Douglas PUD Staff Biologist Analysis

Rationale for Proposed Changes to the District's Dock Policy

Docks, piers, and floats are expected to affect predation on ESA-listed and non-listed salmonids by providing foraging habitat (shade, overhead cover, simple structure, and velocity refuge) for structurally-oriented ambush predators, specifically bass. Due to their life history strategies, smallmouth bass (*Micropterus dolomieui*) and largemouth bass (*M. salmoides*) are the predators most likely to benefit from shoreline development, but northern pikeminnow (*Ptychocheilus oregonensis*) may also benefit. To make the most of the discussion on this topic, it would be useful to have a general understanding of predator-prey interactions.

Predator-prey Interactions

Cooper and Crowder (1979) stated that "reducing structural complexity may remove prey refuges and subject the remaining prey to high risk until they are decimated." Docks, piles, and floats are relatively simple structural elements compared with emergent vegetation, trees with branches, and other forms of natural cover found along undisturbed shorelines.

Sustainable predator-prey interactions in general require the existence of prey refuge to prevent the extermination of the prey organism. Numerous studies have reported increased use of complex cover (e.g., aquatic vegetation, woody debris, substrate interstices, and undercut banks) by prey fishes in the presence of predators, and reduced foraging efficiency of predators due to habitat complexity (e.g., Bugert and Bjornn 1991; Persson and Eklov 1995; Werner and Hall 1988; Tabor and Wurtsbaugh 1991; Wood and Hand 1985). Savino and Stein (1989) demonstrated that refuge is critical for prey fish survival; their study found that largemouth bass captured all prey fish that strayed from areas with aquatic vegetation into open water. Bass also eliminated all prey fish from pools that provided no refuge in a study by Schlosser (1987), while predator and prey were able to coexist in pools with complex cover. Hixon and Beets (1993) provided evidence of the value of complexity in a study of marine reef fish; prey fish were most abundant on reefs where refuge size closely matched the body size of the prey species, and where the number of refuge holes was not limiting. Lynch and Johnson (1989) showed similar results for juvenile bluegill (*Lepomis macrochirus*) in fresh water. Gotceitas and Colgan (1989) found that prey fish in fresh water preferentially selected refuge habitat with greater complexity than was necessary to significantly reduce foraging success of predators. Helfman (1979) suggested that the utilization of small floating objects on bright days by prey fish was related to the visual advantage the prey fish gained by being shaded over a predator approaching from the brightly lit surrounding area.

Shallow water functions as a refuge from predation for small fish, especially in the absence of complex habitat features such as woody debris or submerged vegetation. In Schlosser's study (1987), bass eliminated prey fish from structurally simple pools either by direct consumption, or by forcing the prey fish into shallow-water habitats, thus subjecting prey fish to potentially decreased feeding opportunities. Bass predation also excluded grazing minnows from all but the shallow sections of pools in Oklahoma streams studied by Power et al. (1985). Ruiz et al. (1993) reported that mummichogs (*Fundulus heteroclitus*)(< 51 mm) in a sub-estuary of Chesapeake Bay preferentially occupied shallow water (< 35 cm) in the absence of submerged aquatic vegetation. Collins et al. (1995a; 1995b) found that feeding rates by small fish (< 100 mm) in two Ontario shield lakes were 10 times higher in shallow water (< 20 cm) than in the rest of the littoral zone. Littoral slope has been negatively correlated with fish numbers and positively correlated with fish size (Randall et al. 1996). Brown (1998) observed no piscivores in “littoral fringe” (within 2.5 m of shore) transects in Lake Joseph, Ontario.

While most of the above studies on predator-prey interactions were from warmwater systems, studies of juvenile salmonid response to predators are analogous. Juvenile salmonids modify their behavior in the presence of predators by seeking or orienting to complex refuge (Gregory and Levings 1996; Reinhardt and Healey 1997), emigrating from areas with predators (Bugert and Bjornn 1991), aggregating (Tabor and Wurtsbaugh 1991), and adopting diel vertical migrations (Eggers 1978). The response of juvenile salmonids to predators increases with experience (Healey and Reinhardt 1995) and body size (Reinhardt and Healey 1997). Behavioral responses can be influenced by environmental factors such as visibility. Turbidity reduces predator-avoidance behavior in salmonids (Gregory and Levings 1996; Gregory 1993), and reduces prey mortality rates by reducing the prey-encounter rates of predators (Ginetz and Larkin 1976; Gregory and Levings 1998; Beauchamp et al. 1999). Salmonid predators also modify their behaviors in response to habitat complexity. Piscivorous brook trout in Quebec lakes switched foraging tactics from active cruising to ambushing when prey refuges were present (East and Magnan 1991).

Piers, floats, and piles differ from natural cover/structure elements, such as brush piles, overhanging vegetation, and emergent vegetation, primarily in their lack of structural complexity. This difference is critical for prey fish, which rely on structural complexity for survival in the presence of predators. In developed lakes, piers become the dominant structural features, at the expense of natural complex structures such as woody debris and emergent vegetation. The findings that bass (especially smallmouth bass) persist or thrive along developed shorelines while other species decline, substantiates the concept that bass gain an advantage over prey fish in structurally simple environments (Brown 1998; Bryan and Scarnecchia 1992; Poe et al. 1986; Lange 1999).

Simplification of shoreline habitat, which reduces the availability of prey refuge-habitat, should be avoided. Predator-prey interactions modify the behavior of both predator and prey species. Prey refuges are essential for the continued existence of vulnerable prey species. Complex habitat features that exclude predators, physically or through risk-aversion, can function as prey refuge. Examples of effective prey refuge may include shallow water, complex substrate, aquatic and emergent vegetation, overhanging terrestrial vegetation, undercut banks, and woody debris. In the face of increasing development, the maintenance of habitat function along shorelines will be a challenge.

Shoreline Development

Separating the effects of shorezone structures on juvenile salmon into discussions of the effects of individual structures in isolation may not yield the most appropriate conclusions since development seldom occurs as an isolated structure. The effects of shoreline development in its entirety should also be included in the discussion. Jennings et al. (1999) stated that “fish do not respond to shoreline structures: rather, they respond to a suite of habitat characteristics that are the result of the structure, changes to the riparian zone associated with its placement (vegetation and woody structure removal), and often, intensive riparian zone management that occurs on developed properties." Brazner (1997) found that sites adjacent to human development in Green Bay, Lake Michigan had fewer fish and species, and had fish assemblages consisting of species that were more tolerant of disturbance. Fish species richness and abundance were highest in undeveloped wetland habitats (Brazner 1997). Species richness and total fish abundance were less at developed sites than at undeveloped sites in the littoral zone of Spirit Lake, Iowa (Bryan and Scarnecchia 1992). Poe et al. (1986) found that an undeveloped bay was characterized by a percid-cyprinid-cyprinodontid assemblage, while a developed bay (bulkheaded shoreline, frequent dredging, low macrophyte species richness, reduced water quality) was dominated by a centrarchid (bass, sunfish) assemblage. Both Poe et al. (1986) and (Bryan and Scarnecchia 1992) found that fish species richness was positively correlated with macrophyte species richness. Lange (1999) provided evidence that residential shoreline development is "a likely agent in causing system-wide disruption to fish…." Sites with combinations of development structures (i.e., dock and bank stabilization) had low fish abundance and richness (Lange 1999). Lange (1999) generally concluded that the results of cluster analysis indicated that "sites associated with high occurrence of all forms of development and low occurrence of vegetation, tended to have the lowest total abundance and species richness, regardless of observational scale." Both Jennings et al. (1999) and Lange (1999) found that the scale of one's observations affects conclusions, and the cumulative impacts of multiple development features may be substantial.

Predators and Docks

Bass have been studied extensively throughout their range, including the Columbia River Basin. Smallmouth and largemouth bass demonstrate an affinity for structural elements, and are piscivorous, preying on salmonids when available. Northern pikeminnows in the Columbia River Basin have also been studied extensively, and those studies have established their reputation as the dominant piscine predator on juvenile salmonids, and resulted in the implementation of systematic removal efforts by federal and non-federal operators of hydroelectric projects. While smallmouth (and to a lesser extent, largemouth) bass and northern pikeminnows are known predators of juvenile salmonids in the Columbia River and other systems (Tabor et al. 1993; Poe et al. 1991; Vigg et al. 1991; Gray and Rondorf 1986; Pflug and Pauley 1984; Fayram and Sibley 2000), the role of shoreline development, and specifically docks and piles, in facilitating predation on juvenile salmonids is unclear. Because of the logistical difficulty in study implementation, there have been no specific studies on predation on juvenile salmonids by predators directly associated with docks, but much is known about predator foraging and habitat use in general. From separate studies of habitat use and predation, conclusions can be drawn regarding the potential for shoreline development to influence predation, and those conclusions can provide the basis for management actions in the absence of specific studies.

Smallmouth bass in flowing systems use overhead cover, physical structure, and low current-velocity (Todd and Rabeni 1989; Rankin 1986; Probst et al. 1984), and they take advantage of the velocity refuge afforded by structures located in high-velocity flow to forage in areas that would otherwise be energetically unfavorable (Rankin 1986). Tabor et al. (1993) collected 90-percent of the smallmouth bass sampled in their study of the upper McNary Reservoir from low-velocity backwater areas along the shoreline, where they also observed abundant ocean-type Chinook juveniles. Foraging smallmouth bass in lakes generally select habitats with cover in the form of logs or rocks, drop-offs or outcroppings, and hard substrates without aquatic vegetation. Smallmouth bass in Lake Sammamish often selected residence areas with overhead cover such as docks, submerged logs, or overhanging vegetation, and preferred areas with cobble/gravel substrate and drop-offs, without aquatic vegetation (Pflug 1981; Pflug and Pauley 1984). Smallmouth bass in a Texas reservoir selected rock outcroppings more than other habitat types (Kraai et al. 1991). Haines and Butler (1969) showed that structures that provided darkness were selected most frequently by yearling smallmouth bass. From these studies, it is apparent that habitat use by foraging smallmouth bass in both flowing and static systems is generally similar, with the avoidance of high current velocity being the defining difference between the two environments.

Because of the fluctuations in reservoir surface elevations, the docks that are typically installed in the Columbia River are configured with a fixed-pile pier extending from the shoreline to a terminal float anchored to either piles or submerged anchors. These structures provide in-water structure, velocity refuge, and overhead cover that can attract bass. Bassett (1994) reported that artificial structures placed at depths of 3 to 6 meters were most effective at attracting centrarchids (includes smallmouth bass) during summer. Pflug (1981) observed use of residential docks by smallmouth bass. WDFW personnel electrofishing for bass in 50 to 70 western Washington lakes observed that bass were more often associated with natural structures such as brush piles, beaver lodges, and overhanging willows and, to a lesser degree, were found under docks or adjacent to piles (Bonar, pers. comm., 13 June 2000). Qualitative observations by Bonar (pers. comm., 13 June 2000) suggest that structures concentrate bass in lakes where structure is limiting. In SCUBA surveys of study sites in Lake Washington, 68-percent of all adult smallmouth bass were observed within 2 meters of a dock (Fresh et al. 2003). The use of this habitat was disproportional to its availability: the amount of area within 2 meters of a dock ranged from 4- to 12-percent of available habitat, while the percentage of bass observed in that habitat ranged from 27- to 62-percent, indicating a preference for such habitat (Fresh et al. 2003). Fresh et al. (2003) observed that smallmouth bass displayed a preference for large docks with abundant piles or skirting. Smallmouth bass association with docks in Lake Washington varied by age class and season, with the greatest association generally occurring in June (Fresh et al. 2001).

Northern pikeminnow are the primary predator of juvenile salmonids within Columbia River reservoirs (Zimmerman 1999; Vigg et al. 1991; Poe et al. 1986). Willis et al. (1992) studied northern pikeminnow distribution in the John Day reservoir and tailrace and reported that they selected low velocity habitats, occupied the littoral zone throughout the summer and only concentrated in the tailrace of McNary Dam following cessation of spill. Other studies have also reported a preference by northern pikeminnows for the littoral zone and low velocity habitats in general (Petersen et al. 1993; Beamesderfer and Rieman 1988). Beamesderfer (1983) found that northern pikeminnows prefer current velocities of 1-foot per second or less. Northern pikeminnows, because of their preference for the littoral zone and low-velocity habitat could benefit from shorezone structures such as piers and floats. However, a positive relationship between shorezone structures and northern pikeminnow predation on juvenile salmonids has not been established, and at least in some situations (steep-sloped shoreline, low velocity), northern pikeminnows demonstrate no preference for developed shorelines (Ward et al. 1994); however, their foraging efficiency was greater along developed shorelines.

Docks may also contribute to the reproductive success of bass. Smallmouth bass nest on the substrate in shallow water and the male constructs and guards the nest. Male smallmouth bass in Lake Sammamish generally located nests within 7 to 20 meters of shore, on gently sloping gravel/cobble substrates, devoid of vegetation, at depths of 1 to 3 meters, and associated with a structural element such as a log, boulder, pile, or other artificial structure (Pflug and Pauley 1984; Malcom, pers. comm., 13 April 2000). Unpublished results of a study by the Muckleshoot Indian Tribe in Lake Sammamish indicated that smallmouth bass preferentially located nests proximate to residential piers (Malcom, pers. comm., 13 April 2000). Although residential piers only covered approximately 13 percent of the nearshore zone (0-20 m from shore), 32 percent of the smallmouth bass nests were within 2 meters of piers, and 54 percent were within 2 meters of a pier or other artificial structure (i.e., isolated piles, water pipes, boat launch rails, tires, rebar) (Malcom, pers. comm., 13 April 2000). Shade was apparently not a critical attraction feature of piers for spawning smallmouth bass; instead, the attraction was to physical structure provided by piers, further evidenced by the location of nests adjacent to non-shading structures such as isolated piles (Malcom, pers. comm., 13 April 2000). This finding does not indicate that shade was unimportant to *foraging* smallmouth bass, only that bass were not preferentially locating nest sites in shady locations. The findings of Malcom (pers. comm., 13 April 2000) corroborate the findings of Vogele and Rainwater (1975), who also found that smallmouth bass nests were not closely associated with sheltered habitat in Bull Shoals Reservoir. The majority of smallmouth bass nests were beside submerged stumps in gravel and rubble substrates, while largemouth bass nests were either under artificial brush shelters or adjacent to a submerged log, rock, or tree base (Vogele and Rainwater 1975). Male bass preferentially locate nests adjacent to structural features such as rocks or logs apparently to reduce the perimeter that must be guarded or to provide visual isolation from nearby conspecifics (Heidinger 1975). Thus, pier elements that protrude from the substrate (i.e., piles, boatlifts, etc.) may attract spawning bass.

Largemouth bass are present within the mid-Columbia River; although their behavior and distribution have not been studied, it appears that the ambient water temperature limits both their distribution and reproductive success. It is assumed that their abundance is low, limited by the lack of suitable spawning temperatures in the run-of-the-river reservoirs. Suitable temperatures to support spawning by largemouth bass may be found in the lower Okanogan River. The ecology of largemouth bass has been well studied in other systems. Stein (1970) found that largemouth bass in Lake Washington preferred heavy log and brush cover to all other available habitat (including docks), and considered the lack of this habitat to be a limiting factor. Largemouth bass were often found under docks in early spring in Lake Washington (Stein 1970). One third of the largemouth bass in Lake Baldwin, Florida showed a significant preference for piers in the absence of aquatic vegetation (Colle et al. 1989). Largemouth bass preferred moderate to dense vegetation and silt or sand substrate in Lake Sammamish (Pflug 1981). Nests were constructed at depths from 0.6 to 1.5 meters, in vegetated areas with soft-sediment to gravel substrates, on moderate to steep slopes (Pflug 1981). Others have noted preferences for nest locations adjacent to a structural feature such as a rock, stump, or a slope (Heidinger 1975; Allan and Romero 1975), and locations that provide cover (Vogele and Rainwater 1975). In general, largemouth bass select soft substrates; cover in the form of logs, brush, aquatic vegetation, or other structures; and utilize a variety of prey-capture tactics.

Finally, docks can disrupt the migration of juvenile Chinook, forcing them to travel away from the shoreline to avoid going under the dock (Tabor et al. 2006). This exposes them to predators that often inhabit deeper water.

Predation

The habitat selected by smallmouth bass overlaps closely with the habitat used by juvenile ocean-type Chinook. Bass are generalist piscivores, eating salmonids when their distributions overlap. Bass predation on salmonids in the Columbia River corresponds with the out-migration of smolts in the spring and especially the protracted, shoreline-oriented migration of age-0+ ocean type Chinook during the summer (Gray and Rondorf 1986; Vigg et al. 1991; Tabor et al. 1993; Poe et al. 1991; Zimmerman 1999). This phenomenon is explained by the temporal and spatial overlap in distribution of smallmouth bass and age-0+ ocean-type Chinook, and the temperature preferences of smallmouth bass (Tabor et al. 1993). Prey consumption by smallmouth bass is minimal below 10°C (Coutant 1975; Coble 1975), a temperature which is typically not reached in the Wells Reservoir until May; thus, maximum activity and metabolic rates of smallmouth bass correspond closely with summer-migrating species with extended residence time in the reservoir.

Predation rates by bass on juvenile salmonids have been reported to be substantial where their distributions overlap over extended periods. Pflug and Pauley (1984) reported that smallmouth bass in Lake Sammamish preyed heavily on juvenile salmonids during the month following releases from Issaquah Hatchery. Bonar et al. (2005) estimated coho salmon consumption by largemouth bass in two Western Washington lakes of between 7 and 16 coho per day per bass during spring/early summer. Total estimates of smolt equivalents consumed ranged between 3- and 133-percent of the coho salmon smolts annually produced by the basins (Bonar et al. 2005). Juvenile salmonids comprised 59-percent of the diet of smallmouth bass sampled in upper McNary Reservoir (Tabor et al. 1993). Tabor et al. (2007) estimated that black bass (includes smallmouth and largemouth) consumed a maximum of 1.2-percent of the juvenile ocean-type Chinook exiting Lake Washington. In a study on the lower Yakima River, Fritts and Pearsons (2004) estimated that the annual consumption of hatchery ocean-type Chinook ranged from 1- to 4-percent of the basin releases, and consumption estimates ranged from 4- to 35-percent of the annual basin production of wild ocean-type Chinook.

From these studies it is apparent that consumption of juvenile salmonids by bass varies by location and year, but the magnitude of predation is not trivial. The Wells HCP provides only a few percentage points of tolerance for studies of project mortality, thus even a reduction of one percentage point can be pivotal. At present the District is in Phase III (Additional Juvenile Studies) for subyearling Chinook, primarily because the technology for tagging subyearlings is inadequate due to their small size and protracted migration strategy. However, recent and continuing advances in tag technology (JSATS) raise the expectation that it is only a matter of time until the technology will match our tagging needs and we will be asked to perform survival studies on subyearling Chinook. Protracted reservoir residence by subyearling Chinook in the presence of smallmouth bass and northern pikeminnow under natural conditions will reduce survival estimates relative to those obtained for spring migrants—this we cannot avoid. We can avoid improving foraging opportunities and reproductive success for such predators in the Wells Reservoir by halting the proliferation of structures known to be used by bass for velocity refuge, overhead cover, visual isolation and ambush cover, and nesting sites.

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