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

Volume 3 of 3 – Appendices E-J

Appendix F: Biological Characterization: Bristol Bay Marine Estuarine Processes, Fish and Marine Mammal Assemblages

NOTICE

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U.S. Environmental Protection Agency

Seattle, WA

Biological Characterization:

Bristol Bay Marine Estuarine Processes,

Fish and Marine Mammal Assemblages

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ABSTRACT

Bristol Bay consists of a large, shallow sub-arctic marine estuary with distinct inner and outer bay processes. The entire bay is defined as waters east of the 162° longitude line. The outer bay is heavily influenced by marine currents, tides, and oceanic processes from the Southeastern Bering Sea. The inner bay, generally defined as waters between Cape Constantine in the north and Ugasik Bay in the south (Nushagak and Kvichak bays), are heavily influenced by high volumes of fresh water from several river systems. This fresh water influence dominates the head of Bristol Bay and much of the northern Togiak Bay nearshore zone. Nearshore currents in the larger bay generally follow a counter-clockwise gyre, moving east along the Alaska Peninsula before moving north and eventually west around Cape Newenham. Species assemblages and trophic interactions between marine invertebrates and anadromous, groundfish, and forage species are complex. Walleye pollock, yellowfin and rock sole, and red king crab represent marine species that in larval and juvenile phases are transported along currents into nearshore estuarine nursery habitat. Recent studies suggest complex predator-prey assemblages in nutrient-rich convergence zones between the inner and outer bay complex and along the northern nearshore zone. All five species of Pacific salmon are well established in these waters with historically stable and productive populations. Salmon, a unique keystone species, facilitate energy and nutrient transfer across multiple trophic levels from terrestrial head waters through pelagic marine ecosystems. Outbound migrations of billions of salmon smolt provide nutrition for numerous trophic levels and marine species. As juveniles, salmon smolt are recognized as a forage fish species. In their returning adult phase, they provide a valuable nutrient source to marine mammals and subsidize watersheds in the form of Salmon Derived Nutrients or Marine Derived Nutrients. These outwelling nutrients flushed into estuaries further contribute nutrient to estuarine processes. The range and distribution of Bristol Bay salmon have been documented throughout the Bering Sea, north into the Chukchi Sea and south into the North Pacific and Gulf of Alaska. Several marine mammal species such as killer and beluga whales, seals, and Steller sea lions are all known to inhabit Bristol Bay and pursue juvenile and adult salmon up rivers in the region.

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BRISTOL BAY

For the purpose of this discussion, we define Bristol Bay as the marine waters east of the 162° West longitude line along the shoreline from Cape Newenham to Cape Lieskof (Fig 1). In this context, Bristol Bay comprises approximately 1,300 kilometers of linear shoreline and nearly 65,400 square kilometers of semi-pelagic, nearshore, and estuarine habitat.

Bristol Bay consists of a large, shallow sub-arctic marine estuary with distinct inner and outer bay processes. The inner bay processes are continuously fed large volumes of fresh water from several watersheds and river systems, with salinity gradients increasing toward the 162 longitude line. The benthic topography is essentially flat (average gradient of 0.02 percent) with minimal variations in relief toward the continental slope. Within this gentle contour, Bristol Bay achieves an approximate maximum depth of 70m (Moore 1964, Buck et al. 1974).

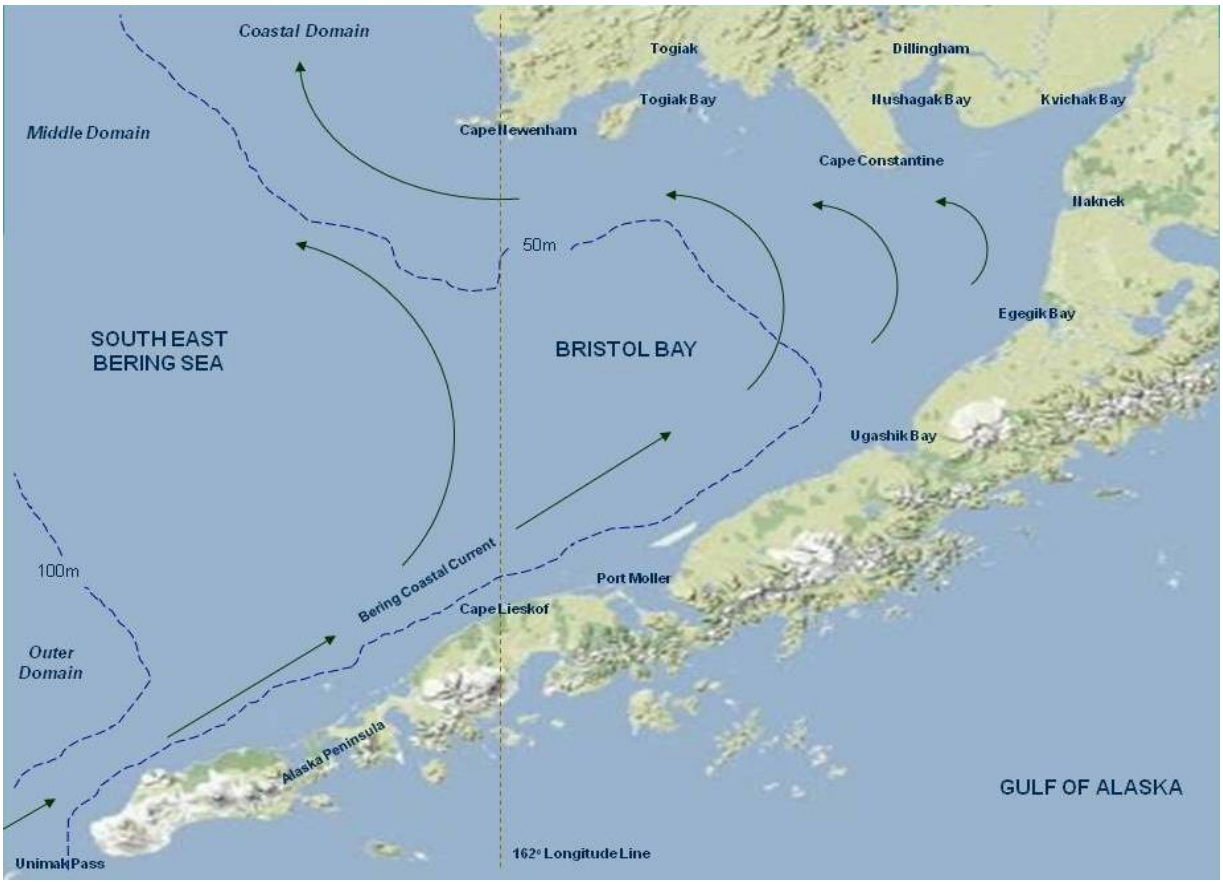

Fig1. Bristol Bay: Showing general current patterns (green arrows), benthic contour lines (50 and 100m blue dash), 162° West longitude line (brown dash), and significant land marks as reference (labeled).

Historically, Bristol Bay has been identified as having two relatively distinct current zones referred to as the inner and outer bays. Currents were generally characterized as moving in a counter-clockwise gyre under the influence of 3- to 23-foot tides (Buck et al. 1974, Straty 1977, Straty and Jaenicke 1980). Recent investigations describe the same waters as three current-

driven domains essentially based on depth: coastal or inner domain (0-50 m depth), a middle domain (50-100 m depth), and an outer or shelf domain (100-200 m) (Kinder and Coachman 1978, Kinder and Schumacher 1981, Coachman 1986, Schumacher and Stabeno 1998, Stabeno et al. 2001). The distinct physical properties can be documented (salinity, temperature, turbidity) at defined depths. However, the waters within each domain are highly interactive, constantly shifting under seasonal weather patterns and tides and currents. Bristol Bay and associated marine and estuarine processes are heavily influenced by often severe Eastern Bering Sea and Arctic weather. The earlier descriptions of the inner and outer bay complexes lie within these more recent descriptions of the middle and inner domains.

Estuarine Processes - Marine Influence

Outer Bristol Bay is essentially an extension of the Eastern Bering Sea. Flood tides from the North Pacific enter the Eastern Bering Sea through several Aleutian Island passes contributing to the Aleutian North Shore Current (Schumacher et al. 1979, Reed and Stabeno 1994, Stabeno et al. 2002 and Stabeno et al. 2005). To the east of Unimak Pass, the remnant of this current continues as the Bering Coastal Current, moving northeasterly along the Alaska Peninsula toward Bristol Bay (Kachel 2011, pers. comm.). Much of this current diverts north along the 50-meter contour forming a subtle, always shifting boundary between inner and outer bay waters (Coachman 1986). These currents eventually flow north and west around Cape Newenham toward Nunivak and Pribilof Islands. Seasonal levels of upwelling marine nitrates, carbon, phosphates and silica are quite high throughout the estuaries' inner domain contributing to the species complexity of Bristol Bay (Buck et al. 1974, Stockwell et al. 2001, Kachel et al. 2002, Coyle and Pinchuk 2002, Stabeno and Hunt 2002, Ladd et al. 2005). Considerable mixing occurs at the convergence of the inner and outer bay waters, often the area between Cape Constantine and Cape Newenham. Benthic substrate in the outer bay generally consists of silts and mud to vast aggregates of sand, gravel, cobble, and boulder (Sharma et al. 1972, NOAA 1987, Smith and McConnaughey 1999).

Estuarine Processes – Terrestrial Influence

Marine characteristics of the inner bay are heavily influenced by continual freshwater runoff from several river systems (Straty 1977, Straty and Jaenicke 1980). Four large rivers flow into Nushagak Bay: the Igushik, Snake, Wood-Tikchik and Nushagak, and three rivers flow into Kvichak Bay: the Naknak, Alagnak, and Kvichak.

The contributing discharge has been assessed as 112×10^{9} cubic meters of fresh water annually (~125,400-cubic feet per second [cfs] annual average) contributed to the inner bay and estuary complex (Buck et al. 1974). The Nushagak and Kvichak Rivers drain 22,172 square miles (14,190,134 acres) of watershed (USGS 2011). The Nushagak River has a mean annual discharge of 28,468 cfs, based on the summation of the Nushagak River gage (USGS No. 15302500, 23,645 cfs) and the Wood River gage (USGS No. 15303000, 4,823 cfs). The Kvichak River USGS gage (USCS No. 15300500) located at Iguigig (the outlet of Lake Iliamna) has an average annual flow of 17,855 cfs. Assuming these three gauges represent an accurate

estimate, the total discharge is 46,323 cfs, or approximately 33,536,000-acre-feet per year[1]. There are many other sources of fresh water contribution not monitored or included in this estimate.

This fresh water influence dominates the head of the bay between April and November. Out-welling water contributions are significantly higher in the summer than winter due to freezing surface water conditions in the watersheds. As a result, summer ebb tide currents often considerably exceed the flood tides. Discharges from these watersheds keep the inner bay waters colder than the outer bay in early spring; however, by mid-summer these temperatures reverse with much warmer terrestrial discharges (Buck et al. 1974)**.** Additionally, the counter-clockwise gyre of the inner bay concentrates these freshwater discharges in Nushagak Bay and maintains lower salinity compared to Kvichik bay. The highest recorded sea surface salinity measurement in the middle estuary of the Nushagak is 10 parts per thousand (ppt), compared to 20ppt in the Kvichik (Radenbaugh 2011, pers. comm.).

The inner Bristol Bay coastal domain exhibits the least fluctuation in saline but the greatest fluctuation in temperature of the three domains, because of the tremendous freshwater influences (Straty and Jaenicke 1980). Earlier studies characterizing temperature and salinity gradients illustrate differences in salinity and temperature between the innermost bay (salinity 28.9% and temp 11.4^{o}C) and the outermost bay (salinity 32.7% and temp 7.4^{o}C) (Buck et al. 1974, NOAA 1987). Recent analysis of oceanographic currents, condition, and nutrients of the inner domain (inner and outer bay) confirms generally shallow, wind-driven, well-mixed, homogenous, nutrient-laden waters (Coyle and Pinchuk 2002, Kachel et al. 2002, Stabeno and Hunt 2002). Benthic substrate in the inner bay consists of mostly a composite of mud, silts, sands, and patchy gravels (Sharma et al. 1972, NOAA 1987, Smith and McConnaughey 1999).

Bristol Bay Marine Fish Assemblages

Inner Estuarine Fish Assemblage

Recent biological surveys in the Nushagak Bay estuary indicate that the dominant species in numbers and biomass include bay shrimp (*Crangon alaskensis*) and two species of *Gammarus*: Gammarid amphipods and mysiids (Radenbaugh 2010, pers. comm.). Walleye pollock (*Theragra chalcogramma),* generally recognized as a semi-pelagic species, have been identified in these nearshore surveys between Protection and Etolin Points. Flatfish species (*Pleuronectiformes*) such as yellowfin sole (*Limanda aspera*) have also been confirmed in nearshore habitats. Numerous other fish and invertebrate species are also abundant.

[1] The total discharge for the three river systems calculated as the annual sum of the daily mean discharges for respective periods of record. Kvichak River 1967-1987, Nushagak River 1977-1993, Wood River 1957-1970.

Nearshore surveys conducted by NOAA's Alaska Fisheries Science Center (NOAA-AFSC) in Nushagak and Togiak bays further illustrate the diversity of nearshore fish and invertebrate species (Olmseth 2009), identifying over 40 fish and invertebrate species. Most captured individuals were less than 20 cm in length. Of these species, shrimp (*Crangonidae*) and rainbow smelt (*Osmerus mordax*) were the most abundant species encountered, occurring in almost every trawl and beach seine. The dominance of these species in catches was especially high in very shallow water with mud and silt bottoms. Forage fish species identified were salmon smolt (*Salmonidae*), capelin (*Mallotus villosus*) and herring (*Clupea pallasii*), as well as poachers (*Agonidae*), sculpin (*Cottoidea*), flatfish (*Pleuronectiformes*), and greenling (*Hexagraaidae*).

Nearshore Fish Assemblages

The importance and contribution of forage fish populations to marine trophic levels and ecosystems are widely recognized. Forage fish species such as Pacific herring, eulachon (*Thaleichthys pacificus*), capelin, and rainbow smelt are all well documented in different nearshore zones of Bristol Bay (Warner and Shafford 1981, Mecklenburg et al. 2002, Bernard 2010). Pacific herring are known to spawn in nearshore waters of Togiak and along the northern shoreline of the Alaska Penninsula (Bernard 2010). Sand lance (*Ammodytes hexapterus*) have been found in particular abundance in these nearshore waters of the Alaska Peninsula (McGurk and Warburton 1992). Bristol Bay salmon smolt are also considered forage fish (Gaichas and Aydin 2010).

Surveys conducted primarily to characterize the presence and distribution of forage fish species (sand lance and rainbow smelt) in Bristol Bay nearshore waters also identified several species of groundfish: Pacific cod (*Gadus macrocephalus*) and walleye pollock as well as juvenile sockeye salmon (*Oncorhynchus nerka*) (Isakson et al. 1986, Houghton 1987). In one phase of this survey, researchers found juvenile sockeye salmon to be more abundant than any forage fish or juvenile ground fish species encountered. Present again, though in lesser numbers, were Pacific herring, capelin, pond and surf smelt, and eulachon. The presence, abundance, and biodiversity of these species in Bristol Bay estuaries and nearshore habitat reflect our current understanding of these areas as nutrient-rich fish nurseries.

Similar surveys of nearshore habitat conducted in neighboring Alaskan waters further illustrate the complexity and diversity of fish and invertebrate assemblages (Norcross et al. 1995, Abookire et al. 2000, Abookire and Piatt 2005, Arimitsu and Piatt 2008, Thedinga et al. 2008, Johnson et al. 2010). Anadromous species, as well as groundfish, forage fish and invertebrate species are all well represented in many of these nearshore and estuarine areas in a variety of different habitat and substrate types throughout Alaskan nearshore and estuarine zones.

Offshore Fish Assemblages

NOAA-AFSC has conducted annual surveys of the Eastern Bering Sea (EBS) offshore and outer Bristol Bay waters since 1982. These surveys provide a representation of the numerous groundfish species that inhabit the EBS and Bristol Bay deeper than the 15-20m contour (Lauth

2010). Data from these surveys are used to monitor status of stocks, assist in establishing annual commercial catch limits, and evaluate trends in ecosystem and trophic level complexity.

Hundreds of fish and invertebrate species inhabit Bristol Bay waters and contribute to countless trophic levels at various life stages. Description of all known species is beyond the scope of this discussion. However, all species identified in these surveys are listed to provide some context (Table 1). To summarize the more commonly recognized species: represented are cod and pollock (*Gadidae*), fifteen species of flatfish (*Pleuronectiformes*), and forage fish species such as herring, eulachon, capelin, smelts, sand lance and sandfish. Dozens of other species of skate (*Rajidae*), poachers (*Psychrolutidae*), greenling (*Hexagrammos)*, rockfish (*Scorpaenidae*), sculpin (*Cottidae*), crab (*Cancer*), and salmon are also well represented.

The transport and distribution of larval marine fish and invertebrate species from offshore to nearshore nursery areas are widely recognized (Norcross et al. 1984, Lanksbury et al. 2007). This relationship between species presence and oceanic and estuarine processes is represented in Bristol Bay in the life histories of species such as red king crab (*Paralithodes camtschaticus***)**, yellow fin and rock sole, and walleye pollock. Larval forms of each species are transported and concentrated in nutrient rich nearshore and estuarine habitat in the inner bay.

The second-largest population of red king crab is located in Bristol Bay (Dew and McConnaughey 2005, Chilton et al. 2010). Although red king crabs at several stages of maturity are found throughout central Bristol Bay, immature larvae and juveniles are often concentrated along nearshore areas in the inner bay depending on environmental influences. A key habitat feature supporting this life history strategy is the "unbroken coastal shelf and longshore current" which transports larval king crab from the EBS and outer Bristol Bay to the inner bay complex. As previously discussed, this current is driven by the Aleutian North Shore Current and Bering Coastal Current. As a result of nektonic and planktonic drift through the Bristol Bay gyre, larval red king crab settle in cobble and gravel substrates of Kvichak Bay (Loher et al. 1998) and are present along nearshore zone in the Togiak district (Olmseth 2009).

The nearshore benthic substrates of inner and outer Bristol Bay are optimal habitat for several species of flatfish and invertebrates that inhabit the EBS (McConnaughey and Smith 2000). Flatfish species are well represented in this nearshore coastal domain as well (Lauth 2010 – Table 1). Life histories of several flatfish species, specifically yellowfin and rock sole, take advantage of similar current mechanisms that transport larvae into favorable nursery areas (Nichol 1998, Wilderbuer et al. 2002, Norcross and Holladay 2005, Lanksbury et al. 2007, Cooper et al. 2011). Larval and juvenile yellowfin sole are present (Olmseth 2010) and abundant in shallow nearshore areas along the northern shore and Togiak Bay (Nichol 1998, Wilderbuer et al. 2002).

Walleye pollock are a semi-pelagic species spawning in open marine waters (Bailey et al. 1999). As discussed in Coyle (2002), pollock in their larval and juvenile forms are also known to be transported into nearshore nursery zones. The presence of pollock eggs and larvae along the north shore of the Alaska Peninsula is apparently fairly common (Bailey et al., 1999). Prevailing currents are northward, along the eastern shore of Bristol Bay (Napp et al., 2000). The eggs and

larvae from the Alaska Peninsula region are apparently transported northward by the current and by August–September the zero year class juveniles are observed off Cape Newenham and Nunivak Island (Bailey et al., 1999).

The trophic relationship between fish (predator) and invertebrate (prey) species is intuitive. A recent investigation of trophic interactions using stable isotopes provides further explanation and illustrates a stronger correlation between pollock and euphasiid populations near the convergence zone within the inner domain (Aydin 2010). Pollock, found in northern nearshore zones feeding on mysiids show "a higher δ15N ratio than pollock in the southwest along the Alaska Peninsula." The results further suggest "Mysiids are more abundant in the diets of pollock in the northern near shore zone than deepwater forage fish". These findings further substantiate our understanding of nearshore and estuarine zones as nutrient rich fish nursery areas, but may also suggest evidence of a terrestrial driven nutrient contribution to a marine estuary.

Bristol Bay Salmon

The ecological role of Bristol Bay salmon is complex. Salmon facilitate energy and nutrient exchange across multiple trophic levels from terrestrial headwaters through marine ecosystems. Each species migrates through these ecotones at slightly different times depending on life history and watershed of origin. Bristol Bay sockeye salmon, because of their abundance, distribution, and overall economic importance, have been more extensively studied than other salmonids in the region. Generally, once in marine waters juvenile salmon spend their first summer in relatively shallow waters on the southeastern Bering Sea shelf, feeding, growing and eventually moving offshore into the Bering Sea basin and North Pacific Ocean (Meyers et al. 2007, Farley et al. 2011, Farley 2012, pers. comm.).

Range and Distribution

Essential Fish Habitat (EFH) for juvenile salmon, because of their broad range and distribution, is generally defined as all marine waters over the continental shelf within the Bering Sea extending north to the Chukchi Sea, and over the continental shelf throughout the Gulf of Alaska and within the inside waters of the Alexander Archipelago (Echave et al. 2011). EFH for immature and mature Pacific salmon includes nearshore and oceanic waters, often extending well beyond the shelf break, with fewer areas in the Alexander Archipelago (Echave et al. 2011). The Magnuson-Stevens Fisheries Conservation and Management Act defines EFH as waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity. For salmon, EFH comprises those fresh and marine waters needed to support healthy stocks and provide long-term sustainable salmon fisheries (Eagleton 2012, pers. comm.).

In their emigration phase, anadromous juvenile salmon occupy shallows of estuaries and nearshore zones though timing, duration, and abundance vary throughout the year depending on species, stock, and life history stage (Groot and Margolis 1991, Quinn 2005). Nearshore and estuary habitats act as a physiologic transition zone supporting the smoltification process and osmoregulatory changes between fresh and saltwater ecotones (Hoar 1976 and 1988, Clarke and

Hirano 1995, Dickhoff et al. 1997). Some sub-yearling salmon (Northwest stocks) have been shown to repeatedly move through zones of low and high salinity (Healey 1982, Levings 1994, Levings and Jamieson 2001). These habitats and associated processes are integral to the survival and growth of salmonid (Simenstad et al. 1982, Simenstad 1983, Thom 1987).

The EBS shelf is important nursery grounds for juvenile Bristol Bay sockeye salmon (Farley et al. 2009). Early models of EBS and North Pacific salmon stocks describe migrations and broad distributions to the south and east in winter and spring, and to the north and west in summer and fall (French et al. 1975, French et al. 1976, Rogers 1987, Burgner 1991, Shuntov et al. 1993). These studies were the first to suggest population migrations crossed the Aleutian Island chain into the North Pacific (Meyers et al. 1996, Myers 2011 pers. comm.). Recent investigations incorporating genetic (DNA) and scale pattern analysis validate these observations (Bugaev 2005, Farley et al. 2005, Habicht et al. 2005, Habicht et al. 2007, Myers et al. 2007). Investigations conducted in the autumn 2008 and winter 2009 substantiate the migration of juvenile Bristol Bay sockeye salmon from the EBS shelf to the North Pacific, south of the Aleutian Island chain (Habitch et al. 2010, Farley et al. 2011, Seeb et al. 2011):

> "In their first oceanic summer and fall, juveniles are distributed on the eastern Bering Sea shelf, and by the following spring immature salmon are distributed across a broad region of the central and eastern North Pacific. In their second summer and fall, immature fish migrate to the west in a band along the south side of the Aleutian chain and northward through the Aleutian passes into the Bering Sea. In subsequent years, immature fish migrate between their summer/fall feeding grounds in the Aleutians and Bering Sea and their winter habitat in the North Pacific. In their last spring, maturing fish migrate across a broad, east-west front from their winter/spring feeding grounds in the North Pacific, northward through the Aleutian passes into the Bering Sea, and eastward to Bristol Bay." (Farley 2011)

More than 55% of ocean age-1 sockeye salmon sampled during those winter surveys in the North Pacific came from Bristol Bay stocks. These broad seasonal shifts in distribution likely reflect both genetic adaptations and behavioral responses to environmental cues (e.g., prey availability and water temperature) that are mediated by bioenergetic constraints (Farley et al. 2011).

Salmon Contribution to Trophic Levels

A recent evaluation was conducted by the NOAA-AFSC Ecosystem Modeling Team to assess the contribution of the Nushagak and Kvichak River sockeye salmon to trophic dynamics in the EBS shelf and North Pacific ecosystems (Gaichas and Aydin 2010). This evaluation provides additional insight into the role and contribution of outbound salmon smolt to Bristol Bay and EBS trophic interactions. Using estimates of outbound salmon smolt survival and adult returns, researchers found that these two rivers account for nearly 70% (56,000 of 81,100 tons) of adult salmon biomass in the EBS. Depending on environmental influences and number of out-migrating and surviving smolt, juvenile sockeye salmon from these two river systems may rank among the top ten forage groups. When compared with only single species stock groups, they rank between fifth and seventh in importance, comparable to Pacific herring or eulachon. In the

open ocean, sockeye salmon represent 47% of total estimated salmon biomass present in the eastern subarctic gyre (Aydin et al. 2003). Bristol Bay sockeye salmon from the Nushagak and Kvichak River systems comprise 26% of total sockeye salmon biomass, and 12% of total salmonid biomass in the entire eastern subarctic gyre. The Nushagak and Kvichak River systems produce a significant portion of all salmon in offshore marine ecosystems and the majority of salmon on the EBS shelf; these salmon represent the majority of juvenile and returning adult salmon biomass (Gaichas and Aydin 2010). Results from an unrelated study indicate outbound salmon smolt may export more nitrogen and phosphorus than adult salmon transported into watersheds from the ocean (Moore and Schindler 2004).

It is well documented that returning adult salmon subsidize watersheds in the form of salmon derived or marine-derived nutrients (Gende et al. 2002, Schindler et al. 2003, Wilson et al. 2004). The contribution of out-welling marine-derived nutrients, mass transport of nutrient back to estuarine processes further expands upon this concept. Nutrient transport is facilitated in the form of partial and whole salmon carcasses or particulates and dissolved nutrients (carbon, nitrogen and phosphorous) moving from watersheds back to estuaries. Earlier studies identified the flow of salmon carcasses out of the coastal watersheds into marine estuaries as a result of high precipitation events (Brickell and Goering 1970, Richey et al. 1975). Salmon-derived nutrients stimulate primary production in estuaries where nitrogen and phosphorus are often limiting nutrients (Rice and Ferguson 1975). Estuarine algae use dissolved marine-derived nutrients, in turn feeding copepods which feed juvenile salmon (Fujiwara and Highsmith 1997). One investigation identified several species of marine invertebrates feeding on salmon carcasses (Reimchen 1994). Stationary whole salmon carcasses were completely consumed in a week. Gende (2004) estimated that 43% of the tagged salmon carcasses washed into the study estuary within days. More recent investigations conducted in Alaskan waters estimate that the contribution of marine-derived nutrients to marine estuarine processes may be as high as 60%, or two thirds of potential nutrient transported back to the estuary (Johnston et al. 2004, Mitchell and Lamberti 2005).

In the Nushagak and Kvichak Bays, marine-derived nutrients liberated from tens of millions of decomposing adult salmon likely have a significant influence on trophic interactions and biodiversity. Estuarine processes such as primary and secondary production and countless marine fish and invertebrate species benefit from this mass transport. These and a multitude of similar studies indicate marine and estuarine vegetation, and larval and juvenile invertebrate and fish populations benefit from outwelling marine-derived nutrients washed back into estuaries.

Bristol Bay - Marine Mammals

The EBS supports numerous species of marine mammals including whales (Cetacea) of the suborders Odontoceti (toothed whales and porpoise) and Mysticeti (baleen whales). Several species of seals (pinnipeds) are also found (Otariidae, Phocidae, and Odobenidae) in these waters (Allen and Angliss 2010). Of marine mammals present in the EBS, twenty species occur in Bristol Bay in significant numbers and regularity to be distinguished in this discussion (Table 2). Three species of baleen whale (fin, right and humpback whales) and one pinniped species

(Western DPS Steller sea lion) found in Bristol Bay are recognized by federal or state agencies as threatened, endangered, or listed as species of concern.

In Bristol Bay, the presence of marine mammals and prey species varies depending on seasonal range and migratory patterns. The variability in seasonal range of sea lions or fur seals, for two examples, prevents us from accurately identifying annual presence and feeding habitats. Because scat and stomach content studies can be conducted only while specimens are on the rookery, the only prey species represented in dietary analysis are those close to the rookeries.

Some data on marine mammal diets show seasonal dependence on salmon. Several studies demonstrate that salmon are a nutritional source for several marine mammal species (Pauly et al. 1998a). Many marine mammals, especially pinniped and ondontocete species, prey on adult and juvenile salmon in nearshore zones.

Pinnipeds

Sea lion predation on salmon has been confirmed from scat and stomach content studies, from which researchers have estimated the level and frequency of consumption (NMFS 1992, Merrick 1995, Merrick et al. 1997, Sinclair and Zeppelin 2002, Trites and Donnelly 2003, Jemison 2011, pers. comm.). Depending on seasonal range and migratory patterns, salmon ranked high as a selected prey species in Steller sea lion diets (Sinclair and Zeppelin 2002). During the summer, the endangered western stock of Steller sea lions relies on salmon, which rank second in frequency of occurrence in summer diets in all regions between 1990 and 1998 (Sinclair and Zeppelin 2002). During the winter, the level of salmon in Steller sea lion diets increased due to out-migrating juvenile Bristol Bay salmon (Sinclair and Zeppelin 2002).

An investigation conducted to determine prey species of northern fur seals in the Pribilof Islands (Sinclair et al. 2008) found that salmon composed part of the diet of fur seals on St. George and St. Paul Islands. Pacific salmon (Oncorhynchus spp.) had a mean annual frequency of occurrence of 14.4%, and 10% in any one year on St. George and St. Paul Islands respectively. In similar nutrition studies of EBS northern fur seals, salmon rank second among fish in frequency of occurrence for animals on both Pribilof Islands from late July though September, 1990-2000 (Gudmundson et al. 2006). Another study indicates that salmon constitute a portion of fur seal diets throughout the Pacific, from California to the species' western Alaskan range (Perez and Bigg 1986).

Harbor seals are also found throughout Bristol Bay and the EBS and also prey upon species of Pacific salmon (Jemison et al. 2000, Small et al. 2003, Hauser et al. 2008, Allen and Angliss 2010, Jemison 2011, pers. comm.). Lake Illiamna supports one of two recognized fresh water populations of harbor seals (Smith et al. 1996). This population is defined as relatively small with maximum aerial counts of hauled-out harbor seals ranging from 137 to 321. These counts do not reflect absolute abundance (Mathisen and Cline 1992, Small 2001). Though this population has colonized Lake Iliamna from Bristol Bay via the Kvichak River, there is no evidence that populations move to and from the salt water estuary to the fresh water lake (Mathisen and Kline 1992, Hauser et al. 2008). Current information indicates the Lake Illiamna population is resident. Harbor seals have also been identified in the Nushagak and Wood River

systems. In the Wood River system, Harbor seals are observed in Lake Aleknagik (B. Andrew 2011, pers. comm., Chythlook 2011, pers. comm., Tinker 2011, pers. comm.). Spotted seals tagged in both Alaskan and Russian sectors of the Bering Sea showed clear seasonal preference for nearshore habitat and associated fisheries. These populations fed mostly on fishes, such as salmon (*Onchorhynchus* spp.), saffron cod (*Eleginus gracilus*), and herring (Burkanov 1989, Lowery et al. 2000).

Toothed Whales

Beluga whales are abundant in Bristol Bay from spring through fall near the mouths of the Kvichak, Nushagak, Wood, and Igushik Rivers. Earlier studies document the importance and contribution of sockeye salmon in beluga nutrition (Brooks 1955). Lensink (1961) noted that belugas fare poorly in Bristol Bay when migratory (anadromous) fish are not available. In addition to following the general movements of its prey, belugas appear to feed specifically where its prey species are most concentrated. The frequency of occurrence of salmon species in beluga stomachs is correlated with the abundance of each species during their respective migrations (Brooks 1955). Studies conducted by Brooks in the 1950s further indicate that belugas feed on both juvenile and adult salmon, as well as on several other forage fish and invertebrate species (Klinkhart 1966).

From 1993 to 2005, the beluga population increased in abundance by 4.8% per year, and while thresholds of prey abundance needed for belugas to thrive are not fully understood, the larger size of red salmon runs before and during the period covered by aerial surveys may partially explain the increased beluga numbers (Lowry et al. 2008). Belugas are well known to travel up these rivers in pursuit of salmon. They have been seen feeding on salmon in the Kvichak River past Levelock to the Igiugig Flats (Cythlook and Coiley 1994, G. Andrew 2011, pers. comm.). In summer, belugas are routinely observed in the Nushagak River (P. Andrew 2011, pers. comm.). In the Wood River system, belugas have been observed in Lake Aleknagik (Fried et al. 1979, B. Andrew, 2011, pers. comm., Tinker 2011, pers. comm.).

Killer whales also inhabit Bristol Bay waters. They have been seen in nearshore waters and frequent the lower river reaches chasing and preying upon salmon and beluga whales (Frost and Lowry 1981, Frost et al. 1992, Allen and Angliss 2010, Quakenbush 2011, pers. comm.). In a recent observation (July 17, 2002), killer whales displayed cooperative feeding behaviors near the Nushagak spit. A pod formed a circle with their tails facing toward the center, fluke slapping on the surface of the water. A male killer whale emerged through the center of the circle with a mouth full of salmon (Tinker 2011, pers. comm.). In the Nushagak River, killer whales have been observed chasing both belugas and coho salmon (Cythlook 2011, pers. comm.). In late fall, in the absence of beluga whales, killer whales pursue late run and fall coho up the Nushagak iver (P. Andrew 2011, pers. comm.).

Though opportunistic feeders, fish-eating killer whales show an affinity to salmon. The results of a 14-year study of the diet and feeding habits of killer whales in Prince William Sound identify two non-associating groups of killer whale, termed *resident* and *transient* (Bigg et al.

1987). The resident group (fish eaters) appears to prey principally on salmon, preferring coho (*O. kisutch*) over other more abundant salmon species (Saulitis et al. 2000). Another distinct population of Alaskan fish-eating killer whales off the coast of British Columbia moves seasonally to target salmon populations (Nichol and Shackleton 1996). Field observations of predation and stomach content analysis of stranded killer whales collected over a 20-year period document 22 species of fish and 1 species of squid that dominated the diet of fish-eating resident killer whales (Ford et al. 1998). Despite the diversity of fish species taken in these studies, fish-eating resident killer whales showed a clear preference for salmon: 96% of fish taken were salmonids. Of the six salmonid species identified, by far the most common was Chinook, representing 65% of the total sample. The second most common was pink at 17%, followed by chum (6%), coho (6%), sockeye (4%), and steelhead (2%) (Ford et al.1998). Though likely a separate population, Bristol Bay killer whales are likely to have similar feeding behaviors.

Sperm whales, another species of toothed whales not identified in Bristol Bay waters as defined in this discussion, have been known to prey upon salmon in the EBS. Though feeding primarily on mesopelagic squid in the North Pacific, the species has also been documented as consuming salmon as well as several other species of fish (Tomilin 1967, Kawakami 1980).

Baleen Whales

Investigations of baleen whale feeding habits in the North Pacific and Bering Sea have documented species such as humpbacks targeting small schooling fish populations, including salmon among numerous species of fish identified (Nemoto 1959, Tomilin 1967, Kawamura, 1980). More recently, humpback whales have been observed off Cape Constantine in the spring, presumably feeding on schooling herring and possibly outmigrating salmon smolts (Cythlook 2011, pers. comm.). In southeast Alaska, humpback whales have been observed preying upon both wild and hatchery out-bound salmon smolts as well as adult pink salmon (Straley et al. 2010, Straley 2011, pers. comm.). Humpback whales have been shown to exhibit site fidelity to feeding areas, and return year after year to the same feeding locations (Baker et al. 1987, Clapham et al. 1997). There is very little interchange between feeding areas (Baker et al. 1986, Calambokidis et al. 2001, Waite et al. 1999, Urban et al. 2000).

Discussion

Habitat Condition

Natural hydrology and associated ecosystem processes in the Bristol Bay region remain functionally intact and in pristine condition, from head water tributaries through marine estuary and nearshore zones. This condition and the connectivity and complexity of intact hydrologic processes are the key habitat attributes accountable for the current abundance and resilience of all existing fisheries. The historic sustainability of the region's salmon populations is the key indicator of this pristine habitat condition. The current abundance of salmon stocks contribute to the productivity of the species, the strength of individual stocks and strength of other regional fisheries at multiple trophic levels. Bristol Bay is identified as EFH for salmon and numerous

fish and invertebrate species that at some stage in their life histories migrate through, rear, or spawn in these waters. As previously noted, these marine estuarine and near shore waters are "fishery nurseries."

Water

Estuary and nearshore habitat is no longer simply viewed as hard substrate or vegetation. Water is recognized as habitat identified as soft substrate on moving convergence zones. Water chemistry, trace elements, salinity and temperature gradients all influence habitat condition, nutrient production, and species abundance. The availability, complexity, and interaction of water and nutrient sources are fundamental to all trophic levels. Water quality influences nutrient availability, in turn influencing all trophic levels, interactions, and the fundamental quality of the habitat. If foraging and prey opportunities are not available, the quality of the habitat is significantly diminished.

Bristol Bay resembles other Alaskan estuaries as subarctic and allochthonous in nature. As discussed above, the inner Bristol Bay estuary is dominated by terrestrial freshwater runoff from seasonal snow melt and rains. Turbidity may minimize photosynthetic influence, production, and associated algal blooms; however, nutrient sources and production are supported in part by the outwelling discharge of detritus, dissolved organic material, and salmon-derived nutrients or marine-derived nutrients, as discussed below. These dissolved organic materials provide an essential energy source for lower trophic levels supporting abundant assemblages of minute bacteria and fungi, through larval and adult stages of plankton, invertebrates, juvenile fish and salmon smolt. The abundance and availability of nutrient sources are essential to the survival of salmon smolt in their early estuarine and marine phase. Successful smolt survival is reflected years later in the strength of returning adult runs and escapement.

Estuaries

In the Columbia River, Rich (1920) recognized young Chinook salmon were found throughout the estuary at various age and size classes throughout the year. Rich concluded that this presence represented; 1) independent populations whose separate movements and rearing patterns reflected different environmental conditions across the basin, and 2) increased estuarine residence time increased growth rates over freshwater cohorts suggesting improved rearing conditions in the estuary (Bottom 2005). Other studies and associated literature on this subject substantiate these conclusions and have increased our understanding of the importance of estuarine habitat to salmon smolt survival (Healey 1982, Levy 1992, Thorpe 1994, Groot and Margolis 1998, Quinn 2005, Koski 2009).

As Koski discussed (2009), several studies in Alaska document different life-history strategies used by Chinook, coho and sockeye juveniles, which reflect increased survival in estuarine habitat (Murphy et al. 1984, Heifetz et al. 1989, Johnson et al. 1992, Thedinga et al. 1993 and 1998, Koski and Lorenz 1999, Halupka et al. 2003). Studies identify marine estuaries as an often preferred habitat choice for coho salmon, providing increased food and growth, expanding their

nursery area, and increasing the overall production from the watershed. These cited studies and numerous others suggest that estuaries are important for the early life history phase of Chinook and sockeye salmon as well. The high productivity of some estuarine habitats in Alaska allows expression of an array of life history patterns (Healey1983). One successful survival strategy involves a combination of both riverine and estuarine rearing allowing salmon to migrate and rear in the estuaries for a summer and in some cases return and over winter in rivers (Reimers 1971, Murphy et al. 1984, 1997, Harding 1993, Koski and Lorenz 1999, Miller and Sadro 2003, M. Wiedmer 2013, pers. comm.). Moving between estuarine and riverine ecotones increases feeding opportunity, allows smolt to achieve critical size (discussed below), and supports osmoregulatory change in their early marine phase. The dominant freshwater influence of inner Bristol Bay facilitates osmoregulatory adjustment prior to exposure to the highly saline marine phase.

Salmon Food Habits

Brodeur and Pearcy (1990) published a review that documented prey of all five North Pacific salmon and ocean phase trout. Feeding habits vary by species, life stage, region, and seasonal prey availability; however, prey species repeatedly identified were euphausiids, hyperiids, amphipods, copepods, pteropods, and chaetognaths. Egg, larval, and juvenile stages of numerous forage fish, groundfish, and invertebrate species were also identified. Landingham and Sturdevant (1997) reported that the prey spectrum for juvenile salmon species was composed of 30 taxa. The six taxa groups of most importance were calanoid copepods, hyperiid amphipods, euphausiids, decapods, larval tunicates and fishes. Other studies identify similar prey assemblages: euphausiids, hyperiids, amphipods, copepods, pteropods, chaetognaths, and polychaetes (Auburn and Ignell 2000, Orsi et al. 2000, Powers et al. 2006, Weikamp and Sturdevant 2008).

Food habit studies conducted in Cook Inlet and Knik Arm further illustrate the importance of estuarine invertebrate prey assemblages for smolt (Houghton 1987, Moulton 1997, summarized in USFWS 2009). These studies analyzed stomach content data and revealed that salmon smolt ingest substantial quantities of food during their residency in estuaries. Salmon smolt tend to be well nourished and in some cases demonstrate prolonged estuarine residence time feeding extensively on plentiful larval and juvenile invertebrate and fish species. Although these studies pertain exclusively to Cook Inlet and Knik Arm, the prey species identified in these studies are also abundant in the Bristol Bay estuary and are discussed and listed in this review (pages 3 and 4, and table 1).

Critical Size

Reliance on abundant prey in the estuary during the early marine phase has been illustrated in the "critical size" discussion. Earlier studies suggested slower growing salmon smolt experience greater size-selective predation (Parker 1968, Willette et al. 1999). Smolt that fail to achieve a critical threshold size by late spring and early summer fail to survive their first winter (Mahnken et al. 1982). Stunted smolt and juveniles suffer protein energy deficiency and are more likely to

become prey for other marine species rather than becoming adult predators. Salmon smolt need to reach a critical size and strength to survive their first year in the open ocean (Beamish 2001 and 2004). Studies of Bristol Bay salmon in their marine phase in the Eastern Bering Sea indicate that reduced growth of some salmon during their first year at sea may lead to substantial mortality (Moss et al. 2005, Farley et al. 2007). Greater nutrition and prey availability lead to larger juvenile salmon which gain a survival advantage over smaller individuals (Farley et al. 2007 and 2011).

Trophic Contribution

Salmon-derived nutrients or marine-derived nutrients subsidize watersheds with organic nutrients such as carbon, nitrogen, and phosphorus, first in the form of whole carcasses and large solids and later as dissolved particulates (Willson et al. 1998, Cederholm et al. 1999, Gende et al. 2002, Naiman et al. 2002). Salmon carcasses, which are considerably enriched in stable isotopes 13 Carbon and 15 Nitrogen (δ13C and δ15N), contribute to primary production in freshwater streams, lakes and estuaries (Stockner 1987, Cederholm et al. 1989 and 2000, Kline et al. 1990 and 1993, Bilby et al. 1996, Wipfli et al. 1998). As discussed above, terrestrial and aquatic species, invertebrates and insects through mammals, as well as aquatic and riparian vegetation, are all influenced by and receive benefit from seasonal pulses of salmon- or marine-derived nutrients (Reimchen 1994, Wilson and Halupka 1995, Bilby et al. 1996 and 1998, Ben-David et al. 1997 and 1998, Wipfli et al. 1998, Cederholm et al. 1999, Gende and Wilson 2001, Helfield and Naiman 2001, Chaloner et al 2002, Chaloner and Wipfli 2002, Darimont and Reimchen 2002, O'Keefe and Edwards 2002, Reimchen et al. 2002 and 2003, Darimont et al. 2003, Mathewson et al 2003, Johnston et al. 2004, Lessard and Merritt 2006, Moore et al. 2007, Christie 2008, Christie and Reimchen 2008, Janetski 2009).

Coastal watersheds drain to the ocean and influence marine estuaries (Milliman 2010, Dade 2012). Stream and riparian productivity can influence downstream estuarine areas through the transport of terrestrial and freshwater dissolved organic material (Murphy 1984, Jauquet et al. 2003, Jonsson and Jonsson, 2003, Cak 2008). It is intuitive then to consider the influence and contribution of salmon- or marine-derived nutrients to the marine estuary production of seasonal larval and juvenile plankton, invertebrate and fish species. One early study to suggest the influence of salmon- or marine-derived nutrients on estuary water chemistry was conducted in Port Walther, Alaska. Brickell and Goering (1970) found that salmon carcasses in Sashin Creek were flushed into the estuary and elevated levels of organic nitrogen. Richey (1975) observed similar flushing of salmon carcasses into estuaries. Reimchen (1994) observed entire salmon carcasses rapidly consumed by several species of estuarine invertebrates. Gende (2004) reported that 43% of tagged carcasses in one watershed washed into the estuary within days. Fujiwara (1997) presented evidence that dissolved salmon- or marine-derived nutrients fuel estuarine productivity and associated bacteria and algae, in turn increasing the numbers of harpacticoid copepods that serve as primary prey for out-bound juvenile salmon. Recent nutrient mass transport estimates indicated “substantial amounts of salmon- or marine-derived nutrients, 46%-60% depending on elemental speciation and environmental influences move directly back to the

estuary" (Mitchell and Lamberti 2005). A similar study suggests marine bivalves in estuaries also benefit from salmon- or marine-derived nutrients as a nutrition source (Chow 2007).

These studies indicate the influence of salmon- or marine-derived nutrients on trophic productivity in marine estuaries. They also suggest a positive feedback mechanism in salmon production, given that decomposing adult salmon provide nutrient subsidizing lower trophic levels and prey species to their out bound prodigy (Fujiwara and Highsmith 1997, Gende et al. 2004). As Aydin explained (2010), "Mysiids, as an inshore zooplankton (appearing in diets primarily in shallow waters of Bristol Bay) have a nitrogen isotope (δ15N) level higher than deepwater forage fish." This strong nitrogen signal was observed in euphausiid and walleye pollock inhabiting northern Bristol Bay nearshore waters (page 6). Though this unusually high nitrogen signal is not fully explained, it may be the result of the seasonal increase of dissolved organic material flushed into the estuary by seasonally high freshwater discharge, both entrained in the current gyre along the northern shore of the inner Bristol Bay. Furthermore, smolt emigration theoretically exports more nutrient to the estuary than previously recognized. Salmon smolt are recognized within the forage fish guild and also contribute later in sub-adult and adult phases in the Bering Sea and North Pacific. The seasonal transfer of nutrient and energy in different forms from terrestrial watersheds to the marine estuary may be represented in this nutrient signal [nitrogen isotope (δ15N)].

Summary

Pacific salmon are viewed as a keystone species influencing the condition of terrestrial and marine ecosystems (Willson and Halupka 1995; Cedarholm et al.1999; Helfield and Naiman 2001; Piccolo et al. 2009). Due to their life history, anadromy, range, and distribution, Bristol Bay salmon clearly represent a link between fresh water, estuarine, and marine systems. Seasonal freshwater discharges transport dissolved organic material and salmon- or marine-derived nutrients to the estuary. This freshwater also provides a buffer to highly saline marine waters and facilitates osmoregulatory adjustment in smolt. The estuary provides rich foraging opportunity and rearing environment that support salmon smolt growth and allows smolt to achieve the size essential for survival in the early marine phase.

At the beginning of their life cycle, emigrating smolt contribute to estuarine and marine productivity as a forage fish species. At the end of their life cycle, adult salmon provide the salmon- or marine-derived nutrients that influence nutrient productivity from watersheds through the estuary. It is suggested these nutrient sources provide a feedback mechanism to their out bound prodigy fueling lower trophic levels, from minute bacteria and fungi, through a multitude of plankton, invertebrate, fish, and marine mammal species.

The Bristol Bay estuary provides EFH for salmon at various life stages as well as countless other marine species. The estuary provides a nutrient rich transition zone where salmon smolt can achieve critical size while acclimating to the marine environment. At an ecosystem level, this pristine condition and connectivity in natural processes are the key habitat attributes responsible for the sustainability of salmon populations as well as other regional fisheries.

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Tables

Table 1: Fish and Invertebrate Species List

Species listed have been identified in the NOAA-AFSC Bering Sea Trawl Surveys between 1982-2010 (Lauth 2010). Caveats: All species found, 1) east of the 162 line, 2) deeper than 15-20m, 3) seasonality of surveys and species presence do not represent complete species diversity, 4) standardized trawl gear mesh is size selective, juvenile and larval specimens of a species may not be well represented, 5) salmon species at any life stage may not be well represented due to seasonality of surveys and migration.

FISH SPECIES	
Common Name	***Scientific Name***
	Salmonidae
Chinook salmon	*Oncorhynchus tshawytscha*
Chum salmon	*Oncorhynchus keta*
Steelhead	*Oncorhynchus mykiss*
	Gadidae
Pacific cod	*Gadus macrocephalus*
Walleye pollock	*Theragra chalcogramma*
Arctic cod	*Boreogadus saida*
Saffron cod	*Eleginus gracilis*
	Anoplopomatidae
Sablefish	*Anoplopoma fimbria*
	Osmeridae
Eulachon	*Thaleichthys pacificus*
Capelin	*Mallotus villosus*
Rainbow smelt	*Osmerus mordax*
Smelt unident	*Osmeridae*
	Clupeidae
Pacific herring	*Clupea pallasi*
	Ammodytidae
Pacific sand lance	*Ammodytes hexapterus*

	Trichodontidae
Pacific sandfish	*Trichodon trichodon*
	Pleuronectidae
Pacific halibut	*Hippoglossus stenolepis*
Yellowfin sole	*Limanda aspera*
Northern rock sole	*Lepidopsetta polyxystra*
Rock sole unident.	*Lepidopsetta sp.*
Flathead sole	*Hippoglossoides elassodon*
Dover sole	*Microstomus pacificus*
Rex sole	*Glyptocephalus zachirus*
Butter sole	*Isopsetta isolepis*
Sand sole	*Psettichthys melanostictus*
Starry flounder	*Platichthys stellatus*
Alaska plaice	*Pleuronectes quadrituberculatus*
Arrowtooth flounder	*Atheresthes stomias*
Kamchatka flounder	*Atheresthes evermanni*
Longhead dab	*Limanda proboscidea*
Sanddab unident.	*Citharichthys sp.*
	Scorpaenidae
Northern rockfish	*Sebastes polyspinis*
	Rajidae
Big skate	*Raja binoculata*
Bering skate	*Bathyraja interrupta*
Starry skate	*Raja stellulata*
Alaska skate	*Bathyraja parmifera*
Aleutian skate	*Bathyraja aleutica*
	Hexagrammos
Whitespotted greenling	*Hexagrammos stelleri*
Rock greenling	*Hexagrammos lagocephalus*
Kelp greenling	*Hexagrammos decagrammus*
Smooth lumpsucker	*Aptocyclus ventricosus*
Greenling unident.	*Hexagrammidae*
	Psychrolutidae

Sawback poacher	*Leptagonus frenatus*
Gray starsnout	*Bathyagonus alascanus*
Sturgeon poacher	*Podothecus accipenserinus*
Aleutian alligatorfish	*Aspidophoroides bartoni*
Arctic alligatorfish	*Ulcina olrikii*
Warty poacher	*Chesnonia verrucosa*
Bering poacher	*Occella dodecaedron*
	Anarhichadidae
Wolf-eel	*Anarrhichthys ocellatus*
Bering wolffish	*Anarhichas orientalis*
	Gymnocanthus sp.
Threaded sculpin	*Gymnocanthus pistilliger*
Arctic staghorn sculpin	*Gymnocanthus tricuspis*
Armorhead sculpin	*Gymnocanthus galeatus*
Northern sculpin	*Icelinus borealis*
Sculpin unident.	*Cottidae*
	Artediellus sp.
Hookhorn sculpin	*Artediellus pacificus*
Irish lord	*Hemilepidotus sp.*
Red Irish lord	*Hemilepidotus hemilepidotus*
Yellow Irish lord	*Hemilepidotus jordani*
	Triglops sp.
Ribbed sculpin	*Triglops pingeli*
Brightbelly sculpin	*Microcottus sellaris*
Warty sculpin	*Myoxocephalus verrucosus*
Great sculpin	*Myoxocephalus polyacanthocephalus*
Plain sculpin	*Myoxocephalus jaok*
	Myoxocephalus sp.
Pacific staghorn sculpin	*Leptocottus armatus*
Antlered sculpin	*Enophrys diceraus*
Spinyhead sculpin	*Dasycottus setiger*
Crested sculpin	*Blepsias bilobus*
Eyeshade sculpin	*Nautichthys pribilovius*
Sailfin sculpin	*Nautichthys oculofasciatus*

Bigmouth sculpin	*Hemitripterus bolini*
Thorny sculpin	*Icelus spiniger*
Spatulate sculpin	*Icelus spatula*
	Liparis sp.
Variegated snailfish	*Liparis gibbus*
Snailfish unident.	*Liparidinae*
	Stichaeidae
Daubed shanny	*Lumpenus maculatus*
Snake prickleback	*Lumpenus sagitta*
Decorated warbonnet	*Chirolophis decoratus*
Bearded warbonnet	*Chirolophis snyderi*
Polar eelpout	*Lycodes turneri*
	Cryptacanthodidae
Giant wrymouth	*Cryptacanthodes giganteus*

INVERTEBRATE SPECIES

Common Name	***Scientific Name***
Octopus	
	Octopodidae sp.
Common Octopus	*Octopoda*
Eastern Pacific bobtail	*Rossia pacifica*
Crab	
	Cancer sp.
Oregon rock crab	*Cancer oregonensis*
Graceful decorator crab	*Oregonia gracilis*
Tanner crab	*Chionoecetes bairdi*
Circumboreal toad crab	*Hyas coarctatus*
Pacific lyre crab	*Hyas lyratus*
Snow crab	*Chionoecetes opilio*
Hybrid tanner crab	*Chionoecetes hybrid*
Helmet crab	*Telmessus cheiragonus*
Hermit crab unident.	*Paguridae*
	Pagurus sp.
Sponge hermit	*Pagurus brandti*

Aleutian hermit	*Pagurus aleuticus*
Splendid hermit	*Labidochirus splendescens*
Knobbyhand hermit	*Pagurus confragosus*
Fuzzy hermit crab	*Pagurus trigonocheirus*
Bering hermit	*Pagurus beringanus*
Alaskan hermit	*Pagurus ochotensis*
Longfinger hermit	*Pagurus rathbuni*
Widehand hermit crab	*Elassochirus tenuimanus*
Hairy hermit crab	*Pagurus capillatus*
Purple hermit	*Elassochirus cavimanus*
Wrinkled crab	*Dermaturus mandtii*
	Hapalogaster sp.
Fuzzy crab	*Hapalogaster grebnitzkii*
Red king crab	*Paralithodes camtschaticus*
Horsehair crab	*Erimacrus isenbeckii*

Shrimp

	Pandalus sp.
Ocean shrimp	*Pandalus jordani*
Alaskan pink shrimp	*Pandalus eous*
Humpy shrimp	*Pandalus goniurus*
Shrimp unident.	*Hippolytidae*
	Lebbeus sp.
Spiny lebbeid	*Lebbeus groenlandicus*
	Crangon sp.
Abyssal crangon	*Crangon abyssorum*
Twospine crangon	*Crangon communis*
Ridged crangon	*Crangon dalli*
Sevenspine bay shrimp	*Crangon septemspinosa*
Crangonid shrimp unident.	*Crangonidae*
	Argis sp.
Arctic argid	*Argis dentata*
	Sclerocrangon sp.
Sculptured shrimp	*Sclerocrangon boreas*
Kuro argid	*Argis lar*

Clams, Mussels, Scallop, Cockles

	Mytilidae sp.
Northern horse mussel	*Modiolus modiolus*

	Mytilus sp.
Blue mussel	*Mytilus edulis*
Weathervane scallop	*Patinopecten caurinus*
Arctic hiatella	*Hiatella arctica*
Arctic roughmya	*Panomya norvegica*
	Yoldia sp.
Crisscrossed yoldia	*Yoldia seminuda*
Northern yoldia	*Yoldia hyperborea*
Discordant mussel	*Musculus discors*
Boreal astarte	*Astarte borealis*
Many-rib cyclocardia	*Cyclocardia crebricostata*
	Mactromeris sp.
Arctic surfclam	*Mactromeris polynyma*
	Tellina sp.
Alaska great-tellin	*Tellina lutea*
	Macoma sp.
Bent-nose macoma	*Macoma nasuta*
	Siliqua sp.
Pacific razor	*Siliqua patula*
Alaska razor	*Siliqua alta*
	Mya sp.
Softshell clam	*Mya arenaria*
Alaska falsejingle (soft oyster)	*Pododesmus macrochisma*
Soft shell unident.	*Anomiidae*
	Ciliatum sp.
Hairy cockle	*Clinocardium ciliatum*
California cockle	*Clinocardium californiense*
	Serripes sp.
Greenland cockle	*Serripes groenlandicus*
Broad cockle	*Serripes laperousii*
	Cyclocardia sp.
	Clinocardium sp.

Coral, Soft coral

	Gersemia sp.
Sea raspberry	*Gersemia rubiformis*
	Gorgonacea sp.
Sea pen (sea whip)	*Pennatulacea*

Snail, snails, welk

	Natica clausa sp.
Aleutian moonsnail	*Cryptonatica aleutica*
Rusty moonsnail	*Cryptonatica russa*
Pale moonsnail	*Euspira pallida*
Great slippersnail	*Crepidula grandis*
Moonsnail eggs unident	*Naticidae eggs*
	Volutopsius sp.
Warped whelk	*Pyrulofusus deformis*
	Beringius sp.
	Beringius kennicottii
	Beringius beringii
	Neptunea sp.
Pribilof whelk	*Neptunea pribiloffensis*
	Neptunea borealis
Lyre whelk	*Neptunea lyrata*
Fat whelk	*Neptunea ventricosa*
	Neptunea heros
Helmet whelk	*Clinopegma magnum*
	Plicifusus kroyeri
	Neptunea sp.
Oregon triton	*Fusitriton oregonensis*
	Tritonia sp.
Rosy tritonia	*Tritonia diomedea*
	Buccinum sp.
Angular whelk	*Buccinum angulosum*
Sinuous whelk	*Buccinum plectrum*
Ladder whelk	*Buccinum scalariforme*
Polar whelk	*Buccinum polare*
Smooth lamellaria	*Velutina velutina*
	Hyas sp.
Snail eggs	*Gastropod eggs*
Snail eggs unident.	*Neptunea sp. eggs*

Barnacles

	Balanus sp.
Giant barnacle	*Balanus evermanni*
Beaked barnacle	*Balanus rostratus*
Barnacle unident.	*Thoracica*

Anemone

	Halipteris sp.
Sea anemone unident.	*Actiniaria*
	Metridium sp.
Clonal plumose anemone	*Metridium senile*
Gigantic anemone	*Metridium farcimen (=Metridium giganteum)*
	Stomphia sp.
	Urticina sp.
Mottled anemone	*Urticina crassicornis*
Chevron-tentacled anemone	*Cribrinopsis fernaldi*
Tentacle-shedding anemone	*Liponema brevicornis*
Stony coral unident.	*Scleractinia*

Star fish, sea star

	Evasterias sp.
Mottled sea star	*Evasterias troschelii*
Giant sea star	*Evasterias echinosoma*
	Leptasterias groenlandica
Blackspined sea star	*Lethasterias nanimensis*
	Henricia sp.
Blood sea star	*Henricia leviuscula*
Tumid sea star	*Henricia tumida*
	Leptasterias polaris
	Leptasterias katharinae
	Leptasterias arctica
	Leptasterias sp.
	Crossaster sp.
Grooved sea star	*Crossaster borealis*
Rose sea star	*Crossaster papposus*
	Asterias sp.
Purple-orange sea star	*Asterias amurensis*
Brittlestarfish unident.	*Ophiuroidea*
Basketstar	*Gorgonocephalus eucnemis*
Notched brittlestar	*Ophiura sarsi*

Sea urchin

	Echinacea sp.

Green sea urchin	*Strongylocentrotus droebachiensis*
	Strongylocentrotus sp.
	Strongylocentrotus polyacanthus
Sand dollar	*Echinarachnius parma*

Sponges

	Stelletta sp.
Stone sponge	*Suberites ficus*
Clay pipe sponge	*Aphrocallistes vastus*
Barrel sponge	*Halichondria panicea*
	Suberites sp.
Sponge	*Porifera*

Jelly fish

	Amphilaphis sp.
Jelly Fish	*Chrysaora melanaster*
Lion's mane	*Cyanea capillata*
Chrysaora jellyfish	*Chrysaora sp.*
Jellyfish unident.	*Scyphozoa*
Comb jelly unident.	*Ctenophora*

Miscellaneous Invertabrate Species

Worm

	Polychaeta
Giant scale worm	*Eunoe nodosa*
Depressed scale worm	*Eunoe depressa*
Striped sea leech	*Notostomobdella cyclostoma*
Echiuroid worm unident.	*Echiura*
Cat worm unident.	*Nephtyidae*
Scale worm unident.	*Polynoidae*
Peanut worm unident.	*Sipuncula*
Tube worm unident.	

Hydroids

	Abietinaria sp.

Bryozoans

Feathery bryozoan	*Eucratea loricata*

Leafy bryozoan	*Flustra serrulata*
	Alcyonidium pedunculatum
Ribbed bryozoan	*Rhamphostomella costata*
Bryozoan unident.	*Bryozoa*

Sea Cucumbers

	Cucumaria sp.
Sea football	*Cucumaria fallax*
Sea cucumber	*Holothuroidea*
	Cucumaria frondosa
Foraminiferan unident.	***Psolus sp.***
	Foraminifera

Ascidians

Orange sea glob	***Aplidium sp.***
Sea pork	*Aplidium californicum*
	Molgula sp.
Sea grape	*Molgula grifithsii*
Sea clod	*Molgula retortiformis*

Table 2: Marine Mammals Species List

Marine mammal species listed have been identified from several sources (Allen 2010, ADFG 2010, BBESI 2001, BB-CRSA 2009).

MARINE MAMMALS	
Common Name	***Scientific Name***
Toothed Whales	***Cetaceans - Ondontocetes***
Beluga whale	*Delphinapterus leucas*
Killer whale	*Orcinus orca*
Pacific white-sided dolphin	*Lagenorhynchus obliquidens*
Harbor porpoise	*Phocoena phocoena*
Dall's porpoise	*Phocoenoides dalli*
Baird's beaked whale	*Berardius bairdii*
Baleen Whales	***Cetaceans – Balenotropha***
Gray whale	*Eschrichtius robustus*
Humpback whale	*Megaptera novaeangliae*
Fin whale	*Balaenoptera physalus*
Minke whale	*Balaenoptera acutorostrata*
Bowhead whale	*Balaena mysticetus*
Sealion	***Pinnipeds - Otariidae***
Steller sea lion (Eastern)	*Eumetopias jubatus*
Northern fur seal (Eastern)	*Callorhinus ursinus*
Seals	***Pinnipeds - Phocidae***
Harbor seal	*Phoca vitulina*
Spotted seal	*Phoca largha*
Bearded seal	*Erignathus barbatus*
Ringed seal	*Pusa hispida*
Ribbon seal	*Histriophoca fasciata*
	Pinnipeds – Odobenidae
Walrus	*Odobenus rosmarus*
	Mustelidae - Lutrinae
Northern Sea Otter	*Enhydra lutris kenyoni*