CHAPTER 5. ENDPOINTS

5.1 Overview of Assessment Endpoints

Selection of assessment endpoints is a key component of the problem formulation stage of an ecological risk assessment. Each endpoint is an explicit expression of the environmental values of concern in the assessment, in terms of both the entity valued (e.g., a species, community, or ecological process) and a potentially at-risk characteristic or attribute of that entity (USEPA 1998). Endpoints can be defined at any level of ecological organization, from within an organism to across ecosystems, depending on the needs of the assessment. In all cases, however, selected endpoints should be relevant to both ecology and decision-maker needs, as well as susceptible to potential stressors (USEPA 1998).

We consider three endpoints in this assessment: (1) the abundance, productivity, or diversity of the region's Pacific salmon and other fish populations; (2) the abundance, productivity, or diversity of the region's wildlife populations; and (3) the health and welfare of Alaska Native cultures. Endpoint 1 is evaluated in terms of direct effects of mining; endpoints 2 and 3 are evaluated indirectly, in terms of effects resulting from fish-related impacts (i.e., via fish-mediated effects). Each of these endpoints meets the criteria of ecological relevance, management relevance, and potential susceptibility to stressors associated with large-scale mining.

The assessment focuses most heavily on Endpoint 1, which is the only endpoint for which direct effects of mining are considered (Section 2.2.1). Most analyses center on Pacific salmon, rainbow trout, and Dolly Varden. This focus reflects the ecological, economic, and cultural significance of these fish species, as well as data availability. Other parts of the region's aquatic ecosystems, including algae, aquatic invertebrates, and smaller resident fishes such as sculpins, also may be affected by large-scale mining. However, these taxa are not as relevant to decision makers and data on their distributions, abundances, and susceptibilities are more limited.

We evaluate Endpoints 2 and 3 indirectly, in terms of the effects of large-scale mining on Endpoint 1 (i.e., via fish-mediated effects). This focus on indirect effects is not meant to suggest that mining would directly affect only fish populations, or that direct effects of mining on wildlife and Alaska Native populations would be inconsequential. Rather, it reflects the ecological and regulatory importance of the region's fisheries and their susceptibility to potential impacts. Under Endpoint 2, we focus on wildlife species that depend on salmon for food (e.g., brown bear, bald eagles, gray wolves, waterfowl) or that are important subsistence foods for Alaska Natives (e.g., moose, caribou). Although Alaska Natives are not the only people who would potentially be affected by mining in the region, Endpoint 3 focuses on Alaska Native populations because of the centrality of salmon and other salmon-dependent resources to their way of life and well-being, and because this assessment was initiated in response to requests from federally recognized tribal governments to restrict large-scale mining in the watersheds. We focus on the primary Alaska Native cultures of the Nushagak and Kvichak River watersheds, the Yup'ik and Dena'ina. Sugpiaq people, who traditionally lived along the Alaska Peninsula within the greater Bristol Bay watershed, still live in this region. However, because the Alaska Peninsula falls outside the Nushagak and Kvichak River watersheds, these cultures were not included in the assessment (Box 5-1). We also recognize that non-Native people have lived in the Bristol Bay region for hundreds of years, and also consider salmon integral to their way of life. Further discussion of the scope of the assessment and how this scope was defined can be found in Chapters 1 and 2.

In the following sections, we discuss each of the three assessment endpoints in greater detail. We present information on the fish and wildlife species considered, including what is known about their life histories, distributions, and abundances both across the Bristol Bay watershed (Scale 1) and within the Nushagak and Kvichak River watersheds (Scale 2). We discuss the Alaska Native populations in the region and examine why the region's salmon fisheries are an ecologically, economically, and culturally important resource.

BOX 5-1. CULTURAL GROUPS IN THE BRISTOL BAY WATERSHED

Within the Bristol Bay watershed there are three main cultural groups: the Yup'ik, the Dena'ina, and the Sugpiaq. Prior to western contact, these three groups tended to be seasonally dispersed, with large populations periodically gathering in a central location. Westernization efforts by both Russia and the United States promoted permanent communities with year-round occupation. Some communities grew around traditional Alaska Native sites (e.g., Nondalton); other communities were built where resources were more concentrated or accessible. Naknek is one of the older recorded communities in the Bristol Bay region, with archaeological surveys indicating that Alaska Natives have occupied the Naknek area for at least 6,000 years.

Although there are descendants of the Sugpiaq that currently live both along the Alaska Peninsula and within the Nushagak and Kvichak River watersheds, this assessment focuses on the primary cultural groups found within the Nushagak and Kvichak River watersheds, the Yup'ik and the Dena'ina.

5.2 Endpoint 1: Salmon and Other Fishes

The Bristol Bay watershed is home to at least 29 fish species, representing at least nine different families (Table 5-1). The region is renowned for its fish populations, and it supports world-class fisheries for multiple species of Pacific salmon and other game fishes (Dye and Schwanke 2009). These resources generate significant benefit for commercial fishers, support valued recreational fisheries (Figure 5-1), and provide sustenance for Alaska Native populations and other rural residents (Figure 5-2, Box 5-2).

In this section we summarize key fish species found in the Bristol Bay watershed, their distributions and abundances in the region, and some of the factors contributing to the significance of these resources. This background information is provided to underscore the uniqueness of the region's fisheries and support the assessment's focus on potential impacts of large-scale mining on these fishes. More detailed discussion of the region's fishes can be found in Appendices A and B.

Table 5-1. Fish species reported in the Nushagak and Kvichak River watersheds. (H) indicates species considered to be harvested—that is, they are well-distributed across these watersheds and are or have been targeted by sport, subsistence, or commercial fisheries. This list does not include primarily marine species that periodically venture into the lower reaches of coastal streams. See Appendix B, Table 1, for references and additional information on the abundance and life history of each species.

Family	Species	Relative Abundance
Salmonids (Salmonidae)	Bering cisco (*Coregonus laurettae*)	Very few specific reports
	Humpback whitefish (H) (*C. pidschian*)	Common in large upland lakes; locally and seasonally common in large rivers
	Least cisco (*C. sardinella*)	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
	Pygmy whitefish (*Prosopium coulterii*)	Locally common in a few upland lakes or adjacent streams
	Round whitefish (*P. cylindraceum*)	Abundant/widespread throughout larger streams in upland drainages; not found in headwaters or coastal plain areas
	Coho salmon (H) (*Oncorhynchus kisutch*)	Juveniles abundant/widespread in upland flowing waters of Nushagak River watershed and in some Kvichak River tributaries downstream of Iliamna Lake; present in some Iliamna Lake tributaries; not recorded in the Lake Clark watershed
	Chinook salmon (H) (*O. tshawytscha*)	Juveniles abundant and widespread in upland flowing waters of Nushagak River watershed and in Alagnak River; infrequent upstream of Iliamna Lake
	Sockeye salmon (H) (*O. nerka*)	Abundant
	Chum salmon (H) (*O. keta*)	Abundant in upland flowing waters of Nushagak River watershed and in some Kvichak River tributaries downstream of Iliamna Lake; rare upstream of Iliamna Lake
	Pink salmon (H) (*O. gorbuscha*)	Abundant (in even years), with restricted distribution, in the Nushagak River watershed and in some Kvichak River tributaries downstream of Iliamna Lake; rare upstream of Iliamna Lake
	Rainbow trout (H) (*O. mykiss*)	Frequent/common; in summer, closely associated with spawning salmon
	Arctic char (H) (*Salvelinus alpinus*)	Locally common in upland lakes
	Dolly Varden (H) (*S. malma*)	Abundant in upland headwaters and selected lakes
	Lake trout (H) (*S. namaycush*)	Common in larger upland lakes and seasonally present in lake outlets; absent from the Wood River lakes
	Arctic grayling (H) (*Thymallus arcticus*)	Abundant/widespread
Lampreys (Petromyzontidae)	Arctic lamprey (*Lethenteron camtschaticum*)	Juveniles common/widespread in sluggish flows where fine sediments accumulate[a]
	Alaskan brook lamprey (*L. alaskense*)	
	Pacific lamprey (*Entosphenus tridentatus*)	Rare
Suckers (Catostomidae)	Longnose sucker (*Catostomus catostomus*)	Common in slower flows of larger streams
Pikes (Esocidae)	Northern pike (H) (*Esox lucius*)	Common/widespread in still or sluggish waters

Table 5-1. Fish species reported in the Nushagak and Kvichak River watersheds. (H) indicates species considered to be harvested—that is, they are well-distributed across these watersheds and are or have been targeted by sport, subsistence, or commercial fisheries. This list does not include primarily marine species that periodically venture into the lower reaches of coastal streams. See Appendix B, Table 1, for references and additional information on the abundance and life history of each species.

Family	Species	Relative Abundance
Mudminnows (Umbridae)	Alaska blackfish (*Dallia pectoralis*)	Locally common/abundant in still or sluggish waters in flat terrain
Smelts (Osmeridae)	Rainbow smelt (*Osmerus mordax*)	Seasonally abundant in streams near the coast
	Pond smelt (*Hypomesus olidus*)	Locally common in coastal lakes and rivers, Iliamna Lake, inlet spawning streams, and the upper Kvichak River; abundance varies widely interannually
	Eulachon (*Thaleichthys pacificus*)	No or few specific reports; if present, distribution appears limited and abundance low
Cods (Gadidae)	Burbot (*Lota lota*)	Infrequent to common in deep, sluggish, or still waters
Sticklebacks (Gasterosteidae)	Threespine stickleback (*Gasterosteus aculeatus*)	Locally abundant in still or sluggish waters; abundant in Iliamna Lake
	Ninespine stickleback (*Pungitius pungitius*)	Abundant/widespread in still or sluggish waters
Sculpins (Cottidae)	Coastrange sculpin (*Cottus aleuticus*)	Abundant/widespread[b]
	Slimy sculpin (*C. cognatus*)	

Notes:
[a] These species are combined here, because juveniles, the most commonly encountered life stage for each, are indistinguishable.
[b] These species are combined here, because they are not reliably distinguished in field conditions, although slimy sculpin is thought to be more abundant and widely distributed.

Figure 5-1. Approximate extents of popular Chinook and sockeye salmon recreational fisheries in the vicinity of the Nushagak and Kvichak River watersheds. Areas were digitized from previously published maps (Dye et al. 2006). Recreational rainbow trout fisheries are also distributed throughout the watersheds.

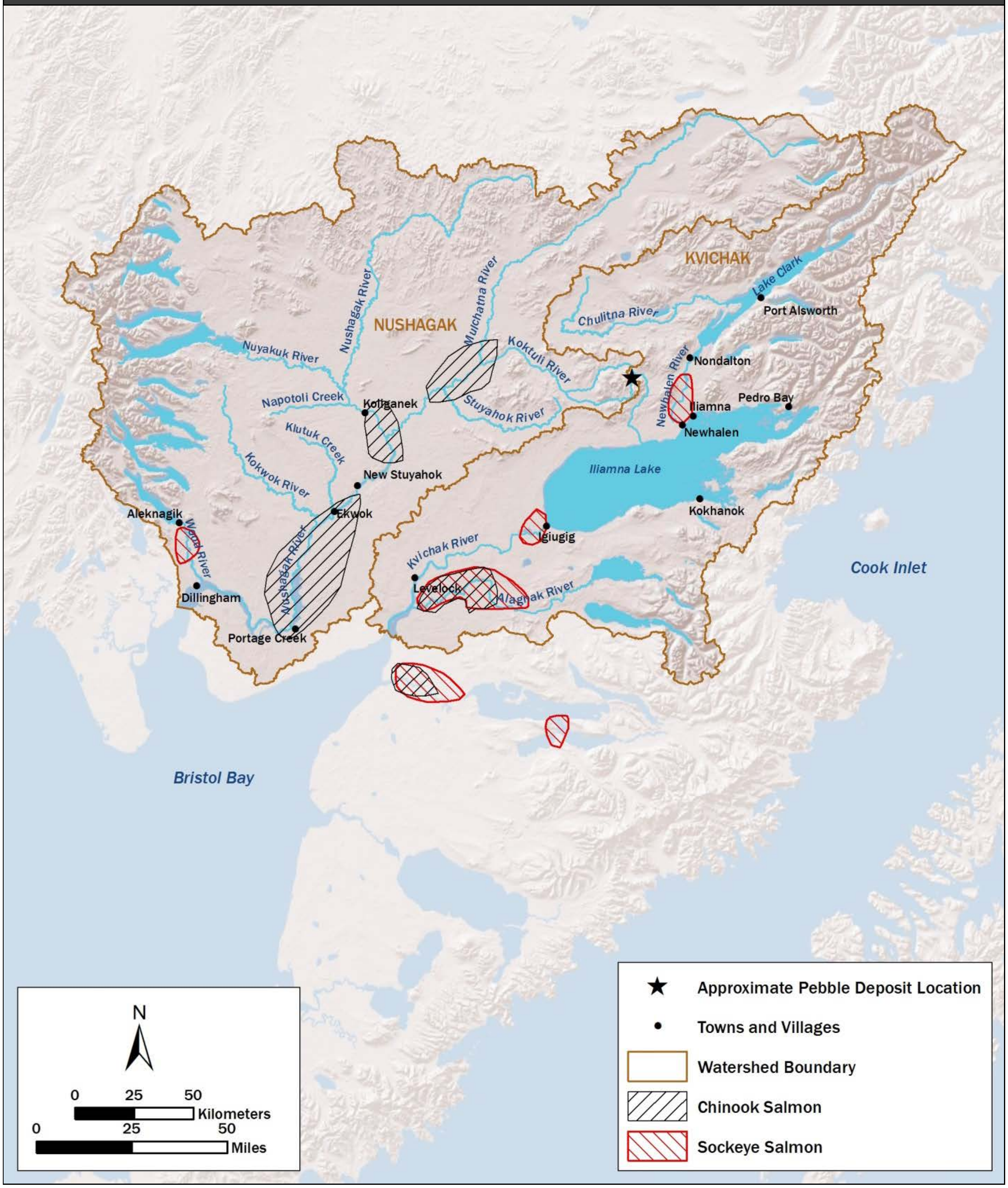
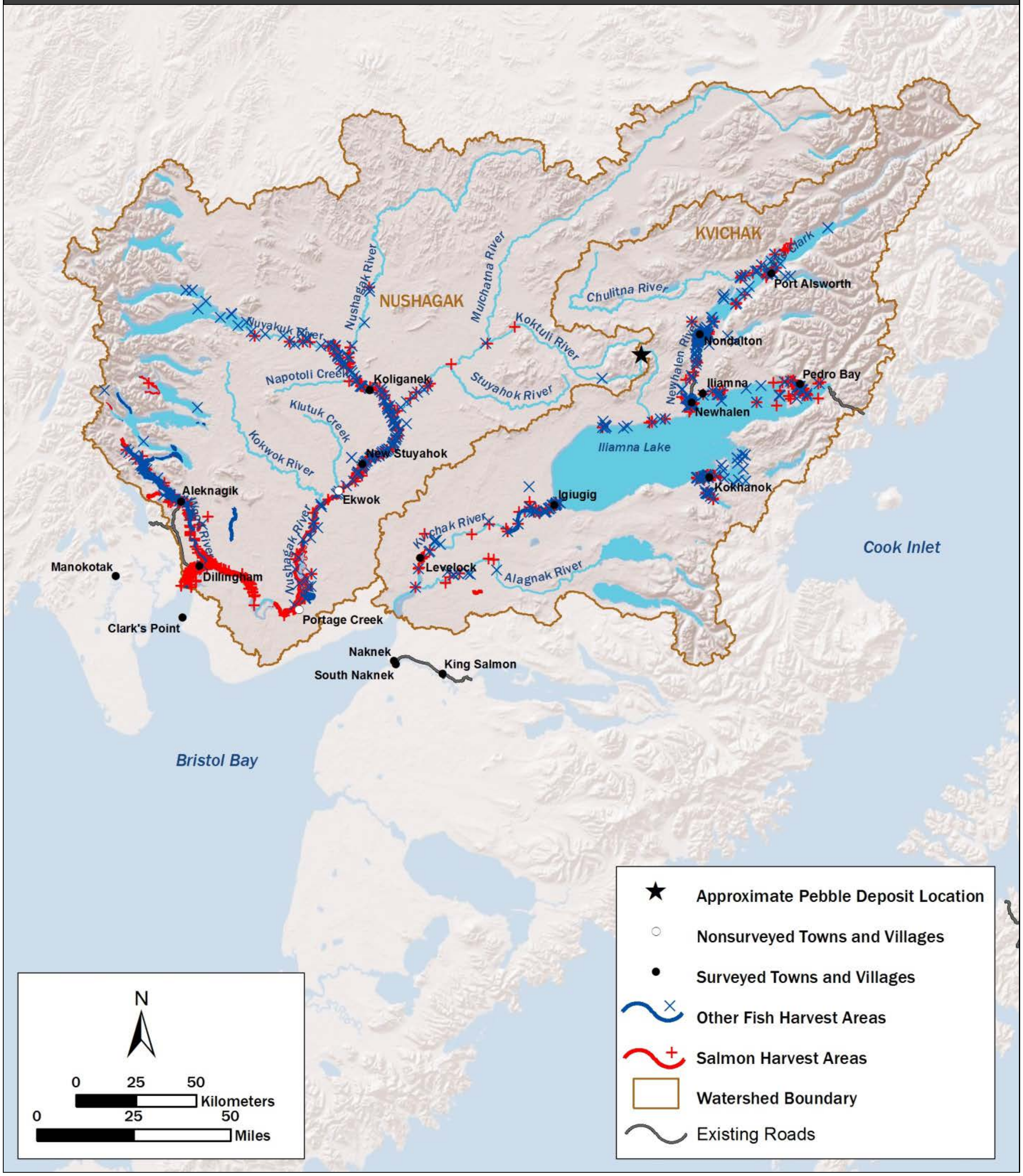


Figure 5-2. Subsistence harvest and harvest effort areas for salmon and other fishes within the Nushagak and Kvichak River watersheds. Other fishes are defined as those non-salmon and whitefish species discussed in the text. Each fish category is designated by a representative individual color and includes all harvest points, lines, or polygons meeting that classification. See Box 5-2 for more detailed discussion of methodology.



BOX 5-2. SUBSISTENCE USE METHODOLOGY

Subsistence use and harvest data were extracted from data collected by the Alaska Department of Fish and Game in collaboration with Stephen R. Braund and Associates (Fall et al. 2006, Krieg et al. 2009, Holen and Lemons 2010, Holen et al. 2011, Holen et al. 2012). These data are a compilation of a multi-year study to document and examine baseline subsistence use and harvest (via both directed or targeted efforts and incidental catches), along with demographic and economic data within the communities near the Pebble deposit. Eighteen communities were interviewed: Aleknagik, Clark's Point, Dillingham, Igiugig, Iliamna, King Salmon, Kokhanok, Koliganek, Levelock, Lime Village, Manokotak, Naknek, New Stuyahok, Newhalen, Nondalton, Pedro Bay, Port Alsworth, and South Naknek.

Members of participating households within each community were asked to document where they hunted, fished, and gathered subsistence resources during the previous year by adding points (used for harvest locations), polygons (used for harvest effort areas), and lines (used to depict trap lines or courses travelled during fish trolling) to various maps. Interviews were conducted from 2004 to 2011; not every community was interviewed in the same year, so the reported years differed between communities. Following completion of interviews, hand-drawn maps were digitized and data compiled for use within a geographic information system. In this assessment, only towns and villages documenting subsistence use and harvest within the Nushagak and Kvichak River watersheds were considered; data points or sections of polygons and lines falling outside the boundary of these watersheds were omitted.

Subsistence use and harvest data were extracted for four representative use categories: salmon, other fishes, wildlife, and waterfowl, based on tables found within each report (e.g., Holen et al. 2012: Table 1-16). Species or other general classifications within each category include:

- **Salmon:** chum salmon, Chinook (king) salmon, pink salmon, salmon, coho (silver) salmon, sockeye salmon, and spawning sockeye (red) salmon
- **Other fishes** *(i.e., non-salmon fish species and whitefishes)*: Arctic char, Dolly Varden, humpback whitefish, lake trout, least cisco, rainbow trout, round whitefish, steelhead trout, trout, and whitefish
- **Wildlife:** black bear, brown bear, caribou, and moose
- **Waterfowl:** black scoter, brant, Canada goose, eggs, geese, gull eggs, lesser snow goose, mallard, pintail, sandhill crane, teal, tern eggs, tundra swan, waterfowl, and white-fronted goose

Data were extracted for all points, lines, and polygons in each category, for each interviewed community. Data were then summed across all communities to produce a cumulative layer for the entire Nushagak and Kvichak River watersheds. Subsistence intensity across the landscape was derived by first generating a 1-km square grid across the Nushagak and Kvichak River watersheds. Each documented point, line, and polygon shapefile was spatially joined and summed across the 1-km grid to account for multiple or overlapping points, lines, and polygons within the same 1-km pixel. Therefore, each pixel represents the total number of points and sections of lines and polygons within its boundaries. Subsistence use was then summed across the four representative use categories to derive total cumulative subsistence use across the Nushagak and Kvichak River watersheds.

This subsistence use metric provides a coarse measure of areas that are used for subsistence uses more than others within the watersheds. However, it is important to note some of the limitations of the subsistence intensity metric. Points represent harvest locations, but the way these data are tabulated does not confer abundance of species harvested within the pixel. Therefore, a point may represent either a single capture or multiple captures of a given species. Although abundance information was collected by the researchers, it was not consistently reported in the geospatial data. Further, the line and polygon files represent general catch areas and not point of actual capture, allowing broad areas to have the same value as an actual point of capture. Finally, since this assessment is focused on fish as the main assessment endpoint, we focus on aquatic species and habitats. Many other plant and animal species included in the subsistence use databases were not used to arrive at this subsistence intensity metric.

5.2.1 Species and Life Histories

5.2.1.1 Salmon

Five species of Pacific salmon spawn and rear in the Bristol Bay watershed's freshwater habitats: sockeye or red (*Oncorhynchus nerka*), coho or silver (*O. kisutch*), Chinook or king (*O. tshawytscha*), chum or dog (*O. keta*), and pink or humpback (*O. gorbuscha*). Because no hatchery fish are raised or released in the watershed, Bristol Bay's salmon populations are entirely wild.

All five salmon species share a trio of life-history traits that contribute to the success and significance of these species in the Bristol Bay region. First, they are anadromous: they hatch in freshwater habitats, migrate to sea for a period of relatively rapid growth, and then return to freshwater habitats to spawn. Second, the vast majority of adults return to their natal freshwater habitats to spawn. This homing behavior fosters reproductive isolation, thereby enabling populations to adapt to the particular environmental conditions of their natal habitats (Blair et al. 1993, Dittman and Quinn 1996, Eliason et al. 2011). Homing is not absolute, however, and this small amount of straying increases the probability that suitable habitats will be colonized by salmon (e.g., Milner and Bailey 1989). Finally, each species is semelparous: adults die after spawning a single time. After completing their upstream migration, females excavate nests (redds) in the gravel and release eggs into them. These eggs are fertilized by one or more competing males as they are released, and the females bury them in the nests. The females and males then die, depositing the nutrients incorporated into their bodies in their spawning habitats (Section 5.2.5).

The seasonality of spawning and incubation is roughly the same for all five species, although the timing can vary somewhat by species, population, and region. In general, salmon spawn from summer through fall, and fry emerge from spawning gravels the following spring to summer. Freshwater habitats used for spawning and rearing vary across and within species, and include headwater streams, larger mainstem rivers, side- and off-channel wetlands, ponds, and lakes (Table 5-2). With some exceptions, preferred spawning habitat consists of gravel-bedded stream reaches of moderate water depth (30 to 60 cm) and current (30 to 100 cm/s) (Quinn 2005). Sockeye are unique among the species, in that most populations rely on lakes as the primary freshwater rearing habitat (Table 5-2).

Both chum and pink salmon migrate to the ocean soon after fry emergence (Heard 1991, Salo 1991). Because sockeye, coho, and Chinook salmon spend a year or more rearing in the Bristol Bay watershed's streams, rivers, and lakes before their ocean migration (Table 5-2), these species are more dependent on upstream freshwater resources than chum and pink salmon. As a result, potential large-scale mining in this region likely poses greater risks to sockeye, coho, and Chinook salmon.

Table 5-2. Life history, habitat characteristics, and total documented stream length occupied for Bristol Bay's five Pacific salmon species in the Nushagak and Kvichak River watersheds.

Salmon Species	Freshwater Rearing Period (years)	Freshwater Rearing Habitat	Ocean Feeding Period (years)	Spawning Habitat	Documented Stream Length Occupied (kilometers)
Sockeye	0–3	Lakes, rivers	2–3	Beaches of lakes, streams connected to lakes, larger braided rivers	4,600
Coho	1–3	Headwater streams to moderate-sized rivers, headwater springs, beaver ponds, side channels, sloughs	1+	Headwater streams to moderate sized rivers	5,900
Chinook	1+	Headwater streams to large-sized mainstem rivers	2–4	Moderate-sized streams to large-sized mainstem rivers	4,800
Chum	0	Limited	2–4	Moderate-sized streams and rivers	3,400
Pink	0	Limited	1+	Moderate-sized streams and rivers	2,200

Notes:
Data compiled from Appendix A, pages 4–13.

5.2.1.2 Other Fishes

In addition to the five Pacific salmon species discussed above, the Bristol Bay region is home to at least 24 other fish species, most of which typically (but not always) remain within the watershed's freshwater habitats throughout their life cycles. The region contains highly productive waters for such sport and subsistence fish species as rainbow trout (*O. mykiss*), Dolly Varden (*Salvelinus malma*), Arctic char (*S. alpinus*), Arctic grayling (*Thymallus arcticus*), humpback whitefish (*Coregonus pidschian*), northern pike (*Esox lucius*), and lake trout (*S. namaycush*), as well as numerous other species that are not typically harvested (Table 5-1). These fish species occupy a variety of habitats throughout the watershed, from headwater streams to rivers and lakes.

In this assessment, we focus primarily on the five Pacific salmon species, rainbow trout, and Dolly Varden (Box 2-3). This focus is not meant to imply that other fish species found in the Bristol Bay watershed are not economically, culturally, or ecologically important, or that they are unlikely to be affected by potential mining-related activities. Rather, it reflects the value of Pacific salmon, rainbow trout, and Dolly Varden as both sport and subsistence fisheries throughout the region, the potential sensitivity of these species to mine development and operation, and the relatively greater amount of information available for these species, particularly in terms of their distributions and abundances.

The species *O. mykiss* includes both a non-anadromous or resident form (commonly referred to as rainbow trout) and an anadromous form (commonly referred to as steelhead). In the Bristol Bay watershed, steelhead generally are restricted to a few spawning streams near Port Moller, on the Alaska Peninsula; thus, most populations throughout the region of the assessment are the non-anadromous form.

The spawning habitat and behavior of rainbow trout are generally similar to that of the Pacific salmon species, with a few key exceptions. First, rainbow trout are iteroparous, meaning that they can spawn repeatedly. Second, spawning occurs in spring, versus summer and early fall for salmon. Juveniles emerge from spawning gravels in summer (Johnson et al. 1994, ADF&G 2012), and immature fish may remain in their natal streams for several years before migrating to other habitats (Russell 1977).

Rainbow trout in the Bristol Bay watershed exhibit complex migratory patterns, moving between spawning, rearing, feeding, and overwintering habitats. For example, many adults in the region spawn in inlet or outlet streams of large lakes, then migrate shortly after spawning to feeding areas within those lakes. Some mature fish may seasonally move distances of 200 km or more (Russell 1977, Burger and Gwartney 1986, Minard et al. 1992, Meka et al. 2003). Often, these migratory patterns ensure that rainbow trout are in close proximity to the eggs and carcasses of spawning salmon, which provide an abundant, high-quality food resource (Meka et al. 2003). The variety of habitat types utilized by rainbow trout is reflected by different life-history types identified in the region, including lake, lake-river, and river residents (Meka et al. 2003). See Appendix B (pages 11–16) for additional information on rainbow trout life history.

Dolly Varden is a highly plastic fish species, with multiple genetically, morphologically, and ecologically distinct forms that can co-exist in the same water bodies (Ostberg et al. 2009). Both anadromous and non-anadromous Dolly Varden are found in the Bristol Bay watershed, and both life-history forms can exhibit complex and extensive migratory behavior (Armstrong and Morrow 1980, Reynolds 2000, Scanlon 2000, Denton et al. 2009). Anadromous individuals usually undertake three to five ocean migrations before reaching sexual maturity (DeCicco 1992, Lisac and Nelle 2000, Crane et al. 2003). During these migrations, Dolly Varden frequently leave one drainage, travel through marine waters, and enter a different, distant drainage (DeCicco 1992, DeCicco 1997, Lisac 2009). Non-anadromous individuals also may move extensively between different habitats (Scanlon 2000).

Dolly Varden spawning occurs in fall, upstream of overwintering habitats (DeCicco 1992). Northern-form anadromous Dolly Varden (the geographic form of Dolly Varden found north of the Alaska Peninsula) overwinter primarily in lakes and in lower mainstem rivers where sufficient groundwater provides suitable volumes of free-flowing water (DeCicco 1997, Lisac 2009). Within the Nushagak and Kvichak River watersheds, juveniles typically rear in low-order, high-gradient stream channels (ADF&G 2012). Because Dolly Varden occur in upland lakes and high-gradient headwater streams (ADF&G 2012)—farther upstream than many other fish species and above migratory barriers to anadromous salmon populations—they may be especially vulnerable to mine development and operation in these headwater areas. See Appendix B (pages 20–25) for additional information on Dolly Varden life history.

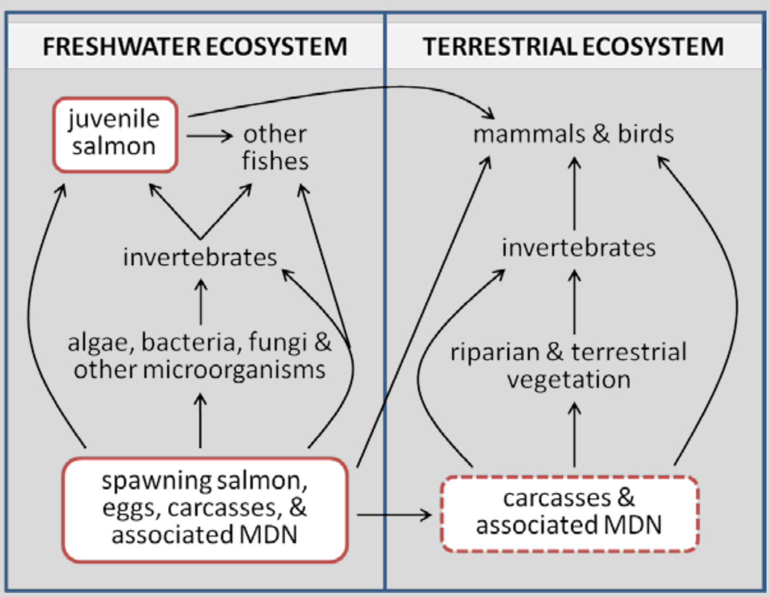
It is important to note that these endpoint species do not exist in isolation from other fish species. The biomass carried into the Bristol Bay watershed's aquatic habitats by spawning salmon is a fundamental driver of aquatic foodwebs (Box 5-3). Many of the species listed in Table 5-1 are prey for, predators of, or competitors with the endpoint species. For example, sculpins, Dolly Varden, and rainbow trout are well-known predators of salmon eggs and emergent fry, and northern pike can be effective predators of juvenile salmon and other fish species (Russell 1980, Sepulveda et al. 2013). Insectivorous and planktivorous fishes (e.g., Arctic grayling and pond smelt, respectively) may prey on similar species as juvenile salmonids (e.g., Hartman and Burgner 1972). Given these foodweb interactions, we recognize that shifts in the relative abundance of species are likely to have repercussions throughout the aquatic community; however, evaluation of the myriad foodweb interactions that could result from large-scale mining is beyond the scope of this assessment.

BOX 5-3. SALMON IN FRESHWATER AND TERRESTRIAL FOODWEBS

Salmon are a cornerstone species in the Bristol Bay region, in that they comprise a significant portion of the resource base upon which both aquatic and terrestrial ecosystems in the region depend (Willson et al. 1998). Adults returning to freshwater systems to spawn import marine-derived nutrients (MDN) back into these freshwater habitats. These nutrients provide the foundation for aquatic and terrestrial foodwebs via two main pathways: direct consumption of salmon in any of its forms (spawning adults, eggs, carcasses, and/or juveniles) and nutrient recycling (Gende et al. 2002).

Because salmon are a seasonally abundant, high-quality food resource in the Bristol Bay watershed, many aquatic and terrestrial species take advantage of this resource (e.g., see Sections 5.3 and 12.1). For example, Willson and Halupka (1995) found that more than 40 species of mammals and birds feed on salmon in southeastern Alaska. Salmon eggs and juveniles are eaten by many fishes, such as other salmon, rainbow trout, northern pike, and Dolly Varden (Appendix B).

The nutrients incorporated into spawning salmon biomass also can have a bottom-up effect on both freshwater and terrestrial ecosystems via nutrient recycling (Gende et al. 2002). Given that these systems tend to be nutrient-poor, MDN contributions play a significant role in the Bristol Bay region's productivity. In lakes and streams, MDN help to fuel the production of algae, bacteria, fungi, and other microorganisms that make up aquatic biofilms. These biofilms in turn provide food for aquatic invertebrates, which are preyed on by juvenile salmon and other fishes. Terrestrial vegetation and invertebrates also receive a salmon-related nutrient subsidy, in the form of carcasses and excreta deposited on land by mammal and bird consumers.



Note that the simplified foodweb above (modified from Willson et al. 1998) focuses on how salmon serve as a resource base within and across freshwater and terrestrial ecosystems. Not all interactions, particularly those mediated by other species (e.g., invertebrates) and those that cross between freshwater and terrestrial ecosystems, are shown on this schematic. It also does not illustrate the role of salmon in estuarine and marine foodwebs, as these habitats are outside the scope of this assessment.

5.2.2 Distribution and Abundance

Fish populations throughout the Bristol Bay watershed have not been sampled comprehensively; thus, estimates of total distribution and abundance across the region are not available. However, available data (e.g., the Anadromous Waters Catalog, the Alaska Freshwater Fish Inventory, escapement and harvest data) provide at least minimum estimates of where key species are found and how many individuals of those species have been caught. More information on the distribution and abundance of key fish species can be found in Appendices A and B. See Section 7.2.5 for additional information on the interpretation of available fish distribution data.

5.2.2.1 Salmon

Most (63%) of the subwatersheds in the Nushagak and Kvichak River watersheds are documented to contain at least one species of spawning or rearing salmon within their boundaries, and 12% are documented to contain all five species (Figure 5-3). Reported distributions for each salmon species in the Nushagak and Kvichak River watersheds are shown in Figures 5-4 through 5-8.

Sockeye is by far the most abundant salmon species in the Bristol Bay watershed (Table 5-3) (Salomone et al. 2011). Bristol Bay is home to the largest sockeye salmon fishery in the world, with 46% of the average global abundance of wild sockeye salmon between 1956 and 2005 (Figure 5-9A) (Ruggerone et al. 2010). Between 1990 and 2009, the average annual inshore run of sockeye salmon in Bristol Bay was approximately 37.5 million fish (ranging from a low of 16.8 million in 2002 to a high of 60.7 million in 1995) (Salomone et al. 2011). Annual commercial harvest of sockeye over this period averaged 25.7 million fish (Table 5-3), and 78% of the average annual subsistence salmon harvest (140,767 salmon) over this period were sockeye (Dye and Schwanke 2009, Salomone et al. 2011). Escapement goals—that is, the number of individuals allowed to escape the fishery and spawn, to ensure long-term sustainability of the stock—vary by species and stock. The current sockeye escapement goal for the Kvichak River ranged from 2 to 10 million fish (Box 5-4). Annual sport harvest of sockeye in recent years has ranged from approximately 8,000 to 23,000 fish (Dye and Schwanke 2009).

More than half of the Bristol Bay watershed's sockeye salmon harvest comes from the Nushagak and Kvichak River watersheds (Figure 5-9B). Sockeye returns to the Kvichak River averaged 10.5 million fish between 1963 and 2011, and this number climbs to 12.1 million fish when returns to the Alagnak River are included (Cunningham et al. 2012). Kvichak River sockeye runs have exceeded 30 million fish three times since 1956, with 48.6, 34.9, and 37.9 million fish in 1965, 1970, and 1980, respectively (Cunningham et al. 2012).

Tributaries to Iliamna Lake, Lake Clark, and the Wood-Tikchik Lakes (Figure 2-4) are major sockeye spawning areas, and juveniles rear in each of these lakes (Figure 5-4). Iliamna Lake provides the majority of sockeye rearing habitat in the Kvichak River watershed, and historically has produced more sockeye than any other lake in the Bristol Bay region (Fair et al. 2012). Riverine sockeye populations spawn and rear throughout the Nushagak River watershed (Figure 5-4).

Table 5-3. Mean annual commercial harvest (number of fish) by Pacific salmon species and Bristol Bay fishing district, 1990 to 2009[a]. Number in parentheses indicates percentage of total found in each district.

Salmon Species	Bristol Bay Fishing District					
	Naknek-Kvichak[a]	Egegik	Ugashik	Nushagak[a]	Togiak	Total
Sockeye	8,238,895 (32)	8,835,094 (34)	2,664,738 (11)	5,478,820 (21)	514,970 (2)	25,732,517
Chinook	2,816 (4)	849 (1)	1,402 (2)	52,624 (80)	8,803 (13)	66,494
Coho	4,436 (5)	27,433 (33)	10,425 (12)	27,754 (33)	14,234 (17)	84,282
Chum	184,399 (19)	78,183 (8)	70,240 (7)	493,574 (50)	158,879 (16)	985,275
Pink[b]	73,661 (43)	1,489 (1)	138 (<1)	50,448 (30)	43,446 (26)	169,182

Notes:
[a] Naknek-Kvichak district includes the Alagnak River; Nushagak district includes the Wood and Igushik Rivers.
[b] Pink salmon data are from even-numbered years; harvest is negligible during odd-year runs.
Source: Appendix A, Table 1.

Chinook salmon spawn and rear throughout the Nushagak River watershed and in several tributaries of the Kvichak River (Figure 5-5), and they are an important subsistence food for residents of both watersheds. Although Chinook is the least common salmon species across the Bristol Bay region, the Nushagak River watershed supports a large Chinook salmon fishery and its commercial and sport-fishing harvests are greater than those of all other Bristol Bay river systems combined (Table 5-3). Chinook returns to the Nushagak River are consistently greater than 100,000 fish per year, and have exceeded 200,000 fish per year in 11 years between 1966 and 2010. This frequently places the Nushagak at or near the size of the world's largest Chinook runs, which is notable given the Nushagak River's small watershed area compared to other Chinook-producing rivers such as the Yukon River, which spans Alaska and much of northwestern Canada, and the Kuskokwim River in southwestern Alaska, just north of Bristol Bay.

Coho salmon spawn and rear in many stream reaches throughout the Nushagak and lower Kvichak River watersheds (Figure 5-6). Juveniles distribute widely into headwater streams, where they are often the only salmon species present (Woody and O'Neal 2010, King et al. 2012). Production of juvenile coho is often limited by the extent and quality of available overwintering habitats (Nickelson et al. 1992, Solazzi et al. 2000).

Chum salmon is the second most abundant salmon species in the Nushagak and Kvichak River watersheds (Table 5-3). Both chum and pink salmon spawn throughout the Nushagak and lower Kvichak River watersheds (Figures 5-7 and 5-8), but do not have an extended freshwater rearing stage.

BOX 5-4. COMMERCIAL FISHERIES MANAGEMENT IN THE BRISTOL BAY WATERSHED

Commercial fisheries management in Alaska is largely focused on achieving escapement goals—management goals based on the optimum range of fish numbers allowed to escape the fishery and spawn—rather than harvest rates (Fair et al. 2012). Thus, management involves allowing an adequate number of spawners to reach each river system while maximizing harvest in the commercial fishery (Salomone et al. 2011). Bristol Bay's commercial salmon fisheries are considered a management success (Hilborn et al. 2003, Hilborn 2006). Several factors have contributed to this success, including a clear management objective of maximum sustainable yield, the escapement goal system, management responsibility falling to a single agency, a permit system that limits the number of fishers, and favorable freshwater habitats and ocean conditions (Hilborn et al. 2003, Hilborn 2006).

Escapement goals for sockeye salmon in the nine major rivers draining the Bristol Bay watershed are listed in the table below. The Alaska Department of Fish and Game (ADF&G) regularly reviews escapement goals for the major salmon stocks in Bristol Bay. These reviews include updates to escapement estimates, revisions to how catch is partitioned to stocks, and revisions to stock-recruit models used to recommend escapement goals. For example, data on sockeye genetic stock composition, age composition, and run timing were used to reconstruct brood tables for the major stocks in 2012 (Cunningham et al. 2012, Fair et al. 2012).

The Kvichak River frequently did not meet its sockeye escapement goal from 1991 through 1999, and in 2001 it was placed into special management status due to chronic low yields (Fair 2003). The cause of this low productivity in Kvichak River sockeye is not entirely known, but marine conditions likely led to this decline (see Appendix A, pages 31–33, for a more detailed discussion of this decline). However, the Kvichak River stock is considered to be rebuilding: escapement goals have been met for the last 5 years, and in 2012 ADF&G recommended that it be removed from special management status (Morstad and Brazil 2012).

Sockeye Salmon Escapement Goals in the Bristol Bay Watershed

River	Escapement Range (thousands of fish)
Kvichak	2,000–10,000
Alagnak	320 minimum
Naknek	800–1,400
Egegik	800–1,400
Ugashik	500–1,200
Wood	700–1,500
Igushik	150–300
Nushagak-Mulchatna	370–840
Togiak	120–270

Once escapement goals are set, the timing and duration of commercial fishery openings are adjusted throughout the fishing season to ensure that escapement goals are met and any additional fish are harvested. Fishery openings are based on information from a number of sources, including pre-season forecasts (expected returns of the dominant age classes in a given river system, based on the number of spawning adults that produced each age class); the test fishery at Port Moller on the Alaska Peninsula; early performance of the commercial fishery; and in-river escapement monitoring. At the beginning of the fishing season, the frequency and duration of openings are primarily based on pre-season forecasts and are managed conservatively. As the season progresses and additional information becomes available, fishing times and areas are continuously adjusted via emergency orders. 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.

This type of in-season management is also used to meet a Chinook salmon escapement goal for the Nushagak River (55,000–120,000 fish). There is a chum salmon escapement goal for the Nushagak River (200,000 fish minimum) and there are Chinook salmon escapement goals for the Alagnak and Naknek Rivers; however, in-season management is not used to help attain these goals (Baker et al. 2009).

See Appendix A for a more detailed discussion of historical and current fisheries management in the Bristol Bay region.

Figure 5-3. Diversity of Pacific salmon species production in the Nushagak and Kvichak River watersheds. Counts of salmon species (sockeye, Chinook, coho, pink, and chum) spawning and rearing, based on the Anadromous Waters Catalog (Johnson and Blanche 2012), are summed by 12-digit hydrologic unit codes. See Section 7.2.5 for details on interpretation of distribution data.

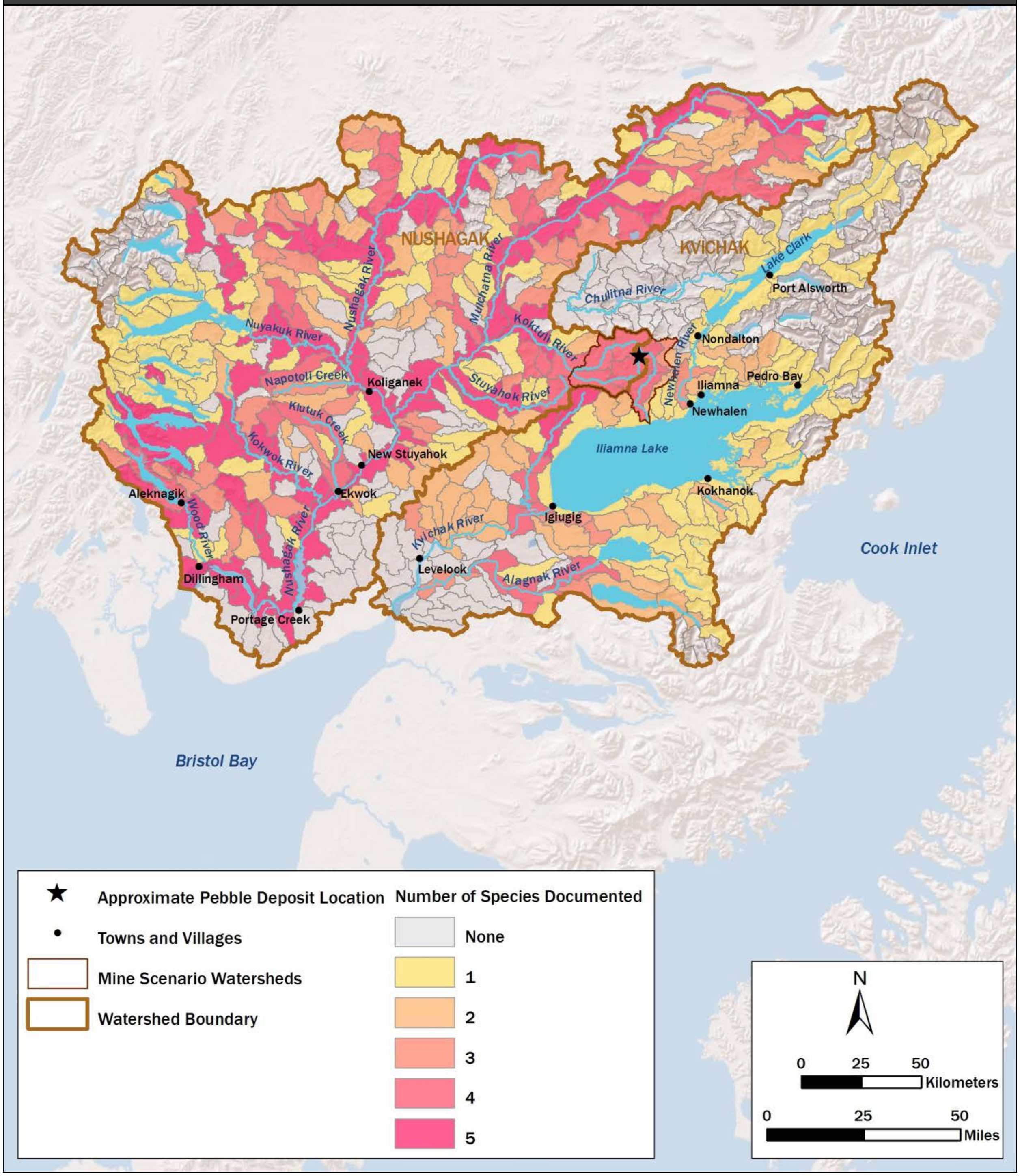


Figure 5-4. Reported sockeye salmon stream distribution in the Nushagak and Kvichak River watersheds. "Present" indicates species was present but life-stage use was not determined; "spawning" indicates spawning adults were observed; "rearing" indicates juveniles were observed. Present, spawning, and rearing designations are based on the Anadromous Waters Catalog (Johnson and Blanche 2012). Life-stage-specific reach designations are likely underestimates, given the challenges inherent in surveying all streams that may support life-stage use throughout the year. See Section 7.2.5 for details on interpretation of fish distribution data.

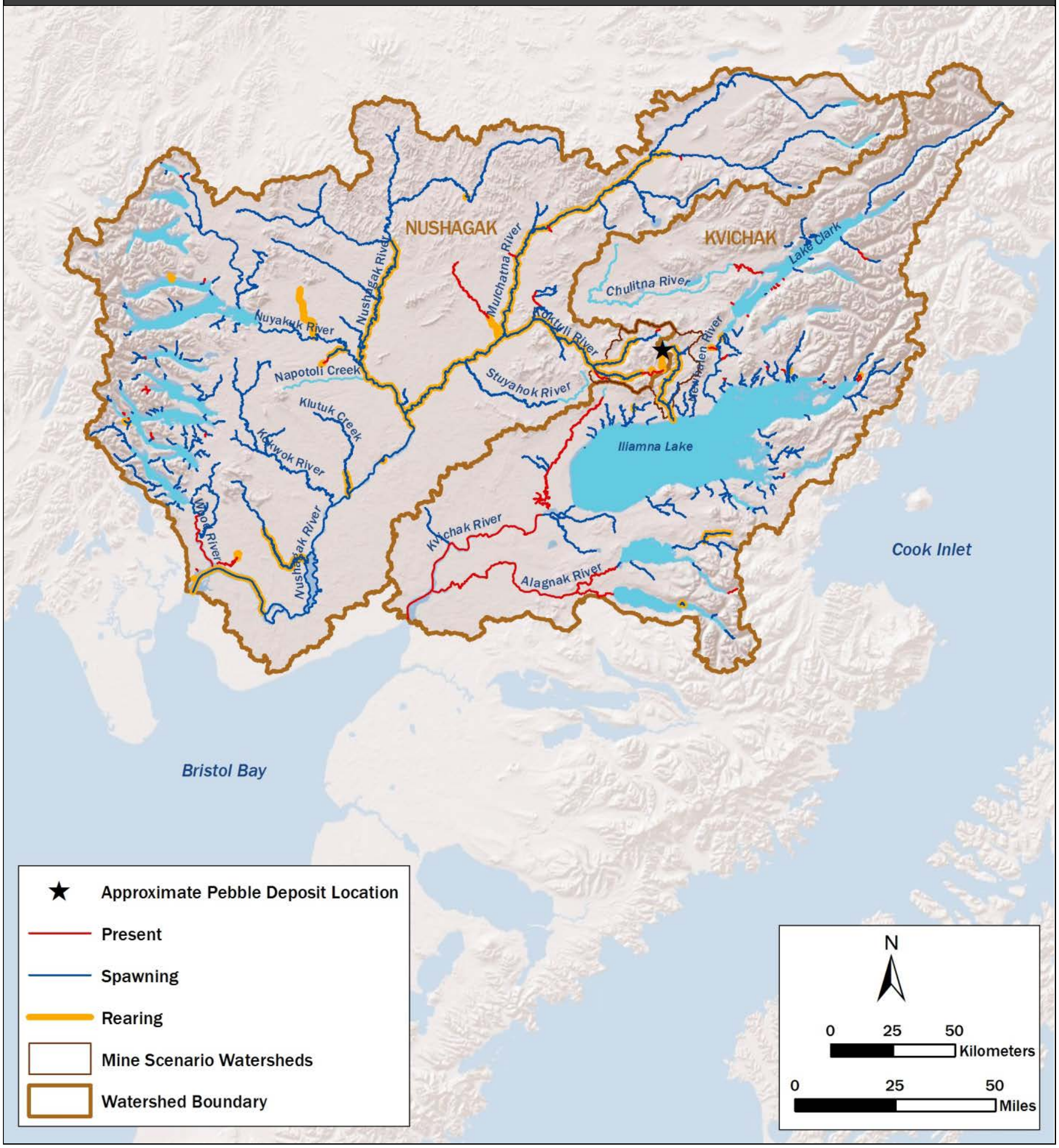


Figure 5-5. Reported Chinook salmon distribution in the Nushagak and Kvichak River watersheds. "Present" indicates species was present but life-stage use was not determined; "spawning" indicates spawning adults were observed; "rearing" indicates juveniles were observed. Present, spawning, and rearing designations are based on the Anadromous Waters Catalog (Johnson and Blanche 2012). Life-stage-specific reach designations are likely underestimates, given the challenges inherent in surveying all streams that may support life-stage use throughout the year. See Section 7.2.5 for details on interpretation of fish distribution data.

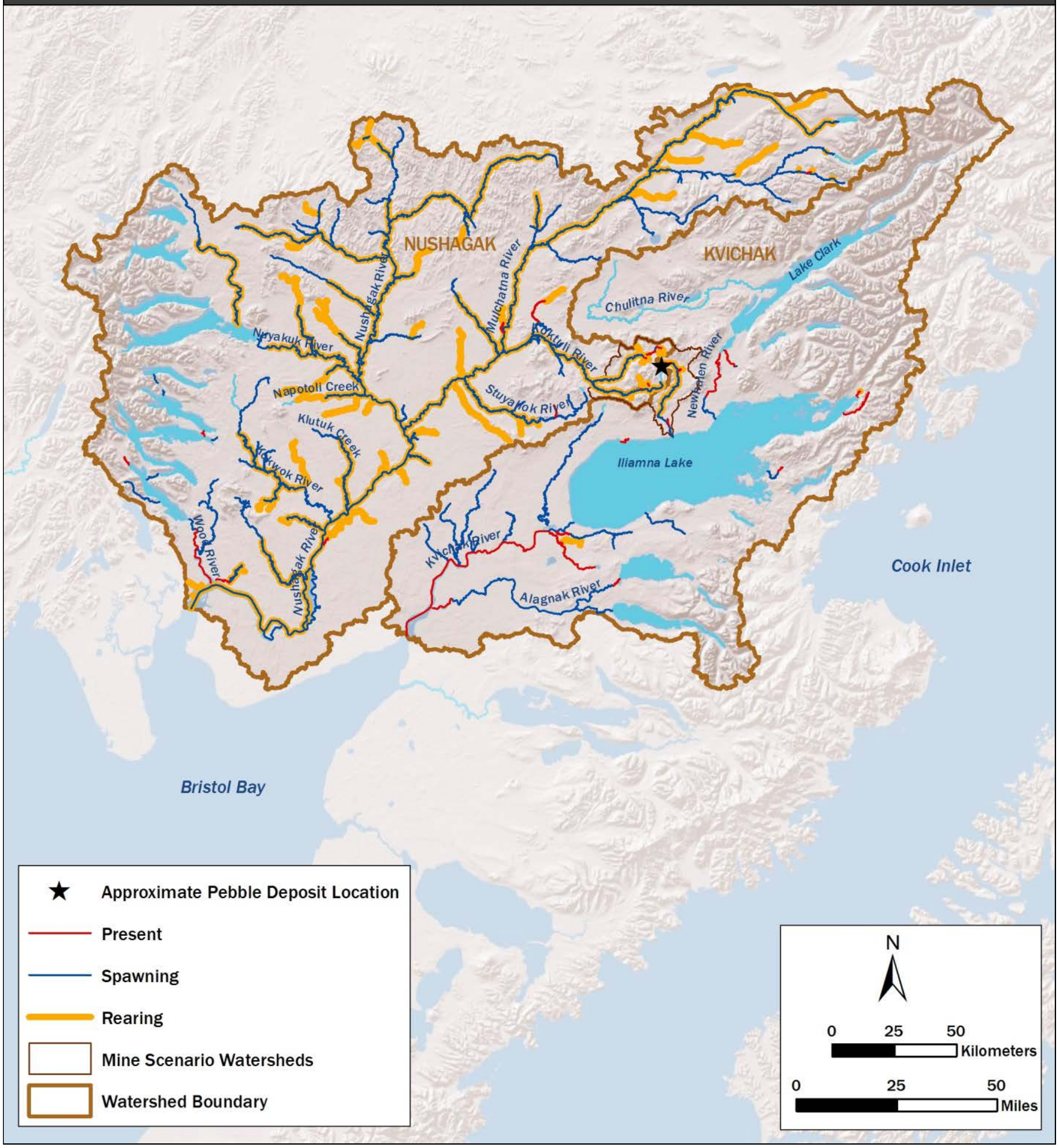


Figure 5-6. Reported coho salmon distribution in the Nushagak and Kvichak River watersheds. "Present" indicates species was present but life-stage use was not determined; "spawning" indicates spawning adults were observed; "rearing" indicates juveniles were observed. Present, spawning, and rearing designations are based on the Anadromous Waters Catalog (Johnson and Blanche 2012). Life-stage-specific reach designations are likely underestimates, given the challenges inherent in surveying all streams that may support life-stage use throughout the year. See Section 7.2.5 for details on interpretation of fish distribution data.

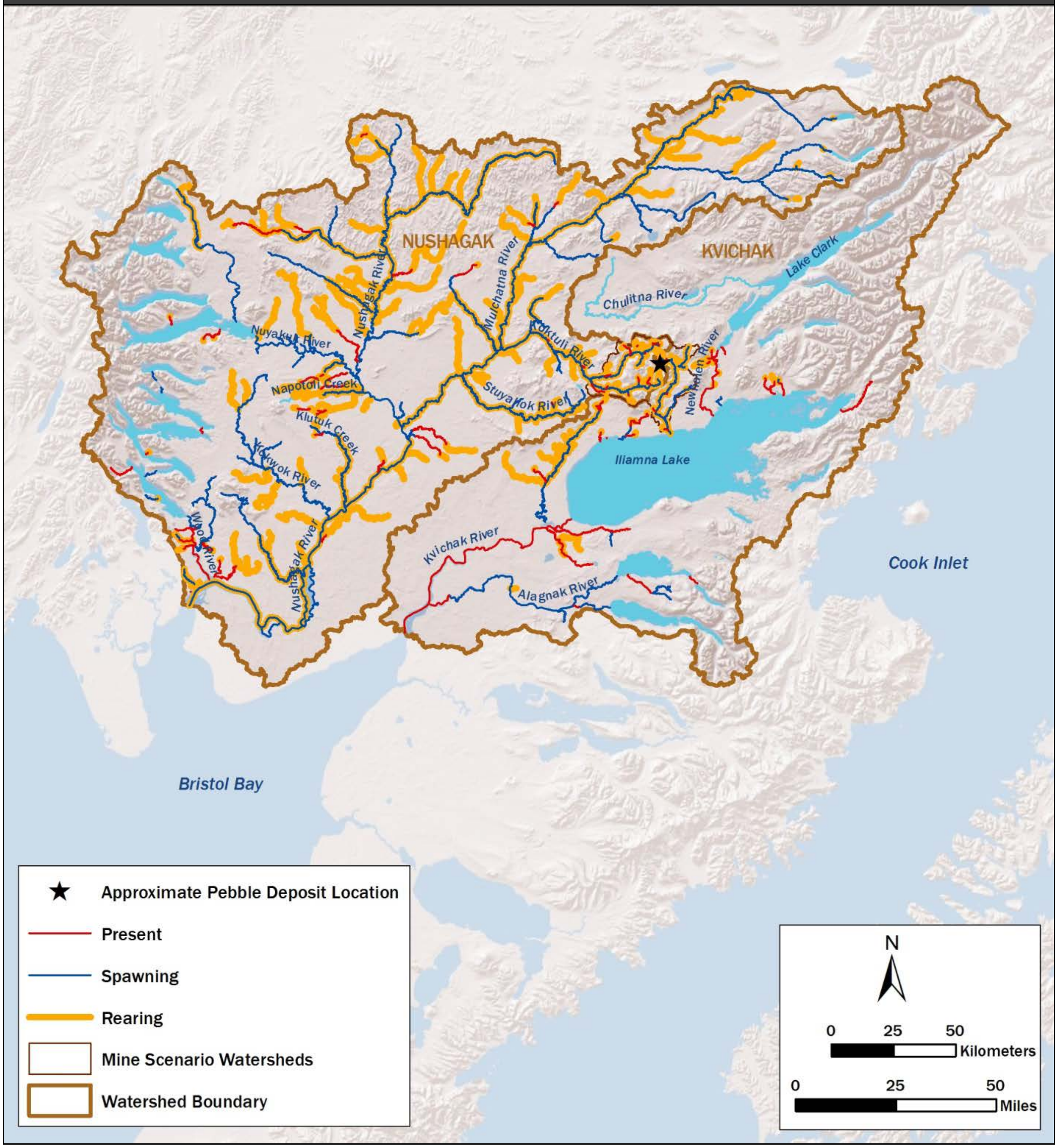


Figure 5-7. Reported chum salmon distribution in the Nushagak and Kvichak River watersheds. "Present" indicates species was present but life-stage use was not determined; "spawning" indicates spawning adults were observed; "rearing" indicates juveniles were observed. Present, spawning, and rearing designations are based on the Anadromous Waters Catalog (Johnson and Blanche 2012). Life-stage-specific reach designations are likely underestimates, given the challenges inherent in surveying all streams that may support life-stage use throughout the year. See Section 7.2.5 for details on interpretation of fish distribution data.

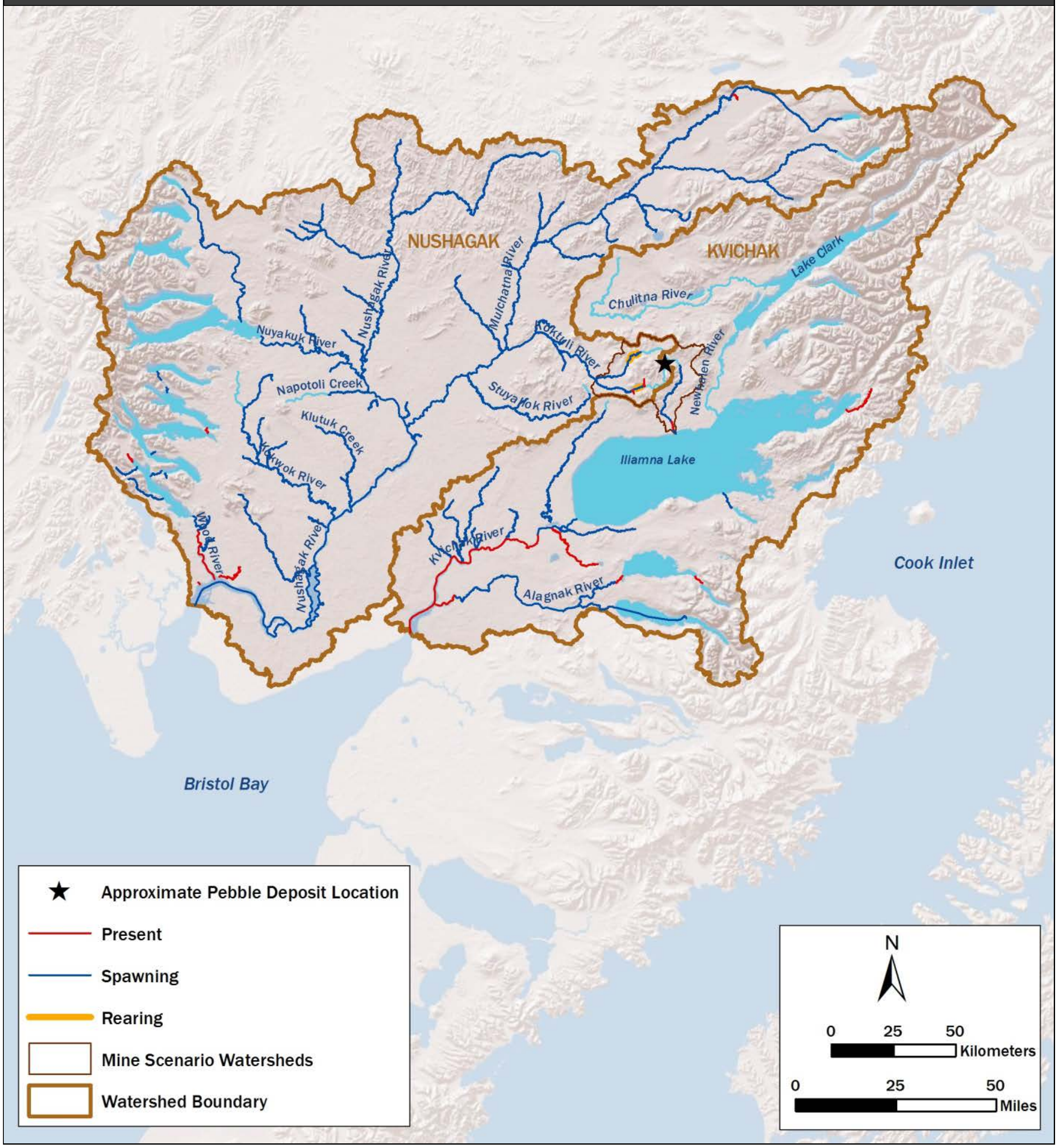


Figure 5-8. Reported pink salmon distribution in the Nushagak and Kvichak River watersheds. "Present" indicates species was present but life-stage use was not determined; "spawning" indicates spawning adults were observed. Present and spawning designations are based on the Anadromous Waters Catalog (Johnson and Blanche 2012). Life-stage-specific reach designations are likely underestimates, given the challenges inherent in surveying all streams that may support life-stage use throughout the year. See Section 7.2.5 for details on interpretation of distribution data.

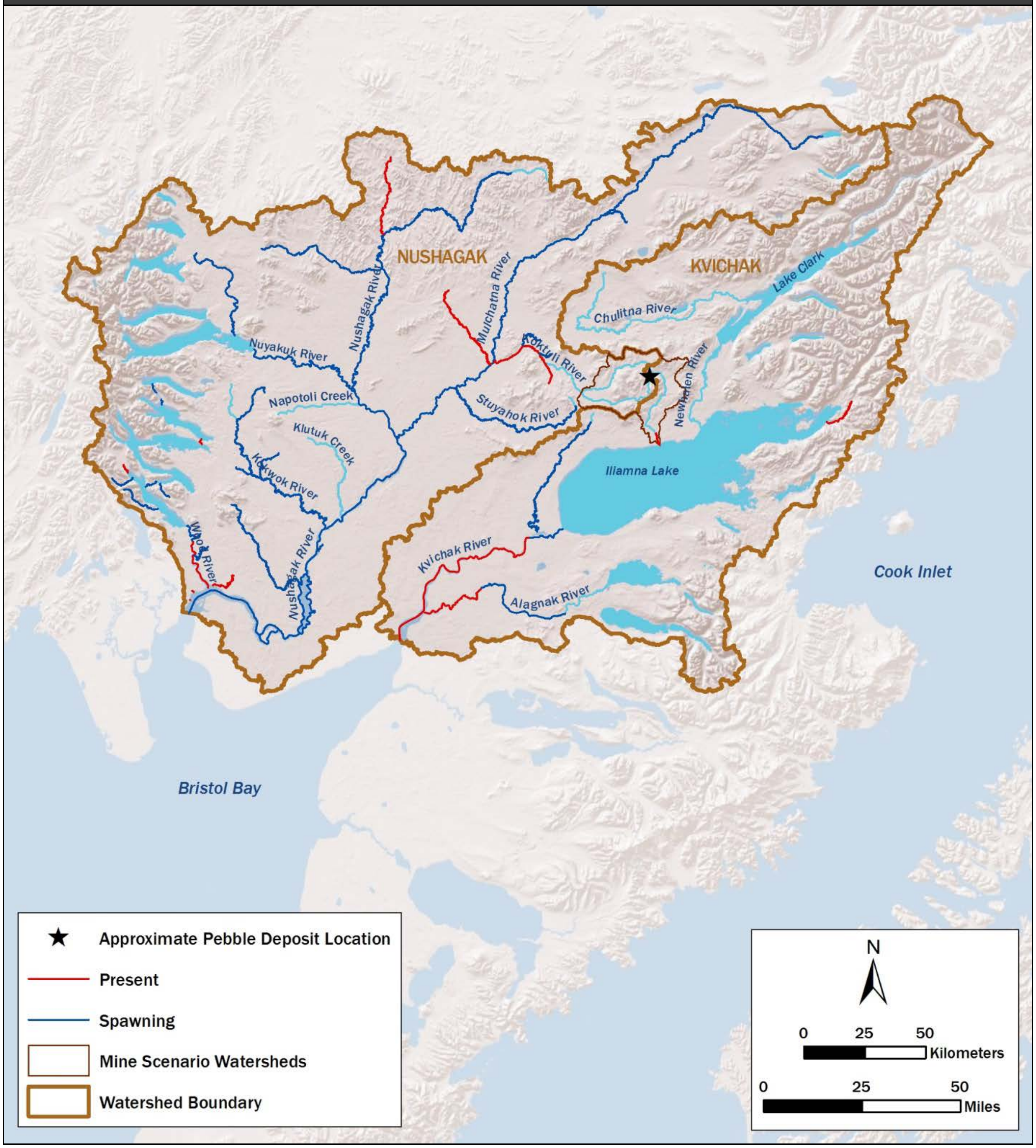
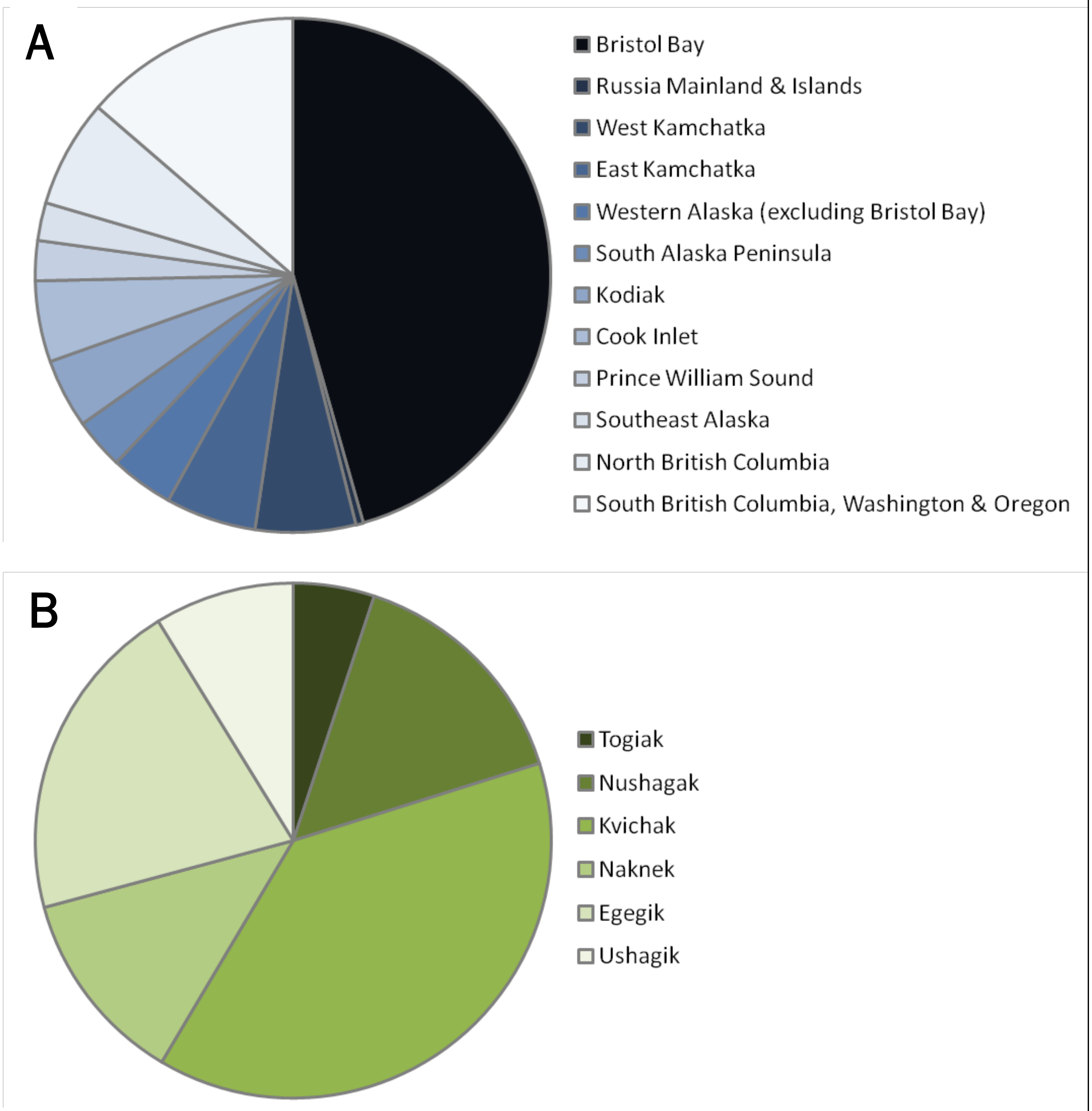


Figure 5-9. Proportion of total sockeye salmon run sizes by (A) region and (B) watershed within the Bristol Bay region. Values are averages from (A) 1956–2005 from Ruggerone et al. 2010 and (B) 1956–2010 from Baker pers. comm. (Appendix A: Tables A2 and A3).



5.2.2.2 Other Fishes

Extensive sampling for rainbow trout and Dolly Varden has not been conducted throughout the Bristol Bay region, so total distributions and abundances are unknown. Figures 5-10 and 5-11 show the reported occurrence of rainbow trout and Dolly Varden throughout the Nushagak and Kvichak River watersheds and provide minimum estimates of their extents.

Between 2003 and 2007, an estimated 183,000 rainbow trout were caught in the Bristol Bay Management Area (Dye and Schwanke 2009). Radio telemetry, tagging, and genetic studies indicate that multiple rainbow trout populations are found within Bristol Bay watersheds (Gwartney 1985, Burger and Gwartney 1986, Minard et al. 1992, Krueger et al. 1999, Meka et al. 2003). The most popular rainbow trout fisheries are found in the Kvichak River watershed, the Naknek River watershed, portions of the Nushagak and Mulchatna River watersheds, and streams of the Wood River lakes system (Dye and Schwanke 2009).

Dolly Varden populations are a significant subsistence resource. In the mid-2000s, subsistence harvests of Dolly Varden and Arctic char combined (Alaska's fisheries statistics do not distinguish between the two species) were estimated at 3,450 fish for 10 communities in the Nushagak and Kvichak River watersheds (Fall et al. 2006, Krieg et al. 2009). From the mid-1970s to the mid-2000s, these two species were estimated to represent between 16.2 and 26.9% of the total weight of the Kvichak River watershed's non-salmon freshwater fish subsistence harvest (Krieg et al. 2005). Dolly Varden also support a popular sport fishery.

Figure 5-10. Reported rainbow trout occurrence in the Nushagak and Kvichak River watersheds. Designation of species presence is based on the Alaska Freshwater Fish Inventory (AFFI point data, ADF&G 2012). Note that points shown on land actually occur in smaller streams not shown on this map. Absence cannot be inferred from this map. See Section 7.2.5 for details on interpretation of fish distribution data.

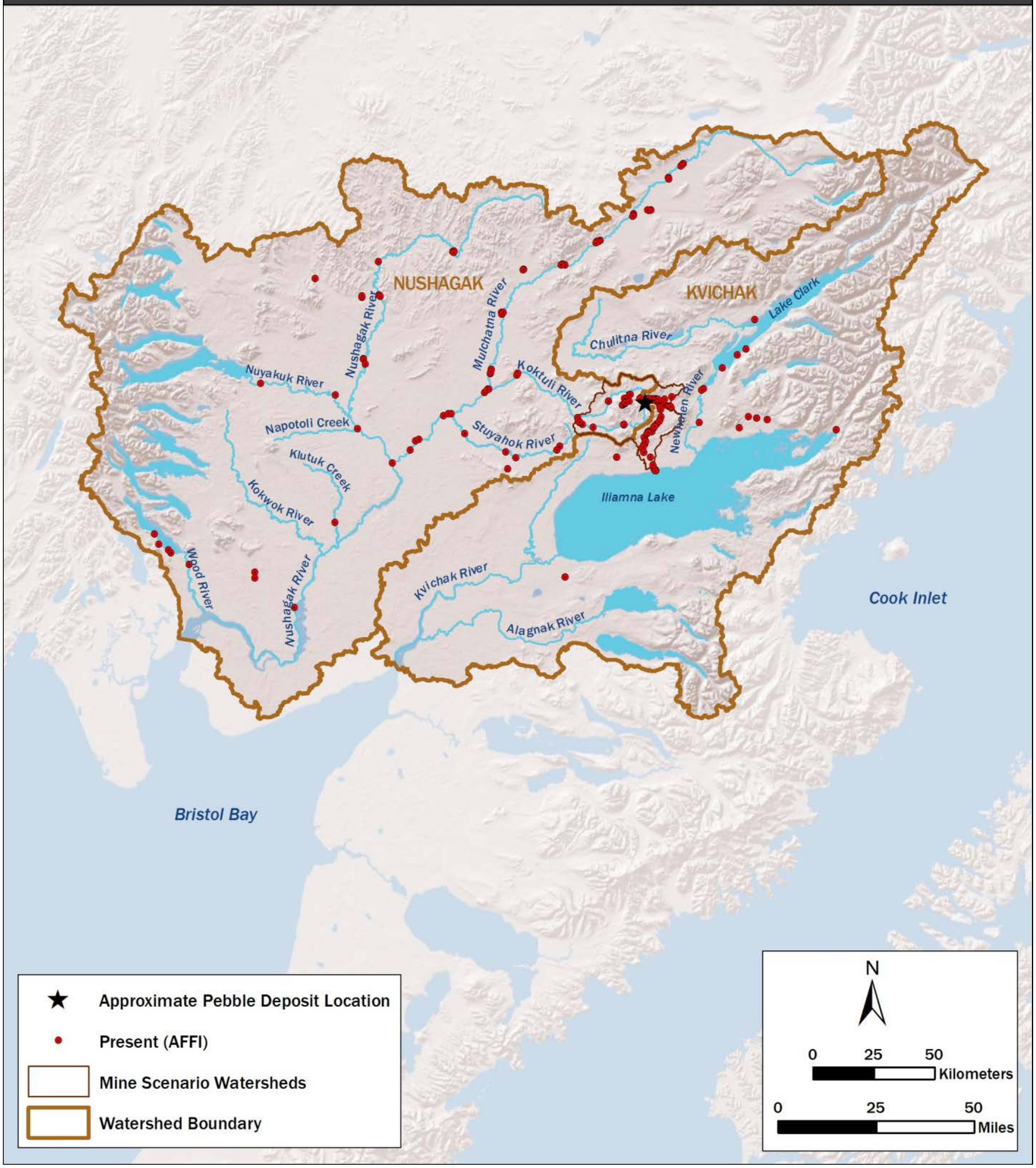
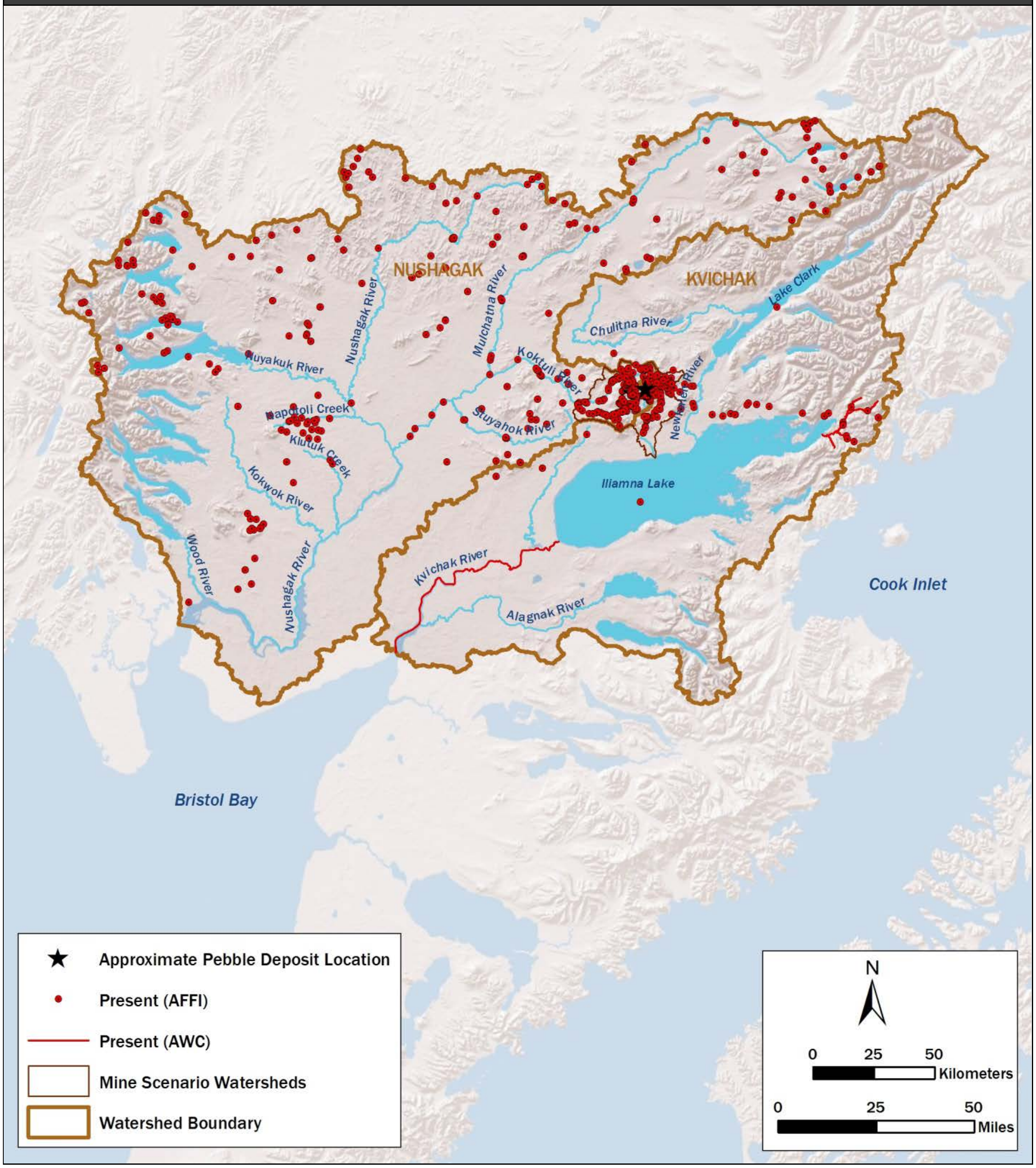


Figure 5-11. Reported Dolly Varden occurrence in the Nushagak and Kvichak River watersheds. Designation of species presence is based on the Alaska Freshwater Fish Inventory (AFFI point data, ADF&G 2012) and the Anadromous Waters Catalog (AWC line data, Johnson and Blanche 2012). Note that points shown on land actually occur in smaller streams not shown on this map. Absence cannot be inferred from this map. See Section 7.2.5 for details on interpretation of fish distribution data.



5.2.3 Economic Implications

The Bristol Bay watershed supports several sustainable, wilderness-compatible economic sectors, including commercial fishing, sport fishing, subsistence hunting and fishing, recreational hunting, and wildlife viewing and other non-consumptive recreation. Each of these sectors generates expenditures or sales that drive the region's economy, generating roughly $480 million (in 2009 dollars) in total direct annual economic benefit (Table 5-4).

Table 5-4. Summary of regional economic expenditures based on salmon ecosystem services. Values are regional expenditures in different economic sectors, expressed in 2009 dollars. Note that estimates of certain year-specific total harvest and sales values vary slightly throughout this report, due to differences in how data were aggregated and reported. See Appendix E for additional information on these values.

Economic Sector	Estimated Direct Expenditure (sales per year, in $ millions)
Commercial fisheries, wholesale value	300.2
Sport fisheries	60.5
Sport hunting	8.2
Wildlife viewing / tourism	104.4
Subsistence harvest	6.3
TOTAL	**479.6**

Roughly 75% of this annual economic benefit results directly from the commercial, sport, and subsistence fishing supported by the Bristol Bay watershed. The commercial salmon fishery currently provides the region's greatest source of economic activity. From 2000 through 2010, the annual commercial salmon catch averaged 23 million fish (170 million pounds). The average annual commercial value of all Bristol Bay salmon fisheries from 1990 to 2010 totaled $116.7 million, $114.7 million of which resulted from the sockeye harvest (Salomone et al. 2011). Thus, sockeye salmon represent the principal species of economic value throughout the Bristol Bay region.

In 2009, fishers received $144 million for their catch, and fish processors received approximately $300 million, which is referred to as the first wholesale value of the fish (Table 5-4, Appendix E). The commercial salmon fishery, which is largely centered in the region's salt waters rather than its freshwater streams and rivers, is closely managed for sustainability using a permit system (Box 5-4). Approximately 26% of permit holders are Bristol Bay residents. The commercial fishery also provides significant employment opportunities, directly employing over 11,000 full- and part-time workers at the season's peak.

The uncrowded, pristine wilderness setting of the Bristol Bay watershed attracts recreational fishers, and aesthetic qualities are rated as most important in selecting fishing locations by Bristol Bay anglers. Sport fishing in Bristol Bay accounts for approximately $60.5 million in annual spending (Table 5-4), $58 million of which is spent in the Bristol Bay region. In 2009, approximately 29,000 sport-fishing trips were taken to the Bristol Bay region (12,000 trips by people living outside of Alaska, 4,000 trips by Alaskans living outside the Bristol Bay area, and 13,000 trips by Bristol Bay residents). These sport fishing activities directly employ over 800 full- and part-time workers. In 2010, 72 businesses and 319 guides were operating in the Nushagak and Kvichak River watersheds alone, down from a peak of 92 businesses and 426 guides in 2008 (Appendix A, Table 4).

Many households participate in the subsistence harvest of fish, which generates regional economic benefits when Alaskan households spend money on subsistence-related supplies. In total, individuals in Bristol Bay communities harvest about 2.6 million pounds of subsistence foods per year. In 2010, the U.S. Census Bureau reported an estimated 1,873 Alaska Native and 666 non-native households in the Bristol Bay region. Goldsmith et al. (1998) estimated that Alaska Native households spend an average of $3,054 on subsistence harvest supplies, whereas non-native households spend an estimated $796 on supplies (values updated to 2009 price levels). Based on these estimates, subsistence harvest activities resulted in expenditures of approximately $6.3 million (Table 5-4). It is important to note that these estimates of expenditures reflect only the annual economic activity generated by these activities and not the value of the subsistence resources harvested. It may be useful to consider calculations such as net economic value, or the value of the resource or activity over and above regular expenditures associated with it. These types of calculations, as well as the regional economic significance of Bristol Bay's salmon fishery, are discussed in Appendix E.

5.2.4 Biological Complexity and the Portfolio Effect

As the previous sections illustrate, the Bristol Bay watershed supports world-class salmon fisheries. These fisheries result from numerous, interrelated factors. Closely tied to the Bristol Bay region's physical habitat complexity (Chapter 3) is its biological complexity, which greatly increases the region's ecological productivity and stability. This biological complexity operates at multiple scales and across multiple species, but it is especially evident in the watershed's Pacific salmon populations. As discussed in Section 5.2.1.1, the five Pacific salmon species found in the Bristol Bay watershed vary in many life-history characteristics (Table 5-5). This variability allows them to fully exploit the range of habitats available throughout the watershed. Even within a single species, life histories can vary significantly. For example, sockeye salmon may spend anywhere from 0 to 3 years rearing in freshwater habitats, then 1 to 4 years feeding at sea, before returning to the Bristol Bay watershed anytime within a 4-month window (Table 5-5).

Table 5-5. Life-history variation within Bristol Bay sockeye salmon populations.

Element of Biological Complexity	Range of Traits or Options
Location within the Bristol Bay watershed	7 major subwatersheds, ranging from maritime-influenced systems on the Alaska Peninsula to more continental systems
Time of adult return to freshwater habitats	June–September
Time of spawning	July–November
Spawning habitat	Major rivers, small streams, spring-fed ponds, mainland beaches, island beaches
Body size of adults	130 to 190-mm body depth at 450-mm male length
Body shape of adults	Sleek, fusiform to very deep-bodied, with exaggerated humps and jaws
Egg size	88–116 mg at 450-mm female length
Time between entry into spawning habitat and death	Days–weeks
Time spent rearing in freshwater	0–3 years
Time spent at sea	1–4 years

Notes:
Data from Hilborn et al. 2003.

This life-history variability, together with the Pacific salmon's homing behavior, results in distinct populations adapted to their own specific spawning and rearing habitats (Hilborn et al. 2003). In the Bristol Bay region, hydrologically diverse riverine and wetland landscapes provide a variety of large river, small stream, floodplain, pond, and lake habitats for salmon spawning and rearing, and environmental conditions can differ among habitats in close proximity. Variations in temperature and streamflow associated with seasonality and groundwater–surface water interactions create a habitat mosaic that supports a range of spawning times across the watersheds. Spawning adults return at different times and to different locations, creating and maintaining a degree of reproductive isolation and allowing development of genetically distinct stocks (Hilborn et al. 2003, McGlauflin et al. 2011). These distinct stocks can occur at fine spatial scales, with sockeye salmon that use spring-fed ponds and streams approximately 1 km apart exhibiting differences in spawn timing, spawn site fidelity, productivity, and other traits that are consistent with discrete populations (Quinn et al. 2012).

Thus, the Bristol Bay watershed's sockeye salmon "population" is actually a sockeye salmon stock complex—that is, a combination of hundreds of genetically distinct populations, each adapted to specific, localized environmental conditions (Hilborn et al. 2003, Schindler et al. 2010). This stock complex structure can be likened to a financial portfolio in which assets are divided among diverse investments to increase financial stability. Essentially, it creates a biological portfolio effect (Schindler et al. 2010), stabilizing salmon productivity across the watershed as a whole as the relative contribution of sockeye with different life-history characteristics, from different regions of the Bristol Bay watershed, changes over time in response to changes in environmental conditions (Hilborn et al. 2003). For example, salmon stocks that spawn in small streams may be negatively affected by low-streamflow conditions, whereas stocks that spawn in lakes may not be affected (Hilborn et al. 2003). Thus, any population containing stocks that vary in spawning habitat is better able to persist as environmental conditions change.

Without this high level of system-wide biological complexity, annual variability in the size of Bristol Bay's sockeye salmon runs would be expected to more than double and fishery closures would be expected to become more frequent (Schindler et al. 2010). In other watersheds with previously robust salmon fisheries, such as the Sacramento River's Chinook fishery, losses of biological complexity have contributed to salmon population declines (Lindley et al. 2009). These findings suggest that even the loss of a small stock within an entire watershed's salmon population may have more significant effects than expected, due to associated decreases in biological complexity of the population's stock complex.

5.2.5 Salmon and Marine-Derived Nutrients

Adult salmon returning to their natal freshwater habitats import nutrients that they obtained during their ocean feeding period—that is, marine-derived nutrients (MDN)—back into those habitats (Cederholm et al. 1999, Gende et al. 2002). Because approximately 95 to 99% of the carbon, nitrogen, and phosphorus in an adult salmon's body are derived from the marine environment (Larkin and Slaney 1997, Schindler et al. 2005), MDN from salmon account for a significant portion of nutrient budgets in the Bristol Bay watershed (Kline et al. 1993). For example, sockeye salmon are estimated to import approximately 12,700 kg of phosphorus and 101,000 kg of nitrogen into the Wood River system annually, and 50,200 kg of phosphorus and 397,000 kg of nitrogen into the Kvichak River system annually (Moore and Schindler 2004). The distribution and relative importance of the trophic subsidies provided by MDN within salmon-bearing watersheds are not expected to be spatially or temporally uniform (Janetski et al. 2009). The magnitude and density of spawning salmon and their by-products (i.e., excreta and gametes) will be highest in areas of high spawning density and where carcasses accumulate. In contrast, MDN influences on aquatic foodwebs may be negligible in headwater streams above the upstream limit of anadromous fish distributions. In these systems, other sources of energy, such as terrestrial inputs and benthic production, will be important (Wipfli and Baxter 2010).

Where salmon are abundant, productivity of the Bristol Bay region's fish and wildlife species is highly dependent on this influx of MDN into the region's freshwater habitats (Box 5-3). When and where available, salmon-derived resources—in the form of eggs, carcasses, and invertebrates that feed upon carcasses—are important dietary components for many fishes (e.g., rainbow trout, Dolly Varden, juvenile Pacific salmon, Arctic grayling). Eggs from spawning salmon are a major food source for Bristol Bay rainbow trout and are likely responsible for much of the growth attained by these fish and the abundance of trophy-sized rainbow trout in the Bristol Bay system. Upon arrival of spawning salmon in the Wood River basin, rainbow trout shifted from consuming aquatic insects to primarily salmon eggs, resulting in a five-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 5 g (Scheuerell et al. 2007). Rainbow trout in Lower Talarik Creek were significantly fatter (i.e., had a higher condition factor) in years with high salmon spawner abundance than in years with low abundance (Russell 1977). Research in Iliamna Lake suggests that between 29 and 71% of the nitrogen in juvenile sockeye salmon, and even higher proportions in other aquatic taxa, comes from marine-derived sources, and that the degree of MDN influence increases with escapement (Kline et al. 1993).

Terrestrial mammals (e.g., brown bears, wolves, foxes, minks), and birds (e.g., bald eagles, waterfowl) also benefit from these subsidies (Box 5-3) (Brna and Verbrugge 2013; this document was originally published as Appendix C of this assessment, but has since been released as a U.S. Fish and Wildlife Service [USFWS] report). Availability and consumption of salmon-derived resources can have significant benefits for these species, including increased growth rates, energy storage, litter size, nesting success, and population density (Appendix A, Brna and Verbrugge 2013). Terrestrial systems of the Bristol Bay watershed also benefit from these MDN (Cederholm et al. 1999, Gende et al. 2002) (Box 5-3). Bears, wolves, and other wildlife transport carcasses and excrete wastes throughout their ranges (Darimont et al. 2003, Helfield and Naiman 2006), which then provide food and nutrients for other terrestrial species.

Finally, by dying in the streams where they spawn, adult salmon subsidize the next generation by adding their nutrients to the ecosystem that will feed their young. This positive feedback is missing from freshwater systems with depleted salmon runs, which may inhibit attempts to renew those runs if trophic resources are limiting those populations (Gresh et al. 2000). It is important to note that, although there is ample evidence for the significant benefits provided by trophic subsidies associated with spawning salmon in the Bristol Bay region, trophic limitations to fish population productivity should not be assumed. For example, Schindler et al. (2005) showed that MDN are indeed important for lake productivity in the Wood River system, but that interception of MDN inputs by the commercial fishery did not appear to be a driver of sockeye salmon population dynamics—likely because spawning habitat is a more limiting resource for this population.

5.2.6 Bristol Bay Fisheries in the Global Context

The Bristol Bay region is a unique environment supporting world-class fisheries, particularly in terms of Pacific salmon populations. The region takes on even greater significance when one considers the status and condition of Pacific salmon populations throughout their native geographic distributions. These declines are discussed briefly below; for additional information on threatened and endangered salmon stocks, see Appendix A (pages 37–41).

Although it is difficult to quantify the true number of extinct Pacific salmon populations around the North Pacific, estimates for the western United States (California, Oregon, Washington, and Idaho) range from 106 to 406 populations (Nehlsen et al. 1991, Augerot 2005, Gustafson et al. 2007). Pacific salmon are no longer found in 40% of their historical breeding ranges in the western United States, and populations tend to be significantly reduced or dominated by hatchery fish where they do remain (NRC 1996). For example, 214 salmon and steelhead stocks were identified as facing risk of extinction in the western United States; 76 of those stocks were from the Columbia River basin alone (Nehlsen et al. 1991). In general, these losses have resulted from cumulative effects of habitat loss, water quality degradation, climate change, overfishing, dams, and other factors (NRC 1996, Schindler et al. 2010). Species with extended freshwater rearing periods—that is, species like sockeye, which dominates salmon production in the Bristol Bay watershed—are more likely to be extinct, endangered, or threatened than species which spend less time in freshwater habitats (NRC 1996). No Pacific salmon populations from Alaska are known to have gone extinct, although many show signs of population declines.

The status of Pacific salmon throughout the United States highlights the value of the Bristol Bay watershed as a salmon sanctuary or refuge (Rahr et al. 1998, Pinsky et al. 2009). The Bristol Bay watershed contains intact, connected habitats that extend from headwaters to ocean with minimal influence of human development. These characteristics, combined with the region's high Pacific salmon abundance and life-history diversity, make the Bristol Bay watershed a significant resource of global conservation value (Pinsky et al. 2009). Because the region's salmon resources have supported Alaska Native cultures in the region for at least 4,000 years and continue to support one of the last intact wild salmon-based cultures in the world (Appendix D), the watershed also has global cultural significance.

5.3 Endpoint 2: Wildlife

Unlike most terrestrial ecosystems, the Bristol Bay watershed has undergone little development and remains largely intact. Thus, it still supports its historical complement of species, including large carnivores such as brown bears (*Ursus arctos*), bald eagles (*Haliaeetus leucocephalus*), and gray wolves (*Canis lupus*); ungulates such as moose (*Alces alces gigas*) and caribou (*Rangifer tarandus granti*); and numerous waterfowl species. Wildlife populations tend to be relatively large in the region, due to the increased productivity associated with Pacific salmon runs (Section 5.2.5). MDN provide a foundational element for the foodwebs in these watersheds and are important for many species of wildlife. Wildlife, in turn, distribute these nutrients from the aquatic to the terrestrial environment, cycling them through the entire ecosystem (Box 5-3). Thus, interactions between salmon and wildlife species are complex and reciprocal.

In this section we summarize key wildlife species in the Nushagak and Kvichak River watersheds, with particular focus on how these species are related to salmon resources. The species selected for characterization—brown bear, moose, barren-ground caribou, gray wolf, bald eagle, waterfowl (as a guild), shorebirds (as a guild), and land birds (as a guild)—are important to ecosystem function, have a direct link to salmon, and/or are important to Alaska Native and non-native residents. Within the Nushagak and Kvichak River watersheds, there are no known breeding or otherwise significant occurrences of any species listed as threatened or endangered under the Endangered Species Act, nor any designated critical habitat. For additional information on wildlife species, readers should consult Brna and Verbrugge (2013). In many cases, little abundance data specific to the Bristol Bay watershed are available, but it is reasonable to assume that species distribution and abundance patterns in this region mirror those observed in similar habitats across southwestern Alaska.

Although this assessment focuses on inland aquatic and nearshore habitats of the Bristol Bay watershed, it should be noted that once the region's Pacific salmon populations migrate to the ocean, they also provide food for marine predators (Appendix F). Marine mammals such as northern fur seals, harbor seals, stellar sea lions, orcas and beluga whales are known to feed on Pacific salmon. These interactions also can be important in freshwater habitats, as one of two freshwater harbor seal populations in North

America is found in Iliamna Lake (Smith et al. 1996). Although this population is not evaluated in this assessment, the National Oceanic and Atmospheric Administration is currently conducting a status review on Iliamna Lake seals to determine if they represent a distinct population segment that may warrant protection under the Endangered Species Act (Appendix F).

5.3.1 Life Histories, Distributions, and Abundances of Species

5.3.1.1 Brown Bears

Brown bears are wide-ranging and feed on many different plant and animal species. They typically spend July through mid-September near streams supporting salmon runs, then move to higher elevations in the fall to feed on berries and other food items before denning in October to November. They emerge in spring and feed on vegetation and carrion, as well as moose and caribou calves. Because of their wide-ranging behavior, they distribute MDN via both deposition of salmon carcasses and excretion of wastes throughout their ranges.

Brown bear density estimates range from roughly 40 bears per 1,000 km^2 in the northern Bristol Bay region (Togiak National Wildlife Refuge and the Bureau of Land Management's Goodnews Block) (Walsh et al. 2010) to 150 bears per 1,000 km^2 along the shore of Lake Clark (Olson and Putera 2007). From July 2006 to July 2007, 621 brown bears were reported harvested from the Alaska Department of Fish and Game's (ADF&G's) Game Management Unit (GMU) 9, which includes the Kvichak River watershed and the Alaska Peninsula. Brown bears are not as abundant in the Nushagak River watershed as the Kvichak River watershed, and densities in both watersheds are lower than on the Alaska Peninsula's Pacific coast, which is home to the highest documented brown bear density in North America (551 bears per 1,000 km^2) (Miller et al. 1997). Brown bears are reported as common in the area surrounding the Pebble deposit, with a 2009 estimated density of 18.4 to 22.5 per 1,000 km^2 (PLP 2011).

5.3.1.2 Moose

Moose habitat is determined by forage opportunities and includes both aquatic and upland areas. Alluvial habitats along the Nushagak and Mulchatna Rivers, where willows and other plants regenerate after scouring and subsequent deposit of river silt, support an abundant moose population. High-quality summer forage, especially near wetlands, is important for nursing cows and calves. It is likely that MDN contribute to increased plant productivity in these alluvial areas (Cederholm et al. 1999, Gende et al. 2002).

Moose abundance in the Nushagak and Kvichak River watersheds was estimated at 8,100 to 9,500 in 2004 (Butler 2004, Woolington 2004). Populations are especially high in the Nushagak River watershed (ADF&G 2011), where felt-leaf willow, a preferred plant species, is abundant (Bartz and Naiman 2005). Moose were considered "low density" (0.04 moose/km^2) in the immediate area of the Pebble deposit and the transportation corridor, but there is a large variance around this estimate (PLP 2011).

5.3.1.3 Caribou

Caribou feed in open tundra, mountain, and sparsely forested areas and can travel for long distances. The Nushagak and Kvichak River watersheds are primarily used by caribou from the Mulchatna herd, one of 31 caribou herds found in Alaska. The Mulchatna herd ranges widely through the Nushagak and Kvichak River watersheds, but also spends considerable time in other watersheds. It numbered roughly 200,000 in 1997 but had decreased to roughly 30,000 by 2008 (Valkenburg et al. 2003, Woolington 2009). Recent surveys reported only a few caribou near the Pebble deposit area and potential transportation corridor (PLP 2011). However, caribou populations and ranges in the Bristol Bay region fluctuate significantly over time, and in previous years the herd was much larger and there was higher-density use of the Pebble deposit area (PLP 2011). Barren-ground caribou on the North Slope of Alaska have demonstrated avoidance of exploration activities (Fancy 1983), and some tribal Elders in the Nushagak and Kvichak River watersheds believe that mining exploration has contributed to avoidance of the Pebble deposit area (Brna and Verbrugge 2013).

5.3.1.4 Gray Wolf

Gray wolf abundance is influenced by prey abundance and availability, but populations are primarily limited by mortality caused by humans. Wolves have flexible diets and can shift to non-ungulate prey species when ungulate prey are scarce, or take advantage of seasonally abundant species such as salmon. Wolves often transport salmon away from streams for consumption or to feed pups through regurgitation.

Gray wolf populations have not been well-studied in the Bristol Bay region, and it is difficult to assess population numbers. Wolves are currently thought to be abundant in the Nushagak River watershed: between 2003 and 2008, reported annual wolf harvest ranged from 60 to 141 in GMU 17, which includes the Nushagak and Togiak River watersheds. In the Kvichak River watershed, numbers are believed to be lower, although populations have increased since the 1990s (Butler 2009).

5.3.1.5 Bald Eagle

Bald eagles generally nest near riparian and beach areas and are primarily piscivorous, although they have a variable diet. Nesting bald eagles rely on salmon resources (Hansen 1987), and inland bald eagles nesting near spawning streams have higher nesting success than those with more distant nests (Gerrard et al. 1975). Birds and non-salmon fishes are also important prey for bald eagles. Salmon abundance in the Nushagak and Kvichak River watersheds affects bald eagle abundance, distribution, breeding, and behavior. Bald eagles, in turn, distribute MDN in their excretions.

Although no comprehensive survey of bald eagles or bald eagle nests has been conducted in the Bristol Bay watershed, limited count data are available for parts of the region. For example, 50 bald eagle nests were recorded along portions of the Nushagak, Mulchatna, and Kvichak Rivers in 2006 (Brna and Verbrugge 2013); approximately half of those nests were categorized as active. The USFWS Bald Eagle Nest Database contains approximately 230 nest records for the Nushagak and Kvichak River watersheds, with 169 of those records collected between 2003 and 2006. Raptor studies in the Pebble deposit area indicate that bald eagles were the most abundant nesting raptor (30% of all raptor nests in 2005) (PLP 2011).

5.3.1.6 Waterfowl

More than 30 species of waterfowl, including ducks (e.g., northern pintail, scaup, mallard, and green-winged teal), geese (e.g., white-fronted, Canada), swans, and sandhill cranes, regularly use the Bristol Bay region (PLP 2011). Diversity of habitat and extent of wetlands and waters provide habitat for migrants and wintering waterfowl, and the region is an important staging area for many species, including emperor geese, Pacific brant, and ducks, during spring and fall migrations.

The *Alaska Yukon Waterfowl Breeding Population Survey* found average late-May abundance indices of 497,000 ducks, 7,700 geese, 15,400 swans, and 5,300 sandhill cranes in the Bristol Bay Lowlands between 2002 and 2011 (Brna and Verbrugge 2013). Salmon are used by some waterfowl as direct sources of prey and carrion, and used indirectly through invertebrates and vegetation. Of the 24 duck species in the Bristol Bay region, at least 11 prey on salmon eggs, parr, or smolts, or scavenge on salmon carcasses (Brna and Verbrugge 2013).

5.3.1.7 Shorebirds

Thirty of 41 shorebird species or subspecies that regularly occur in Alaska can be found in the Bristol Bay watershed (see Brna and Verbrugge [2013] for a summary of different shorebird surveys). Shorebirds use the Bristol Bay watershed primarily during migration and breeding. Significant areas of intertidal habitat exist at Kvichak Bay (530 km^2) and Nushagak Bay (400 km^2). Important foods include abundant intertidal invertebrates and fruits and tubers in upland areas. Shorebirds likely play an important role in the distribution of MDN to terrestrial ecosystems. Adults, young, and eggs also provide a source of food for predatory birds and terrestrial mammals. Although there is not a strong direct link between salmon and shorebirds, it is reasonable to assume that MDN contribute to the abundance of invertebrates in the intertidal zone.

The Bristol Bay/Alaska Peninsula lagoon system, which includes the Nushagak and Kvichak River deltas, is one of the most important migratory shorebird stop-over areas in Alaska. Surveys of the Pebble deposit area in 2004 to 2005 identified 14 shorebird species in the Pebble deposit area (PLP 2011).

5.3.1.8 Land Birds

Approximately 80 species of land birds, both migratory and year-round residents, breed in and adjacent to the Nushagak and Kvichak River watersheds. Land birds eat vegetation (e.g., seeds, berries), invertebrates, and vertebrates. Studies indicate that the abundance of many songbird species is related to the presence of salmon carcasses (Willson et al. 1998, Gende and Willson 2001, Christie and Reimchen 2008). Salmon carcasses provide food for aquatic invertebrate larvae, and MDN contribute to increased plant productivity (Cederholm et al. 1999, Gende et al. 2002), both important food sources for land birds. Few abundance studies have focused on the Nushagak and Kvichak River watersheds, but 2004 to 2005 surveys identified 28 land bird species in the Pebble deposit area (PLP 2011).

5.3.2 Recreational and Subsistence Activities

Many of the species discussed in the preceding sections are important subsistence resources. For example, a 2002 survey of Bristol Bay residents found that 86% and 88% of respondents have consumed moose and caribou meat, respectively (Ballew et al. 2004). Between 1983 and 2006, moose harvest in GMU 17 increased from 127 to 380 moose per year; the upper Nushagak River watershed alone (GMU 17B) had a mean annual harvest of 149 moose (Brna and Verbrugge 2013). Caribou harvest ranged from 1,573 to 4,770 per year between 1991 and 1999, but this estimate is for the entire Mulchatna herd, including those taken outside of the Nushagak and Kvichak River watersheds (Valkenburg et al. 2003).

Waterfowl support recreational and subsistence harvests, as well as wildlife viewing opportunities. There are no reliable estimates of recreational harvests specific to the Nushagak and Kvichak River watersheds. Subsistence harvest of waterfowl is very important in the watershed. The spring harvest provides fresh meat early in the season, after winter food supplies are depleted. Harvest data from 1995 through 2005 for the Dillingham, Nushagak River, and Iliamna subregions (Wentworth 2007, Wong and Wentworth 1999) indicate annual harvests of roughly 10,000 ducks, 2,500 to 2,900 geese, and up to 300 tundra swans, as well as fewer than 500 waterfowl eggs (Brna and Verbrugge 2013).

Sport hunting for caribou, moose, brown bear, and other species also plays a role in the local economy of the Bristol Bay region. In recent years, approximately 1,323 non-residents and 1,319 non-local residents of Alaska traveled to the region to hunt. Miller and McCollum (1994) estimate that non-residents and non-local residents spend approximately $5,170 and $1,319 per trip (values updated to 2009 dollars), respectively. These hunting activities result in an estimated $8.2 million per year in direct hunting-related expenditures (Table 5-4) and directly employ over 100 full- and part-time workers.

5.4 Endpoint 3: Alaska Natives

Alaska Natives are the majority population in the Bristol Bay region, and salmon has been central to their health, welfare, and culture for thousands of years. In fact, Alaska Native cultures in the region represent one of the last intact salmon-based cultures in the world (Appendix D). Much of the region's population practices subsistence, with salmon making up a large proportion of subsistence diets—making Alaska Natives particularly vulnerable to potential changes in salmon resources.

The effect on Alaska Natives resulting from potential mining-related changes in salmon and other fishes was selected as an assessment endpoint because of the nutritional and cultural importance of salmon to Alaska Natives, and because of the U.S. Environmental Protection Agency's (USEPA's) responsibilities to work with federally recognized tribes on a government-to-government basis to protect, restore, and preserve the environment. These responsibilities are set forth in Executive Order 13175, Executive Order 12898, President Obama's 2009 Indian Policy, former USEPA Administrator Jackson's Reaffirmation of USEPA's Indian Policy 2009, USEPA's Policy on Tribal Consultation and Coordination, and USEPA's Region 10 Tribal Consultation and Coordination Procedures. Nine Bristol Bay federally recognized tribes and other tribal organizations petitioned the USEPA in 2010, requesting that the agency use its authority under the Clean Water Act Section 404(c) to restrict or prohibit the disposal of dredged or fill material associated with large-scale mining activities in the Bristol Bay watershed.

5.4.1 Alaska Native Populations

There are 31 Alaska Native villages in the wider Bristol Bay region, 25 of which are located in the Bristol Bay watershed. Fourteen of these communities are within the Nushagak and Kvichak River watersheds, with a total population of 4,337 in 2010 (U.S. Census Bureau 2010). Dillingham (population 2,329) is the largest community; other communities range in size from two (year-round) residents (Portage Creek) to 510 residents (New Stuyahok). Because population in some communities is seasonal, these numbers increase during the subsistence fishing season. Thirteen of these 14 villages—all but Port Alsworth—have federally recognized tribal governments and had an Alaska Native population majority in 2010.

Overall population in the region grew 55% from 1980 to 2000, and remained relatively stable from 2000 to 2010 (U.S. Census Bureau 2010). Population has fluctuated in individual villages since 1980 (Appendix D, Table 2). From 2000 to 2010, nine villages decreased and five villages increased in population. The extent to which these changes reflect natural population fluctuations or whether any gains or losses indicate a long-term trend is unknown. Four of the villages that decreased in population (Dillingham, Igiugig, Aleknagik, and Kokhanok) and one of villages that increased in population (Iliamna) changed less than 10%. Port Alsworth has experienced steady population growth since 1980. Its economy is more closely tied to Lake Clark National Park, and its population contains the smallest proportion of Alaska Natives among the 14 villages. Portage Creek is the smallest village in the region, and its year-round population has fluctuated significantly over the past 40 years (e.g., 48 in 1980, 5 in 1990, 36 in 2000, 2 in 2010), making it difficult to draw conclusions about trends.

5.4.2 Subsistence and Alaska Native Cultures

5.4.2.1 Importance of Salmon to Alaska Native Cultures

The primary Alaska Native cultures present in the Nushagak and Kvichak River watersheds—the Yup'ik and Dena'ina (Box 5-1)—are part of the last intact, sustainable salmon-based cultures in the United States (Appendix D). This is especially significant as other Pacific Northwest salmon-based cultures struggle with degraded resources (Colombi and Brooks 2012). Cultures associated with salmon fishing appeared in these watersheds as early as 4,000 before present (BP) and intensified around 1,000 BP (Appendix D). Currently, the percentage of Alaska Native population in the region's villages ranges from 21.4% (Port Alsworth) to 95.7% (Koliganek) (Appendix D, Table 2). The Yup'ik and Dena'ina cultures still provide the framework and values for everyday life in the region. Among the Yup'ik, over 40% of the population continues to maintain their native language, one of the highest percentages among native cultures in the United States (Appendix D).

In the Bristol Bay region, the subsistence way of life is irreplaceable. Subsistence resources provide high quality foods, foster a healthy lifestyle, and form the basis for social relations for both Alaska Natives and non-Alaska Natives in the villages. These resources, particularly salmon, are integral to the entire way of life in Yup'ik and Dena'ina cultures. The Alaska Federation of Natives (2010) describes subsistence as follows.

> The hunting, fishing, and gathering activities which traditionally constituted the economic base of life for Alaska's Native peoples and which continue to flourish in many areas of the state today…Subsistence is a way of life in rural Alaska that is vital to the preservation of communities, tribal cultures, and economies. Subsistence resources have great nutritional, economical, cultural, and spiritual importance in the lives of rural Alaskans…Subsistence, being integral to our worldview and among the strongest remaining ties to our ancient cultures, are as much spiritual and cultural as it is physical.

For Alaska Natives today, subsistence is more than the harvesting, processing, sharing, and trading of land and sea mammals, fish, and plants. Subsistence holistically subsumes the cultural, social, and spiritual values that are the essence of Alaska Native cultures. There is a strong tradition and practice of sharing and trading subsistence resources. Food is shared with tribal Elders, family living outside of the watershed, and others who may not be able to fully participate in subsistence (Appendix D). This practice was confirmed by tribal Elders interviewed for Appendix D and those who testified at public meetings on the May 2012 draft of the assessment (Box 5-5).

Cultural and personal identity largely revolve around traditional cultural practices such as hunting, fishing, and gathering of wild food resources—that is, subsistence. Tribal Elders and culture bearers continue to instruct young people, particularly at fish camps where cultural values as well as fishing and fish processing techniques are shared. The social system that forms the backbone of the culture, by nurturing the young, supporting the producers, and caring for the tribal Elders, is based on the virtue of sharing wild foods harvested from the land and waters. Sharing networks extend to family members living far from home. The first salmon catch of the year is recognized with a prayer of thanks and shared in a continuation of the ancient First Salmon Ceremony (Appendix D), when those who have caught the first Chinook (king) salmon in the spring share them with tribal Elders and all those in need, as well as friends and family.

Traditional and more modern spiritual practices place salmon in a position of respect and importance, as exemplified by the First Salmon Ceremony and the Great Blessing of the Waters (Appendix D). The salmon harvest provides a basis for many important cultural and social practices and values, including the sharing of resources, fish camp, gender and age roles, and the perception of wealth. Although a small minority of tribal Elders and culture bearers interviewed expressed a desire to increase market economy opportunities (including large-scale mining), most equated wealth with stored and shared subsistence foods (Appendix D). In interviews conducted for Appendix D, the Yup'ik and Dena'ina communities of the Nushagak and Kvichak River watersheds consistently 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. Their ability to continue their reliance on subsistence and their concept of wealth have contributed to the maintenance of vital and viable cultures for at least 4,000 years.

BOX 5-5. TESTIMONY ON THE IMPORTANCE OF SUBSISTENCE USE

The USEPA held a series of public meetings to collect input on the May 2012 draft of the assessment. Many Alaska Natives, including tribal Elders and other tribal leaders, provided testimony on the importance of salmon and the subsistence way of life to Alaska Native cultures in the region. The following are selected quotes representative of this testimony; complete public meeting transcripts are available at www.epa.gov/BristolBay.

- "Our subsistence way of life plays a substantial role in our health both spiritually and physically."
- "From traditional knowledge we keep our culture going. My subsistence life is with my family, which consists of four boys and my wife. I also help my grandmother, grandfather, mother, father, and our other family members. I hold a Bristol Bay drift permit, my family fishes with me both commercially and subsistence. My family processes approximately 4,000 pounds of salmon, kings, reds, silvers, etc. We start when the fish first come into the river, all the way to the very end. My family and I smoke, dry, and freeze the salmon. I brought you some canned salmon to share that we keep year round."
- "The king salmon is a very important part of our fishery. If you cover that portion of the king [Chinook] salmon spawning beds, it is going to make it very hard for us to maintain our culture of people who eat king every year. Is the first fish of the year, it's a very important fish for us and we can't have that huge loss."
- "Fishing is our life and our livelihood. It's what we do for healthy communities, healthy lifestyles. Going out and catching the subsistence fish, smoking these. Passing the traditional knowledge on to younger generations. You hear about how they will make you free, the fish. We have been doing this for 6,000 years and we will want to do it for 6,000 more."
- "The generations that are coming who can be fed from this resource and this land and it's a beautiful interaction and it's one that we are losing around the world. When we realize that we have lost it we strive to get it back, but it is taking a long time for this beautiful balance between human, animal and subsistence lifestyle to come about and evolve."
- "The survival of our culture directly depends on the health of our land, the fish and the wildlife. No amount of money or jobs can replace our way of life and our culture."
- "I am a Dena'ina, and Athabascan Indian. This village is my home. We are very rich people in our culture, our resources, plants, animals and salmon. They all need clean water. That includes us, the Dena'ina people of the land. But only because we are so blessed to have clean water. Salmon have been a great part of our diet for generations and will be in the future."
- "Right now we are getting excited for the kings to come up our river. For everyone works together cutting fish. To dry, salt or vacuum pack for the winter. We do not waste anything, because we fish. Around here it is gold, gold to us which we treasure. When we fill our dry rack, we go walking and help one another."
- "I've lived here for 30 years and I moved here by choice. My experience of living in this area is that people choose to be here whether born or coming here. It's a choice. It is not a scientific fact, but three reasons people choose to be in Bristol Bay is because clean water, the fishery and the lifestyle."
- "This environment has sustained our culture for thousands of years. It sustained jobs and commercial fishing for hundreds of years, and recreation and sport fishing and everything."

The Alaska Native community is also dependent on the regional economy, which is primarily driven by commercial salmon fishing and tourism. The commercial fishing and recreation market economies provide seasonal employment for many residents, giving them both the income to purchase goods and services needed for subsistence and the time to participate year-round in subsistence activities. The fishing industry provides half of all jobs in the region, followed by government (32%), recreation (15%), and mineral exploration (3%) (Appendix E). It is estimated that local Bristol Bay residents held onethird of all 2009 jobs and earned almost $78 million (28%) of the total income traceable to the Bristol Bay salmon ecosystem (Appendix E).

5.4.2.2 Use of Subsistence Resources in the Bristol Bay Watershed

Alaska Native populations, as well as non-Alaska Native residents, have continual access to a range of subsistence foods. As described by Fall et al. (2009), these subsistence resources are the most consistent and reliable component of the local economies in the Bristol Bay watershed, even given the world-renowned commercial fisheries and other recreational opportunities the region supports (Table 5-4). Subsistence uses on state lands are given priority by state law and regulations (i.e., the 1978 State of Alaska Subsistence Act). All citizens of Alaska benefit from a subsistence priority in areas specifically designated as subsistence areas by the State of Alaska. State hunting and fishing regulations apply to lands of the Alaska Native Corporations. These lands were often selected because of their significant value for subsistence activities, and Alaska Native peoples have the exclusive right to occupy and use these lands for subsistence. These rights are not recognized in the State of Alaska Constitution; however the Alaska Federation of Natives has passed resolutions for several years asking for the constitution to be revised. In addition, the Alaska Federation of Natives recommended improvements to management of state and federal subsistence programs. Indigenous hunting and fishing rights are recognized by statute only and therefore can be diminished over time. Their lack of special status makes these rights vulnerable to constitutional challenges, especially challenges based on the right to equality (Duhaime and Bernard 2008).

Virtually every household in the Nushagak and Kvichak River watersheds uses subsistence resources (Appendix D: Table 12). No watershed data are available for the proportion of Bristol Bay watershed residents' diets made up of subsistence foods, as most studies focus on harvest data and are not dietary surveys. A study that included the nearby Yukon-Kuskokwim region found that 22.8 % of calories came from Native (subsistence) foods (Johnson et al. 2009). In 2004 and 2005, annual subsistence consumption rates in the Nushagak and Kvichak River watersheds were over 300 pounds per person in many villages, and reached as high as 900 pounds per person (Appendix D, Table 12; for comparison, an average American consumes 1,996 pounds of food per year). Villages with the highest per capita subsistence usage were Koliganek, Ekwok, Newhalen, Kokhanok, Igiugig, and Levelock.

Subsistence use varies throughout the Bristol Bay watershed, as villages differ in the per capita amount of subsistence harvest and the variety of subsistence resources used. Salmon and other fishes provide the largest portion of subsistence harvests of Bristol Bay communities. On average, about 50% of the subsistence harvest by local community residents (measured in pounds usable weight) is Pacific salmon, and about 10% is other fishes (Fall et al. 2009). The percentage of salmon harvest in relation to all subsistence resources ranges from 29 to 82% in the villages (Appendix D, Table 11). Salmon accounts for an especially high percentage compared to all subsistence resources for Iliamna, Kokhanok, and Pedro Bay. Igiugig, Levelock, and New Stuyahok show the lowest percentage of salmon usage relative to other subsistence resources. Villages in the Nushagak River watershed, especially New Stuyahok, Ekwok, and Dillingham, rely on Chinook salmon to a great extent, whereas villages in the Kvichak River watershed and Iliamna Lake area (e.g., Iliamna, Kokhanok, Iguigig, Newhalen, Nondalton, Pedro Bay, and Port Alsworth) rely more on sockeye salmon. All communities also rely on non-salmon fishes (Table 5-1), but to a lesser extent than salmon. These fishes are taken throughout the year by a variety of harvest methods and fill an important seasonal component of subsistence cycles (Fall et al. 2009). For example, whitefish and other freshwater species provide fresh fish during winter ice-fishing season (Appendix D).

The ADF&G overview of subsistence fisheries in the Bristol Bay watershed (Fall et al. 2009) provides the following information.

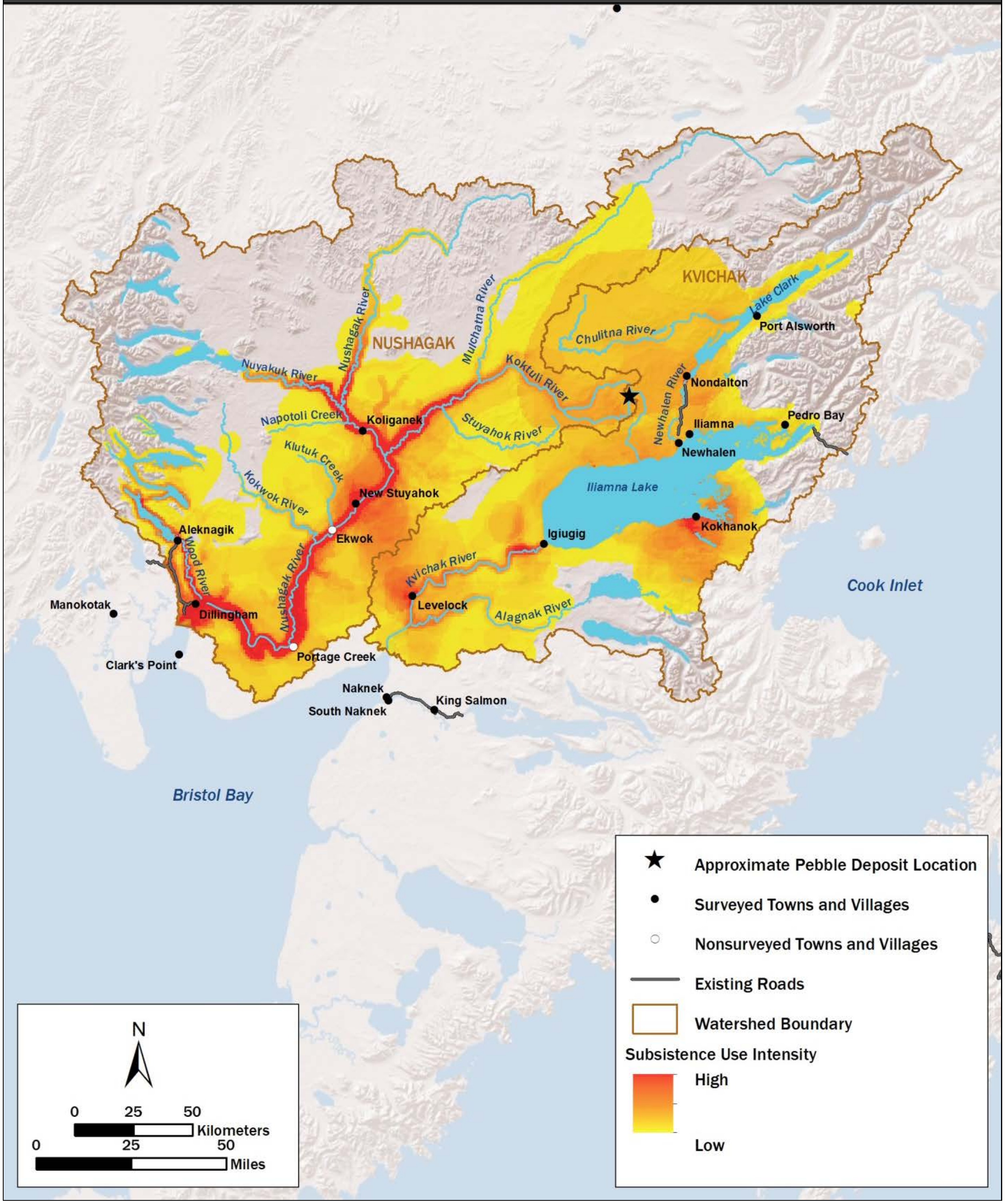
- The number of Bristol Bay subsistence salmon permits issued has been stable since 1990, and the recent 10-year average is 1,146 permits. Most permit holders (84%) are residents of Bristol Bay communities, and most permits are issued for the Nushagak and Naknek/Kvichak districts. Sockeye salmon make up the largest portion of the Bristol Bay subsistence salmon harvest (79% of the 1998–2007 average, based on subsistence salmon permits), followed by Chinook (19%), coho (5%), chum (5%), and pink (2%).
- Annual subsistence harvests for the Bristol Bay management area vary from year to year. Salmon harvest declined from the early 1990s to the early 2000s but has recovered slightly since 2002. Since 1975, the average annual harvest was about 152,371 salmon; the recent 5-year average (2003–2007) was 126,717 salmon.
- The largest decline over the last 15 years has occurred in the Kvichak River watershed subsistence sockeye salmon fishery, historically the largest component of the Bristol Bay subsistence salmon harvest. Declines are due to lower harvests per permit, rather than reduced fishing effort. Since 1996, harvest per day is down 26% in years of escapements under 2 million fish, compared to the previous 13-year average. The long-term average (45 years, for which permit data are available) for this fishery is 66,614 sockeye salmon.
- There has been an overall harvest decline in the Nushagak district from a high of 86,400 fish in 1986 to a low of 40,373 salmon in 2006. The 24-year average harvest (the time for which data are available) is 50,740 fish. However, the number of subsistence salmon permits issued in the Nushagak district has remained relatively stable since 1983.
- Subsistence salmon harvests in the Nushagak district are similar to those in the Kvichak district in terms of harvest levels. For example, in 2007the communities in the Nushagak district harvested 44,944 salmon, compared to 47,538 salmon in the Kvichak River/Iliamna Lake subdistrict, based on permit returns. However, there are differences in the two fisheries. Whereas salmon harvest in the Kvichak River watershed is almost all sockeye salmon (47,473 out of 47,538 in 2007), salmon harvest in the Nushagak district is more varied, with larger harvests of Chinook, coho, and chum salmon. There are also larger communities in the Nushagak district, including Dillingham, Manokotak, Aleknagik, New Stuyahok, and Koliganek.
- Chinook salmon returns are higher in the Nushagak River watershed than in the Kvichak River watershed. In the upper portion of the Nushagak River, residents attempt to harvest large numbers

> of Chinook salmon, their traditionally preferred salmon resource. Chinook salmon spawn early in the season, and it is important to put up these fish for subsistence before commercial fishing starts in earnest (Holen et al. 2012). Substitution of Chinook for sockeye salmon accounts for some, but not all, of the decline in the Nushagak district. Subsistence sockeye salmon harvests in the Kvichak River watershed, including Iliamna Lake and Lake Clark (historically the largest component of the Bristol Bay subsistence salmon fishery), declined by more than 50% during the 1990s and early 2000s. Local subsistence fishers attributed these lowered harvests to poor returns and scarcities of salmon in once reliable and abundant traditional harvest locations. Effort has increased in harvesting salmon in these areas since the low harvest levels seen in early 2000.

Figures 5-2 and 5-12 show areas of subsistence use identified by ADF&G in the Nushagak and Kvichak River watersheds. Clark's Point subsistence use areas overlap with Nushagak and Kvichak River watersheds for caribou, coho salmon, and moose. Clark's Point high per capita harvest rate (1,210 lbs per capita) resulted from a high harvest rate of salmon in 2008. This was three times higher than the harvest levels reported in 1973 and 1989 (Holen et al. 2012). Manokotak subsistence use areas overlap with the Nushagak communities for caribou and moose. Aleknagik moose search areas include part of Nushagak River area (Holen et al. 2012). South Naknek, Naknek, and King Salmon subsistence use areas for waterfowl, rainbow trout, unspecified trout, moose, and berry picking, as well as caribou search areas, overlap the Nushagak and particularly the Kvichak River watersheds (Holen et al. 2011). It should be noted that available subsistence data are coarse and incomplete (Box 5-2), and it is likely that subsistence activities occur outside of the areas identified on the figures. Data used to generate the figures were collected in different years, and at least one village with high recorded subsistence harvests (Ekwok) declined to be surveyed. Also note that these figures do not indicate abundance or harvest, only use.

Although subsistence is a non-market economic activity that is not officially measured, the effort put into subsistence activities is estimated to be the same or greater than full-time equivalent jobs in the cash sector (Appendix E). There is a strong and complex relationship between subsistence and the market economy (largely commercial fishing and recreation) in the area (Wolfe and Walker 1987, Krieg et al. 2007). Market economy income funds goods and services purchased by households and used for subsistence activities (e.g., boats, rifles, nets, snow mobiles, and fuel). In addition to the economic activity generated by the purchase of subsistence goods, subsistence harvests are valued at approximately $60 to $86 per pound, or 34 to 42% of the 2009 per capita income of regional residents (Appendix E).

Figure 5-12. Subsistence use intensity for salmon, other fishes, wildlife, and waterfowl within the Nushagak and Kvichak River watersheds. See Box 5-2 for more detailed discussion of methodology.



The salmon-dependent diet of the Yup'ik and Dena'ina benefits their physical and mental well-being in multiple ways, in addition to encouraging high levels of fitness based on subsistence activities. The interviews conducted for Appendix D confirm ADF&G harvest data that people of the Nushagak and Kvichak River watersheds primarily eat two species of Pacific wild salmon, sockeye and Chinook. These are consumed in different ways, including fresh, salted, pickled, canned, dried, and smoked. Salmon and other traditional wild foods comprise a large part of the people's daily diet throughout their lives, beginning as soon as they are old enough to eat solid food. (Appendix D). Subsistence foods consumed in rural Alaska have demonstrated multiple nutritional benefits, including lower cumulative risk of nutritionally mediated health problems such as diabetes, obesity, high blood pressure, and heart disease (Murphy et al. 1995, Dewailly et al. 2001, Dewailly et al. 2002, Din et al. 2004, Alaska Department of Health and Social Services 2005, Chan et al. 2006, Ebbesson and Tejero 2007) and provision of essential micronutrients and omega-3 fatty acids (Murphy et al. 1995, Nobmann et al. 2005, Bersamin et al. 2007, Ebbesson and Tejero 2007).

A disproportionately high amount of total diet protein and some nutrients comes from subsistence foods. For example, a 2009 study of two rural regions found that 46% of protein, 83% of vitamin D, 37% of iron, 35% of zinc, 34% of polyunsaturated fat, 90% of eicosapentaenoic acid, and 93% of docosahexaenoic acid came from subsistence foods consumed by Alaska Natives (Johnson et al. 2009).

In summary, the roles of salmon as a subsistence food source and as the basis for Alaska Native cultures are inseparable. The characteristics of these subsistence-based salmon cultures have been widely documented (Appendix D). The cultures have a strong connection to the landscape and its resources, and in the Bristol Bay watershed this connection has been maintained for centuries by the uniquely pristine condition of the region's landscape and resources. In turn, the respect and importance given salmon and other wildlife, along with Alaska Natives' traditional knowledge of the environment, has produced a sustainable, subsistence-based economy (Appendix D). This subsistence-based way of life is a key element of Alaska Native identity and serves a wide range of economic, social, and cultural functions in Yup'ik and Dena'ina societies (Appendix D). Appendix D states the following:

> … 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; 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 of either quality or quantity of salmon resources.

It should be noted that, even though the scope of the assessment is focused on villages in the Nushagak and Kvichak River watersheds, subsistence harvest areas do not necessarily correspond with watershed boundaries. As noted previously, villages outside of these watersheds use areas within the watersheds for subsistence activities.