Observations of Chum Salmon (*Oncorhynchus keta*) Redd Construction and Spawning Behavior in a Tributary of South Puget Sound, Washington

Larry Dominguez, Salmon Biologist
Washington Department of Natural Resources
Resource Planning and Asset Management July 1994

Chum salmon (*Oncorhynchus keta*) have the widest natural geographic distribution of all the Pacific salmonids. Chum salmon range from Korea to the Arctic coast of Russia to Monterey, California. Their average adult size is second-largest of the 7 pacific salmonids, topped only by the king salmon (*Oncorhynchus tshawytscha*). Every fall, thousands of adult chum salmon return to Puget sound tributaries to spawn in the lower gradient reaches of large rivers, and small tributaries. The chum are dependent on different habitats through their life history. In the egg pocket environment they are dependent on clean, cold water with sufficient flow or upwelling. As fry, they emerge from the gravel and may promptly migrate downstream into estuaries or migrate slowly downstream while feeding in the spawning areas. In larger, northern rivers, juvenile chum may remain up to a year in fresh water. The fry and juvenile chum depend heavily on the estuarine ecosystem for growth. In the estuaries chum will continue feeding and smolt when they are between 50 and 80mm. Chum generally migrate to coastal waters and continue feeding until they reach between 110-170 mm. From there, the offshore cold water and open ocean life stages begin.

In South Puget Sound, chum salmon generally mature between ages 3 and 5 years old. From 1962-1970 in Puget Sound, three- and four-year-old chum made-up 60.3% and 39.2% of the adult returns, respectively. From 1971-1983, three and four-year-old chum made-up 40.9% and 56.8% of the adult returns, respectively (Salo 1991). Washington and Oregon rarely receive five-year-old adult returns. Russia, Japan, Alaska, and British Columbia record small percentages of five-year-old adult returns.

Female chum salmon in North America generally have a fecundity between 2,000 and 4,000 eggs. Although these figures present a general range, there is some uncertainty in the data due to collection methods.

In the fall of 1991, extensive observations of spawning chum were made on Kennedy Creek, a 13.2 km^2 watershed draining into Totten Inlet, South Puget Sound, just west of Olympia, Washington. Mid-November is the peak spawning period for Kennedy Creek chum. The complete spawning process of the chum salmon in Kennedy Creek can essentially be categorized into seven phases. These categories include site selection/nosing, redd construction, focused egg pocket cleaning, slow-down/probing, pre-spawning/spawning, covering, and guarding. This paper is written for future observers of chum spawning so they could better understand the various stages of their spawning activity and identify key behavior patterns and egg pocket development for predicting spawns.

The number of males associated with one female generally increased through the spawning process. As a female neared her spawn, other males (occassionally smaller-sized jack salmon) were attracted to the redd. Rarely was only one male associated with one female during peak spawning activity in the mainstem. During spawning, usually two or three males participated but as many as six males were observed in a spawn. Egg pocket readiness and female probing activity, combined with intensified male darting and gaping, proved to be the best indicators for predicting an upcoming spawn.

No formal data of spawning behavior was collected. The actual study was concerned with the intragravel environment of the chum egg pocket. The following discussion is based on qualitative observations.

Site Selection

During early periods of the run and/or at initial cutting of the undisturbed gravels, there may not be a male present. The initial cutting passes are infrequent and spread throughout a large area (1-4 m^2). On occasion, the female will abandon this "exploratory" digging site and assumedly redo site selection and initial cutting at another site. These exploratory areas are evident by slight depressions and/or an area of cleaned gravel. This is observed during the initial part of the run where ample spawning areas are available. Widespread exploratory digging may occur throughout the run but may not be as recognizable due to extensive fish activity and the absence of undisturbed spawning areas throughout the whole stream.

Redd Construction

When a site is selected the female continues with cutting and a redd perimeter becomes more evident. Cutting passes range in frequency from once every 5 to 10 minutes to once every 15 to 20 seconds. Male courtship behaviorisms, fighting activities, and the redd's location in the stream (fast or slow water, within or near corridors of upstream migrating fish) seem to affect the frequency of cutting passes. The cutting rate is usually slower in faster moving water. The female apparently needs longer resting periods.

The cutting passes occur when the female turns on either side, fluctuates her caudal fin, moves upstream and flares towards the right or left. The cutting passes average eight strokes and are usually between 5 and 10 caudal strokes. The caudal strokes increase in vigor then wane at the upward end of the redd.

Throughout the construction phase and up until spawning, the quivering and crossing-over behaviors are exhibited. Quivering is best observed when there is little or no water surface turbulence. When males are near the surface, small, stationary ripples can be seen on the water's surface during quivering. This high frequency shaking is usually performed by the dominant male or by a satellite when near or alongside the female. Crossing-over is a behavior performed by the male. The male aligns himself over the female's caudal peduncle and swims from side to side over

the female, aligns himself with the female, then rises up and over to the females other side. This behavior is performed by the satellite males also if the dominant male has left the immediate area of the egg pocket.

Usually there is one male during the early phases of construction. When more males appear, crossing-over and quivering behaviors tend to increase in frequency. Intensified activity, however, is not always a good indicator of an upcoming spawn unless the egg pocket has been observed and considered well-defined and ready. A well-defined egg pocket is absolutely clean of fines, very loose, and contains a small area of larger rocks in the middle of the depression.

Towards the end of the redd construction phase, the downstream end of the depression (also the deepest), will be focused on for egg pocket cleaning. At this time the depression is usually between one-half and one foot deep relative to the undisturbed gravel bed. The excavated materials form a deposition area called the tailspill. This small mound is usually elevated above the existing gravel bed.

Focused Egg Pocket Cleaning

It is apparent that the larger, immovable rocks are the limit of the cutting depth. The deep area of the redd will expose larger rocks that are already present or serve as a Asettling basin" for the larger gravel and/or cobble that is not lifted or pushed out of the depression during cutting activity. At this time the female exhibits her highest cutting frequency for the egg pocket area. Cutting sets (average 8 strokes) can be as frequent as 10 to 15 seconds apart. High numbers of fish and close proximity to other active redds contribute to a disturbing environment which results in less frequent cutting sets.

The cutting activity is concentrated within the deepest area of the redd and confined within an area of about six inch diameter. The cutting now resembles a pumping action in which little or no forward progress is observed. A cloud of fines and sand appear as a result of this cleaning activity. The amount of these particles decreases over time and the designated pocket area becomes more defined. Occasionally the female performs some weaker cuts to the front and sides of the designated egg pocket area.

If only one male had been present initially, most likely more are now participating at this phase. Instances of quivering and crossing-over occur as frequently as five to ten seconds apart. The dominant male usually tolerates one to two passive satellite males without exhibiting voracious fighting behavior. A hierarchy of satellite males has now developed. The satellite males compete with other males for spawning opportunities.

Slow-Down/Probing

Egg pocket cleaning and slow-down/probing are overlapping phases. During this period the female occasionally positions herself into the deepest part of the redd. Moving laterally through the depression, the female stops at a particular spot and arches by depressing her anal fin into the

egg pocket area. A slight gape usually accompanies this probing behavior. Ensuing cutting frequency decreases and cutting sets may now decrease to four strokes or less.

Towards completion of the egg pocket, the cutting strokes may become less vigorous and may include some strokes just upstream of the now well-defined egg pocket area.

Male activity has increased during this probing behavior. The dominant male will now dart in during an exhibition of probing and position himself alongside the female. The male accompanies this action with a gape. The female may show some aggression towards the male. Satellite males have positioned themselves downstream of the courting pair. When the courting pair position themselves together, the satellite males continuously approach the redd in attempts to fertilize the eggs.

Pre Spawning/Spawning

As cutting and cleaning activity decrease, female probing and male darting/gaping increase.[1] If there are several males (>3), a male may make a digging pass upstream of the egg pocket. The female may apparently fake a spawn and proceed with one or two cover digs. A fake spawn may cause milt release from the males. The female may leave for a considerable period of time (up to 1 hour). Fake spawns were deduced from the following observations: 1) cover digs occurred immediately after actual spawns, 2) during an actual spawn with observed eggs, the female did not abandon the redd for extended lengths of time unless a significant covering layer was established, and 3) after a fake spawn, the female eventually returns to continue with probing and egg pocket cleaning activity.

At actual spawn, the participating males will be clued by a prolonged gape of the female. Satellite males will dart into the redd and align with the female as close as possible. The female and mostly all of the males will fully gape for a period ranging from 3 to 8 seconds. A milt cloud will be visible if water conditions permit. Occasionally, the charging of males will move the female out of her position. The female then will abort the spawn, quickly realign at the egg pocket, and try again. In areas of high disturbance, the female will reattempt this several times. She may temporarily leave the redd if the disturbance persists.

The actual spawning incident is very sudden. The presence of milt and occurrence of persistent cover digs are the best indications of spawning occurrence.

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[1]An increase in crossing-over and quivering does not necessarily indicate proximity to spawning. The males may begin to exhibit a mimicry characteristic in which they incorporate female banding and coloration features. At times, the male appears more like a stereotypic female than the actual female does.

Covering

Immediately after egg deposition[2] the female swims slightly upstream, turns to one side, and proceeds with two to four light strokes of the tail. These are noticeably softer strokes than those exhibited during the cutting activity. These strokes may not necessarily be intended to move gravel but rather drive the eggs into the gravel interstices (Tautz and Groot 1975; Schroeder 1982). At Kennedy Creek, however, pea gravel was present immediately upstream of the egg pocket at the time of the spawn. That material was easily mobilized during these cover digs.[3] The female still maintains a forward motion in these cover dig sets. After a set of cover digs, the female turns about and swims downstream towards the rear of the redd where a position over the egg pocket is assumed for another set of cover digs.

Once the initial cover layers are laid down, the cover digs appear to become more vigorous. Covering activity continues and often coincides with the formation of another egg pocket within the same redd.

Guarding

When the female has completed the covering activities, a guarding behavior is displayed. The female will inhibit other fish from spawning in the immediate area. The dominant male may stay with the female but generally moves on to find another female in the process of redd construction. Males can remain sexually active for 10-14 days.

Post-Spawning Watershed Processes

A large spawning population of chum salmon such as that at Kennedy Creek is capable of altering the stream channel. Gravel bars are reduced when cut into and riffles are enlarged when pool tailouts experience dense spawner use. Accumulations of fine sand are observed in eddies. The loosening of the substrate has improved the transport ability of the channel to move sediments through the system. The stream channel in many of these medium gradient, gravel-rich South Puget Sound drainages are susceptible to scour and fill. In this respect, the chum salmon's ability to excavate egg pockets, up to 50 cm in depth, is to their advantage.

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[2]Schroeder (1982) noted that about 35% of the eggs were deposited in the first nest and the last few nests contained only one-half to one-quarter the number of eggs of the first one.

[3]Quinn and Peterson (1994) describe this initial cover layer as an integral part of the chum egg pocket architecture.

After spawning and the first large storms, carcasses are scattered throughout the floodplain and suspended on overhanging branches after the water has receded from flooding. Some carcasses were observed decaying on the banks, dismembered by scavenger wildlife.

Cederholm et al. (1989) present a detailed discussion on the fate of salmon carcasses in streams after spawning. A concurrent spawner survey was conducted by the Washington Department of Fish and Wildlife in Kennedy Creek. The 1991 fall chum escapement for Totten Inlet (the majority returning to Kennedy Creek) was an estimated 16,390 fish. Puget Sound chum average about 10 pounds. That translates into 163,390 pounds of biomass. Nearly 82 tons of nutrients were deposited into Kennedy Creek and Totten Inlet! There is no doubt that this contribution is a significant piece of the Kennedy Creek/Totten Inlet ecosystem.

The life history of the chum and the physical watershed processes are directly connected. They have formed an intricate web of chemical, physical, and biological interactions. To protect these complex and fragile processes would be to maintain the quality of life that has been the Pacific Northwest's signature for millennia.

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1992 Washington State Salmon and Steelhead Stock Inventory. Appendix one: Puget Sound Stocks. South Puget Sound volume. Olympia, WA.

Additional Notes:

In 1996 a Kennedy Creek index survey conducted by WDFW estimated 35,000 live fish the week of November 11. Current projections (as of Nov. 22, 1996 are about 75,000 escapement).