russian Orthodox Church, Koliganek. September 15, 2011. Photo by Alan Boraas

<u>Great Blessing of the Water</u>
There are a lot of folks along the Nushagak, down to Dillingham, and along the chain that are Orthodox because of the Russian influence. They actually have three ceremonies in the church that deal with the salmon. The first one is the Blessing of the Water in the winter time. You have probably seen the newspaper articles about the priest that goes out there and blesses the water. It can be minus 40 or minus 50 [degrees Fahrenheit], and you seem them running that cross in the water, and they never freeze. That in itself is a miracle, I think. The other thing that happens is that, just prior to fishing, the church has a special service of the blessing of all the resources. The third thing is the blessing of the fishing boats. The individual fishermen, when they get done with all their nets and all their gear, they can ask the priest to come and bless their boats. M-81, 9/16/11

They do it every year at Theophany…. It's very important to us; it's a blessing of the water, blessing the river so the fish come in. It's an Orthodox religion ceremony.M-20, 5/18/11

The Holy water is so pure. We believe it is healing, has healing powers. When you are sick or have a cold, have just a little tiny bit. F-69, 9/18/11

And over on the Iliamna side, they will do the same thing that Father will do over here with the water, make holy water. People will come down there too with either buckets or jugs and fill them up. M-65, 9/18/11

I used to live in Portage where there is no clinic. That is the only thing I could give my kids [holy water, when they were sick]. *You know pray upon them and let them make the sign of the cross and let them have a taste of the holy water. F-72, 9/19/11*

That holy water is strong. To be honest with you people, I would not be talking with you right now [if not for holy water]. A long, long time ago, before I become a lady, we were upriver with my mom and dad. My mom was sick too, my grandparents and dad, too, and uncle [name]. In night time, I guess I almost go [die] you know. But my dad, he prayed for me. If you're really true, praying really hard, I guess he'll answer you. My dad tell me I have no more breathing, no more pulse. And when I come to, my dad was holding me like this, up you know, feeling my heartbeat. As soon as I opened my eyes my dad said 'you get up'. I said yeah, I told him I was going to sleep, how come you woke me up? I was going to go to Big Church [heaven], and my dad said 'you can't go to Big Church' When he tell me that, I told him holy water—I call Native way, <u>malishok</u>, holy water, malishok [Yup'ik]--'give me holy water to drink'. He did, my dad, he did. A little bit you know. I opened my mouth, I swallowed, the water was going down into my stomach… I closed my eyes, pretty soon I come through. My dad was up, my momma was sleeping, she was sick too upriver [Yup'ik placename]. I go but I came back. Almost going to that Big Church. My dad he tell me not to go into the church, come back, that's why I become a lady. It's true, I tell you guys the truth, better not forget that. Holy water is strong, that is what made me come back. F-66, 9/18/11

Figure 29. The Eve of Theophany, St. Sergis Orthodox Church, New Stuyahok, January 18, 2012. Photo by Alan Boraas

2. Introduction

Most of the residents of the interior villages of the Bristol Bay drainage are Russian Orthodox Christians or were brought up as Russian Orthodox, and the Orthodox Church, along with the public school and the tribal structure, is among the dominant institutions in the villages. Many of the villages have a resident indigenous priest or priests; for others, clergy visit periodically on a scheduled basis. In some villages Protestant churches have formed: Port Alsworth, and Dillingham have Protestant church buildings, the latter in addition to an Orthodox church.

Beliefs concerning streams and salmon, in those villages where Orthodoxy is the dominant religion, involve a syncretism merging traditional beliefs with Russian Orthodox practice. Dena'ina writer Peter Kalifornsky (1991:249) described syncretism when writing about his great-great-grandfather's nineteenth century message to the Dena'ina people after his conversion to Orthodoxy: "Keep on respecting the old beliefs, but there is God to be believed in; that is first of all things on earth." Russian Orthodoxy itself has a syncretic tradition of melding Middle Eastern-derived Christianity with spirituality influenced by the northern environment. Billington (1970:18-19, and 403) points out that, though Orthodoxy moved north from Greece and Asia Minor into Russia in the ninth century A.D., its long history in the northern forest has shaped the belief system to interpret and interact with aspects of the subarctic taiga. Billington writes, "God came to man not just through the icons and holy men of the Church but also through the spirit-hosts of mountains, rivers, and above all, the forests" (Billington 1970: 403). Consequently, many Russian Orthodox rituals involve interaction with nature. The mystical aspects of Orthodoxy fit well with traditional Dena'ina and Yup'ik beliefs, many of which related to interacting with the landscape on which their survival depended (Boraas, 2013 in press). For the Dena'ina and Yup'ik living in the Nushagak and Kvichak River drainages, beliefs regarding pure water and the return of the salmon, discussed below, ritually and spiritually express the meaning of life as people of the salmon.

Figure 30. Procession going onto the Nushagak River at New Stuyahok for the Great Blessing of the Water. January 19, 2011. Photo by Alan Boraas

3. Great Blessing of the Water

The "Great Blessing of Waters" takes place during the Feast of Theophany, a major event in the Orthodox Church calendar and is celebrated on January 6th of the Julian calendar, the calendar of Orthodoxy (January 19th in the Gregorian calendar). While all church rituals are important, Theophany can be considered to be the third most important church ritual after Christmas and Easter to the Orthodox of the Nushagak and Kvichak watersheds (personal communication, Fr. Alexi Askoak, St. Sergis Russian Orthodox Church, New Stuyahok, January 19th, 2012). A theophany is an event in which God reveals himself to humans and the Great Blessing of the Water marks the baptism of Jesus by John the Baptist. After Jesus' baptism God appears saying, "this is my son whom I love, with him I am well pleased," (Matthew 3: 17, New International Bible). As explained by Fr. Alexi Askoak (personal communication, January 19, 2012), in the Orthodox view, baptism both redeems sin and brings the Holy Spirit to the recipient. Orthodoxy believes in the triune God, consequently Jesus is God and without sin. So Orthodoxy transfers the baptismal ceremony to one of God's most important creations, water, and one of the creations most important to the people of the Nushagak and Kvichak since salmon and related wild foods are dependent on clean water.

An evening church service is held on the eve of Theophany in preparation for the blessing the next day. The two-day ritual is a liminal event with believers moving into a deeply spiritual mental state. At the service I (Alan Boraas) attended, 211 villagers of New Stuyahok were present filling the small church. The next morning a communion service was held involving the personal forgiveness of sins, and, as the sun rose, the people led by the priests went out onto the frozen Nushagak River where an Orthodox cross had been cut into the ice and a small hole had been made to withdraw holy water (Figure 28). There a baptism service was held purifying and sanctifying the water of the Nushagak River. At the moment in the service when the priest dips the cross through the hole in the ice into the water for the third time, God is believed to sanctify the water making it holy. According to Father Michael Oleksa the Great Blessing of the Water is done to "reaffirm the Church's belief that the natural world is sacred and needs to be treated with care and reverence" (Orthodox Church in America, n.d.). The Orthodox Saint John Maximovitch (n.d.) wrote:

> …when we bless waters of lakes, rivers and streams, we ask God to send His blessings upon the waters of His creation so that even though humanity has spoiled the world through sin and abused the environment over many generations, God has not forsaken the world. He sends His spirit to cleanse and sanctify His creation.

"Sin" in the form of human-caused pollution and other contaminants are ritually removed from the water and it is now considered pure and holy (personal communication, Fr. Alexi Askoak, January 19, 2012). In New Stuyahok, and other villages where the ceremony is performed, the now blessed water is dipped from the hole in the ice and saved in containers for personal spiritual use and a large container is taken back to the church for use as holy water. And, interviewees indicate, the water is now pure and clean in preparation for the return of the salmon.

Figure 31. Great Blessing of the Water, Father Alexi Askoak, St. Sergis Church, New Stuyahok. January 19, 2012. Photo by Alan Boraas

Holy water from the sanctified rivers is believed to have curative powers for both physical and mental illness and is drunk or put on the affected part for healing purposes (Fr. Alexi Askoak, personal communication, January 19, 2012). Several interviewees shared very personal incidents of the power of holy water to cure. Fr. Alexi told the story of one bitterly cold Theophany when he frosted his face during the ceremony. When they returned to the church one of the parishioners rubbed holy water on his face and he subsequently did not blister or suffer any ill effects other than one little spot the water had missed which left a mark for several years. Fr. Alexi believes God healed him through the holy water. A young 20-something interviewee in Koliganek movingly told of a time when her children were gravely ill and there was no doctor, health worker, or suitable medicine available. She said, "all I had was holy water." She had the children drink the holy water and in a few days they recovered. She attributes their recovery to the power of the blessed water. An elderly woman movingly told the story of being brought back from near death when she was a child by holy water. Both stories are recounted in the "Voices of the People" at the beginning of this section.

The antiquity of the Great Blessing of the Water in Alaska is apparently as old as Orthodoxy. Hegumen Nikolai was an Orthodox missionary priest stationed in the Nushagak area in 1846 and then transferred to be the first permanent priest in Kenai where he served from 1846 to 1867 (Znamenski 2003:15-18). In his travel journals Hegumen Nikolai describes conducting the Great Blessing of the Water in Kenai in 1862 and 1863 on January 6th, Julian calendar. (Znamenski 2003: 94, 108) (Travel journals, official church documents missionary priests were required to submit to the diocese yearly, have not been translated for earlier years for missionary priests operating in the Dena'ina or Yup'ik areas of the Nushagak and Kvichak watersheds.)

From a secular standpoint, the question is not whether or not holy water has healing efficacy or whether the water is actually purified, but how the Great Blessing of the Water ceremony and holy water reflect values of the people. By elevating water to sacred status, the people of the villages define core values. As described in section II. E. 4 the Dena'ina word for water, *vinłni*, has sacred overtones and water, itself, is sacred. Since the word predates Christianity in southwest Alaska, we can assume sacred water has long been a part of the salmon cultures of the Nushagak and Kvichak watersheds because the people recognize that clean water and salmon are fundamental to life itself. The Great Blessing of the Water ceremony is an extension of that very old concept, rendering in Christianity the belief that water is sacred to life and culture. Through the liturgy of baptism the ceremony becomes a form of world renewal ceremony reestablishing God's intended order

4. Respect and Thankfulness

Water and salmon play additional roles in modern Orthodoxy in the study area as derived, in part, from traditional subarctic spiritual practices. Describing traditional Dena'ina beliefs, Kalifornsky (who was also a devout Orthodox Christian) writes (1991:362-363) that, after putting out his net, "🕓*uq'a shegh dighelagh*" or "a fish swam to me," indicating that the spirit of the salmon had a will and would allow itself to be taken for food if the net-tender had the correct attitude. Today, all interviewees that commented on it believe that salmon have a spirit or soul and that soul is a creation of God. Further, all interviewees who responded report offering a prayer of thanks when they catch salmon, particularly the first salmon as noted in the "Voices of the People" at the beginning of this section. That prayer may be a humble "in one's mind" statement or it may be spoken thanking God for the salmon.

Interviewees also still believe in treating all animals, including salmon, with respect. Several modern practices reflect this belief, for example, using the entirety of a fish for food, except the entrails, which villagers return to the water along with the bones that remain after consumption. To not use all of the edible parts of a salmon is considered to be abuse (interviewees). Another example, interviewees report, is never allowing fish or meat to spoil. Interviewees repeatedly stressed the importance of giving salmon and all subsistence animals respect. This attitude echoes the pre-contact beliefs that animals had a will and, if not treated properly, would not allow themselves to be taken for food, leading to dire consequences for the people (Boraas and Peter 1996:190-192).

5. First Salmon Ceremony

The First Salmon Ceremony is a world renewal ceremony which, like other world renewal ceremonies, recognizes the cyclical onset of the most important yearly event in the culture. As mentioned in Section II.C.2, the First Salmon Ceremony was described by ethnographer Cornelius Osgood (1976:148-9) and was practiced in pre-contact times and is based on a mythical story that merges people and salmon. Because of the importance of salmon in the lives of the Bristol Bay villagers, interviewees report they continue to mark the return of salmon in the spring by a special observance. The actual practice varies, but involves a prayer of thanks to God for the return of the salmon and sharing the first salmon caught in the spring with Elders and others in the community. Typically, according to interviews, each receives a small piece, and there is a general feeling of happiness that the salmon have returned and the cycle of the seasons has begun again and nature will provide the people with sustenance. In some places the First Salmon Ceremony takes place at fish camp, where extended families and others present share the first salmon they catch with one another, including the Elders. In at least one village, New Stuyahok, the ceremony includes sharing the first salmon with "the underground," by placing a small piece of it under the forest mat at the cemetery, symbolically sharing salmon with the deceased ancestors buried there.

Figure 32. Kvichak River and Lake Iliamna at Igiugig. May 16, 2011. Photo by Alan Boraas

G. Messages From the People

At the conclusion of the interviews we asked interviewees if there was anything else they wanted to say, anything we had not covered, and/or any message they wanted the Environmental Protections Agency to hear. The following reflect those comments:

1. Voices of the People

I, myself, get very emotional when the topic of the Pebble Mine comes up. I don't even want to think about it. In the future I don't want to think about total ruin of our way of life. It really saddens me. F-69, 9/18/11

For quite a few years there when we were building up the king salmon run we didn't even fish in June. It was just to build up those runs. It is kind of ironic that the kings we built up are on the Koktuli River where that mine is going to go. It is almost a whole decade that we sacrificed to build up that run. We built it up and now it might go away. M-61, 9/16/11
You don't see Bristol Bay having troubles because our ecosystem is whole and not damaged. We are very appreciative of what we have. In relationship to the mine the place I work up here is the Bristol Bay Economic Development Corporation and… one of the companies we bought is Ocean Beauty Seafoods which is one of the largest salmon producers in Alaska. We put up 161million pounds of commercially caught goods in a year. So I talk to the people and if there is a mine that goes in like pebble and we have copper coming out and affecting our fish, are you interested in buying our fish? These are customers we sell 300-400 thousand pound lots to. No, we are not interested….We don't want ourselves and our kids to eat contaminated foods. M-60, 9/16/11

It is clear, good water to drink. This is what we protect our good water to drink. F-48, 8/20/11

We can't even fathom somebody hurting the salmon. When the pebble mine folks first came in they said they were going to pump the tailings right into the middle of the lake. We said you are going to kill the lake. They said you guys got no say so….We said no you'll kill the lake. We couldn't fathom it. We said you kill the lake and we will go to war. M-60, 9/16/11

Since the Pebble Mine started their exploration, I speak for everyone around here that we have not had the big caribou herds that come through here anymore. F-69, 9/18/11

That is our greatest fear about the mine. The size of the hole and the tailing pond they are going to build. You know you see our KDLG water tower up here and the size of the walls are going to be greater than that and if we get a spill we are done. What we say is that we can't afford the risk. The mine might be safe but there might be an earthquake and pollution happens. We can't afford the risk. M-60, 9/16/11

In Easter they went up to Koliganek the next village up. He said people up there caught white fish and pikes. He said the water is good upriver, it's not like down here. I think it's the water *that is coming down from up Mulchatna. He thinks it's from them working on that pebble up there [pebble mine].* F-23, 5/18/11

There's open water all over. They got drilling rigs that are sitting on open water. You can't walk up there with knee boots you got to have hip boots there is so much water this year. The ground is saturated. M-60, 9/16/11

[Translator of 80+ year old Yup'ik-only speaking Elder] *He is only worried about the Pebble, right now. If the Pebble starts, the water is going to get effected before anything else. That's what he is worried about.*

M-21, 5/18/11*We feel that EPA is very important around here to give us a fair shot at examining this….* [reference to specific individuals deleted] *You know they [state officials] are all for this economic development. You know economic development up in that mine they are going to bring in outsiders they are going to destroy the culture up there like you wouldn't believe. Most of the outsiders will, most of the jobs will go to outsiders and we will be left with the pollution.* M-60, 9/16/11

They [Salmon] would not go there [where water is contaminated] They are also very sensitive to temperature. They have a really keen sensory acuity, not only them, but all the critters, all the birds. …They are so sensitive in every aspect of that word. …It's relying on the renewable resources for our people have been going on for a long time. The respect for it, it is still there for those of us who do respect it. We have been sharing it with everybody. Nobody was jumping up and down, hollering about one group or another, until the Pebble people came. We took all these resources just for granted. We did not know anything about open pit mine or mining. I realize as human beings we need mines. I have to buy bullets now and then. I have to buy a prop for my outboard motor. I have to go buy bearings for my Honda. This is not a place to have that. They cannot have that here. There is no balance there. They talk about coexistence, that is not…that's coming from the other side. That stuff can't coexist with salmon. Are you going to compare coal to copper? Copper is a thousand times more devastating that coal. [M-33, 8/18/11

The drill wells are making all the noise. We were over there, my wife and I were over there last spring, and when we went over there to check out the Pebble, there [we] *saw three other helicopters right in the same area, and that's lots of traffic. We have not had caribou meat around here ever since. Haven't had caribou meat caught here in probably the last six years.* M-68, 9/18/11

Bristol Bay is renowned for what it has to offer. Like I was saying earlier, this region had a very good working agenda before the Pebble people came. M-33, 8/18/11
[Name] went with her and she is about 88 years old [mother and daughter on an Outside mine visit]. They went out to look at mines and [name] cried at every mine she looked at, she couldn't believe that man would be that disrespectful of the earth. She said literally cried… like her brother, mom or dad died. She represents us all, we can't see destroying the earth like that. We're not greenies you know we are far from green but we can you know. Without EPA we are

sunk. …We know it is just a matter of time. All of us have had a few cocktails and drove, one of these times we are going to have a few cocktails and get in a car wreck. It is just a matter of time. Just like that mine. We really feel helpless with the state government. It is like we are dispensable out here and it is better for the big boys to come in. that is what the mine people are telling us. Right guys? When they first started coming? You got no say, so we are coming. M-60, 9/16/11

And what is going to happen when this mine closes up? Our great-great-great grandchildren are going to end up paying for it. If they are fortunate enough to still be living in Bristol Bay if the salmon, the streams are not contaminated and sustained. I hate to think of the future if this mine goes through. The long haul it is going to be devastating. M-62, 9/16/11

We are very rich. With this new mine coming up, I would never trade my fish for money or a new house, or whatever. I'd like to have all that, but I would not trade what we have every year for how many centuries. F-35, 8/18/2011

IV. CONCLUSIONS

As described in Sections II and III, the Yup'ik and Dena'ina village cultures of the Nushagak and Kvichak River watersheds practice a subsistence lifestyle that developed over several thousand years of living in the area and depends primarily on salmon. At the same time the people have incorporated modern technology, political participation and educational standards into a successful transition into the modern world. As illustrated by the Elder and culture-bearer interviews, this lifestyle has built strong, connected networks of extended families and a culture based on sharing, traditional knowledge, and respect for the environment.

Most of the villages have schools (except Pedro Bay where children are home schooled), city government or tribal council, a health clinic, post office, small store, church, airstrip, and electricity and running water in most homes. Homes have radio and satellite TV and many are being connected to high-speed fiber-optic internet. Basketball games in the school gym and bingo at the council building, and sometimes Yup'ik and Dena'ina dancing, and communal sweatbaths are popular in the evenings. Four-stroke outboards on large skiffs, four wheelers, and snow-machines are everywhere. These changes are recent, however; up until about sixty years ago, traditional dog sleds and kayaks provided the transportation, and caring for dog teams took much time and effort. The availability of material goods from beyond the villages was limited, modern housing was nonexistent and formal education was mainly offered through boarding schools. The villages of the study area grew dramatically between 1980 and 2000, probably due to post-ANCSA changes in land-ownership (Fienup-Riordan 1994:39) and the population is now holding steady although there is local village variability.

These changes have resulted in some loss of traditional cultural practices; for instance, people no longer openly practice the Bladder Festival, *Kelek* or *Petugtaq*, although essential elements of these can be found in more informal practices, and in some cases transformed through corollary rituals in the churches (see Section III.F). Other changes have been more severe and have both made the communities more vulnerable to changes in their environment and placed them at higher risk for further cultural and individual losses. Examples of such changes include loss of control over traditional use areas, loss of community members to Western diseases and outmigration of young people, for either employment or education, the latter of which included, in the past, the involuntary placement of children in distant boarding schools, removed from the traditional culture (Interviews, 2011).

Some interviewees expressed a fear of the future that a traditional prophecy of "bad times" told by Elders might be coming true due to economic development resulting in cultural loss characterized as "anomie," the loss of meaningfulness, sense of belonging, and direction in life. The cultural and social impacts associated with Westernization have been described as anomie. Merton (1938: 682) gave a classic definition of anomie where he writes, "At the extreme, predictability virtually disappears and what may be properly termed cultural chaos or anomie intervenes." Anomie, the loss of meaningfulness, sense of belonging, and direction in life has occurred among all Alaskan Native cultures to one degree or another. Anomie increases cultural and individual risk for social ills such as depression and suicide, alcoholism and drug abuse, domestic violence, and aggressive behaviors. Healing practices can include those used for trauma and post-traumatic stress disorders, including traditional practices that reconnect the individual to society and the natural environment through meditative rituals. Traditional drumming, singing, and dancing have been shown to be effective in treating trauma and post-traumatic stress. Culture camps and other methods of cultural revitalization (see Section III.E.4, 5) can be both preventative and healing for children and adults of indigenous cultures. It is critical to assess future risks and vulnerability, and take appropriate measures to reduce both.

Despite colonial disruptions to indigenous peoples in Alaska, the underlying cultures have so far endured among the Yup'ik and Dena'ina people of the study area because of a strong subsistence base. Wholesale changes to the ecosystem that supports their subsistence resources, however, whether they come from large-scale development, including mine development, climate change, high-seas overfishing, and/or declines in the ecological integrity of the North Pacific Ocean such as acidification, carry with them the risk of substantially altering the subsistence lifestyle and the fabric of Yup'ik and Dena'ina cultures. If these risks come to fruition, the Dena'ina and Yup'ik of the Nushagak and Kvichak drainages will, like the salmon cultures described in the introduction, cease to exist.

Among the specific potential risks associated with diminishment in either the quantity or quality of salmon, clean water and consequently subsistence are:

- Cultural and social disruption due to impact on a subsistence species that integrates village societies.
- Degradation of nutrition and physical health due to diminishment of subsistence foods and lifestyle.
- Loss of political power due to becoming a minority in one's own homeland, if there is an influx of outsiders to the region due to extractive resource development.
- Deterioration in mental and emotional health and increase in indicators of social distress (e.g. suicide) in due to the loss of traditional culture, subsistence, and meaning for life.
- Loss of language and traditional ways to express relationships to the land, one another, and spiritual concepts.
- Loss of meaningful work by extended families operating together as a cohesive unit.
- Reduction of gender equity resulting from loss of important economic activities and social networking opportunities, due to the potential diminishment of subsistence foods harvest and preparation, and replacement of this work with jobs that are typically more accessible to men (e.g. mining) or to fewer women (such as those who do not have small children).
- Loss of the means to establish and maintain strong social networks though sharing of subsistence foods.
- Impact on belief systems that revere clean water and a clean environment.
- Increased discord within and among villages between the majority and the minority over subsistence access or development issues has the potential to create long term rifts.

In summary, salmon and clean water are foundational to the Yup'ik and Dena'ina cultures in the Nushagak and Kvichak watersheds. The people in this region not only rely on salmon for a large proportion of their highly nutritional food resources; but salmon is also integral to the language, spirituality, and social relationships of the culture. Because of this interconnection, the cultural viability, as well as the health and welfare of the local population, are extremely vulnerable to a loss either quality or quantity of salmon resources or to deterioration of water quality.

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V. APPENDIX 1. METHODOLOGY, CONSENT FORM and TRIBAL LETTER OF INTRODUCTION

Methodology: Cultural/TEK Study: Bristol Bay Project

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Revised May 24, 2011

Purpose:

The purpose of this qualitative study is to describe the subsistence, nutritional, social, linguistic, and spiritual importance of salmon to the Yup'ik and Dena'ina of the Nushagak and Kvichak River drainages of Bristol Bay. This information will be integrated into a larger study, called the Bristol Bay Assessment, coordinated by the Environmental Protection Agency to be used to determine to proceed with a Section 404c review of the Clean Water Act. This action was requested by nine tribes/villages of the Bristol Bay region. If approved, 404c designation would prohibit any discharge into, fill, or similar modification of a stream or river in the region or other actions that would impact the subsistence fishery.

Design:

The product of this study consists of two parts.

A. Summary of existing research: One part of this assessment consists of a literature and gray literature search and summary of the culture history, linguistic, subsistence and other aspects of cultural lives of the traditional and cultural lives of the Nushagak and Kvichak drainage people as it relates to streams and fishery subsistence, particularly salmon

B. Elder and Culture Bearer Interviews: Second, this study will incorporate elder and culture bearer interviews to ascertain the importance of salmon and other stream-related resources and places in the ideal culture of the people. Ideal culture is a standard to aspire to and thus is a measure of values and ideology that form the core of the people's contemporary identity. We are not undertaking a statistical sample of attitudes reflecting everyone in the culture, but listening to culture bearers who have the status of expert witnesses and act as spokespeople for their respective cultures.

The remainder of this methodology will describe the elder and culture bearer interviews.

Selected Villages

Both time and money prohibit interviews in all villages in the region. Since this is not a statistical study, nor a hearing, we believe that a self-selected group of elders and culture bearers can best represent the perspective of the region. We intend to interview elders from six villages.

Semi-Structured Questions:

The interview format will be semi-structured, meaning the same questions will be asked of each of the elder/culture bearers. The only differences are that there are some questions that will only be asked of women, and some only asked of Yup'ik or Dena'ina respectively. If an elder/culture bearers wishes to provide additional information, that, of course, will be recorded.

Interview Questions

Draft Interview questions will be formulated in the following categories:

- Subsistence
- Nutrition
- Language and Stories
- Place names and Special/Spiritual places
- Social Factors
- Spirituality related to streams and fishery

The draft interview questions will be distributed for review by

- Village councils or similar authority
- E.P.A. personnel
- Selected anthropologists

and reformulated and condensed as needed.

Self-Selection

Village councils, traditional councils, or similar entity will be asked to select elders/culture bearers to be interviewed. We anticipate this will involve about three men and three women in each village.

Release

Interviewees will be asked to sign a consent form allowing the interviewers to use the recorded and transcribed interviews in a written document. In addition the village councils will be asked to sign a release form for the village to permit photographs and video both of individuals or the village to be taken and potentially used in the final product. Restrictions will be respectively adhered to.

Recording and Transcription

Interviews will be recorded either individually or in small groups. A digital recording and transcription will be made. Elders may wish to speak in Yup'ik in which case we ask a translator provide a summary at the time of the interview. Elders and culture bearers will be paid according to current standards for village/Elder interviews. The interviews will be approximately two-hours and conducted at a comfortable place.

The interviews will be transcribed into MS Word documents and both the recording and transcription be archived either at the National Park Service Alaska or suitable repository.

Coding

Word document interviews will be coded. Key words will be set up for use in identifying the subject of the paragraph of the transcribed recording. For example, through sophisticated searches everyone who responded to or used the term "sharing salmon" will be electronically listed and some or all of these responses either quoted or paraphrased in the final document.

Confidentiality

According to Institutional Review Board standards, names of interviewees will not be revealed in the final document. Each interviewee will be asked to sign a consent form that includes the voluntary nature of the interview, confidentiality, and that there is no known or perceived risk in granting the interview.

Peer Review

Both drafts and a final document will undergo peer review. For the purpose of this study anthropologists, EPA reviewers, other scholars, and Village Elders or Culture Bearers are peers.

BRISTOL BAY TEK CULTURAL ASSESSMENT
CONSENT FORM

PRINCIPAL INVESTIGATORS:
Dr. Alan Boraas
Professor of Anthropology
Kenai Peninsula College (UAA)
(907) 262-0360 ifasb@uaa.alaska.edu
Dr. Catherine Knott
Adjunct Professor of Anthropology
Kenai Peninsula College
(907) 235-1674 catherinehknott@gmail.com

DESCRIPTION:
This study intends to assess the importance of salmon, other fish resources, and streams in the cultural lives of the villages in the Bristol Bay drainage.

YOUR ROLE:
You are asked to respond to a series of questions on the importance of salmon, streams and related resources to the people of your village and your area. You may add any additional information you wish. The questions will take one to two hours at a mutually agreed upon place such as the tribal center.

VOLUNTARY NATURE OF PARTICIPATION:
Your participation in this project is voluntary and you may withdraw at any time. Your interview responses will be used in an Environmental Protection Agency assessment to describe the Yup'ik or Dena'ina use and attitudes about salmon and other stream resources.

CONFIDENTIALITY:
Your name will not be attached to your interview responses. Your name and any other identifiers will be kept in a locked file that is only accessible to me or my research associates. Any information from this study that is published will not identify you by name. The information will be kept for four years then stored at the National Park Service, Alaska. It may be used again by approved researchers or tribal/cultural entities for educational purposes.

BENEFITS:
There are no direct benefits to you. You will be given an honorarium at the rate of $80 per hour for an approximately two hour interview.

RISKS:
There are no known risks for participation in this study.

CONTACT PEOPLE:
If you have any questions about this research, please contact the Alan Boraas at the phone number listed above. You may also contact Dr. Claudia Lampman, Compliance Officer, UAA Office of

Research and Graduate Studies, at 907-786-1099 for any questions concerning your rights in this interview

SIGNATURE:

Your signature on this consent form indicates that you fully understand the above study, what is being asked of you in this study, and that you are signing this voluntarily. If you have any questions about this study, please feel free to ask them now or at any time throughout the study.

Signature ________________________________ Date ________________

Printed Name _________________________
Mailing Address:

KENAITZE
INDIAN
TRIBE

WWW.KENAITZE.ORG
PHONE: (907) 283-3633 • FAX: (907) 283-3052
P.O. BOX 988 • KENAI, AK 99611

March 1, 2011

To Whom It May Concern:

The purpose of this letter is to formally introduce our friend and honorary Kenaitze Tribal member, Dr. Alan Boraas. Dr. Boraas has worked with and on behalf of our Tribe for over 30 years. We have found him to be ethical, fair, and responsive to our requests for confidentiality. He respects our Dena'ina culture, traditions, and values, and lives them.

Dr. Boraas asked for this letter of introduction in observance of tribal protocol and because he values and respects our rights to sovereignty and self determination. We have no doubt that you will find him to be a man of integrity who shares our love for our waters and lands.

Please feel free to contact me if you have any questions or concerns.

Sincerely,

Jaylene Peterson Nyren
Executive Director
Kenaitze Indian Tribe

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