Coho Salmon Literature Review for the Sidney Gulch USFS Compound Feasibility Study Project

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For the Five Counties Salmonid Conservation Program

Distribution and Listing Status

Coho salmon (*Oncorhynchus kisutch*) are distributed throughout the North Pacific Ocean basin. From west-to-east, coho salmon inhabit watersheds in northern Japan, Russia's Kamchatka peninsula, the Bering Sea, Alaska, British Columbia, Washington, Oregon and California. Coho salmon's distribution in California is from the Oregon border south Santa Cruz County, predominantly in coastal watersheds as documented by Atkinson et al. (1967).

Over the past several decades, populations of coho salmon in California have experienced large declines, which triggered status reviews and listing determinations of the species under state and federal laws. In California, coho salmon were designated into two evolutionary significant units (ESUs) by the National Marine Fisheries Service (NMFS) for the purpose of listing the species under the Endangered Species Act (ESA). These two ESUs are the Southern Oregon-Northern California Coasts (SONCC) and Central California Coast (CCC), with the ESU break occurring at Punta Gorda. Both ESUs were originally listed as "threatened" in 1997 and 1996, respectively; however in 2003 the listing status of the CCC was changed to "endangered". During the listing process there was wide acknowledgement that comprehensive population and distribution data were lacking for coho salmon in California. Two prominent reviews were conducted that attempted to document the historical and current occupancy of coho salmon in California watersheds, as well as determine missing information (Brown and Moyle 1991 and Brown et al. 1994). The detailed stream list in Brown and Moyle (1991) identified 582 streams in California that were suspected as supporting coho salmon at some time (396 in the SONCC, 182 in the CCC, and four outside the two ESUs). The subsequent report was comprised mostly of summary statistics of apparent occupancy versus historic and the authors estimated that 248 of the 582 historic streams no longer supported coho salmon populations (Brown et al. 1994). A re-analysis of the occupancy of CCC coho salmon found strong evidence that the fish occurred in 336 watersheds, nearly doubling the previous assessment (Spence et al. 2005). Increased research and field-level investigations (post-1995) were credited with this increased value.

In the Klamath River, early research suggested that coho salmon occurred in relatively small numbers throughout the watershed, but with higher concentrations in lower tributaries (Snyder 1931). Brown and Moyle (1991) listed 113 tributary streams in the Klamath-Trinity watershed that supported runs of coho salmon. Interestingly, Weaver Creek and its tributaries such as Sidney Gulch and Little Browns Creek were not included in the Brown and Moyle (1991) report. However, increased field-level investigations during the 2000s lead to increased documentation of current occupancy in watersheds within the SONCC ESU as well (Garwood 2012).

General Life History

The basic life history pattern for coho salmon starts with adults returning from the ocean and migrating upstream to spawning areas where eggs are deposited in gravel-to-cobble sized substrate located in pool-tails and riffles. Each female produces roughly several thousand eggs, which are reduced in number by high mortality rates during incubation, hatching and emergence stages of early life history (Salo and Bayliff 1958). After emergence, young coho salmon spend approximately one year in freshwater before out-migrating to the ocean where they then spend approximately 18 months in a rapid growth phase (Davidson and Hutchinson 1938). Within this general life history pattern, coho salmon exhibit numerous variations that have evolved in response to environmental conditions and other factors (Sandercock 1991).

In northern California, coho salmon adults typically enter rivers for spawning during the onset of winter rains. In some smaller coastal watersheds sufficient rainfall must occur to breach enclosed lagoons (Briggs 1953; Shapovalov and Taft 1954). However, in the Klamath-Trinity watershed coho salmon typically enter in the fall, between September and November, heading up the mainstem channels prior to significant amounts of precipitation. These adults then hold in mainstem pools until the onset of fall/winter rain raises water levels in smaller spawning tributaries. Depending on timing of rain, adult coho salmon may spawn in December through February. Migration rates of adult salmonids are often difficult to estimate; however Neave (1949) recorded adult coho salmon migrating 32 km in two days – approximately 10 miles per day. The mouth of Weaver Creek is approximately 145 river-miles upstream from the mouth of the Klamath River.

Throughout their natural range, most coho salmon return to spawn at age-3, having spent approximately four to six months incubating, 12-15 months rearing in freshwater, and 15-18 months of rapid growth in the ocean (Sandercock 1991). As with other anadromous salmonid species, coho salmon can exhibit a wide range of variation from this typical pattern including two or more years of freshwater rearing (Sandercock 1991). Sexually mature males referred to as “jacks” mature one year earlier than most coho salmon and are often a widely variable part of a spawning run. Murphy (1952) reported that jacks comprised 7% to 34% (18% average) of the adult coho returns at Benbow Dam on the South Fork Eel River between 1939 and 1951. On Morrison Gulch (tributary to Jacoby Creek in Humboldt Bay) jacks comprised 8% to 74% (26% average) of the adult coho salmon returns over 12 spawning seasons (Taylor, unpublished data).

A female coho salmon may construct more than one redd during her spawning episode, which may last up to five days. More than one male may attend an actively spawning female and the female will defend the redd area against use by other females (Sandercock 1991). Post-spawned coho salmon all die, with males often leaving post-spawned females in search of other receptive females, and spawned-out females typically staying near their completed redds until death four to 14 days later (Sandercock 1991).

Incubation of eggs to hatching is dependent on water temperature, with longer development time in colder water. Shapovalov and Taft (1954) reported time-to-hatching durations of 48 days at 8.9^{o}C and 38 days at 10.7^{o}C for coho salmon in Scott and Waddell creeks in Santa Cruz County. After hatching the alevins may spend another four to eight weeks within the streambed substrate prior to emergence (Sandercock 1991). During this period the alevins have a tendency to move deeper into the substrate, probably an adaptive mechanism to avoid being flushed out of the gravel too soon during elevated flows. In Oregon coastal streams, Koski (1966) reported that the average time from egg deposition to emergence of fry was 110 days (range 104-115 days).

Coho fry are about 30 mm in length when they first emerge in the spring to early summer months. By the end of the fall, they may range between 70 mm and 90 mm. Juvenile coho salmon’s preference for pools with abundant wood is well documented, as is their requirement of cool water temperatures during the summer months (Sandercock 1991). Pools with more structurally complex habitat can support more juveniles because the cover elements break a single pool into a multitude of discrete habitats. As the juvenile coho grow, the sizes of the territories they defend also increase (Allen 1969).

Earlier literature described juvenile coho that moved during fall and winter freshets as “nomads” or even fish that were starting the process of becoming smolts (Chapman 1962; Otto and McInerney 1970). However, other studies suggested that a common strategy for over-wintering juvenile coho salmon was to migrate out of larger river systems into smaller streams during late-fall and early-winter storms to seek refuge from possibly higher flows and potentially higher turbidity levels in mainstem channels (Cederholm and Scarlett 1981; Tripp and McCart 1983; Tschaplinski and Hartman 1983; Scarlett and Cederholm 1984). More recent research has better documented the fall and winter movements of juvenile coho salmon into more appropriate winter habitats (Nickelson et al. 1992; Ebersole et al. 2006). Some juvenile coho move into off-channel sloughs and ponds that provide refuge from high flows (Quinn and Peterson 1996). Other fish move from larger channels up into smaller tributaries (Ebersole et al. 2006). Some of these juvenile coho salmon have been documented feeding on eggs laid by adult salmon and steelhead, as well as feeding on the carcasses of spawned-out adults (Wipfli et al. 2003). This important source of protein often leads to significant increases in growth and potentially higher survival rates of coho salmon smolts (Wipfli et al. 2003; Ebersole et al. 2006).

Out-migration to the ocean typically occurs in the spring and is influenced by a host of factors including: fish size, streamflow, water temperature, day length, dissolved oxygen, and availability of food (Shapovalov and Taft 1954). In the Pacific Northwest, out-migration may occur between February and June, with earlier out-migration in the southern range of coho salmon distribution. Most downstream movements of coho salmon smolts occur during night-time hours (Sandercock 1991). The size range of age-1 coho salmon smolts is fairly consistent throughout their range, between 8 cm - 12 cm (Sandercock 1991). Once smolts reach estuary portions of rivers, their growth rates increase dramatically, with near-shore age-1+ coho sampled in the 14 cm -22 cm size range (Fisher et al. 1984).

Ocean migrations of coho salmon from Pacific Northwest watersheds are variable and influenced by productivity and availability of food (Sandercock 1991). Some researchers found fish to make wide-ranging migratory loops around the Gulf of Alaska, whereas others noted schooling coho salmon to remain in near-shore waters when prey items were abundant (Royce et al. 1968; Hartt and Dell 1986).

<u>Coho Salmon – Passage Requirements</u>

As previously described, the upstream migration of adult coho salmon is often triggered by increases in streamflow during, and immediately after, precipitation events. Movement into smaller spawning tributaries often requires that sufficient rains have fallen to “prime” the system so that ample base-flow is present in addition to higher peak flows that trigger migration. Reisner and Bjornn (1979) noted that the minimum water depth that adult coho salmon will move in was 18 cm (approximately seven inches). California Department of Fish and Wildlife (CDFW) fish passage <u>assessment</u> criteria typically use 0.8 ft (approximately 9.5”) as a minimum depth for passage of adult anadromous salmonids. Most of the Five Counties fish passage assessments were completed using a minimum depth of 0.5 ft for adult salmon and steelhead passage. CDFW fish passage assessment methods also consider streamflow velocities and provide maximum values for burst and prolonged swimming modes. Migrating salmon often use a combination of modes while moving upstream based on conditions encountered. Ellis (1962) noted that as flow velocities increased, adult Pacific salmon switched from a steady swimming mode to a resting and darting mode where fish would swim quickly up a shallow riffle and then rest in a low-velocity area before bursting up the next shallow channel reach.

Fish passage design criteria tend to be more conservative than the assessment criteria. For example, CDFW recommends a minimum depth of one-foot when using the hydraulic design option for new culvert replacements. Fish passage designs based on the stream simulation approach do not require minimum depths because the objective of using this method is to emulate passage conditions similar to the natural channel. Probably the most important aspect of emulating the natural channel is that the natural channel offers a variety of flow paths for fish to migrate through. These flow paths also change as flow increases or decreases, but there is always a diversity of depths and velocities for fish to move through. Natural channels also provide pools, eddies, cut-banks, and other low-velocity features that provide important resting areas for fish during their upstream migration.

As previously reviewed, the movement of juvenile coho salmon during the fall and winter is an important life history strategy. Not all juveniles within a specific population will exhibit this type of movement, but those that do often experience superior growth rates and higher survival as out-migrating smolts (Ebersole et al. 2006). Because of their smaller body size, the swimming and leaping capabilities of juvenile salmonids are much less than adult fish. These reduced abilities are reflected in CDFW's fish passage assessment and design criteria. For example, when assessing passage of resident trout and juveniles (greater than six inches in length) a maximum burst speed of 5 ft/sec (compared to adults = 10ft/sec) and a prolonged speed of 4 ft/sec are used. For juvenile salmonids less than six inches in length (typical size of over-wintering coho), the assessment criteria are a maximum burst speed of 3 ft/sec and a prolonged speed of only 1.5 ft/sec.

Passage Considerations specific to Sidney Gulch Project

The United States Forest Service (USFS) flood control channel on Sidney Gulch poses a significant challenge to coho salmon and other native fishes attempting to migrate upstream. The concrete and gunnite floor and walls of the flood control channel create shallow sheet flow with excessive velocities. The channelized reach also lacks pools or other types of low velocity resting areas for migrating fish. Past observations have been made of adult coho salmon successfully migrating through the flood control channel, but with great effort. The following excerpt is from a memo written by the USFS fisheries biologist (Loren Everest) that described observations he made of coho salmon in the Sidney Gulch flood control channel during December of 2001.

"On December 3 and 5, 2001 adult Coho salmon were observed ascending Sidney Gulch through the gunnite channel behind the Forest Service office. On December 3 approximately 10 individual fish were observed in the channel. Adult fish were present in the channel for most of the day. The fish passed the channel with great difficulty, swimming 30 to 50 feet then stopping and resting for 10 to 20 minutes before swimming again. On December 5, six fish were observed in the channel. Individual fish were followed throughout the day to assess the travel time through the channel. All fish possessed distinguishing characteristics of different sizes and markings. Five of the six fish passed the channel with times ranging from 2.5 hours for a jack of 19" to 5.5 hours for a larger fish of approximately 8 pounds. One fish was in the channel for 6.5 hours before tiring and drifting back down the channel. The mean travel time for channel passage was 3.5 hours".

In 2005, concrete cylinders were placed in the flood control channel in an attempt to create resting areas for migrating salmon. Subsequent observations indicated that these cylinders provided limited benefit to migrating adults and no improvement of passage conditions for juvenile salmonids.

Modifications to the existing flood control channel are needed to significantly improve passage conditions for all age classes of salmonids and other native fishes as well (such as sculpins, suckers, dace, sticklebacks, and lampreys). Alternatives should also consider the need to efficiently pass high storm flows and not increase the risk of flooding. In regards to fish passage, options should consider removal of the channel's floor and replacement with a natural streambed, a roughened streambed, or a fishway-like series of pools with drops no greater than six inches. The natural channel or roughened streambed options should also incorporate pools or other types of roughness elements to create resting areas for migrating fish. Outside of the winter migration period, these resting areas could also provide rearing habitat for juvenile salmonids and other resident fish and amphibians.

The feasibility of removing or altering the concrete side walls should also be considered. If feasible, setting back one or both walls could allow the design of a flood terrace which could provide flood flow relief and a more naturally-functioning channel. Alternatives should also strive to reduce seepage during low-flow periods so that surface flow connectivity is maintained. Because of potentially poor water quality conditions during summer months in lower Sidney Gulch, upstream passage for juvenile salmonids may be important over the entire range of migration flows (including low flows) to allow fish to move upstream out of the urbanized reach through downtown Weaverville.

Any modifications to the USFS flood control channel should also consider potential changes in channel elevation and profile that could affect other infrastructure. For example, immediately upstream of the flood control channel there is a culvert underneath Highway 299. All effort should be made to not worsen passage conditions through this culvert when a project is implemented within the flood control channel.

Habitat Considerations specific to Sidney Gulch Project

Modifications to the USFS flood control channel should also consider potential opportunities to enhance salmonid habitat, such as establishment of native riparian vegetation to increase shade cover and bank stability. The current flood control channel may affect (increase) summer water temperatures as low flow sheets across the shallow/flat concrete floor and is exposed to solar radiation. A denser riparian canopy adjacent to the restored channel section may improve water temperatures for over-summering juvenile coho salmon and steelhead.

Instream structures to increase the complexity of rearing habitat should also be considered. These structures could be incorporated into the design of either jump pools or roughened riffles.

Literature Cited

Allen, K.R. 1969. Limitations on production in salmonid populations in streams. *In:* T.G. Northcoate (ed.) Symposium on salmon and trout in streams. H.R. MacMillan lectures in fisheries, Institute of Fisheries, B.C., Vancouver.

Atkinson, C.E., J.H. Rose, and T.O. Duncan. 1967. Pacific salmon in the United States, p. 43-223 *In:* Salmon of the North Pacific Ocean. Part V: spawning populations of North Pacific salmon. International North Pacific Fisheries Commission Bulletin 23.

Briggs, J.C. 1953. The behavior and reproduction of salmonid fishes in a small coastal stream. California Fish and Game Bulletin 94: 62p.

Brown, L. R. and P. B. Moyle. 1991. Status of coho salmon in California. Report prepared for National Marine Fisheries Service, Southwest Fisheries Science Center. 134 p.

Brown, L. R., P. B. Moyle, and R. M. Yoshiyama. 1994. Historical decline and current status of coho salmon in California. North American Journal of Fisheries Management 14:237–261.

Cederholm, C.J. and W.J. Scarlett. 1981. Seasonal immigrations of juvenile salmonids into four small tributaries of the Clearwater River, Washington, 1977-1981, p. 98-110. *In* E.L. Brannon and E.O. Salo, editors. Proceedings of the Salmon and Trout Migratory Behavior Symposium. School of Fisheries, University of Washington, Seattle, WA.

Chapman, D.W. 1962. Aggressive behavior in juvenile coho salmon as a cause of emigration. J. Fish. Res. Board Can. 19:1047-1080.

Davidson, F.A. and S.J. Hutchinson. 1938. The geographic and environmental limitations of the Pacific salmon (genus *Oncorhynchus*). Bull. Bur. (US) 48: 667-692.

Ebersole, J.L., P.J. Wigington, J.P. Baker, M.A. Cairns and M.R. Church. 2006. Juvenile coho salmon growth and survival across stream network seasonal habitats. Transactions American Fisheries Society 135: 1681-1697.

Ellis, D.V. 1962. Preliminary studies on the visible migrations of adult salmon. Journal Fish. Res. Board Canada 19: 137-148.

Fisher, J.P., W.G. Pearcy, and A.W. Chung. 1984. Studies of juvenile salmonids off the Oregon and Washington coast, 1983. Oregon State University Oceanography Cruise Report 84-2. Sea Grant Program 85-004: 29 p.

Garwood, J. 2012. Historic and Recent Occurrence of Coho Salmon (*Oncorhynchus kisutch*) in California Streams within the Southern Oregon/Northern California Evolutionarily Significant Unit. CDFG, Fisheries Branch Administrative Report 2012-13: 77 p.

Hallock, R.J. and D.H. Fry. 1967. Five species of salmon, *Oncorhynchus*, in the Sacramento River, California. California Fish and Game Bulletin 53: 5-22.

Hartt, A.C. and M.B. Dell. 1986. Early oceanic migrations and growth of juvenile Pacific salmon and steelhead trout. International North Pacific Fish. Comm. Bull. 46: 105 p.

Koski, K.V. 1966. The survival of coho salmon (*Oncorhynchus kisutch*) from egg deposition to emergence in three Oregon coastal streams. Master's thesis, Oregon State University, Corvallis, OR. 84 p.

Murphy, G.I. 1952. An analysis of silver salmon counts at Benbow Dam, South Fork of Eel River. California Fish and Game Bulletin 38: 105-112.

Neave. 1947. Game fish populations of the Cowichan River. Bulletin Fisheries Res. Board Can. 84:132.

Nickelson, T.E., J.D. Rogers, S.L. Johnson, and M.F. Solazzi. 1992. Seasonal changes in habitat use by juvenile coho salmon (*Oncorhynchus kisutch*) in Oregon coastal streams. Can. J. Aquat. Sci. 49: 783-789.

Otto, R.G. and J.E. McInerney. 1970. Development of salinity preference in pre-smolt coho salmon, *Oncorhynchus kisutch*. J. Fish. Res. Board Can. 27: 793-800.

Quinn, T. P., and N. P. Peterson. 1996. The influence of habitat complexity and fish size on over-winter survival and growth of individually marked juvenile coho salmon (Oncorhynchus kisutch) in Big Beef Creek, Washington. Canadian Journal of Fisheries and Aquatic Sciences 53:1555–1564.

Royce, W.F., L.S. Smith and A.C. Hartt. 1968. Models of oceanic migrations of Pacific salmon and comments on guidance mechanisms. Fish. Bull. (U.S.) 66: 441-462.

Salo, E.O and W.H. Bayliff. 1958. Artificial and natural production of silver salmon (*Oncorhynchus kisutch*) at Minter Creek, Washington. Res. Wash. Dep. Fish. 4: 76p.

Sandercock, F.K. 1991. Life history of coho salmon. Pages 395-446 in Pacific salmon life histories, edited by C. Groot and L. Margolis. UBC Press, Vancouver, B.C.

Shapovalov, L. and A.C. Taft. 1954. The life histories of the steelhead rainbow trout (*Salmo* gairdneri) and the silver salmon (*Oncorhynchus kisutch*) with special reference to Waddell Creek, CA, and recommendations regarding their management. California Fish and Game Bulletin 98: 375p.

Snyder, J.O. 1937. Salmon of the Klamath River, California. I. The salmon and fishery of the Klamath River. California Fish and Game Bulletin 34: 122p.

Spence, B.C., S.L. Harris, W.E. Jones, M. Goslin, A. Argawal, and E. Mora. 2005. Historical Occurrence of coho salmon in streams of the Central California Coast coho salmon evolutionary significant unit. NOAA-TM-NMFS-SWFSC-383. 80p.

Taylor, R.N. 2014. Unpublished Morrison Gulch spawner survey data summaries, 2001 - 2013. Five County Salmon Conservation Group.

Tripp, D. and P. McCart. 1983. Effects of different coho stocking strategies on coho and cutthroat trout production in isolated headwater streams. Can. Tech. Rep. Fish. Aquat. Sci. 40: 452-461.

Tschaplinski, P.J. and G.F. Hartman. 1983. Winter distribution of juvenile coho salmon (*Oncorhynchus kisutch*) before and after logging in Carnation Creek, British Columbia, and some implications for over-wintering survival. Can J. Fish Aquat. Sci. 40: 452-461.