BIOLOGICAL EVALUATION – SUPPLEMENT: IMPACTS OF ENTRAINMENT ON BULL TROUT

SKAGIT RIVER HYDROELECTRIC PROJECT LICENSE (FERC NO. 553) AMENDMENT:

ADDITION OF A SECOND POWER TUNNEL AT THE GORGE DEVELOPMENT

Final

July 2012

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1 INTRODUCTION

In July 2011, Seattle City Light (SCL) submitted an application to the Federal Energy Regulatory Commission (FERC) for a non-capacity amendment to the license for the Skagit River Hydroelectric Project (FERC Project No. 553) (Project). The amendment includes the following improvements and provisions:

- Construction of a second power tunnel between Gorge Dam and Powerhouse (the Gorge 2nd Tunnel).
- An adjustment to FERC boundary along the route of the Gorge 2nd Tunnel.
- The addition of currently voluntary flow measures to the Skagit River to the License.

The application to the FERC includes a Biological Evaluation (BE) which addresses impacts on species listed as Threatened or Endangered under the Endangered Species Act from the proposed action. The proposed action consists of: 1) the non-capacity license amendment, including the new power tunnel, Project boundary adjustment, and formalization of currently voluntary downstream flow measures; and 2) ongoing operation of the Project under the license as amended. The proposed action covers existing facilities and ongoing operations because several species, including bull trout (*Salvelinus confluentus*), were not listed as threatened or endangered when the Project was licensed in 1995.

The U.S. Fish and Wildlife Service (USFWS) conducted an initial review of the BE in December 2011 and requested that SCL provide some additional information to address the impacts of entrainment on bull trout at Skagit Project facilities. Bull trout moving downstream through the Skagit Project reservoirs pass through either turbines or spillways and may be directly injured or killed, or indirectly impacted if they are made temporarily more vulnerable to predation due to disorientation and stress. This supplement is in response to the USFWS's request and includes the following information:

- Physical properties of existing and proposed Skagit River Project facilities that influence entrainment;
- Spill history at existing dams and proposed spill for the Gorge 2nd Tunnel;
- Bull trout in Skagit Project reservoirs;
- Bull trout entrainment at Ross/Diablo/Gorge dams ;
- Estimated take under baseline entrainment conditions;
- Estimated take of the proposed action; and
- Proposed conservation actions.

Each of these topics is addressed below.

2 PHYSICAL PROPERTIES OF EXISTING & PROPOSED PROJECT FACILITIES THAT INFLUENCE ENTRAINMENT

2.1 Existing Project Facilities

The Skagit River Hydroelectric Project includes the Ross, Diablo, and Gorge developments with a total installed generating capacity of 650.25 MW. Information on the dams and reservoirs was provided in the BE. This section describes the features at each development that influence entrainment—the intakes, spillgates, spillways, and turbines. Since the time the BE was written, SCL has converted all recorded Project elevations from NAV 29 to NAV 88 (NAV 88 = NAV 29 + 3.94 ft). All facility and reservoir elevations in this section are reported in NAV 88.

2.1.2 Ross

Ross Lake is a storage reservoir that is filled in the spring/early summer and drawn down in the fall/winter. At full pool, the elevation of Ross Lake is 1,606.44 ft NAV 88 (1602.5 ft NAV 29). The Skagit Project license requires that SCL attempt to fill the reservoir as early and as full as possible after April 15 each year, subject to adequate runoff, anadromous fisheries protection flows, flood protection, minimized spill, and firm power generation needs. Subject to these constraints, and hydrological conditions permitting, SCL is required to achieve full pool conditions by July 31 and maintain as close to full pool as possible through Labor Day of each year.

SCL typically begins drawing down Ross Lake shortly after Labor Day of each year. The Skagit License requires that Ross Lake be drawn down annually to provide 60,000 acre-ft of flood storage by November 1 and 120,000 acre-ft by December 1, which must be maintained through March 15. The flood storage elevation of the reservoir is 1,595.94 ft (NAV 88), or 10.5 ft below full pool. The normal winter drawdown is about 75 ft, to elevation 1,532 ft. In years of high precipitation, such as 2011 and 2012, the drawdown can be 90 to 100 ft.

There are four mechanisms for discharging water from Ross Lake: the power tunnels, which deliver water to the powerhouse; and the spillways, broom gates (aka 1340-valves), and by-pass valves, which all move water through the dam (Table 1). The spillways release water from the top portion of the reservoir; the broom gates are mid-way down the dam; and the by-pass valves are near the bottom.

Table 1. Summary data for Ross Dam discharge structures[1].

Discharge Structure	No.	Size	Exit Elevation	Exit Distance Below Full Pool (1,607 ft elevation)	Vertical Distance to Plunge Pool (1,209 ft elevation)
Power tunnels	2	26 ft diameter	1,453 ft to 1,427 ft	154 to 180 ft	NA – water travels through penstocks to powerhouse
Spillways	6 (19 gates)	Gates=30 ft wide, 35 ft high	1,586 ft	21 ft	377 ft
Broome gates (1340 Valves)	2	6 ft diameter pipe	1,344 ft	263 ft	135 ft
By-Pass Valves	2	6 ft diameter pipe	1,269 ft & 1,254 ft	353 ft & 388 ft	11 ft

[1] All elevations are in NAV 88 and rounded.

2.1.1.1 Power Tunnel Intakes

Water used to generate power at Ross Powerhouse leaves the reservoir via two power tunnels, each 26 ft in diameter. The intake gates for the power tunnels are at the bottom of the reservoir, which is at elevation 1,427 ft at this location. The intake structure for the power tunnels is in a rock embankment on the left side of the reservoir (facing downstream), about 200 ft upstream of Ross Dam. Each intake is 50 ft wide and divided into two sections by a concrete wall (Figure 1). The sections are covered by intake screens or trash racks which extends to the bottom of the reservoir. Openings between the bars on the trash rack are 3.5 inches wide.

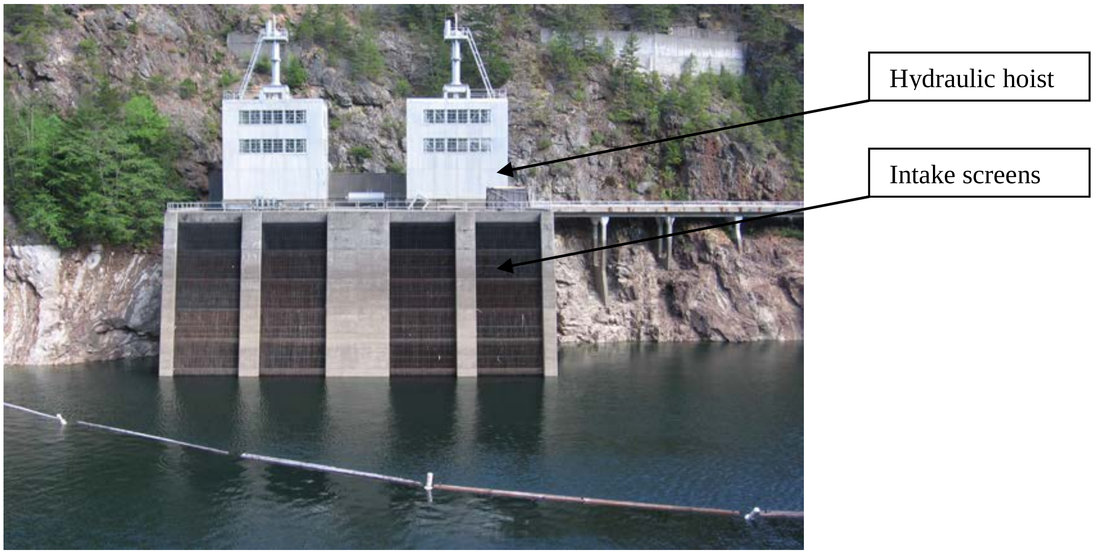


Figure 1. Ross intake structure.

2.1.1.2 Spillways, Broom Gates, and By-Pass Valves

Ross Dam has 12 spillways, 6 on each side of the dam (Figure 2). Water through each spillway is controlled by a tainter-style spillgate, which has a radial arm and can therefore be closed with less effort than a flat gate. The spillgates are controlled from the top of the dam with a chain/gearbox/electric motor assembly. The upstream crest of each spillway is at elevation 1,586 ft, which is 21 ft below full pool elevation (1,607 ft). The distance from the spillway crest to the downstream water surface elevation (1,209 ft, Diablo Lake full pool) is about 377 ft.

On the downstream side of each spillway, a deflector extends 85 ft from elevation 1,604 ft to 1,519 ft and channels the flow straight down the spillway (Figure 2). The spillways are lined with porous drain tiles to smooth the flow. The spillways on both sides of Ross Dam were designed to be operated in synchrony; water is always released from at least one spillway on each side and in matched pairs (the most outside spillway on the right side with the most outside spillway on the left). This allows the water releases to meet in the middle of the dam and helps dissipate some of the spill energy.

If water needs to be evacuated very quickly from Ross reservoir two sets of valves can be opened in addition to the spillgates. The broome gates are used to open two 72-inch pipes that exit Ross Dam at elevation 1,344 ft; water is discharged downstream through butterfly valves (which are either open or closed) located about 135 ft above the water surface of Diablo (Figure 3). The by-pass valves are even lower in the dam, at elevations 1,269 and 1,254 ft. Water enters two 72-inch pipes and is discharged through hollow jet valves (which can be throttled) at elevation 1,220 the spillway crests (1,586 ft); the by-pass valves alone would be used to drain the reservoir when water levels drop below the broom gates (1,344 ft). The broome gates and by-pass valve intakes

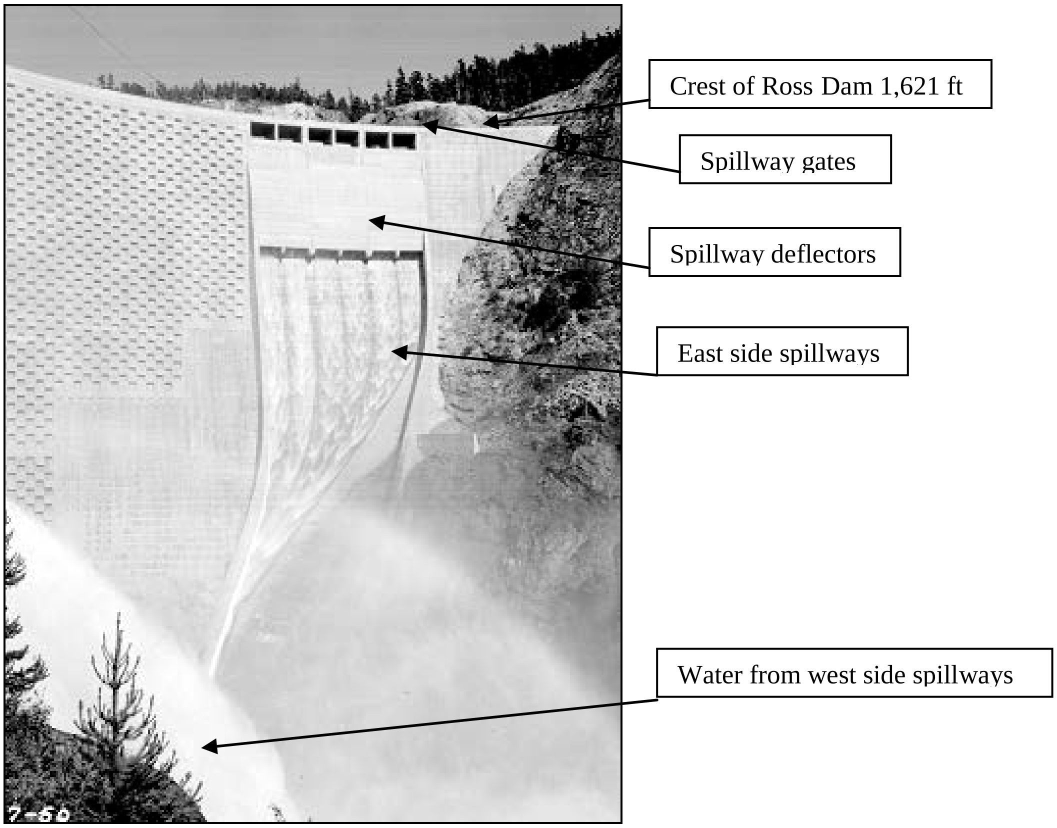


Figure 2. Ross spill gates (east side) in full operation.

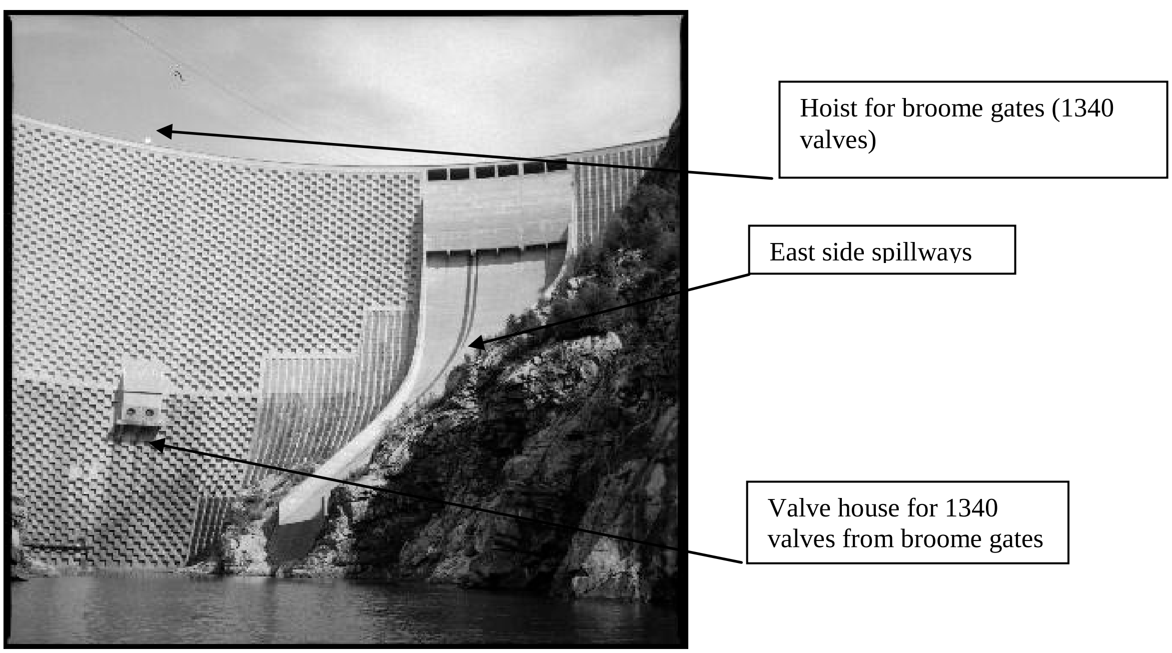


Figure 3. Valve house in downstream side of Ross Dam.

are covered by trash racks and are controlled from the top of the dam through hoist mechanisms that are operated manually. The broom gates and by-pass values are reserved for emergency use only and have never been used except for testing, which occurs annually.

2.1.1.3 Turbines

There are four Francis-style turbines in Ross Powerhouse. Water enters each through a 16-ft diameter penstock and discharges into the tailrace through a draft tube at an elevation of 1,189 ft, about 20 ft below the water surface of the Diablo Lake. The inlets to each turbine are spiral shaped; guide vanes direct the water tangentially to the runner or turbine wheel.

2.1.2 Diablo

Diablo Reservoir has full pool elevation of 1,209 ft (NAV 88; 1,205 ft NAV 29). Under typical operations the water surface elevation of Diablo Reservoir ranges from 1,209 to 1,204 ft. Drawdown of the reservoir normally does exceed 10 ft to maintain boat dock operations and avoid navigation hazards exposed at lower elevations. Summary statistics for Diablo intakes, spillways, and outlet valves are provided in Table 2.

Table 2. Summary data for Diablo Dam discharge structures[1].

Discharge Structure	No.	Size	Exit Elevation	Exit Distance Below Full Pool (1,209 ft elevation)	Vertical Distance to Gorge Reservoir (879 ft elevation)
Power tunnels	2 (only 1 in use)	19.5 ft diameter (15 ft x 20 ft opening)	1,084 ft to 1,104 ft	105 to 125 ft	NA – water travels through penstocks to powerhouse
Spillways	5 (19 gates)	Gates=19 ft wide, 20 ft high	1,191 ft	18 ft	312 ft
Outlet Valves	4	78-in (3) and 72 in (1) diameter	1,048 ft	161 ft	169 ft

[1] All elevations are in NAV 88 and rounded.

2.1.2.1 Power Tunnel Intakes

Water used to generate power at Diablo Powerhouse exits the reservoir via a single power tunnel, about 15 x 20 ft in size. There are two intakes but only one is in use. Both are built into a rock abutment just to the right of Diablo Dam (facing downstream) (Figure 4). The intake gate is at the bottom of the reservoir, which is at elevation 1,084 ft at this location. Each intake is 40 ft wide and divided into two sections by a concrete wall. Each section is covered by an intake screen or trash rack which extends to the bottom of the reservoir. Trash rack openings are about 2.5 to 2.75 inches wide.

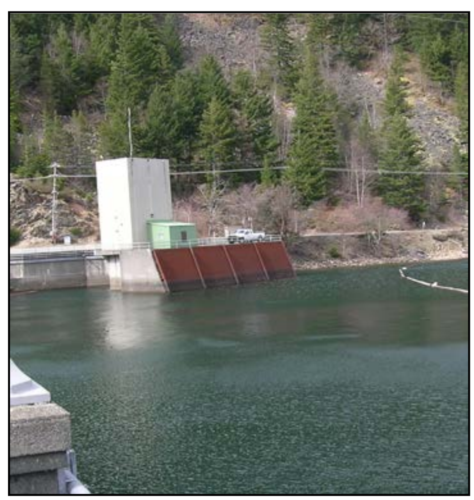


Figure 4. Diablo intake structure.

2.1.2.2 Spillways and Outlet Valves

Diablo Dam has 5 spillways, 3 on the south side of the dam with 7 spill gates and 2 on the north side of the dam with 12 spillgates. Like Ross, tainter style spillgates control the amount of water released through the spillways. The spillgates are controlled from the top of the dam with a chain/gearbox/electric motor assembly. The upstream crest of each spillway is at elevation 1,191 ft, which is 18 ft below full pool elevation (1,209ft). The distance from the spillway crest to the downstream water surface elevation (879 ft, Gorge Lake full pool) is about 312 ft, however, water from the spillways falls onto the rocky abutments on each side of the dam before reaching Gorge reservoir (Figures 5 and 6).

Figures 5 and 6. Diablo spillways under normal conditions and in use.

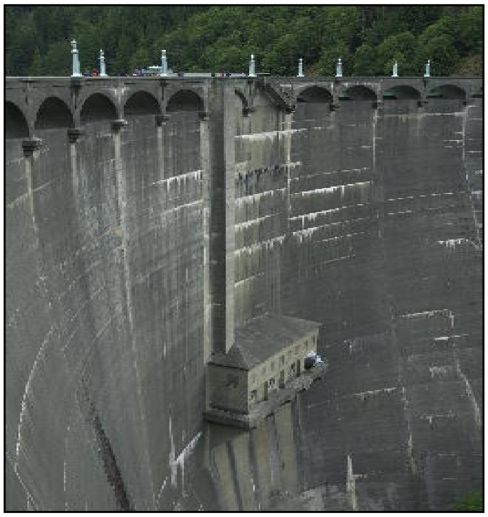
If water needs to be evacuated very quickly from Diablo reservoir four outlet valves in the middle of the dam can be opened in addition to the spillgates (Figures 7 and 8). The pipes for these valves exit the dam at elevation 1,048 ft; three of the pipes are 78 inches in diameter and have butterfly valves on the downstream side; the fourth pipe is 72 inches in diameter and is outfitted with a Larner Johnson valve. Water flowing into the pipes is controlled upstream by broome gates. The outlet valves can also be used to release water if reservoir levels are below the spillgate crest. The outlet valves are opened annually for testing but are otherwise reserved for use under emergency conditions.

2.1.2.3 Turbines

There are two Francis-style turbines in Diablo Powerhouse. Water enters each through a 15-ft diameter penstock and discharges into the tailrace through a draft tube at an elevation of 850 ft, about 29 ft below the water surface of the Gorge Lake.

2.1.3 Gorge

Gorge reservoir has a maximum elevation of 879 ft (NAV 88; 875 ft NAV 29) and is usually kept full or near full to provide maximum head for Gorge Powerhouse. For maintenance purposes the reservoir is occasionally drawn down about 50 ft to elevation 829 ft. There is no



Figures 7 and 8. Valve house on Diablo Dam under normal conditions and with valves open for testing.

minimum flow in the Gorge Dam bypass reach. Under normal operations the bypass reach receives water only from side streams, seeps, and precipitation runoff. Summary statistics for Gorge intakes, spillways, and outlet valves are provided in Table 3.

Table 3. Summary data for Gorge Dam discharge structures[1].

Discharge Structure	No.	Size	Exit Elevation	Exit Distance Below Full Pool (879 ft elevation)	Vertical Distance to Skagit River (704 ft elevation)[2]
Power tunnels	1	15.4 ft x 20.5 ft	799 ft to 819 ft	60 to 80 ft	NA – water travels through penstocks to powerhouse
Spillways	2 Gates	Gates = 50 ft wide by 60 ft high	829 ft	50 ft	125 ft
Outlet Valves	2	≈20 ft diameter	768 ft	111 ft	64 ft

[1] All elevations are in NAV 88 and rounded.
[2] Elevation of Skagit River below Gorge Dam was estimated from a topographic map from a survey conducted in 2003 for road construction. The bottom of the river is approximately 704 ft elevation (NAV 88); the actual water level of the small pool of water immediately downstream of the dam is unknown and will vary depending on precipitation and runoff.

2.1.3.1 Power Tunnel Intakes

Water used to generate power at Gorge Powerhouse exits the reservoir via a single power tunnel, about 15.4 x 20.5 ft in size. The intake structure is in a rock abutment about 100 ft upstream from the dam on the left bank (facing downstream) (Figure 9). The intake gate is at the bottom of the reservoir, which is at elevation 799 ft at this location. The intake is about 40 ft wide and divided into two sections by a concrete wall. Each section is covered by an intake screen or trash rack which extends to the bottom of the reservoir. Intake screen openings are 3.5 inches wide.

2.1.3.2 Spillway and Outlet Valve

Gorge Dam has a single spillway with two gates on the left side of the dam (facing downstream). Releases are controlled through two wheel gates, which are operated from a fixed structure on top of the dam. The upstream crest of the spillway is at elevation 829 ft, which is 50 ft below full pool elevation (879 ft). The vertical distance from the spillway crest to the Skagit River channel downstream of the dam is about 125 ft. Water in the spillway is directed into the channel by training walls on each side (Figures 9 and 10). Unless Gorge is spilling (Figure 10) the channel immediately downstream of the dam normally has only a shallow pool of water.

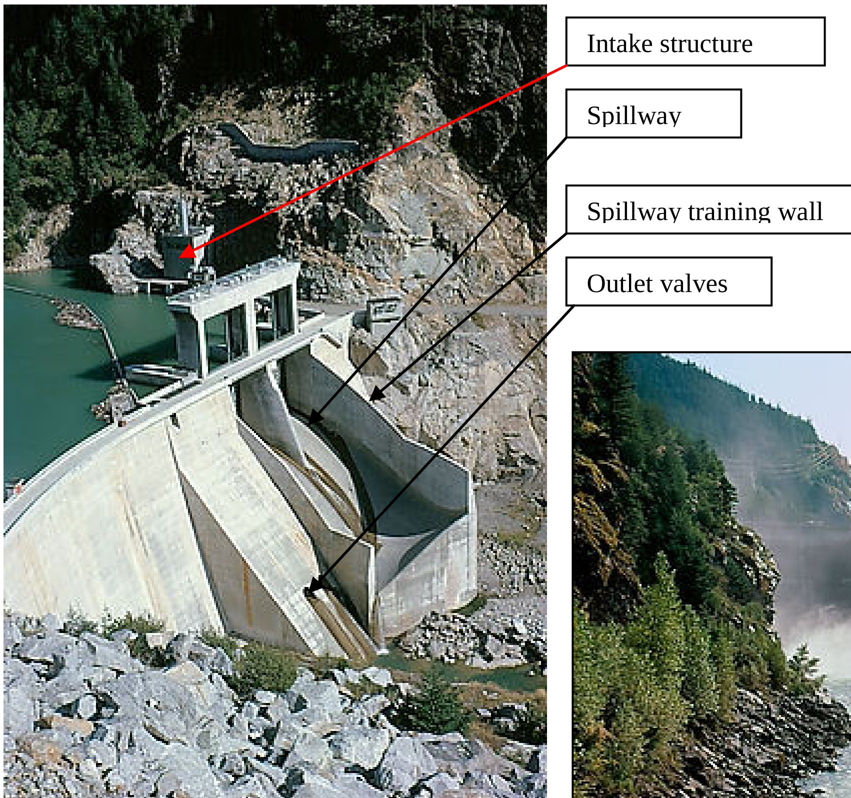


Figure 9. Gorge Dam, intake structure, spillway, and outlet valves.

Figure 10. Gorge Dam spilling.

In addition to the spillway, two outlet valves can be used to evacuate water from Gorge reservoir. Located at elevation 768 ft, these valves are 111 ft below full pool and 64 ft above the level of the Skagit River downstream. Unlike the outlet valves at Ross and Diablo dams, which are tested annually but reserved for emergency use, the outlet valves at Gorge are also used when the Gorge is not generating due to maintenance work on the spill gates or power tunnel. This situation occurs only occasionally but is necessary to maintain fish flows below Gorge Powerhouse.

2.1.3.3 Turbines

There are four Francis-style turbines in Gorge Powerhouse. Water enters each through a 20-ft diameter penstock and discharges into the tailrace through a draft tube at an elevation of 468 ft, about 17 ft below the water surface of the Skagit River. Gorge Powerhouse is about 3 miles downstream of Gorge Dam.

2.2 Proposed Project Facilities

The Gorge 2nd Tunnel will not alter the number or physical features of the existing spillways, power tunnels intakes, valves, or turbines at any of the Skagit Project developments. Operation of the Project will not change with the addition of Gorge 2nd tunnel. The operation of the three Project reservoirs and flows downstream of the Project will remain the same. There will be no *de facto* changes in operations or Skagit River flows downstream of the Project resulting from the proposed action.

3 SPILL AT EXISTING AND PROPOSED PROJECT FACILITIES

Two types of spill occur at the Skagit River Project—planned and unplanned. Planned spills occur for a maintenance purpose. Maintenance activities typically interrupt generation requiring a spill to maintain a normal reservoir elevation or to provide the needed minimum flow for downstream fish protection. Unplanned spills usually result from a full reservoir and inflows that exceed maximum generation capacity.

3.1. Spill History

Spill data from the three Skagit dams were compiled for the 15 year period from 1997-2011. These data were analyzed to determine frequency, magnitude, and duration of each spill event (Table 4). Diablo Dam spilled most frequently on an annual basis, at nearly 4-times per year. Ross Dam spills much less frequently due to its large reservoir storage capacity; at one spill every two years. Overall, spilling at any of the three projects occurs only 4 to 9 days per year, greatly reducing the risk of spill on fish. Unplanned spill usually occurs in the spring but the specific timing varies by project. Spill from Ross Dam, although rare, typically occurs in June or July near the tail end of refill from snowmelt, or less frequently, in early fall as a result of extreme storms when the flood control storage in the reservoir is relatively low. Unplanned spills from Gorge and Diablo dams generally parallel any Ross spill event. However, both these reservoirs lack active storage volume and can spill anytime inflows exceed generation capacity during fall and winter storm periods.

Table 4. Spill frequency, magnitude and duration, 1997-2011, for the three Skagit Project dams.

Project Development	Number of Spills (1997-2011)	Spills per Year	Average Spill Duration (Days)	Average Spill Flow (cfs)	Percent of Year Spilling
Gorge	35	2.3	8.8	4,431.5	5.6%
Diablo	58	3.9	5.9	2,264.9	6.2%
Ross	8	0.5	4.4	4,102.5	0.6%

3.2. Spill with the Gorge 2nd Tunnel

Once operational, the second power tunnel at the Gorge development will not change the number or duration of spills from Gorge Dam. However, during the construction phase of the Gorge 2nd Tunnel project water will need to be spilled from Gorge Dam for a two-to-three month period when the new tunnel is being connected to the existing tunnel. As described in the BE (June 2011), Gorge Reservoir has little storage capacity so water will need to be spilled rather than directed through the powerhouse to maintain adequate minimum flows for fish downstream.

4 BULL TROUT IN SKAGIT PROJECT RESERVOIRS

All three reservoirs at the Skagit Hydroelectric Project are inhabited by rainbow trout (*Oncorhynchus mykiss*), bull trout, and Dolly Varden (*Salvelinus malma*); red shiners (*Cyprinella lutrensisare*) are common in Ross Lake and present in Diablo Lake. Brook trout (*Salvelinus fontinalis*) and a few cutthroat trout (*Oncorhynchus clarkia*) also occur in Ross Lake. While any of these species can be entrained, this section focuses on the habitat and biology of the federally threatened bull trout in the reservoirs.

4.1. Habitat Properties of Skagit Project Reservoirs

Of the three Skagit Project reservoirs, Ross Lake supports the largest bull trout population. This is due primarily to the large size of this reservoir compared to Diablo and Gorge reservoirs. At full pool, Ross Lake has a volume of 1,444,000 acre-ft and surface area of 11,700 acres. In comparison, Diablo Lake has a volume of 90,400 acre-ft and surface area of 910 acres, while Gorge Lake has a volume of 8,158 acre-ft and surface area of 240 acres. This means that Ross Lake has 13 times more surface area than Diablo Lake, and 49 times more surface area than Gorge Lake at full pool elevations.

Moreover, Ross Lake has a much larger drainage area than Diablo and Gorge lakes, and possesses more suitable tributary habitat for bull trout spawning and juvenile rearing than these smaller two reservoirs. Ross Lake has a drainage area of almost 1,000 sq-miles, and contains a number of major tributaries used by bull trout for spawning and rearing, including the upper Skagit River in British Columbia, and Big Beaver, Little Beaver, Lightning, and Ruby creeks. Bull trout have been documented to spawn and rear throughout much of the upper Skagit River drainage in B.C., including the mainstem Skagit, Sumallo, Klesilkwa, and Skaist rivers. The Ross Lake drainage contains over 312,000 sq-ft of spawning habitat, based on a survey of tributary habitat that is accessible to the fish in the reservoir (Tappel 1989).

In comparison, Diablo Lake has a watershed drainage area of 125 sq-miles. Although Thunder Creek is the largest tributary to Diablo Lake, bull trout have not been found spawning in this drainage during fish surveys conducted by National Park Service (NPS) biologists over the past decade (Reed Glesne, NPS, pers. comm. April 2012). Spawning may be difficult for bull trout in Thunder Creek due to the flashy hydrology and high turbidity levels that occur in this stream due to glacial runoff. Thunder Creek possesses the largest number of glaciers in North Cascades National Park, and is the most glacially influenced tributary within the Skagit River basin. Other Diablo Lake tributaries that are potentially used by bull trout are Colonial Creek and Rhode Creek. However, these two streams together provide less than 800 sq-ft of spawning habitat area. The Diablo Lake drainage contains approximately 11,000 sq-ft of tributary spawning habitat that is accessible to fish (Tappel 1989), with Thunder Creek providing 9 percent of this habitat.

Finally, Gorge Lake has a watershed drainage area of 34 sq-miles. Stettatle Creek is the only known fish bearing tributary to Gorge Lake, and only the lowest 1.1 miles of this stream are accessible to fish in Gorge Lake due to a natural falls barrier located downstream of the confluence with Bucket Creek. Stettatle Creek contains high quality habitat with cold water and clean gravels, albeit limited in quantity due to the short length of the stream that is accessible to fish from Gorge Lake. The total amount of spawning habitat accessible to bull trout in the Gorge Lake drainage is approximately 2,300 sq-ft (Tappel 1989).

4.2. Species Composition of Native Char in Reservoirs

Over the last 15 years or so various genetic analyses have been conducted on native char in the reservoirs for the Skagit River Project. Results for each reservoir are summarized below.

4.2.1 Ross Lake

Based upon genetic analysis of native char in the upper Skagit, bull trout are the dominant native char species in Ross Lake. Genetic analysis completed by McPhail and Taylor (1995) found that the majority of native char sampled in the mainstem areas of the upper Skagit River in British Columbia were bull trout. Dolly Varden were found primarily in major tributaries to the upper Skagit, including Nepopekum Creek, and the upper Klisilkwa River drainages. This study determined that 70 percent of the native char sampled in the Skagit River and major tributaries within British Columbia were bull trout. More recently, Smith (2010) completed a genetic analysis of bull trout captured in Ross Lake and tributaries to this reservoir from collections conducted by SCL from 2001 through 2006, and by the NPS in the Lightning Creek drainage in 2002. Genetic analysis was conducted on 80 native char collected in Ross Lake, and all of these fish were genetically determined to be bull trout. Dolly Varden were found to be the dominant native char species in the middle and upper reaches of Lightning Creek, a major tributary to Ross Lake. These fish were collected above a large rock falls that may be a barrier to the upstream migration of bull trout residing in Ross Lake. All of the native char sampled in Ross Lake were collected by angling, and it is possible that Dolly Varden (which are smaller than bull trout) were not effectively sampled using this method. No eastern brook trout were identified in the Ross Lake genetic analysis.

The native char captured in Ross Lake and the upper Skagit River for SCL's migration and genetics studies ranged from 345 to 720 mm total length (TL), and had an average length of 556 mm TL (Figure 11; R2 Resource Consultants 2009). Native char smaller than 350 mm were captured in horizontal gill nets during a baseline fish survey of Ross Lake completed by the Washington Department of Fish and Wildlife (WDFW) in 2006 (Figure 12; Downen 2011), with total of 24 native char captured in Ross Lake during this survey. McPhail and Taylor (1995) documented that the average size of Dolly Varden spawners in the upper Skagit River drainage is 120 mm TL, with the largest adult Dolly Varden observed in this study measuring 245 mm. Adult bull trout are much larger than adult Dolly Varden in the upper Skagit River drainage. Given that the average size of a Dolly Varden spawner is 120 mm (McPhail and Taylor 1995), and the average size of a bull trout adult is about 600 mm (R2 Resource Consultants 2009), adult bull trout are, on average, almost six times larger than adult Dolly Varden. Based upon the results of these studies, any native char over 300 mm TL in the upper Skagit River drainage are likely bull trout.

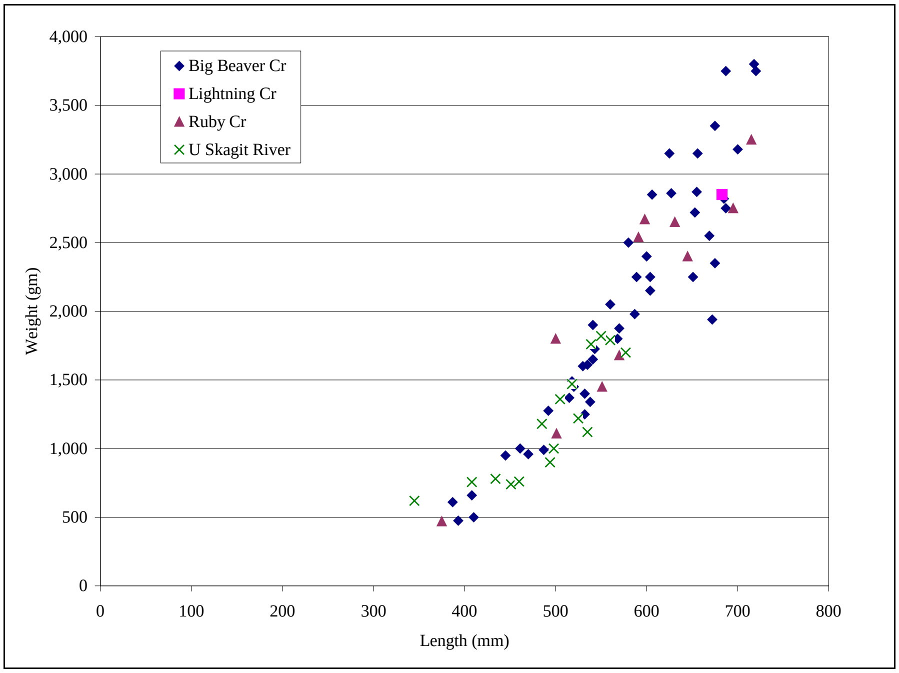


Figure 11. Lengths and weights of native char captured in Ross Lake from hook-and-line sampling conducted for SCL, 2001-2006. These fish were captured at the mouths of Big Beaver, Lightning, and Ruby creeks, and the upper Skagit River immediately upstream of Ross Lake (R2 Resource Consultants 2009).

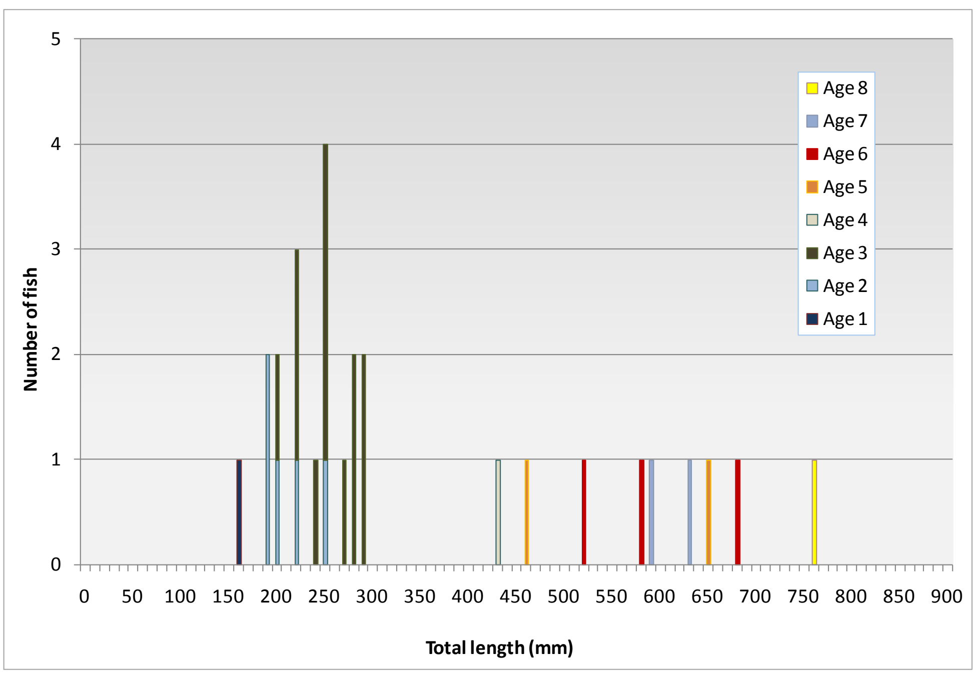


Figure 12. Length-frequency plot of native char sampled by gill nets in Ross Lake during August 2006 (source: Downen 2011).

4.2.2 Diablo Lake

WDFW completed a baseline assessment of the fish composition of Diablo Lake during 2005 (Downen 2006). Fish were sampled using vertical and horizontal variable-panel gill nets. A total of 55 native char where captured during the 2005 fish survey. The majority of native char captured in Diablo Lake were less than 350 mm TL, and only three fish captured during this survey were over 400 mm TL (Figure 13). Based upon the genetic analysis of tissue samples collected from 48 native char collected during the 2005 survey, 40 were determined to be Dolly Varden, while 8 were indentified as Dolly Varden – bull trout hybrids (Small et al. 2007). Three of these hybrid fish were designated as bull trout based upon a statistical analysis of their genetic markers (i.e, they are bull trout with some Dolly Varden ancestry). Based upon the results of this analysis, the composition of native char in Diablo Lake is 83 percent Dolly Varden, 12 percent Dolly Varden – bull trout hybrids, and 6 percent bull trout. NPS biologists completed a survey of Diablo Lake using the same gill netting sampling procedures in 2010. Of 14 native char captured only three were over 400 mm TL. These three larger fish were determined to be bull trout, while the remainder of the fish captured during the 2010 fish survey were Dolly Varden. Assuming that the larger fish are bull trout, 21 percent of native char in Diablo Reservoir would be bull trout, while 79 percent would Dolly Varden or Dolly Varden – bull trout hybrids. The combined results of the 2005 and 2010 surveys suggest that the majority of native char in Diablo Lake are Dolly Varden.

4.2.3 Gorge Lake

University of Washington (UW) biologists collected native char in Stettatle Creek, the major tributary of Gorge Lake, for SCL in 2009 and completed a genetic analysis of tissue samples obtained from these fish (Smith 2010). Of 59 native char sampled during this survey, 15 were determined to be Dolly Varden. Most of the fish sampled by UW in Stettatle Creek were juvenile bull trout, confirming that bull trout are spawning and rearing in Stettatle Creek. Based upon the results of genetic analysis completed by UW, 75 percent of native char in Stettatle Creek were bull trout and 25 percent were Dolly Varden. WDFW sampled 22 native char in Gorge Reservoir in August 2006; these fish ranged in from 130 to 751 mm TL (Downen 2011). Only four of the native char sampled in Gorge Reservoir by WDFW during the 2006 survey were over 400 mm TL (Figure 14).

4.3. Genetic Similarity of Bull Trout in Reservoirs and Skagit River

Bull trout in Gorge Lake were found to be genetically very similar to the bull trout in the Ross Lake drainage (including collections from Big Beaver Creek, Lightning Creek, Ruby Creek, and the upper Skagit River, B.C. (Smith, 2010). The results of a genetic baseline analysis of the Skagit River basin completed by UW concluded that bull trout in Gorge Lake should be part of the Upper Skagit River Core Area, which is defined in the USFWS recovery plan for the Puget Sound Bull Trout Recovery Unit (USFWS 2004). Further, bull trout in the upper Skagit River drainage upstream of Gorge Dam (including Gorge, Diablo, and Ross Lakes) are genetically distinct from bull trout in the Skagit River drainage downstream of Gorge Dam (Figure 15). Finally, bull trout juveniles collected in Stettatle Creek, the only known spawning area for bull trout in Gorge Lake, were not genetically distinct from bull trout in the Ross Lake drainage (Smith 2010).

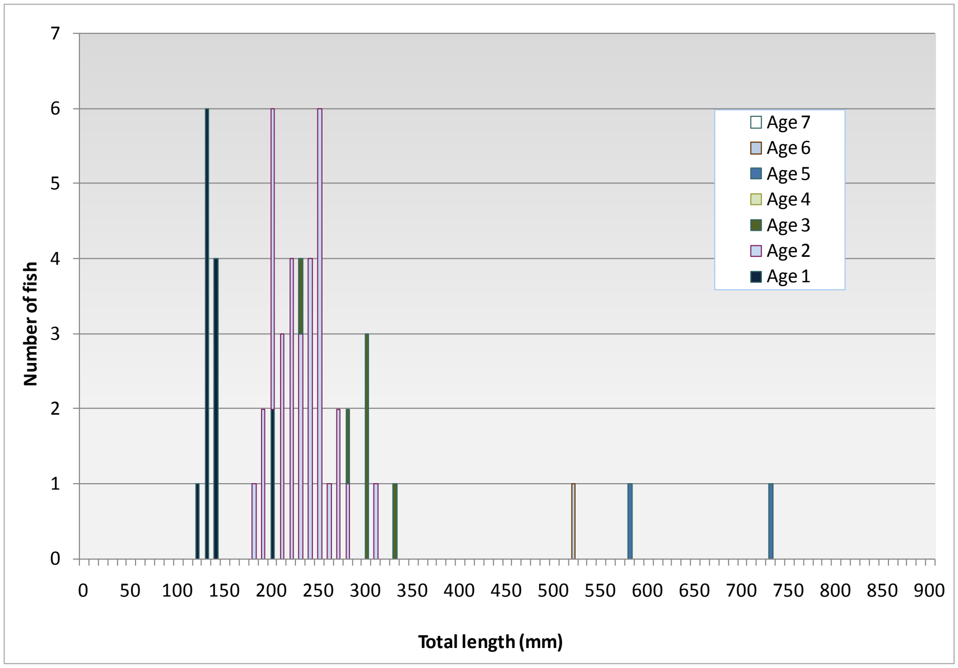


Figure 13. Length-frequency plot of native char sampled by gill nets in Diablo Lake during August 2005 (source: Downen 2011).

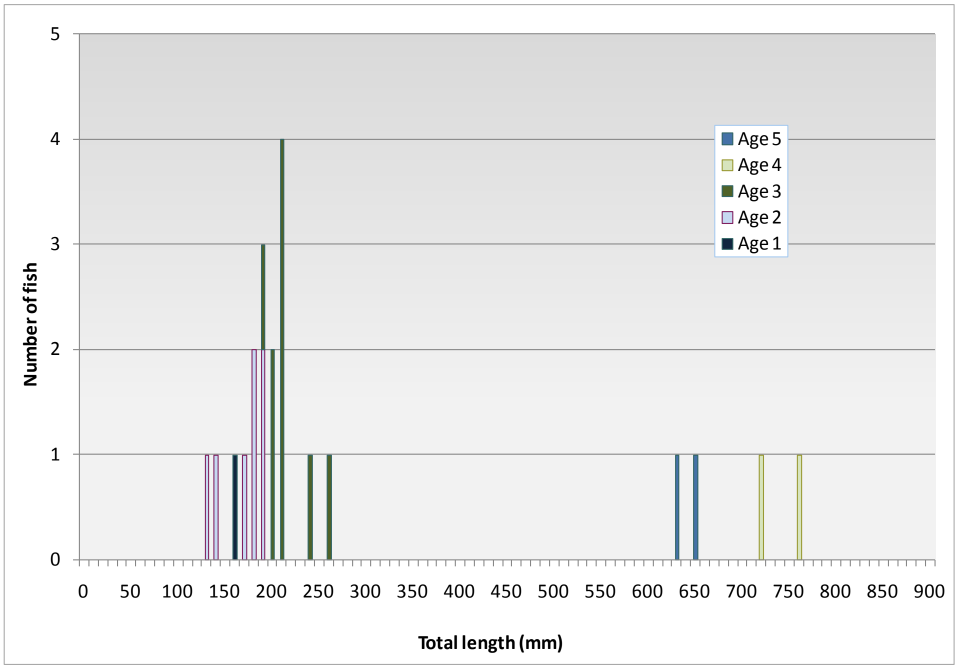


Figure 14. Length-frequency plot of native char sampled by gill nets in Gorge Lake during August 2006 (source: Downen 2011).

Almost all of the native char that have been genetically analyzed in Diablo Lake to date were found to be Dolly Varden. The few genetic samples (n = 3) for bull trout in Diablo Lake were obtained from fish that were determined to contain a significant level of Dolly Varden hybridization. Consequently, there is insufficient genetic data to determine the genetic

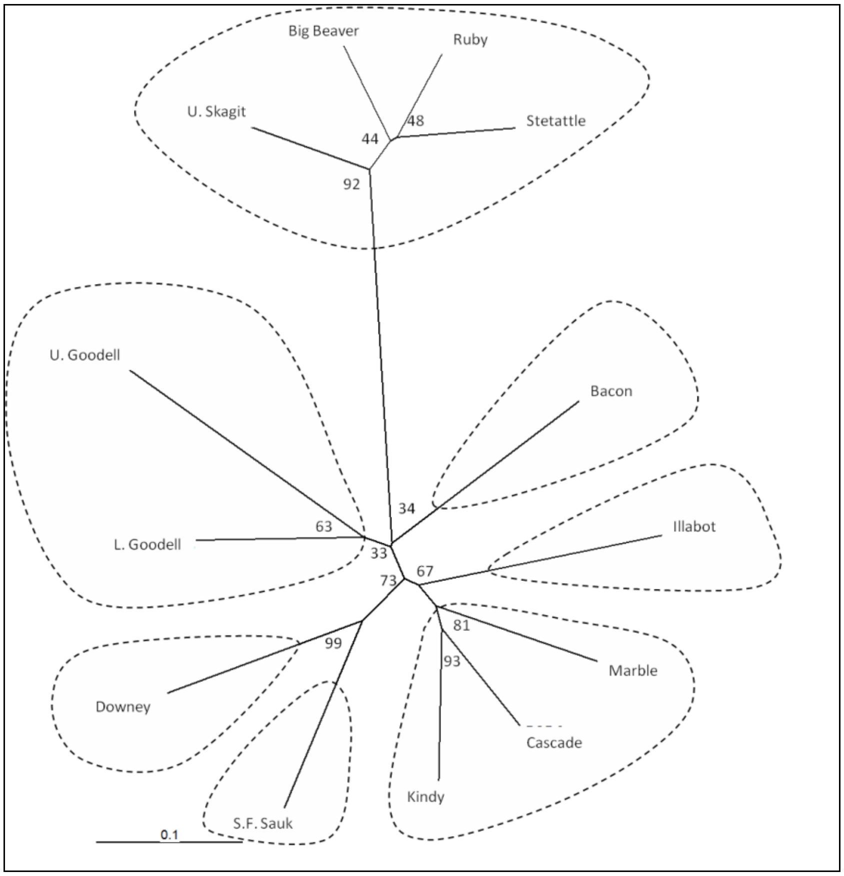


Figure 15. Unrooted neighbor-joining (NJ) dendrogram of bull trout collections from the Skagit River Basin using Cavalli-Sforza and Edwards (1967) chord distance to display genetic relationships among collections. Subbasin collections pooled for genetic assignment tests are outlined with dashed lines (source: Smith 2010).

relationship of bull trout in Diablo Lake with the population in Ross Lake. However, bull trout in Diablo should be genetically similar to the Ross Lake population, since bull trout in Gorge Reservoir (downstream of Diablo Reservoir) were found to be genetically similar to Ross Lake bull trout.

4.4. Bull Trout Abundance

The abundance of native char and rainbow trout in the upper Skagit River, British Columbia (above Ross reservoir) was estimated by snorkel counts completed during the summers of 1998, 2009, 2010, and 2011 (Anaka and Scott 2011). These snorkel counts were completed within a 36 km index section of the mainstem Skagit River above Ross Lake. The results of these snorkel counts indicate that native char populations in the upper Skagit River increased ten-fold in 2011 from the abundance measured in 1994 (Figure 16). The abundance of native char almost doubled from 2009 to 2011. Virtually all of the native char (96%) counted during these surveys were over 400 mm TL. Juvenile bull trout were not effectively sampled during these snorkel surveys, so the relative abundance of juvenile fish in the upper Skagit River remains unknown. The introduction of redside shiners into Ross Lake within the last decade, and the rapid

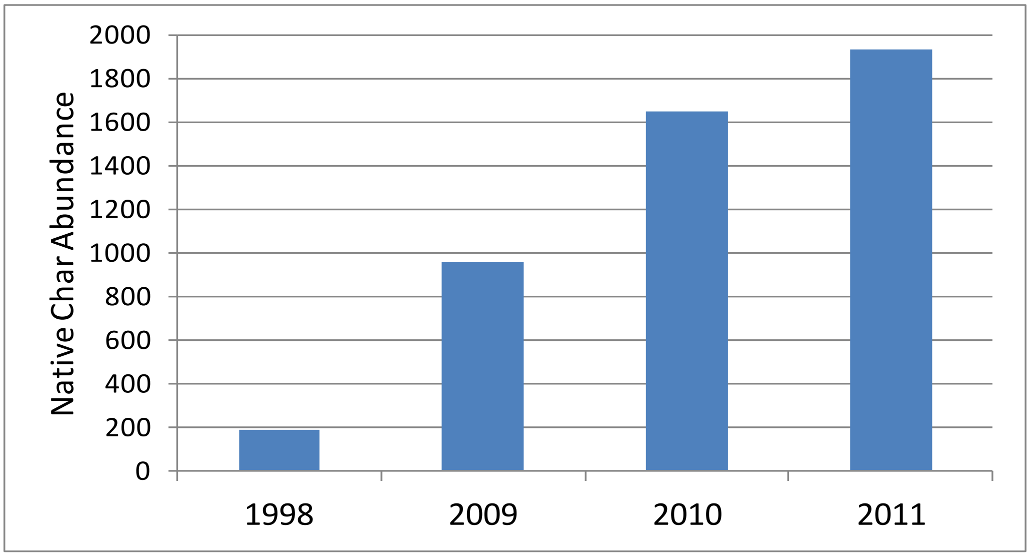


Figure 16. Abundance of native char in a 36-km index reach of the upper Skagit River above Ross Lake: 1998 through 2011. (source: Jesson 2011). Over 98 percent of the fish counted in 2011 are presumed to be adult bull trout based upon length criteria.

increase of redside shiner populations in Ross Lake since 2003, have been identified as major factors contributing to the increase in bull trout abundance in the Ross Lake drainage (Downen 2011). The food base of bull trout in Ross Lake, which was formerly limited to rainbow trout and small native char, has been greatly expanded due to the rapid increase in the abundance of redside shiners over the past decade. Based upon the results of snorkel surveys conducted along the edges of Ross Lake in 2006, the redside shiner population in Ross Lake was estimated to exceed 1.2 million fish (Downen 2011).

Assuming that a total length of 300 mm represents a conservative breakpoint for separating adult bull trout and Dolly Varden, almost all of the fish counted in the 2006 survey of Ross Lake (more than 96%) were adult bull trout. The total abundance of bull trout from the 2011 snorkel count was 1,938 fish (Jesson 2011). Assuming that this index area represents 40 percent of the high-quality bull trout spawning habitat present in the Ross Lake drainage, an expanded population estimate for all spawning areas in the drainage would be 4,800 adult bull trout. If it is assumed that 30 percent of adult bull trout in the basin were present in Ross Lake during the upper Skagit River August 2011 snorkel survey period, the abundance estimate for adult bull trout in the Ross Lake drainage would increase to 6,900 fish. The percentage of adult bull trout in Ross Lake (during the survey period) from the basin-wide estimate assumes that bull trout don't spawn every year (skip spawning), and that some adult bull trout reside in the rivers on a year-round basis (i.e., fluvial life history). For non-spawning periods of the year, we estimate that 70 percent of bull trout in the Skagit Basin have an adfluvial life history type, and thus reside in Ross Lake most of the year. The assumption that the majority of bull trout in the Ross Lake drainage have an adfluvial life history is supported by the finding that most of the forage fish base for bull trout is in the reservoir. Based upon these assumptions, the number of adult adfluvial bull trout in Ross Lake is estimated to be 4,800 fish.

The abundance of adult bull trout in Diablo and Gorge lakes is more difficult to estimate, since no index-area snorkel counts of fish have been conducted in the tributaries like those completed in the upper mainstem Skagit River, British Columbia. Bull trout have not been observed to date during spawning surveys conducted by NPS biologists in Thunder Creek (Reed Glesne, pers. comm., 2011), and only a few adult bull trout have been observed in fall snorkel surveys conducted in Stettatle Creek (R2 Resource Consultants 2009). WDFW completed a gill net survey of fish in Diablo Lake during August 2005 which successfully captured native char. However, all of these fish were later identified by genetic analysis as Dolly Varden, or Dolly Varden – bull trout hybrids. Only a few fish over 300 mm in length were captured during gill net surveys conducted in Diablo and Gorge lakes, suggesting either that adult bull trout are scarce in these two reservoirs, or that the netting methods employed in the surveys did not effectively sample larger fish.

Because of limitations in the survey data obtained to date from Diablo and Gorge lakes and tributaries, we estimated the number of bull trout in these reservoirs based upon the Ross Lake estimate. We used the Ross Lake estimate of 4,800 adult fish, and down-scaled this number to Diablo and Gorge lakes based upon the surface area of the three reservoirs at full pool elevation. Diablo Lake has a surface area that is $1/13^{th}$ that of Ross Lake, while the surface area of Gorge Lake is $1/49^{th}$ that of Ross Lake. The corresponding abundance estimate for Diablo Lake is 370 bull trout, and the estimate for Gorge Lake is 100 bull trout.

The actual numbers of bull trout in these two reservoirs is likely to be lower than these estimates because Diablo Lake may be lacking a spawning population of bull trout due to poor spawning conditions in the Thunder Creek basin, and because spawning habitat in Gorge Lake is limited to a little over one-mile of habitat downstream of a major falls barrier on Stettatle Creek. This is substantiated by the low angling success for bull trout measured in Diablo and Gorge lakes during a creel census conducted in these reservoirs by WDFW in 2002 and 2003. Only six bull trout were caught in Diablo Lake during the 2002-2003 census for 584 hours fished. In Gorge Lake, 41 bull trout were caught during this two-year census period for 100 hours fished (WDFW 2003, unpublished data). The higher number of bull trout caught in Gorge Lake compared to Diablo Lake is possibly due to the confirmed presence of a reproducing population in Stettatle Creek.

5 BULL TROUT ENTRAINMENT AT GORGE/DIABLO/ROSS DAMS

Bull trout at Ross, Diablo, or Gorge dams move downstream either by passing over the spillways or passing through the turbines. Fish will continue to be entrained at the intakes and spillways of all three projects for the remainder of the license period. It is currently unknown how many bull trout are entrained at the dams and by which pathway. Factors that could affect the magnitude of downstream entrainment include the magnitude and duration of the spill, level of generation, time of year, and the size and behavioral characteristics of bull trout. Opportunities for turbine entrainment occur at Gorge, Diablo and Ross dams whenever generation is underway, which is constantly on a year-round basis. During short periods of planned and un-planned plant outages water would not typically flow through the intake structure. During periods of infrequent plant outage turbine entrainment would not take place. Alternatively, spill entrainment is a rare occurrence that takes place during periods of plant outage or flooding. On an annual basis the

Skagit dams spill 1-2 percent of the time (see Section 3.1). Spill flow levels and duration vary greatly ranging from a few hundred to a few thousand cfs and for as short as an hour to several days or weeks at a time depending on the circumstances.

Once completed, the Gorge 2nd Tunnel project will not alter entrainment opportunities since there will be no new withdrawals or discharges into the Skagit River. Likewise, the operation of the three projects will not change with the addition of Gorge 2nd tunnel. However, during the construction phase of the Gorge 2nd Tunnel project water will need to be spilled from Gorge Dam during a two-to-three month period when the new tunnel is being connected to the existing tunnel. During that period, bull trout entrained over the spillways may incur a level of injury or mortality that may exceed injury or mortality rates that would result from entrainment through the powerhouse and turbines.

5.1. Bull Trout Forebay Use and Entrainment in Skagit Reservoirs

There are presently no data on entrainment rates of bull trout at the intakes of Ross, Diablo, and Gorge dams. It is assumed that some bull trout are entrained by the power intakes of all three dams. The results of a multiple-year acoustic tracking study in Ross Lake strongly suggests that the number of adult bull trout entrained into the power intakes of the Skagit dams is relatively small. This is based upon the low percentage of time that bull trout studied in Ross Lake were observed to spend in the vicinity of the intakes. Only three fish were found to be frequent users of the intake area, and many fish did not move into the intake area at all. Further, those bull trout that did spend time near the intakes did so without being entrained into the intake tunnel. These results suggest that bull trout are behaviorally and physically able to avoid entrainment during those periods when in the vicinity of the intakes. The methods and results of the bull trout acoustic tracking study in Ross Lake and the relevance of this study to entrainment rates are summarized in Sections 5.1.1 and 5.1.2 below.

The trash racks at Ross, Diablo, and Gorge dams may also prevent larger bull trout from being entrained into the intakes. The bull trout captured in Ross Lake ranged between 350 and 750 mm in total length (see Figure 11), and adult bull trout in Gorge and Diablo lakes likely fall within this size range. Assuming that the width of the head of a bull trout is 15 percent of its total length (Ladell 2003), the heads of these fish would range from 56 mm (2.2 inches) to 120 mm (4.7 inches). Because the trash racks at Ross Dam are 3.5 inches wide, bull trout larger than 600 mm total length (head width = 3.6 inches) would be excluded from the intakes. Since the trash racks at Diablo and Gorge dams are 2.5 inches wide, bull trout larger than 450 mm total length (head width = 2.6 inches) would be excluded from the intakes. Given the widths of the trash racks, approximately half of the adult bull trout in Ross Lake would be excluded from the intakes, while the majority of adult bull trout in Diablo and Gorge lakes would be excluded from the intakes.

5.1.1 Ross Lake Acoustic Telemetry Study Methods

SCL has been studying the habitat use (including depths and temperatures), daily migration patterns, and seasonal migration timing of bull trout in Ross Lake using acoustic telemetry. This study has been conducted using Vemco acoustic tags, which are surgically implanted in a fish. The tags transmit an ultrasonic acoustic signal at approximately two minute intervals for a period of around two years. These transmissions are digitally encoded with an identification number for each tag (and thus each fish). These tags can optionally include pressure and/or temperature sensors that transmit the depth and temperature of the tag along with the identification number. The acoustic signals (or "pings") are received and recorded on a continuous basis with Vemco VR2W acoustic receivers. The receivers are deployed underwater, typically on a cable or fixed object (e.g., boat dock). Data are downloaded from the receivers while they are deployed in the field using a laptop computer and blue-tooth wireless connection.

We deployed ten acoustic receivers in Ross Lake in late September, 2009 (Table 5). Receivers were deployed at three locations in the Ross Dam forebay: a log boom located immediately in front of the dam power intakes, the Ross Dam boathouse, and at the outer log boom that separates the forebay from the rest of the reservoir (Figure 17). An additional receiver was deployed at the dock of Ross Lake Resort in November 2011. Four receivers were also placed in the middle of Ross Lake, with the southern most of these located at the NPS outer log boom located northeast of Ross Lake Resort, and the other mid-reservoir receivers located on NPS buoys located north of Big Beaver Creek, southwest of Lightning Creek, and north of Little Beaver Creek (Figure 17). Receivers were also deployed near the mouths of major tributaries on weighted lead lines, including Ruby Creek, Big Beaver Creek, and Lightning Creek (Figure 17). Data were downloaded from the receivers twice a year. The most recent receiver download date included in this analysis was February 24, 2012.

Table 5. Location and deployment date of acoustic receivers located in Ross Lake.

Site	Deployment Date	Latitude	Longitude	Location Notes
Ross Dam Intake	9/23/2009	48.73177	-121.06660	Attached to log boom in front of Ross Dam intake
Boat House	9/30/2009	48.73236	-121.06750	Ross Dam boat house
Ross Lake Resort	12/20/2011	48.73900	-121.06044	Attached to front of Ross Lake Resort
Forebay Log Boom	9/30/2009	48.73476	-121.06540	SCL log boom that separates forebay from reservoir
Outer Log Boom	9/30/2009	48.73706	-121.05419	Outer NPS log boom
Ruby Creek Outlet	9/30/2009	48.73004	-121.02532	Lead line receiver located near mouth of Ruby Creek
Big Beaver Creek South	9/30/2009	48.76682	-121.04427	Lead line located just south of Big Beaver Creek mouth
Big Beaver Creek North Buoy	9/23/2009	48.78943	-121.05430	NPS buoy north of Big Beaver Creek
Lightning Creek Buoy	9/23/2009	48.86501	-121.03259	Central reservoir adjacent to mouth of Lightning Creek
Lightning Creek Mouth	9/30/2009	48.87482	-121.01878	Lead line receiver located at mouth of Lightning Creek
Little Beaver Creek Buoy	9/23/2009	48.93562	-121.07712	NPS buoy north of Little Beaver Creek mouth

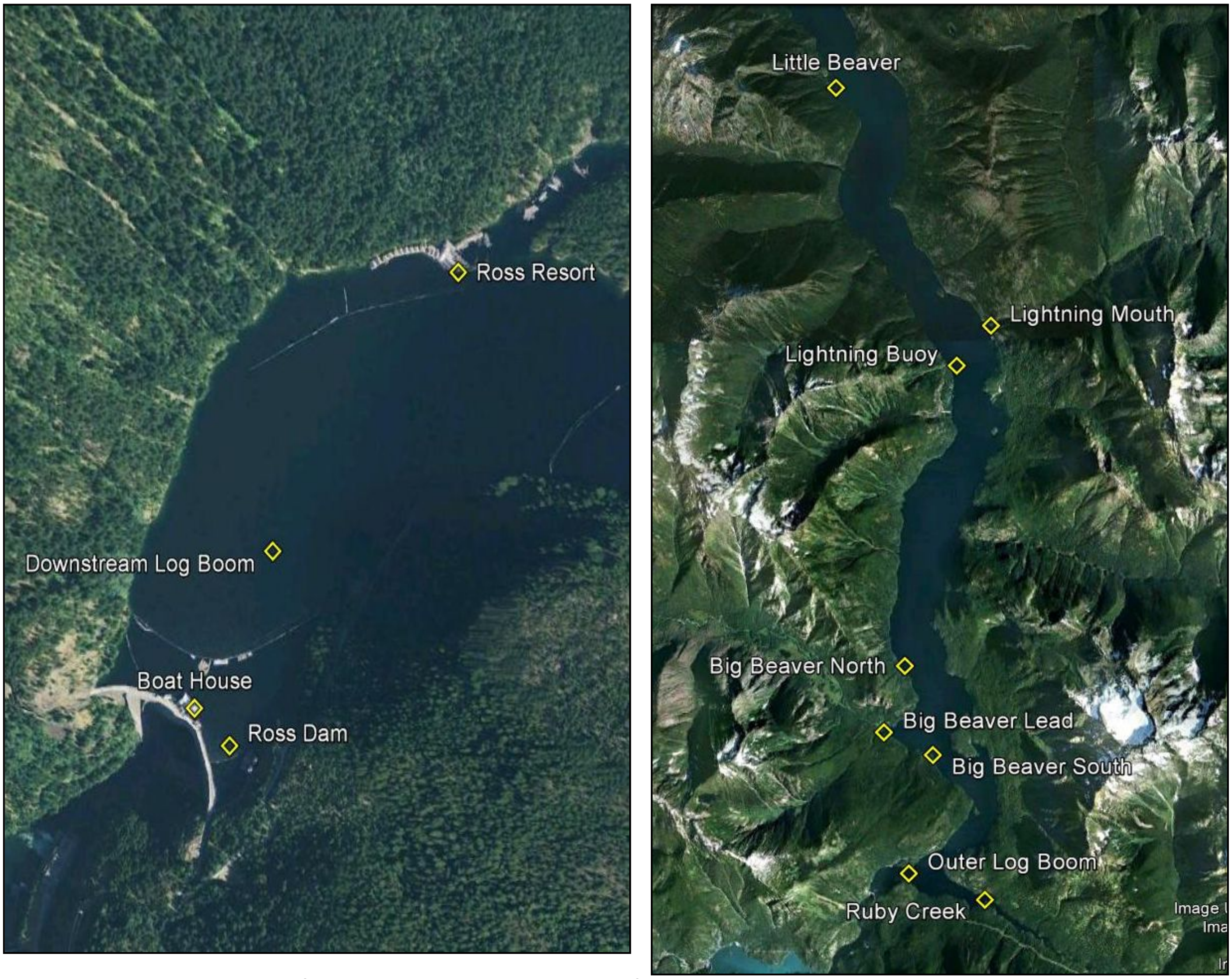


Figure 17. Aerial photo of Ross Lake showing location of acoustic receivers.

Acoustic tags were implanted in 40 bull trout during the fall of 2009 (Table 6). Bull trout were captured with hook-and-line at the mouths of Big Beaver and Ruby creeks. Fish were surgically implanted with acoustic tags provided they were of sufficient size (i.e., tag weighed less than 2% of the biomass of the fish), and provided they were in good physical condition. Tag implantation surgeries of all bull trout were conducted by R2 Resource Consultants, following the collection guidelines specified in their USFWS research collection permit. Fish were anesthetized in buffered MS-222, and surgically implanted with tags through an incision placed in the abdominal wall anterior to the pelvic fins. All fish implanted with acoustic tags were allowed to fully recover in a live car placed within the cold outflow currents of the tributary prior to being released.

All 40 of the bull trout were implanted with Vemco V13 tags. Thirty of these tags (tag code A69-1206-787 and codes A69-1303-17737 through A69-1303-24696) were standard “pinger” V tags, meaning that they transmit the identification code of the fish only (Table 6). These tags have a diameter of 13 mm, a length of 36 mm, and weigh 6 g in water. Eight of the tags were

Table 6. Tagging and detection data summary for acoustic tags implanted in bull trout in Ross Lake.

Tag Code	Tag Type	Length (mm)	Weight (g)	Sex	Tag Site	Tag Date	Last Detection	Days	Last Detection Site
A69-1206-3067	Pinger	530	1600	f	Big Beaver Cr	10/5/2006	3/12/2011	1619	Downstream Log Boom
A69-1206-3070	Pinger	600	2400	f	Big Beaver Cr	10/19/2006	11/5/2009	1113	Outer Log Boom
A69-1105-1	Temp/Pressure	465	820	f	Ruby Cr	9/30/2009	4/9/2011	556	Ross Dam
A69-1105-3	Temp/Pressure	431	750	f	Ruby Cr	9/30/2009	8/16/2011	686	Big Beaver South
A69-1105-5	Temp/Pressure	558	1750	m	Big Beaver Cr	10/8/2009	4/20/2011	559	Big Beaver South
A69-1105-7	Temp/Pressure	447	860	m	Big Beaver Cr	10/8/2009	7/17/2011	647	Big Beaver South
A69-1105-9	Temp/Pressure	447	1140	f	Big Beaver Cr	10/8/2009	5/18/2011	587	Big Beaver South
A69-1105-11	Temp/Pressure	451	1200	f	Big Beaver Cr	10/8/2009	8/6/2011	668	Lightning Mouth
A69-1105-13	Temp/Pressure	482	1050	m	Ruby Cr	10/9/2009	3/4/2011	511	Ross Dam
A69-1105-15	Temp/Pressure	463	850	m	Ruby Cr	9/30/2009	5/17/2011	595	Big Beaver South
A69-1105-137	Pressure	463	980	f	Ruby Cr	10/9/2009	9/20/2010	347	Little Beaver
A69-1105-139	Pressure	489	1200	m	Ruby Cr	10/9/2009	7/29/2010	294	Ruby Creek
A69-1105-141	Pressure	470	1180	f	Big Beaver Cr	10/9/2009	8/6/2010	302	Big Beaver South
A69-1105-142	Pressure	531	1850	f	Big Beaver Cr	10/9/2009	6/25/2010	260	Little Beaver
A69-1206-787	Pinger	375	750	f	Big Beaver Cr	10/9/2009	8/26/2011	687	Lightning Mouth
A69-1303-17737	Pinger	493	1250	m	Big Beaver Cr	10/8/2009	2/2/2010	118	Outer Log Boom
A69-1303-17743	Pinger	568	2100	m	Big Beaver Cr	10/8/2009	11/4/2010	392	Big Beaver North
A69-1303-17748	Pinger	565	2140	m	Big Beaver Cr	10/9/2009	6/3/2010	237	Big Beaver North
A69-1303-17749	Pinger	410	800	m	Big Beaver Cr	10/9/2009	12/4/2010	422	Ruby Creek
A69-1303-17751	Pinger	379	820	m	Big Beaver Cr	10/9/2009	11/13/2010	401	Outer Log Boom
A69-1303-17755	Pinger	550	1700	m	Ruby Cr	10/15/2009	10/22/2010	373	Ruby Creek
A69-1303-17759	Pinger	547	1650	m	Ruby Cr	10/15/2009	12/29/2010	440	Outer Log Boom
A69-1303-24677	Pinger	553	1840	m	Big Beaver Cr	9/24/2009	5/22/2011	606	Big Beaver South
A69-1303-24678	Pinger	365	800	f	Big Beaver Cr	9/24/2009	6/6/2011	621	Big Beaver South
A69-1303-24679	Pinger	497	1400	m	Big Beaver Cr	10/8/2009	5/28/2011	597	Big Beaver South
A69-1303-24680	Pinger	426	820	m	Big Beaver Cr	10/8/2009	6/17/2011	617	Big Beaver South
A69-1303-24681	Pinger	425	800	m	Big Beaver Cr	10/8/2009	5/3/2011	572	Big Beaver South
A69-1303-24682	Pinger	460	1050	m	Big Beaver Cr	9/24/2009	7/13/2010	293	Little Beaver
A69-1303-24683	Pinger	460	1100	m	Ruby Cr	9/24/2009	11/21/2010	423	Little Beaver
A69-1303-24684	Pinger	557	1850	f	Ruby Cr	9/24/2009	5/30/2011	614	Outer Log Boom
A69-1303-24685	Pinger	510	1280	m	Ruby Cr	9/24/2009	3/21/2011	544	Big Beaver South

Tag Code	Tag Type	Length (mm)	Weight (g)	Sex	Tag Site	Tag Date	Last Detection	Days	Last Detection Site
A69-1303-24686	Pinger	458	1050	m	Ruby Cr	9/24/2009	12/21/2010	453	Lightning Mouth
A69-1303-24687	Pinger	455	1200	f	Ruby Cr	9/24/2009	5/18/2011	602	Big Beaver South
A69-1303-24688	Pinger	497	1250	f	Big Beaver Cr	9/23/2009	4/29/2011	584	Big Beaver South
A69-1303-24689	Pinger	403	750	f	Big Beaver Cr	9/23/2009	6/2/2011	617	Outer Log Boom
A69-1303-24690	Pinger	473	1150	m	Big Beaver Cr	9/23/2009	12/19/2010	453	Lightning Mouth
A69-1303-24691	Pinger	575	2000	m	Big Beaver Cr	9/23/2009	12/3/2010	437	Big Beaver North
A69-1303-24692	Pinger	380	750	f	Big Beaver Cr	9/23/2009	6/1/2011	616	Outer Log Boom
A69-1303-24693	Pinger	510	1600	m	Big Beaver Cr	9/23/2009	6/5/2011	621	Big Beaver South
A69-1303-24694	Pinger	503	1350	f	Big Beaver Cr	9/23/2009	10/26/2010	398	Big Beaver South
A69-1303-24695	Pinger	441	900	f	Big Beaver Cr	9/23/2009	6/6/2011	621	Downstream Log Boom
A69-1303-24696	Pinger	457	1100	m	Big Beaver Cr	9/23/2009	6/5/2011	621	Big Beaver South

13TP sensor tags (tag codes A69-1105-1 through A69-1105-15), which include depth and temperature sensors. These sensor tags were previously untested in the Skagit Project reservoirs and were implanted in bull trout to test their potential use for obtaining *in situ* depth and temperature data from bull trout. Finally, we implanted four pressure sensor tags in bull trout (tag codes A69-1105-137 through A69-1105-142). The sensors tags have the same diameter and weight as the pinger tags, but have a greater length (45 mm).

The tags were implanted in bull trout from Ross Lake having total lengths ranging 365 to 600 mm, and with a mean length of 480 mm (Figure 18). The weight of the tagged fish ranged from 750 to 2400 g, with a mean weight of 1260 g (Figure 19). The weight of all the tagged bull trout exceeded the minimum fish biomass requirements by a substantial amount, with the tags ranging from 0.3 to 0.8 percent of fish weight.

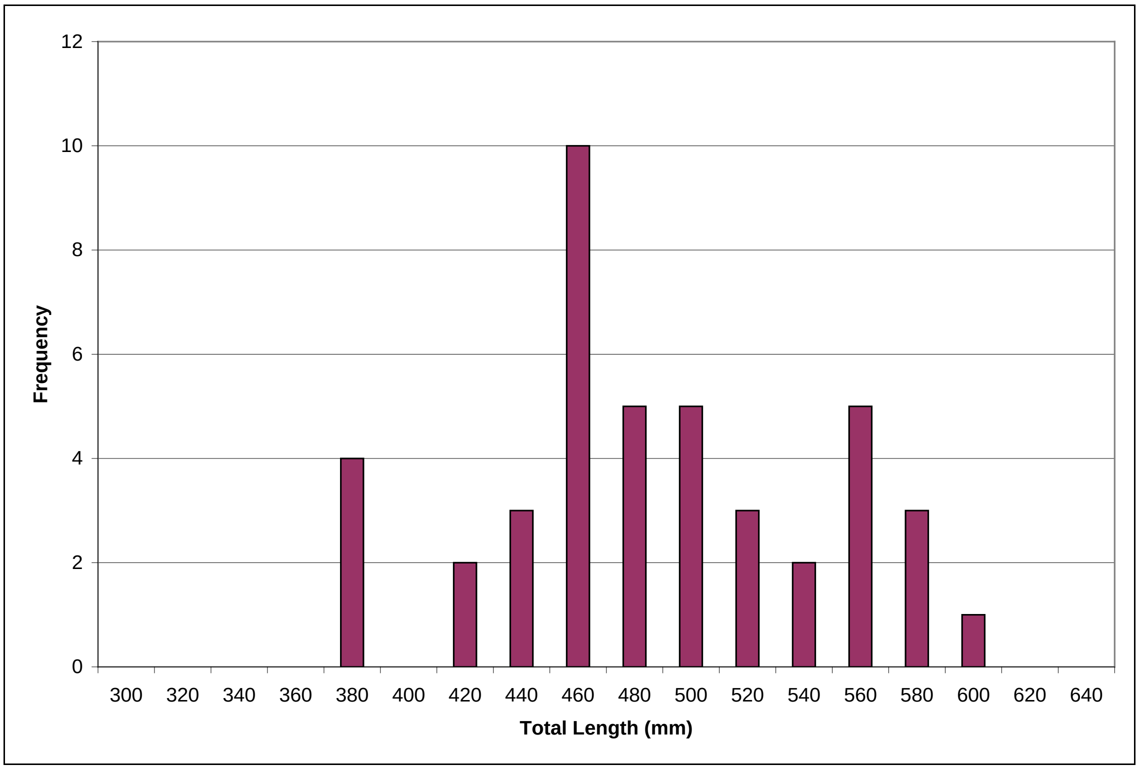


Figure 18. Frequency plot of total lengths of bull trout implanted with acoustic tags in Ross Lake.

5.1.2 Ross Lake Acoustic Telemetry Study Results

All 40 bull trout implanted with acoustic tags were detected by the Ross Lake receiver array during the fall 2009 through winter 2012 monitoring period. In addition, two tags implanted in bull trout during the fall of 2006 were detected during this monitoring period. These two tags (codes A69-1206-3067 and A69-1206-3070) were actively transmitting for over five years, which is two years beyond their expected battery life. The fact that all 40 tags implanted in fish were detected proved that all fish survived the tag implantation surgeries. The minimum tag detection period for a bull trout implanted with an acoustic tag in 2009 was 117 days, while the maximum tag detection period for fish tagged in 2009 was 687 days (Figure 20). The average detection period for the bull trout tagged in 2009 was 500 days. The rated battery life for these

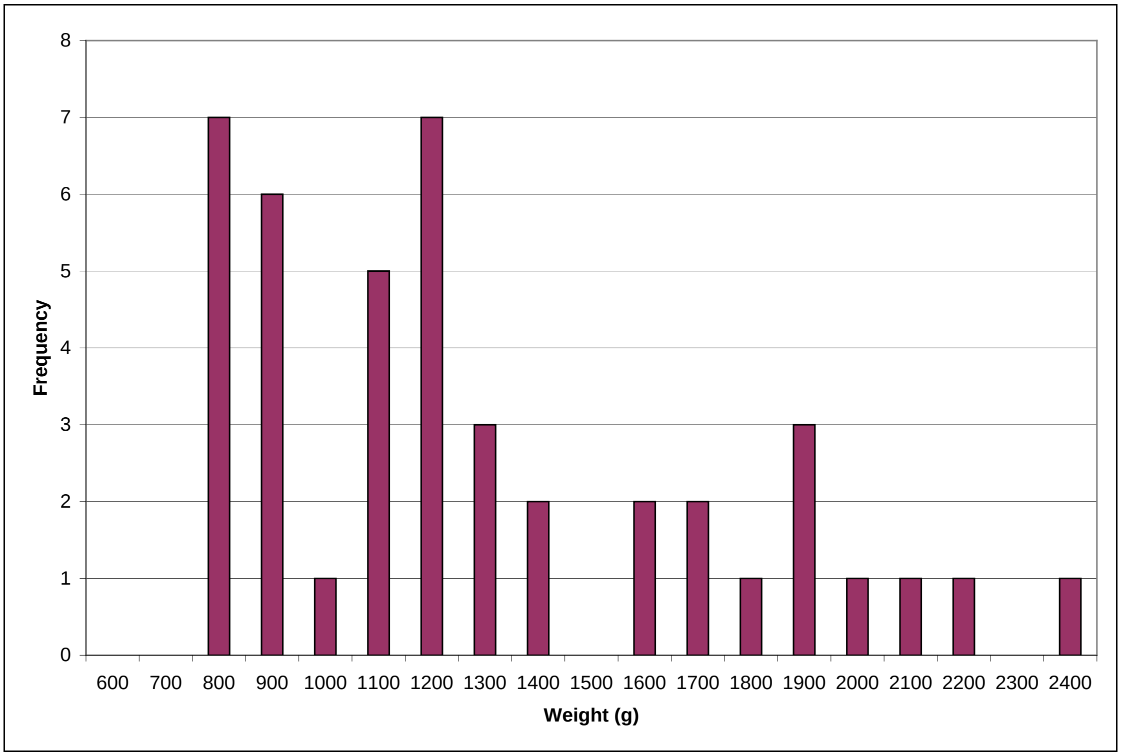


Figure 19. Frequency plot of biomass of bull trout implanted with acoustic tags in Ross Lake.

tags was 576 days, which means that the average detection period for the implanted fish was just below the maximum expected detection period based upon battery life.

As of the September 2011 receiver array download, there were over 1.6 million data points recorded from the bull trout tags. The total number of tag detections increased to over 2.4 million data points for the February 2012 receiver array download. An analysis of tag detections over time indicates that bull trout in Ross Lake were detected on very close to a continuous basis, with the only major gaps in detections observed when certain fish likely moved into tributary streams in August and September prior to spawning. These fish apparently returned to the reservoir in October and November following spawning. The very large number of detections recorded indicates that acoustic conditions for the ultrasonic tag transmissions in Ross Lake are excellent. Based upon overlap in data for the same tag transmissions among different receivers in the reservoir, it is estimated that tags were being detected up to two kilometers away from the receivers. The manufacturer of the acoustic tags and receivers, Vemco Inc., confirmed that detections at these distances are possible under excellent acoustic conditions.

5.1.2.1 Bull Trout Detections near Ross Dam Intakes

The detection data were analyzed to determine if any of the 42 tagged bull trout detected during the two year monitoring period were entrained into the Ross Dam power intakes. This was done by using Microsoft Access to extract a continuous life history record for each tagged fish from the 2.4 million record database. Excel was then used to plot out the spatial detection record for each fish, as well as the depth record for those fish implanted with pressure or temperature/pressure sensor tags. Most importantly, was the identification of those fish that were last detected at the receiver deployed on the log boom located immediately in front of the

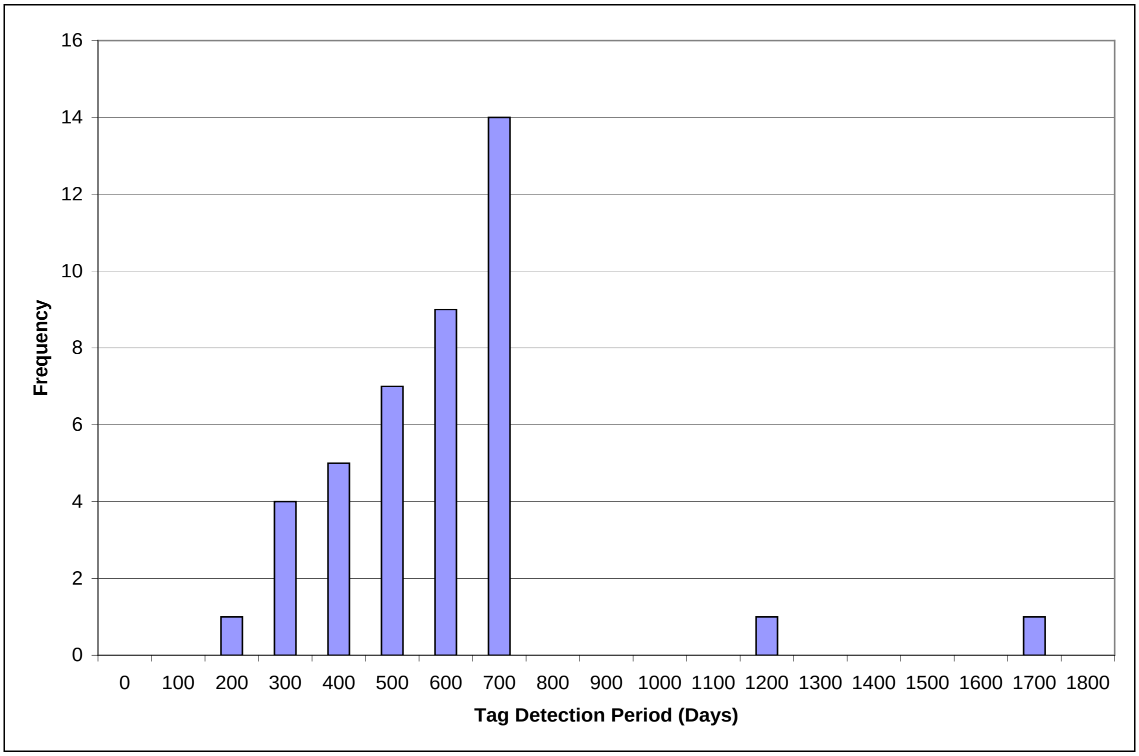


Figure 20. Frequency plot of detection period in days for acoustic tags implanted in bull trout in Ross Lake.

intake ("Ross Dam" receiver). Any fish that were last detected at the intake receiver were considered to have been entrained into the power intakes.

Only two (2) of the 42 tagged fish we tracked in Ross Lake were last detected at the "Ross Dam" acoustic receiver located near the intakes (Table 6). These were a female bull trout tagged at Ruby Creek on Sept. 30, 2009 (A69-1105-1), and a male bull trout tagged at Ruby Creek on Oct. 9, 2012 (A69-1105-13). Both of these fish were implanted with temperature/pressure sensor tags, which allowed us to examine the last detection of these fish in terms of depth.

The first of these fish (A69-1105-1) was detected for 556 days. Close inspection of the data for this fish show it moved from 197 ft (60 m) in depth to the surface of the reservoir at the "Outer Log Boom" receiver on January 28, 2011. This fish showed a zero depth and negative pressure reading, indicating that the fish had been removed from the water. The fish then made two migrations from the bottom to the surface on January 28th. The fish was then detected at the bottom of the reservoir near the Ross Dam on Feb. 2, 2011, where it remained stationary at the same depth through April 9, 2011. The fish was sporadically detected at the same location on May 31, June 22, and June 29, indicating that the tag battery had slowly failed. The lack of any movement from this fish with respect to position and depth for a period of 147 days indicates that the fish was dead at the bottom of the reservoir until the tag battery expired. We determined that this fish died in the reservoir on February 2, 2011, and subsequently concluded that it had not been entrained by the intakes when it was last detected on June 29, 2011.

The second fish that was last detected at the "Ross Dam" receiver (A69-1105-13) exhibited a very different behavioral pattern in terms of depth use compared to the first fish. The second fish moved from the "Outer Log Boom" receiver located in the Ruby Creek Arm portion of the reservoir to the Ross Dam forebay on February 2, 2011. This fish then remained very active as determined through the analysis depth and receiver location data through March 3, 2011. On this day, the fish moved from the downstream log boom to the Ross Lake boat house, and then in front of the Ross Dam intakes. The fish made two vertical migrations during the day, and was actively moving when it was last detected at 9:30 pm at 55 ft (16.7 m) depth in front of the intakes. Based upon these data, we concluded that this fish was entrained into the power intakes at 9:30 pm on March 3, 2011. This particular bull trout was determined to be a "frequent user" of the forebay area of the reservoir, having spent a total of 41 days in the forebay area.

The majority of the tagged bull trout (31 out of 42 tags) were last detected at receivers located near the mouths of Big Beaver Creek, Ruby Creek, Lightning Creek, and Little Beaver Creek (Table 6). These fish were likely migrating into these tributaries to spawn when they were last detected. Many fish (7) were last detected at the NPS log boom ("Outer Log Boom" receiver) located in the Ruby Creek Arm of the reservoir. Based upon analysis of the acoustic tag data, we determined that one (1) bull trout of the 42 tagged bull trout was entrained into the Ross Dam intake.

We also examined the amount of time that the tagged bull trout spent in the vicinity of the Ross Dam intakes during the total period in which they were detected. This was done to determine the amount time during the migratory history of the fish in which they were at some risk of entrainment. We found that 5 of these fish never migrated into the intake area, and that 31 of the fish spent less than 10 days of their migratory history in the vicinity of the intakes (Figure 21). In terms of percentage of their total migratory history, the majority of bull trout (31 out of 42) spent one percent or less of their detection lifespans near the intakes of the reservoir, while six of these fish spent between one and three percent of their detection lifespans near the intakes (Figure 22).

Only five of the tagged bull trout were determined to be "frequent users" of the area of the reservoir near the intakes. These five fish spent between 39 and 164 days in the vicinity of the intakes (Figure 21). Never-the-less, only one of these "frequent users" was determined to have been entrained into the intakes, suggesting that the majority of the fish that frequently move in front of the intakes are behaviorally able to avoid entrainment. Three of these fish spent between 8 and 10 percent of the time near the intakes, while two fish spent 24 percent of their detection lifespans near the intakes (Figure 23). Of the detections near the intakes, most of these (over 50%) occurred during the months of May and October (Figure 23). The least number of detections near the intakes occurred during the winter months of January, February, and March, and the summer months of July and August.

5.1.2.2 Bull Trout Detections within Ross Dam Forebay

The acoustic tagging data were also analyzed to determine the amount of time that bull trout spent in the forebay area of the reservoir to assess the relative risk of entrainment into the spillways of Ross Dam during infrequent spill events. The majority of tagged bull trout (32 of 42) spent less than 10 days of their total detection lifespans in the forebay area of Ross Dam

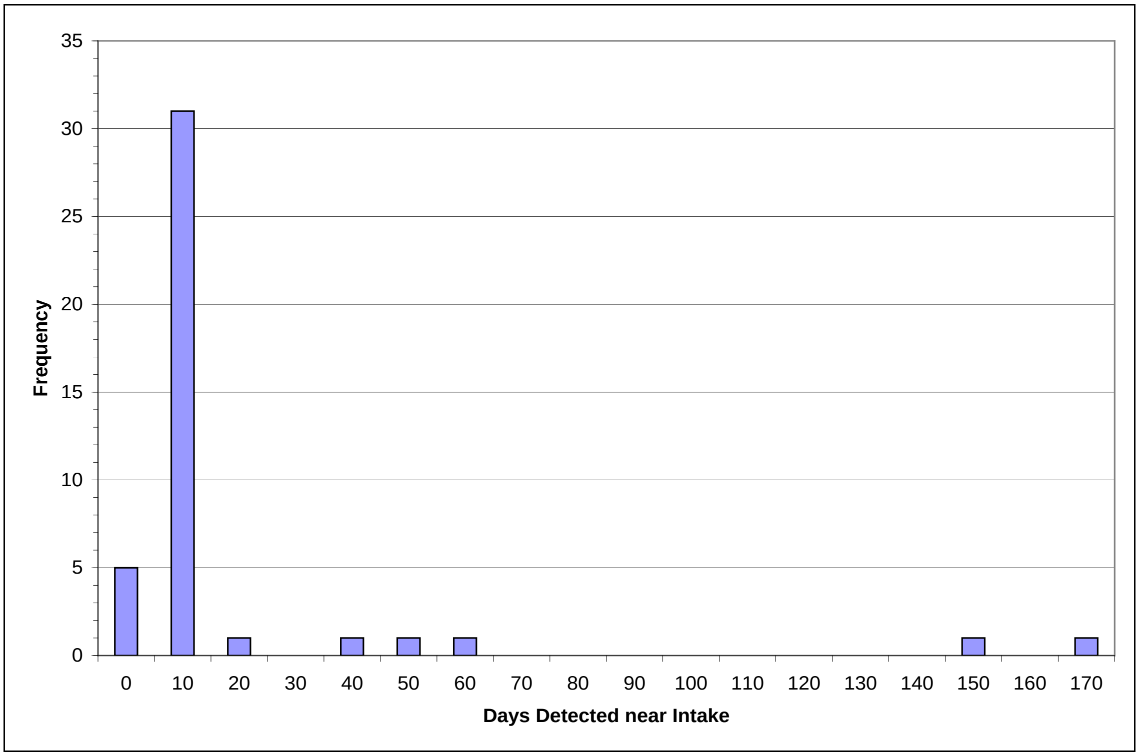


Figure 21. Frequency plot of number of days that individual bull trout were detected near the Ross Lake intake.

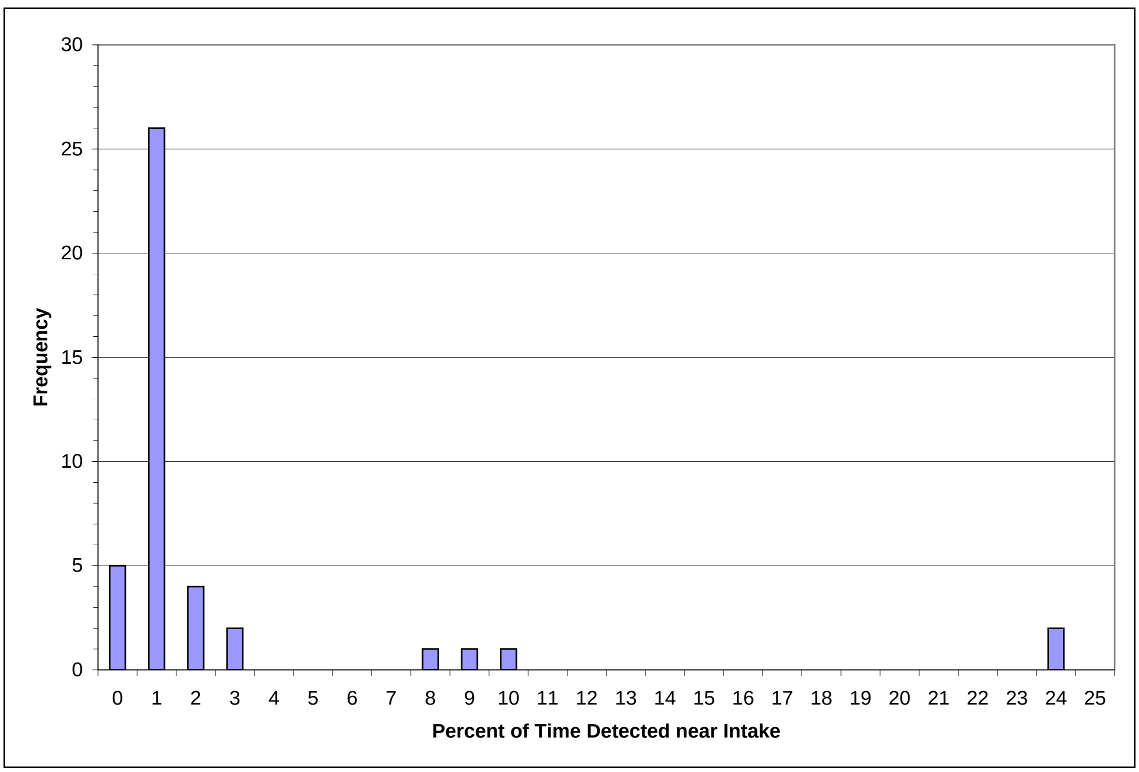


Figure 22. Frequency plot of percent of time that individual bull trout were detected near the Ross Lake intake.

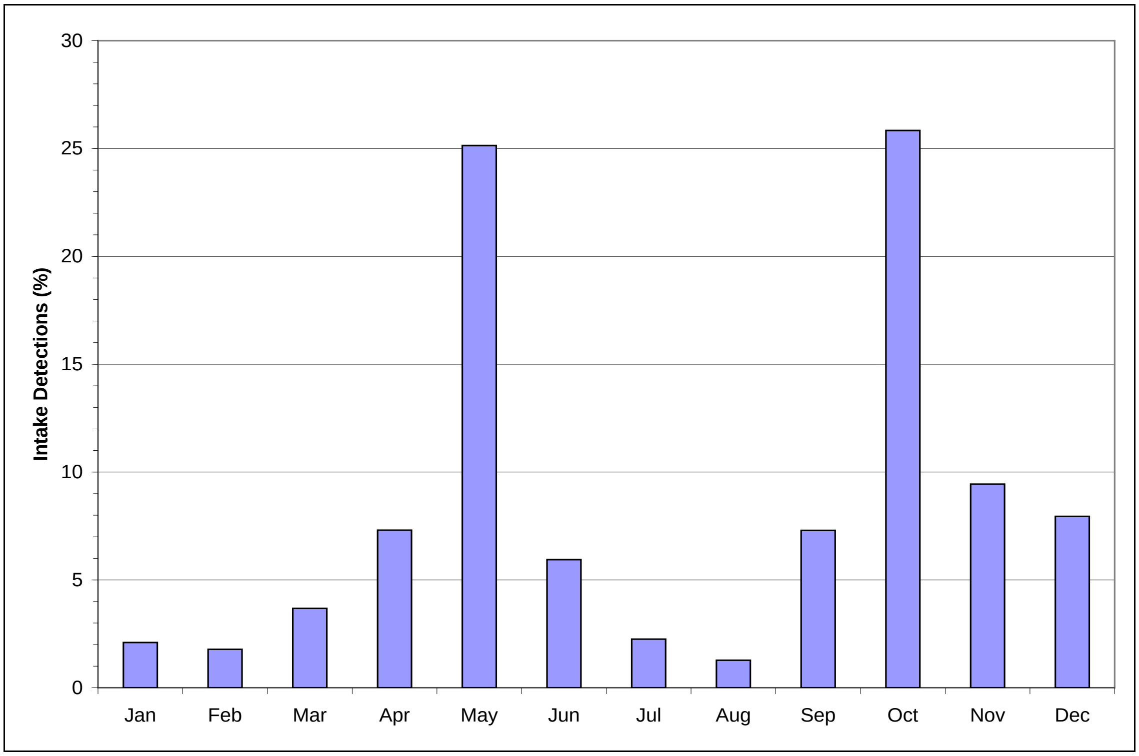


Figure 23. Percent of bull trout tag detections near Ross Lake intake by month.

(Figure 24). Five of the tagged fish spent between 11 and 30 days in the forebay. Only four bull trout were considered to be "frequent users" of the forebay by spending more than 40 days of the detection lifespans in this area. In terms of percentage of time, most bull trout (32 of 42) spent less than one percent of their detection lifespans in the forebay (Figure 25). The four "frequent users" spent between 11 and 24 percent of their lifespans in the forebay. Of the forebay use detections, the majority of these (50%) occurred during the months of May and October. Forebay detections were least frequent from January through March, and from June through September.

These data indicate that most Ross Lake bull trout spend relatively little time in the forebay of the reservoir; for this reason, entrainment rates of these fish into the spillways are probably very low. This conclusion is supported by the University of Washington's genetic study. Of several hundred bull trout genetically sampled in the mainstem river downstream of the Skagit Hydroelectric Project, none were found to have originated from the Skagit River above dams (Smith 2010). This study found that bull trout above and below the Skagit Hydroelectric Project at Gorge Dam can be genetically differentiated with a high level of certainty. However, these genetic findings do not preclude the possibility of Ross Lake fish moving into Diablo Lake, or Diablo Lake fish moving into Gorge Lake, since bull trout in these reservoirs are not genetically distinct.

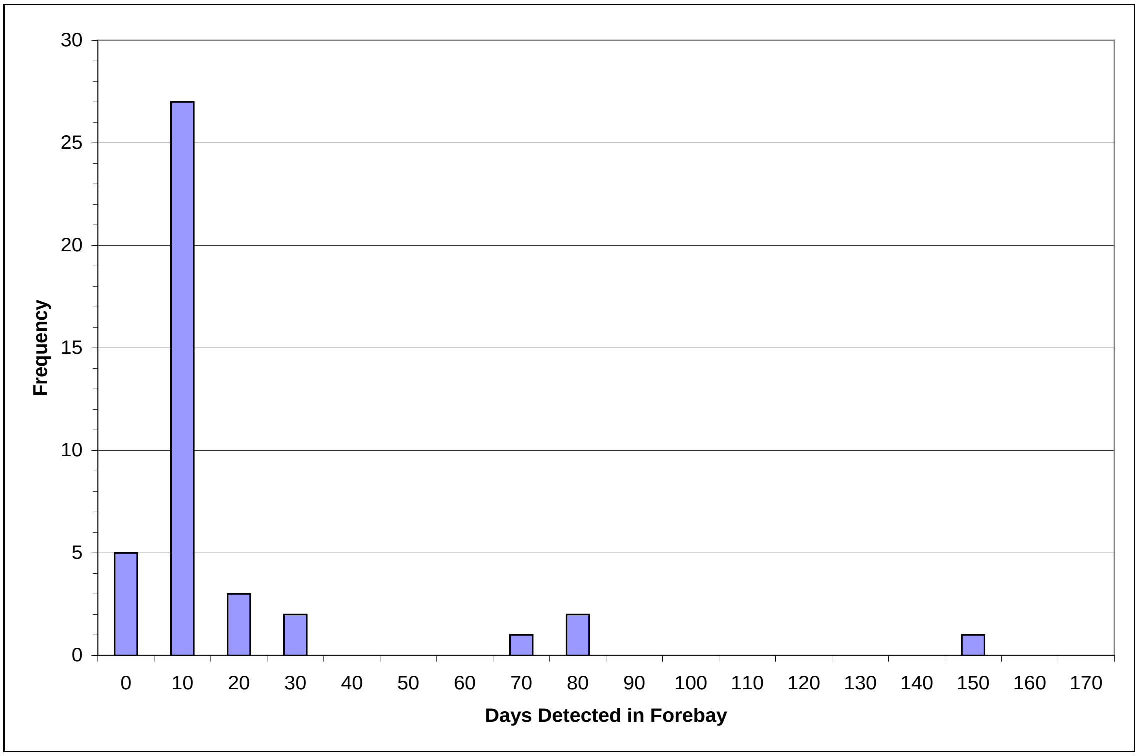


Figure 24. Frequency plot of number of days that individual bull trout were detected within the Ross Lake forebay.

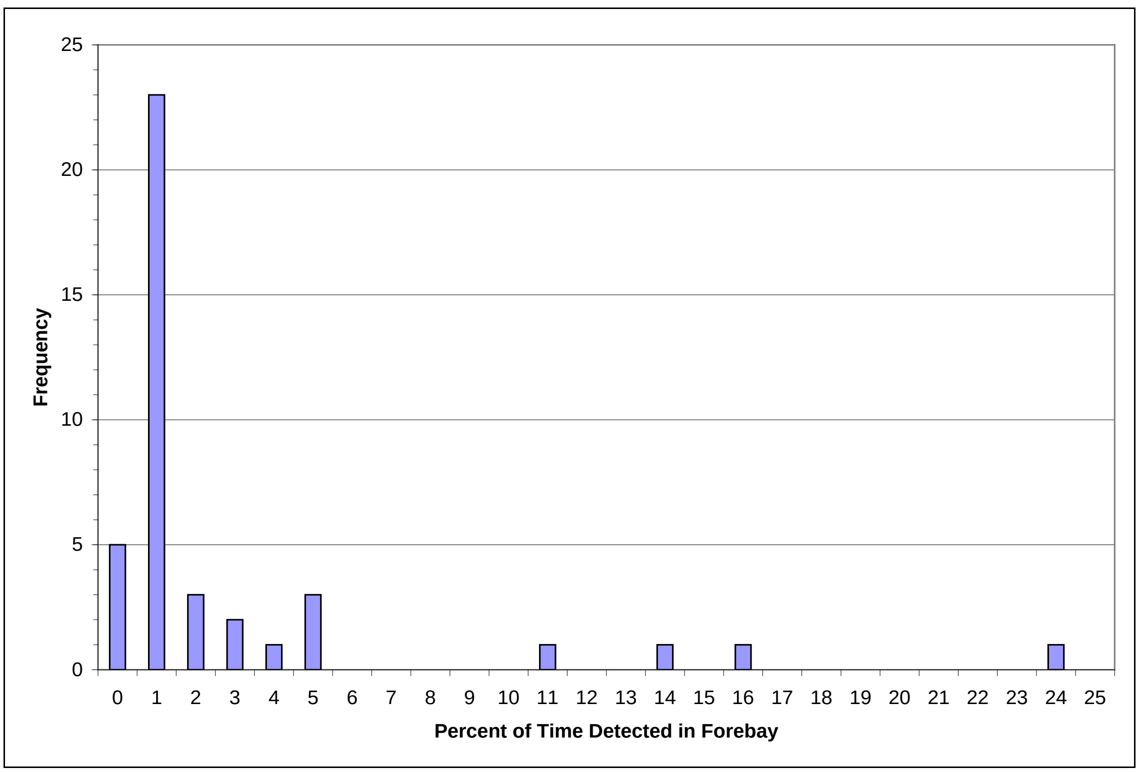


Figure 25. Frequency plot of percent of time that individual bull trout were detected within the Ross Lake forebay.

5.2. Turbine Mortality Rates

There are a total of 10 Francis style turbines at the three Skagit Project powerhouses. Depending on actual generation levels various combinations of these turbines will continue to operate daily through the remainder of the license term. Turbine entrainment and mortality levels are not expected to change over baseline conditions as a result of the proposed actions. In the absence of turbine mortality study data a predictive model was used to estimate turbine mortality rates based on physical and operation variables for three bull trout size ranges.

The risk of mortality associated with fish passage through a turbine is a function of the hydraulic and physical conditions that would be experienced by the fish during the passage. The Department of Energy contracted a study to investigate these various conditions and develop predictive equations for estimating survival given the specific parameters of a given turbine design (Franke *et. al*., 1997). The goal was to develop a tool that could be used to evaluate the potential for producing improvements with new innovative turbine designs. However, the tool can also be used to investigate the probable survival of fish passing through conventional turbine designs. This model was used to evaluate survival of fish passing through the turbines located at the three Skagit Project powerhouses.

What follows is a brief summary of the hydraulic and physical conditions that were found to have potential negative impact on fish during turbine passage.

- **Strike –** Physically contacting solid structures at high velocity. This could include striking turbine blades, wicket gates, stay vanes, or other mechanical or fixed components within the turbine environment.

- **Shear –** Exposure to a transition zone between two bodies of water that are moving at different velocities. If a fish is in a body of water that is moving at a constant velocity then the fish will also move at that velocity and there will be no negative impacts on the fish regardless of the magnitude of the velocity. However, if a fish moves into a transition zone where velocities are significantly varying over small lateral distances then the fish can experience significantly different velocities on either side of its body at the same time. This can tear off scales or rip open portions of the operculum, or even bruise tissue on the fish.

- **Grinding –** Getting caught between moving and stationary mechanical components of a turbine. This can result in injury due to pinching or bruising, or can result in complete severing of the body.

- **Turbulence –**Turbulence is generally associated with areas where large amounts of energy are dissipated through rapid mixing of flows, typical in plunge pools and stilling basins below spillways or water falls. Exposure to turbulent conditions can disorient fish, leaving them at greater risk to predation. Turbulence also occurs within turbine passage environments, generally within the draft tube and the plunge pool where the flow is decelerating and spreading out. However, turbulence in a draft tube is generally less than in a plunge pool. This is because energy lost to turbulence in a draft tube is not available for power production so a well-designed draft tube will minimize the turbulence to maximize the power production.

- **Cavitation –** In localized areas of extreme high velocities the effective water pressure can fall sufficiently below the saturated vapor pressure of the liquid, which causes small air bubbles to form in the flow. As these bubbles move back into more normal pressure zones they rapidly collapse which results in localized shock waves that can be strong enough to cause pitting in the steel blades of turbines. If a fish is immediately adjacent to a collapsing air bubble the associated shock wave can be extremely injurious.

- **Pressure Changes –** Rapid pressure changes typical in passage through high-head turbines can result in bursting of the swim bladder or blood embolisms. Some species of fish are more susceptible to these effects than others due to their physiology, with salmonids being more resistant to problems associated with pressure changes than are perch or bass, for example. The potential for injuries associated with gas embolisms can be compounded by high levels of dissolved gasses in the water (see discussion under the previous bullet).

Franke *et al.*, (1997) examined a number of alternative approaches to estimating mortality from turbine passage. Based on the analysis of measured survival data and knowledge of the theoretical flow field, mortality is implicitly addressed as a function of the energy dissipated in the turbine. As a result, their model does not explicitly calculate the individual effects of turbulence and strong velocity gradients, nor the effects of grinding, scraping or wall strike, but correlates mortality with physical and operational parameters of turbine configuration. The predictive equation for Francis turbines uses turbine size, rotational speed, number of blades, flow rate, and the length of the fish entrained to estimate the probability that a fish of a given size will come near to, or into, contact with a structural element as it passes through the turbine. This model relies on the assumption that strike, shear, grinding and cavitation conditions are all most pronounced very near to, or in contact with, the turbine blades or other fixed components of the turbine.

Importantly, the Franke equations, and specifically the introduction of the parameter lambda (λ), allow for collective consideration of the many specific mechanisms contributing to injury and mortality during turbine passage. Not all of these factors result from simple “strike”. The analysis and resulting correlation of lambda with the geometrical variable NL/D (see definition below) capture the zonal nature of the mechanical and fluid mortality mechanisms associated with the blade zone and introduce the term "blade zone encounter" to replace "leading edge strike” terminology.

The equation also adjusts the estimate for head and mechanical efficiency of the turbine. The magnitude of potential pressure change is directly related to the head across the turbine, while turbulence is typically inversely proportional to mechanical efficiency, with lower efficiencies generally correlating with higher levels of turbulence in the system and higher efficiencies correlating with minimal levels of turbulence.

5.2.1 Predictive Mortality Equation for Francis Turbines

As part of the development of the turbine passage mortality predictive equations, Franke *et al.,* (1997) compiled hundreds of turbine mortality study results. Information was gathered for each site concerning turbine characteristics so that the study results could be correlated to estimated physical conditions experienced. The predictive equation for mortality through Francis turbines was used to estimate the likely survival rate through the many different turbine configurations in use during the mortality studies.

The mortality correlation factor, lambda (λ), relates mortality estimates derived from field studies with the probability that a fish of a given length would encounter injurious hydraulic or mechanical conditions upon passage through the turbine, most notably contact with a turbine blade as discussed above. Subsequent analysis of the degree of correlation of lambda with the non-dimensional variable NL/D across a range of representative projects yielded estimates of the likely range of lambda associated with turbines with similar operational characteristics.
The predictive equation developed for Francis turbines is provided with description below:

$$M = \lambda\left(\frac{NL}{D}\right).\left[\frac{\frac{\cos a_a}{8Q\omega d} + \sin a_a}{\pi\left(\frac{r}{R}\right)}\right]$$

Where:
M = Estimated Mortality rate
N = Number of Turbine Blades
L = Fish Length (m)
D = Turbine Diameter (m)

$Q\omega d$ = Discharge Coefficient = $\frac{Q}{\omega D^3}$
Q = Turbine Flow Rate (m3/s)
ω = Rotational Speed (radians/s)
r = Distance Out from the Axis of Turbine to the Fish (m)
R = Maximum Radius of the Turbine (m)

Therefore, the ratio (r/R) represents the relative position of the fish with:
r/R = 0.50 being relatively close to the turbine hub,
r/R = 0.75 being about mid-span of the turbine blade, and
r/R = 1.0 being at the outer tip of the turbine blade
The angle a_a is obtained from:

$$\tan a_a = \pi.\varepsilon\omega d.\frac{n}{2\,Q\omega d.\left(\frac{r}{R}\right)}$$

Where:
n = Turbine Efficiency

$\varepsilon\omega d$ = Energy Coefficient = $g.\frac{H}{(\omega.D)2}$
With:
g = Acceleration of Gravity (9.81 m/s2)
H = Net Head on Turbine (m)
λ = Mortality Correlation Factor

5.2.2 Application of the Predictive Methodology

Given a suitable selection of mortality studies at projects comparable to the facilities at Skagit Project, the Franke *et al.* (1997) equations were used to derive estimates of turbine passage mortality. The equation above can be rearranged to yield lambda as a function of the term NL/D. When the data for each of the comparable projects is plotted, a linear model can be applied to yield parameter estimates and confidence intervals that allow a range of estimated mortalities for the Skagit Project to be calculated.

Correlation factors (lambdas) were developed only for salmonids. This is because significant differences in body shape and physiology result in different levels of susceptibility to certain hazardous conditions upon passage through turbines. The compilation of field study results and associated turbine characteristics provided by Franke *et al.* (1997) was searched for past studies comparable to the conditions present at SCL's Skagit River Project.

In this case, 40 studies at 18 sites were used to derive lambda values for salmonids at Skagit. The pertinent data are provided in Table 7. The key criteria used to refine the comparable sites were turbine size, species studied, and lengths of fish used in trials.

Table 7. Turbine mortality studies for salmonids at comparable sites[1] (from Franke *et al.*, 1997).

Station	Avg length (mm)	Q (m^3/sec)	# Blades	rpm	H (m)	D_1 (m)	D_2 (m)	B	Est Surv % (1hr)	Effi-ciency	Lam-bda
Alcona, MI	317.0	47.20	16	90.0	13.11	2.54	2.91	1.02	89.40	0.90	0.089
Baker, WA	100.0	15.57	19	300.0	76.20	1.52	1.66	0.46	64.00	0.90	0.514
Baker, WA	100.0	15.57	19	300.0	76.20	1.52	1.66	0.46	72.00	0.90	0.400
Colton, NY	100.0	14.07	19	360.0	80.77	1.50	1.63	0.45	68.00	0.90	0.398
Colton, NY	175.0	14.07	19	360.0	80.77	1.50	1.63	0.45	31.00	0.90	0.490
Colton, NY	250.0	14.07	19	360.0	80.77	1.50	1.63	0.45	7.00	0.90	0.462
Cushman Plant 2 (1960)	58.0	22.65	17	300.0	137.16	2.11	2.21	0.48	77.30	0.90	0.831
Cushman Plant 2 (1961)	89.0	22.65	17	300.0	137.16	2.11	2.21	0.48	72.00	0.90	0.668
Cushman Plant 2 (1961)	127.0	22.65	17	300.0	137.16	2.11	2.21	0.48	52.00	0.90	0.802
E. J. West, NY	100.0	76.46	15	113.0	19.20	3.33	3.79	1.30	65.20	0.90	0.928
E. J. West, NY	175.0	76.46	15	113.0	19.20	3.33	3.79	1.30	90.60	0.90	0.143
E. J. West, NY	250.0	76.46	15	113.0	19.20	3.33	3.79	1.30	95.60	0.90	0.047
Five Channels, MI	108.0	33.05	16	150.0	10.97	1.40	1.60	0.56	95.80	0.90	0.085
Five Channels, MI	317.0	33.05	16	150.0	10.97	1.40	1.60	0.56	70.00	0.90	0.208
Hardy, MI (Unit 2)	108.0	14.44	16.0	163.6	30.48	2.13	2.40	0.79	71.40	0.90	0.522
Hardy, MI (Unit 2)	317.0	14.44	16	163.6	30.48	2.13	2.40	0.79	68.60	0.90	0.195
Higley, NY	100.0	19.11	13	257.0	14.02	1.22	1.39	0.49	70.00	0.90	0.473

Station	Avg length (mm)	Q (m^3/sec)	# Blades	rpm	H (m)	D_1 (m)	D_2 (m)	B	Est Surv % (1hr)	Effi-ciency	Lam-bda
Higley, NY	175.0	19.11	13	257.0	14.02	1.22	1.39	0.49	44.00	0.90	0.504
Higley, NY	250.0	19.11	13	257.0	14.02	1.22	1.39	0.49	61.00	0.90	0.246
Leaburg, OR	100.0	31.15	15	225.0	27.13	2.29	2.59	0.86	95.20	0.90	0.071
Lequille, NS	100.0	9.91	13	519.0	117.96	1.37	1.46	0.34	52.00	0.90	0.725
Minetto, NY	100.0	42.48	16	72.0	5.18	3.53	4.07	1.46	92.00	0.90	0.157
Minetto, NY	175.0	42.48	16	72.0	5.18	3.53	4.07	1.46	91.00	0.90	0.101
Minetto, NY	250.0	42.48	16	72.0	5.18	3.53	4.07	1.46	92.00	0.90	0.063
North Fork, OR	125.0	70.79	15	139.0	41.45	2.95	3.30	1.05	74.00	0.90	0.636
Rogers, MI (Units 1 & 2)	108.0	10.85	15	150.0	11.89	1.52	1.75	0.61	89.90	0.90	0.142
Rogers, MI (Units 1 & 2)	317.0	10.85	15	150.0	11.89	1.52	1.75	0.61	61.20	0.90	0.185
Ruskin, BC	86.0	113.27	15	120.0	39.62	3.79	4.24	1.36	89.50	0.90	0.426
Schaghiticoke, NY	100.0	11.61	17	300.0	43.59	2.03	2.27	0.72	56.00	0.90	0.509
Schaghiticoke, NY	175.0	11.61	17	300.0	43.59	2.03	2.27	0.72	27.00	0.90	0.482
Schaghiticoke, NY	250.0	11.61	17	300.0	43.59	2.03	2.27	0.72	11.00	0.90	0.411
Seton Creek, BC	86.0	127.43	15	120.0	43.28	3.66	4.09	1.29	90.80	0.90	0.398
Shasta, CA (January)	102.0	90.61	15	138.5	115.82	4.67	4.97	1.18	72.00	0.90	1.320
Shasta, CA (January)	254.0	90.61	15	138.5	115.82	4.67	4.97	1.18	71.00	0.90	0.549
Shasta, CA (January)	152.0	90.61	15	138.5	115.82	4.67	4.97	1.18	89.00	0.90	0.348
Shasta, CA (November)	102.0	90.61	15	138.5	115.82	4.67	4.97	1.18	84.00	0.90	0.754
Shasta, CA (November)	152.0	90.61	15	138.5	115.82	4.67	4.97	1.18	69.00	0.90	0.981
Shasta, CA (November)	254.0	90.61	15	138.5	115.82	4.67	4.97	1.18	90.00	0.90	0.189
Vernon, VT/NH	154.0	51.93	15	74.0	10.36	3.96	4.54	1.61	97.40	0.90	0.046
Vernon, VT/NH	143.0	36.25	14	133.0	10.36	1.58	1.82	0.64	85.10	0.90	0.268

[1] Q=turbine flow rate; H=net head on turbine; B = turbine runner height at inlet; D_1= inlet diameter; D_2= outlet diameter of the runner.

The calculated lambda values were plotted versus the non-dimensional ratio NL/D (Figure 26). The solid line is a best fit linear relationship, the dashed lines above and below represent 90% confidence intervals and the red lines represent 90% prediction intervals for parameter estimation. The solid line has an equation of lambda = -0.1118*(NL/D) + 0.554. 90% prediction intervals were used to calculate the probable range of lambda values for fish of any given length passing through the turbines. Table 8 presents the physical and operational characteristics of the

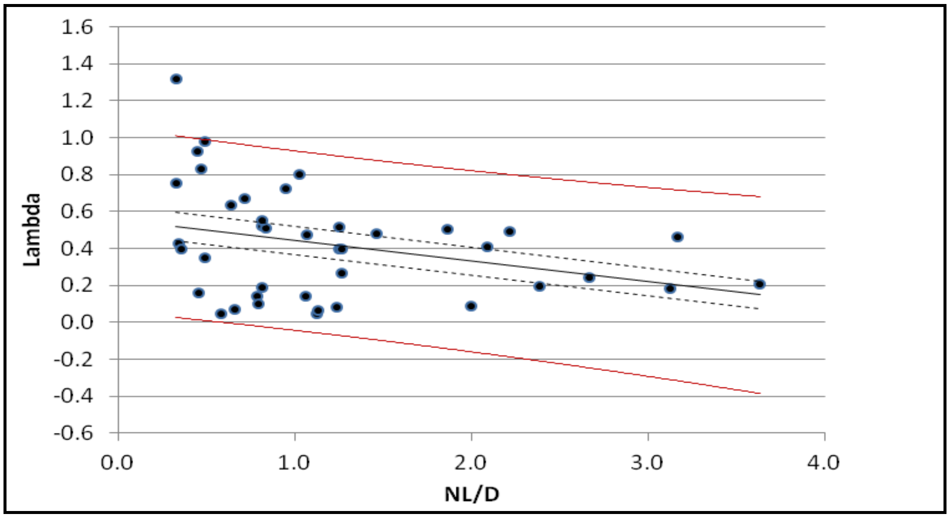


Figure 26. Lambda vs. NL/D; Solid line represents linear best fit, dashed lines 90% confidence interval, red lines 90% prediction interval.

Table 8. Physical and operating parameters for turbines considered in this study. Superscripts indicate identical units.

Power-house	Unit	Number of Blades (N)	Net Head H (m)	Flow Q (m^3)	Speed (rpm)	Inlet Diameter D (m)	Outlet Diameter D (m)	Inlet Height B (m)	Efficiency (%)
Ross	41[a]	15	100.6	80	150	4.52	3.87	0.73	93
	42[b]	17	100.6	85	150	4.27	3.87	0.73	96
	43[b]	17	100.6	85	150	4.27	3.87	0.73	96
	44[a]	15	100.6	80	150	4.52	3.87	0.73	93
Diablo	31[c]	15	97.5	92	171	3.79	3.44	0.73	96
	32[c]	15	97.5	92	171	3.79	3.44	0.73	96
Gorge	21[d]	13	106.7	32	257	2.72	2.26	0.48	94
	22[d]	13	106.7	32	257	2.72	2.26	0.48	94
	23[d]	13	106.7	33	257	2.72	2.26	0.48	93
	24	17	107.9	95	164	4.06	3.45	0.78	94

various turbine designs in use at the three Skagit River Project powerhouses. Calculations based on these parameters (above) assumed operation at peak efficiency under average net head conditions.

5.2.3 Turbine Mortality Estimates for the Skagit Project

A summary of the mortality results for three size classes is presented in Table 9. In all cases the lower 90% confidence bound included zero and thus was not presented. Figures 27, 28 and 29 present mortality estimates across a range of lengths of fish for each of the five types of turbine in use at the three powerhouses.

Table 9. Estimated mortalities for all turbines for 3 fish size classes. Mean and upper 90% confidence interval presented. Lower 90% bound was 0% for all units; superscripts indicate identical units.

Powerhouse	Unit	0.1m (4")		0.3m (12")		0.6m (24")	
		Mean	Upper	Mean	Upper	Mean	Upper
Ross	Unit 41[a]	0.06	0.11	0.14	0.30	0.21	0.53
	Unit 42[b]	0.07	0.13	0.16	0.35	0.22	0.60
	Unit 43[b]	0.07	0.13	0.16	0.35	0.22	0.60
	Unit 44[a]	0.06	0.11	0.14	0.30	0.21	0.53
Diablo	Unit 31[c]	0.07	0.13	0.16	0.35	0.22	0.60
	Unit 32[c]	0.07	0.13	0.16	0.35	0.22	0.60
Gorge	Unit 21[d]	0.08	0.15	0.18	0.41	0.22	0.69
	Unit 22[d]	0.08	0.15	0.18	0.41	0.22	0.69
	Unit 23[d]	0.08	0.15	0.18	0.41	0.22	0.69
	Unit 24	0.07	0.13	0.17	0.36	0.22	0.63

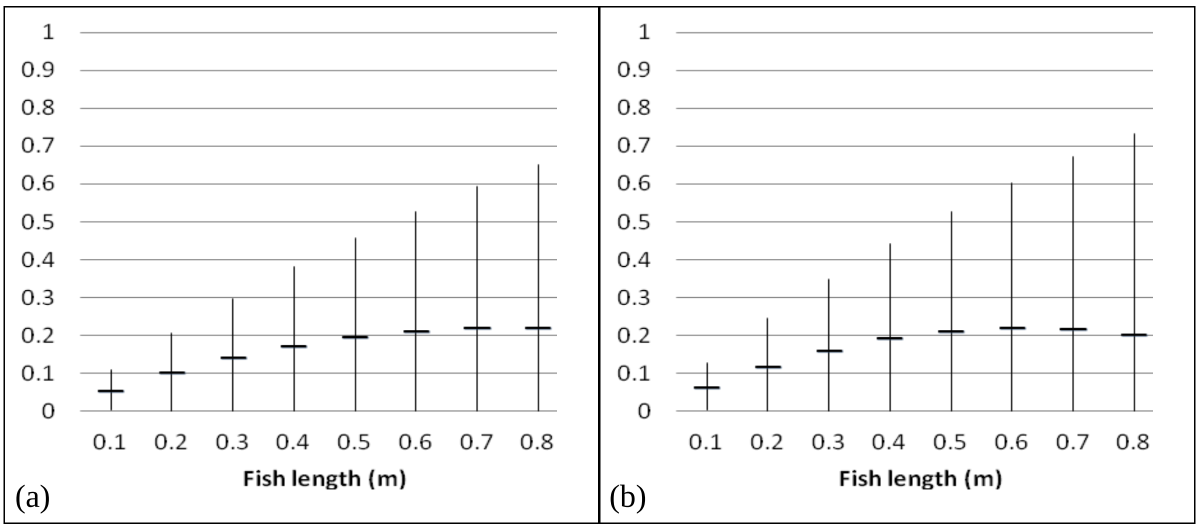


Figure 27. Mortality estimates for Ross Powerhouse (a) units 41 and 44; (b) units 42 and 43. Probability of mortality on the y-axis.

Overall results indicate estimated mortalities are relatively consistent across the entire Skagit project ranging from 6-8 percent for smaller 4 inch fish and 21-22 percent for larger 24 inch fish. The highest relative mortalities resulted from Units 21, 22 and 23 at Gorge Powerhouse. Compared with the other units, these units are smaller, faster rotating units. All things being equal, a fish passing through these units has a relatively greater chance of encountering the danger zones within the turbine than at the other slower, larger units. When charted with turbine mortality levels from comparable hydro projects the worst case mortalities rates from the Skagit Project turbines fall within the expected ranges as shown in Figure 30.

5.3. Spill Mortality Rates

There are 13 spillways at the Skagit Project dams but spilling at any of the three projects typically occurs only 4 to 9 days per year, greatly reducing the risk of spill on fish. The likelihood that fish would pass through one of the spillways is a function of which spillway is

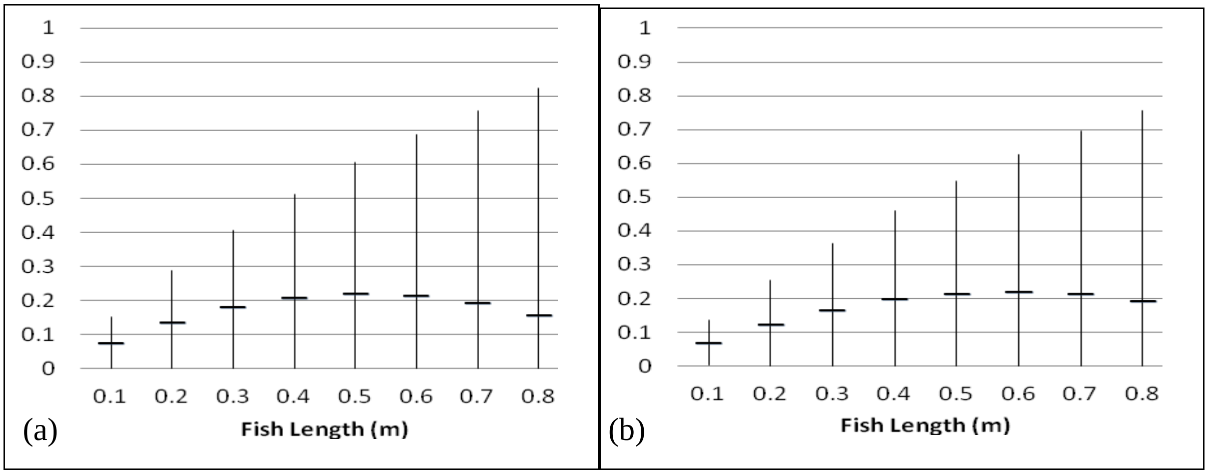


Figure 28. Mortality estimates for Gorge Powerhouse (a) units 21, 22 and 23; (b) unit 24. Probability of mortality on the y-axis.

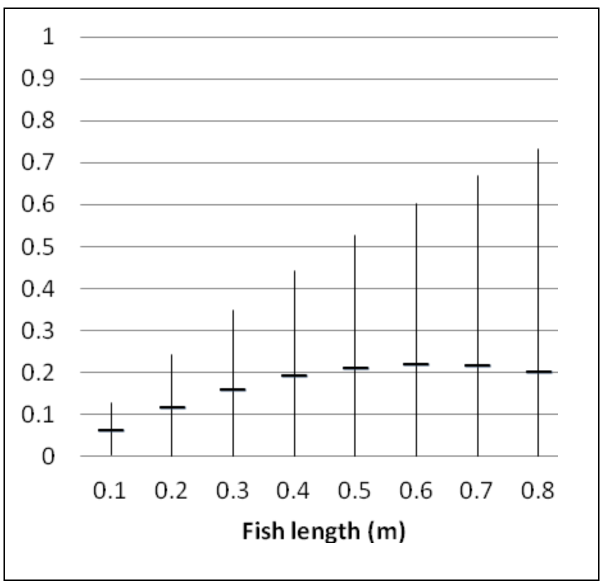


Figure 29. Mortality estimates for Diablo Powerhouse units 31 and 32.
Probability of mortality on the y-axis.

open, the volume of water passing over the spillway, the location of the spillway intake, the volume of the reservoirs, and the migratory behavior and movement patterns of bull trout in the vicinity of the intake. The risk of injury or mortality from spillway passage depends on the conditions experienced by the fish during passage over the spillway, and upon reintroduction to the spilling basin below each dam. When a fish passes over a spillway, it is subject to injury and mortality from the following factors: 1) rapid pressure change; 2) rapid deceleration; 3) exposure to high shear velocities; 4) turbulence; 5) striking force of the fish on the water in freefall; and 6) scraping and abrasion (Ruggles and Murray 1983). These factors were defined in Section 5.2.

It is expected that the greatest impact on fish from spill occurs when the flow passing over a spillway enters the spilling basin, or plunge pool, at the base of a dam. Injury and mortality can also be significant from scraping and abrasion if spillway flow passes over rough surfaces such

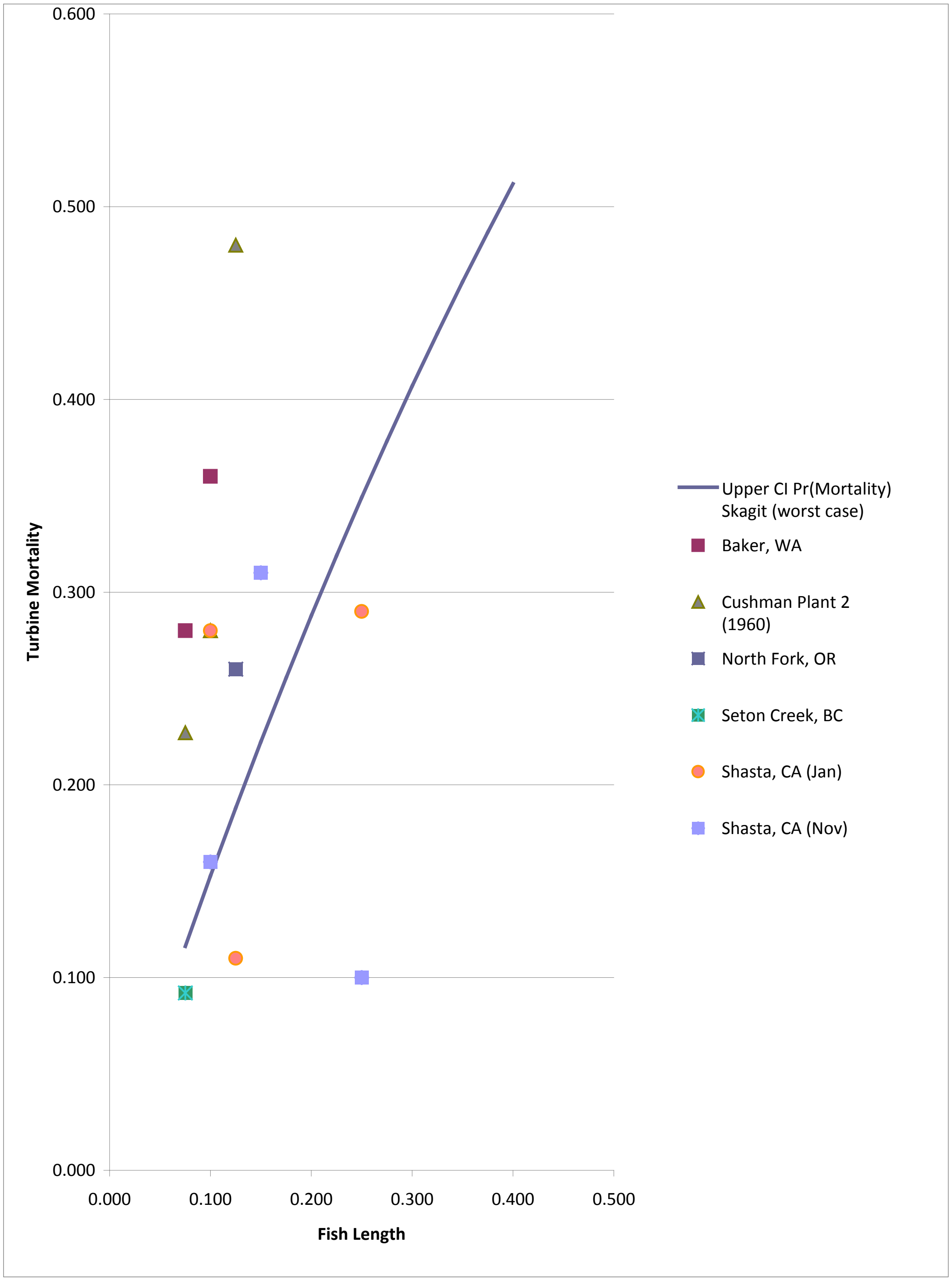


Figure 30. Turbine mortality from comparable projects showing Skagit worst case (confidence interval).

as bedrock. Spill mortality estimates are based on results reported from similar projects in the northwestern region of North America. Therefore, the estimates are provided in terms of probable ranges of mortality.

Spillway mortality studies performed at higher head dams show the highest mortality rates, with mortality increasing with increasing hydraulic head (R2 Resource Consultants, Inc. 1998). Spillway mortality rates are greatest for dams over 200 ft in height, with water velocities in the spillways exceeding 100 ft per second, and result in fish mortality rates typically greater than 50 percent. Studies of spillway passage for juvenile salmonids at Upper Baker Dam, a tributary to the Skagit River which is over 240 ft high, resulted in mortality rates estimated between 50 and 82 percent, depending upon species and spill conditions (Hamilton 1955). Mortality rates exceeding 50 percent also occurred at the spillways of Yale Dam, Washington (Vernon and Hourston 1957) which is over 240 ft in height, and of Cleveland Dam, British Columbia (Schoeneman et al. 1955) which is over 320 ft in height. Mortality rates can also be high at dams where the spillway dissipates onto exposed rocks. This was the case for Elwha Dam, Washington which is over 100 ft high with a mortality rate estimated to be 37 percent due to striking injuries from fish hitting the rocks in the plunge pool (Shoeneman et al. 1955). Mortality rates of 30 percent were estimated for juvenile salmonids passing over spillways and striking exposed rocks below Condit Dam, Washington, which was over 130 ft in height (Seiler and Newhauser 1985) before it was removed in 2011.

Laboratory studies on spill mortality have shown that fish exposed to shear conditions resulting from spill flow velocities less than about 60 ft per second experience little or no mortality. High shear velocities can occur in the area where a spillway enters the stilling basin of a dam. Injuries occur when fish passing over the spillway rapidly decelerate into the stilling basin, which results in de-scaling at moderate velocities, and fatal injuries to the operculum, gills, and head at higher velocities (R2 Resource Consultants 1998). Fish residing in a stilling basin can also be injured or killed if they come in contact with the high velocity stream leaving the spillway. Injury and mortality rates rapidly increase when spill flow velocities increase above 60 ft per second (R2 Resource Consultants 1998). The size of the fish tested also had a significant effect, with fish greater than about 200 mm showing a greater resistance to the shear forces.

Injuries and mortality from exposure to high shear velocities are most likely to occur at Ross Dam, since the spillways focuses water into the plunge pool in a largely coherent stream (see Figure 2). Shear velocity injury and mortality is not likely to occur at Diablo Dam, since water released from the spillway dissipated into a non-coherent stream over a bedrock sill located over 150 ft above the plunge pool (see Figure 6). However, injuries due to scraping and abrasion are likely to be high when fish pass over the bedrock sill located immediately below the Diablo Dam spillways. Also, fish passing over the bedrock sill below the Diablo spillways then experience a freefall drop of over 150 ft, which would likely result in striking force injuries to the fish when they hit the surface of the plunge pool. Shear velocity injuries and mortalities are also unlikely to occur at Gorge Dam, since velocities are attenuated by a training wall located along side of the spillway (see Figure 10). Spillway injuries and mortalities at Gorge Dam are likely to occur if fish strike the spillway training wall, if they are scraped or abraded while moving along this wall, or while passing through high turbulence zones occurring in the lower spillway and plunge pool.

Fish that pass over spillways where the water dissipates into an incoherent stream (i.e., freefall conditions) are susceptible to surface strike injuries when they impact the surface of the plunge pool. Larger fish have the greatest freefall injury and mortally rates, since these fish have relatively low air drag values (their surface area to weight ratio is low), and achieve high terminal velocities. Salmonid fish larger than 30 cm in length were found to have mortality rates of 10 percent when they fell from a height of 50 ft, 30 percent from a height of 100 ft, and over 80 percent from a fall of 300 ft (Regenthal 1956). In contrast, the fins and body surface of small fish provide a high amount friction while moving though the air, and these fish attain low terminal velocities and subsequently have high survival rates under freefall conditions. Juvenile salmonids between 10 and 20 cm in length were found to have low mortality rates that did not exceed 5 percent even when falling from heights greater 200 ft (Sweenie and Ritchie 1981). Fish between 20 and 30 cm in size had intermediate survival rates, with mortality rates reaching approximately 15 percent when falling from heights greater than 200 ft (Regenthal 1956).

Field studies estimating spill mortality have not been conducted at Skagit Project dams. Spillway mortality field study results from other high head dams vary and outcomes are not always predictable. However, there is a strong overall relationship between the spillway height (i.e., hydraulic head) and mortality rates of salmonid fish, as determined from a literature review on spillway mortality for wide range of dams in the Pacific Northwest (R2 Resource Consultants 1998). In general, spillway passage mortality rates are less than 5 percent for dams with spillways less than 100 ft in height, and then increase to approximately 10 percent for spillways up to 180 ft in height. Mortality rates increase rapidly with dam elevation when spillways are more than 180 ft in height. Mortalities over 50 percent are predicted for dams which are 240 ft, and over 90 percent for dams over 300 ft in height.

The high spill mortality rates at these dams are the direct result of high spillway velocities, which increase to the square of spillway height (R2 Resource Consultants 1998). Water passing through the Ross Dam spill gates, which are 377 ft above the plunge pool, would attain a maximum velocity of about 160 ft per second when it enters the stilling basin. Based upon laboratory studies, these velocities would result in mortality rates of 100 percent. However, during an abnormally long spill period, 60 days in 1972, a reported 14 rainbow trout, tagged in Ross, were recaptured in both Diablo and Gorge. This indicates that spills at Ross Dam can result in the successful downstream dispersal of fish (Johnston 1989). In recent years, Ross Dam has spilled rarely, with the vast majority of water from the upper Skagit passing through the Ross Powerhouse into the upstream end of Diablo Lake.

The Diablo Dam spillways are approximately 130 ft above the bedrock outcroppings over which they discharge, which would result in spillway velocities of about 100 ft per second. The fish passing over the Diablo bedrock outcroppings then undergo a vertical freefall of about 200 ft to the plunge pool below. The spillway drop from the crest of Gorge Dam is 125 ft, which would result in velocities of about 90 ft per second.

6 TAKE ESTIMATE OF BASELINE ENTRAINMENT CONDITIONS

Incidental Take estimates for bull trout from turbine and spill mortality were estimated for each reservoir and for the entire Skagit Project under baseline conditions. Methods and assumptions are provided in the following sections.

6.1. Turbine Take Estimation

6.1.1 Ross Dam

Based upon forensic analysis of over 2.4 million data points collected from 42 tagged bull trout in Ross Reservoir, we determined that only one fish was entrained into the power intakes at Ross Dam over the two-year continuous monitoring period. We also determined from a spatial analysis of habitat use in the reservoir that most bull trout spend relatively little time (less than one percent of their detection life spans) near the Ross Dam intakes, and are therefore at low risk of entrainment. Finally, the majority of fish (4 out of 5) that were determined to be "frequent users" of the intake area were not entrained into the intakes, meaning that these fish are capable of behaviorally avoiding entrainment. As described in Section 5.1, the trash racks at Ross Dam may exclude bull trout larger than 600 mm total length from the intakes. We are assuming that bull trout are able to move through the trash racks for estimating entrainment take, but intend to examine the potential exclusion of fish by the trash racks in future studies.

The fraction of entrained bull trout during the two-year monitoring period was estimated by dividing the number of entrained bull trout (1) by the total number of tagged bull trout (42). Therefore:

(1) Fraction Entrained = Number Entrained / Number Tagged

This resulted in an entrainment fraction of 0.0238 for the two-year study period. The entrainment fraction was then divided by the number of years in which entrainment was monitored to calculate the percentage of bull trout entrained per year:

(2) Annual Entrainment % = (Entrainment Faction / Years) x 100

This resulted in an annual entrainment of 1.19 percent.

The number of bull trout entrained per year was calculated by multiplying the annual entrainment percentage by the estimated population size of bull trout in Ross Lake, which is 4,800 adult fish.

(3) Number Entrained per Year = Entrainment Percentage x Population Size

Based upon this, an estimated 57 bull trout are entrained into the Ross Dam power intakes per year. It was assumed that the majority of juvenile bull trout in the drainage remain in their tributary based upon the documented life history of this species, and are not vulnerable to entrainment at Ross Dam.

Finally, the annual mortality of bull trout through the turbines was calculated by multiplying the number of entrained bull trout by the percentage of these fish killed in turbine passage, which is 22 percent for entrained fish that are 600 mm in total length.

(4) Annual Turbine Mortality = Number Entrained per Year x Turbine Mortality Fraction

Based upon this calculation, the estimated annual turbine mortality estimate for Ross Dam is 13 bull trout. Therefore, the annual Incidental Take estimate for turbine mortality at the Ross Hydroelectric Project is 13 adult bull trout.

6.1.2 Diablo and Gorge Dams

Acoustic tracking of bull trout in Diablo Lake and Gorge Lake has not been conducted. However, the abundance of bull trout in these reservoirs was estimated based upon the methods and assumptions described in Section 4.4. It is assumed that the percentage of bull trout entrained in Diablo and Gorge reservoirs would be proportionally greater than Ross Lake due to the greater size of the intakes of these reservoirs relative to their surface areas. First, the intake area of each reservoir was calculated, which is 300 sq-ft at Gorge and Diablo dams, and 1,062 sq-ft at Ross Dam. Next, the ratio of the intake area to the surface area of each reservoir was calculated. And finally, multipliers for Diablo and Gorge reservoirs were calculated by dividing the intake surface area to reservoir surface area ratio by the ratio for Ross Lake. Annual entrainment percentages for Diablo and Gorge were calculated as follows:

(5) Diablo Entrainment % = Ross Lake Entrainment % x 3.6

(6) Gorge Entrainment % = Ross Lake Entrainment % x 13.8

The percentage of bull trout entrained on an annual basin for Diablo Lake and Gorge lakes are 4.3 percent and 16.4 percent, respectively. Applying Equation 3 to these numbers, we estimate that 16 adult bull trout are entrained into the power intakes of each reservoir per year.

Using a turbine mortality value of 22 percent for Diablo and Gorge Dams, the estimated annual turbine mortality is 4 adult bull trout at Diablo Dam, and 4 adult bull trout at Gorge Dam.

As described in Section 5.1, the trash racks at Diablo and Gorge dams may exclude bull trout larger than 450 mm total length from the intakes. We are assuming that bull trout are able to move through the trash racks for estimating entrainment take, but will examine the potential exclusion of fish by the trash racks in future studies.

6.2. Spill Take Estimation

6.2.1 Ross Dam

Spill mortality at Ross Dam was calculated based using the percentage of time that bull trout spend in the forebay area of the reservoir. From the analysis of the acoustic tag data described in Section 5.1.2, it was determined that bull trout spend on average 3.2 percent of their reservoir residency time within the forebay of Ross Lake. This is the zone within which bull trout could be entrained into the spillways during a spill event. Based on the spill frequency analysis described in Section 3.1, spills occur 0.6 percent of the time at Ross Dam on an average annual basis. The percentage of time in which bull trout are vulnerable to spill is obtained by multiplying the average time that bull trout spend in the forebay by the amount of time that spill occurs. On average, bull trout in Ross Lake are present in the forebay while a spill is occurring 0.019 percent of the time.

To calculate the number of bull trout entrained into the spillways during a spill event on an average annual basis, the estimated population of bull trout in Ross Lake (4,800 adults) was multiplied by the percent of time that fish are located in the forebay during a spill event (0.019%). The mean number of adult bull trout entrained into the Ross Dam spillways is predicted to be 1 fish per year. This is a conservative estimate, since it is assumed that all fish in the forebay would be entrained into the spillways during a spill event.

Assuming that mortality rates of adult bull trout passing over the spillways in 100 percent, the annual Incidental Take for spillway mortality at Ross Dam would be 1 adult bull trout per year. Based upon the literature review on spillway mortality described in Section 5.3, there is good evidence that some bull trout survive spillway passage at Ross Dam. However, even with a conservative mortality value of 100 percent mortality value the estimated annual mortality for bull trout entrained into the spillways is low because spill events occur infrequently at Ross Dam, and because bull trout use the forebay infrequently.

6.2.2 Diablo and Gorge Dams

The annual take of bull trout entrained into the Diablo and Gorge spillways during periods of spill was estimated based upon the entrainment rate value calculated at Ross Lake. The Ross Lake spillway entrainment rate value for adult bull trout (0.019%) was adjusted by the percent of time that Diablo Dam (6.2%) and Gorge Dam (5.6%) spill on an annual basis, as calculated in Section 3.1. The Ross Lake entrainment rate value was then multiplied by the ratio of the volume of Ross Lake to Gorge and Diablo lakes. This was necessary to account for the smaller volume of Gorge and Diablo lakes, which would be expected to have higher levels of bull trout spillway entrainment rates compared to Ross Lake. Based upon these adjustments, the annual spillway entrainment rate for bull trout at Diablo Dam would be 3.2 percent, and the annual spillway entrainment rate for bull trout at Gorge Dam would be 31.7 percent.

The number of adult bull trout entrained into the spillways during spill events at Diablo and Gorge Dams was calculated by multiplying the estimated annual spillway entrainment rate at each dam by the population of bull trout calculated for each reservoir (370 adult bull trout in Diablo Lake, and 100 adult bull trout in Gorge Lake). The number of bull trout entrained into the spillways of Diablo Dam each year would be 12 fish, and the number entrained into the spillways of Gorge Dam would be 32 fish.

Annual spillway mortality at Diablo and Gorge dams was calculated by multiplying the spillway mortality rates estimated at each dam by the number of entrained into the spillways each year. The spillway mortality rate for Diablo Dam used for this purpose was 55 percent and the spillway mortality rate for Gorge Dam was 10 percent (see Section 5.3). The resulting estimated number of bull trout killed during spill events at Diablo Dam was 6 fish, and for Gorge Dam was 3 fish. Thus, the annual Incidental Take for spillway mortality is 6 adult bull trout at Diablo Dam, and 3 adult bull trout at Gorge Dam.

7 TAKE ESTIMATE OF PROPOSED ACTION

Incidental take for the two-month spill that will be required during the construction of the Gorge 2nd Tunnel was calculated based upon the number of bull trout killed during average annual spill events at Gorge Dam (3 adult bull trout per year). Spill at Gorge Dam occurs on average of 8.8 days during the year under existing conditions (see Section 3.1). In comparison, the spill duration during the construction of the Gorge 2nd Tunnel is expected to be about 90 days (conservative estimate). Based upon these values, the duration of spill during construction of the Gorge 2nd Tunnel will be 10.2 times greater than that occurring under existing condition. The mortality of adult bull trout during the extended construction spill at Gorge Dam was estimated by multiplying the exiting annual spill mortality value by 10.2. Thus, the estimated Incidental Take for spillway mortality occurring under the proposed action is 32 bull trout.

8 PROPOSED CONSERVATION MEASURES

Three conservation measures are proposed to address Incidental Take of bull trout under current operations of the Skagit Projects, and Incidental Take of this species caused by construction-related spillway entrainment and mortality at Gorge Dam under the proposed action. These measures include: 1) continuing and expanding the acoustic telemetry program in Ross Lake; 2) implementing an acoustic telemetry program in Diablo and Gorge Lakes; 3) deploying receivers immediately below each of the three dams to better detect power intake and spillway entrainment; and 4) completing the construction related spill at Gorge Dam during a period of time when Bull trout presence in the forebay is low. With the exception of measure 4, all of these actions would commence in 2012, and would be conducted for a period of three years following implementation. These actions would have three main objectives. The first is to improve estimates of the number of bull trout being entrained by the power intakes and spillways at the three Skagit dams, and to monitor take in accordance with the Incidental Take Statement (ITS) that will be issued by the USFWS. The second objective is to develop a better estimate on the population size of bull trout in Ross, Diablo, and Gorge reservoirs. The final objective is to minimize take during the construction phase spill at Gorge Dam.

We will submit an annual report to the USFWS over the three-year period described above that summarizes the bull trout acoustic tracking we have conducted in the three Skagit Project reservoirs, and that provides an accounting of Incidental Take caused by intake entrainment or spillway passage that we have documented through the acoustic monitoring program.

8.1. Acoustic Telemetry in Ross Lake

The existing acoustic telemetry program for bull trout in Ross Lake would be continued and expanded as a conservation measure. The current program was implemented in 2009, with 40 bull trout tagged with acoustic transmitters during the fall of 2009. The majority of tags used in 2009 were “pinger” tags, meaning that they transmit the identification code of the fish only. The tags have an expected life span of less than two years, so the majority of the 2009 tags are no longer transmitting at this time. In order to continue and expand the study, an additional 20 bull trout in Ross Lake were tagged with temperature/depth sensor tags during October 2011. These tags were used to improve information on the behavior and habitat use of bull trout in Ross Lake, especially in the forebay and intake are of Ross Dam. These tags have an expected lifespan of about two years, which means that they will be transmitting data until the fall of 2013. Additional tags will be deployed in 2013 to continue the monitoring possible power intake or spillway entrainment of bull trout in Ross Lake. These data, combined with that from the sensor tags deployed in 2009 and 20011, will result in an extensive database on the temperatures and depths used by bull trout in Ross Lake.

Following our consultation meeting with the USFWS in February 2012, the possibility of implementing 3-D tracking capabilities in the forebay of Ross Lake using Vemco tags and receivers was examined. This would allow tracking of how often bull trout swim immediately in front of the power intakes, and during what times of the year this occurs. Vemco was contacted in late February 2012 to discuss the equipment and logistical requirements for 3-D tracking of bull trout in the Ross Lake forebay. Then, SCL's acoustic tagging consultant (R2 Resource Consultants) conducted range sensitivity tests in March 2012 to determine if 3-D tracking was feasible in the forebay. Based upon these tests, Vemco confirmed that 3-D tracking was feasible in the forebay. SCL purchased the equipment required for 3-D tracking in April 2012, and plans to implement this upgraded tracking program during the summer of 2012.

8.2. Acoustic Telemetry in Gorge and Diablo Lakes

Four receivers were deployed in Gorge Lake in March 2012. The receivers are located below the Diablo Powerhouse tailrace; in the free-flowing section of the Skagit River immediately upstream of the Stettatle Creek confluence; in the reservoir immediately below the State Highway 20 bridge crossing; and in the reservoir forebay. A receiver was also deployed in Diablo Lake below the Ross Powerhouse intakes in March 2012. An additional four additional receivers will be deployed in Diablo Lake during the summer of 2012. Two of these receivers will be deployed on buoys in the mid-section areas of the reservoir, one was sited on a lead line near the mouth of Thunder Creek, and one was installed in the forebay area of Diablo Dam.

A total of 10 bull trout in Diablo Lake and 10 bull trout in Gorge Lake will be captured during 2012 and implanted with temperature/depth sensor tags. These fish will then be monitored over a period of two years (life expectancy of tags) to determine how frequently fish migrate into and use the forebay areas of these two reservoirs and if fish pass through the turbines or over the spillways. As of the end of March 2012, a single adult bull trout in Gorge Lake had been captured and tagged.

8.3. Turbine and Spillway Passage Monitoring

An acoustic receiver was deployed in Diablo Lake immediately below the Ross Powerhouse tailrace in March 2012 to monitor the movement of any tagged bull trout that have passed through the Ross Dam turbines or over the spillways. A receiver was also deployed in Gorge Lake immediately below the Diablo Powerhouse tailrace in March 2012 to monitor bull trout passing through the Diablo Dam turbines or spillways. The receiver currently deployed in the Skagit River immediately downstream of the Gorge Powerhouse tailrace will be maintained and monitored to determine if tagged bull trout that have passed through the Gorge Powerhouse turbines or passed the Gorge Dam spillways.

Data from these receivers will be downloaded twice per year to determine if any bull trout tagged in Ross, Diablo, and Gorge lakes have passed through the turbines or over the spillways of any of the three Skagit dams. Spill data for the three dams will be examined, along with the acoustic data collected in the forebay and below the tailrace of each dam, to determine if these bull trout were entrained into the intakes and passed through the turbines, or if they passed over the spillways. We will also be able to determine if the fish survived turbine or spillway passage if the acoustic data indicate that the fish are remaining active following passage. Any tagged fish that remain inactive following turbine or spillway passage will be presumed to be mortalities. A Vemco V100 handheld receiver equipped with a directional hydrophone will be used to survey Diablo and Gorge lakes and area of the river immediately below the Gorge Powerhouse tailrace to determine the location and depth of any tagged bull trout, or expelled tags from dead fish, that have passed through Project turbines or spillways.

8.4. Entrainment Avoidance at Gorge Dam During Construction Phase Spill

Our proposal is to provide a June 1 to August 15 spill release into the Gorge bypass reach during the 2½ month plant shutdown required to construct the tunnel connections. This action will minimize entrainment into the spillway. As described in the BE, there is a construction-related need to spill at Gorge Dam during the later stages of tunnel completion. When the new tunnel and existing tunnel are connected, the project will need to drain the existing Gorge power tunnel and halt hydroelectric production at the Gorge Powerhouse. The June 1 to August 15 time period was explicitly selected for connecting the tunnels to reduce the potential for adverse effects on listed fish species such as bull trout and Chinook salmon. Our acoustic data showed that forebay detections were least frequent from January through March, and from June through September. This suggests that there should be a low incidence of Bull trout in the Gorge forebay during this time period.

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