EFFECTS OF DOCKS IN WELLS DAM POOL ON SUBYEARLING SUMMER/FALL CHINOOK SALMON

by

D.W. Chapman, PhD.

P.O. Box 2289
McCall, Idaho 83638

December 15, 2007

EFFECTS OF DOCKS IN WELLS DAM POOL ON SUBYEARLING SUMMER/FALL CHINOOK SALMON

by

D. W. Chapman, PhD.

Box 2289
McCall, Idaho 83638

Introduction

At the request of Douglas County Public Utility District, I researched the following question: "Will increased numbers of docks in the littoral zone of Wells Dam pool reduce survival of juvenile summer/fall Chinook salmon (*Oncorhynchus tschawytscha*)?"

I reviewed pertinent published literature, reports, and theses. I contacted researchers familiar with the requirements of juvenile Chinook salmon. I synthesized conclusions and my opinion from those sources and my own work on Chinook salmon ecology. I toured Wells Dam pool by boat.

I ordered the following material with Conclusions first, followed by Opinion, Supporting Basis for Conclusions and Opinion and, finally, the Cited Publications and Reports.

Conclusions

1. Subyearling Chinook salmon use shallow, inshore areas in both day and night between the time when they emerge from the redd (primarily in March and April) and the time when they reach about 60 mm in length (generally in June). During this time interval, their behavior places them in sites in Wells pool where additional docks have been proposed.

2. In the early rearing period, subyearlings prefer overhead cover in the form of overhanging vegetation. Docks may offer a surrogate for such cover. As the subyearlings grow, they tend to use open water or small woody debris more, and to associate less with overhanging cover.

3. Subyearling Chinook salmon continue to use shallow, inshore areas at night after they begin to move downstream in what has been called a feeding migration. At dusk they tend to move offshore and downstream, then move laterally back to shallows where they rest on the bottom during the night. At dawn they again move offshore and downstream. Their nocturnal behavior in Wells pool will tend to place them in littoral sites where additional docks have been proposed.

4. As subyearlings grow, they use deeper water at night, and the rate of downstream movement increases. With growth, more fish move downstream at night rather than inshore. Some subyearlings remain in mainstem Columbia River reservoirs over the first winter of life, and migrate as yearlings. After subyearlings reach sizes larger than 60 to 70 mm, their behavior greatly reduces their vulnerability to predators in littoral zones, hence their vulnerability around docks.

5. When groups of subyearling Chinook move along the shoreline in shallow water and encounter a dock, they have been observed to move into slightly deeper water and either pass directly under the structure or swim around the outboard end of the dock.

6. Smallmouth bass (*Micropterus dolomieu*) and northern pikeminnows (*Ptychocheilus oregonensis*) constitute the principal fish predators that should be expected to use areas beneath and around docks. These two species will move to access concentrations of prey. I anticipate that they would do so in response to behavior of subyearling Chinook salmon noted in #1,#2, and #3 above, where abundance of juveniles makes predator movement bioenergetically profitable.

7. Consumption of subyearling Chinook salmon by smallmouth bass varies widely in importance. For example, smallmouth bass in Lake Washington are not important predators on subyearling Chinook salmon. But in the Yakima River they have been reported to consume a minimum of 197,000 subyearlings, mostly production from naturally-spawning adults.

8. The degree to which predation under and around existing and proposed docks may reduce abundance of returning adult summer/fall Chinook is unknown. Biological compensation may lead to increased growth, hence reduced mortality, of the surviving cohort. However, I suspect most compensation occurs in the first few weeks after fry emergence, not during the seaward migration.

9. After late June, likelihood of ecologically significant predation in proposed and existing dock areas declines because of increased subyearling size, use of deeper reservoir areas, and propensity for more night movement downstream. The greatest potential for predation occurs in late April, May, and to a lesser extent in early June, when subyearlings are small and water in littoral areas warms.

10. Docks probably increase carrying capacity of Wells pool for smallmouth bass by providing structural cover, at least temporary access to prey, and visual isolation for nest sites.

Opinion

To avoid increases in mortality of subyearling summer/fall Chinook salmon, managers should discourage placement of more docks in littoral zones of Wells pool.

Supporting basis for conclusions and opinion

Summer/fall Chinook fry emerge from redd gravels between mid-February and the end of April in the Wenatchee River (unpublished snorkel observations, Don Chapman Consultants, Boise, ID). Chapman et al. (1994) suggested that fry emerge at about the same time in the Okanogan and Methow rivers. In the Wells spawning channel, fry emerged in the same interval during 1968 to 1971 (Allen et al. 1968, 1969, 1971; Allen 1970).

Subyearling Chinook salmon produced in mid-Columbia tributaries, the lower Chelan River, and in tailraces of dams upstream from Rock Island Dam (Chief Joseph Dam, Wells Dam, Rocky Reach Dam) tend now to spend several weeks in the reservoirs before they arrive at Priest Rapids Dam in July, August and later. This rearing period leads to arrival at McNary Dam in late August to late fall (Chapman et al. 1994).

Connor et al. (2003) identified four migrational phases in subyearling Chinook in the main Snake River; (1) discontinuous downstream dispersal along the shorelines of the free-flowing river, (2) abrupt and mostly continuous downstream dispersal offshore in the free-flowing river, (3) passive, discontinuous downstream dispersal offshore in the first reservoir encountered *en route* to the sea, and (4) active and mostly continuous seaward migration. Phase 1 is of most concern in considerations of effects of docks upon the degree of mortality caused by predators upon subyearling Chinook salmon.in Wells pool. Although Phase 1 of Connor et al. (2003) refers to free-flowing river segments, in Wells pool it would encompass behavior of subyearlings that enter the pool shortly after emergence from redds in the lower Methow River, Okanogan River, and in the main Columbia River.

Chapman et al. (1994) stated that the available data supported the hypothesis that mainstem impoundments have delayed downstream movement peaks for subyearling fall Chinook, perhaps by two to three weeks. They were unsure whether the net effect of delayed movement and growth in reservoir rearing contributes to the future gene pool more or less. Subyearlings that migrate in August now are larger than they were in the pre-dam period. Pre-dam work of Mains and Smith (1964) reported mean size of subyearlings as about 83 mm in July. Current size of subyearlings at McNary Dam in July is over 100 mm.[1]

In the Columbia River, predation is the principal mechanism responsible for mortality associated with migration through reservoirs (Chapman et al. 1994). Rieman et al. (1991) estimated that 2.7 million juvenile salmon were consumed annually in John Day Reservoir in 1983-1986, and that northern pikeminnows took 78% of the kill.

The effects of existing and proposed docks in Wells pool on mortality of subyearling fall Chinook depend largely upon whether predator and prey distributions coincide in time and space, upon habitat complexity, and upon the degree to which predators consume subyearlings in such overlap. As noted above, juvenile summer/fall Chinook use shallow, littoral areas for several weeks after fry emerge from redds, hence I would expect them to occupy littoral areas close to, or under, docks. But do predator species use the same areas?

The answer is "yes." In Lake Washington, Washington, 72% of observed smallmouth bass lay within 2 m of some sort of structure, and 68% of all adults were seen within 2 m of a dock (Fresh et al. 2003). The amount of area at a site within 2 m of a dock ranged between 4% and 12% at the four sites with the most smallmouth bass, but the percentage of bass seen within 2 m of a dock ranged from 27% to 62%. They preferred large docks with large numbers of pilings. Fresh et al. (2003) concluded that "…addition of structure (e.g., docks and complex wood) to sites where smallmouth bass are rare or absent in Lake Washington will have little effect on abundance of smallmouth bass at this site. Further, we believe that such changes should also have little effect on predation mortality by smallmouth bass on juvenile Chinook salmon in Lake Washington. However, at sites in Lake Washington where smallmouth bass are abundant, we recommend managers should seek to reduce the amount of dock structure at sites, especially in the shallowest areas."

[1] Growth of subyearlings, assessed as the changes in the mean of lengths over time among the cohort sample, should be termed "apparent growth." Apparent growth results from actual growth in the cohort and from increased mean size caused by selective take by predators of smaller members of the cohort.

Reading of Fresh et al. (2003) reveals that smallmouth abundance negatively correlated with the amount of mud and positively correlated with the amount of cobble. Thus, a dock placed over a mud substrate in shallow water should attract few smallmouth bass, while one placed over cobble in shallow water would encourage more bass to use the area under and around the new dock.

Smallmouth bass seem to prosper or at least maintain numbers when subjected to shoreline modification, including addition of docks (Bryan and Scarnecchia 1992; Fresh et al. 2003). In this they are unusual. Lange (1999) found that although shoreline development in general reduced species richness, individual permanent docks caused fish to aggregate there. I would expect smallmouth bass to increase their numbers in Wells pool if more docks are added to the shoreline. This would lead to increased kill of subyearling Chinook salmon by smallmouth bass. Naughton and Bennett (2004) reported relatively little kill of juvenile salmonids by smallmouth bass in the Snake River (Lower Granite Reservoir), but opined that higher flows reduce predation. They also, after reviewing literature on predation by smallmouth bass on juvenile salmonids, that "…Highest incidences of predation occurred when smallmouth bass and juvenile Pacific salmonids coexist in littoral areas." Largemouth bass (*Micropterus salmoides*) use the lower Okanogan River, which tends to be warmer than other Wells pool segments (T. Kahler, personal communication), and I would expect them to associate with littoral cover elements, including docks, and to ambush subyearling Chinook salmon that use those areas in late spring.

Fayram and Sibley (2000) found that juvenile salmonids comprised 28% and 38%, respectively, in the diet of smallmouth bass larger than 150 mm in Lake Washington and in the Lake Washington Ship Canal area during the salmonid outmigration. Tabor et al. (1993) examined stomachs of smallmouth bass and northern pikeminnow in 6 km of the Colmbia River near Richland, Washington. They sampled the two species in May 2-3 and June 20-21. Juvenile salmonids made up 59% of the diet by weight in smallmouth bass and were present in 65% of the stomachs. Smallmouth bass were estimated to consume from 1.4 (May 2-3) to 1.0 (June 20-21) salmonids per predator daily. Northern pikeminnows consumed from 0.55 (May 2-3) to 0.34 (June 20-21) salmonids per predator daily. Subyearling Chinook salmon comprised most of the salmonids consumed by pikeminnows.

In Lake Sammamish, Washington, juvenile salmon made up the major part of the diet of smallmouth bass in May, the month when most salmon migrated through the lake. Consumption of young salmon then decreased through the summer (Pflug and Pauley 1984). I would expect exactly the same pattern of prey consumption in Wells pool. The overlap of smallmouth bass and subyearling Chinook salmon in littoral areas would maximize in May and early June. Warming water would also contribute to consumption of subyearlings by bass. Adult smallmouth bass initially moved into littoral zones of Lake Washington in May as water warmed to 50 F (Fresh et al. 2003). One should expect northern pikeminnow to move into shallow water in spring as well, with warming water and approach of spawning season.

Northern pikeminnow prey extensively upon juvenile salmonids when the latter migrate through John Day reservoir (Poe et al. 1991), and in the lower Columbia River downstream from Bonneville Dam (Petersen and Poe 1993).. Salmonids made up about 67% of prey by weight in John Day pool.. Smallmouth bass were less important predators, with salmonids making up only 4% of their diet by weight. Northern pikeminnow preferred salmonids in May and August. Salmonid prey in the latter month would consist mostly of subyearling summer/fall Chinook. Beamsesderfer and Rieman (1991) noted that northern pikeminnows are not important predators upon migrating juvenile anadromous salmonids in free-flowing rivers because they prefer low-velocity areas, while the migrating salmonid juveniles move in faster water and at night. But preference of northern pikeminnows for low velocities and gently sloping littoral areas (Petersen and Poe 1993) would potentially put them in the stream and reservoir areas used by subyearling summer/fall Chinook salmon, especially in the first two months after the latter emerge from redds.

Zimmerman (1999) compared diets of adult smallmouth bass, walleyes and northern pikeminnow in impounded and unimpounded reaches of the lower Columbia River and lower Snake River during the outmigration of salmonids from 1990 to 1996. Northern pikeminnows consumed more salmonids than did other predators. Length of prey and length of predator were positively correlated for smallmouth and northern pikeminnow. However, Pflug and Pauley (1984) showed that smallmouth as small as 100 mm consumed juvenile salmon as large as 40 mm. Inasmuch as a smallmouth can reach 100 mm when only one year old, and smallmouth often live to age 9 or older, essentially all age classes of this predator can consume subyearling Chinook salmon. It is safe to assume that a smallmouth bass of age 2 can consume any subyearling Chinook that it can capture in spring and summer.

Smallmouth bass in the Yakima River in spring of 1998 consumed at least 197,000 subyearling Chinook salmon, 85% of them consisting of progeny of natural spawners (Fritts and Pearsons 2004). Fritts and Pearsons (2004) concluded that smallmouth bass can have negative effects on ocean-type Chinook salmon, particularly those from natural spawning because the juveniles are generally smaller and available longer than hatchery fish.

Walleye at about 3 inches in length begin consuming juvenile fish, and become primarily piscivorous when they reach 6 inches (Wydoski and Whitney 2003). Vigg et al. (1991) established that walleye in John Day pool had the highest salmonid component in their diet in July and relatively high components in May and August. Although the northern pikeminnow is by far the most important consumer of juvenile salmonids in Columbia River reservoirs, walleye take a substantial share. Beamesderfer and Nigro (1989) estimated that walleye annually consumed up to 2% of the salmonid run from 1983 to 1986 in the lower Columbia River. Tinus and Beamsderfer (1994) estimated losses of salmonids to walleye at up to 2 million fish per year, and those to pikeminnow at up to 4 million. Walleye are not known to reproduce in Wells pool (R. Clubb, personal communication), but rather derive from areas upstream from Grand Coulee Dam. Hence, walleye in Wells pool are more probably associated with deeper portions of the pool than with the littoral zone where existing and proposed docks lie.

Common mergansers (*Mergus merganser*) commonly use Wells pool, and fish communally in littoral areas. They frequently haul out and rest on docks. They pursue prey beneath docks while they forage along the shoreline. However, there is no evidence that suggests dock structures make their predation more efficient.

Rondorf and Gray (1987) studied distribution of subyearling Chinook in McNary pool. Subyealings entered the pool shortly after they were released from the hatchery environment or emerged from redds in the Hanford Reach. They used shallow littoral areas in May, and favored water less than 2 m deep. As they reached about 80 mm in June, they began to move to water deeper than 2 m. Catch in beach seines per haul was highest in May, decreased in early June, increased slightly in late June, and dropped to zero in mid-July. Chapman et al. (1994) reported results of snorkeling work by one of the authors (Hillman) and four other observers in four sites in Rock Island pool. Subyearling Chinook used backwater areas along the river margin. The fish rested on sand/silt substrate in water velocity of less than 1 cm/s. Most of the Chinook that they observed used water less than 100 cm deep, where they shared the habitat with redside shiners and sticklebacks. McGee et al. (1983), in purse-seine sets, captured more fish in Wells pool along the left shoreline, an area with more littoral zones.

Burley and Poe (1994), citing Ledgerwood et al. (1991) noted that subyearling Chinook tend to use nearshore, shallow habitat. Based on radiotelemetry, they noted that northern pikeminnow prefer to use nearshore areas, which leads to overlap with habitat used by subyearling Chinook. Fresh et al. (2003) reported that 68% of all adult smallmouth bass observed in SCUBA surveys in Lake Washington were within 2 m of a dock

Tabor et al. (2006) concluded that the vulnerability of subyearling Chinook salmon in Lake Washington to predation by smallmouth and largemouth bass can be attributed to the small size of the subyearlings, their tendency to migrate when water temperature exceeds 15 C when bass activity is high, and subyearling use of nearshore areas overlaps with use by bass. However, Tabor et al. (2006) opined that predation by bass has a minor impact on Chinook salmon and other salmonid populations in the Lake Washington system.

Kemp et al. (2005) examined behavior of migrating subyearling Chinook salmon in covered and uncovered channels at McNary Dam in 12-17 June 2003. This study in fact used actively migrating fish from the fish bypass system at McNary Dam. The authors found that about 75% of the juveniles avoided overhead cover. However, the fork lengths of fish that they tested averaged about 95 mm. I would expect fish of this size in mid-June to be moving actively toward the sea, rather than feeding in littoral zones. Kemp et al. (2005) extensively discussed possible reasons why subyearlings in their tests avoided overhead cover. However valid those explanations for actively-migrating large subyearlings, they have little bearing on behavior of newly-emerged subyearlings of sizes between 33 mm and 60 mm, the size range of concern with respect to existing and proposed docks in Wells pool .

Garland et al. (2002) sampled subyearling Chinook salmon in Lake Wallula to assess habitat preferences in riprap and unaltered banks. Their sampling in May captured fish with an average length of about 53-57 mm, closer to lengths of concern in the issue of dockage in Wells pool. They found that substrate size negatively correlated with density of subyearlings, which avoided riprap with diameters that exceeded 256 mm, possibly because fish predators may use large riprap . Overhead cover was not evaluated in this study. Few fish associated with water faster than 0.4 m/s or lateral slopes steeper than 25%.

In Lake Washington, subyearling Chinook salmon feed most on chironomid pupae in May, and shift to *Daphnia* in June (Koehler et al. 2006). These changes reflect association of smaller fish in May with littoral areas, and movement to deeper limnetic water of subyearlings as growth occurs and water warms. I would expect a very similar shift in Wells pool.

Koehler (2002) found fewer chironomid larvae (mean abundance 337-631/m^2) in a highly developed marina site than in its paired matural marsh site (mean abundance 2209-8405/ m^2. I expect areas around proposed docks, which often lie next to developed shoreline segments, to have reduced densities of chironomids.

Dock pilings may enhance reproduction of smallmouth bass by providing visual isolation for nesting fish. At the same time, fish that protect a nest should spend less time foraging. The two factors may work to offset each other. Docks and associated poles and posts will provide perches for avian predators (e.g., belted kingfisher *Ceryle alcyon* L). I speculate here.

In the Wenatchee River, newly-emerged Chinook fry use stream margins in shallow water (<60 cm) and low velocities (<10 cm/s). They also use only areas with instream cover (woody debris, vegetation, or large substrate) and overhead brush. Clusters of these fish can contain as many as 1,400 fry in 2 m^2 (Hillman et al. 1989a). At night, fry use stream margins in quiet water near cover (Hillman et al. 1989b). As the juveniles grow, they move into faster and deeper water in daytime, and rest all night in shallow, quiet water. Later, with additional growth, they use deeper sites at night.

Work on subyearling Chinook behavior in Lake Washington (Tabor et al. 2006) supports observations by Hillman et al. (1989a). Tabor et al. (2006) reported higher abundance iof subyearlings under overhanging vegetation with small woody debris than in sections with only small woody debris. Large numbers of Chinook salmon were often observed directly under overhanging vegetation, especially in daytime surveys between March 24 and April 9. Later, in May 2-16, subyearlings still used overhanging vegetation during the day, but also used more open areas.

In the Hanford Reach of the Columbia River, subyearlings mostly used areas where mean water velocities were less than 45 cm/s and where the lateral bank slope was low (Tiffan et al. 2006). In this mainstem shoreline habitat with little woody debris and vegetation, cover needs were met by low water velocity and substrate of small gravel and cobble.

C. Peven (personal communication), after review of literature on predator/prey behavior in the Columbia River, concluded that spring-migrating salmonids (spring Chinook, sockeye, and steelhead) have a low likelihood of encountering predators that might associate themselves with docks in the littoral zone. However, during their late spring and early summer feeding migration, subyearling Chinook salmon have a much higher likelihood of encountering ambush predators like smallmouth bass under shore-based structures.

"Biological compensation" for an agent of increased mortality in early life stages of fish can lead to increased growth and survival of the surviving members of a year-class cohort. Chapman et al. (1994) briefly reviewed this concept as it related to summer/fall Chinook salmon. Norman (1992) concluded that egg deposition negatively correlated with smolt-to-adult survival. That is, smolt-to-adult survival tended to increase when egg numbers were lower. This does not mean that *numbers* of returning adults would be higher when egg deposition is low. The safest approach with respect to mortality agents that affect juvenile fall Chinook salmon is "Do no harm." One certainly should not rely on the concept of biological compensation to allow additional anthropogenic mortality.

Not all docks create the same conditions beneath and around them. Docks with solid floors, log floats, and secured on two or more driven pilings would provide more shadowed hiding spots for smallmouth and largermouth bass. Docks with high ability to transmit light, and suspended upon a minimal number of plastic or fiberglass floats, anchored with cable system, would reduce predator ambush sites when compared to docks with solid floors and piling supports.

Docks separated from the shoreline and over deeper water are preferable to solid docks attached directly to the shoreline. The Corps of Engineers requirement for temporary and permanent docks calls for 11 feet and 17 feet, respectively, of depth at the inshore end of floating docks (R. Clubb, personal communication).[2]

I observed a wide spectrum of dock types on Wells pool. Some appear better than others with respect to minimizing dock-caused incremental predation on subyearling Chinook salmon. For example, docks with minimal plastic flotation and open deck mesh are improvements over log floats and solid decking. Even so, they offer shade and dark structure for predators. White plastic floats quickly become dark in color as algae attaches to them, eliminating or reducing any advantage of the light coloration. In my opinion, all types of docks that I observed, whether of old or new construction, tend to increase predation on subyearling summer/fall Chinook over that extant in the same area without docks.

[2] Although not the focus of my report, the effect of docks on yearling salmon is of some concern, especially in the lower Methow and Okanogan rivers, even though these fish migrate rapidly downstream in spring and tend to move in deeper water than subyearlings. Northern pikeminnows and smallmouth bass may take advantage of reduced velocity and cover under docks, preying on yearling salmonids that pass under or close to the floats.

Literature cited

Allen, R. L. 1970. Wells summer Chinook salmon spawning channel. Annual Report, Washington Department of Fisheries, Olympia, WA.

Allen, R. L., B.D. Turner, and J. E. Moore. 1968. Wells summer Chinook salmon spawning channel. Annual Report, Washington Department of Fisheries, Olympia, WA.

____________________________________. 1969. Wells summer Chinook salmon spawning channel. Annual Report, Washington Department of Fisheries, Olympia, WA.

____________________________________. 1971. Wells summer Chinook salmon spawning channel. Annual Report,Washington Department of Fisheries, Olympia, WA

Beamesderfer, R. C., and A. A. Nigro. 1989. Status, biology, and alternatives for management of walleye in John Day Reservoir: a review. Oregon Department of Fish and Wildlife Information Report 89-2, Portland, OR.

Beamesderfer, R. C., and B. E. Rieman. 1991. Abundance and distribution of northern squawfish, walleyes, and smallmouth bass in the John Day Reservoir, Columbia River. Trans. Amer. Fish. Soc. 120:439-447.

Bryan, M. D., and D. Scarnecchia. 1992. Species richness, composition, and abundance of fish larvae and juveniles inhabiting natural and developed shorelines of a glacial Iowa lake. Environ. Biol. Fishes 35:329-341.

Burley, C., and T. Poe. 1994. Significance of predation in the Columbia River from Priest Rapids Dam to Chief Joseph Dam. Draft Report, Contr. No. 430-486. Washington Department of Wildlife (Olympia, WA) and National Biological Survey (Cook, WA) to Chelan, Douglas, and Grant County Public Utility Districts.

Chapman, D., A. Giorgi, T. Hillman, D. Deppert, M. Erho, S. Hays, C. Peven, B. Suzumoto, and R. Klinge. 1994. Status of summer/fall Chinook salmon in the mid-Columbia River. Don Chapman Consultants, Inc, Boise, ID.411 p. + App.

Connor, W. P., R. K. Steinhorst, and H. L. Burge. 2003. Migrational behavior and seaward movement of wild subyearling fall Chinook salmon in the Snake River. No. Amer. J. Fish. Manage. 23:414-430.

Fayram, A. H., and T. H. Sibley. 2000. Impact of predation by smallmouth bass on sockeye salmon in Lake Washington. No. Amer. J. Fish. Manage. 20:81-89.

Fresh, K. L., D. Rothaus, K. W. Mueller, and C. Waldbillig. 2001. Habitat utilization by predators, with emphasis on smallmouth bass, in the littoral zone of Lake Washington. Washington Department of Fish and Wildlife. Final Report prepared for Seattle Public Utilities, Seattle, WA.

Fresh, K. L., D. Rothaus, K. W. Mueller, and C. Waldbillig. 2003. Habitat utilization by smallmouth bass in the littoral zones of Lake Washington and Lake Union/Ship Canal. 2003 Lake Washington Chinook salmon workshop. King County Department of Natural Resources, January 24, 2003. Shoreline, WA.

Fritts, A. L. and Todd N. Pearsons. 2004. Smallmouth bass predation on hatchery and wild salmonids in the Yakima River, Washington. Trans. Amer. Fish. Soc. 133:880-895.

Garland, R. D., K. F. Tiffan, D. W. Rondorf, and L. O. Clark. 2002. Comparison of subyearling fall Chinook salmon's use of riprap revetments and unaltered habitats in Lake Wallula of the Columbia River. No. Amer. J. Fish. Manage. 22:1283-1289.

Hillman, T. W., D. W. Chapman, and J. S. Griffith. 1989a. Seasonal habitat use and behavioral interaction of juvenile Chinook salmon and steelhead. 1: Daytime habitat selection. Pages 42-82 IN: Don Chapman Consultants, Inc., Summer and winter ecology of juvenile Chinook salmon and steelhead trout in the Wenatchee River, Washington. Final report to Chelan County Public Utility District, Wenatchee, WA.

Hillman, T. W., D. W. Chapman, and J. S. Griffith. 1989b. Seasonal habitat use and behavioral interaction of juvenile Chinook salmon and steelhead. 2: Nighttime habitat selection. Pages 84-108 IN: Don Chapman Consultants, Inc., Summer and winter ecology of juvenile Chinook salmon and steelhead trout in the Wenatchee River, Washington. Final report to Chelan County Public Utility District, Wenatchee, WA.

Kemp, P.S., M. H. Gessel, and J. G. Williams. 2005. Seaward migrating subyearling Chinook salmon avoid overhead cover. J. Fish Biology 67:1381-1391.

Koehler, M. E. 2002. Diet and prey resources of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) rearing in the littoral zone of an urban lake. M.S. Thesis, University of Washington, Seattle, WA.

Koehler, M. E., K. LO. Fresh, D. A. Beauchamp, J. R. Cordell, C. A. Simenstad, and D. E. Seiler. 2006. Diet and bioenergetics of lake-rearing juvenile Chinook salmon in Lake Washington. Trans. Amer. Fish. Soc. 135:1580-1591.

Ledgerwood, R., E. Dawley, L. Gilbreath, P. Bentley, B. Sandford, and M. Schiewe. 1991. Relative survival of subyearling Chinook salmon that have passed through the turbines or bypass system of Bonneville Dam second powerhouse, 1990. NMFS Annual Report to U.S. Army Corps of Engineers, Contr. No. E86900104. 90 p.

Lange, Marc. 1999. Abundance and diversity of fish in relation to littoral and shoreline features. M.S. Thesis, Univ. of Guelph, Ontario, Canada.

Mains, E., and J. Smith. 1964. The distribution, size, time and current preferences of seaward migrant Chinook salmon in the Columbia and Snake Rivers. Washington Department of Fisheries Fisheries Research Papers Vol. 2(3):5-43.

McGee, J. A., R. Rulifson, C. Heath, and R. F. Leland. 1983. Juvenile salmon monitoring Methow River, Okanogan River and Wells Dam forebay April-May 1983 and summer downstream migrant monitoring June-July 1983. Douglas County Public Utility District No. 1, East Wenatchee, WA.

Naughton, G. P., and D. H. Bennett. 2004. Predation on juvenile salmonids by smallmouth bass in the Lower Granite Reservoir system, Snake River. No. Amer. J. Fish. Manage. 24:534-544.

Norman, W.T. 1992. Factors controlling variation of naturally spawning fall Chinook salmon in the upper Columbia River. M.S. Thesis, University of Washington, Seattle, WA.

Petersen, J. H., and T. P. Poe. 1993. System-wide significance of predation on juvenile salmonids in Columbia and Snake River reservoirs. Annual Report 1992, J. H. Petersen and T. P. Poe, Eds., U.S. Fish and Wildlife Service, Cook, WA., Report to Bonneville Power Administration, Portland, OR, Project No. 90-078, Contract No. DE-AI79-90BP07096.

Pflug, D. E. and G. B. Pauley. 1984. Biology of smallmouth bass (Micropterus dolomieui) in Lake Sammamish, Washington. Northwest Science 58:118-130.

Poe, T. P., H. C. Hansel, S. Vigg, D. E. Palmer, and L. A. Prendergast. 1991. Feeding of predaceous fishes on out-migrating juvenile salmonids in John Day Reservoir, Columbia River. Trans. Amer. Fish. Soc. 120:405-420.

Rieman, B. E., R. C. Beamesderfer, S. Vigg, and T. P. Poe. 1991. Estimated loss of juvenile salmonids to predation by northern squawfish, walleyes, and smallmouth bass in John Day Reservoir, Columbia River. Trans. Amer. Fish. Soc 120:448-458.

Rondorf, D. W., and G. A. Gray. 1987. Distribution and abundance of age-0 chinook salmon in a Columbia River reservoir. U.S. Fish and Wildlife Service draft report, Cook, WA.

Sergeant, C. J., and D. A. Beauchamp. 2006. Effects of physical habitat and ontogeny on lentic habitat preferences of juvenile Chinook salmon. Trans. Amer. Fish. Soc. 135:1191-1204.

Tabor, R. A., R. S. Shively, and T. P. Poe. 1993. Predation on juvenile salmonids by smallmouth bass and northern squawfish in the Columbia River near Richland, Washington. No. Amer. J. Fish. Manage. 13:831-838.

Tabor, R. A., H. A. Geqarns, C. M. McCoy III, and S. Camacho. 2006. Nearshore habitat use by juvenile Chinook salmon in lentic systems of the Lake Washington Basin. U.S. Fish and Wildlife Service Annual Report, 2003 and 2004, Lacey, WA.

Tabor, R. A. 2007. Smallmouth bass and largemouth bass predation on juvenile Chinook salmon and other salmonids in the Lake Washington basin. No. Amer. J. Fish. Manage. 27:1174-1188.

Tiffan, K. F., L. O. Clark, R. D. Garland, and D. W. Rondorf. 2006. Variables influencing the presence of subyearling fall Chinook salmon in shoreline habitats of the Hanford Reach, Columbia River. No. Amer. J. Fish. Manage. 26:351-360.

Tinus, E. S.l, and R. C. Beamesderfer. 1994. An update on the distribution, fisheries, and biology of walleye in the lower Columbia River. Oregon Department of Fish and Wildlife, Information Report 94-3, Portland, OR.

Vigg, L., T. P. Poe, L. A. Prendergast, and H. C. Hansel. 1991. Rates of consumption of juvenile salmonids and alternative prey fish by northern squawfish, walleyes, smallmouth bass, and channel catfish in John Day Reservoir, Columbia River. Trans. Amer. Fish. Soc. 120:421-438.

Wydoski, R. S., and R. R. Whitney. 2003. Inland fishes of Washington. Amer. Fish. Soc., Bethesda, MD and Univ. of Washington Press, Seattle, WA. 322 p.

Zimmerman, M. P. 1999. Food habits of smallmouth bass, walleyes, and northern pikeminnow in the lower Columbia River basin during outmigration of juvenile anadromous salmonids. Trans. Amer. Fish Soc. 128:1036-1054.