

EFH 5-year Review for 2010: Summary Report

Appendix 5 Salmon FMP species reviews

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Chinook salmon review by W. R. Heard

Worksheet A – New species-specific habitat information since the EFH EIS

1. Published reports

New publications related to Chinook salmon EFH-EIS not in earlier cited references.

Ford, J.K.B., and G. M. Ellis. 2005. Prey selection and food sharing by fish-eating “resident” killer whales (*Orcinus orca*) in British Columbia. Can.Sci. Advisory Secretariat. Res. Doc.2005/041. Fisheries and Oceans Canada, Pacific Biol. Station, Nanaimo, B. C. (Available at <http://www.dfo-mpo.gc.ca/csas>).

Heard, W. R., E. Shevlyakov, O. V. Zikunova, and R. E. McNicol. 2007. Chinook salmon-trends in abundance and biological characteristics. N. Pac. Anadr. Fish Comm. Bull. No. 4:77-91.

Moulton, L. L. 2005. Baseline surveys of fish habitats in eastern National Petroleum Reserve-Alaska, 2004. Conoco Phillips, Alaska, Anchorage.

Shepard, M. P., and A.W. Argue. 2005. The 1995 Pacific Salmon Treaty: Sharing Conservation Burdens and Benefits. University of British Columbia Press. Vancouver.

Orsi, J.A., D.M. Clausen, A.C. Wertheimer, D.L. Courtney, and J.E. Pohl. 2006. Diel epipelagic distribution of juvenile salmon, rockfish, sablefish and ecological interactions with associated species in offshore habitats of the northeast Pacific Ocean. (NPAFC Doc. 956). 26 p. Auke Bay Lab., Alaska Fish. Sci. Cen., Nat. Mar. Fish. Serv., NOAA, 11305 Glacier Highway, Juneau, AK 99801-8626, USA.

Orsi, J. A., M. V. STurdevant, J. M. Murphy, D. G. Mortensen, and B. L. Wing. 2000. Seasonal habitat use and early marine ecology of juvenile Pacific salmon in Southeastern Alaska. N. Pac. Anadr. Fish Comm. Bull. No. 2:111-122.

Eiler, J. H., T. R. Spencer, J. J. Pella, and M. M. Masuda. 2006. Stock composition, run timing, and movement patterns of Chinook salmon returning to the Yukon River basin in 2004. U.S. Dep. Commer., NOAA Tech. Memo., NMFS-AFSC-165, 107 p.

Wessel, M. L., W. W. Smoker, and J. E. Joyce. 2006. Variation of morphology among juvenile Chinook salmon of hatchery, hybrid, and wild origin. Trans. Am. Fish. Soc. 135:333–340.

Wessel, M. L., W. W. Smoker, R. M. Fagen, and J. E. Joyce. 2006. Variation of agonistic behavior among juvenile Chinook salmon (*Oncorhynchus tshawytscha*) of hatchery, hybrid, and wild origin. Can. J. Fish. Aquat. Sci.. 63:438-447.

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Rodgveller, C.J., W.W. Smoker, A.K. Gray, J.E. Joyce, and A.J. Gharrett. 2005. Effects of inbreeding and family origin on variation of size of Chinook salmon *Oncorhynchus tshawytscha* fry. Alaska Fishery Research Bulletin 11:73-81.

Eiler, J. H., T. R. Spencer, J. J. Pella, M. M. Masuda, and R. R. Holder. 2004. Distribution and movement patterns of Chinook salmon returning to the Yukon River basin in 2000-2002. U. S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-148, 99 p.

Guthrie, C. M., and R. L. Wilmot. 2004. Genetic structure of wild chinook salmon populations of southeast Alaska and northern British Columbia. Environ. Biol. Fish. 69:81-93.

2. Unpublished data, other relevant information

3. Management changes

Management changes involve new Chinook salmon protocols for treaty fisheries in Southeast Alaska. Also, under the treaty-related Yukon River Salmon Agreement management changes due to poor status of stock are occurring in inriver fisheries and in BSAI groundfish fisheries.

Chinook Salmon - Worksheet B – Determinations on whether EFH needs to be changed, species-specific.

1. EFH Description Update

Does new information warrant change to EFH Description?

Yes, see text changes, also changes needed on Maps. Several changes in text are needed to update current knowledge of Chinook EFH-related issues. See track changes in text. The Chinook salmon distribution map for SE Alaska does not include several 20-30 year old runs of hatchery stocks. Also, based on recent reports of adult Chinook salmon along the arctic coast of Alaska see changes indicated on the enclosed Chinook maps for southeast and arctic areas.

Does new description, and any associated information, change the level of information known for the species life stage (i.e., not-identified to Level 1; Level 1 to 2*)? **No**

2. Research and Information Needs

Do data gaps exist?

Yes. More research is needed regarding the stock origins and potential impacts of bycatch of Chinook salmon in certain GOA and BSAI groundfish fisheries.

Is information most recent and best available? **Unknown**.

3. Fishing Activities

Does fishing activity have more than temporary or minimal affects?

Yes, significant changes in fishing activities involving Chinook salmon are required under the new salmon treaty accords with Canada. Also, Chinook salmon bycatch in some groundfish fisheries may be having adverse impacts on certain stocks requiring management changes in some fisheries.

If yes, does fishing activity have an adverse affect to EFH. Not directly to Chinook salmon habitats directly but to the potential health of the stocks.

4. Cumulative Impacts

Are cumulative effects discussed? **Yes**

5. Habitat Areas of Particular Concern (HAPC)

Are there specific ecologically significant, rare, or sensitive sites, relevant to your species, that are particularly vulnerable to human perturbation, which the Council might want to consider identifying as HAPC. **No**

* EFH Information Levels: Level 1 - Distribution (general) data available; Level 2 - Habitat-related density data available; Level 3 - Growth, reproduction, or survival rates within habitats are available; Level 4 – Production rates by habitat are available. See FMP for EFH Level specifics by life stage.

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4. Non-fishing Activities

Are any non-fishing activities known to be affecting the stock?

Yes. Habitat disruptions, especially in the Pacific Northwest are continuing to impact Chinook salmon stocks throughout Alaska EEZ waters. See text writeups.

5. Priorities

Are there any priorities for EFH Conservation that the Council may want to consider?

Yes. Chinook salmon bycatch in GOA and BSAI fisheries are on the Council's agenda.

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2.6 Habitat Description for Chinook Salmon (*Oncorhynchus tshawytscha*) Life History and General Distribution

Chinook salmon, also called king, spring, or tye salmon, are the least abundant and largest of the Pacific salmon. They are distinguished from other species of Pacific salmon by their large size, the small black spots on both lobes of the caudal fin, black pigment at the base of the teeth, and a large number of pyloric caeca. The natural freshwater range of the species includes large portions of the Pacific rim of North America and Asia. In North America, Chinook salmon historically ranged from the Ventura River in California (lat. ~34°) to Kotzebue Sound in Alaska (~66° N); in addition, the species has been identified in North America in the Mackenzie River, which drains into the Arctic Ocean. Recent reports indicate increased occurrence of Chinook salmon in arctic waters of the Beaufort Sea along the Alaska coast that may be reflective of climatic changes. These reports include adults collected annually in Elson Lagoon near Point Barrow and in Ublutuooh River, a tributary stream near the mouth of the Coville River in 2004. In Asia, natural populations of Chinook salmon have been documented from Hokkaido Island, Japan (~42° N) to the Andyr River in Russia (~64° N). Within this range, the largest rivers tend to support the largest aggregate runs of Chinook salmon and have the largest individual spawning populations. Major rivers near the southern and northern extremes of the range support populations of Chinook salmon comparable to those near the middle of the range. For example, in North America, the Yukon River near the north edge of the range and the Sacramento-San Joaquin River system near the south edge of the range have historically supported Chinook salmon runs comparable to those of the Columbia River and the Fraser River, which are near the center of the species range along this Pacific coast.

In marine environments, Chinook salmon range widely throughout the North Pacific Ocean and the BS, from lat. 38°. The southern edge of the marine distribution expands and contracts seasonally and between years depending on ocean temperature patterns. While the marine distribution of Chinook salmon can be highly variable even within a population, there are general migration and ocean distribution patterns characteristic of populations in specific geographic areas. For example, Chinook salmon that spawn in rivers from the Rogue River in Oregon south to California disperse and rear in oceanic waters off the Oregon and California Coast, whereas those that spawn north of the Rogue River to southeast Alaska migrate north and westward along the Pacific coast. These migration patterns are of particular interest for the management of Chinook salmon in the EEZ off Alaska, as they result in the harvest of fish from Oregon, Washington, British Columbia, and Alaska within the management zone.

Pacific salmon have a generalized life history that includes the incubation and hatching of embryos and emergence and initial rearing of juveniles in freshwater; migration to oceanic habitats for extended periods of feeding and growth; and return to natal waters for completion of maturation, spawning, and death. Within this general life history strategy, Chinook salmon display diverse and complex life history patterns and tactics. Their spawning environments range from just above tidewater to over 3,200 km from the ocean, from coastal rainforest streams to arid mountain tributaries at elevations over 1,500 m. At least 16 age categories of mature Chinook salmon have been documented, involving three possible freshwater ages and total ages of 2 to 8 years, reflecting the high variability within and among populations in length of freshwater, estuarine, and oceanic residency. Chinook salmon also demonstrate variable ocean migration patterns and timing of spawning migrations.

This variation in life history strategy has been explained by separating Chinook salmon into two races: stream- and ocean-type fish. Stream-type fish have long freshwater residence as juveniles (1 to 2 years), migrate rapidly to oceanic habitats, enter freshwater as immature or “bright” fish, and spawn far upriver in late summer or early fall. Ocean-type fish have short, highly variable freshwater residency (from a few days to 1

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year), extensive estuarine residency, enter fresh-water at a more advanced state of maturity, and spawn within a few weeks of freshwater entry in the lower portions of the watershed. Within these two types, there is also substantial variability due to a combination of phenotypic plasticity and genetic selection to local conditions. For example, adult run-timing is strongly influenced by in-river flow volumes and temperature levels.

Chinook salmon have distinctly different feeding habits and distribution and in ocean habitats than do other species of Pacific salmon. Chinook salmon are the most piscivorous of the Pacific salmon, and are also distributed deeper in the water column. While other species of salmon generally are surface oriented, utilizing primarily the upper 20 m, Chinook salmon tend to be at greater depths and are often associated with bottom topography. Because of their distribution in the water column, the majority of Chinook salmon harvested in commercial troll fisheries are caught at depths of 30 m or greater, and Chinook salmon is the most common salmon species taken as bycatch in mid-water and bottom trawl fisheries.

Declines in the abundance of Chinook salmon have been well documented throughout the southern portion of the range. Concern over coast-wide declines from southeast Alaska to the Pacific Northwest was a major factor leading to the signing of the Pacific Salmon Treaty between the United States and Canada in 1985. Wild Chinook salmon populations have been extirpated from large portions of their historic range in a number of watersheds in California, Oregon, Washington, Idaho, and southern British Columbia, and a number of evolutionarily significant units (ESUs) have been listed by National Marine Fisheries Service as at risk of extinction under the Endangered Species Act (ESA). Habitat degradation is the major cause for extinction of populations; most are related to dam construction. Urbanization, agricultural land use and water diversion, and logging are also factors contributing to habitat degradation and the decline of Chinook salmon. The development of large-scale hatchery programs, have, to some degree, mitigated the decline in abundance of Chinook in some areas. However, genetic and ecological interactions of hatchery and wild fish have also been identified as risk factors for wild populations, and the high harvest rates directed at hatchery fish may cause over-exploitation of co-mingled wild populations.

Fisheries

Because of their large size and excellent taste, Chinook salmon are highly prized by commercial, sport, and subsistence fishers. In Alaska, approximately 1 million Chinook salmon are harvested annually. While this is less than 1 percent of the annual salmon catch in the state, Chinook salmon typically are the focus of a disproportionately larger amount of management and regulatory effort because of the conservation concerns and intense allocation issues for this species.

In most of the state, there is no directed harvest of Chinook salmon in the EEZ. Most fishing effort takes place in the coastal or riverine waters of the state. The FMP for salmon in the Alaska EEZ prohibits commercial harvest in the EEZ, with a few exceptions. The most notable exception is the commercial troll harvest off of southeast Alaska. While much of this fishery is also in state waters, it has been traditionally managed since Alaska statehood (1959) with little recognition of the boundary separating state and federal waters. Chinook and coho salmon are the primary target species of this hook-and-line fishery.

The commercial troll fishery for Chinook salmon in southeast Alaska developed in the early 1900s. The fishery occurred all year with no overall catch limits. Peak harvests of Chinook were in the 1930s, when annual catch averaged over 600,000. Concurrent with the development of the Columbia River hydroelectric dams, catches declined to average 250,000 to 350,000 Chinook annually. Beginning in 1978, ADF&G and the Council set harvest limits for the fishery in the first FMP for salmon in Alaska. These limits were initially a harvest range of 286,000 to 320,000 Chinook salmon for the southeast Alaska troll fishery. The FMP also

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banned commercial salmon fishing in the EEZ west of long. 175° E, banned fishing for salmon with nets throughout the EEZ (with a few specific exceptions), and imposed time closures on commercial trolling in the EEZ east of long. 175°.

These harvest ranges became part of a 15-year stock rebuilding program begun in 1981 for stocks that spawn in southeast Alaska and in transboundary rivers that originate in Canada and flow through southeast Alaska. In 1985, the Pacific Salmon Treaty between the United States and Canada included specific provisions for rebuilding Chinook salmon stocks coast-wide. The Chinook Annex to the treaty established specific total catch limits for Chinook in southeast Alaska and in certain fisheries in British Columbia in 1985 and 1986; subsequently, the catch limits were to be negotiated annually. The catch ceiling in southeast Alaska was originally established at 263,000 "treaty fish," with a provision for additional harvest of fish produced by new enhancement operations in the region. The catch ceiling included an allocation for incidental catch of Chinook salmon in net fisheries directed at other salmon species, as well as the commercial and recreational troll harvests. It resulted in a reduction of approximately 100,000 Chinook in the commercial troll fishery relative to its average catches over the prior two decades.

In 1990, the Council revised the salmon FMP to reduce redundant regulation of the salmon fisheries in the EEZ with ADF&G and the Pacific Salmon Commission (PSC). While recognizing that the salmon fisheries require Federal participation and oversight stipulated in the Magnuson Act, the Council deferred setting harvest levels to ADF&G and the PSC, and regulation of the sport and commercial fishery to ADF&G providing the harvest levels and allocations are consistent with Council goals and objectives stated in the FMP and the National Standards of the Magnuson-Stevens Act. To date, the Council has not exercised its option of specifying management measures in the EEZ that differ from state regulation.

Management and catch limits in the southeast Alaska Chinook salmon fishery have continued to be a contentious issue. While Chinook salmon spawning in southeast Alaska and the transboundary rivers have been generally stable or increasing in abundance since the establishment of the PSC management regime, abundance of many wild populations of Chinook salmon in British Columbia and the Pacific Northwest have not recovered or have continued to decline. Fixed harvest levels were formulated to result in decreasing exploitation rates of Chinook salmon in mixed-stock fisheries: as wild stocks rebuilt and enhancement activities increased, general abundance of Chinook salmon in the mixed-stock fisheries, in concert with catch ceilings, would result in a lower proportion harvested by these fisheries. In the first few years after the Treaty, this concept seemed reasonable, but poor survivals due to ocean conditions in the early 1990s resulted in declining abundances in the ocean fisheries, so that fixed harvest levels result in increasing exploitation. Due to this and other allocation and conservation concerns, there has been no agreement on catch ceilings within the PSC since 1993. In 1995, ADF&G proposed a management regime based on the estimated abundance of Chinook salmon. ADF&G implemented this abundance-based management approach in 1995, but tribal groups and the state management agencies in the Pacific Northwest sued successfully for the closure of the fishery in August of 1995. In 1996, the fishery reopened with a management ceiling agreed to by the United States Commissioners (which represent both Alaska and Pacific Northwest interests) to the PSC. In 1997, the United States Commissioners agreed to apply an abundance-based management approach using a modified version of the original ADF&G proposal. The agreement calls for setting preseason catch targets based on the forecasts made by the Chinook Technical Committee (CTC) of the PSC, then refining these preseason forecasts using catch per unit effort data from the summer troll fishery. This agreement was implemented by ADF&G in 1997, but was not agreed to by Canada in the PSC process. This non-agreement boiled over in July of 1997 into a temporary blockade of Alaska ferries trying to enter the Port of Prince Rupert by disgruntled Canadian fishermen.

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With the treaty process stalled government-to-government negotiations culminated in the successful renewal of long-term fishing arrangements in 1999 under the Pacific Salmon Treaty. This arrangement implemented by a Letter of Agreement (LOA) concept between the two countries and scheduled to last for a 10-year period was based on the abundance-based management principle. In 2009 a new 10-year treaty accord was agreed to that defined two new management regimes for Chinook salmon classified as aggregate

An AABM fishery is an abundance-based regime that constrains catch or total mortality to a numerical limit computed from either a pre-season forecast or an in-season estimate of abundance, from which a harvest rate index can be calculated, expressed as a proportion of the 1979 to 1982 base period. An ISBM fishery is an abundance-based regime that constrains to a numerical limit the total catch or the total adult equivalent mortality rate within the fisheries of a jurisdiction for a naturally spawning Chinook salmon stock or stock group. ISBM management regimes apply to all Chinook salmon fisheries subject to the Treaty that are not AABM fisheries. Southeast Alaska fisheries targeted on Chinook salmon presently are AABM fisheries.

Because fish from Chinook salmon ESUs that have been listed as threatened or endangered occur in the southeast Alaska troll fishery, NMFS reviews the fishery under Section 7 of the ESA and, in association with the Biological Opinion, issues an incidental take statement that covers the ESA listed fish that are inadvertently and unknowingly taken in the fishery. The biological assessment has found that the take of listed ESUs in the fishery has been incidental to other stocks and a small percentage of the total mortality, either on a single year or cohort basis. To date, NMFS has found that this fishery is not likely to jeopardize the continued existence or recovery of ESA-listed species.

Chinook salmon fisheries in Alaska have some bycatch associated with them. Generally, the numbers of other species taken during directed Chinook fishing is small and not considered a conservation issue. The most important bycatch issue in tartgeted Chinook salmon fisheries involves commercial and recreational hook-and-line fisheries where the capture of undersized Chinook salmon must be released. While the majority of these fish survive the hooking encounter, large numbers can be hooked and substantial mortality incurred. The Pacific Salmon Treaty requires accounting for the degree of such bycatch mortality, and the CTC uses this information in modeling the status and abundance of component stocks.

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Other fisheries not directed on Chinook salmon also catch this species as bycatch. The most important fisheries where Chinook salmon are caught as bycatch involve ocean trawl fisheries for groundfish in the Gulf of Alaska (GOA) and the Bering Sea Aleutian Islands (BSAI). Groundfish fishery bycatch of Chinook salmon, especially in BSAI fisheries, can be significant and potentially with severe implications on the health of stocks of Chinook salmon in the bycatch. For example in 2007 Chinook salmon bycatch in the BSAI groundfish fisheries was 130 thousand fish which has raised concern for the status of some Western Alaska stocks.

Directed fisheries of Chinook salmon in Alaska include marine commercial and recreational hook-and-line fisheries; marine commercial gill-net and seine fisheries; and estuarine and riverine gill-net (both set-net and drift), recreational, personal use, and subsistence fisheries. Two types of impacts can occur: (1) direct effects of the gear to habitat and (2) bycatch or entanglement of non-target species. In the marine fisheries, direct impact of the gear to marine habitats is limited, but some localized effects can occur, such as trolling weights damaging coral or purse seines damaging kelp beds or benthic structure. Because these types of impacts also endanger the gear itself, they are typically self-limiting. Bycatch and entanglement of non-target species can occur in the marine fisheries, such as bycatch of demersal rockfish in hook-and-line fisheries, and entanglement of seabirds and marine mammals in net fisheries. In the estuarine and riverine fisheries, direct impact to riparian vegetation and channel morphology can occur from the shore-based fishing gears, such as

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set-nets and recreational fishing. Where use levels are high, this type of impact can be sufficient to require restoration management initiatives. An example is the Kenai River restoration work needed to repair damage from recreational fishing for Chinook salmon and other salmonids.

Relevant Trophic Information

Chinook salmon eggs, alevins, and juveniles in freshwater streams provide an important nutrient input and food source for aquatic invertebrates, other fishes, birds, and small mammals. The carcasses of Chinook adults can also be an important nutrient input in their natal watersheds, as well as providing food sources for terrestrial mammals such as bears, otters, and minks, and birds such as gulls, eagles, and ravens. Because of their relatively low abundance in coastal and oceanic waters, Chinook salmon in the marine environment are typically only an incidental food item in the diet of other fishes, marine mammals, and coastal sea birds. In some areas, however, new research has suggested that selective predation by killer whales on Chinook salmon may have detrimental impacts on certain stocks.

Approximate Upper size limit of juvenile fish (in cm): 71 cm total length. This is the regulatory minimum harvest size used in the Alaska hook-and-line fisheries in order to minimize catches of immature fish. However, because Chinook salmon can mature at ages of 2 to 8 total years, the term “juvenile” is better defined by physiological progress of maturation rather than a threshold size.

Habitat and Biological Associations

Chinook salmon occur over a broad geographic range, encompassing different ecotypes and very diverse habitats. Across the geographic range that the species has colonized, populations of Chinook salmon have developed localized adaptations to site specific characteristics. These local adaptations result in different and diverse characteristics of biological importance, including timing of spawning, adult and juvenile migration timing, age and size at maturity, duration of freshwater residency, and ocean distribution. Chinook salmon have been studied and managed intensively for decades. There is a large body of literature describing their biology and ecology. For freshwater habitats, however, habitat-specific information for Chinook salmon in particular watersheds is sparse, especially in the northern portion of the range, and for estuarine and marine habitats, there is little data beyond presence/absence or density information. The range in the amount of habitat specific information by life-history stage is reflected in the information levels assigned the different life-history stages. EFH is defined for this species on the basis of watershed-specific information available about the species' distribution, and its known range of marine distribution within the EEZ.

Eggs/Spawning: Chinook salmon spawn in a broad range of habitats. They have been known to spawn in water ranging from a few centimeters deep to several meters deep, and in channel widths ranging from small tributaries 2 to 3 m wide to the main stems of large rivers such as the Columbia and Sacramento. Typically, redd (nest) size is 5 to 15 m², and water velocities are 40 to 60 cm/sec. The depth of the redd is inversely related to water velocity; generally the female buries her eggs in clean gravel, 20 to 36 cm deep. Because of their large size, Chinook salmon are able to spawn in higher water velocities and utilize coarser substrates than other salmon species. In general, female Chinook salmon select sections of the spawning stream with high subgravel flow. Because their eggs are the largest of the Pacific salmon, with a correspondingly small surface-volume ratio, they may be more sensitive to reduced oxygen levels and require a higher rate of irrigation. Fertilization of the eggs occurs simultaneous with deposition. Males compete for the right to breed with a spawning females. Chinook females remain on their redds 6 to 25 days after spawning, defending the area from superimposition of eggs from another female.

Larvae/Alevins: Fertilized eggs begin their 5- to 8-month period of embryonic development and growth in intragravel interstices. To survive successfully, the eggs, alevins and pre-emergent fry must first be protected

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from freezing, desiccation, stream bed scouring or shifting, mechanical injury, and predators. Water surrounding them must be non-toxic and of sufficient quality and quantity to provide basic requirements of suitable temperatures, adequate supply of oxygen, and removal of waste materials. Rates of egg development, survival, size of hatched alevins and percentage of deformed fry are related to temperature and oxygen levels during incubation. Generally, low oxygen levels are non-lethal early, but lethal late in development. Under natural conditions, 30 percent or less of the eggs survive to emerge from the gravel as fry.

Juveniles: Chinook salmon are typically 33 to 36 mm in length when they emerge from the incubation gravel.

Residency in freshwater and size and timing of seawater migration are highly variable. Ocean-type fish can migrate seaward immediately after yolk absorption. The majority of ocean-type fish migrate at 30 to 90 days after emergence, but some fish move seaward as fingerlings in the late summer of their first year, while others overwinter and migrate as yearling fish. Stream-type fish, in contrast, generally spend at least 1 year in freshwater, migrating as 1- or 2-year-old fish. In Alaska, the stream-type life history predominates although ocean-type life histories have been documented in a few Alaska watersheds. Water and habitat quality and quantity determine the productivity of a watershed for Chinook salmon. Both stream- and ocean-type fish utilize a wide variety of habitats during their freshwater residency, and are dependent on the quality of the entire watershed, from headwater to salt water. The stream/river ecosystem must provide adequate rearing habitat, and migration corridors from spawning and rearing areas to the sea. Stream-type juveniles are more dependent on freshwater ecosystems because of their extended residence in these areas. The principal foods in freshwater are larval and adult insects. The seaward migration of smolts is timed so that the smolts arrive in the estuary when food is plentiful. Migration and rearing habitats overlap. Stream flows during the migratory period tend to be high, which facilitates seaward movement and provides some sheltering from predation.

After entering saltwater, Chinook juveniles disperse to oceanic feeding areas. Ocean-type fish have more extended estuarine residency, tend to be more coastal oriented, and do not generally migrate as far as stream-type fish. Stream – type Chinook salmon juveniles once they enter marine environments may migrate quickly to distant ocean feeding areas. Coded wire tagged Columbia River stocks of stream-type Chinook salmon have been recovered in Southeast Alaska waters within four months after their release from hatcheries.

Food in estuarine areas include epibenthic organisms, insects, and zooplankton.

Adults: Chinook salmon typically remain at sea for 1 to 6 years. They have been found in oceanic waters at temperatures ranging from 1 to 15°C. They do not concentrate at the surface as do other Pacific salmon, but are most abundant at depths of 30 to 70 m. Fish make up the largest component of their diet at sea, although squid, pelagic amphipods, copepods, and euphausiids are also important at times.

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Ocean distribution patterns have been shown to be influenced by both genetics and environmental factors. Migratory patterns in the ocean may have evolved as a balance between the benefits of accessing specific feeding grounds and the energy expenditure and dispersion risks necessary to reach them. Along the eastern Pacific rim, Chinook salmon originating north of Cape Blanco on the Oregon coast tend to migrate north towards and into the GOA, while those originating south of Cape Blanco migrate south and west into waters off Oregon and California. As a result, Chinook salmon that occur in the EEZ fishery in Alaska originate from the Oregon coast to southeast Alaska. Not all stocks within this large geographic area are distributed into the southeast Alaska fishery, however. For example, Puget Sound stocks do not normally migrate that far north.

Habitat Concerns

Habitat loss and alteration have reduced, and in some cases, extirpated Chinook salmon over a large portion

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of their range. Losses of Chinook habitat have occurred as a result of other resource development, such as hydroelectric power and logging, agriculture, and urbanization. Most habitat loss has occurred in freshwater ecosystems that support Chinook salmon development; estuarine rearing areas have also been affected in some areas by industrial development, urbanization, and dredging. The oceanic environment of Chinook salmon is considered largely unchanged by anthropogenic activities, although offshore petroleum production and local, transitory pollution events such as oil spills do pose some degree of risk.

Offshore petroleum production and large-scale transport of petroleum occurs in the Alaska EEZ, although at this time there is no offshore production of petroleum in the commercial troll area of the EEZ. Offshore oil and gas development and transport will inevitably result in some oil entering the environment at levels exceeding background amounts. The *Exxon Valdez* oil spill was shown to have direct effects on the survival and habitats of pink salmon. Chinook salmon were not directly affected, because of their different habitat utilization in the spill area. In general, the early life history stages of fish are more susceptible to oil pollution than juveniles or adults.

By far, the most serious habitat concern for Chinook salmon is the degradation of the freshwater watersheds that support those stages of their life history. Dams and impoundments for hydroelectric power and water diversion have caused large-scale extirpation of Chinook salmon in the Pacific Northwest by eliminating access to anadromous fish, and have altered the spawning, rearing, and migration corridors of Chinook salmon in many watersheds. There are presently no dams in place or in planning that would block rivers used by Chinook salmon in Alaska. However, because many Chinook salmon harvested under the FMP for Alaska originate in the Pacific Northwest, these types of habitat impacts in other regions directly affect the Alaska fishery.

Logging and associated road construction has resulted in degraded habitat by causing increased erosion and sedimentation, changes in temperature regimes, and changes in seasonal flow patterns. Timber harvest has been a major resource use in southeast Alaska, and it is increasing in southcentral Alaska. Timber harvest in the Pacific Northwest and British Columbia also impacts the Alaska fishery because of the presence of stocks from these regions in the Alaska EEZ.

Placer mining has caused serious degradation of Chinook habitats in some river systems, especially in Yukon River drainages. While these impacts are of concern, most of the stocks directly affected do not migrate into the Chinook fishery managed under the FMP.

Urbanization and coastal development can have pronounced effects on coastal ecosystems, particularly estuaries, through modification of the hydrography, biology, and chemistry in the developed area. Increased nutrient input, filling of productive wetlands, and influx of contaminants commonly occur with coastal development. These impacts can reduce or eliminate rearing potential for juvenile Chinook salmon. Increased levels of coastal development in Alaska as well as in the Pacific Northwest and British Columbia can be expected.

There is a definite south-north cline to the degree of habitat degradation and the status of Chinook populations in the eastern Pacific. Habitat degradation in Alaska is certainly a management concern, but to date has not had the degree of impacts on Chinook populations as in the Pacific Northwest. In southeast Alaska, logging is considered the largest potential threat to anadromous fish habitat. Relatively little logging has occurred, however, in watersheds supporting Chinook salmon in the region. However, because of the stock composition of the fish harvested in the EEZ of southeast Alaska, freshwater ecosystems in the Pacific Northwest represent essential fish habitat for sustaining the diversity and abundance of Chinook salmon throughout the Alaska EEZ including Pacific Northwest stocks occurring in other parts of the GOA and Berng

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SPECIES: Chinook Salmon, *Oncorhynchus tshawytscha*

Stage - EFH Level	Duration or Age	Diet/Prey	Season/Time	Location	Water Column	Bottom Type	Oceanographic/Riverine Features	Other
Eggs and larvae (alevins)	50 to 250 days	NA	late summer, fall, winter, early spring	streambeds	intragravel 20 to 80 cm deep	G	Riverbed	DO < 3 mg/l lethal, optimum >7 Temp 0-17 C, Optimum 4-12 C
Juveniles (freshwater)	days-years	insect larvae and adults, zooplankton	year-round, depending on race	streams, sloughs, rivers	surface to several meters	varied	Pools, stream and river margins, woody debris	Extremely varied freshwater life history. DO < 2 mg/l lethal, optimum >7 Temp 0-22 C, Optimum 8-12 C
Juveniles (Estuary)	days-6-months	copepods, euphausiids, amphipods, juvenile fish	spring, summer, fall	BCH, BAY	N, P	All bottom types	estuarine, littoral	Sea-type can be estuarine dependent Temp 2-22 C, Optimum 8-12 C Salinity 0-33 ppt
Juvenile (marine)	6 to 9 months: Up to first marine annulus	epipelagic fish, euphausiids, large copepods, pelagic amphipods	spring-winter	IP, ICS, MCS, OCS, USP, BSN	P	All bottom types	UP, F, G, CL, E	Initially surface oriented; some stocks move rapidly offshore, some remain nearshore. Temp: 1-15 C, Optimum 5-12 C
Immature and Maturing Adults (marine)	2 to 8 years of age	epipelagic fish (herring, sand lance, smelt, anchovy), shrimp, squid	Year Round	BAY, IP, ICS, MCS, OCS, USP, BSN	N, P	All bottom types	UP, F, G, CL, E	Not surface oriented until maturing. Use salinity gradients, olfaction for terminal homing. Temp: 5-22 C
Adults (freshwater)	2 weeks to 4 months	little or none	Spawning: (July-Feb) Freshwater Migration: Year round, varies greatly among populations	Rivers, large streams and tributaries	0.5-10 m	Alluvial bottom types; G for spawning	Deep pools for resting, Riffles, pool-riffle transition for spawning	Entry timing to freshwater highly variable. Temp: 1-26 C, Optimum 4-15 C

Chum Salmon Review by John Joyce

Worksheet A – New species-specific habitat information since the EFH EIS

1. Published reports

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2. Unpublished data, other relevant information n/a

3. Management changes n/a

Chum Salmon Review Joyce

Worksheet B – Determinations on whether EFH needs to be changed, species-specific.

1. EFH Description Update

Does new information warrant change to EFH Description?

No, EFH is broadly described in terms of the marine distribution, If the FMP is widened to include estuarine, river and anadromous waters then more detail could be included in regard to potential impacts, logging, mineral and land development, enhancement, hydropower etc.

Does new description, and any associated information, change the level of information known for the species life stage (i.e., not-identified to Level 1; Level 1 to 2*)? **No**

2. Research and Information Needs

Do data gaps exist?

No.

Is information most recent and best available? **Yes. Recent research and management information is increasing the understanding of what defines the habitat needs of chum salmon especially in their ocean life stages. Work currently underway will augment the current knowledge base.**

3. Fishing Activities

Does fishing activity have more than temporary or minimal affects?

No, not to habitat but bycatch is ongoing issue being addressed.

If yes, does fishing activity have an adverse affect to EFH.

4. Cumulative Impacts

Are cumulative effects discussed? **Yes**

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* EFH Information Levels: Level 1 - Distribution (general) data available; Level 2 - Habitat-related density data available; Level 3 - Growth, reproduction, or survival rates within habitats are available; Level 4 – Production rates by habitat are available. See FMP for EFH Level specifics by life stage.

5. Habitat Areas of Particular Concern (HAPC)

Are there specific ecologically significant, rare, or sensitive sites, relevant to your species, that are particularly vulnerable to human perturbation, which the Council might want to consider identifying as HAPC.

No

4. Non-fishing Activities

Are any non-fishing activities known to be affecting the stock?

Yes. Habitat disruptions and climate change, especially in the Pacific Northwest are continuing to impact chum salmon stocks

5. Priorities

Are there any priorities for EFH Conservation that the Council may want to consider?

No.

Habitat Description for Chum salmon (*Oncorhynchus keta*)

Management Plan and area(s): Salmon Fisheries in the EEZ Off the Coast of Alaska, NPFMC, 1990

Life History and General Distribution

Chum salmon spawn in streams emptying into the North Pacific Ocean north of about 40°N in both Asia and North America. In Asia, chum salmon spawn in streams on the east side of the Korean peninsula in both South and North Korea northward, including Japan, China (tributaries to the Amur River), Russia and westward into the Arctic Ocean as far west as the Lena River. In North America, chum salmon spawn in streams entering the North Pacific Ocean as far south as northern California and northward in streams along the coasts of Oregon, Washington, British Columbia, and Alaska on into the Bering Sea, Arctic Ocean and Beaufort Sea as far east as the Mackenzie River in Northwest Territory. Critical habitat was designated on September 2, 2005, for the threatened Columbia River ESU and Hood Canal Summer-run ESU.

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Chum salmon spawn in Yukon Territory, Canada, in tributaries of the Yukon River. Only populations small in numbers spawn north and east of the Noatak River, which enters the ocean at Kotzebue, Alaska, and south of Tillamook Bay, Oregon. However, recent significant temperature increases in the Arctic could lead to a significant change in salmon distribution in the future and current higher salmon catches may indicate

In general, chum salmon spawn in the lower reaches of coastal streams less than 100 miles upstream from the ocean. Two notable exceptions are the Yukon River in North America and the Amur River in Russia and China where chum salmon migrate upstream more than 1,500 miles to spawning areas. In Prince William Sound, and to a lesser extent Southeast Alaska, chum salmon will spawn in the intertidal portions of streams in areas where ground water upwells into the streams. Chum salmon throughout their range tend to build their redds in areas of streams where ground water (about 4 to 7 C.) upwells. Because of their dependence (or at least preference) for groundwater sources for spawning and incubation, chum salmon populations are particularly vulnerable to natural or development cased perturbations to stream hydrology.

In North America, chum salmon return from the ocean to spawn, for the most part, between June and January. In general, spawning starts earlier in the north and ends later in the southern part of their range. Of course, major exceptions in this pattern occur. The latest spawning in Southeast Alaska occurs in the Chilkat River, near Haines, Alaska, in September through January. Most chum salmon spawning in Alaska is usually finished by early November. Most spawning in Washington/Oregon takes place in August through November; however, August spawners have been declining in recent years. Chum salmon return to the Quilcene National Fish Hatchery in December and the Nisqually River, near Olympia, Washington has spawners during January and February and sometimes into March.

So called summer and fall races of chum salmon occur in Asia and North America. Summer and fall races both enter the Yukon River. The summer chum salmon start entering the river in May and the fall chum enter the river in June and July. The fall stocks tend to spawn farthest up river in September through November. Summer chum are more abundant than fall chum in the Yukon River; however, the

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fall chum are larger. In southern Southeast Alaska and northern British Columbia summer chum enter mostly [mainland rivers](#) in mid June and spawning may extend into late October and early November. Fall chum in southern Southeast Alaska and northern British Columbia spawn mostly in streams on the Islands and spawning typically occurs during September and October. Unlike the Yukon River, summer chum salmon in southern Southeast Alaska and northern British Columbia are larger than the fall stocks for the same age, even though the summer stocks may spawn more than 3 months earlier.

Chum salmon return to spawn as 2- to 7-year olds. Two-year old chum are rare in North America and occur primarily in the southern part of their range, e.g., Oregon. Seven-year old chum are also rare and occur mostly in the northern areas. In general, chum salmon get older from south to north. Three- and four-year olds tend to dominate in the southern areas and four, five, [and six](#)-year olds tend to dominate in the more northern areas. For the most part older chum salmon are larger than younger fish but much overlap occurs between the age groups. The largest chum salmon in North America (and probably the world) occur in the Portland Canal area which forms the border between Alaska and British Columbia.

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Chum salmon fry, like pink salmon, do not overwinter in the streams but migrate (mostly at night) out of the streams [and rivers](#) directly to the sea shortly after emergence. The range of this outmigration occurs between February and June but most fry leave [freshwater](#) during April and May. Chum salmon do tend to linger and forage in the intertidal areas at the head of bays. Estuaries are very important for chum salmon rearing during the spring and summer.

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Juvenile chum salmon are present in the coastal waters mostly during July through October(?), and generally move to the north and west along the coasts of Oregon, Washington, British Columbia, and Alaska. Most juvenile chum salmon are thought to leave the coastal waters and move south into the North Pacific Ocean between Kodiak and False Pass during late fall. After chum salmon form an annulus on their scales (January - March) they are considered immature. They may remain immature for several years until they start maturing and begin their migration to their spawning streams.

Both Asian and North American chum salmon winter in the North Pacific but Asian chum salmon migrate much further east than North American chum salmon migrate to the west. North American chum salmon are seldom found west of 175°E, however, Asian salmon are found eastward to at least 140°W. However, Asian and North American stocks of chum salmon are intermingled on the high seas.

After the 1976-77 Regime Shift in the North Pacific Ocean most chum salmon stocks increased in abundance through the mid-1990s. The Regime Shift apparently created very favorable ocean conditions for all species of salmon from northern British Columbia to northern Alaska. However, as the abundance increased age at maturity increased and the size at age decreased drastically. Chum salmon of the same age in the early 1990s weighed up to 46% less than they weighed in the early 1970s. During this same time, Asian chum salmon also matured older and their size at age declined. These changes in size and age at maturity as population numbers increased suggests that the North Pacific Ocean may have carrying capacity limits for chum salmon under certain conditions. [More recent data suggests that this trend in smaller size of mature fish has changed. Hatchery production of chum salmon in Alaska is large. Particularly in Southeast Alaska where enhanced fish accounted for 85% of the chum salmon catch. Current research in Alaska and the Pacific Northwest is addressing the impacts of enhancement on chum salmon populations.](#)

Fisheries

Chum salmon are captured primarily in purse seines and gill-nets in North America after traps were outlawed in Alaska in 1960. Some chum salmon are captured in troll fisheries, primarily in Canada.

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Major fisheries occur for chum salmon from southern Washington to the Noatak River in northwestern Alaska. Significant declines of chum salmon in Oregon in the 1940s caused the state to abandon net fisheries and the stocks still have not recovered.

Most net fisheries for chum salmon occur in the coastal waters in Alaska but some in-river gill-net fisheries occur in the larger rivers for both commercial and subsistence fisheries. Chum salmon are often captured incidentally in fisheries targeting pink or sockeye salmon. Large incidental catches of chum salmon occur in Southeast Alaska and Prince William Sound. While in the past this may have been true -- there are large and valuable fisheries directed fisheries occurring on chum salmon, primarily those from hatchery production in Southeast Alaska due at least in part to the development of better markets for both the flesh and eggs of chum salmon. When the Pacific Salmon Treaty between the U.S.A. and Canada was signed in 1984 chum salmon in Portland Canal (on both sides of the border but particularly in Canada) were identified as a major conservation concern. The cause of this problem was blamed on incidental capture of chum salmon in fisheries targeting pink and sockeye salmon.

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Chum salmon have also been captured incidentally in the trawl fisheries for pollock in the Bering Sea. Apparently, chum salmon are "scooped" at the surface when the trawl is being let out and brought in. In some years this can be a major problem, e.g., in 1994 when about 250,000 chum were estimated to be part of the bycatch. Chum Salmon bycatch in trawl fisheries has been an area of concern addressed by the management council and thru directed research to identify stock composition and attempt to mitigate such bycatch.

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Relevant Trophic Information

_____ Gear Impacts on Habitats of Chum or other Species of Fish

Chum salmon fisheries utilize seines, gill-nets, and troll gear and there are no apparent impacts of the gear on marine or freshwater habitats. Chum salmon can be impacted by trawl fisheries and non directed salmon fisheries. Size selectivity could be an issue in gillnet fisheries targeting other species.

Upper Size Limit of Juvenile Fish

If the term juvenile chum salmon refers to the fry stage up to the time of the first annulus formation in the ocean, which occurs in January-March, the upper size limit is about 30 cm. Juvenile chum salmon in the outside waters of Southeast Alaska in mid to late August range in size up to about 25 cm.

Sources of Additional Information

Ocean Ecology and Distribution –

NPAFC, BASIS Program NOAA Contact Jamal Moss 907-789-6609

Southeast Management, ADFG

Steve Heintz, Alaska Department of Fish and Game, Ketchikan 907-225-9677

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Genetic Composition of bycatch

Jeff Guyon, NMFS, Auke Bay Laboratory, Juneau, (907) 789-6079

Enhancement Impacts and General Information

John Joyce, NMFS, Auke Bay Laboratory, Juneau, (907) 789-6618

Habitat and Biological Associations

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Eggs and Spawning: Chum salmon spawn in gravel in streams, side-channel sloughs, and intertidal portions of streams when the tide is below the spawning area. In all of these areas upwelling ground water is often the common denominator. Many side-channel sloughs have very little current on the surface and can be very silty; however, the upwelling ground water keeps the silt in suspension in the intragravel water. The upwelling water also keeps these spawning areas with slow moving surface water from freezing in the winter. The depth that eggs are deposited in the streams varies according to the gravel size, current, and size of the female but the range is about 8 to 50 cm. Eggs and sperm are deposited in the redd simultaneously and each female spawns with up to 6 males at the same time. Several redds are constructed by each female and different males may be involved in the spawning act in subsequent redds. Stream life of both sexes varies and is longer in the early stages of the run (about 14 days) and shorter near the end of the run (as few as 6 days) in coastal streams.

Larvae/alevins: Fertilized eggs incubate in the streambed gravel for about five to eight months. Eggs, alevins, and pre-emergent fry can be killed by desiccation, freezing, mechanical injuries due to streambed shifting, e.g., during floods, and predators. The intragravel water during incubation and rearing must be of suitable temperatures and be free of toxins with adequate oxygen and flow to remove waste products. Survival from deposited eggs to emergent fry is highly variable, ranging from about 1% to 20%. The health of the eggs and emerging fry is also dependent on gravel composition, spawning time, spawning density, and genetic characteristics. In general chum salmon eggs have to be fertilized in water above 4 C. and in salinity less than 2 parts per thousand. Dissolved oxygen levels during incubation need to be above 3 to 4 mg/l.

Juveniles: After emerging from the streambed (as early as February and as late as June) schooling chum salmon fry migrate downstream, mostly at night, to the estuaries where they tend to feed in the intertidal grass flats and along the shore. Chums can utilize these intertidal wetlands for several months before actively migrating out of bays and into channels on the way to the outside waters. Pink salmon on the other hand tend to move more directly to more open water areas. Chum salmon utilize a wide variety of food items, including mostly invertebrates (including insects), and gelatinous species. Offshore movement of larger juveniles occurs mostly in July - September.

Adults: Chum salmon reside in the ocean for about one to six years. Adults mature at ages 2 through 7 years; however, 2- and 7-year old chum salmon are rare. Throughout their range 3-, 4-, and 5-year olds are common but 3- and 4-year old salmon dominate the southern stocks and 4-, 5-, and 6-year old chum salmon dominate the northern stocks. Slow or rapid growth in the ocean can modify age at maturity. Slower growth during the second year at sea causes some chum salmon to mature one or two years later. Chum salmon eat a variety of foods during their ocean life, e.g., amphipods, euphausiids, pteropods, copepods, fish, and squid larvae. Chum salmon also utilize gelatinous zooplankton for food more often than any of the other species of salmon. Chum salmon have a much larger stomach than the other species of salmon and this large capacity may allow them to utilize the nutrients from the gelatinous zooplankton more efficiently.

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Asian and North American chum salmon are intermingled on the high seas as immature and during their last year at sea. Recently, immature and maturing chum salmon from Washington, British Columbia, and southeast Alaska have been identified in the Bering Sea in August. Chum salmon spawn mostly in November in Washington and southern British Columbia so these fish are capable of long distant migrations in their last year in the sea.

Special Habitat Concerns: Chum salmon are subject to the same habitat concerns as the other species of salmon, e.g., habitat destruction or silting due to logging and road building activities, blockages due to dams, and pollution. In addition, chum salmon have two habitat requirements that are essential in their life history that make them very vulnerable: (1) reliance on upwelling ground water for spawning and incubation, and (2) reliance on estuaries/tidal wetlands for juvenile rearing after migrating out of the streams. The hydrology of upwelling ground water into stream gravel is highly complex and poorly understood. Whatever activities change the amount and quality of ground water that upwells would very likely affect chum salmon survival in a negative manner. Drilling activities and uplift of land masses due to earthquakes are two phenomena known to affect ground water. Wetlands and estuaries near communities are very vulnerable to pollution and filling activities that would negatively affect essential chum salmon rearing areas.

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Chum salmon will spawn in intertidal portions of streams, most notably in Prince William Sound. The intertidal portion of streams is very vulnerable to coastal pollution from oil spills et al. In Prince William Sound, chum salmon spawners are active in the intertidal zone of streams from late June through September. Eggs, alevins, and fry are in the intertidal gravel from late June through May. That leaves a very narrow “window” in June when the intertidal zone may be free of adults, eggs, alevins, or fry.

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SPECIES: Chum salmon, *Onchorhynchus keta*

Stage	EFH Level	Duration or Age	Diet/Prey	Season/Time	Location	Water Column	Bottom Type	Oceano-graphic Features	Other
Eggs and larvae		90-125 d	eggs predated by birds,	early summer, fall, winter, and early spring	intragravel in stream beds WC, LK, BCH	7.5 to 50 cm in gravel depth	small to coarse gravel CB, G	NA	Develop at 1-10°C, eggs hatch at 52-173 d, larvae emerge from gravel 146-325 d
Juveniles (freshwater)		1-15 d; short streams = 1d, longer rivers=30 d	fry are predated by birds, fish and mammals	spring	rivers and streams WC, LK, BCH	generally migrating in upper portion of water column	varied	NA	downstream migration is mostly in darkness
Juveniles (estuarine)		2-3 months	copepods, euphausiids, decapod larva, amphipods, gelatinous zooplankton	summer	EST, initially nearshore, then offshore in bays and inlets, along kelp beds	generally occupying the upper portion of water column	varied: K, SAV	NA	Preference for increasing salinities, school with other salmon and Pacific sandfish
Juveniles, (marine)		3 to 6 months	copepods, euphausiids, decapod larva, amphipods, gelatinous zooplankton	summer, fall, and winter prior to annulus formation in Jan.-Mar.	coastal, ICS, MCS, OCS; moving further offshore with growth	generally migrating in upper portion of water column	varied: K, SAV	UP, F, CL, E	Coastal and shelf migrations move into oceanic waters in later stages
Immature and maturing adults (marine)		6 to 10 months	fish, squid, euphausiids, amphipods, copepods, and gelatinous zooplankton	spring, summer, and early fall	Oceanic to nearshore in final migration	P, N	NA	UP, F, CL, E: Regional stocks have specific oceanic migratory patterns	Rapid marine growth; onset of maturation timing varies widely among stocks; generally earlier north, later south
Adults (freshwater)		2-7 yrs of age from egg to mature adult, final stage 1-2 months	Active feeding ceases, digestive organs atrophy	spawning (June-January)	WC, LK, BCH	Varied, holding in pools, spawning on shallow riffles, pools or side-channel sloughs	small to coarse gravel CB, G	NA	sexual dimorphism in spawners, males develop large teeth, called dog salmon

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Coho salmon review by J. A. Orsi

Worksheet A – New species-specific habitat information since the EFH EIS

1. Published reports

Cited in the Habitat Reference Document:

These 14 references were merged from previous draft into the original reference list:

MERGE NEW REFERENCES WITH ORIGINAL REF'S

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3. Management changes. None are needed

Worksheet B – Determinations on whether EFH needs to be changed, species-specific.

1. EFH Description Update

Does new information warrant change to EFH Description? No Map only? No
If yes, explain.

Does new description, and any associated information, change the level of information known for the species life stage (i.e., not-identified to Level 1; Level 1 to 2)?

No

2. Research and Information Needs

Do data gaps exist? Yes
If yes, list.

The ocean life history profile describing coho seasonal abundance is not complete in the EEZ of Alaska and beyond. Little information exists on the extent of ocean distribution of juveniles in late fall, and their ensuing distribution as adults from early winter to spring.

Is information most recent and best available? Yes
If no, explain.

3. Fishing Activities

Does fishing activity have more than temporary or minimal affects? No
If yes, explain.

If yes, does fishing activity have an adverse affect to EFH?
If yes, explain.

4. Cumulative Impacts

Are cumulative effects discussed? Y or N
If no, explain.

5. Habitat Areas of Particular Concern (HAPC)

Are there specific ecologically significant, rare, or sensitive sites, relevant to your species, that are particularly vulnerable to human perturbation, which the Council might want to consider identifying as HAPC? No
If yes, list.

6. Non-fishing Activities

Are any non-fishing activities known to be affecting the stock? Unknown
Explain, if possible.

7. Priorities

Are there any priorities for EFH Conservation that the Council may want to consider?
Explain.

Possibly. Two publications may point to some consideration.

Regarding the integrity of wetland habitats, a recent publication on estuarine-rearing strategy of nomad coho fry, Koski (2009) points to the importance of summer and fall estuarine habitats to these fry. Koski (2009) identifies this late summer and fall estuarine habitat as important for coho nomad fry that spend several months in estuaries then reinvade freshwater just prior to winter. Therefore, ensuring connective ness in wetland habitats among coho natal streams and adjacent non-natal over wintering freshwater habitats is important.

On distinctive populations of coho salmon migrating through southeast Alaska waters, Halupka et al. (2003), identifies watersheds or populations meeting some criteria for conservation consideration (See p 1083, Table A.2.). In this reference, three coho stocks are identified as having early timing (e.g., Plotnikof Lake, Pavlof River, and George Inlet): these stocks have also been called "summer run" coho. The data quality identified on these summer coho stocks is characterize as "limited" by Halupka et al. (2003). These summer run stocks enter lake systems early in the year, hold in the lake for months, then move upstream to spawn. I have observed George Inlet summer run coho myself leaving the estuary to enter freshwater in early July. This is remarkable since coho are generally the latest of all the salmon species to spawn, and typically enter the entrance to natal streams fairly dark, in contrast to summer run coho that enter freshwater dime bright from the ocean. This unique life history trait of summer run coho is rare in southeast, and may not be expressed in any other Alaska localities.

Habitat Description for Coho Salmon
(Oncorhynchus kisutch)

Comment [jao1]: Section reviewed by Joe Orsi, AFSC, ABL, March 2010

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Management Plan and Area(s) Salmon Fisheries in the EEZ off the Coast of Alaska, NPFMC, 1990

General Distribution and Life History

Coho salmon are widely distributed in cool areas of the North Pacific Ocean and most adjoining fresh and estuarine waters. Coho use more diverse habitats than other anadromous salmonids. They spawn in most accessible freshwater streams throughout their range, rear for at least 1 year in fresh or estuarine waters, and spend about 18 months at sea before reaching maturity. In North America, coho range along the Pacific coast from Monterey Bay, California, to Point Hope, Alaska, through the Aleutians (Figure 1). The species is most abundant in coastal areas from central Oregon north through southeast Alaska. In the southern part of their range, coho stocks are generally depressed from historical levels, and hatcheries are often used to supplement wild runs. The Central California Coast Evolutionary Significant Unit (ESU) and the Southern Oregon/Northern California Coast ESU are listed as threatened species under the Endangered Species Act. Coho are cultured for market in several countries; attempts to establish self-sustaining coho runs in other areas of the world have had limited success.

In the NMFS Alaska Region, most coho are wild fish with a distribution north to Point Hope on the eastern Chukchi Sea, west and south to the limits of U.S. territorial waters, and east to the Canadian border as far north as the Yukon River drainage. Coho catch in the Alaska Region is at historically high levels, and trends in abundance of most stocks are rated as stable.

Fishery

Important commercial, sport, and subsistence fisheries for coho occur from the Soviet Far East through the Bering Sea and along the west coast of North America as far south as central California. Trolling, gill nets, and purse seines are the primary commercial gear types used to harvest coho. Gill nets, dip nets, rod and reel, traps, fish wheels, long lines, and snagging gear are also used to harvest coho for subsistence and personal use. Subsistence fisheries are often cultural or traditional and take precedence over other fisheries. Personal use fisheries require a sport fishing license or exemption. Both subsistence and personal use fisheries are restricted to designated locations and specified bag limits. Sport catches of coho are taken by hook and line and snagging.

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Most coho from the Alaska Region migrate to sea as smolts after 1 to 2 years of fresh water residence, spend about 12-16 months at sea, then recruit to fisheries along return migration routes to natal streams. All adult coho spend exclusively one marine winter prior to their return migration, notwithstanding, precocious males ("jacks") that return after a brief period of ocean residence. Fisheries in the Alaska Region primarily target adult coho in areas such as the open ocean (commercial salmon troll), along coastal marine migration corridors (limit purse seine and sport/charter), near the mouths of rivers and streams (commercial drift gillnet, set net, personal use, subsistence, and sport), and in freshwater migration areas (sport, personal use, subsistence, and set net). Those fisheries coincide with migrations toward spawning areas from July through October. A few areas are stocked annually with juvenile coho to provide put-and-take sport fishing. Many private non-profit regional aquaculture associations produce significant numbers of coho to supplement commercial fisheries in the Alaska region.

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Bycatch depends on gear type, but is usually limited to other salmon species. Chinook salmon bycatch is limited by regulation or treaty in most coho fisheries, but other salmon species are often targeted as part of the fishery. Species such as steelhead, Dolly Varden, [walleye](#) pollock, Pacific cod, halibut, [ling cod](#), salmon sharks, and coastal rockfish make up a small part of the catch.

Relevant Trophic Information

Adult coho provide important food for bald eagles, terrestrial mammals (e.g., brown bear, black bear, and river otter), marine mammals (e.g., Steller sea lion, harbor seal, beluga, and orca), and salmon sharks. Adults also transfer essential nutrients from marine to freshwater environments. Juveniles are eaten by a variety of birds (e.g., gulls, terns, kingfishers, cormorants, mergansers, herons), fish (e.g., Dolly Varden, steelhead, cutthroat trout, and arctic char), and mammals (e.g., mink and water shrew). Juvenile coho are also significant predators of pink salmon fry during their seaward migration. [Adult coho are highly piscivorous, and experience remarkably high growth rates compared to the other species of salmon. Upon their return ocean migration, adult coho feed on forage fish such as Pacific herring, Pacific sand lance, and Pacific sardines, and may also feed on the juveniles of important commercial species such as pink salmon and sablefish.](#)

Potential Gear Impacts on the Habitats of this or Other Species

Directed fisheries on coho salmon in Alaska include marine commercial and recreational hook-and-line fisheries; marine commercial gill-net and seine fisheries; and estuarine and riverine gill-net (both set-net and drift), recreational, personal use, and subsistence fisheries. Two types of impacts can occur: (1) direct effects [of the fishing gear on habitat; and \(2\) bycatch or entanglement of non-target species.](#) In the marine fisheries, direct impact of the gear on marine habitats is limited, but some localized effects can occur, such as trolling [lead](#) weights damaging coral or purse seines damaging kelp beds or benthic structure. Bycatch and entanglement of non-target species can occur in the marine fisheries, such as bycatch of demersal rockfish in hook-and-line fisheries, and entanglement of seabirds and marine mammals in net fisheries. In the estuarine and riverine fisheries, direct impacts on riparian vegetation and channel morphology can occur from fishing activities, such as damage to the stream bank from boat wakes and removal of woody debris to provide access. Trampling of stream banks and the stream channel can also damage coho habitat. Where use levels are high, this type of impact may require restoration or management initiatives. An example is the Kenai River where restoration work was needed to repair damage from recreational fishing for [Chinook](#) salmon and other salmonids.

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Approximate Upper Size Limit of Juvenile Fish (in 35 cm

Sources for Additional Distribution Data

Adults: ADF&G, Commercial Fisheries Management and Development Division, 907-465-4160; ADF&G, Sport Fish Division, 907-465-4180; ADF&G, Subsistence Division, 907-465-4147;

Juveniles: ADF&G, Habitat and Restoration Division, 907-465-4105; USFS, Region 10 Office of Wildlife, Fish Ecology, and Watershed, 907-586-8752; NMFS, Alaska Fisheries Science Center, Auke Bay Laboratories, 907-789-[6030](#).

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The known distribution of adults and juveniles is given in the current ADF&G *Atlas to the Catalogue of Waters Important for Spawning, Rearing, or Migration of Anadromous Fishes*. The Catalogue and Atlas are divided into six volumes corresponding to the State's six resource management regions (Arctic,

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Interior, Western, Southwest, Southcentral, and Southeast). The principal contact for the ADF&G catalogue/atlas project is Ed Weiss, ADF&G Regional Office in Anchorage (907-267-2305). Copies of the entire Atlas and Catalogue are available for inspection at the ADF&G Habitat and Restoration Division Regional Offices in Fairbanks and Anchorage and the Headquarters Office in Juneau. Copies of a regional volume of the Atlas are available for inspection at ADF&G offices in Ketchikan, Wrangell, Petersburg, Sitka, Haines, Yakutat, Palmer, Cordova, Glennallen, Soldotna, Homer, Kodiak, Sand Point, King Salmon, Dillingham, Bethel, Delta Junction, Tok, Nome, and Dutch Harbor.

Habitat and Biological Associations

Juvenile and adult coho are highly migratory and depend on suitable habitat in their migration routes. Unobstructed passage and suitable water depth, water velocity, water quality, and cover are important elements in all migration ~~habitats~~. ~~Soon after emergence in spring, fry may move around considerably seeking optimal, unoccupied habitat for rearing. In fall, juveniles may migrate from summer rearing areas to areas with winter habitat. Such juvenile migrations may be extensive within the natal stream basin or between basins through salt water or connecting estuaries as "nomad" fry. Seaward migration of coho smolts occurs usually after 1-2 years in fresh water. The migration is timed primarily by photoperiod and occurs in spring, usually coincident with a spring freshet. During this transition, coho undergo major physiological changes to enable them to osmoregulate in salt water and are at that time, especially sensitive to environmental stress. In summer and early fall, juvenile coho are often associated with tidal or ocean currents over the continental shelf and primarily occupy the upper 30 meters of the water column. Once at sea, juvenile Alaska coho generally migrate north and further offshore into the North Pacific Ocean, Gulf of Alaska, or Bering Sea. After 12 to 14 months at sea, coho adults then migrate to coastal areas destined for their natal streams.~~

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Egg/Larvae: Fertilized eggs and larvae require incubation in porous substrate that allows constant circulation of cool, high-quality water that provides oxygen and removes waste.

Interstitial space in the substrate must be great enough to allow growth and movement through the gravel to accommodate emergence. Sand or silt in the substrate can limit intragravel flow and trap emerging fry. As the yolk sac is absorbed, the larvae become photopositive and move through the substrate into the water column. Fry emerge between March and July, depending on when the eggs were fertilized and water temperature during development.

Juveniles (Fresh Water): In Alaska, juvenile coho usually spend 1-2 years in fresh or estuarine waters before migrating to sea, although they may spend up to 5 years where growth is slow. Coho need to attain a length of about 85 mm to become smolts. Coho smolt production is most often limited by the productivity of freshwater and estuarine habitats used for juvenile rearing. Survival from eggs to smolts is usually less than 2%. If spawning escapement is adequate, sufficient fry are usually produced to exceed the carrying capacity of rearing habitat. In this case, carrying capacity of summer habitat sets a density-dependent limit on the juvenile population. This summer population is then reduced by density-independent mortality over winter depending on the severity of winter conditions, fish size, and quality of winter habitat.

Coastal streams, lakes, estuaries, and tributaries to large rivers can all provide coho rearing habitat. The most productive habitats are in smaller streams less than fourth order having low-gradient alluvial channels with abundant pools often formed by large woody debris or fluvial processes. Beaver ponds can provide some of the best summer rearing areas for juvenile coho. Coho juveniles also may use brackish-water estuarine areas in summer and ~~then these nomad fish may~~ migrate upstream ~~into different~~ fresh water ~~systems~~ to overwinter.

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During the summer rearing stage, fish density tends to be highest in areas with abundant food (drifting aquatic invertebrates and terrestrial insects that fall into the water) and structural habitat elements (e.g., large woody debris and associated pools). Preferred habitats include a mixture of different types of pools, glides, and riffles with large woody debris, undercut banks, and overhanging vegetation which provide advantageous positions for feeding. Coho grow best where water temperature is between 10 and 15°C, and dissolved oxygen (DO) is near saturation. Juvenile coho can tolerate temperatures between 0° and 26°C if changes are not abrupt. Their growth and stamina decline significantly when DO levels drop below 4 mg/l, and a sustained concentration less than 2 mg/l is lethal. Summer populations are usually constrained by density-dependent effects mediated through territorial behavior. In flowing water, juvenile coho usually establish individual feeding territories, whereas in lakes, large pools, and estuaries they are less likely to establish territories and may aggregate where food is abundant. Growth in summer is often density-dependent, and the size of juveniles in late summer is often inversely related to population density.

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In winter, food is less important and territorial behavior fades. Juveniles aggregate in freshwater habitats that provide cover with relatively stable temperature, depth, velocity, and water quality. Winter mortality factors include hazardous conditions during winter peak stream flow, stranding of fish by ice damming, physiological stress from low temperature, and progressive starvation. In winter, juveniles prefer a narrower range of habitats than in summer, especially large mainstream pools, backwaters, and secondary channel pools with abundant large woody debris, and undercut banks and debris along riffle margins. Survival in winter, in contrast to summer, is generally not density-dependent, and varies directly with fish size and amount of cover and ponded water, and inversely with the magnitude of the peak stream flow.

The seaward migration of smolts in native stocks is typically in May and June, and is presumably timed so that the smolts arrive in the estuary when food is plentiful. Habitat requirements during seaward migration are similar to those of rearing juveniles, except that smolts tend to be more fragile and more susceptible to predation. High streamflow aids their migration by assisting them downstream and reducing their vulnerability to predators. Turbidity from melting glaciers may also provide cover from predators. Migration cover is also provided by woody debris and submerged riparian vegetation. Migrating smolts are particularly vulnerable to predation because they are concentrated and moving through areas of reduced cover where predators congregate. Mortality during seaward migration can exceed 50%.

Juveniles (Estuarine): Juvenile coho primarily use estuarine habitat during their seaward migration in spring, but can also use this habitat for rearing later in the summer and fall as nomads. Intertidal sections of freshwater streams (i.e., stream-estuary ecotones) can be important rearing habitat for age-0 coho from May to October. These areas may account for one-quarter of the juvenile production in small streams. Growth in these areas is particularly rapid because of abundant invertebrate food. Habitats used include glides and pools during low tide, and coho occupy the freshwater lens during high tide. In fall, juvenile coho nomads move upstream to fresh water to overwinter, and often move into non-natal streams.

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During seaward migration, coho smolts may be present in the estuary from May to August. Rapid growth during the early period in the estuary is critical to survival because of high size-dependent mortality from predation.

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Juveniles (Marine): After leaving fresh water, coho in the Alaska Region spend up to 4 months in coastal waters before migrating offshore and dispersing throughout the North Pacific Ocean and Bering Sea. Marine invertebrates are the primary food when coho first enter salt water, and fish prey increase in importance as the coho grow. In southeast Alaska, juvenile coho primarily occupy the upper 30 m of the water column in inside waters from June to August, and then move offshore by September. Offshore, juvenile salmon are concentrated over the continental shelf within 37 km of shore where the shelf is narrow, but may extend to at least 74 km from shore in some areas. Stock-specific aggregations have not been noted at this stage. However, along the Alaska continental shelf, stock-specific migrations have identified Alaska and non-Alaska stocks of juvenile coho to migrating as far north and west as Kodiak Island during their fish summer at sea.

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Immature and Maturing Adults (Marine): Most coho occupy epipelagic areas in the central Gulf of Alaska and Bering Sea during the 12 to 14 months after leaving coastal areas. Some coho also use coastal and inshore waters at this life stage, but those are likely to be smaller at maturity. The spatial distribution of suitable habitat conditions is affected by annual and seasonal changes in oceanographic conditions; however, coho generally use offshore areas of the North Pacific Ocean and the Bering Sea from 40 to 60° north latitude (Figure 2). The distribution of ocean harvest is generally more northerly than that for stocks from other regions (Figure 3).

Growth is the objective at this stage of the coho life cycle, and bioenergetics are controlled mainly by food quantity, food quality, and temperature. Food for salmon is most abundant above the halocline which may range from 100 to 200 meters in depth in the North Pacific. The bioenergetics of growth is best in epipelagic offshore habitat where forage is abundant and sea surface temperature is between 12 and 15°C. Coho rarely use areas where sea surface temperature exceeds 15°C.

Most coho remain at sea for about 16 months before returning to coastal areas and entering fresh water to spawn, although some precocious males will return to spawn after about 6 months at sea. Before entering fresh water to spawn, most coho slow their feeding and begin to lose weight as they develop secondary sex characteristics. Survival from smolt to adult averages about 10 percent.

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Adults (Freshwater): Adult coho enter fresh water from early July through December and spawn from September through January. Coho generally spawn in late fall and have the latest spawn time of all the salmon species, however a select few stocks have been identified as having an early run timing, also called "summer run". Fidelity to natal streams is high and straying rates are generally less than 5 percent. The fish feed little and migrate upstream using olfactory cues that were imprinted in early development.

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Adult coho may travel for a short time and distance upstream to spawn in small streams or may enter large river systems and travel for weeks to reach spawning areas more than 2,000 km upstream. Upstream migrations are blocked where fall heights exceed 3.3 m or falls more than 1.2 m high have jumping pools less than 1.25 times the falls height. Blockages also occur where stream gradient exceeds 12 percent for more than 70 m, or 16 percent for more than 30 m, or 20 percent for more than 15 m, or 24 percent for more than 8 m.

Spawning sites selected for use have relatively silt-free gravels ranging from 2 mm to 10 cm in diameter, well-oxygenated intragravel flow, and nearby cover. In Alaska streams, between 2,500 and 4,000 eggs are deposited among several nests by each female coho.

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Several males may attend each female, but larger males usually dominate by driving off smaller males. Soon after spawning, adult coho die in or near the spawning areas.

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SPECIES: Coho Salmon (*Oncorhynchus kisutch*)

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Stage -EFH Level	Duration or Age	Diet/Prey	Season/Time	Location	Water Column	Bottom Type	Oceanographic/Riverine Features	Other
Eggs/Larvae	150 days at optimum temperature	NA	Fall/winter	WC, LK	Intra-gravel	G	Streambed	DO < 2 mg/l lethal, optimum >8 mg/l; Temperature 0-17°C; optimum 4.4-13.3°C ; substrate 2-10 cm with <15% fines (<3.3 mm), optimum <5% fines
Juveniles, Fresh water (fry to smolt)	1-5 yrs, most (>90%) 1-2 yrs	invertebrates and fish	Entire year	WC, LK	Entire column	N/A	Pools, woody debris, currents for migration	DO lethal at <3 mg/l, optimum at saturation; Temperature 0-26°C; optimum 12-14°C.
Juveniles, Estuarine	1-6 months	Invertebrates and fish	Rearing - summer, <u>fall</u> Migration - spring	EST	Mid-water and surface, P, N	N/A	Pools, glides, <u>connected wetlands, salt marsh, etc.</u>	<u>Age 0 coho nomad fry spend time in stream-estuary ecotone into late fall and reinvade freshwater to rear and smolt later</u>
Juveniles, Marine	up to 4 months	fish and invertebrates	June - September	BCH, ICS, MCS, BA, IP	P, N	N/A	UP, CL	Temperature <15°C; Depth <10 m
Immature/ Maturing Adults, Marine	12-14 months	Fish (e.g., herring, sand lance)		BCH, ICS, MCS, OCS, USP, LSP, BSN, BAY, IP	P, N	N/A	U	Temperature range 1-26°C; optimum 12-14°C
Adults, Fresh water	up to 2 months	little or none	migration - <u>fall or summer</u> ; spawning - fall, winter	WC, LK	Deep parts of streams and lakes	Alluvial bottom types	Deep pools, Pool-riffle transition	Temperature range 1-26°C; optimum 12-14°C

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Pink salmon review by W.R. Heard

Worksheet A – New species-specific habitat information since the EFH EIS

1. Published reports

Relevant additional and new pink salmon publications

Skud, B.E. 1973. Factors regulating the production of pink salmon. *Rapports et Proces-Verbaux Reunions Conseil International por l'Exploration de la Mer*, 164: 106-112.

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Smoker, W. W. and W. R. Heard. 2007. Productivity of Alaska's salmon hatchery ocean ranching program and management of biological risk to wild Pacific salmon. In: T. M. Bert (ed.), *Ecological and Genetic Implications of Aquaculture Activities*. Pp. 361-381. Springer, Dordrecht, The Netherlands.

Gilk, S. E., I. A. Wang, C. L. Hoover, W. W. Smoker, S. G. Taylor, A. K. Gray, and A. J. Gharrett. 2004. Outbreeding depression in hybrids between spatially separated pink salmon, *Oncorhynchus gorbuscha*, populations: Marine survival, homing ability, and variability in family size. *Environ. Biol. Fish.* 69:287-297.

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Wertheimer A. C., W. W. Smoker, J. Maselko, and W. R. Heard. 2004. Relationship of size at return with environmental variation, hatchery production, and productivity of wild pink salmon in Prince William Sound, Alaska: does size matter? *Rev. Fish Biol. Fish.* 14(3):321-334.

Carls, M. G., G. D. Marty, and S. D. Rice. 2003. Is pink salmon spawning habitat recovering from the Exxon Valdez oil spill?, p. 335-348. In *Proceedings of the Twenty-sixth Arctic and Marine Oilspill Program (AMOP) Technical Seminar*, Environment Canada, Ottawa, Ont.

Wertheimer, A. C., W. R. Heard, and W. W. Smoker. 2004. Effects of hatchery releases and environmental variation on wild-stock productivity: Consequences for sea ranching of pink salmon in Prince William Sound, Alaska, p. 307-326. *In* K. M. Leber, S. Kitada, T. Svasand, and H. L. Blankenship (editors), *Stock enhancement and sea ranching 2*. Blackwell Science Ltd, Oxford.

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2. Unpublished data, other relevant information

3. Management changes. No management changes are needed

Worksheet B – Determinations on whether EFH needs to be changed, species-specific.

1. EFH Description Update

Does new information warrant change to EFH Description?

No, on Map No

Does new description, and any associated information, change the level of information known for the species life stage (i.e., not-identified to Level 1; Level 1 to 2⁺)?

No

2. Research and Information Needs

Do data gaps exist?

Yes. More open ocean research especially during the winter period is a high priority need to better understand the causes of variable year class strength and high fluctuations in marine survival of pink salmon. Recent development of reasonably accurate forecasts on pink salmon run strength have been developed for southeast Alaska based on marine life period just prior to when juveniles enter the open ocean environment. This forecast model, however, does not account for how fluctuations in variable oceanic conditions affect juvenile pink salmon. The need for similar oceanic research focused on a broad array of biophysical metrics [ecosystem approach] also applies to other salmon species.

Is information most recent and best available?

Yes

3. Fishing Activities

Does fishing activity have more than temporary or minimal affects?

Yes. In recent years a significant proportion of Alaska's pink salmon harvest comes from hatchery programs, especially in Prince William Sound. In 2007 for example pink salmon represented 53% by weight of the total commercial Alaska salmon catch with 43% of this amount originating from hatcheries.

If yes, does fishing activity have an adverse affect to EFH? Nothing that is apparent.

4. Cumulative Impacts

Are cumulative effects discussed?

Yes.

5. Habitat Areas of Particular Concern (HAPC)

Are there specific ecologically significant, rare, or sensitive sites, relevant to your species, that are particularly vulnerable to human perturbation, which the Council might want to consider identifying as HAPC?

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Yes. Remaining pockets of Exxon Valdez oil in PWS may have residual effects on wild pink salmon populations, especially in intertidal areas.

6. Non-fishing Activities

Are any non-fishing activities known to be affecting the stock?

Unknown

7. Priorities

Are there any priorities for EFH Conservation that the Council may want to consider? Explain.

Habitat Description for Pink salmon (*Oncorhynchus gorbuscha*)

Management Plan and area(s) Salmon Fisheries in the EEZ Off the Coast of Alaska, NPFMC, 1990

Life History and General Distribution

The natural freshwater range of pink salmon includes the Pacific rim of Asia and North America north of about 40°N. Within this vast area, spawning pink salmon are widely distributed in coastal streams of both continents up to the Bering Strait. North, east and west of the Bering Strait, spawning populations become more irregular and occasional. Centers of large spawning populations occur at roughly parallel positions along the two continents from about latitudes 44°N to 65°N in Asia and about 48°N to 64°N in North America. In marine environments along both the Asian and North American coastlines pink salmon occupy ocean waters south of the limits of spawning streams.

Pink salmon are distinguished from other Pacific salmon by having a fixed two-year life span, being the smallest of the Pacific salmon as adults (averaging 1.0-2.5 kg), the fact that the young migrate to sea soon after emerging from the gravel, and developing a marked hump in large maturing males. This last characteristic is responsible for the vernacular name humpback salmon used in some areas. Because of the fixed two-year life cycle, pink salmon spawning in a particular river system in odd and even years are reproductively isolated from each other and have developed into genetically different lines. In some river systems, like the Fraser River in British Columbia, only the odd-year line exists; returns in even years are negligible. In Bristol Bay, Alaska, the major runs occur in even years, whereas the coastal area between these two river systems is characterized by runs in both even and odd years. In different parts of the range populations are sometimes characterized by the phenomena of dominance where one brood line is much stronger than the other brood line. Upon emergence, pink salmon fry migrate quickly to sea and grow rapidly as they make extensive feeding migrations. After eighteen months in the ocean the maturing fish return to their river of origin to spawn and die.

Pink salmon are considered to have either the simplest or most specialized life cycle within the genus, depending on whether Pacific salmon originated from marine or freshwater ancestors. One view holds that *Oncorhynchus* evolved from an ancestral freshwater form of Pacific *Salmo* during the Pleistocene, probably in the vicinity of the present-day Sea of Japan. Under this scenario, pink salmon that rely least on the freshwater environment are the most specialized. Pink salmon have 52 chromosomes, fewer than other Pacific salmon, which also may suggest specialization. Another view considers Salmonidae as relatively primitive teleosts, of probable marine pelagic origin, and about five million years old. This alternative view to freshwater origin of Pacific salmon is supported, in part, by Pliocene fossils from California and Oregon. The marine origin view holds that during evolution salmonids tended towards greater dependence on fresh water and away from dependence on the sea. Under this scenario, pink salmon, with the least dependence on the freshwater environment, is considered the least advanced extant *Oncorhynchus* species.

Fisheries

Pink salmon are the most abundant Pacific salmon, contributing about 40% by weight and 60% in numbers of all salmon caught commercially in the North Pacific Ocean and adjacent waters. Coastal fisheries for pink salmon presently occur in Asian (Japan and Russia) and North America (Canada and the United States) with major fisheries in both Russia and the U.S. Historically some pink salmon were caught in high seas fisheries by Japan and Russia. Most pink salmon in the U.S. are caught in Alaska

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where major fisheries occur in Southeast, Prince William Sound, and Kodiak regions. Lessor fisheries for pink salmon occur in Cook Inlet, Alaska Peninsula and Bristol Bay regions. Alaska fisheries for pink salmon occur primarily within State of Alaska territorial seas (inside 3-miles).

Pink salmon catches have been at historic records in Alaska over the past decade with catches exceeding 100 million fish in several years. Most pink salmon in Alaska are caught by purse seines with smaller commercial catches made by set and drift gill net and troll fisheries. Recreational fisheries in Alaska usually harvest between 200 and 400 thousand pink salmon annually. Historically, pink salmon in Alaska have been harvested, on average, at between 60% and 75% of the total annual run.

Purse seine fisheries for pink salmon have some bycatch associated with them, primarily other salmon. The most important bycatch issue is in the Southeastern region where younger marine-age chinook salmon, similar in size to adult pink salmon, are caught in pink salmon purse seine fisheries. The total harvest of chinook salmon in this region is controlled by quotas under auspices of the Pacific Salmon Treaty. The Alaska Board of Fisheries allocates a portion of the quota for chinook salmon as an allowable bycatch in purse seine fisheries targeted on pink salmon.

Measured marine survivals of pink salmon, from entry of fry into stream mouth estuaries to returning adults, have ranged from 0.2% to over 20%. Scientists, in general, believe that much of the natural mortality of pink salmon in the marine environment occurs within the first few months before advanced juveniles move offshore into more pelagic ocean waters. Pink salmon populations can be very resilient, rebounding from weak to strong run strength in regional stock groups within one or two generations.

Relevant Trophic Information

Pink salmon eggs, alevins, and fry in freshwater streams provide an important nutrient input and food source for aquatic invertebrates, other fishes, birds and small mammals. In the marine environment, pink salmon fry and juveniles are food for a host of other fishes and coastal sea birds.

Subadult and adult pink salmon are known to be eaten by fifteen different marine mammals, sharks, other fishes such as Pacific halibut, and humpback whales. Because pink salmon are the most abundant salmon in the North Pacific, it is likely they comprise a significant portion of the salmonids eaten by marine mammals.

Millions of pink salmon adults returning to spawn in thousands of streams through out Alaska provide significant nutrient input into the trophic level of these coastal watersheds. Adult pink salmon in streams are major food sources for gulls, eagles, and other birds, along with bear, otter, mink and other mammals.

Describe any potential gear impacts on the habitats of this or species.

Because pink salmon are primarily caught in purse seines there are no known gear impacts to the marine habitats where these fisheries occur.

What is the approximate upper size limit of juvenile fish (in cm)? Roughly 25 cm.

Provide source (agency, name and phone number or literature reference for any possible additional distribution data.

[William R. Heard, NMFS, Auke Bay Laboratory, 907-789-6003](#)

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Habitat and Biological Associations (if known) Narrative

Eggs and Spawning: Pink salmon choose a fairly uniform spawning bed in small and large streams in both Asia and North America. Generally, these spawning beds are situated on riffles with clean gravel, or along the borders between pools and riffles in shallow water with moderate to fast currents. In large rivers, they may spawn in discrete sections of main channels or in tributary channels. Pink salmon avoid spawning in quiet deep water, in pools, in areas with a slow current, or over heavily silted or mud-covered streambeds. Places selected for egg deposition is determined by the optimal combination of two main interconnecting variables: depth of water and velocity of current.

On both the Asian and North American sides of the Pacific Ocean, pink salmon generally spawn at depths of 30-100 cm. Well populated spawning grounds of pink salmon are mainly at depths of 20-25 cm, less often reaching depths of 100-150 cm. In dry years, when spawning grounds are crowded, nests can be found at shallower depths of 10-15 cm. Current velocities in pink salmon spawning grounds varied from 30 to 100 cm/s, sometimes reaching 140 cm/s. Directly over the redds, about 5-7 cm from the surface, the velocity can range from 30 to 140 cm/s but usually averages from 60 to 80 cm/s.

In general, pink salmon select sites in gravel where the gradient increases and the currents are relatively fast. In these areas, surface stream water must have permeated sufficiently to provide intragravel flow for dissolved oxygen delivery to eggs and alevins. Chum salmon, by contrast, tended to select spawning sites in areas with upwelling spring water and a relatively constant water temperature, without much regard to surface stream water. Pink salmon spawning beds consist primarily of coarse gravel with a few large cobbles, a large mixture of sand, and a small amount of silt. High quality spawning grounds of pink salmon can best be summarized as clean, coarse gravel. [Pink salmon like sockeye salmon tend to spawn in large groups on riffles here elaborate courtship and defensive behavior patterns occur. Both species can develop large humps on the backs of spawning males. A common name for spawning pink salmon is humpback salmon.](#)

Larvae/alevins: Fertilized eggs begin their five- to eight-month period of embryonic development and growth in intragravel interstices. To survive successfully, the eggs, alevins and pre-emergent fry must first be protected from freezing, desiccation, stream bed scouring or shifting, mechanical injury and predators. Water surrounding them must be non-toxic and of sufficient quality and quantity to provide basic requirements of suitable temperatures, adequate supply of oxygen, and removal of waste materials. Collectively, these requirements are, on average, only partially met even under the most favorable natural conditions. Overall freshwater survival of pink salmon from egg to advanced alevin and emerged fry, even in highly productive streams, commonly reaches only 10%-20% and at times is as low as about 1%.

Rates of egg development, survival, size of hatched alevins and percentage of deformed fry are related to temperature and oxygen levels during incubation. Temporary low stream temperatures or dissolved oxygen concentrations, however, may be relatively unimportant at some developmental stages, but lethal at others. Generally, low oxygen levels are non-lethal early, but lethal late in development. Eggs subjected to low dissolved oxygen levels hatched prematurely at a rate dependent on the degree of hypoxia. Spinal deformities occurred in eggs incubated at 3.0° and 4.5°C before gastrulation. In one study, over 50% of developing pink salmon eggs died at dissolved oxygen levels of 3-4 mg/l, and among those that hatched many alevins were deformed.

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Juveniles: Newly emerged pink salmon fry show a preference for saline water over fresh water which may, in some situations, facilitate migration from the natal stream area. Schools of pink salmon fry may move quickly from the natal stream area or remain to feed along shorelines up to several weeks. The timing and pattern of seaward dispersal is influenced by many factors, including general size and location of the spawning stream, characteristics of adjacent shoreline and marine basin topography, extent of tidal fluctuations and associated current patterns, physiological and behavioral changes with growth, and, possibly, different genetic characteristics of individual stocks.

Early marine schools of pink salmon fry, often in tens or hundreds of thousands of fish, tend to follow shorelines and, during the first weeks at sea, spend much of their time in shallow water of only a few centimeters deep. It has been suggested that this onshore period involves a distinct ecological life history stage in both pink and chum salmon. In many areas throughout their ranges, pink salmon and chum salmon fry of similar age and size co-mingle in both large and small schools during early sea life. Juvenile pink salmon in the Bering Sea off the northeastern Kamchatka coast are found in one of three hydrological zones during their first three to four months of marine life: (1) the littoral zone, up to 150 m from shore; (2) open parts of inlets and bays from 150 m to 3.2 km from shore; and (3) the open parts of the large Karaginskiy Gulf, 3.2 to 96.5 km from shore. Distribution within these regions is seasonally related to the size of pinks, with an offshore movement of larger fish in August and September. [Pink salmon in other regions.](#)

[different marine habitat zones during the first three to four month at sea. Along the North American coastline once juveniles reach open ocean areas they tend to remain on continental shelf waters until October–November.](#)

Pink salmon juveniles routinely obtain large quantities of food sufficient to sustain rapid growth from a broad range of habitats providing pelagic and epibenthic foods. Collectively, diet studies show that pink salmon are both opportunistic and generalized feeders and on occasion they specialize in specific prey items. Diel sampling of stomachs showed fewer and more digested food items at night than during the day indicating that juvenile pinks are primarily diurnal feeders.

Adults: Ocean growth of pink salmon is a matter of considerable interest because, although this species has the shortest life span among Pacific salmon, it also is among the fastest growing. Entering the estuary as fry at around 3 cm in length, maturing adults return to the same area 14-16 months later ranging in length from 45 to 55 cm.

The population biology of pink salmon revolves around the two-year life cycle. A phenomena of cycle dominance between odd- and even-year brood lines within specific regions is common. Dominance can be weak or strong, complete or non-existent. It can also shift between brood lines. With complete dominance, the “off-year” line is absent while non-dominance is characterized by similar population strength between odd- and even-year runs. Although many causes for dominance and its various characteristics in pink salmon populations have been proposed, none satisfactorily explains the event. Genetically, pink salmon are more similar within odd- or even-year brood lines across broad geographic regions than across brood lines within the same stream. It has been suggested for some geographic areas that present odd- and even-year pink salmon populations arose from separate glacial refuges during late Pleistocene times.

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Scientists have recognized six distinct ocean migration patterns for regional stock groups of pink salmon throughout the North Pacific. Only two of these stock groups, those originating in Washington state and British Columbia and those originating in Southeastern, Central and Southwestern Alaska, occur in marine waters where they might interact in some way with the salmon fisheries off the coast of Southeast Alaska. Pink salmon from these two broad stock groups co-mingle in the Gulf of Alaska during their second summer at sea while migrating towards natal areas.

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Wertheimer, A.C., J.A. Orsi, E. A. Fergusson, and M.V. Sturdevant. 2009. Forecasting pink salmon harvest in southeast Alaska from juvenile abundance and associated environmental parameters, 2008 returns and 2009 forecast. 2009. NPAFC Doc. 1202. 19 pp. (Available at <http://www.npafc.org>).

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SPECIES: Pink salmon, *Onchorynchus gorbuscha*

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Eggs and larvae	90-125 d	eggs predated by birds, fish and mammals	late summer, fall, winter, and early spring	intragravel in stream beds WC, LK, BHC	15 to 50 cm in gravel depth	medium to coarse gravel CB, G	NA	Develop at 1-10°C, eggs hatch at about 100 d, larvae emerge from gravel about 125 d post hatch
Juveniles, freshwater	1-15 d; short streams = 1d, longer rivers=15 d	fry are predated by birds, fish and mammals	spring	rivers and streams WC, LK, BHC	generally migrating in upper portion of water column	varied	NA	downstream migration is mostly in darkness
Juveniles, estuarine	2-3 months	copepods, euphausiids, decapod larva, amphipods	summer	EST, initially nearshore, then offshore in bays and inlets, along kelp beds	generally occupying the upper portion of water column	varied: K, SAV	NA	Preference for increasing salinities, school with other salmon and Pacific sandfish
Juveniles, marine	3 to 6 months	copepods, euphausiids, decapod larva, amphipods	summer, fall, and early, pre annlus winter	coastal, ICS, MCS, OCS; moving further offshore with growth	generally migrating in upper portion of water column	varied: K, SAV	UP, F, CL, E	Coastal and shelf migrations move into oceanic waters in later stages
Immature and maturing adults marine	6 to 10 months	fish, squid, euphausiids, amphipods, and copepods	spring, summer, and early fall	Oceanic to nearshore in final migration	P, N	NA	UP, F, CL, E: Regional stocks have specific oceanic migratory patterns	Rapid marine growth; onset of maturation timing varies among stocks; earlier north, later south
Adults, freshwater	2 yrs of age from egg to mature adult, final stage 1-2 months	Active feeding ceases, digestive organs atrophy	spawning (Aug-Oct)	WC, LK, BCH	Varied, holding in pools, spawning on shallow riffles	medium to coarse gravel CB, G	NA	sexual dimorphism in spawning males, called humpback salmon

Sockeye salmon review by E. V. Farley

Worksheet A – New species-specific habitat information since the EFH EIS

1. Published reports

New publications related to Sockeye salmon EFH-EIS not in earlier cited references.

Bugaev, A.V., and K.W. Myers. 2009. Stock-specific distribution and abundance of immature sockeye salmon in the western Bering Sea in summer and fall 2002–2004. N. Pac. Anadr. Fish Comm. Bull. 5: 71–86.

Farley, E.V., Jr., M. Trudel. 2009. Growth rate potential of juvenile sockeye salmon in warmer and cooler years on the eastern Bering Sea shelf. Journal of Marine Biology 2009:640215.

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Farley, E.V., Jr., J.M. Murphy, M.D. Adkison, L.B. Eisner, J.H. Helle, J.H. Moss, and J. Nielsen. (2007). Early marine growth in relation to higher survival for Bristol Bay sockeye salmon (*Oncorhynchus nerka*). Fishery Bulletin 105:121 – 130.

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Mantua, N.J., N.G. Taylor, G.T. Ruggione, K.W. Myers, D. Preikshot, X. Augerot, N.D. Davis, B. Dorner, R. Hilborn, R.M. Peterman, P. Rand, D. Schindler, J. Stanford, R.V. Walker, and C.J. Walters. 2009. The salmon MALBEC Project: a North Pacific-scale study to support salmon conservation planning. N. Pac. Anadr. Fish Comm. Bull. 5: 333–354.

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2. Unpublished data, other relevant information

3. Management changes

Sockeye salmon review by E. V. Farley

Worksheet B – Determinations on whether EFH needs to be changed, species-specific.

1. EFH Description Update

Does new information warrant change to EFH Description?

Yes, see text changes, also changes needed on Maps. Several changes in text are needed to update current knowledge of Sockeye salmon EFH-related issues. The Sockeye salmon distribution maps are currently being updated by life history stage.

Does new description, and any associated information, change the level of information known for the species life stage (i.e., not-identified to Level 1; Level 1 to 2*)? **No**

2. Research and Information Needs

Do data gaps exist?

No. Previous data gap on the distribution of western Alaska sockeye salmon in the Western Bering Sea has been addressed by Bugaev and Myers 2009 as a result of BASIS research

Is information most recent and best available? **Unknown**.

3. Fishing Activities

Does fishing activity have more than temporary or minimal affects?

No,

If yes, does fishing activity have an adverse affect to EFH. Not directly to Chinook salmon habitats directly but to the potential health of the stocks.

4. Cumulative Impacts

Are cumulative effects discussed? **Yes**

.

5. Habitat Areas of Particular Concern (HAPC)

Are there specific ecologically significant, rare, or sensitive sites, relevant to your species, that are particularly vulnerable to human perturbation, which the Council might want to consider identifying as HAPC.

Yes. The eastern Bering Sea shelf is a rearing habitat for juvenile western Alaska sockeye salmon. Current oil and gas lease sales in the North Aleutian Basin have the potential to

* EFH Information Levels: Level 1 - Distribution (general) data available; Level 2 - Habitat-related density data available; Level 3 - Growth, reproduction, or survival rates within habitats are available; Level 4 – Production rates by habitat are available. See FMP for EFH Level specifics by life stage.

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adversely impact the juvenile salmon rearing habitat if an oil spill or other human caused catastrophe occurs in the lease area.

4. Non-fishing Activities

Are any non-fishing activities known to be affecting the stock?

Yes. Habitat disruptions and climate change, especially in the Pacific Northwest are continuing to impact Sockeye salmon stocks throughout Alaska EEZ waters. See text writeups.

5. Priorities

Are there any priorities for EFH Conservation that the Council may want to consider?

No.

Habitat Description for Sockeye Salmon (*Oncorhynchus nerka*)

Management Plan and Area(s)

History and General Distribution

The natural freshwater range of sockeye salmon includes the Pacific rim of Asia and North America north of about 40°N. Within this area, the primary spawning grounds of sockeye salmon in North America extend from tributaries of the Columbia River to the Kuskokwim River in western Alaska, and on the Asian side, the spawning areas are found mainly on the Kamchatka Peninsula. Spawning populations become more irregular and occasional north of the Bering Strait, on the north coast of the Sea of Okhotsk, and in the Kuril Islands. Centers of the two largest spawning complexes in the North Pacific rim occur in the Bristol Bay watershed of southwestern Alaska and the Fraser River drainage of British Columbia. In marine environments along both the Asian and North American coastlines sockeye salmon occupy ocean waters south of the limits of spawning systems.

Sockeye salmon exhibit a greater variety of life history patterns than other members of the genus *Oncorhynchus*, and characteristically make more use of lake rearing habitat in juvenile stages. Although sockeye salmon are primarily anadromous, there are distinct populations called kokanee which mature, spawn and die in fresh water without a period of sea life. Typically, but not universally, juvenile anadromous sockeye utilize lake rearing areas for one to three years after emergence from the gravel, however, some populations utilize stream areas for rearing and migrate to sea soon after emergence. Anadromous sockeye may spend from one to four years in the ocean before returning to fresh water to spawn and die in late summer and fall.

The adaptations of sockeye salmon to lake environments appear to require more precise homing to spawning areas, both as to time and location than is found in the other species of Pacific salmon. Although available spawning localities are more restricted because of the usual requirement of a lake rearing environment for the juveniles, the overall success of this adaptation is indicated by the fact that sockeye are much more abundant than chinook (*O. tshawytscha*) and coho salmon (*O. kisutch*), which utilize stream rearing environments as juveniles. Juvenile sockeye salmon in fresh water do not need the territorial stream behavior displayed by juvenile chinook and coho salmon, but do exhibit schooling tendencies more characteristic of pelagic feeding fishes.

Other distinctions of sockeye salmon include growth rate and size at maturity. Sockeye do not exhibit the rapid marine growth of coho or pink salmon (*O. gorbuscha*) which mature and return to fresh water after a single winter in the ocean, or of chinook or chum salmon (*O. keta*) which attain a much larger average size at maturity. The flesh of sockeye is a darker red than that of the other salmon species, a color long considered to be a marketing attribute of the canned and, more recently, the fresh or fresh-frozen product.

Fisheries

Sockeye salmon are an important component, and often the most lucrative fishery for Pacific salmon. Coastal fisheries for sockeye salmon presently occur in North America (Canada and the United States) and Asia (Japan and Russia) with major fisheries in all areas except Japan. From 1920 through 1945, sockeye salmon were caught on the high seas by a Japanese mother ship fishery. This fishery started again in 1953 and a land based driftnet fishery moved sufficiently offshore to begin substantial catches of

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sockeye in 1958. Restrictions in fishing areas resulting from renegotiation of international fishery treaties ended the high seas fisheries in the mid 1980s. In recent years, about 22% of the numbers and 28% by weight of all salmon caught commercially in the North Pacific Ocean and adjacent waters were sockeye. Catches in North America, primarily Alaska and British Columbia, have always been greater than Asian catches. North American catches averaged about 30 million through 1940, declined to 10-15 million in the early 1960s and surged to 40 million and more in the 1990s to 2000s. The recent record high catches resulted primarily from an increase in run magnitudes of natural stocks in central and western Alaska. Historically, Asian catches of sockeye salmon have averaged fewer than 10 million fish. Most sockeye salmon in the U.S. are caught in Alaska where major fisheries occur in Southeast, central and westward areas. In Alaska, sockeye fisheries occur primarily within State territorial seas (inside 3-miles).

Sockeye salmon catches have been at historic records in Alaska over the past decade with catches exceeding 60 million fish in several years. Most sockeye salmon in Alaska are caught by set and drift gill net fisheries. Recreational fisheries in Alaska usually harvest between 200 and 400 thousand sockeye salmon annually, mostly in river system of the Kenai Peninsula in central Alaska. Subsistence catches of sockeye salmon are not universally maintained, but the catches are important, particularly to native people in a number of localities. The Fraser River Indian tribes recorded annual subsistence catches for the years 1970-82 of 240,000. The subsistence catch of sockeye salmon in the United States was 315,000 in 1993, and over 307,000 was caught in Alaskan waters.

Gill net fisheries for sockeye salmon have some bycatch associated with them, primarily other salmon. The most important bycatch issue is in the southeastern region where younger marine-age chinook salmon, similar in size to sockeye, are caught in sockeye net fisheries. The total harvest of chinook salmon in this region is controlled by quotas under auspices of the Pacific Salmon Treaty. The Alaska Board of Fisheries allocates a portion of the quota for chinook salmon as an allowable bycatch in gill net fisheries.

Measured marine survivals of sockeye salmon, from entry of smolts into stream mouth estuaries to returning adults, have ranged from about 5% to over 50%. Scientists, in general, believe that much of the natural mortality of sockeye salmon juveniles in the marine environment occurs within the first few months, and is probably influenced by three factors of unknown relative importance: (1) size and age at seaward migration; (2) timing of entry into the marine environment; and (3) length of stay in the ocean. Variations in oceanographic conditions and in marine predator populations (fish, mammals and birds) undoubtedly have affected the marine survival of sockeye populations in different ways around the North Pacific rim, but these effects are poorly understood.

Relevant Trophic Information

Sockeye salmon eggs, alevins, and juveniles in freshwater streams and lake systems provide an important nutrient and food source for aquatic invertebrates, other fishes, birds and small mammals. In the marine environment sockeye salmon juveniles are food for many other fishes and coastal sea birds. Adult sockeye salmon are known to be eaten by marine mammals and sharks.

Millions of sockeye salmon adults returning to spawn in thousands of streams through out Alaska provide significant nutrient input into the trophic level of these coastal watersheds. Adult sockeye salmon in streams are major food sources for gulls, eagles, and other birds, along with bear, otter, mink and other mammals.

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Describe ___ potential gear impacts on the habitats of this or other species.

Because sockeye salmon are primarily caught in gill nets there are no known gear impacts to the habitats where these fisheries occur.

What is the approximate upper size limit of juvenile fish (in cm)? Roughly 25 cm.

Provide source (agency, name and phone number or literature reference for any possible additional distribution data.

Karl Hofmeister, Alaska Department of Fish and Game, 907-465-4250
Andy MacGregor, Alaska Department of Fish and Game, 907-465-4224
David Barto, Alaska Department of Fish and Game, 907-465-4268

Habitat and Biological Associations (if known) Narrative

Eggs and Spawning: Sockeye salmon generally spawn in late summer and autumn. Within this period, time of spawning for different stocks can vary greatly, apparently because of adaptations to the most favorable survival conditions for spawning, egg and alevin incubation, emergence, and subsequent juvenile feeding. Although timing of spawning varies little from year to year within a specific spawning area, there are great differences in timing among spawning areas. The timing of spawning appears to be dependent to some degree on the temperature regimen in the gravel where the eggs are incubated. This varies distinctly among spawning area types. In the Bristol Bay region of Alaska, spawning begins in late July in the smaller streams, in early to mid-August in the tributaries of some lakes, and in late August to mid-September in most lake beach areas. In Lake Kuril and its tributaries spawning continues from the end of June until early February with the main spawning occurring from September to November.

Among the species of Pacific salmon, the sockeye salmon exhibits the greatest diversity in adaptation to a wide variety of spawning habitats. The selection of habitats and timing of spawning by a sockeye stock are linked to success of survival, not only during spawning and incubation of the eggs and alevins, but also in the chain of freshwater and marine environments to which the progeny are subsequently exposed. In most instances, but not all, the subsequent environment of the juveniles is a lake or lake chain, and the behavior of the juveniles after emergence depends on the location of the spawning area in relation to the lake rearing area to be utilized. Lake-beach spawning has been recorded in most sockeye lake systems, and is apparently important habitat. Sockeye are also known to spawn in areas which lack lake rearing habitat. These “river spawning” or “sea type” sockeye lay their eggs in river systems with no lake, and emergent fry apparently feed in the stream or low-salinity estuaries for several months before migrating to offshore ocean areas. The circumstances surrounding the initial establishment of a spawning colony and the subsequent adaptive behavior of the progeny can only be surmised. However, the continued use of a specific spawning environment by a sockeye stock depends on the precise homing ability of the species, in which straying to other potential spawning locations is minimal.

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The composition of spawning substrate utilized by sockeye salmon varies widely. Some lake-beach spawning occurs to a depth of nearly 30 m in areas of strong upwelling groundwater. In some lakes mass spawning takes place over large angular gravel, too large to be moved by salmon in the normal digging process. The eggs settle in the crevices between the rocks. Generally, however, spawning along lake beaches and in streams takes place in gravel small enough to be readily dislodged by digging, and the digging process tends to remove the silt and clean the gravel where the eggs are deposited. Water depth does not seem to be a critical factor to sockeye in selecting a spawning site. In the small streams and spring ponds it is common to observe pairs of salmon in the spawning process with their dorsal surfaces protruding from the water. In larger rivers, spawning depths are generally not great because riffle areas are preferred. Spawning on lake beaches can extend to considerable depths. It is clear that sockeye can detect upwelling groundwater areas along lake beaches and in spring ponds areas in which to spawn. Generally, the spawning beds are situated in areas with clean gravel, or along the borders between pools and riffles in shallow water with moderate to fast currents. In large rivers, they may spawn in discrete sections of main channels or in tributary channels.

Superimposition is minimized by the territorial defense of the redd by the female following egg deposition, which protects the redd for a few days. Female territory is partly a function of spawner density. Estimates of the capacity of streams to support spawning sockeye were based on density of one female/2 m². In spawning channels, maximum fry production was achieved at the spawner density of one female/m².

Larvae/alevins: Fertilized eggs begin their five- to eight-month period of embryonic development and growth in intragravel interstices. To survive successfully, the eggs, alevins and pre-emergent fry must first be protected from freezing, desiccation, stream bed scouring or shifting, mechanical injury and predators. Water surrounding them must be non-toxic and of sufficient quality and quantity to provide basic requirements of suitable temperatures, adequate supply of oxygen, and removal of waste materials. Collectively, these requirements are, on average, only partially met even under the most favorable natural conditions. Overall freshwater survival of sockeye salmon from egg to advanced alevin and emerged fry, even in highly productive streams, commonly reaches only 10%-20%, and at times is as low as 1%.

Rates of egg development, survival, size of hatched alevins and percentage of deformed fry are related to temperature and oxygen levels during incubation. Temporary low stream temperatures or dissolved oxygen concentrations, however, may be relatively unimportant at some developmental stages, but lethal at others. Generally, low oxygen levels are non-lethal early, but lethal late in development.

Juveniles: Fry emergence apparently begins in early to mid-April in most instances, peaks in early to mid-May, and ends in late May to early June. Newly emerged sockeye salmon fry show a marked negative rheotaxis, and actively swim downstream to lakes. In some lake outlet spawning areas, the emerging fry swim laterally in an attempt to reach the river banks and avoid being swept downstream. The emergence behavior of fry in lakeshore spawning areas has not been reported. It has been suggested that the seasonal timing of sockeye fry emergence, optimizes the timing of dispersal into their feeding habitat, particularly to take advantage of the seasonal peak abundance of zooplankton of appropriate size. It is postulated that fry emerging earlier or later than the optimum may

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suffer greater mortality, and thus that timing is a response to this selective pressure. The survival value in entering the lake early is to take advantage of feeding in the lake as long as possible during the summer, thus achieving larger size in preparation for spring smoltification. Annual timing of fry migration and its seasonal pattern is a function of the seasonal timing of the adult spawning period, ecological factors within the incubation habitat that affects development rate and alevin behavior, and transit time needed by the fry to reach their feeding habitat.

Upon entering nursery lakes, sockeye fry disperse quickly into their lake feeding areas. Movement of fry into the nursery areas may be direct and immediate, or sequential, the latter involving occupation of intermediate feeding areas for a period of time. The plasticity of response suggests definite racial adaptations to a variety of different environmental conditions. Intermediate feeding and growth can occur along outlet river banks before migration into the nursery lake. In-lake dispersions of fry is probably a mechanism whereby the lake zooplankton is effectively utilized as food for the juvenile fish.

Sockeye salmon juveniles typically spend one or more growing seasons in the limnetic zone of a nursery lake before smoltification. The transition in feeding behavior and diet from the time of emergence of the fry from stream or lakeshore to the time of smoltification takes many forms. In general, it is a shift from dependence on dipteran insects to pelagic zooplankton. The annual growth attained by juvenile sockeye and length of residence in fresh water varies greatly among populations in different lake systems, as well as between years within individual lakes. Factors affecting growth are highly complex and include (1) size and species composition of the food supply; (2) water temperature and thermal stratification of the lake; (3) photoperiod and length of growing season; (4) relative turbidity of the lake and available light intensity in the water column; (5) intra- and interspecific competition; (6) parasitism and disease; (7) feeding behavior of juvenile sockeye to minimize predation; and (8) migratory movements to seek favorable feeding environments. Growth influences durations of stay in fresh water before smoltification, and within many lake populations the larger members of a year class tend to migrate to sea earlier the spring or migrate a year earlier than smaller members. In the more southern systems, smoltification after one year is nearly universal. Size is not strictly the determinant for duration of stay in fresh water, because some populations with very poor freshwater growth in their first year migrate as yearlings, whereas other populations exhibiting good first-year growth migrate predominantly after a second year of growth. Emergent fry of "river spawning" or "sea type" sockeye which spawn in systems lacking lake rearing habitat, feed in the stream or low-salinity estuaries for several months before migrating to offshore ocean areas.

Sockeye fry at the beginning of lake life are between 25 and 31 mm and weigh between 0.1 and 0.2 g. Yearling smolts vary greatly in size; average range 60 to 125 mm and 2.0 to 30.0 g. After a second year of growth in a lake, two-year old smolts often overlap the size range of yearlings, and have been reported at an average of 200 mm and 84.0 g at Hidden Lake in central Alaska. Sea type sockeye smolts are typically the same size as yearling smolts when they migrate to offshore ocean areas.

After smoltification and exodus from natal river systems in spring or early summer, juvenile sockeye enter the marine environment where they reside for one to four years, usually two or three years, before returning to spawn. Depending on the stock, they may

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reside in the estuarine or nearshore environment before moving into oceanic waters. They are typically distributed in offshore waters by autumn following outmigration. During the initial marine period, yearling sockeye forage actively on a variety of organisms, apparently preferring copepods and insects, but also eating amphipods, euphausiids, and fish larvae when available. Their growth rate is about 0.6 mm/d.

After entering the open sea during their first summer, juvenile sockeye salmon remain in a band relatively close to the coast. Off the outer coast of British Columbia and southeast Alaska, the juveniles are often recorded on the open sea in late June. By July, the fish are found moving northwestward into the Gulf of Alaska. Sampling in the North Pacific has shown that by October juvenile sockeye are still somewhat distributed primarily nearshore. Evidence indicates the northwestward movement up the eastern Pacific rim is followed by a southwestward movement along the Alaska Peninsula. An offshore movement into the Gulf of Alaska in late autumn or winter is conjectured for the location of age 1 sockeye in early spring.

Adults: Sockeye salmon from different regions differ in growth rate and age and size at maturity. Growth in length is greatest during the first year at sea, and increase in weight is greatest during the second year. Most sockeye spend two to three years feeding in the ocean before their final summer of return. There is substantial variation in size among populations within an age class. In Alaska, the average size of females that had spent 2 years in the ocean ranged from 45 to 54 cm, and of those that had spent 3 years the average ranged from 51 to 60 cm.

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SPECIES: Sockeye salmon, *Onchorynchus nerka*

Stage	Duration or Age	Diet/Prey	Season/ Time	Location	Water Column	Bottom Type	Oceanographic Features	Other
Eggs and larvae (alevins)	eggs: 90-100 d larvae: 100-125 d	NA	late summer, fall and winter	WC, LK	Intragravel	CB, G	NA	Develop at 1-10°C, eggs hatch about 100 d, alevins emerge from gravel about 125 d post hatch
Juveniles, Freshwater	1 to 3 years, fry emerge and move quickly to lakes, or, rarely, 3-4 mo in estuaries	copepods, bosminids, Daphnia chironomids dipterans, stoneflies	for yearling and older smolt, early to late summer for sea type run	WC, LK EST	P, N	NA	NA	Preference pelagic feeding in lakes, usually not with other fishes, except when predators present
Juveniles, estuarine	1-4 mo	copepods, amphipods,	spring, summer, fall	BCH, EST, to 30 m	P, N	NA	UP, CL	larger fish progressively farther from shore
Juveniles, marine	6-8 mo	copepods, amphipods, small fishes, squid mysids, euphausiids	early summer to late winter	BCH, ICS, MCS, IP BAY	P, N	NA	UP, CL	movements from near-shore to offshore areas
Adult, immature and maturing, marine	1 - 4 yrs from smolt to mature adult	copepods, amphipods, insects, small fishes, squid	immature: year round 1-3 yr	BCH, ICS, MCS, OCS, USP, LSP, BSN, BAY, IP	P, N	NA	UP	migration timing for different regional stock groups varies; earlier in the north, later in the south
Adults, freshwater	2 - 4 mo	no active feeding in freshwater	Spawning migration (May-August)	WC, LK	depth in streams <10 cm, depth in lakes to 20 m	CB, G	NA	migration timing for different regional stock groups varies; earlier in the north, later in the south