RECLAMATION
Managing Water in the West

Coho Salmon Production Potential in the Bumping River Basin

Storage Dam Fish Passage Study
Yakima Project, Washington

Technical Series No. PN-YDFP-009

U.S. Department of the Interior
Bureau of Reclamation
Pacific Northwest Region
Boise, Idaho

March 2007

U.S. Department of the Interior

Mission Statement

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian tribes and our commitments to island communities.

U.S. Bureau of Reclamation

Mission Statement

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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Introduction

This technical report presents information regarding coho salmon production potential in the Bumping River basin above Bumping Lake Dam. This information is a key component in determining estimates of biological and economic benefits attributable to proposed fish passage features at the dam.

Objectives

The Bureau of Reclamation (Reclamation) is leading a cooperative investigation with the Yakama Nation (YN), state and Federal agencies, and others, to study the feasibility of providing fish passage at the five large storage dams of the Yakima Project. These dams—Bumping Lake, Kachess, Keechelus, Cle Elum, and Tieton—were never equipped with fish passage facilities. Four of the five reservoirs were originally natural lakes and historically supported Native American fisheries for sockeye salmon and other anadromous and resident fish. Implementation of passage features at the dams has the potential to reintroduce sockeye salmon to the Yakima River basin; increase populations of upper basin steelhead, coho salmon, and Chinook salmon; restore life history and genetic diversity of salmon; and reconnect isolated populations of bull trout. Two species in the basin, bull trout and Mid-Columbia steelhead, are listed as threatened under the Endangered Species Act (ESA).

Project Purpose

Authority

Authority to undertake a feasibility study is contained in Public law No. 96-162, *Feasibility Study, Yakima River Basin Water Enhancement Project,* (Act of December 28, 1979, 93 Stat. 1241). The study area is in the Yakima River basin in south central Washington on the east side of the Cascade Range and includes most of Yakima, Kittitas, and Benton counties.

Core team

Reclamation is supported in this effort by a core team of biologists, engineers, and other specialists from Federal, state, and local entities. Partners include the YN, National Oceanic Atmospheric Administration (NOAA Fisheries), the U.S. Fish and Wildlife Service (USFWS), Washington Department of Fish and Wildlife (WDFW), Washington Department of Ecology, Washington Department of Agriculture, and local irrigation districts.

Background

Reclamation's commitment to study the feasibility of fish passage at the five large storage dams of the Yakima Project is documented in agreements, permits, and litigation settlements associated with the Keechelus Dam Safety of Dams (SOD) construction. Early in 2001, many Yakima Basin interests viewed the proposed Keechelus SOD construction as an opportunity to add fish passage features at Keechelus Dam. Reclamation carefully considered this issue but determined that fish passage facilities could not be added to Keechelus Dam under existing SOD authority.

To respond to the stated fish passage concerns, Reclamation negotiated a "mitigation agreement" with WDFW and also agreed to certain conditions contained in the State of Washington Hydraulic Project Approval (HPA) permit for the Keechelus SOD modifications. These conditions included specific tasks and milestone dates regarding the feasibility study, and the installation of interim (temporary, experimental) fish passage features at the dams. Reclamation also agreed to seek funding and implement passage where determined to be feasible.

Phase I Assessment

Reclamation completed a *Phase I Assessment Report* in 2003 (Reclamation 2003). The Phase I assessment process examined a range of options and opportunities for providing fish passage and potentially reestablishing populations of anadromous salmonids in some tributaries of the five Yakima Project storage reservoirs. From this initial assessment, it appeared that some form of upstream and downstream passage for anadromous salmonids and bull trout connectivity would be technically possible at all the storage projects.

Change in Scope

Early in the study process it became apparent that programmed funding was not sufficient to evaluate all five storage dams in detail. For this reason, the scope of the study was reduced to reflect detailed evaluation of passage features only at Cle Elum and Bumping Lake dams. Successful implementation of fish passage at Cle Elum and Bumping Lake dams could eventually lead to future detailed study of the other three dams (Kachess, Keechelus, and Tieton). The intent, to the extent possible, is to meet all of the essential Keechelus Dam SOD requirements outlined in the Record of Decision, the HPA, and the Mitigation Agreement.

Feasibility Study

In fiscal year 2004, following completion of the *Phase I Assessment Report*, Reclamation began detailed studies to evaluate the feasibility of providing fish passage at Cle Elum and

Bumping Lake dams. The Yakima River Basin fisheries co-managers (WDFW and YN) developed an *Anadromous Fish Reintroduction Plan* that outlines the sequence and timing for reintroducing anadromous salmonids above the reservoirs (Fast and Easterbrooks 2005). They proposed a phased approach starting with coho salmon *(Oncorhynchus kisutch)*, followed by sockeye salmon *(O. nerka)*, and eventually Chinook salmon *(O. tshawytscha)* and steelhead *(O. mykiss)*. Reclamation's evaluation of production potential follows this phased approach. The following Technical Reports support Reclamation's estimates of coho and sockeye salmon production potential above Cle Elum and Bumping Lake dams.

- *Coho Salmon Production Potential in the Cle Elum River Basin, Storage Dam Fish Passage Study, Yakima Project, Washington, Technical Report Series No. PN-YDFP-007*, Bureau of Reclamation, Boise, Idaho, March 2007.

- *Assessment of Sockeye Salmon Production Potential in the Cle Elum River Basin, Storage Dam Fish Passage Study, Yakima Project, Washington, Technical Report Series No. PN-YDFP-008*, Bureau of Reclamation, Boise, Idaho, March 2007.

- *Coho Salmon Production Potential in the Bumping River Basin, Storage Dam Fish Passage Study, Yakima Project, Washington, Technical Report Series No. PN-YDFP-009*, Bureau of Reclamation, Boise, Idaho, March 2007.

- *Assessment of Sockeye Salmon Production Potential in the Bumping River Basin, Storage Dam Fish Passage Study, Yakima Project, Washington, Technical Report Series No. PN-YDFP-010*, Bureau of Reclamation, Boise, Idaho, March 2007.

Coho salmon in the Yakima River Basin

Coho salmon were native to the Yakima River basin (Wydoski and Whitney 2003). Tuck (1995) stated that coho salmon spawning was quite widespread in the Yakima River basin, including the Bumping River. Haring (2001) also noted that coho salmon were assumed to have used virtually every low-gradient stream in the Yakima Basin prior to extensive habitat alteration. Adult coho salmon passage data from Roza Dam for the period 1941 to 1968 indicated that the endemic Yakima River stock had early run timing (Haring 2001). Coho salmon were considered extirpated in the Yakima Basin in the 1970s, but a recent reintroduction program has shown some success. Starting in 1985, coho salmon smolts from the lower Columbia River were released below Wapato Dam to provide harvest opportunities. Some of the returning adults spawned naturally; adult progeny of these spawners began showing up at Roza Dam in 1997 and from 1997 to 2005 their numbers ranged from 1 in 2003 to 556 in 2001 (Table 1). Hatchery adult returns from 1999 to 2005 have ranged from none in 2003 to 65 in 2001 (YKFP 2005 http://www.ykfp.org/).

Table 1. Natural-origin (wild) and hatchery adult coho salmon counted at Roza Dam, 1997 to 2005.

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005
Wild	3	7	22	143	556	43	1	33	28
Hatchery			5	5	65	4		3	3

Some Life History Requirements for Coho Salmon

Adult coho salmon generally migrate upstream at water temperature ranging from 7.2°C to 15.6°C (Reiser and Bjornn 1979 cited in Laufle et al. 1986). Spawning normally occurs in riffles or where ground water seepages occur, in minimum water depth of 0.18 m, at water temperatures ranging from 4.4°C to 9.4°C, and velocities ranging from 0.3 to 0.91 m/sec (Thompson 1972). Davidson and Hutchinson (1938 cited in Sandercock 1991) stated that the optimum temperature for coho salmon egg incubation was 4°C to 11°C.

Coho salmon require dissolved oxygen concentrations at or near saturation, generally around 8 to 9 mg/L, for best swimming performance and growth; symptoms of DO deprivation begin to occur at about 6 mg/L, even though under certain circumstances salmonids can survive DO concentrations less than 5 mg/L (Bjornn and Reiser 1991). Bell (1991) reported preferred water temperature for coho salmon as ranging between 11.6°C and 14.4°C, while Brett (1952) reported a temperature range of from 12° to 14°C is close to the optimum for maximum growth efficiency.

Jones and Moore (1999) noted that juvenile coho salmon survive best in low gradient habitats (generally less than four percent), while Bradford et al. (1997) and Reeves et al. (1989) indicated that juvenile coho salmon use tributaries with a stream gradient less than three percent with complex and deep pools or beaver ponds, abundant large woody debris in the channel, and where the rearing reaches were less than 10 m wide and flowed through wide valleys. Optimum juvenile rearing habitat consists of a mixture of pools and riffles, with abundant instream and bank cover, with summertime water temperatures between 10° and 15°C (Reiser and Bjornn 1979 cited in Laufle et al. 1986). Young fish prefer low velocity areas but move to higher velocity areas as they grow (Lister and Genoe 1970 cited in Sandercock 1991).

Coho salmon generally spend one growing season in freshwater and two growing seasons (about 18 months) in the ocean before returning as 3-year-old adults (Hassler 1987) to spawn in their natal streams (Beamish et al. 2004).

Assessment of coho salmon production potential

In this paper we estimate the production potential for coho salmon in the Bumping River basin upstream from Bumping Lake. Production potential is the estimated number of salmon that might be produced from a population under a particular set of natural environmental circumstances (Oregon Coastal Salmon Restoration Initiative Conservation Plan 1997). The estimate of production potential for coho salmon described here is based on substantial stream survey information from the Wenatchee National Forest (WNF) Naches Ranger District (NRD) and Cle Elum Ranger District (CRD) staff biologists, literature values for redd size and fecundity, information from an existing coho salmon supplementation program in the Yakima Basin, and additional information on habitat characteristics and limiting factors from various sources.

The study area for this assessment of coho salmon production potential is the Bumping River and Deep Creek upstream from Bumping Lake, which were identified by Reclamation (2003) as potentially providing about 9.6 km of new habitat for anadromous salmonids when upstream and downstream fish passage is re-established (Figure 1).

We used two approaches to estimate coho salmon production potential in the Bumping River basin, first by estimating the number of spawning adults that the available spawning habitat would support, and second by estimating juvenile rearing/overwintering habitat that would be available in the newly accessible river reaches. Suitable spawning habitat is primarily a function of substrate composition, suitable water velocity and depth; spawning site selection by fish is complex and likely based on a range of environmental or microhabitat conditions such as depth, flow, and substrate size (Bjornn and Rieser 1991) that might differ for the same species in different streams (McHugh and Budy 2004). Rearing/overwintering habitat also includes cover for protection from predators and availability of prey. The results of both approaches for estimating production have limitations based on the quality and quantity of data and assumptions that will result in some level of uncertainty in estimating production potential.

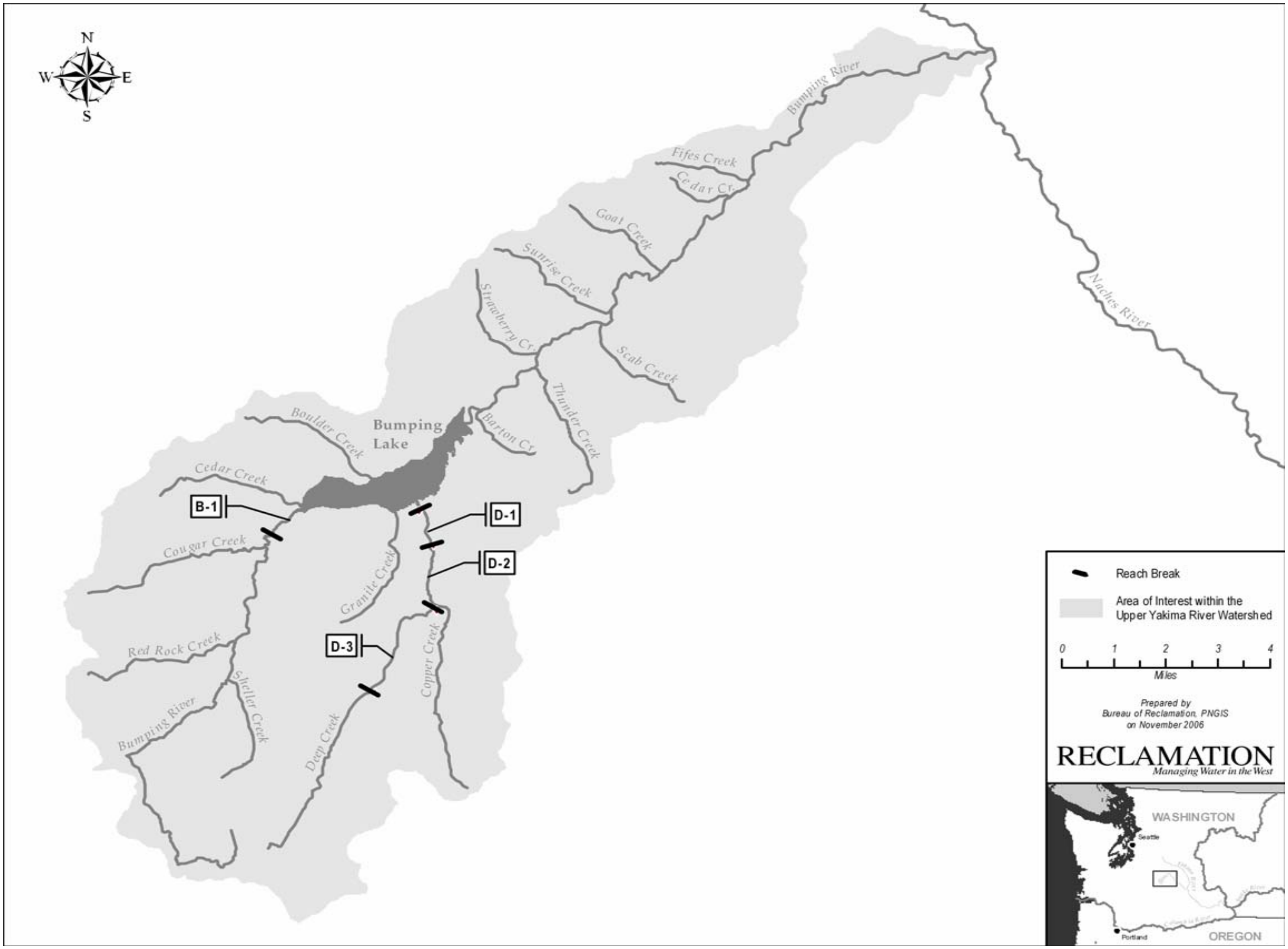

Figure 1. Bumping River basin showing sampled reaches in upper Bumping River and Deep Creek.

Nickelson (1998) noted that overwintering pool habitat in coastal systems is important for juvenile coho salmon, and is the primary bottleneck to coho salmon smolt production, which could be a factor limiting coho salmon production in the system (Nickelson et al. 1992). Similarly, McMahon (1983), citing several authors, noted that the amount of suitable winter habitat may be a factor limiting coho salmon production. On the other hand, Baranski (1989) noted that available rearing habitat during the summer low flow period is a limiting factor in Puget Sound coho salmon production. As will be discussed below, low flow conditions in the Bumping River and Deep Creek upstream from Bumping Lake occur in the late summer, during which time the several stream surveys were conducted, with substantially increased flow in the fall and winter.

Nickelson (1998) developed a coho salmon production potential model for Oregon coastal rivers; however, coastal rivers are different in several respects from inland rivers such as Bumping and Deep Creek. Volume and timing of runoff differ between moister coastal climates and drier inland climates. Montgomery et al. (1999) reported that "[h]igh flows in rain-dominated watersheds generally occur in winter, whereas high flows in snowmelt-dominated watersheds generally occur in spring." Therefore, we used some aspects of Nickelson's (1998) model in this assessment with some caution. In addition, juvenile coho salmon have been documented to rear in lakes, although this is not their typical rearing strategy (Sandercock 1991). Juvenile coho salmon could potentially rear in Bumping Lake but we suspect would have limited success doing so, considering the oligotrophic nature of the lake (Lieberman and Grabowski 2006).

As mentioned above, we utilized both the spawning habitat availability and the juvenile rearing/overwintering habitat approaches to estimate the production potential for coho salmon in the Bumping River basin above the lake. The methods used and the results obtained are described below. These results were compared with potential production assessments in other river systems, and a discussion is provided.

Methods

Available Spawning Habitat

Overview

We estimated the amount of available spawning habitat in the Bumping River and Deep Creek based on a suite of environmental parameters including substrate composition, stream gradient and the size range of substrate used by spawning coho salmon reported in the literature and the estimated areal extent of substrate in this size range in riffles determined from USFS stream surveys and subsequent analyses. We considered the average size of coho salmon redds and area "recommended" per redd (Burner 1951), then incorporated an average fecundity of 2,500 for coho salmon, estimates of some life stage survivals from Nickelson (1998), Reeves et al. (1989) and others, and estimated the number of spawning females that would be needed to fully and uniformly utilize or seed the estimated amount of spawning habitat available under a range of assumptions, without superimposition of redds. We estimated the number of smolts that could be produced and the number of adults that would return at several smolt to adult return (SAR) rates. SAR is smolt to adult return from smolt outmigration from the Bumping River to adult return to the Bumping River.

Substrate suitability

Coho salmon select spawning substrate ranging in size from a pea to an orange (OCSRI 1997); 13 to 102 mm (Reiser and Bjornn 1979 as cited in Laufle et al. 1986); 39 to 137 mm, averaging 94 mm (Briggs 1953 cited in Sandercock 1991); 9 to 100 mm, with less than 20 percent sand (Fleming and Gross 1989); 75 to 150 mm, with less than 20 percent embedded fine material. Salmon reportedly can spawn in substrate with a median diameter up to about 10 percent of their body length (Kondolf and Wolman 1993), which explains in part the size range of gravels used by spawning coho salmon; larger adult fish can move and therefore spawn in larger-sized substrate than smaller fish.

Stream surveys of the Bumping River were conducted by fisheries biologists from the WNF NRD in 2003 and of Deep Creek by biologists from the Cle Elum RD in 2005. These stream surveys provided the information to assess coho salmon production potential in the Bumping River basin. The lowermost 1.28-km reach of the Bumping River was considered, along with 8.33 km of three reaches of Deep Creek, up to impassable barriers.

The stream surveys of the Bumping River and Deep Creek reported the percentage of sand, gravel, cobble, boulder, and bedrock at numerous locations in riffles in each of the reaches indicated in Figure 1. From these data, we summarized the percent composition of substrate type in riffles by reach (Table 2). Particle size categories are shown in Table 3.

Table 2. Percent substrate composition in riffles in one reach of the Bumping River and three reaches of Deep Creek surveyed by USFS WNF staff in 2003 and 2005.

Reach	Length, km		Sand[a]	Gravel	Cobble	Boulder	Bedrock
B-1 n = 1[b]	1.28	Avg. %	10	40	50	0	0
		Range					
B-1 side channels[c]	3.18						
D-1 n = 2	1.45	Avg. %	22	41	38.5	1.7	0
		Range	5-39	38-44	27-50		
D-2 n = 1	2.68	Avg. %	7	33.3	44	17.1	0
		Range					
D-3 n = 2	4.2	Avg. %	7.5	68.0	24.6	0	0
		Range	0-15	36.8-99.0	1-48.1	0	0

Source: U.S. Forest Service stream inventories for the Bumping River and Deep Creek.

Note: The Bumping River reach is designated B-1; Deep Creek reaches were surveyed in 2005, and are designated D-1 through D-3.

[a] Substrate size range: Sand, silt and clay (< 2 mm); Gravel (2-64 mm); Cobble (64-256 mm); Boulder (256-4096 mm); Bedrock (> 4096 mm).

[b] n = number of sites sampled during the Forest Service stream survey.

[c] Data were insufficient to estimate substrate composition of side channels, although they are reported to provide suitable spawning and/or rearing habitat (Yuki Reiss, USFS, NRD, Naches, WA, November 21, 2006, pers. comm.).

We calculated the area of riffle habitat in each reach from the recorded length and width of riffles. We then adjusted the area of riffle habitat by the percentage of gravel/cobble within the 12 to 128 mm size range. The USFS reported only riffles and pools in most stream surveys. This somewhat coarse habitat delineation could likely overestimate the extent of riffles, since other habitat types might have been present but not identified. Less information was recorded and reported for side channels, which were extensive in reach B-1 (Yuki Reiss, USFS, NRD, Naches, WA, November 21, 2006, pers. comm.).

The size range of suitable spawning substrate for coho salmon based on the reported literature values would fall within the mid range of gravel up to the lower range of cobble, that is, medium through very coarse gravel and small cobble (Table 3). From stream pebble counts and sizes at selected transects we calculated the percent of the sample in the size range 12 to 128 mm. This size range mostly bracketed the size range of suitable spawning substrate reported above.

Table 3. Particle sizes of several gravel and cobble categories identified during the surveys of Bumping River and Deep Creek in 2003 and 2005. Particle type and size categories highlighted in bold are considered suitable spawning substrates for coho salmon based on values reported in the literature.

	Particle type	Size, mm
Sand		<2
Gravels	Very fine	2-4
	Fine	4-6
	Fine	6-8
	Medium	8-12
	Medium	**12-16**
	Coarse	**16-24**
	Coarse	**24-32**
	Very Coarse	**32-48**
	Very Coarse	**48-64**
Cobble	**Small**	**64-96**
	Small	**96-128**
	Large	128-192
	Large	192-256

Source: USFS, 2003

Note: The duplicate categories for several particle types were reported as such in the USFS stream survey data.

The Wenatchee National Forest Land and Resource Management Plan (WNF 1990) states that spawning gravel contain no more than 20 percent fine sediment (sediment less than 1.0 mm in size); excessive fine sediment results in embedded substrate conditions, and at high concentrations reduces the quality of salmonid spawning habitat.

Watershed Analysis ratings (Schuett-Hames et al. 1999) are based on the percent of a gravel sample that is less than 0.85 mm in diameter. Cederholm and Reid (1987) reported that coho salmon eggs and alevins are severely affected by particles smaller than 0.85 mm. Samples with less than 12 percent fine sediment are considered GOOD, samples with 12 to 17 percent fine sediment are considered FAIR, and samples with greater than 17 percent fine sediment are consider POOR. Geometric mean diameter (D_g) of spawning gravel is the most sensitive measure of salmonid survival to emergence, and percentage of particles less than 0.85 mm is the most sensitive indicator of changes to substrate induced by land management activities (Young et al. 1991). The average percent sand in reaches B-1 through D-3 ranges from 7 to 22 (Table 2); reach D-1 had the high of 22 percent sand, placing it in the poor category, while the other three reaches had less than 10 percent sand, in the good category.

Coho salmon would likely be able to utilize the four reaches of the Bumping River and Deep Creek that have reported average gradients of less than 2 percent (U.S. Forest Service, 2004, 2006) (Table 3).

Redd Size

To estimate the number of redds and therefore the number of spawning female fish that the available habitat could support, it was necessary to assign an average area required for a single spawning pair of salmon to construct and defend a redd. The average size of a coho salmon redd reported by various authors cited in Sandercock (1991) was about 1.5 m^2. Crone and Bond (1976 cited in Sandercock 1991) indicated the average area of gravel disturbed (presumably for a redd) was 2.6 m^2, while Burner (1951) noted an average redd size of 2.8 m^2. Nickelson (1998) estimated an average redd size of 3 m^2. Fleming and Gross (1989) reported an equation from Tautz (1977) for estimating redd size:

$$\text{Avg. redd size} = (FL/31)^2 * 2{,}358\ cm^2 * 4 * 0.7$$

where FL is the average fork length (cm) of females in the population, 4 is the modal number of nests per redd, 0.7 adjusts for nest overlap, and 2,358 cm^2 is the area used by a 31-cm female during construction. We used the average fork length of 63.04 cm for 1,036 adult coho salmon measured by the YN in 2003 at the collection facility at Roza Diversion Dam on the Yakima River (Joel Hubble, YN, 2004, pers. comm.). This yielded an average redd size of 2.7 m^2. Averaging the reported and calculated redd sizes yields a redd size of 2.5 m^2. Salmon are also believed to require some additional defensible space larger than the redd itself to reproduce successfully. Burner (1951) recommended that the area needed for spawning coho salmon should be about four times the redd size, which based on 2.5 m^2 would be about 10 m^2. In our estimate of production potential, we used 10 m^2 as the area needed for a single female coho salmon to spawn.

Fecundity

In order to estimate the number of juveniles that might be produced from the estimated number of spawning adults the available habitat would support, we needed an estimate of the average fecundity of female coho salmon. Fecundity of adult salmon varies with fish size and latitude (Wydoski and Whitney 2003, Nemeth et al. 2004). Salo and Bayliff (1958; cited in Sandercock 1991) developed a regression equation to predict the number of eggs produced per female based on standard length. Only fork length data were available for the 1,036 adult coho salmon returning to Roza Dam in 2003; however, the average fork length of 63.04 cm included both male and female salmon. Using this average in Salo and Bayliff's regression equation

$$y = -2596 + 84.53x$$

where y = number of eggs per female and x = standard length (cm)

we obtained an average fecundity of 2,733 eggs per female. Nickelson (1998) used a fecundity of 2,500 eggs per female in his coho salmon production model. Substituting 2,500 in Salo and Bayliff's (1958) equation produced a fish standard length of 60.3 cm, which was probably close to the average standard length of the coho salmon measured in 2003 since standard length is less than fork length. Thus, we felt justified using Nickelson's fecundity of 2,500 eggs per female in this potential production assessment.

Estimation of coho salmon production

The steps we took to assess the production potential for coho salmon in the Bumping River and Deep Creek above Bumping Lake included calculating the areal extent of riffles and pools from WNF NRD and CRD stream surveys, estimating the percent of substrate in the size range reported to be suitable for coho salmon spawning, adjusting the amount of riffle habitat by that percentage, incorporating information about redd size, calculating the number of spawning female coho salmon needed to fully utilize the habitat, then incorporating average fecundity to calculate the number of eggs those females could produce, and for egg to smolt survival of 1.5 percent, estimating the number of smolts that could be produced. Egg to smolt survival of 1.5 percent was selected based on a range of estimates from literature. Neave and Wickett (1953 cited in Sandercock 1991) reported egg to smolt survival for British Columbia coho salmon as 1 to 2 percent, Reeves et al. (1989) listed an egg to smolt survival of 0.02 (2 percent), Nickelson (1998) used egg to smolt survival of about 0.3 percent in his model, and Anderson and Hetrick (2003) estimated egg to smolt survival of 2.1 and 1.7 percent in Kametolook and Clear Creek, Alaska, respectively.

From the number of coho salmon smolts estimated to be produced, we estimated the number of adults returning at smolt to adult returns (SARs) of from one to six percent. This range of SARs was selected to bracket annual variability expected to occur, those observed both historically and recently, and the interim objective of the NPCC's 2003 Mainstem Amendment of achieving SARs in the two to six percent range (average four percent) for Snake River and upper Columbia River salmon and steelhead (NPCC 2003). Using SARs from the Bumping River back to the Bumping River simplifies calculations and eliminates the need to consider life stage-specific survival during outmigration, residence time in the estuary and ocean and during the adult upstream migration, and harvest in the ocean or the Columbia River.

Juvenile rearing/overwintering habitat approach

Overview

Juvenile coho salmon exhibit considerable plasticity in behavior and use of habitat (Sandercock 1991). During early rearing they utilize riffles and pools in streams, but as water temperatures decrease they move to tributaries, side channels, or deeper pools with some structure for overwintering. In some cases they move considerable distances both upstream and downstream from summertime rearing areas to overwintering habitat

(Sandercock 1991). Low summertime river flows and overwintering habitat conditions may be factors limiting coho salmon production. Both of these time periods have been noted as constituting production bottlenecks (Nickelson 1998, Baranski 1989).

Estimation of pool habitat

We used stream survey data for the Bumping River and Deep Creek collected by the WNF NRD and CRD in late summer during low flow to estimate the number and area of pool habitat conditions in low gradient reaches of the Bumping River and Deep Creek up to impassable barriers. This would be a minimum estimate of rearing/overwintering habitat, since as noted above, juvenile coho salmon also use tributaries and side channels as well as deep pools for overwintering. Bumping River reach B-1 has an estimated 3,177 m of side channel habitat while three reaches of Deep Creek have an estimated 3,169 m of side channel habitat. Reeves et al. (1989) stated that stream habitat surveys should be done during the low-flow period in late summer or early fall, and another in late winter or early spring during nonflood flows to accurately portray habitat conditions and availability; however, only data from late summer stream surveys were available for this assessment; potential changes in available habitat as a result of increased fall streamflows are discussed below.

We calculated the area of pools in the four reaches of the Bumping River and Deep Creek from the dimensions of the pools reported in the several stream surveys. We estimated the average size of pools per reach. We recognize that the number, size, and depth of pools and side channels could change with the increase in flows that occurs from late summer to early winter discussed below. Some information was available about the substrate and amount of cover in the form of large woody debris or other material present in the pools. Many mid-channel pools in Deep Creek were formed by woody debris; boulders, bedrock, and streambends also formed some pools. Some of the larger pools in the Bumping River or Deep Creek would not be expected to provide homogeneous or uniformly suitable rearing/overwintering habitat conditions; coho salmon often concentrate around the edges and near structure in large pools, and intraspecific competition could force smaller fish to less suitable habitat (Sandercock 1991).

From the area of pools in the river reaches, we estimated the number of juveniles that could be expected to survive to the following spring to outmigrate as smolts. We estimated the number of outmigrating smolts using three density values to show a range of possible outcomes: 0.25 and 0.5 overwintering juveniles per m^2 (Pete Bisson, USFS, Olympia, WA, March 2004, pers. comm.), and one overwintering juvenile per m^2 (Keeley et al. 1996). We estimated the number of smolts per 100 m^2 of pool habitat that could be produced within each reach. From the number of fish expected to survive the winter and become smolts the next year, we calculated number of fish per km for the accessible length of the Bumping River and Deep Creek to compare with published values. To compare potential production based on total area of habitat in the reaches, we summed riffle and pool area and calculated number of smolts per 100 m^2 of reach.

We estimated number of returning adults based on SAR from one to six percent, based on 0.25 overwintering juvenile coho salmon per m^2 (Pete Bisson, USFS, Olympia, WA, pers. comm.). We calculated the number of adult fish per km and compared these to numbers reported in the literature.

To understand better the annual hydrologic conditions in the Bumping River watershed, we examined the computed daily average Bumping River inflows for the 20-water-year period 1986 to 2005. We used data from the Bumping River since long-term flow data from Deep Creek were not available. The annual flow regime in Deep Creek is expected to be similar to that observed for the Bumping River although the magnitude of flows may be different (Chris Lynch, USBR, Yakima, WA, November 27, 2006, pers. comm.). Following annual low late summer flows, there was a substantial increase in flow and periodic freshets from early October through late November in Bumping River computed flows, with flows decreasing later in December but remaining greater than the late summer low flows (Figure 2). The about four- to eight-fold increase in flow from early October to late November with subsequent decrease likely alters conditions in the river substantially, may alter the amount of spawning habitat available as estimated from existing stream surveys, may redistribute juvenile fish, and may improve or expand rearing/overwintering habitat for juvenile coho salmon, although quantitative stream survey information for this time period is not available to verify the extent of habitat change. Since information is lacking to describe quantitatively habitat conditions during the fall and winter, this assessment may underestimate the extent of coho salmon overwintering habitat, since it relies on an estimate of pool habitat available based on the late summer stream conditions. Without additional late wintertime stream surveys, we do not know to what extent the increased flow during the fall and winter would change habitat conditions and availability for juvenile coho salmon.

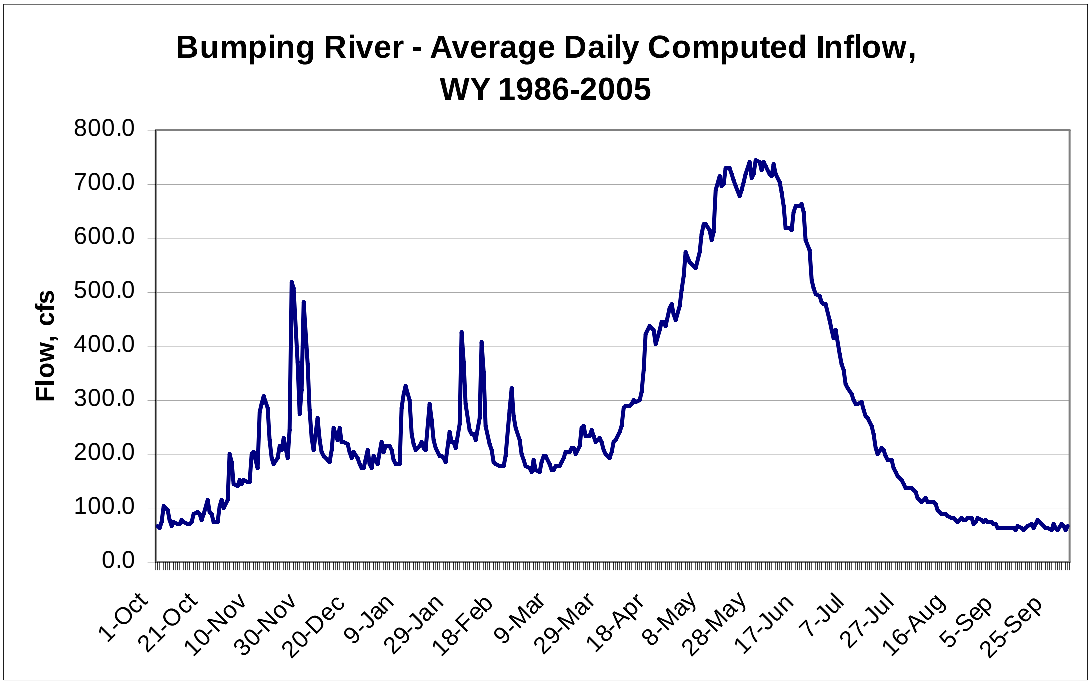

Figure 2. Average daily computed Bumping River flow for the period 1986 to 2005.

Related Investigations

Additional information was required to complement the stream survey information to evaluate the ability of the Bumping River basin to support re-introduced anadromous salmonids. A survey to assess the abundance and distribution of benthic macroinvertebrates that would constitute a food source for rearing juvenile coho salmon, and an estimate of the nutrient concentration that influences primary production were deemed necessary and appropriate. These two studies were conducted by biologists from Reclamation's Technical Service Center in Denver, CO, and described briefly below.

Bumping River Benthic Macroinvertebrate Survey

A benthic macroinvertebrate survey of the Bumping River and Deep Creek was conducted in September 2003 and September 2004 to assess benthic macroinvertebrate species composition and standing crop in the Bumping watershed above Bumping Lake. The planned spring 2004 sampling was not conducted since the river reaches were inaccessible. Sampling focused on riffle/run types of lotic habitat; however, a small number of instream pools were also sampled. A kick method was used, along with a Surber sample at a subset of the sampling sites. Surber samples (0.09 m^2) were used to relate kick-net dry weight biomass to g/m^2 using the regression equation:

$$\text{grams dry weight of invertebrates}/m^2 = 0.0569 + 1.3551 \times \text{grams of invertebrates/kick-net}$$

(R^2 = 0.8433, P = 0.0005, n = 9). Macroinvertebrate taxa richness and abundance and dry weight biomass were determined. Results were compared to water quality biological criteria developed by the Washington State Department of Ecology (Merritt et al. 1999). Functional feeding groups were assigned based on the primary feeding mechanism of the group, with categories defined as predators, scrapers, shredders, collector-filterers, and collector-gatherers. Standing crop categories promulgated by Mangum (1989) were used to relate biomass data collected in this survey to fish production. Periphyton and coarse particulate organic material (CPOM) were also sampled. Complete details of the survey are reported by Nelson (2005).

Nutrient Concentrations in the Bumping River upstream from Bumping Lake

Water samples were collected to determine nutrient concentration in the Bumping River upstream from the lake concurrent with a limnological study conducted on Bumping Lake that took place monthly from September 2003 to October 2004, except during the winter. Nutrient concentration analyses were conducted in the Water Quality Laboratory at Reclamation's Technical Service Center, Denver, CO. Complete details of the survey are reported by Lieberman and Grabowski (2006).

Results

Available spawning habitat approach

Bumping River reach B-1 and Deep Creek reaches D-1 through D-3 have about 57 percent substrate in the suitable spawning size range, 12 to 128 mm. We estimated that the four reaches of the Bumping River and Deep Creek upstream from the lake to impassable barriers, with an average gradient less than 3 percent had 18,218 m^2 of suitable spawning substrate that could accommodate 1,822 female coho salmon (Table 4). From the estimated 2,500 eggs per female and a 1.5 percent egg to smolt survival, 68,364 smolts could potentially be produced (Table 4). This assumes that all suitable spawning habitat in the four reaches of the Bumping River and Deep Creek are fully and uniformly utilized by spawning coho salmon. This estimate does not include potential spawning in side channels where we had limited information.

SAR by reach for one to six percent, based on 1.5 percent egg to smolt survival, are shown in Table 5. For comparison, the Yakima Coho Master Plan (Yakama Nation 2003) reported SARs in 2001 for hatchery and wild adult coho salmon as 1.8 percent and 3.8 percent, respectively, and in 2002, 0.04 percent and 0.87 percent, respectively.

Table 4. Production potential for coho salmon in the Bumping River and Deep Creek considering the number of smolts that could be produced based on estimated extent of suitable spawning substrate.

Reach	Reach length, m	Average gradient	Total riffle length, m	Total pool length, m	Total riffle area (m^2), calculated from USFS stream surveys	Percent suitable substrate, 12-128 mm, from pebble counts	Adjusted riffle area (m^2)	No. of potential redds at 10 m^2 each	No. of females required at one per 10 m^2	Estimated no. of eggs produced per reach at fecundity of 2500 eggs per female	No. smolts at 1.5% egg to smolt
B-1	1,252	1.9	524	729	4,968	55	2,732	**273**	**273**	**682,500**	**10,238**
D-1	1,445	1.4	626	768	3,244	60	1,946	**195**	**195**	**487,500**	**7,313**
D-2	2,690	1.0	1,743	938	11,047	54	5,965	**597**	**597**	**1,492,500**	**22,388**
D-3	**4,209**	1.8	**2,161**	**2,048**	12,839	59	7,575	**758**	**758**	**1,895,000**	**28,425**
Total	**9,596**		5,054	4,483	32,098		**18,218**	**1,822**	**1,822**	**4,557,500**	**68,364**
Note: Extensive side channels with apparently suitable spawning and/or rearing substrate are associated with these lower stream reaches, but data were not available to estimate extent of spawning or rearing substrate there.											

Table 5. Estimated number of returning adult coho salmon in reaches of the Bumping River and Deep Creek based on available spawning habitat and a 1.5 percent egg to smolt survival and SAR of one to six percent.

		SAR					
Reach	No. of smolts	1 %	2 %	3 %	4 %	5%	6 %
B-1	10,238	102	205	307	410	512	614
D-1	7,313	73	146	219	293	366	439
D-2	22,388	224	448	672	896	1,119	1,343
D-3	28,425	284	569	853	1,137	1,421	1,706
Total	68,364	684	1,367	2,051	2,735	3,418	4,102
Fish/km		71	142	214	285	356	427
Note: SARs are based on 1.5 percent egg to smolt survival, and refers to adult coho salmon returning to the Bumping River.							

Juvenile rearing/overwintering habitat approach

We estimated that 29,836 m^2 of pool habitat was present in the four reaches of the Bumping River and Deep Creek during the late summer low flow period (Table 6). The number and average size of pools in the several reaches are shown in Table 6. If these pools were used as rearing/overwintering habitat by juvenile coho salmon, at densities ranging from 0.25 to one juvenile per m^2, we estimated that from 7,458 to 29,836 smolts could be produced in the Bumping River and Deep Creek upstream from the lake (Table 6). At 0.25 smolt per m^2, the number of fish per linear meter of stream was 0.78, less than the average of 1.12 coho salmon smolts per linear meter of stream reported by Baranski (1989) for coho salmon in 10 Puget

Sound streams, but it was within Baranski's (1989) reported range of 0.26 to 2.24. Based on 0.25 smolt per m^2, 75, 149, 224, 298, 373, and 447 adult coho salmon would be expected to return at one to six percent SARs, respectively (Table 6). The calculated number of smolts per 100 m^2 of combined riffle and pool habitat within each reach is shown in Table 7; these were at the lower end of the range of values reported in the literature.

Table 6. Potential production of coho salmon smolts and number of returning adult coho salmon based on overwintering pool habitat in the lower reaches of the Bumping River and Deep Creek. Number of returning adults is based on 0.25 smolts per m^2 of pool habitat and SARs from one to six percent.

Reach	No. pools	Avg. size of pools, m^2	Pool area, m^2	Estimated no. of smolts at 0.25 per m^2 of pool habitat	Estimated no. of smolts at 0.5 per m^2 of pool habitat	Estimated no. of smolts at 1 per m^2 of pool habitat	SAR					
							1 %	2 %	3 %	4 %	5%	6%
B-1	28	194.3	5,440.4	1,360	2,720	5,440	13.6	27.2	40.8	54.4	68.0	81.6
D-1	31	182.2	5,648.2	1,412	2,824	5,648	14.1	28.2	42.4	56.5	70.6	84.7
D-2	47	110.5	5,193.5	1,298	2,597	5,194	13.0	26.0	38.9	51.9	64.9	77.9
D-3	86	157.6	13,553.6	3,388	6,777	13,554	33.9	67.8	101.6	135.5	169.4	203.3
Total			29,835.7	7,458	14,918	29,836	75	149	224	298	373	447
Fish/km *				777			8	16	23	31	39	47

Note: SAR based on smolt to adult return from Bumping Lake back to Bumping Lake spawning sites.
* Based on sum of reach lengths from Table 4 = 9.6 km.

Table 7. Potential production of smolts per 100 m^2 in several reaches of the Bumping River and Deep Creek, based on 0.25 juveniles per m^2 rearing/overwintering in pool habitat, and total area of habitat in the reaches.

	Reach				
	B-1	D-1	D-2	D-3	Total
Total reach area, riffles + pools, m^2	10,368	8,892	16,241	26,393	61,893
Total smolts	1,360	1,412	1,298	3,388	7,458
Smolts per 100 m^2 of total reach area	13	16	8	13	12

Related Investigations

Benthic Macroinvertebrate Survey

Benthic macroinvertebrate dry weight biomass in the Bumping River and Deep Creek upstream from the lake was lower in September 2004 than in September 2003 (Table 8, summarized from Nelson 2005). The rivers were not sampled in spring 2004. Lower dry weight biomass occurred in the Bumping River than in Deep Creek in September 2003, while two Deep Creek sites both had lower dry weight biomass in September 2004. These sites would be described by Mangum's (1989) criteria for standing crop as poor to fair.

Organic Material

CPOM biomass (dry weight) was more abundant in Deep Creek in September 2003 than in September 2004. The Bumping River was only sampled in September 2003, so no seasonal comparison is possible.

Nutrient Concentrations in the Bumping River and Deep Creek

Concentrations of NO_3-NO_2-N in Bumping River and Deep Creek for the study period September 2003 to October 2004 averaged 0.0085 mg/L (range 0.003 – 0.017 mg/L) compared to an average of 0.0121 mg/L (range 0.002 – 0.041 mg/L) in Bumping Lake at mid-lake station BMP-2; ortho-phosphorus in inflow averaged 0.0036 mg/L (range 0.001 – 0.007 mg/L) compared to 0.0032 mg/L (range 0.001 – 0.008 mg/L) in the lake. Total nitrogen in the inflow averaged 0.1394 mg/L (range 0.050 – 0.460 mg/L) compared to 0.1638 mg/L (range 0.050 – 0.260 mg/L) in the lake, while total phosphorus averaged 0.0.0049 mg/L (range 0.003 – 0.010 mg/L) compared to 0.0065 mg/L (range 0.003 – 0.028 mg/L) in the lake (Lieberman and Grabowski 2006).

Table 8. Macroinvertebrate dry weight biomass (g/m^2), CPOM (g), and periphyton (g/m^2) in several reaches of the Bumping River and Deep Creek. Summarized from Nelson (2005).

Site	CPOM, [a] g	Periphyton, g/m^2	Macroinvertebrates dry weight biomass (g/m^2) [b]				Potential for supporting fishery [c]
			Sept 2003	Mar 2004 [d]	Sept 2004	Average	
BR+1	33.61	8.7	0.6431 (0.2003)	--	--	0.6431	Poor - Fair
DR+1	10.64 (2.51)	2.0 (0.2)	0.7495 (0.2045)	--	0.4473 (0.1964)	0.5984	Poor - Fair
DR+2	7.13 (1.52)	2.0 (0.2)	0.6646 (0.2010)	--	0.4414 (0.1964)	0.5530	Poor - Fair
Avg.			0.6857	--	0.4444		

[a] Coarse particulate organic material in kick sample; macroinvertebrate food source.
[b] Based on the regression derived from Surber samples: grams of invertebrates/m^2 = 0.0569 + 1.3551 x grams of invertebrates/kick-net. Standard error of predicted values in parentheses.
[c] Standing crop (g/m^2) categories are: poor = 0.0-0.5; fair = 0.6-1.5; good = 1.6-4.0; and excellent = 4.1-12.0 (Mangum 1989).
[d] Planned sampling was not conducted in spring 2004 since the rivers were inaccessible.

Discussion

The four reaches of the Bumping River and Deep Creek upstream from Bumping Lake to impassable barriers had an estimated 18,218 m^2 of suitable spawning substrate for coho salmon that we estimate could produce 68,364 smolts if the habitat were fully utilized by 1,822 adult pairs. However, spawning fish may select spawning areas based on some suite of microhabitat conditions such as water flow and depth, temperature, groundwater influences, and other factors that will not become apparent until a sufficient number of tagged adult coho salmon return to spawn in the Bumping River and Deep Creek and are tracked to spawning areas, or the rivers are surveyed for redds and carcasses.

For juvenile rearing/overwintering habitat, which may be the factor that limits coho salmon production in the Bumping River and Deep Creek more so than available spawning habitat, we conservatively estimated that the Bumping River and Deep Creek could produce about 7,458 coho salmon smolts at 0.25 smolts/m^2, or about 12 smolts per 100 m^2 of total reach area, ranging from 8 to 16 for the several reaches (Table 7). However, Bumping River and Deep Creek have extensive side channels for which physical data were not available and were therefore not considered in this assessment but which might provide additional spawning and rearing habitat. Increasing summertime water temperatures may force rearing fish to disperse downstream. Chapman (1965 cited in Sandercock 1991) reported a production of 18 to 67 smolts per 100 m^2 over a 4-year period in three Oregon coastal streams. Tripp and McCart (1983 cited in Sandercock 1991) reported production of 8.4 to 8.5 smolts per 100 m^2, while Armstrong and Argue (1977 cited in Sandercock 1991) reported 125 to 141 smolts per 100 m^2 in side channels of the Cowichan River in British Columbia, but these fish may have been concentrated in overwintering habitat after migrating from upstream. Baranski (1989) reported that the number of coho salmon smolts captured in 10 Puget Sound streams over a 10-year period averaged 18 coho salmon smolts per 100 m^2, ranging from 8 to 26. Estimates for coho salmon smolt production in the Bumping River basin are within the range of reported estimates. The benthic macroinvertebrate study (Nelson 2005) indicated that the highest benthic fauna dry weight biomass rated just "fair" in its potential for supporting a fishery on Mangum's (1989) scale. Nelson (2005) did not assess benthic macroinvertebrate abundance in side channels, so we can only speculate that the side channels here would provide some additional food as well as additional rearing/overwintering habitat.

Bradford et al. (1997) reported that stream length was useful in predicting mean smolt abundance, and that streams between 48 to 50 °N latitude were most productive, with those between 46 to 48 °N latitude somewhat less so. Bumping Lake is about 46.873 °N latitude. Bradford et al. (1997) related $\log_e$ mean coho salmon smolt abundance to $\log_e$ stream length (km) in the equation:

$$Y = 6.90 + 0.97X$$

with Y = $\log_e$ mean coho salmon smolt abundance and X = $\log_e$ stream length (km). From this equation we calculate that the 9.6 km of the Bumping River and Deep Creek could produce 8,900 coho salmon smolts, about 19 percent more than the 7,458 smolts we estimated could be produced assuming 0.25 smolts per m^2 of overwintering habitat, but only about 13 percent of the 68,364 smolts estimated produced at 1.5 percent egg to smolt survival in the spawning habitat approach.

Bradford et al. (2000) analyzed 14 datasets and reported that about 19 spawning females per km, ranging from 4 to 44, were needed for full smolt recruitment. This was at low spawner abundance. Based on the rearing/overwintering approach described here, a similar number of spawning females would require about a five percent SAR based on the number of smolts produced at 0.25 smolts/m^2. Beidler et al. (1980 cited in Nickelson et al. 1992) noted that at least 25 spawners per km were needed to seed juvenile rearing habitat in some Oregon coastal streams. Our assessment of production potential indicates 23 adult fish per km at 0.25 smolts per m^2 of rearing/overwintering pool habitat and three percent SAR (Table 6). Estimated adult returns for one to three percent SAR are in the range reported by Bradford et al. (2000). Shaul and Van Alen (2001) reported low average spawner and smolt densities of 5 to 6 females per km and 213 to 420 per km, respectively, in interior Taku River tributaries compared to coastal streams. They suggest that low coho salmon densities may be characteristic of interior habitats, perhaps similar to the Bumping River basin. The 5 to 6 females per km Shaul and Van Alen (2001) reported is similar to the estimate of 8 adults per km for 0.25 smolts per m^2 of rearing/overwintering pool habitat and the number of returning adults at one percent SAR estimated here.

Environmental factors will influence coho salmon production; Baranski (1989) observed significant variability in coho salmon smolt production among years in Puget Sound streams. One factor relative to juvenile coho salmon rearing successfully in the Bumping River and Deep Creek is the available prey base. Streams vary in productivity and the rates of primary and secondary production determine in large part the amount of food available for fish (Bjornn and Rieser 1991). The Bumping River and Deep Creek upstream from the reservoir have relatively low productivity, as indicated by the 2003 and 2004 macroinvertebrate study (Nelson 2005). Mangum (1989) stated that invertebrate biomass levels below 0.5 g/m^2 resulted in poor fisheries, and biomass levels between 0.6 and 1.0 resulted in fair fisheries. Weng et al. (2001) found that juvenile salmonids experienced higher growth rates when streams were enriched to the point where benthic invertebrate biomass was in the range of 0.6 to 0.8 g/m^2, while Hetrick et al. (1998) found that salmon streams contained 0.5 to 1.0 g/m^2 of invertebrate biomass. Benthic macroinvertebrate prey in the 2003 – 2004 study was at the upper end of the “poor” range and at the lower end of the “fair” range for fish production. Since the streams were not sampled in spring 2004, we have no information about benthic macroinvertebrate dry weight biomass during that period. Competition for limited food resources would likely occur with resident fish and other species of reintroduced anadromous salmonids.

McMahon (1983) reported that a pool to riffle ratio of 1:1 provides optimum food and cover conditions for coho salmon parr. Deep Creek had a slightly higher ratio of pools to riffles, ranging from 1.1:1 to 1.4:1. Nelson's (2005) benthic macroinvertebrate study found that Reach B-1 had higher dry weight biomass per m^2 than the two reaches sampled in Deep Creek. McMahon (1983) reported that benthic invertebrate production seemed to be greater in rubble, followed by bedrock, gravel, and sand. Reach B-1 had 50 percent cobble and boulder substrate combined (there was no separate "rubble" substrate category), 0 percent bedrock, 40 percent gravel, and 10 percent sand (Table 2). Reach D-1 had 40.2 percent cobble and boulder substrate combined, 0 percent bedrock, 41 percent gravel, and 22 percent sand. Reach D-2 had 61.1 percent cobble and boulder substrate combined, 0 percent bedrock, 33.3 percent gravel, and 7 percent sand. Reach D-3, by contrast, had less percent cobble-boulder (24.6) and bedrock (0), and 68 percent gravel and 7.5 percent sand.

Nutrient concentrations in the Bumping River and Deep Creek were on average a little lower than those in oligotrophic Bumping Lake. The dam constructed on the outlet of Bumping Lake in 1909 to 1910 eliminated anadromous salmonid access to the lake, and eliminated the annual infusion of marine-derived nutrients that apparently contributed to a more productive system upstream from the lake and presumably in the lake itself. As a nearby example, an analysis of Cle Elum Lake sediments found that before 1906, there was an average of 19 percent more phosphorus deposited in the lake sediments each year (Dey 2000). Although sediment data are not available for Bumping Lake, this same condition may prevail. When passage for adult anadromous salmonids is re-established at Bumping Lake Dam, and the number of returning adult salmonids increases over time, we would expect an increase in stream and lake nutrient levels and productivity.

If excess fry are produced in a fully seeded system, some fry may be forced downstream away from the spawning and early rearing area due to territorial behavior of the fish (Ruggles 1966 cited in Sandercock 1991), crowding or changing environmental conditions. This movement would redistribute rearing juvenile coho salmon into areas of the river where habitat might be less suitable. Conversely, habitat away from spawning and early rearing habitat may be more structurally complex and support a larger or more diverse and abundant food base (Sandercock 1991). Juvenile coho salmon are also reported to rear in lakes, although this is not their typical rearing strategy.

The water temperature data collected on the Bumping River and Deep Creek in 2003 and 2005 by the U.S. Forest Service suggested that maximum summertime water temperatures sometimes exceed the preferred range for rearing coho salmon, but did not approach their lethal temperature.

Coho salmon production potential could be affected by interspecific competition from native resident fish, both salmonids and nonsalmonids. Bull trout have been documented in the Bumping River and Deep Creek. If reintroduction of other anadromous salmonids proceeds as planned by the fisheries co-managers, additional interspecific competition may occur.

River and lake studies to elucidate predator-prey relationships may be needed to provide fisheries co-managers with sufficient information to implement changes in sport fishing regulations, if necessary. The carrying capacity of the river and tributaries could change annually to some degree due to fluctuating environmental and atmospheric conditions that influence the timing and extent of runoff and the effects on the riverine habitat, as well as biological production.

Summary

The estimate of smolt production based on the availability of spawning habitat seems optimistic compared to the estimates from the rearing/overwintering approach, especially in light of the closer correspondence of rearing/overwintering estimates to values reported in the literature. The number of juvenile coho salmon estimated from the rearing/overwintering habitat approach is comparable to and falls within the range of values reported in the literature for number of smolts per 100 m^2 stream habitat, estimates based on stream length and latitude, and reported estimates of the number of spawning female fish per km needed for full smolt recruitment. We feel that our estimate of production potential is reasonable and conservative, considering the low streamflow conditions during which the stream surveys were conducted and on which this assessment is based, the presence of extensive side channels, for which physical data and macroinvertebrate abundance were not available, and the potential increase in habitat availability with increased fall and winter flows. This assessment indicates that in the Bumping River basin upstream from Bumping Lake could support a self-sustaining coho salmon population and would require a 1.5 percent egg to smolt survival coupled with about a 5.5 percent smolt to adult return, or some combination thereof. To illustrate, based on the juvenile rearing/overwintering habitat approach described above, a return of 410 adult coho salmon with equal sex ratio would result in 205 females producing an estimated 512,500 eggs. A 1.5 percent egg to smolt survival would produce 7,686 outmigrants, and with a 5.5 percent SAR, 422 adults would be expected to return. The Yakima Coho Master Plan (Yakama Nation 2003) reported SARs up to 3.8 percent for wild coho salmon in 2001, but only 0.87 percent in 2002. Four percent SAR is the average interim SAR objective (ranging from two to six percent) in the NPCC mainstem amendment for Snake River and upper Columbia River salmon and steelhead (NPCC 2003). An EDT model for the upper Yakima Basin predicted a total spawner escapement of 486 adults for current conditions with SAR of 1.5 to 1.8 percent, and 88,945 spawners for historic conditions with SAR of 6.3 to 6.9 percent.

A return of 410 adult coho salmon to the Bumping River would not seem unreasonable, since recent returns to the Yakima River counted at Prosser Dam were as high as 6,138 adults in 2000, but dropped substantially to 818 in 2002 (Yakama Nation 2003).   However, the low abundance of macroinvertebrate prey and warm summertime water temperatures, among other environmental factors, might limit coho salmon production in the Bumping River, at least until productivity in the streams and lake increases from the eventual infusion of marine-derived nutrients from returning adults.

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