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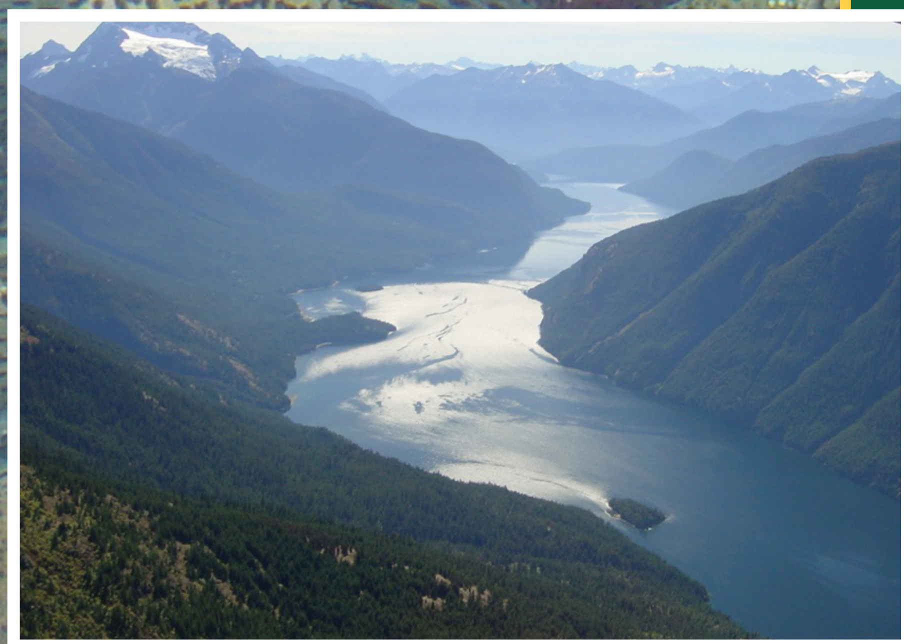
Ross Lake Rainbow Broodstock Program, Upper Skagit Reservoir Fish Community Surveys and Management Plan



by Mark Downen

Washington Department of
FISH AND WILDLIFE
Fish Program
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FINAL REPORT:
ROSS LAKE RAINBOW BROODSTOCK PROGRAM, UPPER SKAGIT RESERVOIR FISH COMMUNITY SURVEYS AND MANAGEMENT PLAN

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EXECUTIVE SUMMARY

The 1991 Settlement Agreement for re-licensing the Seattle City Light upper Skagit hydroelectric project provided for development of a native rainbow trout broodstock from Ross Reservoir to supplement the Gorge and Diablo reservoir trout fisheries. This provision was based on the premise that a paucity of spawning habitat limited fishery recruitment, and on a long history of fish stocking. Moreover, it provided for enhancement of rainbow trout fisheries in waters draining to the lower Skagit River with the stock presumed to be historically present and native to the basin.

The development of an enhancement program for native rainbow trout needed to be consistent with principles of hatchery reform. Given the fragmentation of this upper Skagit population by hydro-electric dams and the lack of functional spawning and rearing habitat in Diablo and Gorge reservoirs, WDFW elected to manage rainbow trout above Gorge Canyon as a single population. This approach is consistent with recent genetic studies of O. mykiss in the Skagit Basin, which reveal strong genetic similarities among the Diablo, Gorge, and Ross Lake populations. Spawning rainbows inhabiting Ross Lake and its tributaries account for more than 90% of the overall population. Although program fish would likely account for at least 50% of the rainbow spawners in the lower reservoirs, they would account for no greater that 10% of the total spawning population even if they accounted for 100%, yielding a maximum proportion of Hatchery Origin Spawners (pHOS) estimate of < 0.1. Equal numbers of wild and F2 rainbow used for broodstock replacement yield a proportion Natural Origin Brood (pNOB) estimate of 0.50, generating a conservative proportionate Natural Influence (PNI) estimate of 0.83.

In 2002 the Washington Department of Fish and Wildlife (WDFW) began implementation of the program. The department focused on four primary activities: broodstock development; fish production; investigation of the life history and status of Ross Lake rainbow trout populations to inform broodstock management; standardized baseline surveys of Diablo and Gorge reservoirs; and the development of management recommendations for enhancing reservoir fisheries.

WDFW assessed several tributaries to Ross Lake including Ruby, Big Beaver, Roland, Dry, Lightning, Little Beaver, and Silver creeks for potential sources of rainbow trout spawners. Larger tributaries proved difficult for live capture of incoming spawners while many of the smaller tributaries lacked populations large enough to provide sustainable collection opportunity. Only two smaller tributaries, Roland and Dry creeks, met both criteria.

The first collection of wild broodstock originated from Roland Creek in June of 1999 when WDFW had conducted a pilot study to evaluate fish collection, spawning, and rearing techniques for this program. Beginning in 2002, WDFW made annual collections of wild broodstock from Roland and Dry creeks. Within three years Marblemount Hatchery conducted its first egg take from hatchery-reared Ross rainbow, and began releasing fish into Diablo and Gorge reservoirs. From 2006 through 2009 production ranged from 200,000 to 345,000 eggs. Annual releases of upper Skagit rainbow trout ranged from 1,000 to 286,000 fish into Diablo and 2,040 to 4,000 fish into Gorge. Several alpine lakes within the Skagit basin also received plants of Ross Lake rainbow between 2006 and 2009.

As the project progressed, the Ross Lake rainbow broodstock program evolved. Annual collections from wild populations were used to produce each cohort of hatchery broodstock which in turn produced the quantity of fish needed to stock the reservoirs. Information concerning age class structure of the donor populations was used to develop the spawning protocols implemented in the hatchery. Annual monitoring of age class structure of the natural Dry and Roland creek populations from 2002 through 2004 indicated that the majority of males spawned at Age 2 and the majority of females spawned at Age 3 with Age 2, 3 and 4 males and females present in the populations. This diversity of spawning ages within the populations and the dominance of different brood years for males and females suggested strong inherent mechanisms for genetic out-crossing. Matrix spawning and outcrossing males and females by brood year were implemented to maximize genetic diversity of fish produced in the hatchery.

The Roland Creek population exhibited substantially larger returns than the Dry Creek population every year from 2002 through 2008 except in 2003 when the escapement for Dry Creek was larger. Escapement for Roland Creek ranged from 276 to 854 for spawners and averaged 470 spawners across a seven year period. Escapement for Dry Creek ranged from 103 to 330 spawners and averaged 216 spawners across the same period. Broodstock collections for 2002, 2003, and 2004 ranged from 80 and 150 fish. After 2004 collection targets were reduced to 25 fish per year based on the recommendations of WDFW geneticists.

Dry Creek consistently recruited spawners earlier, peaked earlier, and exhibited a narrower timing window than Roland Creek, presumably due to its steeper, smaller watershed and associated hydrologic characteristics. The cumulative spawning curves for both populations exhibited multiple peaks, with the initial peak for Dry Creek being its most prominent and the second peak for Roland Creek being its most prominent. In Roland Creek the onset of spawning correlated with increasing stream temperature to about 10°C, and with declining flows modulated by the attenuation of snowmelt runoff.

Prudent fish management necessitated a baseline assessment of abundance, growth and condition of fish in the reservoirs. The WDFW conducted comprehensive surveys of the fish populations in Diablo Reservoir in August 2005 and Gorge Reservoir in 2006 to assess these fish community attributes. These communities were sampled with standardized combinations of variable mesh horizontal and vertical gill nets under a systematic sampling regime. Angler reports of declining growth rates in rainbow trout in Ross Reservoir led WDFW to conduct an index survey there in August 2006 with a standardized combination horizontal gill net sets. Although a fundamentally different research question in Ross necessitated a replicated index sampling approach to maximize sample size, standardization of sampling gear allowed for population comparisons.

Species composition in all three reservoirs was comprised of rainbow trout (*Oncorhynchus mykiss*), non-native eastern brook trout (*Salvelinus fontinalis*), and two native char species, Dolly Varden (*Salvelinus malma*) and bull trout (*Salvelinus confluentus*). However, positive differentiation of Dolly Varden and bull trout was not possible in the field. Therefore they are referred to collectively throughout this report as native char. In Diablo rainbow trout were dominant in number and biomass, comprising 47.1 and 51.9% of the sample respectively. Rainbow trout also dominated the species composition in Gorge and Ross by number, 68.5% and

40% respectively, while native char accounted for the majority of biomass in the catch. In addition to these species, red side shiners (*Richardsonius balteatus*) were documented in Ross Lake for the first time in 2006 where they were captured in small numbers in the fine mesh panels of horizontal gill nets and accounted for 2% by number and less than 1% by biomass. Catch per unit effort for rainbow trout was highest in Ross Lake at 21.1 fish per night followed by Diablo at 13.4 fish per night and then Gorge at 8.9 fish per night.

Age 1, 2, and 3 rainbow trout were well represented in all three reservoirs, and growth rates for these fish were highest through Age 1, nearly identical to fish collected from tributaries to Ross Lake. Growth of Age 2, 3 and 4 rainbow trout collected from Diablo and Gorge fell consistently below Ross Lake rainbow collected in the index survey, but not significantly so. Condition, expressed in relative weight (Wr), was below the national 75^{th} percentile (Wr = 100) for all size classes but acceptable for the post-spawn season in which they were sampled.

Proportional stock densities for native char for Diablo, Gorge and Ross, calculated based on published values for bull trout, were 60 ± 28, 80 ± 22, 77 ± 17 respectively. While Age 1, 2, and 3 native char made up the majority of the catch, several Age 5, 6, 7, and 8 fish were also sampled. Regular observations of char exhibiting phenotypic characteristics of both native char and eastern brook provoked collection of tissue from all char sampled from Diablo in 2005 for future analysis of the relative contributions of Dolly Varden and bull trout to the presumed native char complex of Diablo Lake, and to provide samples for future investigations of the potential for hybridization with eastern brook trout. Time and resources precluded similar collections in Gorge and Ross. The genetic analysis of tissue samples collected from 50 adult char in Gorge Reservoir and over 100 adult char in Ross Lake, collected by Seattle City Light, found that most fish in Ross Reservoir were bull trout, and that the majority of fish in Gorge Reservoir were bull trout (Smith 2011). Bull trout / Dolly Varden hybrids were found to be present in Ross Lake and Gorge Reservoir, while bull trout / eastern brook trout hybrids were also found in Gorge Reservoir.

Catch rates of rainbow trout in Diablo and Gorge support the premise of lower abundances of rainbow trout in the two reservoirs, but may also be explained by increased emigration opportunity due to the spill regimes of the lower reservoirs. Lower growth rates may be influenced by overall cooler water temperatures and shorter water residence times in the lower reservoirs but could also reflect lower system productivity. Regular standardized monitoring of these rainbow trout populations will be necessary to guard against overstocking. Diablo and Gorge reservoirs should be surveyed at least once every four years or one trout generation. Systematic sampling to maximize independence of net set samples should be conducted with variable mesh, multiple panel experimental gill nets. Mesh sizes should range from half-inch stretched to 2 1/2 inches stretched and include at least three intermediate sizes. Calculations of species composition by number and biomass, species distribution, catch per unit effort, stock density indices, length frequency by age class, condition factor expressed in terms of relative weight, and scale-based age class analysis will provide useful information on both community and population level variability and change over time.

Initially, a conservative rate of 80,000 Ross Lake rainbow fingerlings served as a starting point for the Gorge and Diablo Reservoir fish stocking program. This was based on stocking densities applied to relatively unproductive alpine lakes then adjusted to an annual program. Rearing fish at Marblemount Hatchery through the winter and planting larger fish in the spring was intended to reduce competition with eastern brook and predation by sub-adult native char. However, seven years of investigation on Ross Lake have led to more comprehensive understanding of what constitutes a robust native fish community under the conditions imposed by the hydroelectric projects. In the Ross system numerous streams of varying order produce a diversity of habitats and life history opportunities for rainbow trout and native char. Both species use the larger streams to rear for 1 to 2 years. Rainbow trout also use smaller streams and migrate to the lake in large numbers during their first summer.

Gorge and Diablo are extremely limited in both spawning and rearing habitat for rainbow trout. The inability of stream habitats to produce adequate numbers combined with low productivity and perpetually constrained forage to drive growth result in poor recruitment into the fishery. In order to provide a stable fishery, a minimum density of 20 to 30 fish (greater than 300mm TL)/acre would be desirable. A multifaceted management approach that augments multiple trophic levels of these populations would be recommended to achieve these fishery objectives.

Therefore the stocking strategy should employ the use of both fry and fingerlings. Initial stocking rates under this strategy should be approximately 160 fish/acre for 1,200 fish per pound (fpp) fry in September and about 80fish/acre for 200 fpp fingerlings in May, resulting in about 158,000 fry and 79,000 fingerlings for Diablo and 34,000 fry and 17,000 fingerlings for Gorge. An additional 10,000 fry should also be produced for the stocking of alpine lakes within the Skagit Basin and 5,000 for broodstock replacement. The total production would be 303,000 rainbow trout for the program. These initial stocking densities should be adjusted based on growth and condition data collected from the monitoring program and harvest data collected through regular creel survey efforts. Introduction of Ross Lake rainbow trout into Diablo will enhance the sport fishery, reestablish downstream dispersal opportunity for rainbow trout populations from the upper to the lower Skagit, and may increase the long-term viability of rainbow trout in Gorge and Diablo reservoirs.

Founded on a framework of adaptive management, the primary purpose of this program is to enhance recreational opportunity by increasing the numbers and quality of rainbow trout available to anglers in Gorge and Diablo reservoirs. Information gathered during standardized stock assessment surveys will provide metrics for abundance and quality as evidenced by increases in unbiased catch per unit effort estimates. However, direct fisheries measures should also be employed. Pre-stocking catch rates of less than one fish per angler and one fish per hour could certainly be improved. Minimum target catch rates for year round lowland lakes of 2.5 fish/angler would be a meaningful goal for boat anglers on Gorge and Diablo reservoirs.

ROSS LAKE RAINBOW TROUT BROODSTOCK DEVELOPMENT

PURPOSE

In accordance with the Diablo and Gorge Lake Fisheries Section 7.6.4 of the 1991 Skagit Fisheries Settlement Agreement, the purpose of the Diablo and Gorge Reservoir Fishery Enhancement and Ross Lake Rainbow Trout Captive Broodstock Program is to supplement rainbow trout populations in Diablo and Gorge Reservoirs in a manner consistent with the Wild Salmonid Policy (WSP), NPS management policies, and with the Northwest Forest Aquatic Conservation Plan (NWFACP). This program is also intended to meet standards set forth by the Hatchery Scientific Review Group (HSRG).

These policies are largely consistent with one another, emphasizing management directives that conserve of native stocks while minimizing impacts on wild populations. Through a combination of wild fish collection and captive rearing of Ross Reservoir rainbow trout broodstock, the WDFW seeks to develop a sustainable, long-term program that will support the native populations, minimize impacts of cultured fish to wild populations in the basin, and enhance recreational opportunity.

BACKGROUND

Upper Skagit rainbow trout are considered one of the most important native trout stocks in the region. These fish are believed to descend from native summer-run steelhead that at some time in the past were able to ascend natural barriers and colonize the Upper Skagit River Basin (Johnston 1989). Although early surveys of the river led fisheries biologists to conclude that the Diablo Canyon was a barrier to salmon migration upstream, the presence of Dolly Varden, bull trout, and rainbow trout suggested that at certain times, migratory forms of these species may have ascended the canyon. However, compelling evidence suggests the upper Skagit once flowed into the Fraser River, giving rise to a competing hypothesis that native char and rainbow colonized the upper Skagit from the Fraser. Regardless of these species' origins, the construction of Gorge and Diablo dams in 1917 and more significantly construction of Ross Dam between 1937 and 1954, impeded opportunity for downstream migration which could have occurred in the free flowing waters of the Skagit River.

The impounding of the Gorge, Diablo, and Ross reservoirs inundated many miles of river habitat and fragmented upper Skagit fish populations. It also created hundreds of hectares of lake-like habitat for fish and for recreational activity. Partially as mitigation for the loss of river habitat but mainly for the enhanced recreational opportunity the Washington Department of Game, established in 1933, began a long history of stocking rainbow trout into Diablo and Gorge reservoirs. These reservoirs provided limited spawning habitat for rainbow trout and isolation from upstream populations greatly reduced their viability. The broodstocks used by WDG originated in California and were domesticated over long periods in Washington State hatcheries. However, the extensive and diverse spawning and rearing tributaries to Ross Lake precluded the need for supplementation with hatchery trout.

The Ross Lake fishery has always been managed through wild production, and more recently with selective harvest and gear regulations. During the 1980's and 90's, through Washington Department of Fish and Wildlife (WDFW) study efforts and the most recent Seattle City Light (SCL) hydroelectric project relicensing process, several steps were taken to address declining trends in rainbow trout production in Ross Reservoir. Management strategies emphasized approaching carrying capacity through harvest regulation change and habitat access enhancement. In 1989, WDFW concluded that the numbers and life history characteristics of Ross Lake rainbow populations were being adversely impacted by contemporary fish management policies and implemented new seasons, gear restrictions, closed waters, and size and creel limits. The WDFW also identified adverse impacts to the rainbow trout populations caused by manipulations of the environment. Activities of the SCL hydroelectric project contributed to fish losses through spill, drawdown impacts on zooplankton and benthos productivities, reduced fish access to spawning habitat, and redd inundation (Johnston 1989).

These concerns led to a multi-faceted mitigation proposal during the most recent relicensing process. In 1991, final mitigation measures for rainbow trout in Ross Reservoir were agreed upon that focused on restoring access to spawning habitats. Mitigations included inspection and removal of transitory barriers to migration in the drawdown zone and formation of the Ross Reservoir Resident Trout Working Group. The rainbow trout resource in Ross Reservoir continues to be managed for wild production. Co-managers of the resource under US jurisdiction, WDFW and National Park Service (NPS), operate from the Wild Salmonid Policy (WSP) and from the Northwest Forest Aquatic Conservation Plan (NWFACP), respectively. These policies as well as NPS management policies emphasize similar management strategies and require extending principles based on native and wild fish production to include all three reservoirs above the anadromous zone.

The management approach implemented in Ross Reservoir could not be used to address under-seeding of Diablo Reservoir (910 acres) and Gorge Reservoir (240 acres). Fragmentation, fish losses through the dams, inconsistent recruitment from Ross Reservoir populations, inundated riverine rearing habitat, and limited spawning habitat had all contributed to reduce opportunity to fish for and catch rainbow trout in the lower reservoirs. Yet habitat access enhancement was not an option for mitigation of Diablo and Gorge Reservoir fishery impacts due to the paucity of available spawning habitat. In the Diablo system only Thunder Creek was thought to have potential rainbow spawning and in Gorge spawning habitat availability was limited to Stetattle Creek. Some spawning may also occur in the tailraces of the dams. Mitigation for these fisheries took the form of a supplementation program entitled "Diablo and Gorge Lake Fisheries". Section 7.6.4 of the Skagit Fisheries Settlement Agreement provides the implementation and funding guidelines associated with this program. In 1991, $300,000 in Seattle City Light (SCL) relicensing settlement funds were set aside for the enhancement of rainbow trout fisheries through supplementation in Diablo and Gorge reservoirs. However, few specific program goals were outlined; only that up to 400,000 fingerlings derived from native stock could be planted into Ross, Diablo, and Gorge Reservoirs each year. Fish would only be reintroduced into Ross to replace fish taken for the broodstock program and Diablo and Gorge would receive annual plantings.

In June and July of 1999, WDFW conducted a pilot study to evaluate fish collection, spawning, and rearing techniques for the program. Hatchery personnel collected 35 fish and 4,500 eggs from Roland Creek, an east bank tributary to Ross Reservoir. Fish were dip netted from the creek and held in a net pen at the tributary mouth until ready to be live-spawned. Eggs were transferred to the Marblemount Hatchery facility and fry were reared until the spring of 2000 when a scouring event on Roland Creek led to the release of the fish back into their originating water. In 2002 WDFW developed a comprehensive proposal for implementing this element of the licensing agreement.

PROGRAM OBJECTIVES

In order to fulfill the purpose of the Diablo and Gorge Reservoir Fishery Enhancement and Ross Lake Rainbow Trout Captive Broodstock Program, several program objectives have been outlined. Program activities such as reservoir fish community surveys and monitoring, creel surveys and broodstock collection activities were consistent with the following objectives.

1) Supplement rainbow trout populations in Diablo and Gorge Reservoirs in a manner consistent with HSRG, the Wild Salmonid Policy, NPS management policies, and with the Northwest Forest Aquatic Conservation Plan.
2) Emphasize conservation of native stocks and minimize impacts on wild populations through a combination of wild fish collection and captive rearing of Ross Reservoir rainbow trout broodstock.
3) Develop a sustainable, long-term program that will support the native populations, minimize impacts of cultured fish to wild populations in the basin, and enhance recreational opportunity.

Mitigation for project impacts and resource enhancements in the Ross Lake drainage has focused primarily on increasing fish access to spawning habitat. The goal of WDFW's Ross Reservoir fish management program continues to be expansion of the rainbow trout populations through enhanced utilization of available spawning and rearing habitat. Mitigation for project impacts and enhancements of fisheries in Diablo and Gorge Reservoirs however, has taken the form of supplementation as outlined in the Skagit River Hydroelectric Project (FERC No. 553) Fisheries Settlement Agreement. Supplementation in the lower reservoirs has the potential to generate increased and consistent angling opportunity, which may relieve pressure on the populations of Ross Lake as well by potentially reducing fishing effort and harvest there. This is a particularly relevant issue since Endangered Species Act (ESA) protection of bull trout has eliminated harvest of this predator, which until the recent appearance of redside shiners in the upper Skagit watershed, had been largely dependent on the rainbow trout forage base.

In order to develop a supplementation program consistent with the HSRG, WSP, NPS management policies and the NWFACP a broodstock with native origins needed to be developed and maintained that minimized inbreeding, disease transfer, domestication, and interaction with wild populations. The overall population structure throughout the system of reservoirs had to be examined to determine the extent of reproductive isolation and genetic diversity within and among major spawning tributaries. Potential donor stocks required sufficient numbers in order to provide genetically diverse parents while remaining robust despite the harvest of gametes.

Sterilization of planted fish was considered as a valid option where wild populations existed in waters managed through supplementation (Hindar et al. 1991) but Ross Lake rainbow were considered a better alternative due to their historic presence in the watershed. Finally, hatchery influences on the broodstock have been minimized by utilizing fish culture practices that imitate natural growth rates, age class mixing, and density management and by maintaining a genetic linkage to donor stocks.

DEVELOPMENT

Upper Skagit rainbow trout constitute an important native population on the west side of the Cascade Mountains. Perhaps more appropriately viewed at a meta-population, it represents a genetically unique and diverse resource worthy of high standards regarding protection and conservation. Therefore any supplementation program developed for the purposes of harvest should meet or exceed standards set forth by the HRSG. Upper Skagit rainbow trout have not been assigned to any Evolutionarily Significant Unit (ESU) or Demographically Independent Population (DPS). However, the Ross Lake rainbow broodstock program has been developed to meet criteria of an integrated program for a Primary Population.

Given the fragmentation of this upper Skagit population by hydro-electric dams and the lack of functional spawning and rearing habitat in Diablo and Gorge reservoirs, WDFW has managed rainbow trout above Gorge Canyon as a single population. This approach seems consistent with recent genetic studies of O. mykiss in the Skagit Basin, which reveal strong genetic similarities among the Diablo, Gorge, and Ross Lake populations (Kassler and Warheit 2012). Spawning rainbows inhabiting Ross Lake and its tributaries account for more than 90% of the overall population (Johnston 1989). Although program fish likely account for at least 50% of the rainbow spawners in the lower reservoirs, they would account for no greater that 10% of the total spawning population even if they accounted for 100%, yielding a maximum proportion of Hatchery Origin Spawners (pHOS) estimate of < 0.1. Equal numbers of wild and F2 rainbow used for broodstock replacement yield a proportion Natural Origin Brood (pNOB) estimate of 0.50, generating a conservative proportion Natural Influence (PNI) estimate of 0.83.

The initial proposal for establishing a supplementation program for Diablo and Gorge reservoirs began with identifying the Ross Reservoir rainbow trout stock as the obvious candidate for this program. Several tributaries of Ross Reservoir have historically harbored populations with sufficient numbers so as not to exceed harvesting sex products from more than 10% of the annual spawning population (**TABLE 1**). The largest tributary in the system, the Ruby Creek drainage, has not been surveyed for spawning fish but accounts for as much as 47% of the total fry contribution into the reservoir from US tributaries (Wyman 1975).

TABLE 1. Numbers of spawning rainbow trout in tributaries with average returns exceeding 500 spawners (Johnston 1989).

Tributary	1991	1992	1993	1994
Lightning	51	1554	963	604
Roland	107	597	1012	1067

Fish Collection

Several locations were explored for potential sources of spawning rainbow trout during June and July of 2002. These included three larger tributaries, Big Beaver, Lightning and Ruby creeks, and several smaller tributaries including Pierce, Silver, and Hozomeen creeks (**FIGURE 1**). Seining the arms of the larger creeks proved unsuccessful due to submerged debris. Snorkeling counts were conducted at the mouths of Lightning and Ruby creeks each week to determine entry timing and to attain a general sense of the magnitude of these populations (**FIGURE 2**). Later gill net sets at the mouths of these streams indicated fish were staging there prior to ripening, whereas fish tended to enter the smaller streams ready to spawn.

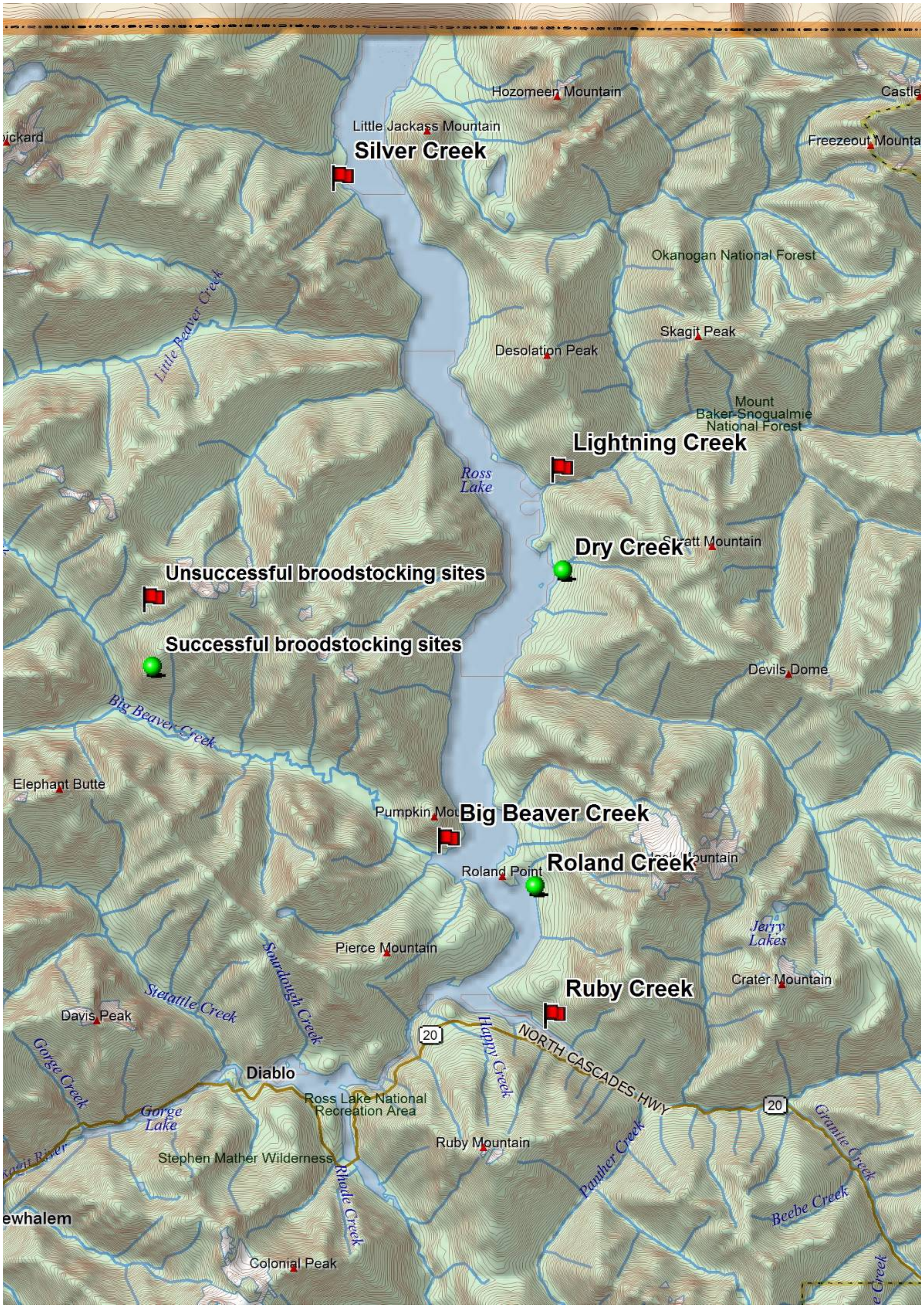

FIGURE 1. Locations throughout Ross Lake where WDFW explored rainbow trout broodstocking options. Green symbols represent successful broodstocking sites while red represent unsuccessful sites.

Most of the smaller tributaries did not harbor sufficient numbers of spawning rainbow to provide for gamete collection. All spawning fish collected were from Roland and Dry creeks where numbers of observed spawners were monitored. Numbers of fish observed do not include numbers of collected fish (**TABLE 2**).

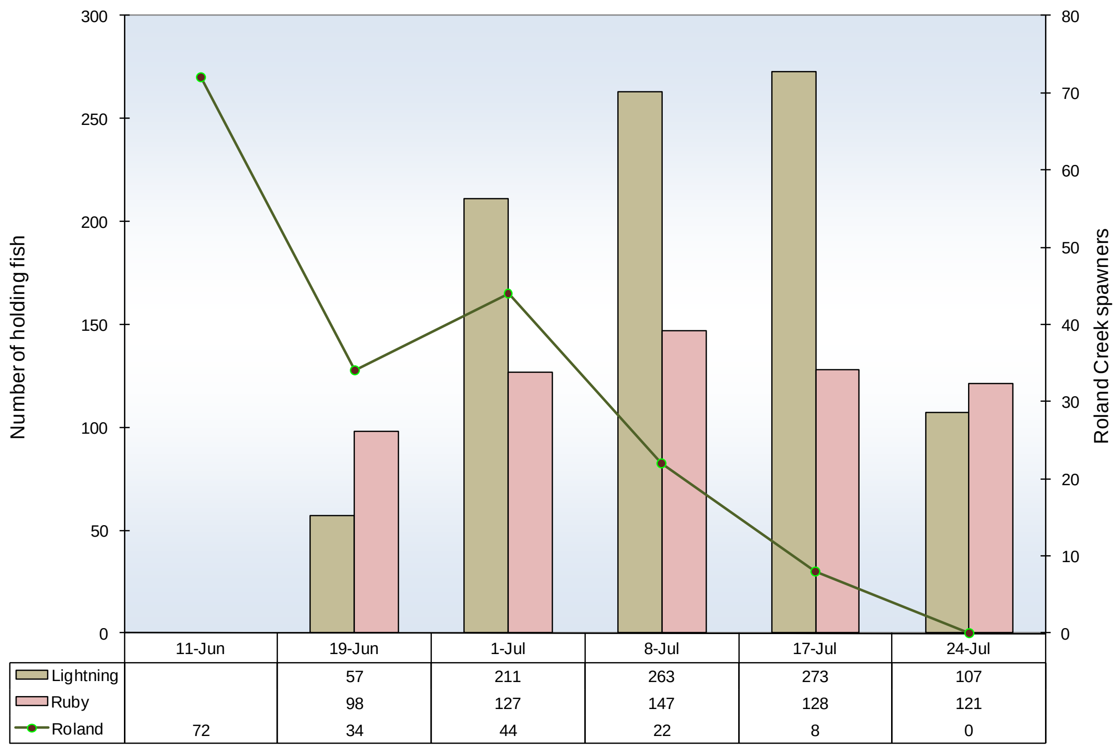

FIGURE 2. Relationship of snorkeling counts of holding rainbow trout at the mouths of Ruby and Lightning Creeks and spawning curve of Roland Creek rainbow in summer of 2002.

TABLE 2. Date, location and number of fish observed on spawning surveys during the 2002 spawning season.

Date	Water	# Observed	#Collected
6/19/2002	Roland	35	20
6/26/2002	Roland, Dry	52, 17	23, 5
6/28/2002	Roland	17	12
7/02/2002	Roland	84	42
7/09/2002	Roland	73	42
7/17/2002	Roland	15	5
	Total	276	149

Different collection methods were assessed in order to develop the most efficient means of collection while maintaining minimal impact on natural spawners and their habitat. In 2002, seining and dip-netting were used. In 2003, a temporary weir was installed at the mouth of Roland Creek so that disturbance to spawning habitat above would be minimized and fish spawning in Roland could be enumerated. Fish collected from Dry Creek were dip netted in the lower 20m of the stream below the majority of spawning habitat (**TABLE 3**).

TABLE 3. Date, location and number of fish collected from Roland and Dry creeks, Ross Reservoir, during the 2003 spawning season.

Date	Water	Spawned		Passed		Surveys
		F	M	F	M	
06/11/2003	Roland	13	13	18	22	75 observed above weir
06/13/2003	Roland	8	8	22	17	
	Dry	7	7	5	14	23 observed above collection zone
06/15/2003	Roland	2	2	17	11	
	Dry	12	12	11	16	86 staging at creek mouth
Totals		42	42	73	80	
Estimated egg take		16,800				

By 2004, a collection method was developed that protected the majority of spawning habitat from intrusive sampling while allowing efficient collection over the course of the run. Prior to the entry of rainbow trout to Dry and Roland creeks WDFW staff conducted annual habitat surveys to assess transient blockages to upstream migration and qualitative changes in spawning habitat. Dry and Roland creeks form dynamic habitats where volatile flows interacting with large amounts of coarse woody debris contributed to high variability in the amount and quality of spawning habitat on annual basis. Each season the collection zone would be based on the amount of available habitat and in season adjustments for broodstock collection goals were made based on correlated spawning surveys (**FIGURE 3**).

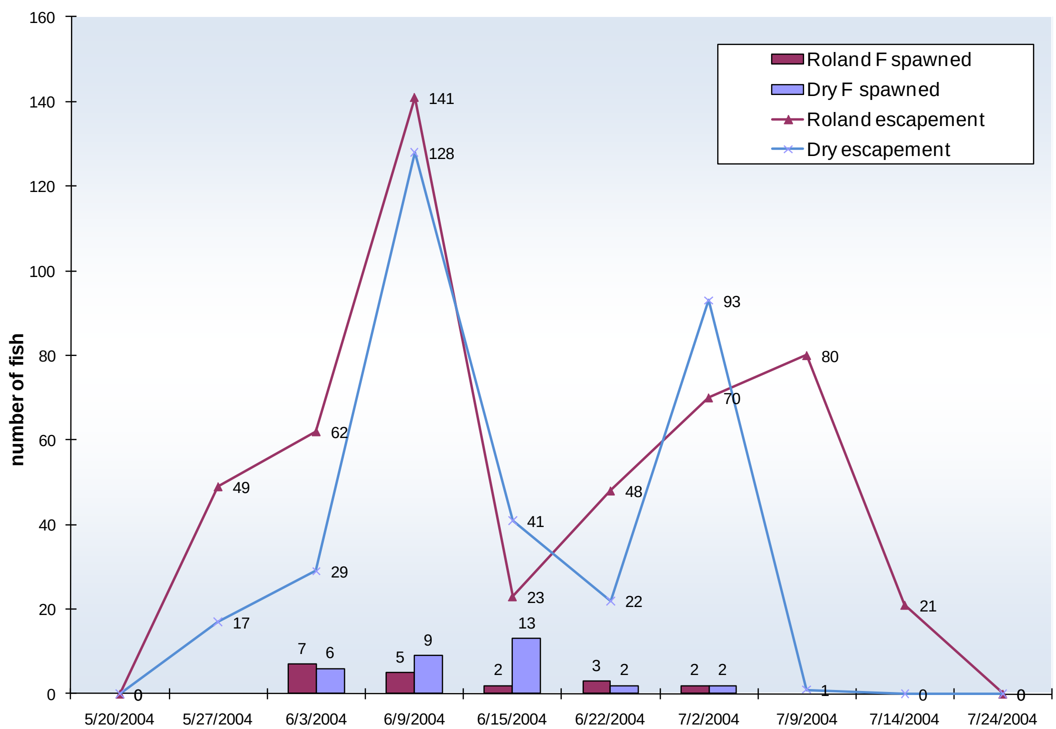

FIGURE 3. Relationship of live fish counts in Roland and Dry creeks and live broodstock capture in 2004.

Refinements related to broodstock management further reduced our impacts on spawning populations. Consultation with WDFW and US Forest Service geneticists has led to the conclusion that a small but frequent infusion of genes will maintain connectivity between populations of wild and hatchery stocks and will help offset selective pressures of the hatchery environment. Therefore, captive broodstock would receive annual infusion of wild Ross Lake rainbow genes. Each spring 10 to 50 fish will be collected from the donor stock tributaries and gametes would be transported to the hatchery to be spawned with hatchery stock.

Spawning

Of 149 fish collected in 2002, WDFW staff spawned 46 females and 46 males. The remaining fish were not spawned due to their failure to mature during the spawning period. Holding unripened spawners in net pens on the reservoir caused the fish reabsorb their gametes, indicating the importance of stream water temperature characteristics in the maturation and ovulation of Ross Lake rainbow trout. Two fish were sacrificed to determine sexual maturity, and all other fish were released alive into Ross Reservoir.

Of 237 fish handled in 2003, WDFW staff spawned 42 females and 42 males. Fish were spawned from a portable net pen on site, but not held longer than 24 hours. The remaining fish were not spawned due to need to provide adequate escapement to spawning habitat above the collection sites. The 2003 contribution of Dry Creek fish to the broodstock gene pool was much greater than in 2002 when the population was first discovered.

Subsequent to these first two years of experimentation and methodology development, WDFW engaged in more frequent collections focused in shorter reaches. Eggs and sperm were collected in groups of five in small airtight containers then transported on ice back to Marblemount hatchery.

Production

WDFW personnel developed specific protocols for mating and holding of the broodstock. Two raceways were identified at the WDFW Marblemount Hatchery for holding four age classes of captive broodstock (1,000 fish per brood year) and production numbers of as many as 300,000 fingerlings. One raceway was dedicated at the Marblemount facility to the four year classes of broodstock separated by screens, and another raceway was dedicated from March through May for yearling production. Both raceways receive sufficient well water (318 gpm) throughout the year to prevent the exposure of the broodstock or production fingerlings to diseases carried in surface waters. Indoor facilities for incubation, hatching and early rearing on pathogen-free water are more than sufficient according to WDFW hatchery staff. Rainbow trout were isolated from other species and stocks through accommodation in reserved vertical stack trays, shallow troughs, and ponds.

Eggs and sperm were taken from live fish, placed into individually labeled containers at the point of collection and transported in iced coolers to the Marblemount hatchery. Due to the sensitivity of eggs to handling, hatchery personnel estimated the number of taken eggs as being 500 per female for 47 females totaling 23,500 eggs. Fully gravid females probably contained more eggs, but many of the females collected were already partially spawned. Since eggs are sampled for numbers of eggs/gram, weighed in mass, then divided by the number of females sampled, this fecundity estimate is probably low.

In the first year, 2002, hatchery fish culture practices had to be developed and adapted to this new stock with inherently wild characteristics. Losses were high initially with egg to fry mortality approaching 80% (**TABLE 4**). These losses were attributed to losses of activated sperm due to transport time, difficulties estimating numbers of alevins in the hatchery due to their susceptibility to handling stress, and losses from the alevin to fry stage resulting from the sensitivity of fish to premature feeding. Even within a given egg-take week, fish size and emergence timing varied somewhat, making the more premature fish in a given group susceptible to fungal infection. However, after initial high losses, survival from fry to fingerling improved to nearly 82%.

TABLE 4. Life stage-specific numbers and mortality of rainbow trout collected and reared at Marblemount Hatchery in 2002.

Take Date	Green Eggs	Loss	Eyed Eggs	Loss	Alevins	Loss	Fry	Loss	Yearlings
03-Jul	10,000	0.38	6188	0.14	5,296				
10-Jul	11,000	0.38	6787	0.33	4,574				
17-Jul	2,000	0.17	1651	0.88	198				
24-Jul	500	0.25	377	0.99	5				
Total	23,500	0.36	15,003	0.33	10,073	0.53	4,750	0.80	3,905

Mortality improved at every life stage in 2003 yielding cumulative mortality from green egg to fry of 40% (**TABLE 5**). As in 2002, highest losses occurred at the green and eyed egg stages, 17.3 and 19.8% respectively. Water temperature and fungus were likely contributors to loss.

TABLE 5. Life stage-specific numbers and mortality of rainbow trout collected and reared at Marblemount Hatchery in 2003.

Take Date	Green Eggs	Loss	Eyed Eggs	Loss	Alevins	Loss	Fry	Loss	Yearlings
11-Jun	5,200	0.28	3,720	0.22	2,910				
13-Jun	5,200	0.18	4,260	0.27	3,131				
16-Jun	5,600	0.62	5,250	0.13	4,570				
Total	16,000	0.17	13,230	0.20	10,611	0.11	9,474		

Once F1 captive brood came into production in 2006, Marblemount hatchery began producing more than 200,000 rainbow trout eggs each year for release into Gorge and Diablo reservoirs.

Wild fish collections averaged 18 males and 6 females annually from 2006 through 2009 and were spawned with equal numbers of F2 captive broodstock to produce the next year class brood replacement fish. Approximately 400 males comprised of 60% Age3, 38% Age 4, and 2% Age

5, and 400 females comprised of 37% Age 3, 46% Age 4, and 17% Age 5 were spawned each year to meet the production goal of 300,000 eggs (**TABLE 6**).

TABLE 6. Age composition and egg takes of Ross Lake rainbow trout spawned at Marblemount Hatchery from 2006 through 2009.

	Wild		Age 3		Age 4		Age 5		Eggs	Brood eggs
	M	F	M	F	M	F	M	F		
2006	22	10	238	187	169	232	0	0	339,670	1,970
2007	28	0	260	146	57	120	24	103	202,902	0
2008	8	6	282	146	143	266	11	26	280,140	3,000
2009	15	5	57	120	165	123	7	148	343,592	4,221
								Total	1,166,304	
								Average	291,576	

Upper Skagit rainbow trout constitute an important population due to their genetic distinctness and diversity (Pflug et al. 2013).

Growth

In 9 months 2002 brood Ross rainbow fry grew from approximately from 5000 fpp in September to 130fpp the following June. Water temperature was a constant 48^{o} F and likely a limiting factor for growth of these fish. In 18 months the 2002 brood year grew to 60 fpp with total lengths ranging greatly from 72 mm to 185 mm (**FIGURE 4**). Growth was monitored and compared with fish sampled in wild environments of the Ross drainage the following year. Although the 2003 brood grew faster than the 2002 brood class, growth rates for Ross rainbow in the hatchery were far below the rates of other domesticated stocks.

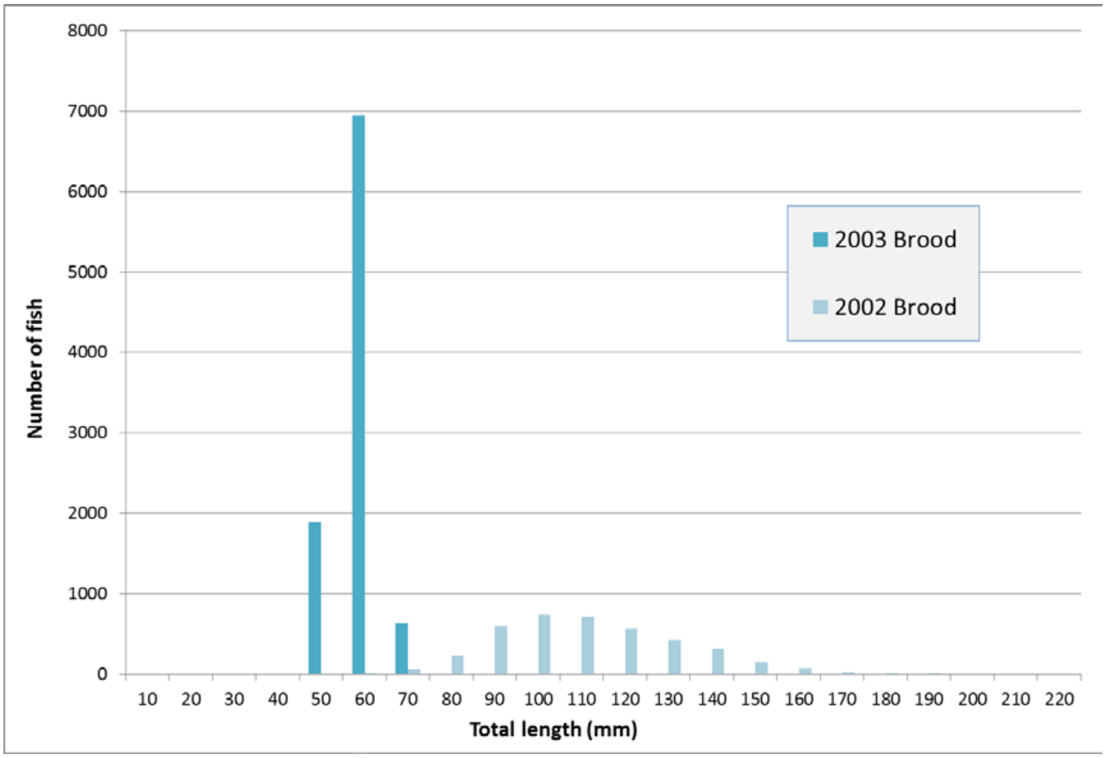

FIGURE 4. Length Frequency of 2002 and 2003 Ross rainbow trout brood held at Marblemount Hatchery, Marblemount, Washington.

Disease

In order to satisfy WDFW and NWIFC disease policy requirements, ovarian fluids and kidney/spleen samples were collected from 25 fish each year from 2002 through 2005. No diseases were detected in fish sampled from fish spawned at Ross Lake. However, external parasites, freshwater copepods, were noted on many adult fish, and in 2006 heavy infestation of the cestode *Bothriocephalus* were discovered in adult rainbow trout throughout Ross Lake.

Trials for the hemorrhagic fish virus IHN, were conducted with 2002 brood in order to assess the susceptibility of this stock to this common anadromous water pathogen. Ross rainbow fry were highly susceptible to the IHN strain (220-90) at both test temperatures, known to affect other rainbow trout stocks but suffered lower mortality when exposed to IHN strains endemic to the Skagit basin and North Puget Sound (**FIGURE 5**).

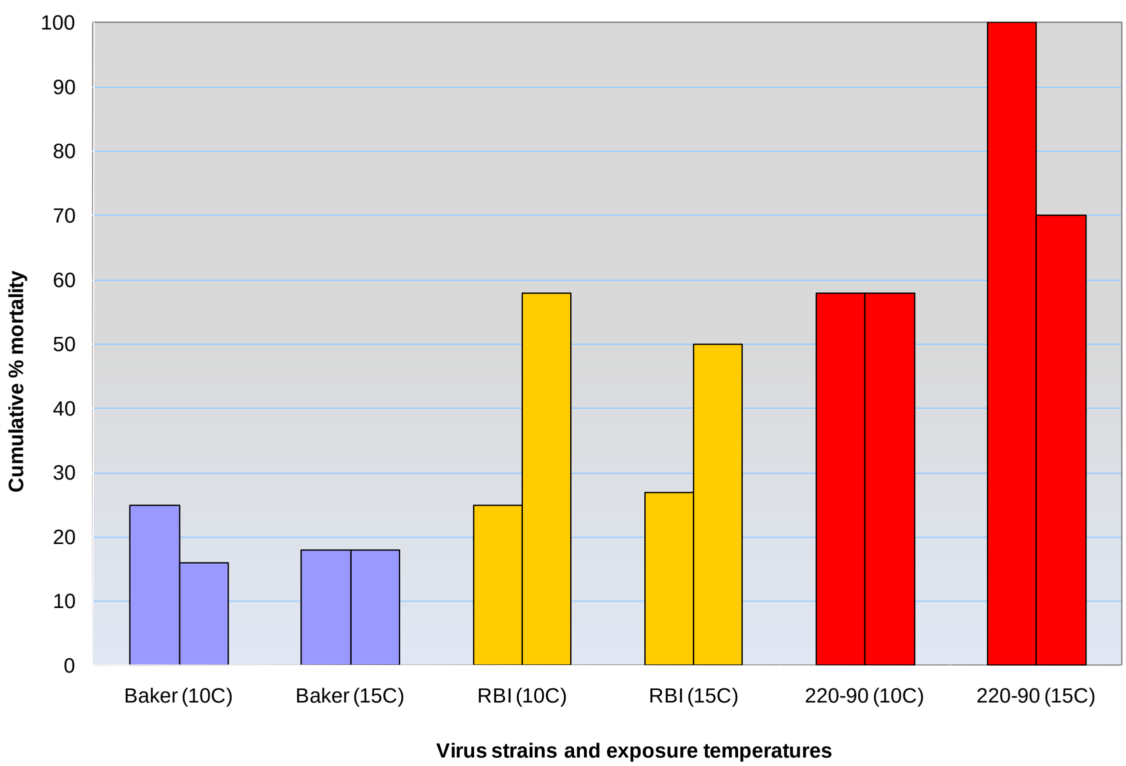

FIGURE 5. Cumulative mortality of Ross Lake rainbow trout fry exposed to three strains of the virus IHN in 2003.

Disposition of Fish

WDFW made its first pilot collection of wild broodstock from Roland Creek, a tributary to Ross Lake in 1999 and annual collections began in 2002. Within three years of broodstock collection in Roland and Dry creeks WDFW conducted its first egg take from hatchery-raised Ross rainbow, and began releasing fish into Diablo and Gorge reservoirs. From 2006 through 2009 production ranged from 200,000 to 345,000 eggs and annual releases of upper Skagit rainbow trout ranged from 1,000 to 286,000 fish into Diablo and 2,040 to 4,000 fish to Gorge (**TABLE 7**).

TABLE 7. Annual releases and densities expressed as fish/ acre of upper Skagit rainbow trout into Gorge and Diablo Reservoirs from 2004 through 2009.

	Diablo (910 acres)		Gorge (210 acres)	
Year	Number	FPA	Number	FPA
2004	1,326	1.5	830	4.0
2005	6,000	6.6	388	1.8
2006	89,022	97.8	2,600	12.4
2007	186,000	204.4	40,000	190.5
2008	66,000	72.5	20,000	95.2
2009	85,000	93.4	44,000	209.5
Total	433,348	79.4	107,818	85.6

From 2005 through 2008, several alpine lakes within the Skagit basin also received plants of Ross Lake rainbow (**TABLE 8**, **FIGURE 6**). After consulting with National Park Service and US Forest Service staff, WDFW made the decision to replace Mt. Whitney origin rainbow trout traditionally stocked into alpine lakes in the Skagit Basin with Ross Lake rainbow trout. While Mt. Whitney rainbow trout, produced from a captive broodstock held at the Eells Springs Hatchery, are not known to reproduce in alpine lake environments, eliminating the potential for downstream dispersal of this non-native stock was consistent with the National Park Service EIS Management Plan for Alpine Lakes (NPS 2008) and recommended as a preferred management strategy in wilderness areas in the Skagit Basin (Downen 2004).

TABLE 8. Alpine lakes grouped by sub-basin within the Skagit drainage that received substitutions of Ross Lake rainbow for traditionally stocked Mt. Whitney rainbow trout.

Basin	Name	County	Method	Date	Stocked	Org
Baker	Maiden	Whatcom	FW	9/24/2007	1,500	WDFW
	Watson, U	Whatcom	FW	9/10/2008	1,125	WDFW
Baker Total					2,625	
Cascade	Buller	Skagit	JO	10/6/2007	-	TB
	Falls, L	Skagit	FW	9/24/2007	2,500	WDFW
	Hidden	Skagit	FW	9/26/2006	4,000	WDFW
	La Rush	Skagit	TR	10/1/2007	75	WDFW
	La Rush	Skagit	JO	9/02/2008	150	TB
	Long Gone	Skagit	FW	9/24/2007	1,000	WDFW
	Snowking	Skagit	FW	9/24/2007	1,200	WDFW
Cascade Total					8,925	
Chilliwack	Copper	Whatcom	FW	9/26/2006	1,000	WDFW
	Kwahnesum	Whatcom	FW	9/24/2007	1,200	WDFW
Chilliwack Total					2,200	
Skagit	Josephine, U	Skagit	JO	8/16/2008	140	TB
	Splendor	Skagit	JO	9/12/2007	111	TB
	Thornton, L	Whatcom	FW	9/10/2008	6,375	WDFW
Skagit Total					6,626	
Skagit -U	Jerry # 1	Skagit	FW	9/24/2007	2,000	WDFW
	Ridley	Whatcom	JO	5/14/2003	500	TB
	Ridley	Whatcom	JO	9/24/2007	200	TB
	Sub Zero	Whatcom	FW	9/26/2006	500	WDFW
	Willow	Whatcom	JO	5/26/2005	120	TB
	Willow	Whatcom	FW	9/26/2006	500	WDFW
	Willow	Whatcom	JO	9/15/2007	400	TB
Skagit -U Total					4,220	
Suiattle	Indigo	Snohomish	FW	9/26/2006	2,000	WDFW
	Lime Twist	Snohomish	JO	9/14/2008	240	TB
	Rivord	Skagit	FW	9/24/2007	1,000	WDFW
Suiattle Total					3,240	
Thunder	Wing	Skagit	JO	9/28/2006	495	TB
Thunder Total					495	
Grand Total					28,331	

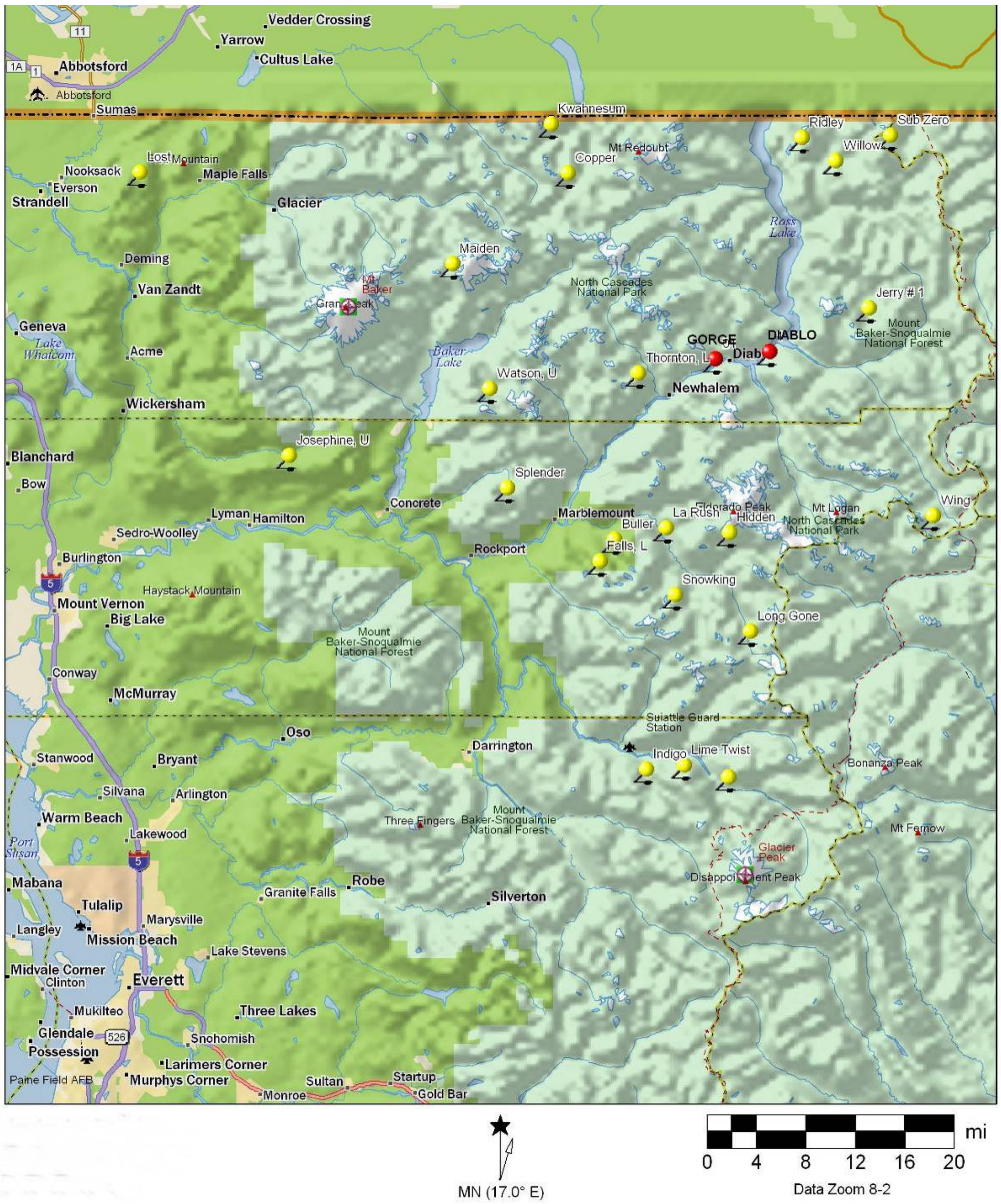

FIGURE 6. Distribution of upper Skagit rainbow stocking above Seattle City Light hydroelectric projects within the Skagit Basin between 2000 and 2008.

BIOLOGY OF ROSS LAKE RAINBOW TROUT POPULATIONS OF ROLAND AND DRY CREEKS

PROGRAM POPULATION MONITORING ACTIVITIES

WDFW explored several locations for potential sources of spawning rainbow trout during June and July of 2002. These included Lightning, Ruby, Silver, and Hozomeen Creeks. Seining the arms of the larger creeks proved unsuccessful. Smaller tributaries did not support large enough spawning populations to meet gamete collection needs. Ultimately, all spawning fish collected were from Roland and Dry Creeks (**FIGURE 7**) where numbers of observed spawners could be effectively monitored.

Due to heavy superimposition of redds and communal spawning throughout the spawning season, WDFW conducted weekly surveys, counting live fish. Fish were categorized as either spawning fish, those actively on a redd, or holding fish, those staging in the creek to spawn. Holding spawners were identified by size (>250mm) and behavior, schooling in pools or riffles below the spawning reaches. Counts represent the total weekly occurrence of these categories, from which area-under-the-curve abundance estimates were calculated.

In 2003 and 2004 a temporary weir was installed at the mouth of Roland Creek so that disturbance to spawning habitat above would be minimized and fish spawning in Roland Creek could be accurately enumerated. However, after 2004 WDFW established a protocol of only collecting fish in the first 200m of stream. This allowed the majority of spawners to move past the collection zone and spawn undisturbed. Fish collected from Dry Creek were dip netted in the lower 20m of the stream below the majority of spawning habitat. Reported fish observed do not include numbers of collected fish (see **TABLE 1**).

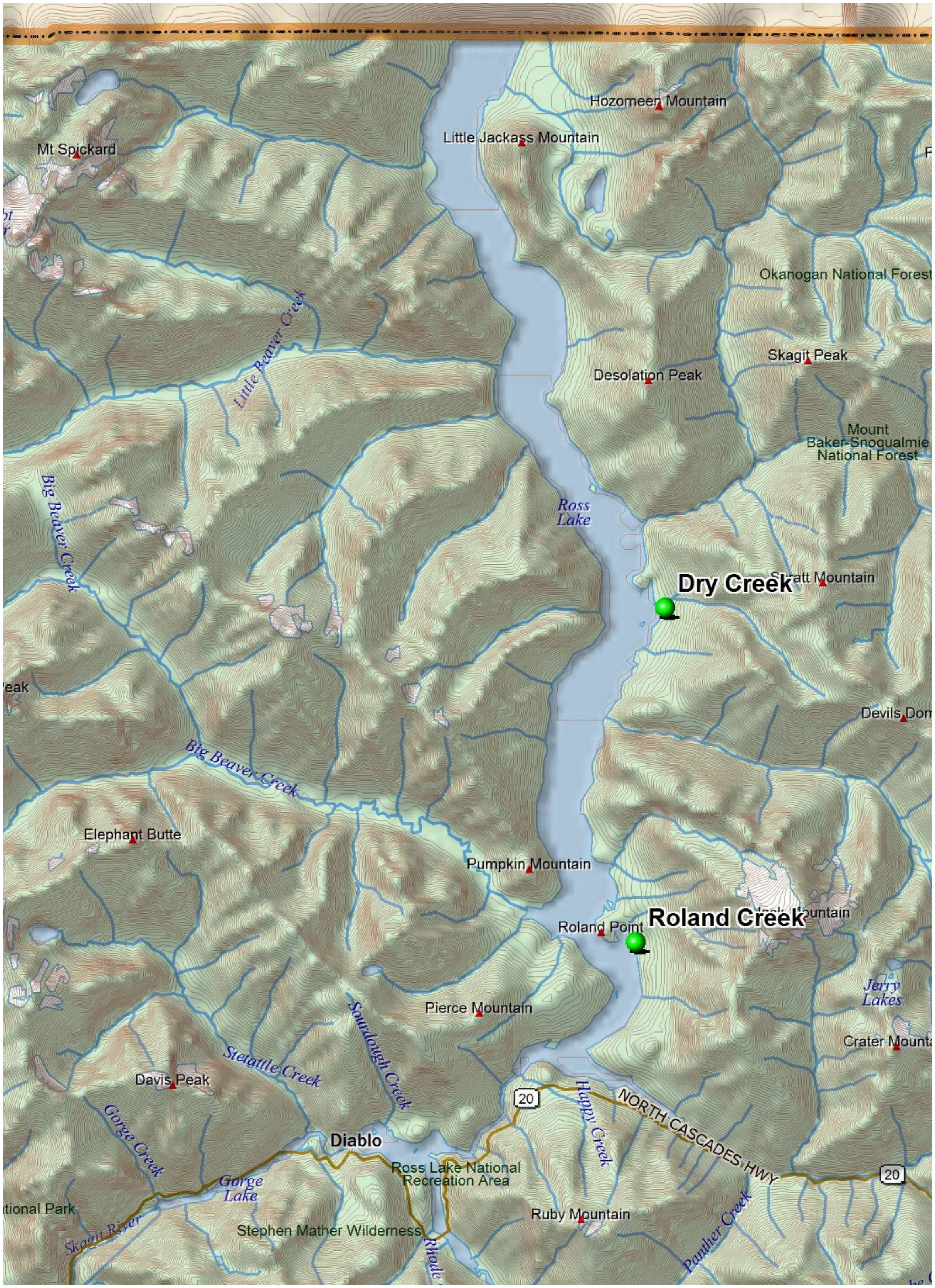

FIGURE 7. Ross Reservoir vicinity and locations of donor populations for captive rainbow trout 2002 brood year.

METHODS AND MATERIALS

Relatively large numbers of spawning rainbow in short stream reaches resulted in high densities of live fish and continuous superimposition of redds. Therefore, live fish were counted or visually estimated during weekly foot surveys. Spawning surveys were conducted from the first week in June until late July when fish were no longer present in the stream. Lengths, sex, scales, otoliths and tissue samples for DNA testing were collected from fish sampled randomly over the course of the run. Locations of fish assemblages, barriers and the last fish observed in each stream were recorded with a handheld Magellan 310 GPS unit and imported into GIS coverages.

Fish ages were determined from scales by the Washington Department of Fish and Wildlife Scale Lab. Following methods developed by Washington Department of Game (WDG), a minimum of five randomly selected fish were aged in each 10 mm size class (Johnson 1989, Loof 1995). Percentages of age classes in each size class were applied to length frequencies of fish collected randomly over the course of the run, and were then applied proportionately to counts corresponding to the temporal distribution of the run (Ketchin 1954). The size and age class structures of captured male and female rainbow trout were evaluated by constructing stacked length frequency histograms (frequency of fish captured in a given size class and age class). Vertical bar graphs were constructed to compare the age structures and average total length was calculated for males and females at Age 1 through 5 for 2002, 2003, and 2004 spawning populations. Sex ratio, age class structure, and length frequency were then estimated for the total run size, which was calculated using the area under the curve method.

Area under the curve was determined using the trapezoidal area under the trend line over the course of the run to estimate fish days and then divided by a standardized stream life of six days to yield an escapement estimate. Six days was assumed to be the average stream life of spawning fish based on stream residence data collected in 2003 when WDFW operated a weir on Roland Creek. Stream residence time was estimated based on the percentage of females entering the stream in spawning condition and the proportions of downstream kelts in relation to passed unripe spawners from the previous week. This estimate also proved consistent with maturation data collected at the Marblemount Hatchery. In 2003 a Tidbit temperature logger was installed so that spawning activity could be plotted against water temperature. Spawning curves were constructed for each run and plotted against the hatchery returns. Cumulative spawning curves were also constructed by totaling live fish observations by week number.

RESULTS

Roughly even numbers of male and female rainbow trout ranging from 180 to 420 mm were sampled throughout a three year period from 2002 through 2004 (**FIGURE 8** and **FIGURE 9**). Males were dominated by Age 2 fish with some three and a few four year fish (**FIGURE 10**), while females were dominated by Age 3 fish with some age two and a few age four fish as well (**FIGURE 11**). All sampled fish spawning in Roland and Dry creeks appeared to be first-time spawners with the exception of one large male (374mm), which was determined by scale analysis to have spawned at least one time previously.

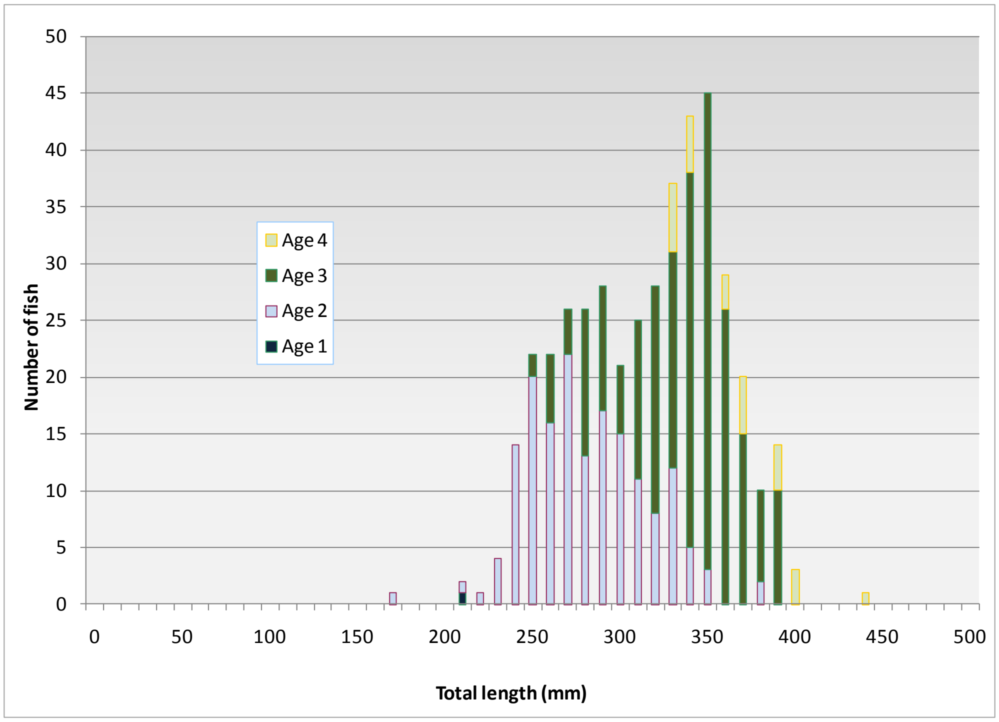

FIGURE 8. Length and age frequency distribution of male rainbow trout spawners collected from Dry and Roland creeks in June of 2002, 2003, and 2004.

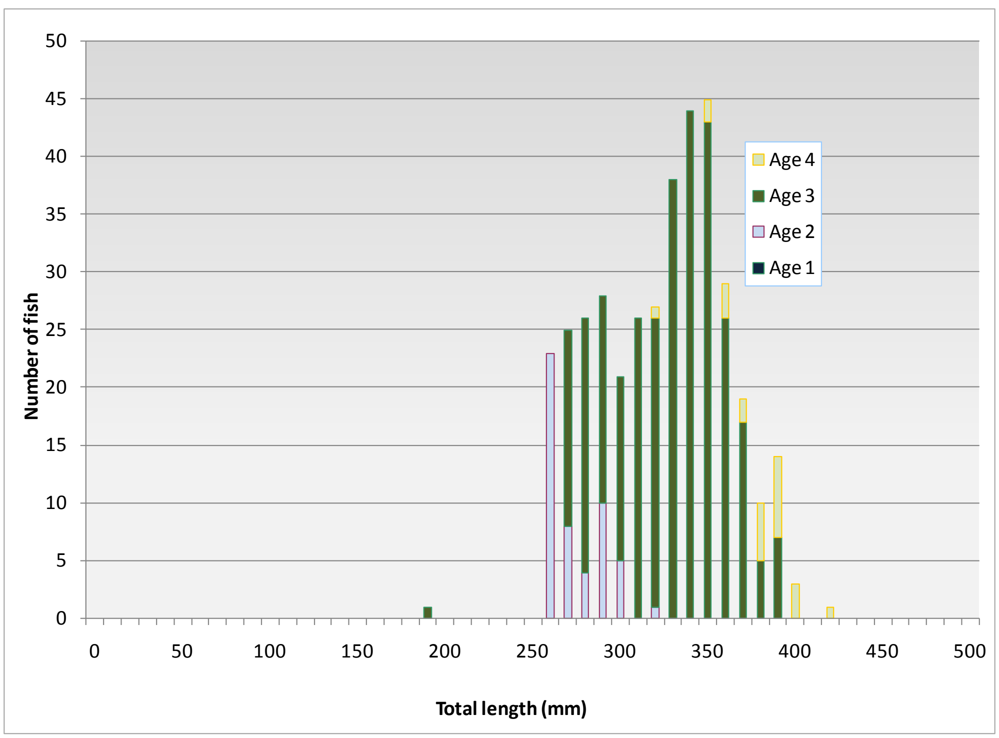

FIGURE 9. Length and age frequency distribution of female rainbow trout spawners collected from Dry and Roland creeks in June of 2002, 2003, and 2004.

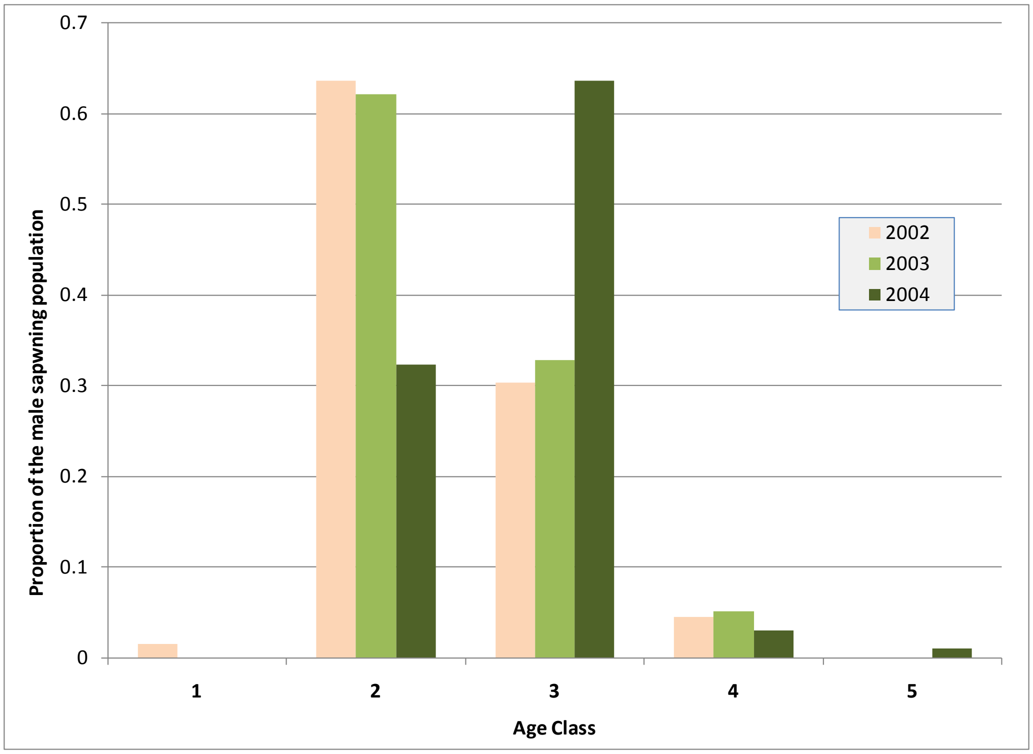

FIGURE 10. Age class distribution of male rainbow trout spawners collected from Dry and Roland creeks in June of 2002, 2003, and 2004.

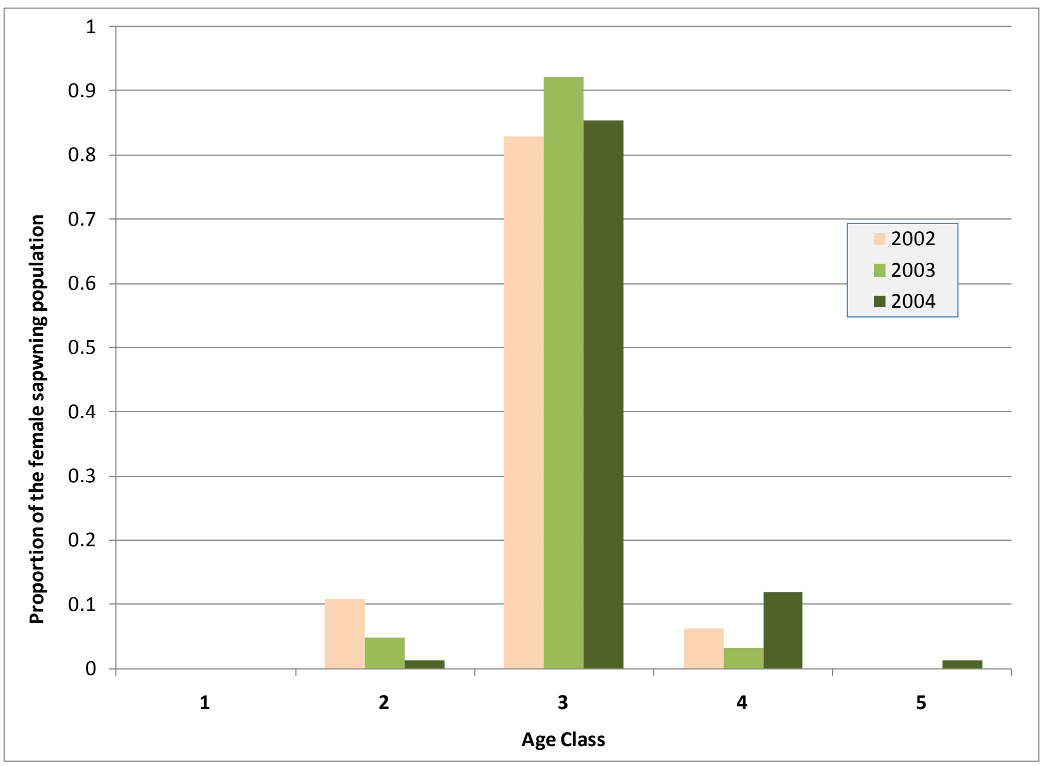

FIGURE 11. Age class distribution of female rainbow trout spawners collected from Dry and Roland creeks in June of 2002, 2003, and 2004.

This diversity of spawning ages within the populations and the dominance of different brood years for males and females suggested strong inherent mechanisms for genetic out-crossing.

Average total lengths of each age class demonstrated a persistent pattern of larger females at each age class than males (**TABLE 9**). The only exception to this trend was for Age 3 rainbow in 2002. Uneven sample size precluded statistical determination of significant differences. However, this was surprising given the differential energy expenditures between males and females in gamete production.

TABLE 9. Numbers and average total lengths of male and female spawners sampled from Roland and Dry Creeks from 2002 through 2004.

		Age				
2002		1	2	3	4	5
	Males	1	42	20	3	0
	TL_{avg}	205.0	261.5	334.3	366.3	ns
	Females	0	7	53	4	0
	TL_{avg}	ns	282.1	328.3	368.3	ns
2003						
	Males	0	36	19	3	0
	TL_{avg}	ns	273.9	321.0	386.7	ns
	Females	0	3	58	2	0
	TL_{avg}	ns	295.0	328.9	389.0	ns
2004						
	Males	0	32	63	3	1
	TL_{avg}	ns	264.1	319.8	362.7	ns
	Females	0	1	64	9	1
	TL_{avg}	ns	298.0	331.1	367.7	397.0

In 2003 water temperature was monitored during the rainbow trout spawning season (**FIGURE 12**). From April through May temperature oscillated regularly between 4 and 7^{o}C. In early June water temperature began oscillating steadily upward to 10^{o}C, which coincided with the onset of spawning. Whether water temperature is a proximal cue or not is still unknown. However, the ultimate cue for spawning appears to be the stabilization of flows as snow melt from lower elevations diminishes.

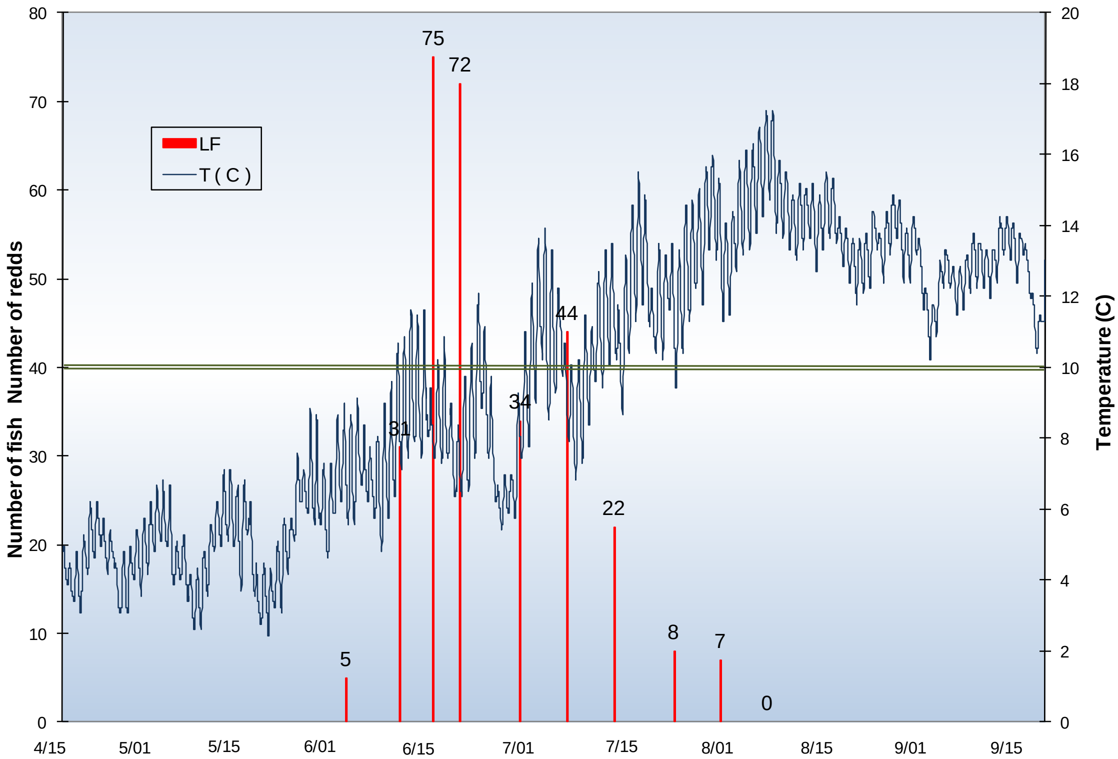

FIGURE 12. Relationship between water temperature and spawn timing of rainbow trout in Roland Creek in 2003.

The Roland Creek population exhibited substantially larger returns than the Dry Creek population every year from 2002 through 2008 except in 2003 when the escapement for Dry Creek was larger (**TABLE 10**). Escapement for Roland Creek ranged from 276 to 854 for spawners and averaged 470 spawners across a seven year period (**FIGURE 13**). The escapement for Dry Creek ranged from 103 to 330 spawners and averaged 216 spawners across the same period. Egg collections for 2002, 2003, and 2004 varied between 80 and 150 fish. After 2004, collection targets were reduced to 25 fish per year. Larger escapements in Roland Creek were a function of more abundant spawning and rearing habitat.

TABLE 10. Rainbow trout spawner escapement estimates for Roland and Dry creeks, tributaries to Ross Reservoir, for the 2002 through 2008 spawning seasons.

Year	Dry Creek	Roland Creek
2002	175	485
2003	330	276
2004	330	501
2005	247	854
2006	103	285
2007	158	412
2008	170	479

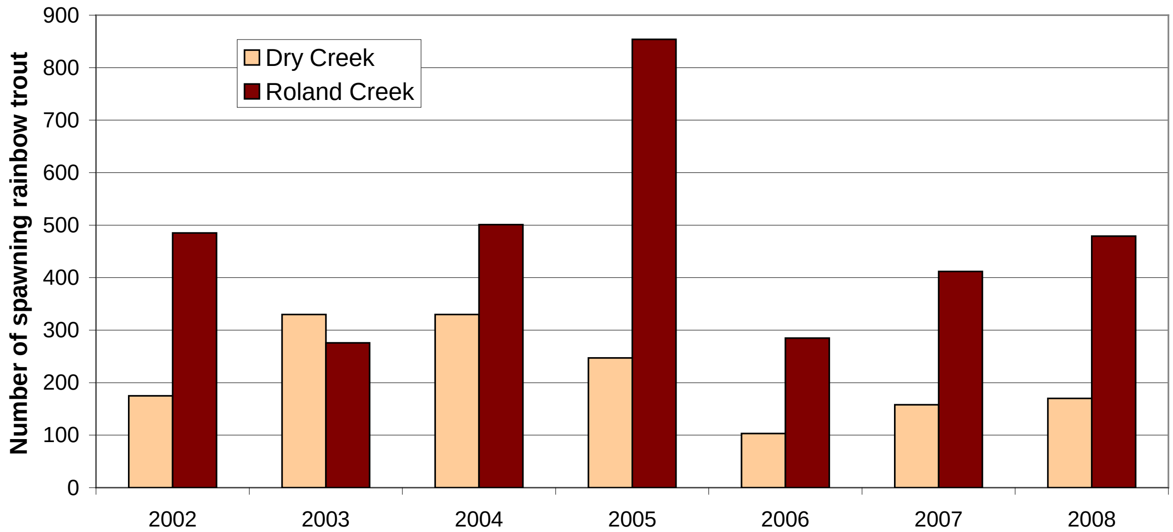

FIGURE 13. Escapement of rainbow trout as estimated by the Area Under the Curve method (AUC) to Dry and Roland Creeks from 2002 through 2008.

Roland Creek consistently supported rainbow trout spawning well beyond the trail crossing, approximately 400m above Ross Reservoir full pool elevation. Its lower reaches are lower gradient than Dry Creek and form better pool riffle complexes. Greater discharge over longer periods also provides more habitat for later spawning and rearing.

Dry Creek consistently recruited spawners earlier, peaked earlier, and exhibited a narrower timing window that Roland Creek (**FIGURE 14**). The cumulative spawning curves for both populations exhibited multiple peaks. The initial peak for Dry Creek was also its most prominent while the second peak was the most prominent for Roland Creek. In Roland Creek the onset of spawning correlated with increasing stream temperature to about 10°C and with declining flows and the attenuation of snow melt runoff.

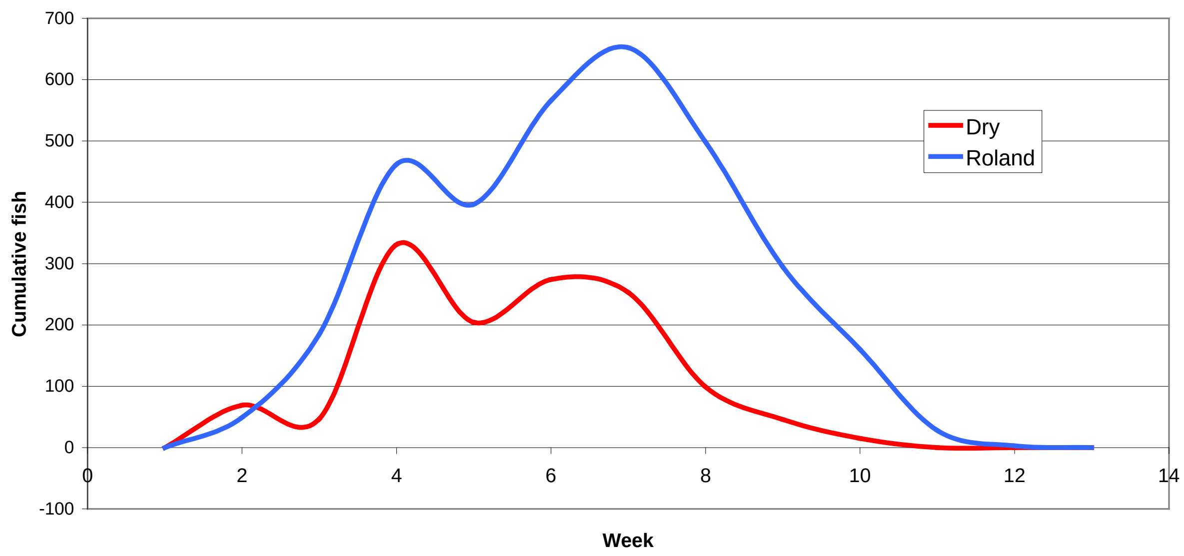

FIGURE 14.Cumulative spawn timing averaged across all years for Dry and Roland creek rainbow trout populations.

THE RESERVOIRS

BACKGROUND

The Skagit River Hydroelectric Project consists of a series of dams with hydroelectric power-generating stations on the Skagit River in northern Washington State. Gorge dam, the lowest of three dams, was constructed from 1921 to 1924, and was the first completed. Gorge dam inundated an incised canyon which included the mouth of Stetattle Creek, the only major tributary in that reach of the Skagit River. Today only Stettattle Creek supports regular spawning of rainbow trout (*Oncorhynchus mykiss*) and the potential complex of bull trout (*Salvelinus confluentus*) and Dolly Varden (*Salvelinus malma*), hereafter referred to collectively as native char.

Although Diablo Dam was begun in 1918 when Seattle City Light (SCL) began construction in the upper Skagit River (**FIGURE 15**), it was not completed until 1930. This dam inundated 25 kilometers of riverbed and 1,000 acres of old growth forest. Four kilometers of Thunder Creek, the only major tributary to this reach of the Skagit River, was opened to upstream movement of fish when the historic barrier was inundated. Eight other minor tributaries including Colonial, Pyramid, and Sourdough creeks probably provided little, if any, accessible habitat for native fish historically. Today only Thunder and Colonial creeks are known to support regular spawning of rainbow trout and the potential complex of bull trout and Dolly Varden.

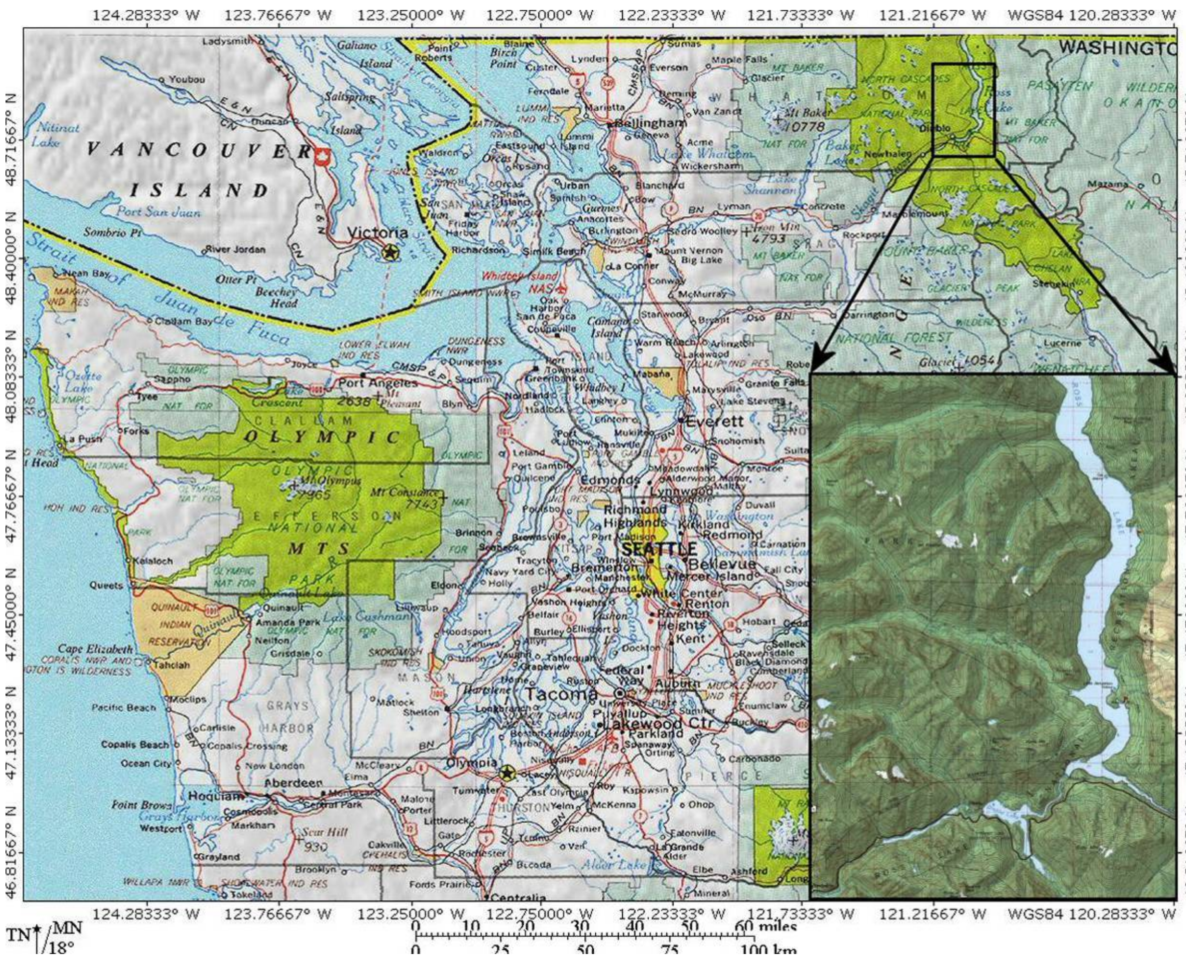

FIGURE 15. Diablo Reservoir is located near the Canadian border with Washington State within the current boundaries of North Cascades National Park.

The largest and uppermost dam on the Skagit River is Ross Dam. Construction began in 1930 and the first two of three planned phases were complete by 1940. At that time the dam stood 305 feet above the river. As the reservoir filled the inundation zone was opened to logging but some 30 million board feet were ultimately inundated. In 1943 the first stage of the third and final phase raised the dam to 475 feet, and the completion of the third phase in 1949 raised the dam to its current height of 550 feet. The resulting reservoir encompassed 11,678 acres and extended 23 miles north into British Columbia. Several major tributaries to the upper Skagit feed the reservoir, including Ruby, Lightning, Silver, and Big Beaver creeks. All harbor spawning populations of native rainbow trout, bull trout, and Dolly Varden.

Prior to the construction of the first dam, only native rainbow trout and native char inhabited the upper Skagit Basin. According to Smith and Anderson (1921), anadromous fish species were prevented from migrating beyond the canyon above Newhalem. However, the presence of both rainbow trout and native char suggests migratory forms of these species may have negotiated the canyon historically. However, alternate connections to the Fraser River system have also been hypothesized. Eastern brook trout (*Salvelinus foninalis*) and Yellowstone cutthroat trout (*Oncorhynchus clarki bouveri*) and westslope cutthroat trout (*Oncorhynchus clarki lewisi*) were planted in lakes and streams by the US Forest Service (USFS), the Washington State Department of Game (WDG, now Washington Department of Fish and Wildlife), as well as by individual miners, loggers, and sportsmen (Downen 2003). These species became established in many lakes and stream reaches by the 1930's, including Thunder Creek, both above and below the current fish barrier.

The construction of Ross Dam in 1954 eliminated whatever possible upstream movement of fish that may have occurred, and limited the downstream dispersal of native rainbow trout into the lower Skagit to periodic spilling activity of the dam. During an abnormally high spill period in 1972, a number of rainbow trout, tagged in Ross, were recaptured in Diablo. No injuries were reported in these fish, and gas bubble disease has never been observed in fish in Diablo Lake, indicating successful downstream dispersal of spilled fish (Fisheries Research Institute, University of Washington 1977). However, in recent years, Ross Dam has spilled rarely, with the vast majority of water from the upper Skagit passing through the Ross Dam powerhouse at the upstream end of Diablo Lake. Current water management of the Ross Reservoir has all but eliminated downstream dispersal of fish.

While Ross Lake functions as a storage reservoir that is drawn down dramatically in autumn and winter and filled in the spring, the water level of Diablo fluctuates modestly on a diurnal cycle for power generation. Water residence time is low and the glacial waters that feed it are nutrient-poor, resulting in oligotrophic conditions with low chlorophyll-a and limited zooplankton production. Thunder Creek contributes about 15% of the flow through Diablo, carrying substantial glacial till that results in reduced visibility and diminished light penetration in the reservoir. Discharge from Ross Reservoir strongly influences temperature profiles in Diablo, which stratifies weakly, but does not develop a strong thermocline in summer and fall as Ross does. Diablo generally exhibits cooler surface temperatures and lower alkalinity, conductivity, and pH than Ross, and vertical oxygen concentrations remain near saturation year round in Diablo (Fisheries Research Institute, University of Washington 1977).

The WDG stocked Diablo annually with rainbow and cutthroat trout from as early as 1941 through the mid-1980's (**FIGURE 16**). Yellowstone cutthroat trout were stocked in 1941, 1952, 1953, and 1954 before the WDG shifted permanently to various California strains of domesticated rainbow trout. Annual numbers fluctuated from 6,000 to 242,000 fish annually, with fish ranging from 1,358 fish/lb to 4.7 fish/lb in size. In 1957, WDG proposed stocking Lake Whatcom kokanee salmon (*Oncorhynchus nerka*) into Diablo but this proposal was opposed due to insufficient numbers of available fish, and was apparently never acted upon. The only deviation from rainbow trout after 1954 was the stocking of sea-run coastal cutthroat trout (*Onchorynchus clarki clarki*) in 1972 and again in 1981.

Historic creel survey data consists chiefly of angler interviews, yielding catch rates and species composition. No historic effort data exists. From the 1930's to the present rainbow trout have consistently dominated the catch with minor contributions of eastern brook trout, cutthroat trout and native char (**FIGURE 17**). Inconsistent data collection and sampling effort make drawing conclusions about historic fishery data cautionary. However, there appears to be a consistent long-term trend of declining catch rates. Aging of the reservoir may help explain this, but

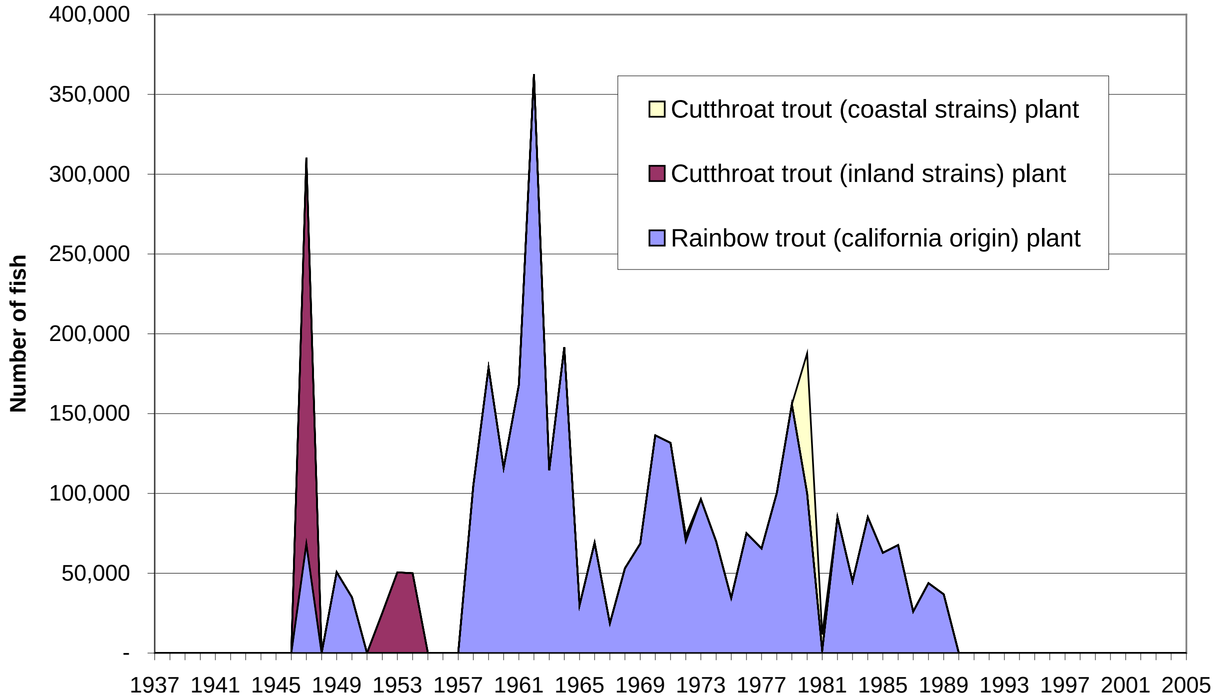

FIGURE 16. Historic planting numbers and species composition for Diablo Lake compiled from Washington Department of Fish and Wildlife files.

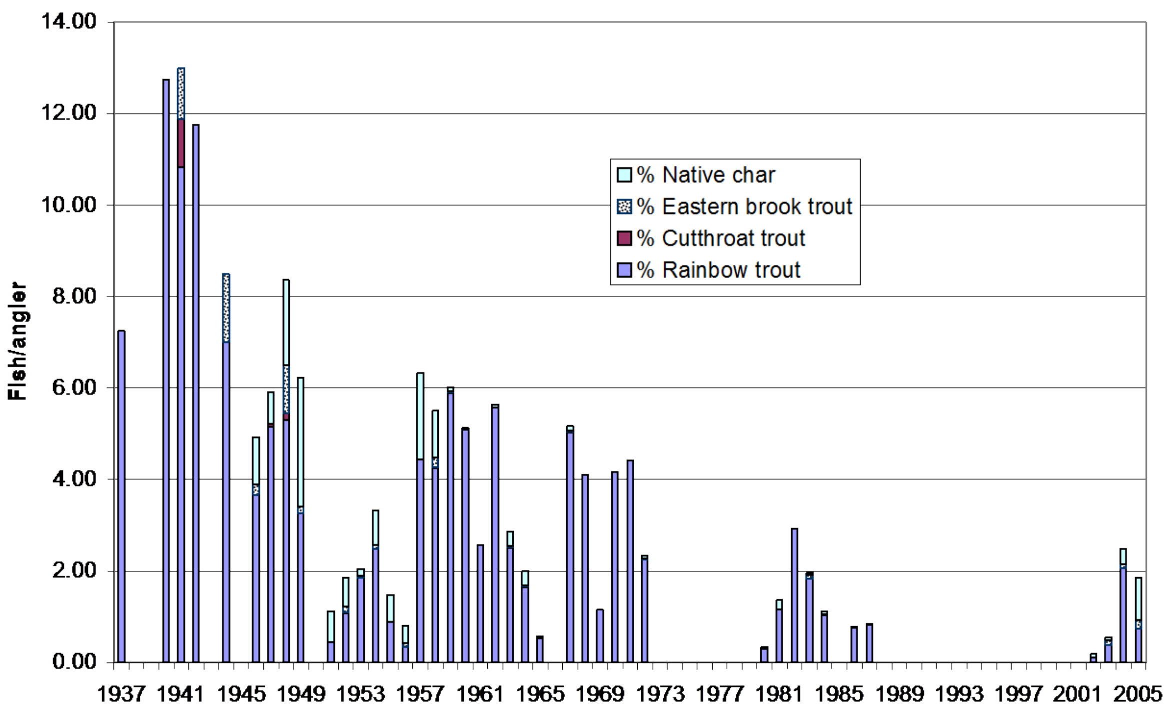

FIGURE 17. Historic catch rates (Fish/angler) and species composition of the Diablo Lake fishery compiled from Washington Department of Fish and Wildlife files.

past fisheries managers attributed success of this fishery to stocking, citing lack of spawning habitat for natural reproduction.

Historic, biological data for fish populations in Diablo Reservoir are limited, particularly with regard to population-level assessments. In 1973, University of Washington Fisheries Research Institute staff collected 45 rainbow trout, 12 native char, one eastern brook trout, and two cutthroat trout, but length, weight, and age data do not appear in their reports. In September 1985, National Park Service staff collected 16 rainbow trout, 13 native char, and two eastern brook trout (**TABLE 11**). Data from this sampling effort were derived from only one gill net set, limiting results for species composition, distribution, age class structure, and growth, and precluding meaningful comparisons with subsequent surveys.

TABLE 11. Species composition of fish captured by National Park Service biologists in Diablo Reservoir in September 1985 by weight and number.

	Species composition				
	by weight		by number		Size range (mm TL)
Species	(kg)	(%) wt	(#)	(%) n	
Eastern brook trout (*Salvelinus fontinalis*)	0.225	4.53	2	6.45	222 -226
Native char (*Salvelinus* spp)	1.792	36.08	13	41.94	133 -283
Rainbow Trout (*Oncorhynchus mykiss*)	2.95	59.39	16	51.61	120 -386

The 1991 Settlement Agreement for re-licensing of the Seattle City Light upper Skagit hydroelectric project provided for development of a native rainbow trout broodstock from Ross Reservoir to supplement the Diablo Reservoir fishery. This provision was based on the premise that lack of spawning habitat resulted in limited recruitment, and on a long history of fish stocking. More recent biological assessments have also pointed to issues raised in bull trout recovery, particularly fragmentation and isolation of rainbow trout populations that were once connected prior to the construction of Ross Dam.

In 2002 WDFW began the collection phase for the broodstock program, and in 2005 WDFW conducted its first egg take from hatchery-raised Ross Lake rainbow. That same year WDFW began releasing sub-yearling fish into Diablo Reservoir, and the Skagit Flow/Non-flow committee authorized funding to conduct a baseline study on the existing rainbow trout population. Knowledge of abundance, growth and condition will help WDFW and NPS form management guidelines for future rainbow trout introductions. Mitochondrial DNA collections were also collected for the purposes of understanding the origins of current Diablo rainbow trout populations, how that genetic profile changes with infusion of Ross rainbow trout, and for assessing the native char complex and its interaction with the non-native eastern brook trout population. In August of 2005 WDFW conducted a comprehensive survey of the fish populations in Diablo Lake to establish a comparable baseline and to support future fish management decisions.

FISH SURVEY METHODS AND MATERIALS

One WDFW biologist and two scientific technicians surveyed Diablo Reservoir during August 1 through August 5, 2005; Gorge Reservoir during August 15 through August 17, 2006; and Ross index sites during July 31 through August 2, 2006. Fish were captured using two sampling techniques: horizontal and vertical gill netting. Two configurations of horizontal experimental gill nets were deployed. One type (45.7 m long × 2.4 m deep) was constructed of four sinking panels (two 7.6 m long and two 15.2 m long) of variable-size (13, 22, 25, and 51 mm square) monofilament mesh, and the other (33 m long x 3.1 m deep) was constructed of six sinking panels each 10.3m long of variable size (13, 19, 25, 13, 19, 25 mm square) monofilament mesh. Three vertical gill net sets composed of panels (all 33 m deep x 2.4 m wide) of variable size (15, 21, and 32 mm square) were attached with clips every 4 m with PVC spreaders and suspended from the surface mooring buoys.

For Diablo and Gorge reservoirs, sampling locations were selected by dividing the shoreline into four geographically distinct regions; the deep pelagic region directly behind the dam, the middle region where Thunder Arm and the old Skagit River bed converged, Thunder Arm, and the Skagit River reach below the Ross powerhouse (**FIGURE 18** and **FIGURE 19**). Those regions were then divided into consecutively numbered sections of about 400 m each as determined from a 1:24,000 USGS map. From those sections, sample sites were then chosen systematically to maximize spatial independence and geographic coverage. For index sites on Ross Reservoir, sampling locations were selected to provide adequate samples to assess growth and other population-level characteristics for rainbow trout (**FIGURE 20**). Vertical gill nets were not used on Ross.

Horizontal net types were randomly assigned, and vertical net sets were deployed near the centroids of three of the four major basins. Two gill nets of each horizontal type were set perpendicular to the shoreline and one set of three-panel vertical gill nets were set for each of three nights for a standardized 2:2:1 ratio. For sinking horizontal nets, the small-mesh end was attached onshore and the large-mesh end was anchored offshore. Maximum effective depth was about 30 m for horizontal nets, though a range of shallower depths were sampled. Vertical nets were suspended from mooring buoys to fish the top 33 m of the pelagic zone. Although larger fish were observed with a hydro-acoustic fish finder near the bottom at greater depths, we decided not to risk losing a sinking net where course woody debris could be an issue.

All fish captured were identified to species, with the exception of native char, which could not be more specifically identified based solely on meristics. Fish were sexed by internal examination, measured to the nearest mm and assigned to 10-mm size classes based on total length (TL). Fish were weighed to the nearest 0.5 g. Scales and otoliths were removed from up to 5 fish from each size class for aging. Scale samples were mounted, pressed, and the fish aged according to Jearld (1983) and Fletcher et al. (1993). Scales were also measured for standard back-calculation of growth. Otoliths were cleaned and read under a standard dissecting microscope. Tissue samples, taken from the pelvic fin, were collected from all species and stored in alcohol for future Mitochondrial DNA analysis.

FIGURE 18. Sampling locations for variable panel vertical and horizontal gill nets used to collect fish from Diablo Reservoir in August 2005.

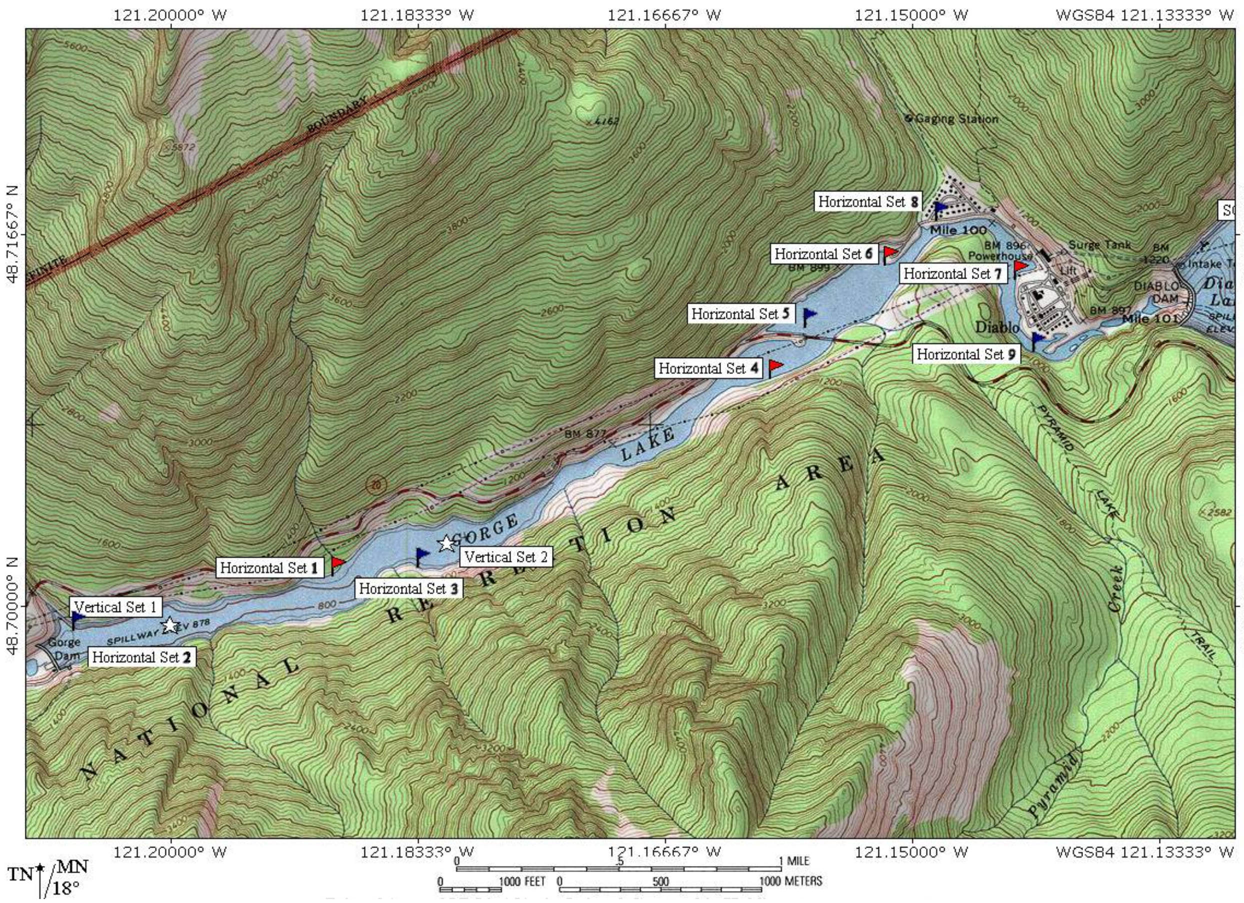

FIGURE 19. Sampling locations for variable panel vertical and horizontal gill nets used to collect fish from Gorge Reservoir in August 2006.

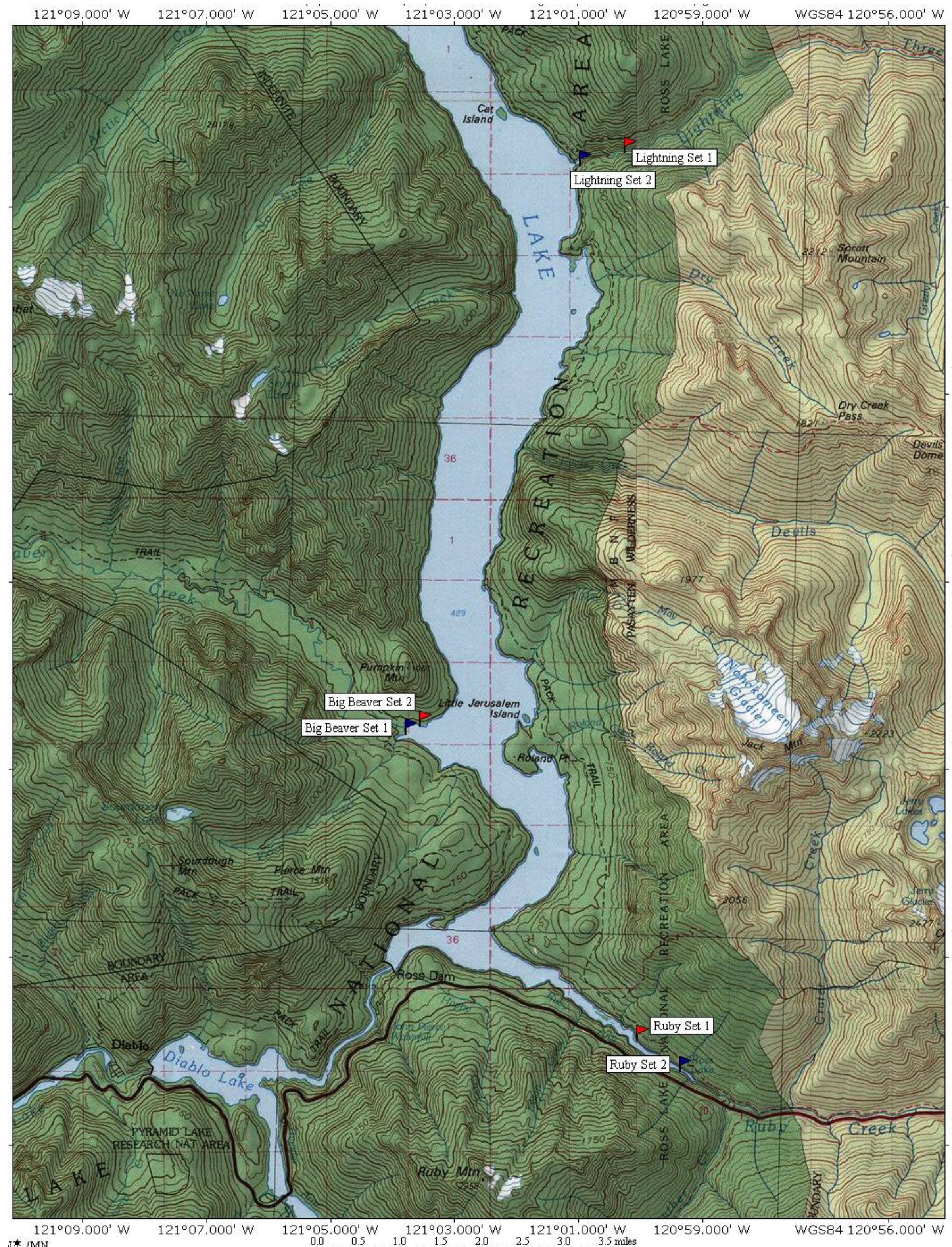

FIGURE 20. Sampling locations for variable panel vertical and horizontal gill nets used to collect fish from Ross Reservoir in August 2006.

Data analysis

Evaluations of species composition, size structure, growth, and condition (plumpness or robustness) of fish provide useful information on population age class structures, relative species abundances and interaction, and the adequacy of the food supplies for various foraging niches (Ricker 1975, Kohler and Kelly 1991). This information also aids in the development of responsible fish management strategies and forms the basis for sound adaptive management. The balance and productivity of the fish community may also be assessed based upon these evaluations (Swingle 1950; Bennett 1962).

Species composition was determined by weight (kg) of fish captured using procedures adapted from Swingle (1950). The species composition by number of fish captured was determined using procedures outlined in Fletcher et al. (1993). While young-of-year or small juveniles are often not considered because large fluctuations in their numbers may distort results (Fletcher et al. 1993), we would have included them had any been collected, since their relative contribution to total species biomass would have been small. Moreover, the overall length frequency distribution of fish species indicate successful spawning, lentic habitat use and initial survival during a given year, as demonstrated by a preponderance of fish in the smallest size classes. Although many of these fish would be subject to natural attrition during their first winter (Chew 1974), resulting in a different size distribution by the following year, the presence of these fish in the system relates directly to fecundity and interspecific and intraspecific competition at lower trophic levels (Olson 1997).

Catch per unit effort (CPUE) by gear type was determined for each fish species (number of fish/net night). Net nights equate to 16 hour sets from 1600 hours to 0800 hours the following day. CPUE was calculated for each species based on all fish and based only on stock- size fish and larger. Stock length which varies by species (see **TABLE 12** and discussion below) refers to the minimum size of fish having recreational value. Although sample locations were systematically selected based on habitat type in order to minimize variability due to habitat differences within the lake, 80% confidence intervals (CI) were determined for each mean CPUE by species and gear type. CI was calculated as the mean ± $t_{(\alpha, N\text{-}1)} \times SE$, where t = Student's t for α confidence level with n-1 degrees of freedom (two-tailed) and SE = standard error of the mean. Since it is standardized, CPUE is a useful index for comparing relative abundance of stocks between lakes and confidence intervals express the relative uniformity of species distributions throughout the lakes.

The size structure of each species captured was evaluated by constructing a stacked length frequency histogram (percent frequency of fish captured in a given size class by age class). Although length frequencies are generally reported by gear type, length frequency of upper Skagit reservoir fish are reported with combined gear types. Selectivity of gear types not only biases species catch based on body form, and behavior, but also based on size classes within species (Willis et al. 1993). Therefore, an unbiased assessment of length frequency is unlikely under any circumstance. A standardized 1:2:2 gear type ratio adjusts for differences in sampling effort between sampling times and locations. Furthermore, differences in size selectivity of gear types may in some circumstances result in offsetting biases (Anderson and Neumann 1996).

The proportional stock density (PSD) of each fish species was determined following procedures outlined in Anderson and Neumann (1996). PSD, which was calculated as the number of fish ≥ quality length/number of fish ≥ stock length×100, is a numerical descriptor of length frequency data that provides useful information about size class structure. Stock and quality lengths, which vary by species, are based on percentages of world-record lengths. Again, stock length (20-26% of world-record length) refers to the minimum size fish with recreational value, whereas quality length refers to fish that are from 36 to 41% of world-record in length.

The relative stock density (RSD) of each fish species was examined using the five-cell model proposed by Gabelhouse (1984). In addition to stock and quality length, Gabelhouse (1984) introduced preferred, memorable, and trophy length categories (**TABLE 12**). Preferred length refers to fish 45-55% of world-record length, memorable length refers to fish 59-64% of world-record length, whereas trophy length refers to fish 74-80% of world-record length. Like PSD, RSD can provide useful information regarding size class structure, but is more sensitive to changes in year-class strength. RSD was calculated as the number of fish ≥ specified length/number of fish ≥ stock length×100. For example, RSD P was the percentage of stock length fish that also were longer than preferred length, RSD M, the percentage of stock length fish that also were longer than memorable length, and so on. Eighty-percent confidence intervals for PSD and RSD were selected from tables in Gustafson (1988). Values specific to species captured in the upper Skagit reservoirs were adapted from (Hayatt and Hubert, 200 and 2001).

TABLE 12. Proportional and relative stock density values for species collected from Diablo Reservoir in August 2005. Fish length thresholds are expressed in millimeters.

Species	Stock	PSD	RSD-P	RSD-M	RSD-T
Eastern brook trout	200	300	400	500	600
Bull trout	300	500	650	800	1000
Rainbow trout	250	400	500	650	800

Age and growth of fishes in Diablo Reservoir were evaluated with direct length- at-age measurements (Jearld 1983; Fletcher et al. 1993). Unknown reabsorption rates in higher elevation waters with short growing seasons precluded the use of traditional back calculation methods such as direct proportion or Lee's modification of the direct proportion method (Carlander 1982). Using the direct proportion method, total length at annulus formation was back-calculated as $L_n = (A \times TL)/S$, where A is the radius of the fish scale at age n, TL is the total length of the fish captured, and S is the total radius of the scale at capture. Using Lee's modification, L_n was back-calculated as $L_n = a + A \times (TL - a)/S$, where a is the species-specific standard intercept from a scale radius-fish length regression. However, reabsorption of scale material during the winter season has the potential to introduce error actual growth rates in excess of annual variability in growth. Mean calculated lengths at age n are therefore reported for all species are reported in the respective species sections. Mean back-calculated lengths at age n for rainbow trout are also presented in graphic form for comparison of growth between year classes, as well as with rainbow trout collected from two tributaries of Ross Lake, Dry and Roland Creeks.

A relative weight (W_r) index was used to evaluate the condition of fish in the lake. A W_r value of 100 generally indicates that a fish is in good condition when compared to the national standard (75^{th} percentile) for that species. Furthermore, W_r is useful for comparing the condition of different size classes within a single population to determine if all sizes are finding adequate forage or food (ODFW 1997). Following Murphy et al.(1991), the index was calculated as $W_r = W/W_s \times 100$, where W is the weight (g) of an individual fish and W_s is the standard weight of a fish of the same total length (mm). W_s is calculated from a standard $\log_{10}$weight-$\log_{10}$length relationship defined for the species of interest. The parameters for the W_s equations of many coldwater fish species, including the minimum length recommendations for their application, are listed in Anderson and Neumann (1996). The relative weight equation used for native char and eastern brook trout were adopted from Hyatt and Hubert (2000) and (2001) respectively who developed a relative weight equations for these species (**TABLE 13**). Relative weight (W_r) values from this study were compared to the national standard ($W_r = 100$).

TABLE 13. Intercepts, slopes and minimum lengths used to calculate relative weight values (Wr) for fish species collected in upper Skagit reservoirs in 2005 and 2006.

Species	Intercept (a)	Slope (b)	Min Length
Rainbow trout (Oncorhynchus mykiss)	-4.898	2.990	120
Eastern brook trout (*Salvelinus fontinalis*)	-5.186	3.103	120
Native char (*Salvelinus* spp)	-5.327	3.115	120

One of the primary objectives of the 2006 Ross Lake survey was to assess growth and condition of rainbow trout and determine the possible contributing factors for any measured declines. Lethally sampled rainbow trout, eastern brook trout, and native char from Ross lake were examined for internal and external parasites. With the discovery of the internal cestode parasite infecting most rainbow trout and some native char, a categorical scale was developed to quantify the degree of infection. If no parasites were observed in the body cavity then the fish was considered uninfected. With 1 to five cestodes in the body cavity the fish was scored as low, with five to ten, medium, and with more than ten cestodes present in the body cavity the fish was scored as high. The proportion of rainbow trout in each category was then calculated and compared with relative weight and length. Native char were graphically analyzed by plotting number of fish in each category by length.

Fish Survey Results and Discussion

Diablo Reservoir 2005 Fish Population Survey

Species Composition and Distribution

No fish were collected in the vertical gill nets. All results are calculated from horizontal gill net samples. Rainbow trout dominated the species composition of fish captured in Diablo Reservoir both by weight (47.1%) and number (51.9%), and ranged in length from 109 to 388 mm (**Table 14**). Eastern brook trout made up 24.1% of the catch by weight and 30.3% by number while native char made up 28.7% by weight but only 17.7% by number. Eastern brook ranged in size from 116 to 290 mm in total length and native char ranged in size from 115 to 730 mm in total length.

Table 14. Species composition of fish captured in Diablo Reservoir in August 2005 by weight and number.

	Species composition					
	by weight		by number		Size range (mm TL)	
Species	(kg)	(%) wt	(#)	(%) n	Min	Max
Rainbow Trout (*Oncorhynchus mykiss*)	19.3	0.471	161	0.519	109 -	388
Eastern brook trout (*Salvelinus fontinalis*)	9.9	0.241	94	0.303	116 -	290
Native char (*Salvelinus* spp)	11.7	0.287	55	0.177	115 -	730
Red side shiner (*Richardsonius balteatus*)	0.0	0.000	0	0.000	80-	102
Total	40.9	1.000	310	1.000		

Of twelve sites were sampled with horizontal experimental gillnets in Diablo reservoir, rainbow trout were collected at every littoral zone sampling location in the reservoir and were the dominant species at five of the twelve sampling sites (**Figure 21**). Eastern brook trout were collected from all but one site and were dominant at three of the twelve sites. Eastern brook trout were collected in greatest abundance in warm embayments along the northern shore and nearer the head of the reservoir. Native char were sampled much less frequently but made up substantial proportions of the sample near the powerhouse and Thunder Creek where water temperatures were colder. Native char were the dominant species collected in the Skagit River reach. No fish were sampled in the pelagic zone with the vertical gill nets.

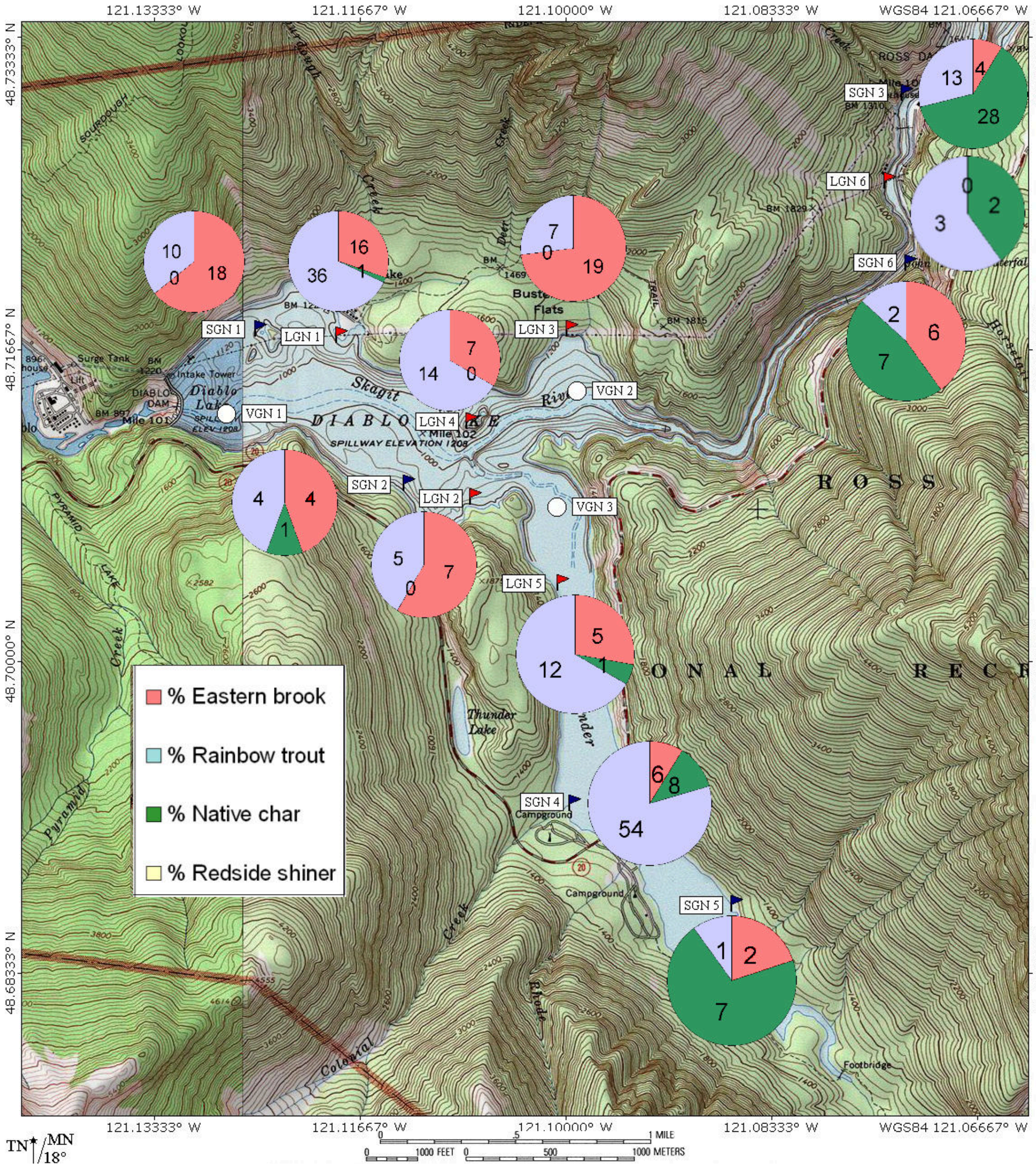

FIGURE 21. Species compositions at each sampling location for the Diablo fish community baseline survey of 2005**.** Numbers indicate sample size (numbers of each species) captured at each site.

Catch per Unit Effort

Catch rates were highest for rainbow trout, averaging 14 fish/net night for the short small-mesh nets and 12.83 fish/net night for the longer large-mesh nets (**TABLE 15**). Eastern brook trout CPUE was nearly half that of rainbow trout for the small-mesh nets and two-thirds that of rainbow for the large-mesh nets, while CPUE for native char was almost two-thirds that of rainbow in the small-mesh nets and negligible in the large-mesh nets. Catch rates for stock-length rainbow trout were about one third those calculated for all rainbow trout, and CPUE for stock-length eastern brook trout was about one-half that calculated for all eastern brook trout. The CPUE for stock-length native char was substantially smaller, about 14% of the CPUE calculated for all native char.

TABLE 15. Catch per unit effort and standard error around the mean for all fish captured and stock-length fish captured in Diablo Reservoir in August 2005.

Species	Repeating gill net (fish/night [b])	n (net nights [b])	Progressive gill net (fish/night [b])	n (net nights)	Vertical gill net (fish/night [b])	n (net nights [b])
All fish						
Rainbow trout	14.00 ± 10.54	6	12.83 ± 6.33	6	0	1
Eastern brook	6.67 ± 3.01	6	9.00 ± 3.73	6	0	1
Native char	8.50 ± 5.30	6	0.67 ± 0.43	6	0	1
Stock length fish						1
Rainbow trout	5.17 ± 3.68	6	4.00 ± 3.31	6	0	1
Eastern brook	3.67 ± 1.31	6	5.67 ± 2.76	6	0	1
Native char	0.83 [a]	6	0.00 [a]	6	0	1

[a] Sample size insufficient to calculate confidence intervals
[b] Net nights equate to 16 hour sets from 1600 hrs to 0800 hrs the following day

Stock Density Indices

Despite robust sample sizes for stock-length rainbow trout (55 greater than 250 mm TL) and eastern brook trout (56 greater than 200 mm TL), stock density indices were hardly worth calculating (**TABLE 16**). No rainbow trout over 400 mm were sampled, resulting in proportional and relative stock densities of 0. Nor were any eastern brook trout over 300 mm were sampled, resulting in proportional and relative stock densities of 0. While sample size for stock-length native char (greater than 300 mm) was low, five fish, three measured over 500 yielding a PSD of 60 ± 28 and one was greater than 650 mm yielding a PSD-P of 20. Sample sizes were too small to calculate confidence intervals for relative stock density values.

TABLE 16. Traditional stock density indices, including 80% confidence intervals for stock-length trout collected from Diablo Reservoir in August 2005.

Species	n	PSD	RSD-P	RSD-M	RSD-T
Rainbow trout	55	0	0	0	0
Eastern brook	55	0	0	0	0
Native char	5	60 ± 28	20 [a]	0	0

[a] Sample size insufficient to calculate confidence intervals

Eastern brook trout-age, length, and condition

WDFW collected 94 eastern brook trout char from Diablo Reservoir in August 2005, ranging in length from 116 to 290 mm TL and ranging in age from one to two years (**FIGURE 22**).

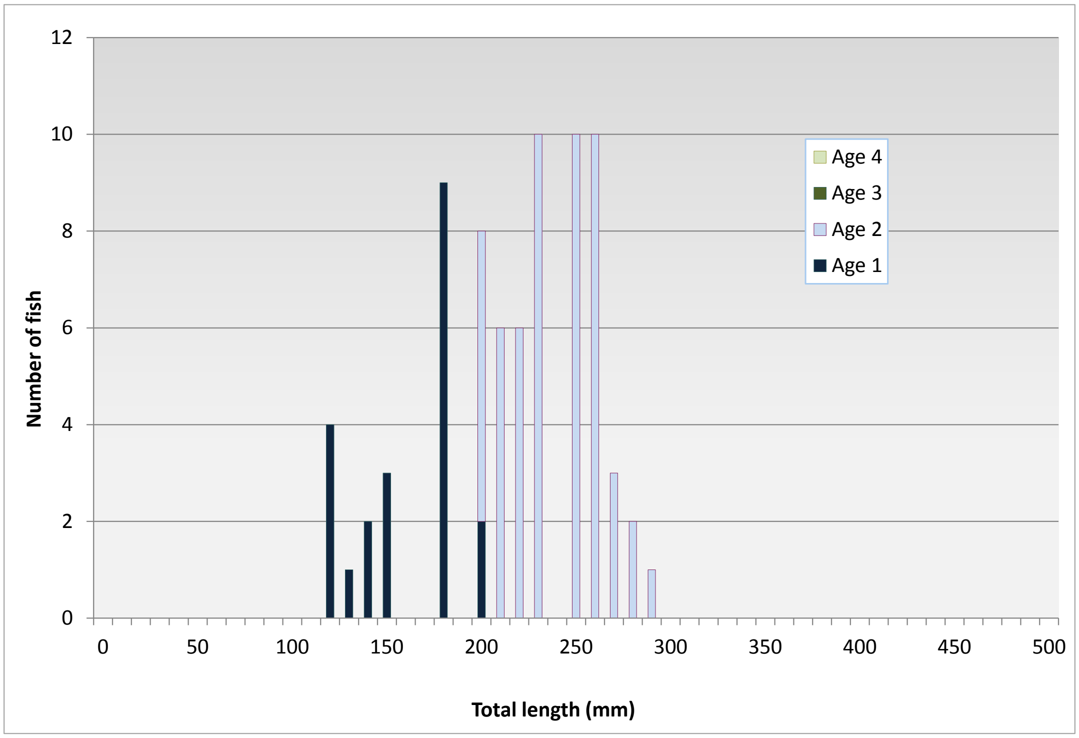

FIGURE 22. Length frequency histogram by age class of eastern brook trout captured in Diablo Reservoir in August 2005**.**

Eastern brook trout averaged 167.3 mm ± 26.2 (n = 4) at age one and 235.2 mm ± 26.6 (n= 19) at Age 2 (**TABLE 17**). Mean lengths indicate that growth for Diablo eastern brook trout are not characteristic of a population with excessive reproduction with respect to the available forage base through Age 3. No eastern brook trout older than Age 2 were sampled. This might be explained by an absence of spawning-aged fish, if they were already staging to spawn in Thunder Creek and other streams outside the littoral zone of the reservoir, and thus, outside the study area.

TABLE 17. Age and growth of eastern brook trout sampled from Diablo Reservoir in August 2005.

	Age				
	1	2	3	4	5
TL(avg)	167.3 ± 26.2	235.2 ± 26.9	ND	ND	ND
n	4	19	0	0	0

Condition of eastern brook trout sampled from Diablo Lake was slightly below the 75th percentile compared with national standards but consistent with that of eastern brook collected in 1985 by NPS and well within an acceptable range (**FIGURE 23**). Relative weight (Wr) values showed no trend with length or age for these fish, which would be expected to be approaching their spawning cycle. Eastern brook trout collected from Diablo were generally deep-bodied and did not show any signs of stunting, a phenomena unfortunately characteristic of eastern brook trout populations in western Washington wilderness lakes.

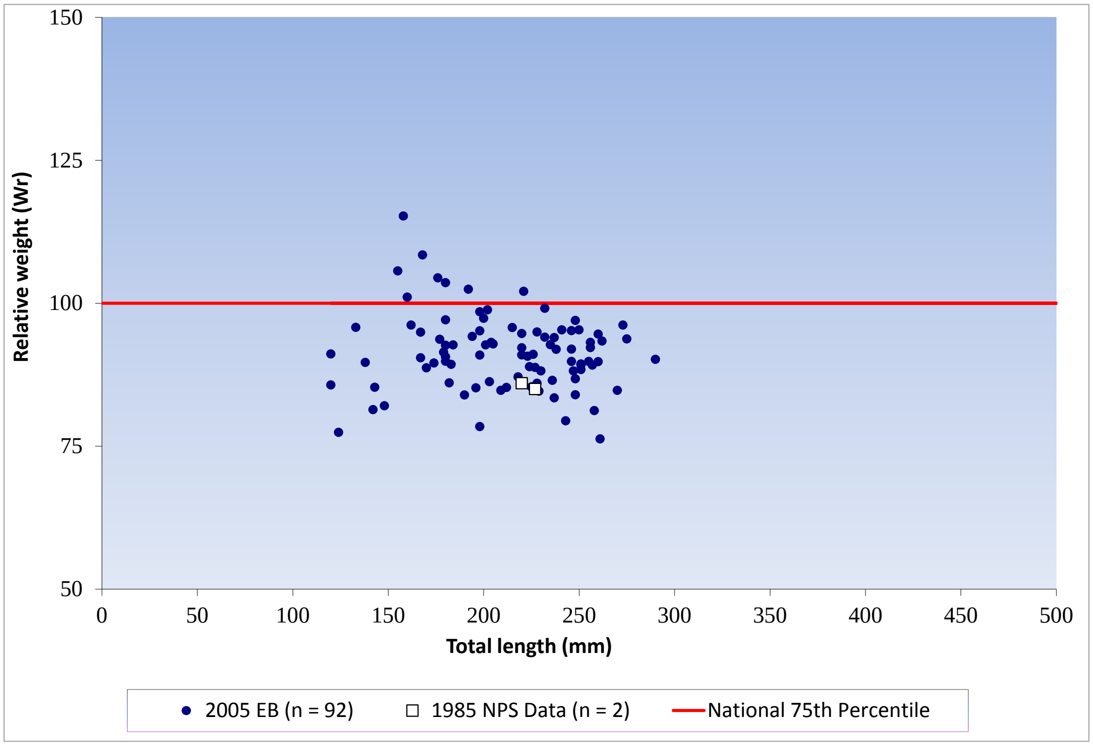

FIGURE 23. Relationship between total length and relative weight (Wr) of eastern brook trout captured in Diablo Reservoir in August 2005.

Native Char age, length, and condition

The potential complex of Dolly Varden (*Salvelinus malma*) and/or bull trout (*Salvelinus confluentus*) inhabiting Diablo Lake, will be referred to as native char in this report because there was no established protocol for distinguishing these species in the field and what their relative contributions might have been to the catch. Delineation between these species in Washington State has not been dependable based upon morphological and meristic characteristics (WDFW 1998). Some samples collected by the US Fish and Wildlife Service (USFWS) in 2001 from Thunder Creek were determined to be Dolly Varden based upon genetic analysis. However, morphological characteristics of fish collected by WDFW, including maxillary size and branchiostegal ray counts, have been consistent with those of bull trout (Haas and McPhail 1991). However, ray counts are difficult and may have led to misidentification..

WDFW collected 55 native char from Diablo Reservoir in August 2005, ranging in length from 115 to 730 mm TL, and ranging from one to six years in age (**FIGURE 24**).

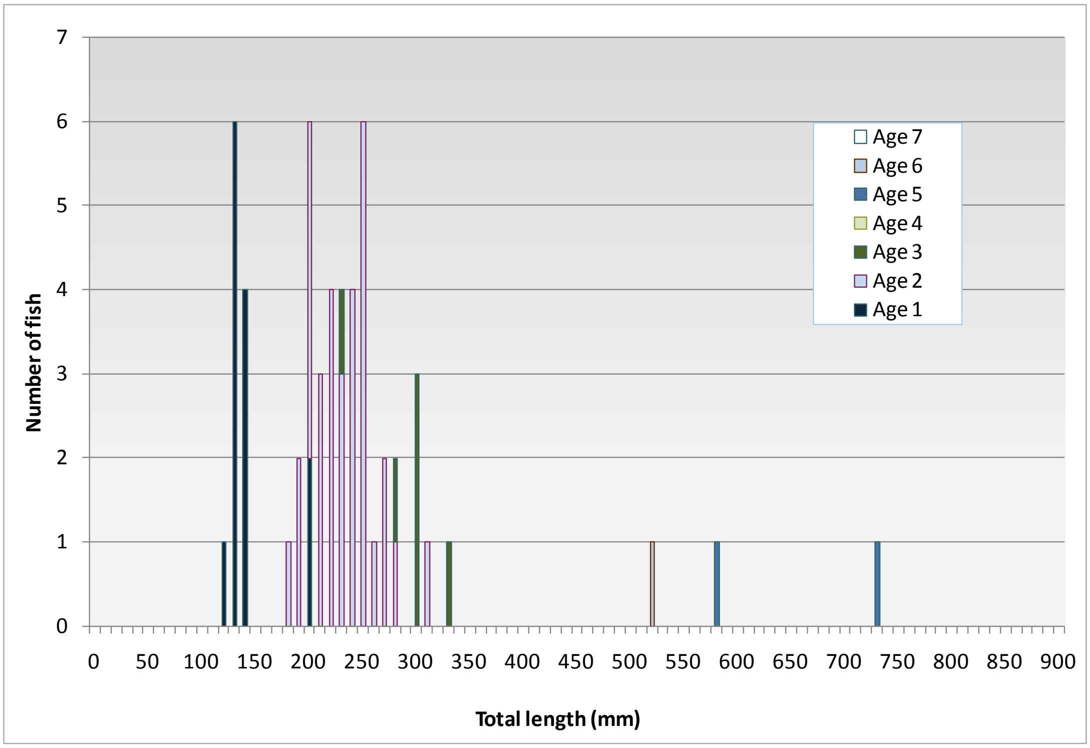

FIGURE 24. Length frequency histogram by age class of native char captured in Diablo Reservoir in August 2005.

Native char averaged 140.2 mm ± 26.0 TL (n = 6) at Age 1, 234.9 mm ± 29.3 (n = 18) at Age 2, and 286.0 mm ± 36.2 (n = 5) at Age 3, 652+110.3 (n = 2) at Age 5, and 520 mm (n = 1) at Age 6 (**TABLE 18**). No age four native char or char older than Age 6 were collected. The dramatic increase in length from age three to five suggests a major acceleration in growth, likely the result of diet shifting from macroinvertebrates to fish.

TABLE 18. Age and growth of native char sampled from Diablo Reservoir in August 2005.

	Age				
	1	2	3	4	5
TL(avg)	140.2 ± 26.0	234.9 ± 29.3	286.0 ± 36.2	ND	652.0 ± 110.3
n	6	18	5	0	2

	Age				
	6	7	8	9	10
TL(avg)	520.0 b	ND	ND	ND	ND
n	1	0	0	0	0

Condition of native char was generally above the national 75th percentile for bull trout and consistent with fish collected in the 1985 NPS sample for age one, two and three fish (**FIGURE 25**). Condition for the three larger individuals sampled was only slightly below the national 75th

percentile. The sample size for larger fish was insufficient to determine whether the three individuals sampled were typical for their age and size or whether any trends existed for the native char population.

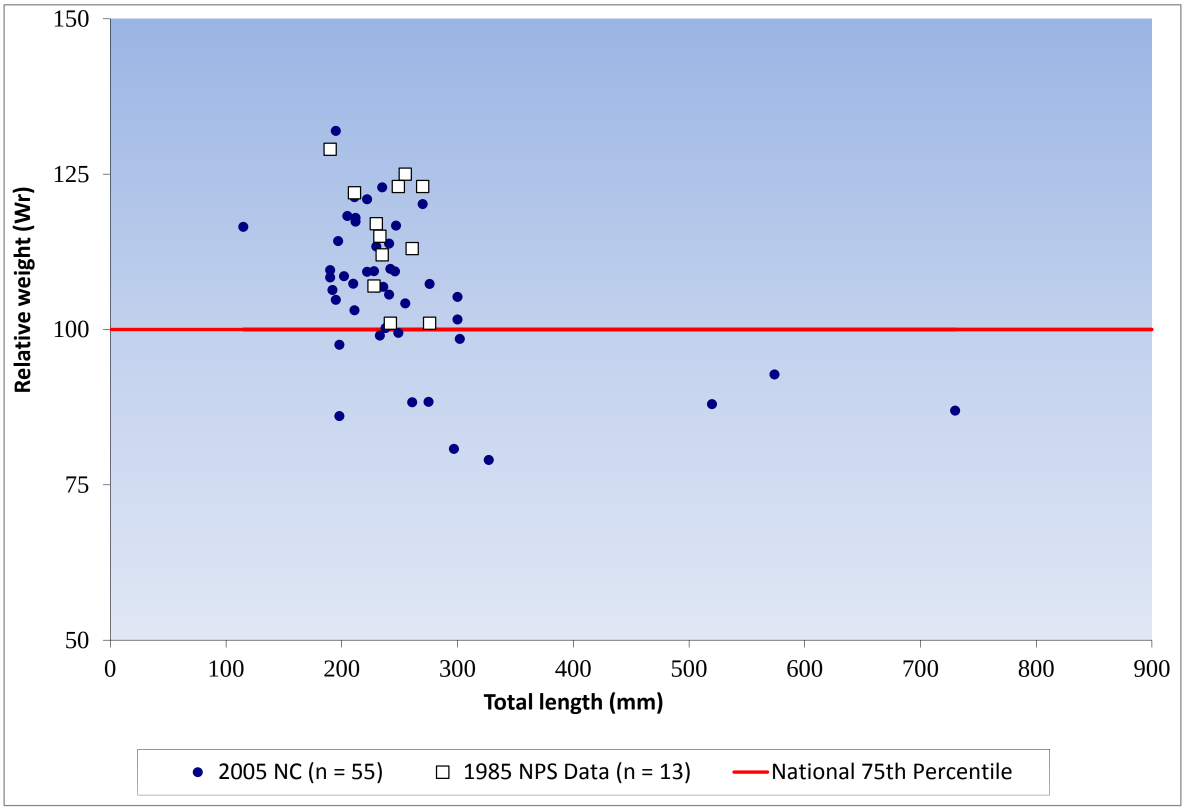

FIGURE 25. Relationship between total length and relative weight (Wr) of native char captured in Diablo Reservoir in August 2005.

Native char were, in general, easily distinguishable from the non-native eastern brook trout by the lack of vermiculations on the dorsal surface, lack of black spotting on the dorsal fin, size in the case of the three larger individuals sampled, and distinctly different flesh color of fish lethally sampled. However, a small number of sub-adult fish were difficult to distinguish because they appeared to have morphological characteristics of both species, such as black spotting on the dorsal fin without vermiculation on the dorsal surface and vice versa. Genetic material in the form of fin tissue samples was collected from all char for future investigation of the hybridization question and currently resides at the Washington Department of Fish and Wildlife genetics lab in Olympia, Washington.

Limitation of spawning habitat, which includes the upper reach of the reservoir just below the powerhouse, the first few linear meters of several small, high-gradient tributaries, about 200 meters of Colonial Creek and approximately four kilometers of Thunder Creek, raises the possibility of hybridization. These habitat limitations greatly reduce the potential for environmental gradients with respect to temperature, and elevation. Diablo Reservoir and associated tributaries represent an artificially segregated system with limited environmental heterogeneity. This somewhat closed system provides an opportunity to examine the potential for hybridization of native char with non-native eastern brook trout under conditions where resulting sympatry of these species provides the greatest potential for co-mingling during spawning. Genetic analysis in Diablo Reservoir has been relatively limited compared to that completed in Ross Lake and Diablo Reservoir. However, hybrids between bull trout and eastern brook trout, as well as hybrids between Dolly Varden and eastern Brook trout, have been found in limited genetic samples analyzed to date in this reservoir (Maureen Small, WDFW, pers. comm. 2011).

Rainbow trout age, length, and condition

WDFW sampled 161 rainbow trout from Diablo Reservoir in August 2005, ranging in length from 109 to 388 mm TL and ranging from one to four years in age (**FIGURE 26**).

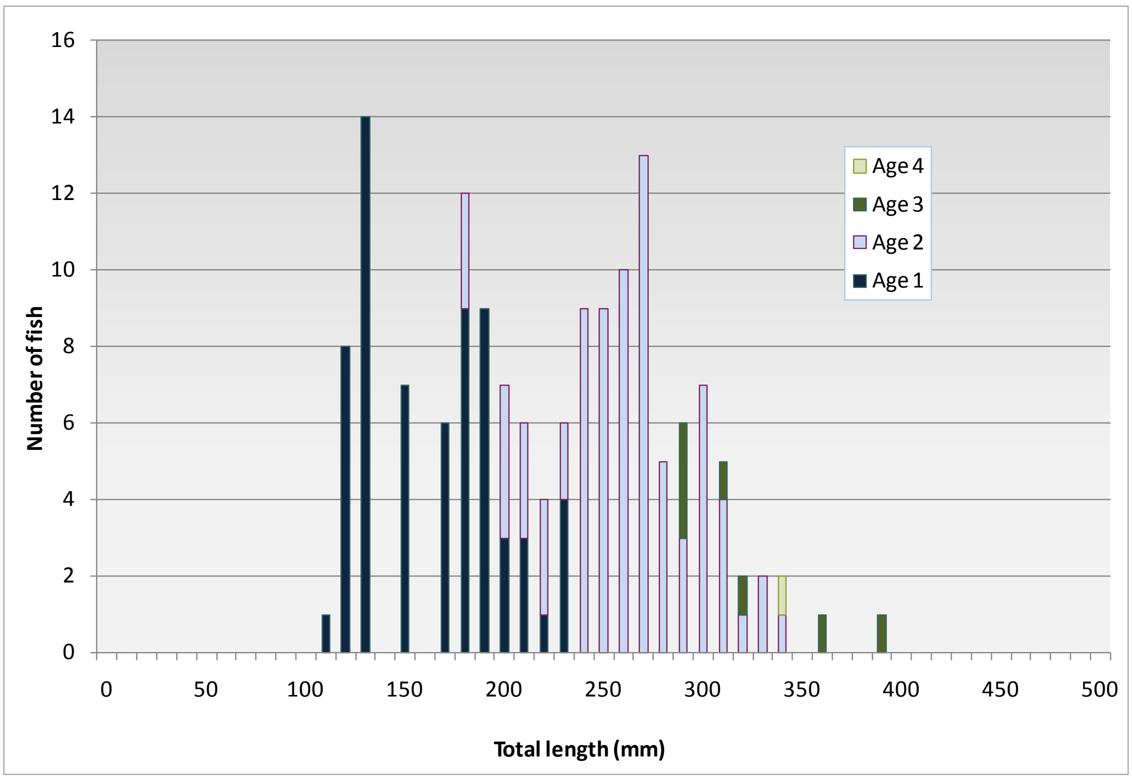

FIGURE 26. Length frequency histogram by age class of rainbow trout captured in Diablo Reservoir in August 2005**.**

Rainbow trout averaged 165.9 mm $\pm$ 36 (n = 33) at Age 1, 259.5 mm $\pm$ 37.6 (n= 48) at Age 2, 322.7 mm $\pm$ 41.1 (n =10) at Age 3, and 331 mm (n = 1) at Age 4 (Table 19). No rainbow trout older than age four were sampled. Paucity of older fish in the sample may have been the result of post-spawning mortality from the recent spawning cycle. Small introductions of rainbow trout from surplus egg takes on Ross were introduced into Diablo in 2004 and 2005. However ,the numbers were small (Table 7) and unlikely to have noticeably influenced the structure of the population in Diablo.

TABLE 19. Age and growth of rainbow trout sampled from Diablo Reservoir in August 2005

	Age				
	1	2	3	4	5
TL(avg)	165.9 ± 36.0	259.5 ± 37.6	322.7 ± 41.1	331.0	ND
n	33	48	6	1	0

Condition of rainbow trout sampled from Diablo Lake was generally below the 75th percentile compared with national standards but consistent with fish sampled by NPS in 1985 and within an acceptable range (**FIGURE 27**). Relative weight values appeared to trend slightly downward with respect to length, raising the possibility of inter-age class competition. A standard regression of Wr to TL for rainbow trout yielded a weak (R^2 = 0.07) but significant relationship (p = 0.0006). However, the expected preponderance of females and post-spawn fish at the high end of the length frequency distribution may also explain this, since Diablo rainbow trout had recently completed their spawning cycle.

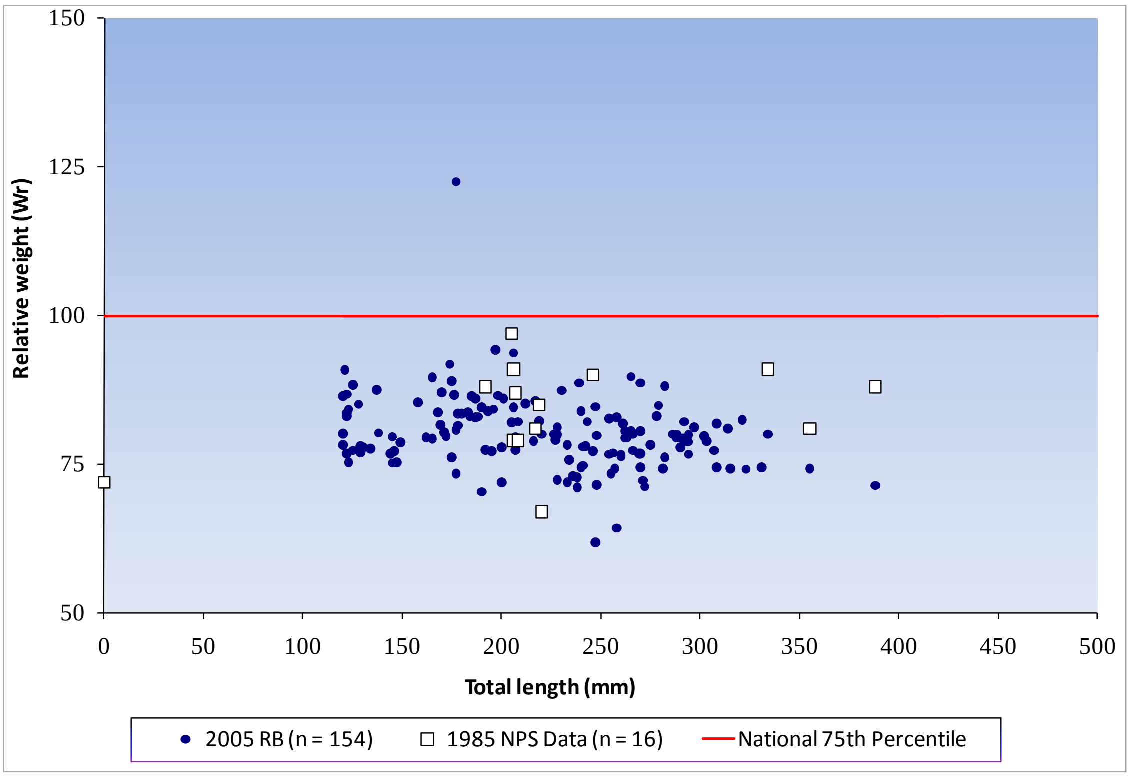

FIGURE 27. Relationship between total length and relative weight (Wr) of rainbow trout captured in Diablo Reservoir in August 2005**.**

Growth of rainbow trout could only be assessed through age four due to the lack of older fish in the sample, and sample size was too small for age four fish (n = 1) to draw strong conclusions about growth beyond age three. At age one, fish were similar in length to fish sampled from the Ross Lake tributaries, Dry and Roland Creeks, during 2002 and 2003 broodstock collections. At age two, Diablo rainbow trout fish averaged 29.3 mm less than Dry Creek (n = 13) fish and 17.4 mm less than Roland Creek (n = 64) fish in total length. At age three Diablo rainbow trout averaged 34.7 mm less than Dry Creek fish (n = 34). However, Roland Creek three year olds (n = 98) averaged only 12.9 mm more than Diablo rainbow in total length. The two age four fish collected from Diablo averaged 7 mm less than Dry Creek fish (n = 4) but 20.3 mm less than Roland Creek fish (n = 8).

Despite consistent differences in mean length between Diablo rainbow trout and those sampled from Ross Lake tributaries for each of the four age classes, the differences do not appear to be significant individually. Unequal sample sizes, differences in dates of collection, and differences in brood years make further statistical analysis inappropriate. However, the differences are systematic, and while small sample size of Diablo four year olds precludes any statistical comparison with the Ross fish, the lack of rainbow over 400 mm for this level of sampling effort and resulting sample size is of some concern.

The genetic composition of rainbow trout in Ross, Diablo and Gorge reservoirs has recently been analyzed as part of a larger study on Skagit River steelhead. These fish cluster separately from lower Skagit River steelhead and from introduced non-native stocks (Kassler and Warheit 2012), consistent with observations that most domesticated California stocks used historically by WDFW have not demonstrated high survival in western Washington wilderness lakes. Some Canadian stocks have been planted in high lakes within North Cascades National Park (Downen 2003), and may contribute to the ancestry of the current population in Diablo, but it is likely that the strongest genetic influence is that of upper Skagit rainbow. These samples should be included in future assessments of the Ross Lake rainbow trout stock, though they are unlikely to influence management decisions regarding the introduction of upper Skagit rainbow trout into Diablo.

Gorge Reservoir 2006 Fish Population Survey

Species Composition and Distribution

No fish were collected in the vertical gill nets. All results are calculated from horizontal gill net samples. Rainbow trout dominated the species composition of fish captured in Gorge Reservoir by number, making up 68.5% of the number of fish sampled and ranging in length from 103 to 320 mm while native char dominated the catch by weight, making up 54% of the biomass but only 18% of the number of fish sampled ranging in size from 130 to 751 mm in total length (**TABLE 20**). Eastern brook trout made up 6.8% of the catch by weight and 13.7% by number. Eastern brook ranged in size from 158 to 290 mm.

TABLE 20. Species composition of fish captured on Gorge Reservoir in August 2006.

	Species composition				
	by weight		by number		Size range (mm TL)
Species	(kg)	(%) wt	(#)	(%) n	
Rainbow trout (*Oncorhynchus mykiss*)	8.635	0.340	85	0.685	103 -320
Eastern brook trout (*Salvelinus fontinalis*)	1.72	0.068	17	0.137	158 -290
Native char (*Salvelinus* spp)	15.059	0.593	22	0.177	130 -751
Red side shiner (*Richardsonius balteatus*)	0	0.000	0	0.000	
Total	25.414	1.000	124	1.000	

Rainbow trout were collected at every littoral zone sampling location in the reservoir and were the dominant species at eight of the nine sampling sites. Eastern brook trout were collected from six of the nine sites (**FIGURE 28**). Eastern brook trout were collected in greatest abundance in shallow embayments along the northern shore and back eddy habitats of the reservoir. Native char were sampled much less frequently but made up substantial proportions of the sample near the powerhouse and Stetattle Creek where water temperatures were colder. Differences in water temperature may have influenced the distribution of char. Native char were the dominant species collected at one site near the powerhouse. No fish were sampled in the pelagic zone with the vertical gillnets. However, no redside shiners were collected from Diablo reservoir in 2005.

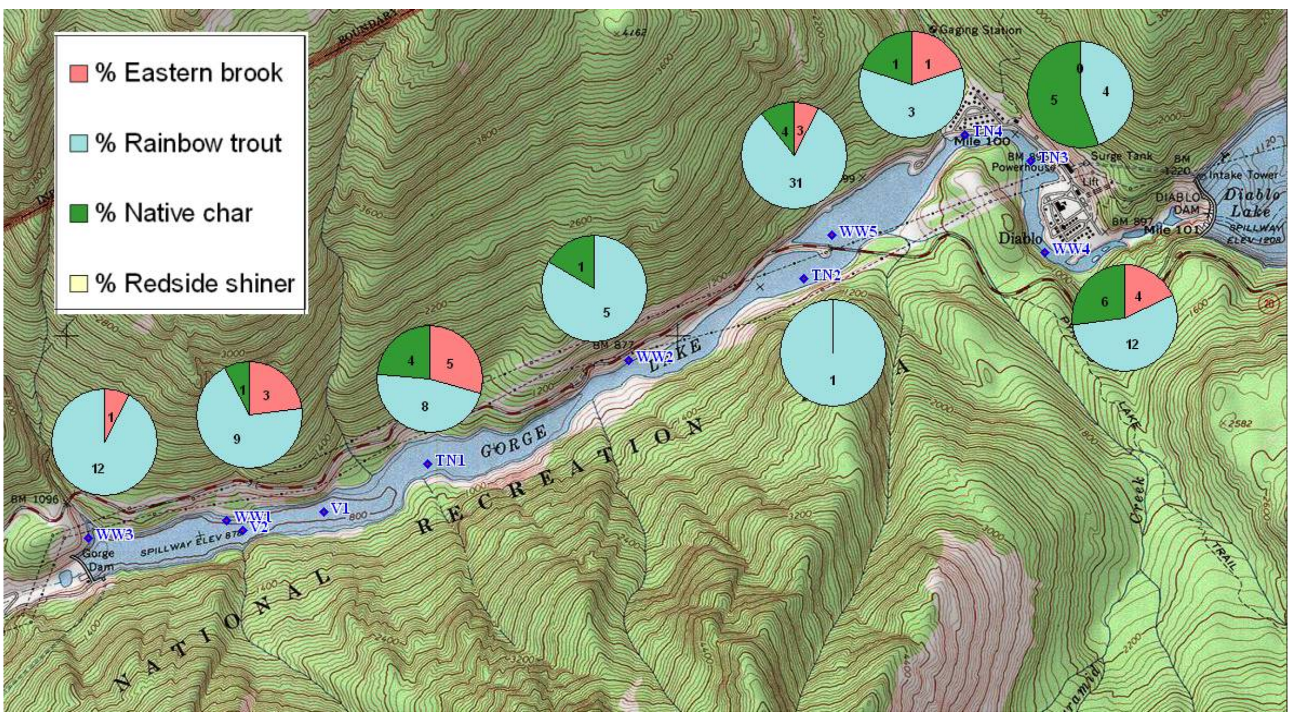

FIGURE 28. Species compositions at each sampling location for the Gorge fish community baseline survey of 2006**.** Numbers indicate sample size (numbers of each species) captured at each site.

Catch per Unit Effort

Catch rates were highest for rainbow trout, averaging 4 fish/net night for the short small-mesh nets and 13.8 fish/net night for the longer large-mesh nets (**TABLE 21**). Eastern brook trout CPUE was less than half that of rainbow trout for the small-mesh nets and a quarter that of rainbow for the large-mesh nets, while CPUE for native char was almost a quarter that of rainbow in the small-mesh nets and negligible in the large-mesh nets. Catch rates for stock-length rainbow trout were about 20% those calculated for all rainbow trout, and CPUE for stock-length eastern brook trout was about one-half that calculated for all eastern brook trout. The CPUE for stock-length native char was substantially smaller, about a third of the CPUE calculated for all native char.

TABLE 21. Catch per unit effort and confidence intervals around the mean for fish captured on Gorge Reservoir in August 2006.

Species	Repeating horizontal net (fish/night)	n (net nights)	Progressive horizontal net (fish/night)	n (net nights)	Vertical gill net (fish/night)	n (net nights)
All fish						
Rainbow trout	4 ± 1.89	4	13.8 ± 5.75	5	0	2
Eastern brook	1.5 [a]	4	2.2 ± 0.94	5	0	2
Native char	2.5 ± 1.53	4	2.4 ± 1.44	5	0	2
Stock length fish						2
Rainbow trout	0.5 ± 0.37	4	3.2 ± 2.85	5	0	2
Eastern brook	1 ± 0.91	4	1.4 ± 0.65	5	0	2
Native char	0.25 [a]	4	0.8 ± 0.48	5	0	2

[a] Sample size insufficient to calculate confidence intervals

Stock Density Indices

Despite robust sampling effort, sample sizes for stock-length rainbow trout (18 greater than 250 mm TL) and eastern brook trout (11 greater than 200 mm TL) were fairly small and stock density indices were hardly worth calculating (**TABLE 22**). No rainbow trout over 400 mm were sampled, resulting in proportional and relative stock densities of 0. Nor were any eastern brook trout over 300 mm were sampled, resulting in proportional and relative stock densities of 0. While sample size for stock-length native char (greater than 300 mm) was low, only five fish, four measured over 500 yielding a PSD of 80± 23 and two were greater than 650 mm yielding a PSD-P of 40.

TABLE 22. Proportional and relative stock densities for fish captured on Gorge Reservoir in August 2006.

Species	n	PSD	RSD-P	RSD-M	RSD-T
Rainbow trout	0	0	0	0	0
Eastern brook	0	0	0	0	0
Native char	5	80 ± 22.93	40±28.08	0	0

Eastern Brook Trout age, length, and condition

WDFW collected 17 eastern brook trout char from Gorge Reservoir in August 2006, ranging in length from 158 to 290 mm TL and ranging in age from one to three years (**FIGURE 29**).

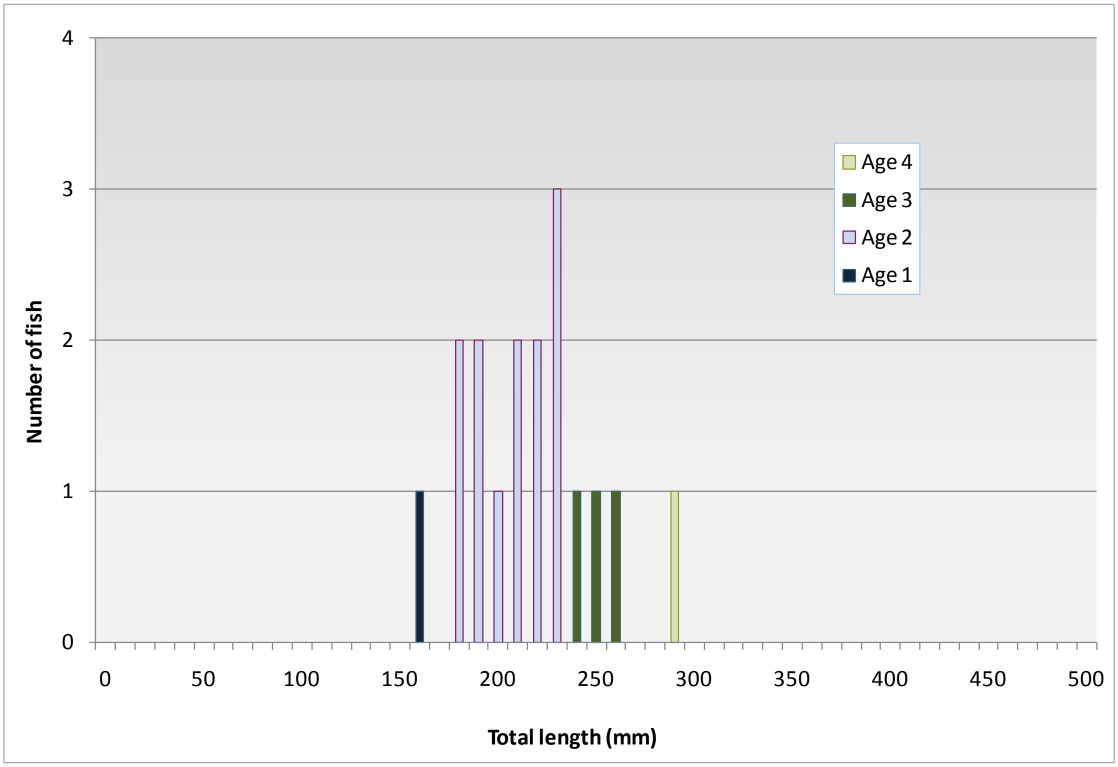

FIGURE 29. Length frequency distribution of eastern brook sampled from Gorge Reservoir in August 2006.

Eastern brook trout averaged 208.3 mm ± 17.1 (n= 7) at age two, and 242.5 mm ± 7.8 (n = 2) at age three (**TABLE 23**). No eastern brook aged one were sampled. Mean lengths indicate that growth for Gorge eastern brook trout are not characteristic of a population with excessive reproduction with respect to the available forage base through age three. However, suppressed growth rates could be influenced by colder water temperatures and low water retention times in Gorge. No eastern brook trout older than age three were sampled. This might be explained by an absence of spawning-aged fish, if they were already staging to spawn in Stettattle Creek and other streams outside the littoral zone of the reservoir, and thus, outside the study area.

TABLE 23. Age and growth of eastern brook trout sampled from Gorge Reservoir in August 2006.

	Age				
	1	2	3	4	5
TL_{avg}	ND	208.3± 17.1	242.5± 7.8	ND	ND
n	0	7	2	0	0

Condition of eastern brook trout sampled from Gorge Lake was slightly below the 75th percentile compared with national standards and well within an acceptable range (**FIGURE 30**). Relative weight values showed a slight downward trend with length and age for these fish, which would be not be expected as they were approaching their spawning cycle. Eastern brook trout collected from Gorge were generally deep-bodied and did not show typical signs of stunting, a phenomena unfortunately characteristic of many eastern brook trout populations in western Washington wilderness lakes.

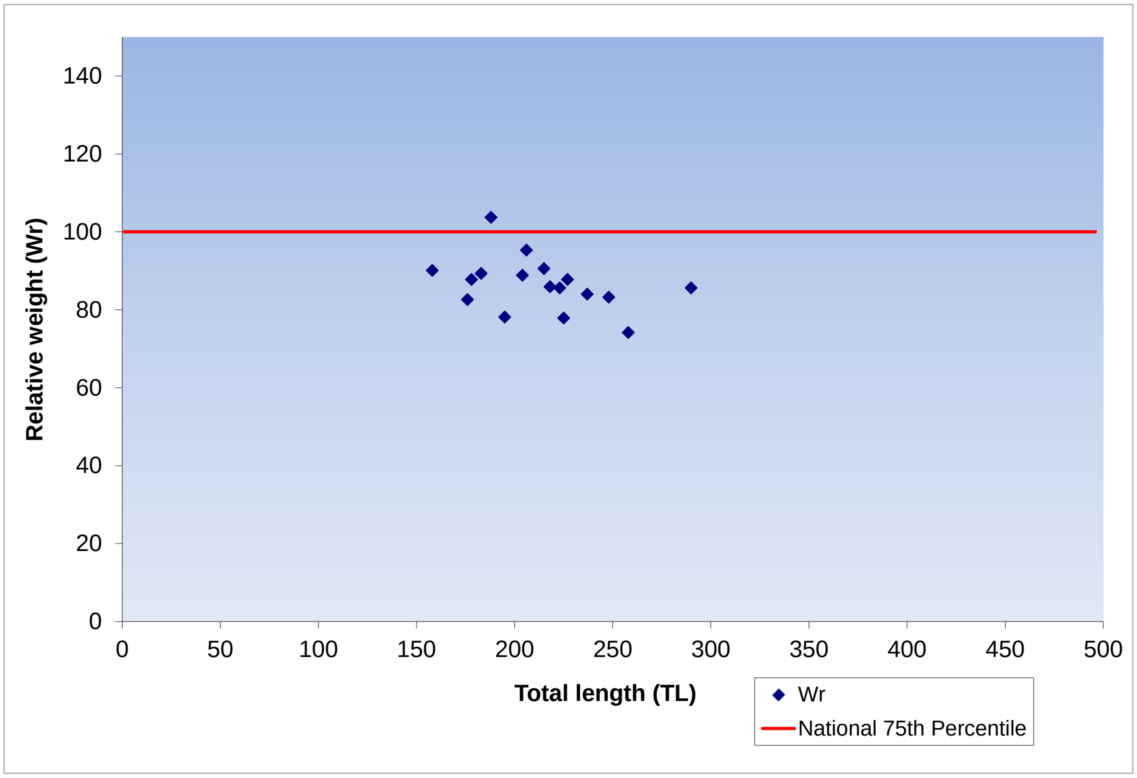

FIGURE 30. Relative weight for eastern brook sampled from Gorge Reservoir in August 2006

Native Char age, length, and condition

The potential complex of Dolly Varden (*Salvelinus malma*) and/or bull trout (*Salvelinus confluentus*) inhabiting Gorge Lake, will be referred to as native char in this report because it is currently suspected that both species exist in the reservoir but unknown what their relative contributions might be. Delineation between these species in Washington State has not been dependable based upon morphological and meristic characteristics (WDFW 1998). Some samples collected by the US Fish and Wildlife Service (USFWS) in 2001 from Thunder Creek were determined to be Dolly Varden based upon genetic analysis (USFWS 2001). However, morphological characteristics of fish collected by WDFW, including maxillary size and branchiostegal ray counts, have been consistent with those of bull trout (Haas and McPhail 1991).

WDFW sampled 22 native char from Gorge Reservoir in August 2006, ranging in length from 130 to 751 mm TL, and ranging from one to six years in age (**FIGURE 31**).

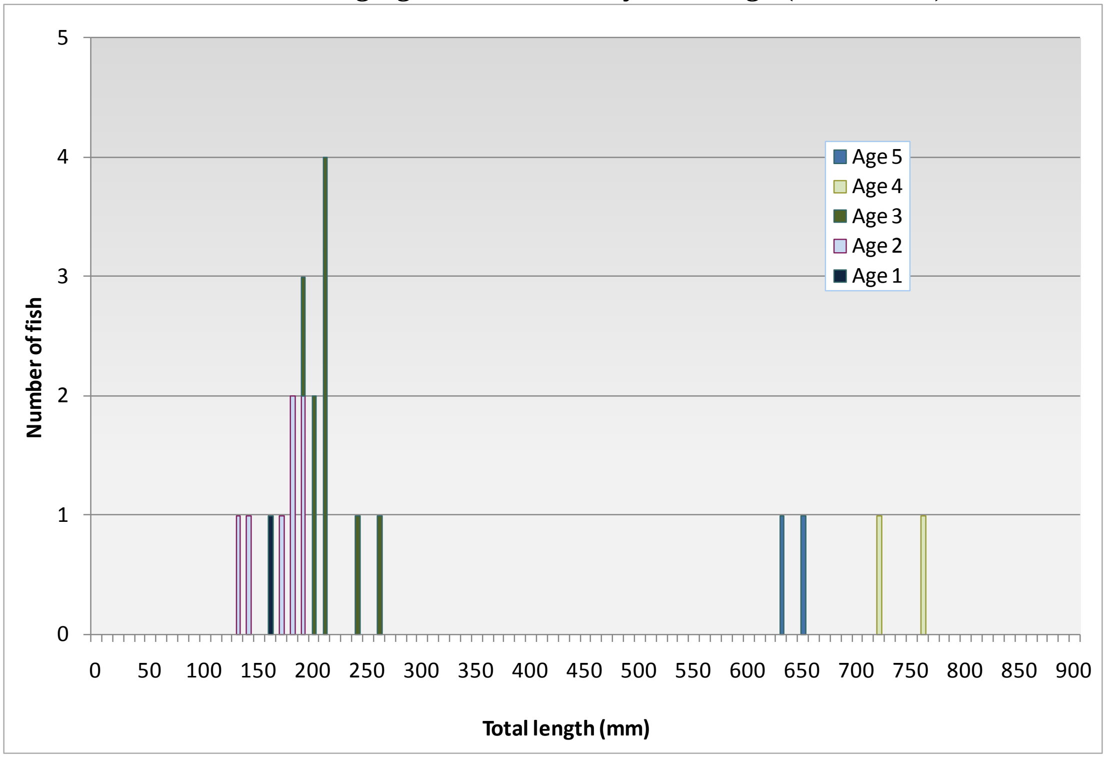

FIGURE 31. Length frequency distribution of native char sampled from Gorge Reservoir in August 2006.

Native char averaged 165.3 mm $\pm$ 23.0 TL (n = 7) at Age 2, 206.3 mm $\pm$ 16.4 (n = 6) at Age 3, and 577.3 mm $\pm$ 266.9 (n = 3) at Age 4, and 639.5mm$\pm$14.8 at Age 5 (**TABLE 24**). No native char age one or older than age five were collected. Growth rates for these fish were very slow in the first three years but the dramatic increase in length from age three to four suggests a major acceleration in growth, probably resulting from a diet shift to forage fish.

TABLE 24. Age and growth of native char sampled from Gorge Reservoir in August 2006.

	Age				
	1	2	3	4	5
TL_{avg}	ND	165.3$\pm$ 23.0	206.3$\pm$ 16.4	577.3$\pm$ 266.9	639.5$\pm$ 14.8
n	0	7	6	3	2

Condition of native char was generally well above the national 75th percentile (**FIGURE 32**). Condition for two of the four larger individuals sampled was consistent with or slightly above the national 75th percentile. The sample size for larger fish was insufficient to determine whether the four individuals sampled were typical for their age and size or whether any trends existed for the native char population.

Native char were, in general, easily distinguishable from the non-native eastern brook trout by the lack of vermiculations on the dorsal surface, lack of black spotting on the dorsal fin, size in the case of the three larger individuals sampled, and distinctly different flesh color of fish lethally sampled. However, a small number of sub-adult fish were difficult to distinguish because they appeared to have morphological characteristics of both species, such as black spotting on the dorsal fin without vermiculation on the dorsal surface and vice versa.

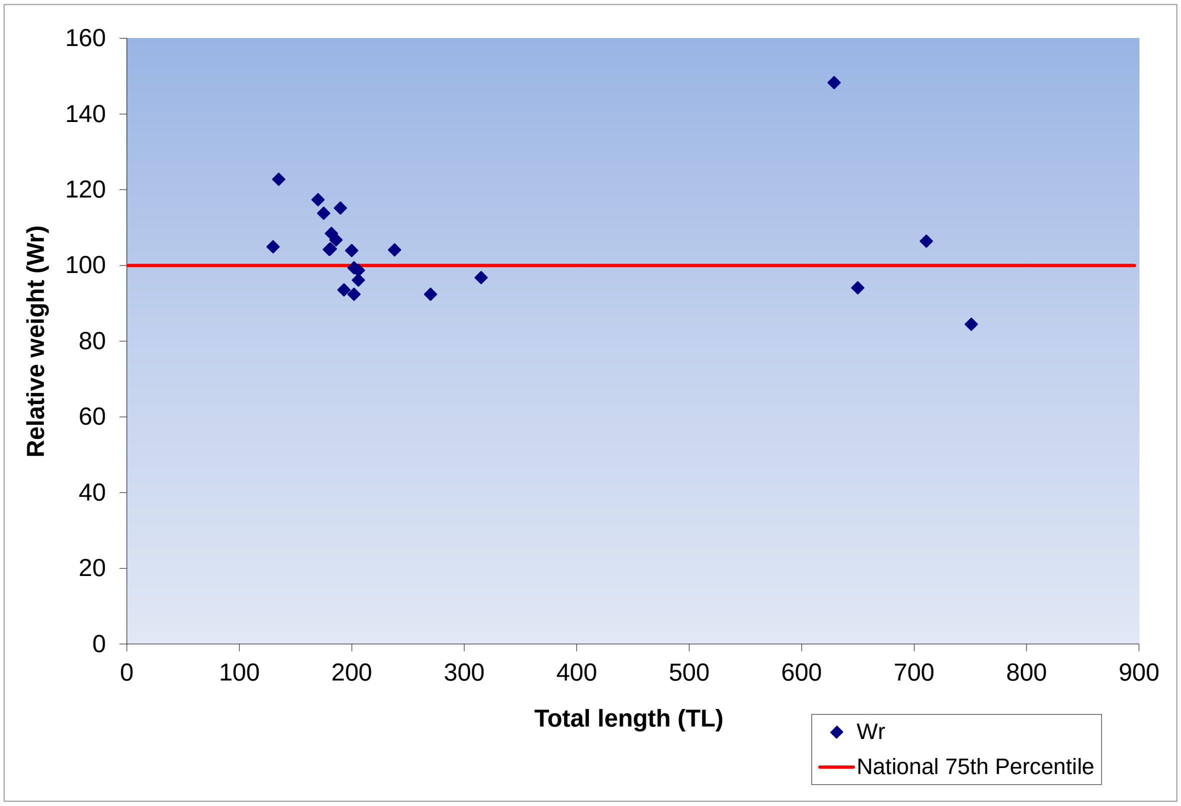

FIGURE 32. Relative weight for native char sampled from Gorge Reservoir in August 2006.

Limitation of spawning habitat, which includes the upper reach of the reservoir just below the powerhouse, the first few linear meters of several small, high-gradient tributaries, and about 500 meters of Stetattle Creek raises the possibility of hybridization. These habitat limitations greatly reduce the potential for environmental gradients with respect to temperature, and elevation. The Gorge Reservoir and associated tributaries represent an artificially segregated system with limited environmental heterogeneity. This somewhat closed system provides an opportunity to examine the potential for hybridization of native char with non-native eastern brook trout under conditions where resulting sympatry of these species provides the greatest potential for co-mingling during spawning. The first step, however, will be to determine whether the native char are bull trout or Dolly Varden or some combination of the two.

Rainbow Trout age, length, and condition

WDFW sampled 85 rainbow trout from Gorge Reservoir in August 2006, ranging in length from 103 to 320 mm TL and ranging from one to four years in age (**FIGURE 33**).

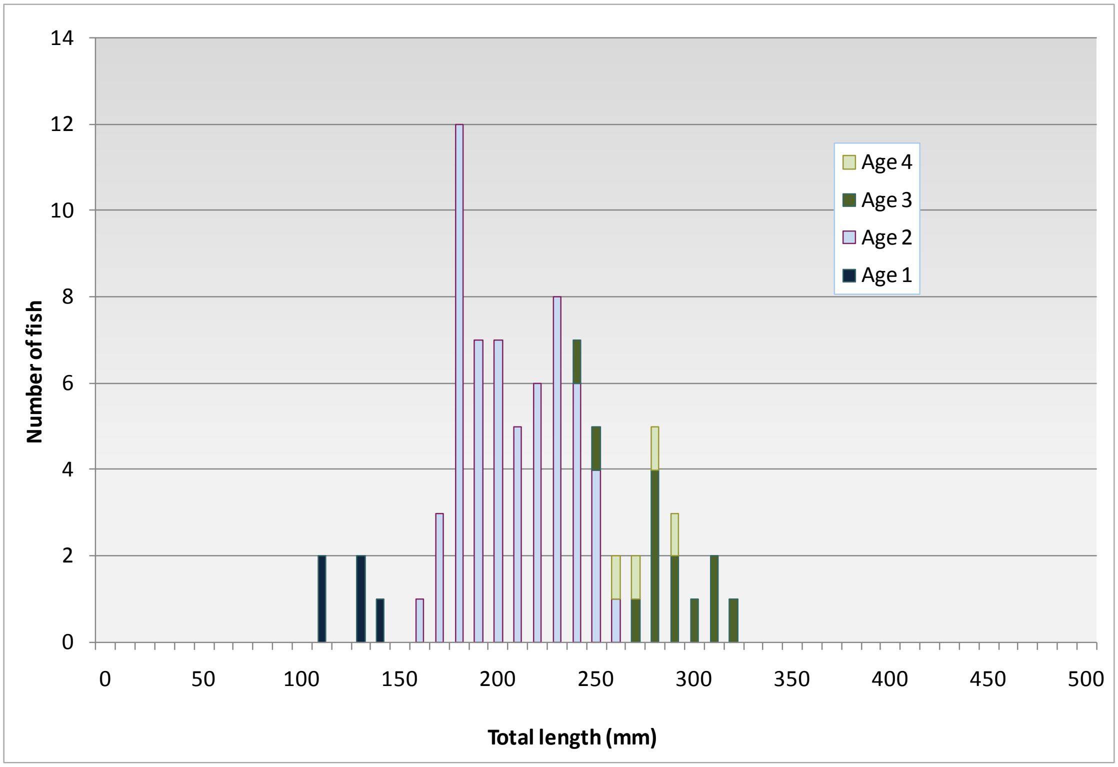

FIGURE 33. Length frequency distribution of rainbow trout sampled from Gorge Reservoir in August 2006.

Growth rates appeared low for rainbow trout, which averaged 119.0 mm ± 15.4 (n = 4) at Age 1, 204.6 mm ± 26.3 (n= 39) at Age 2, 278.8 mm ± 24.3 (n =13) at Age 3, and 267.8 mm ± 14.4 (n = 4) at Age 4 (**TABLE 25**). No rainbow trout older than age four were sampled. Paucity of older fish in the sample may have been the result of post-spawning mortality from the recent spawning cycle.

TABLE 25. Age and growth of native char sampled from Gorge Reservoir in August 2006.

	Age				
	1	2	3	4	5
TL_{avg}	119.0± 15.4	204.6± 26.3	278.8± 24.3	267.8± 14.4	ND
n	4	39	13	4	0

Condition of rainbow trout sampled from Diablo Lake was below the 75th percentile compared with national standards but consistent with fish sampled from Diablo and within an acceptable range (**FIGURE 34**). Relative weight values showed no trend with respect to length, suggesting slow growth was more likely a thermal regime phenomenon than the result of inter-age competition.

Growth of rainbow trout could only be assessed through age four due to the lack of older fish in the sample, and sample size was too small for age four fish (n = 4) to draw strong conclusions about growth beyond age three. Age 2, 3 and 4 rainbow trout sampled from Gorge were dramatically smaller than spawners sampled from Ross Lake. Age 2 fish, averaged 73.4 mm less than Dry Creek fish (n = 13) and 61.6 mm less than Roland Creek fish (n = 64) in total length. At age three Gorge rainbow trout averaged 73.85 mm less than Dry Creek fish (n = 34), and 61.6mm less than Roland Creek fish (n = 98), and at age four they averaged 99.2 mm less than Dry Creek fish (n = 4)and 102.5mm than Roland Creek fish (n = 8) rainbow in total length. These growth rates are likely influenced by both water temperature and reservoir productivity.

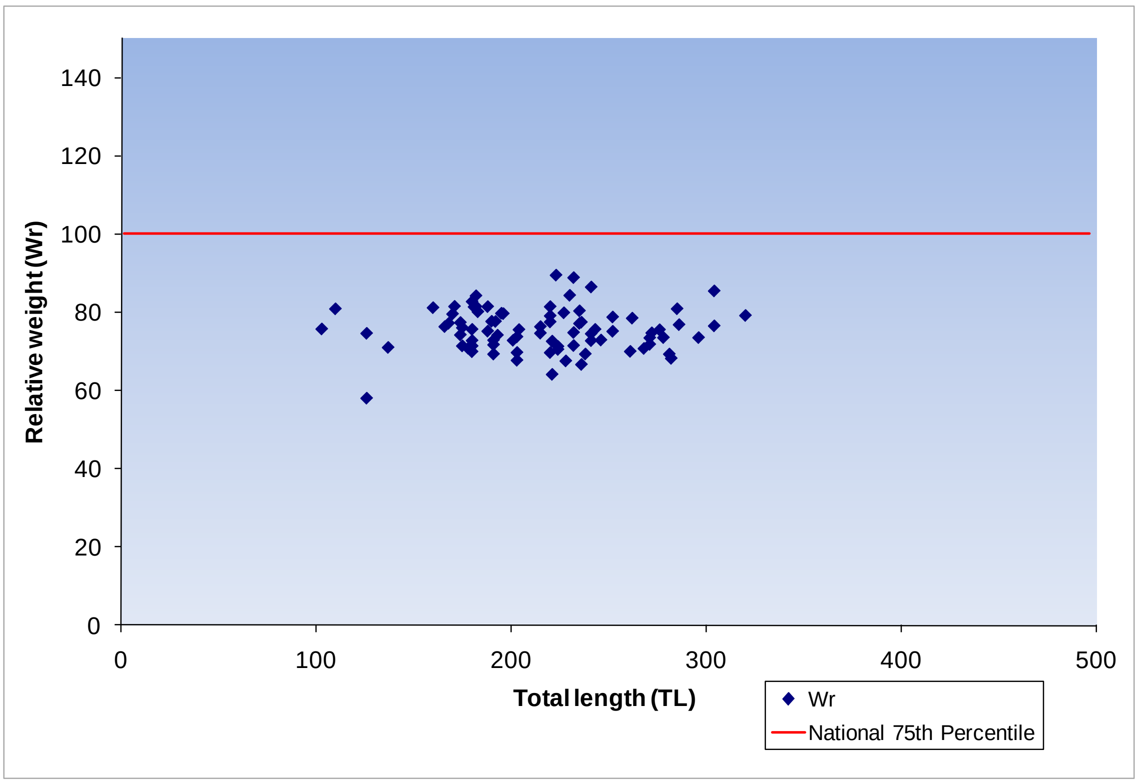

FIGURE 34. Relative weight for rainbow trout sampled from Gorge Reservoir in August 2006.

Consistent differences in mean length between Gorge rainbow trout and those sampled from Ross Lake tributaries for each of the four age classes do appear to be significant. However, unequal sample sizes, differences in dates of collection, and differences in brood years and the possibility that Gorge samples were biased by variability in maturity rates make further statistical analysis inappropriate. The differences are systematic, and while the small sample size of Gorge four year olds precludes any statistical comparison with the Ross fish, the lack of rainbow over 400 mm for this level of sampling effort and resulting sample size is noteworthy.

Based on 2010 samples collected from Stetattle Creek, the genetic composition of rainbow trout in Gorge Lake was recently identified as originating to Ross Lake rainbow. (Todd Kassler, WDFW, personal communication). This is not surprising given the recent history of stocking Ross Lake rainbow from the Marblemount hatchery. It would be expected that these fish were derived from some combination of upper Skagit and introduced non-native stocks. However, most domesticated California stocks used historically by WDFW have not demonstrated high survival in western Washington wilderness lakes and have inconsistent spawn timing with native stocks and have left no detectible legacy in Gorge. Some Canadian stocks have been planted in high lakes within North Cascades National Park (Downen 2003), and may contribute to the ancestry of the current population in Diablo, but it is likely that the strongest genetic influence is that of upper Skagit rainbow. These samples should be included in future assessments of the Ross Lake rainbow trout stock, though they are unlikely to influence management decisions regarding the introduction of upper Skagit rainbow trout into Gorge.

Ross Lake 2006 Fish Population Survey

Species Composition and Distribution

Vertical gill nets were not used to sample fish on Ross Lake. All results are calculated from horizontal gill net samples. Rainbow trout dominated the species composition of fish captured at Ross Lake index sites both by number, making up 77.9% of the sample and ranging in length from 121 to 325 mm (**TABLE 26**). Eastern brook trout made up less than 1% of the catch by weight and 1.8% by number while native char made up 50.2% by weight but only 14.7% by number. Eastern brook ranged in size from 200 to 308 mm in total length and native char ranged in size from 186 to 760 mm in total length. The collection of 4 adult redside shiners, ranging from 98 to 109 mm TL, represented the first documented capture of this species in Ross Lake.

TABLE 26. Species composition of fish captured on Ross Reservoir in August 2006.

	Species composition				
	by weight		by number		Size range (mm TL)
Species	(kg)	(%) wt	(#)	(%) n	
Rainbow trout (*Oncorhynchus mykiss*)	19.129	0.473	127	0.779	121 - 325
Eastern brook trout (*Salvelinus fontinalis*)	0.375	0.009	3	0.018	200 - 308
Native char (*Salvelinus* spp)	20.292	0.502	24	0.147	186 - 760
Red side shiner (*Richardsonius balteatus*)	0.047	0.001	4	0.025	98 - 109
Total	40.417	1.000	163	1.000	

Rainbow trout were collected at all three sampling locations in the reservoir and in each replicate net set (**FIGURE 35**). They were the dominant species at index sampling sites and in all but one replicate net set. Eastern brook trout were collected from only one site, in Ruby Arm, and in both replicates at that site. Native char were sampled at all index sites and in all replicate net sets. Native char were the dominant species collected in one of the Big Beaver net sets, the one nearest the turbidity curtain at the inflow. No fish were sampled in the pelagic zone with the vertical gill nets.

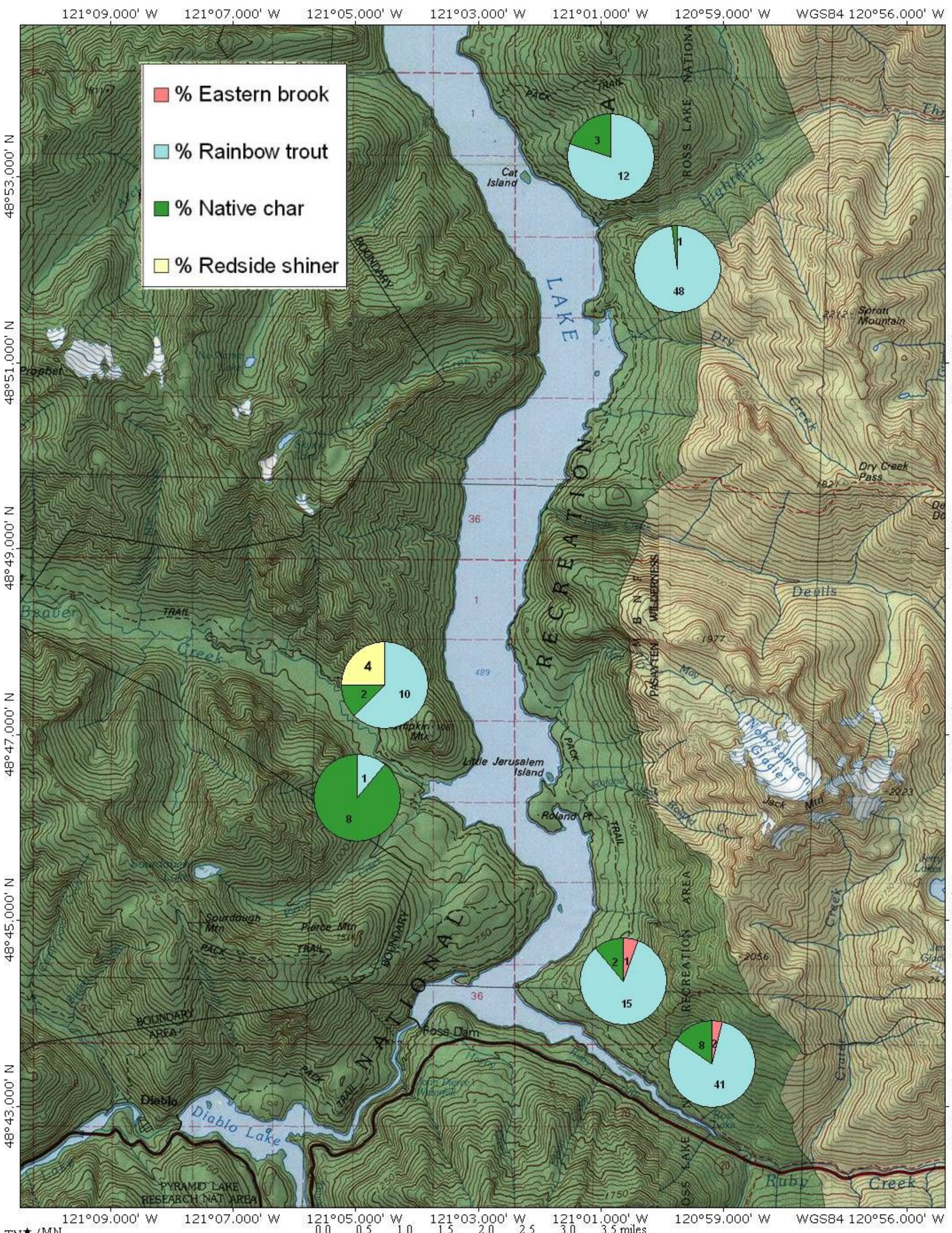

FIGURE 35. Species compositions at each sampling location for the Ross Lake fish community baseline survey of 2006

Catch per Unit Effort

Catch rates were highest for rainbow trout, averaging 18 fish/net night for the short small-mesh nets and 24.3 fish/net night for the longer large-mesh nets (**TABLE 27**). Eastern brook trout CPUE was less than one fish/net night for the small-mesh nets and the large-mesh nets, while CPUE for native char was about a third that of rainbow in the small-mesh nets and negligible in the large-mesh nets. Catch rates for stock-length rainbow trout were about 60% those calculated for all rainbow trout, and CPUE for stock-length eastern brook trout was equal to that calculated for all eastern brook trout. The CPUE for stock-length native char was substantially smaller, about a third of the CPUE calculated for all native char.

TABLE 27. Catch per unit effort for fish captured on Ross Lake in August 2006.

Species	Repeating horizontal gill net (fish/night)			n (net nights)	Progressive horizontal gill net (fish/night)			n (net nights)	Vertical gill net (fish/night)	n (net nights)
All fish										
Rainbow trout	18.0	±	15.29	3	24.3	±	15.28	3	NA	0
Eastern brook	0.7		[a]	3	0.3		[a]	3	NA	0
Native char	6.3	±	2.14	3	1.7	±	0.43	3	NA	0
Stock length fish										0
Rainbow trout	9.3	±	7.45	3	17.3	±	13.03	3	NA	0
Eastern brook	0.7		[a]	3	0.3		[a]	3	NA	0
Native char	2.3	±	1.86	3	0.7	±	0.43	3	NA	0

[a] Sample size insufficient to calculate confidence intervals (CI).

Proportional Stock Density Indices

Despite robust sample sizes for stock-length rainbow trout (55 greater than 250 mm TL) and eastern brook trout (56 greater than 200 mm TL), stock density indices were hardly worth calculating (**TABLE 28**). No rainbow trout over 400 mm were sampled, resulting in proportional and relative stock densities of 0. Nor were any eastern brook trout over 300 mm were sampled, resulting in proportional and relative stock densities of 0. While sample size for stock-length native char (greater than 300 mm) was low, only nine fish, four measured over 500 yielding a PSD of 78± 17.76 and two were greater than 650 mm yielding a PSD-P of 22.

TABLE 28. Proportional and relative stock densities for fish captured on Ross Lake in August 2006.

Species	n	PSD			RSD-P			RSD-M	RSD-T
Rainbow trout	80	0			0			0	0
Eastern brook	2	0			0			0	0
Native char	9	78	±	17.76	22	±	17.76	0	0

Eastern Brook Trout age, length, and condition

Only three eastern brook trout were captured on Ross Lake in August 2006. All three fish were stock length, measuring 200, 204, and 308 mm in length with relative weights of 86, 78, and 65 respectively. These relative weights were all below the national 75th percentile. All three fish were captured in Ruby arm and all were Age 3.

Native char age, length, and condition

The potential complex of Dolly Varden (*Salvelinus malma*) and/or bull trout (*Salvelinus confluentus*) inhabiting Ross Lake, will be referred to as native char in this report because there is no established protocol for distinguishing these species in the field in the reservoir so it is unknown what their relative abundance might be to catch. Delineation between these species in Washington State has not been dependable based upon morphological and meristic characteristics (WDFW 1998). Based upon the genetic analysis of tissues samples collected between 2002 and 2008, bull trout are the dominant char species present in Ross Lake. Of the approximately 100 native char samples in Ross Lake during this period, all were determined to be bull trout (Smith 2011). Both bull trout and Dolly Varden populations have been identified in the upper Skagit Basin above Ross Lake, where these species tend to segregate along gradients of elevation and water temperature. Dolly Varden have been found to be present in the tributaries to Ross Lake and the upper Skagit River (British Columbia). Dolly Varden were found to be the dominant char species in Lightning Creek (Smith 2011), as well as major tributaries to the upper Skagit River in British Columbia (McPhail and Taylor 1995). Bull trout / Dolly varden hybrids have also been detected in native char samples collected in the upper Skagit (McPhail and Taylor 1995; Smith 2011). However, morphological characteristics of fish collected by WDFW, including maxillary size and branchiostegal ray counts, have been consistent with those of bull trout (Haas and McPhail 1991).

WDFW sampled 24 native char from Ross Reservoir in August 2006 and they were present at all three index sites and in each replicate net set (**FIGURE 36**).

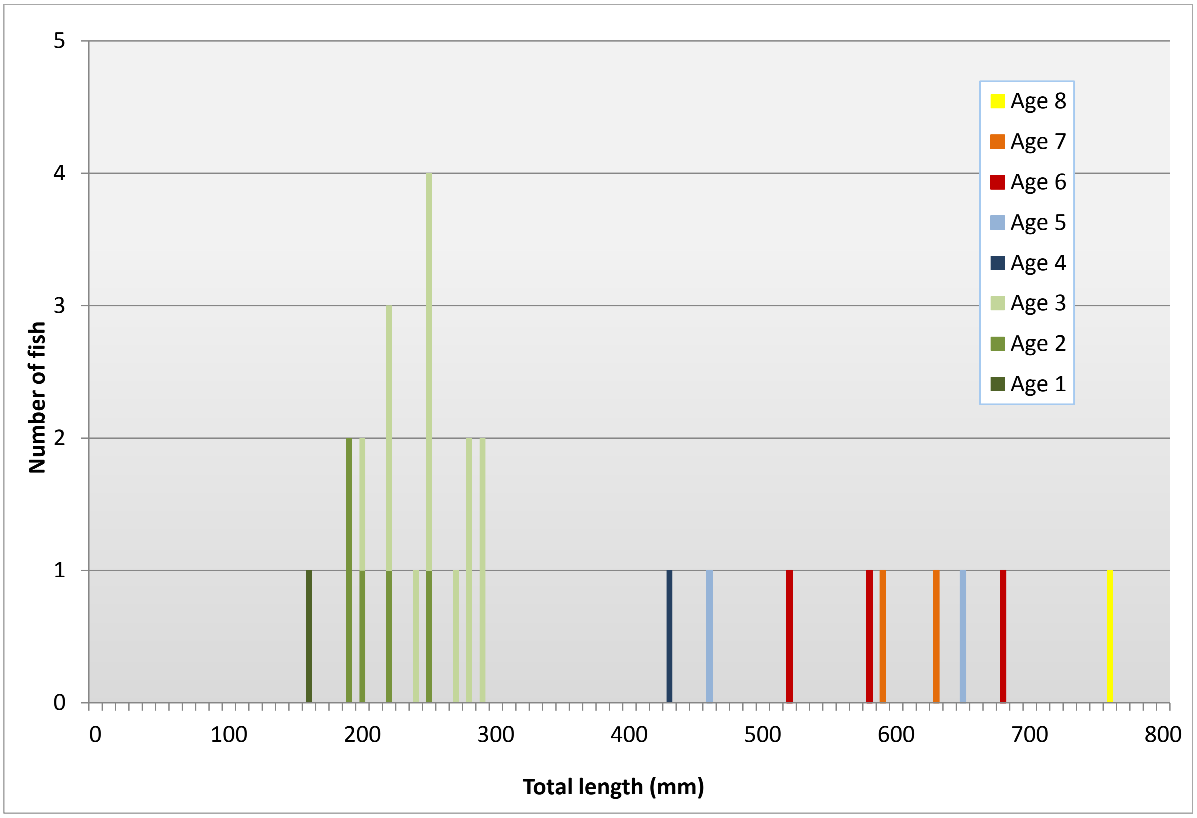

FIGURE 36. Length frequency distribution of native char sampled from Ross Lake in August 2006.

Fish ranged in length from 186 to 760 mm TL, and ranged from two to eight years in age (Figure 36). Native char averaged 209.0 mm ± 25.9 TL (n = 4) at Age 2, and 251.9 mm ± 29.5 (n = 11) at Age 3. Samples of older fish yielded average sizes of 428 mm for Age 4, 460 for Age 5, 546.5 for Age 6, 630.7 for Age 7, and 760 for Age 8 (**TABLE 29**). No native char age one or older than age eight were collected. Growth rates for these fish were very slow in the first three years but the Ross char demonstrated the same dramatic increase in length from age three to four as the Diablo and Gorge populations, indicating a major acceleration in growth, probably resulting from a diet shift to forage fish.

TABLE 29. Age and growth of native char sampled from Ross Lake in August 2006.

	Age				
	1	2	3	4	5
TL_{avg}	ND	209.0 ± 25.9	251.9 ± 29.5	428.0	460.0
n	0	4	11	1	1

	Age				
	6	7	8	9	10
TL_{avg}	546.5 ± 40.3	630.7 ± 43.2	760.0	ND	ND
n	2	3	1	0	0

Condition of native char was generally well above the national 75th percentile (**FIGURE 37**). Relative weight values for native char ranged from 75 to 140 with values for Age 1, 2, and 3 fish tending above 100 and values for older fish falling below 100. Condition for two of the four larger individuals sampled was only slightly below the national 75th percentile. The sample size for larger fish was insufficient to determine whether the three individuals sampled were typical for their age and size or whether any trends existed for the native char population.

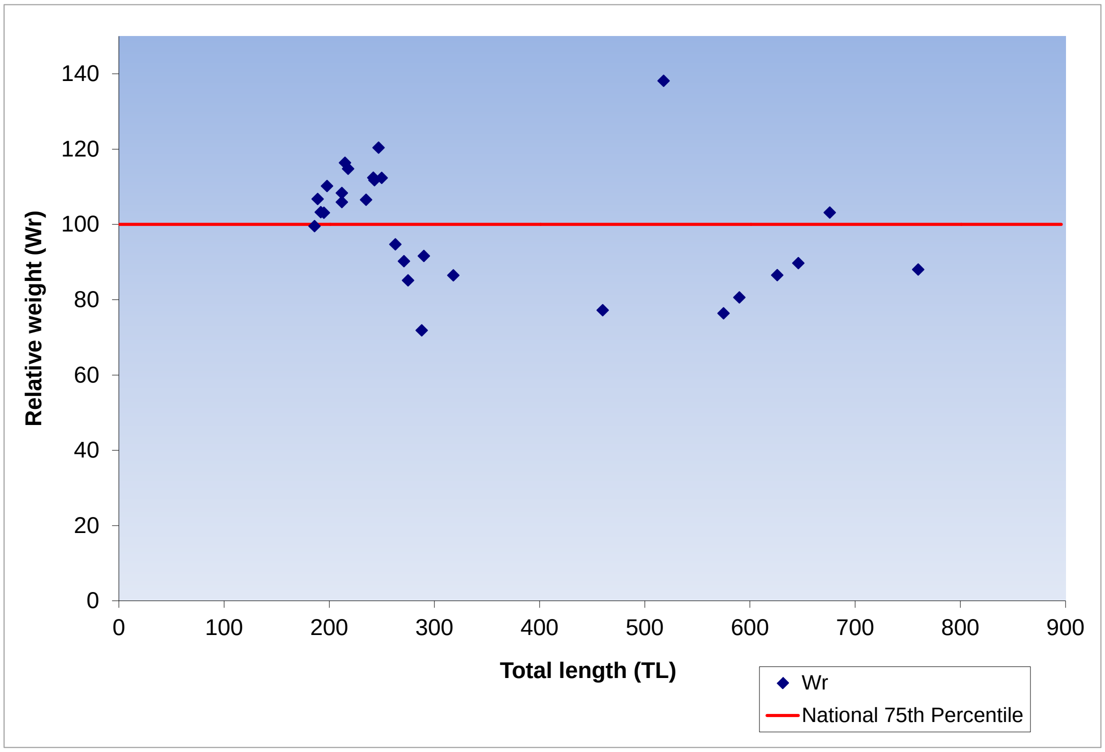

FIGURE 37. Relative weight for native char sampled from Ross Reservoir in August 2006.

Native char were, in general, easily distinguishable from the non-native eastern brook trout by the lack of vermiculations on the dorsal surface, lack of black spotting on the dorsal fin, size in the case of the three larger individuals sampled, and distinctly different flesh color of fish lethally sampled. However, a small number of sub-adult fish were difficult to distinguish because they appeared to have morphological characteristics of both species, such as black spotting on the dorsal fin without vermiculation on the dorsal surface and vice versa.

Field observations of small, poorly conditioned fish led to a systematic examination of the fish for internal parasites. The primary parasite identified in rainbow trout and native char was a cestode of the genus *Bothriocephalus*, common in *Salvelinus* and *Oncorhynchus* spp. The adult life stage inhabits the gut of adult fishes while the larvae are proceroid in copepods.

Parasite load was assessed by counting the numbers of visible cestodes within the body cavity, particularly on the exterior gut wall and around the pyloric ceca. A scale was devised, one to five being Low, 5 to ten being Moderate, and greater than 10 being high. Native char ranging from 170 to 220mm in total length had no or low cestodes present while larger, older fish were more likely to have low, moderate of high numbers of visible cestodes present (**FIGURE 38**). This may be the result of dietary transmission from rainbow trout.

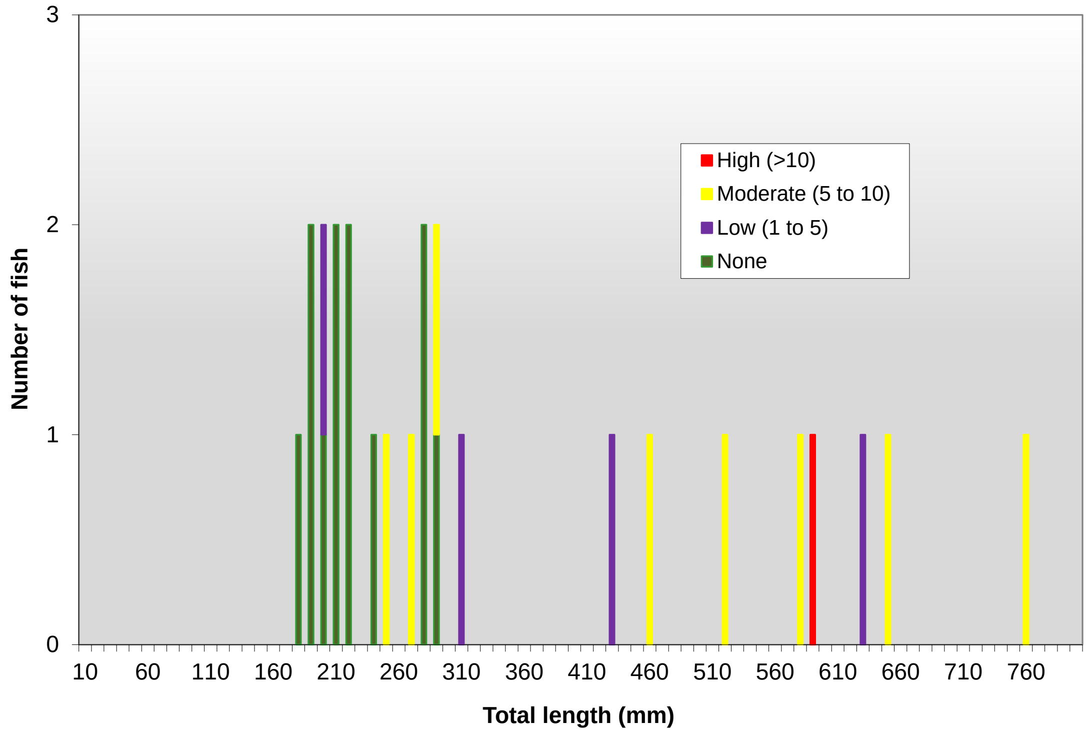

FIGURE 38. Length Frequency with respect to internal parasite load for native char sampled from Ross Reservoir in August 2006.

Rainbow trout age, length, and condition

WDFW sampled 127 rainbow trout from Ross Reservoir in August 2006, ranging in length from 121 to 325 mm TL and ranging from one to four years in age (**TABLE 30** and **FIGURE 39**). Growth rates appeared highly variable and diminished with increasing age for rainbow trout, which averaged 159.4 mm ± 39.1 (n = 5) at age one, 239.3 mm ± 40.2 (n= 50) at age two, 281.8 mm ± 29.5 (n =29) at age three, and 285.9 mm ± 30.4 (n = 7) at age four. No rainbow trout older than age four were sampled. Paucity of older fish in the sample may have been the result of post-spawning mortality from the recent spawning cycle.

TABLE 30. Age and growth of rainbow trout sampled from Ross Lake in August 2006

	Age				
	1	2	3	4	5
TL(avg)	159.4 ± 39.1	239.3 ± 40.2	281.8 ± 29.5	285.9 ± 30.4	ND
n	5	50	29	7	0

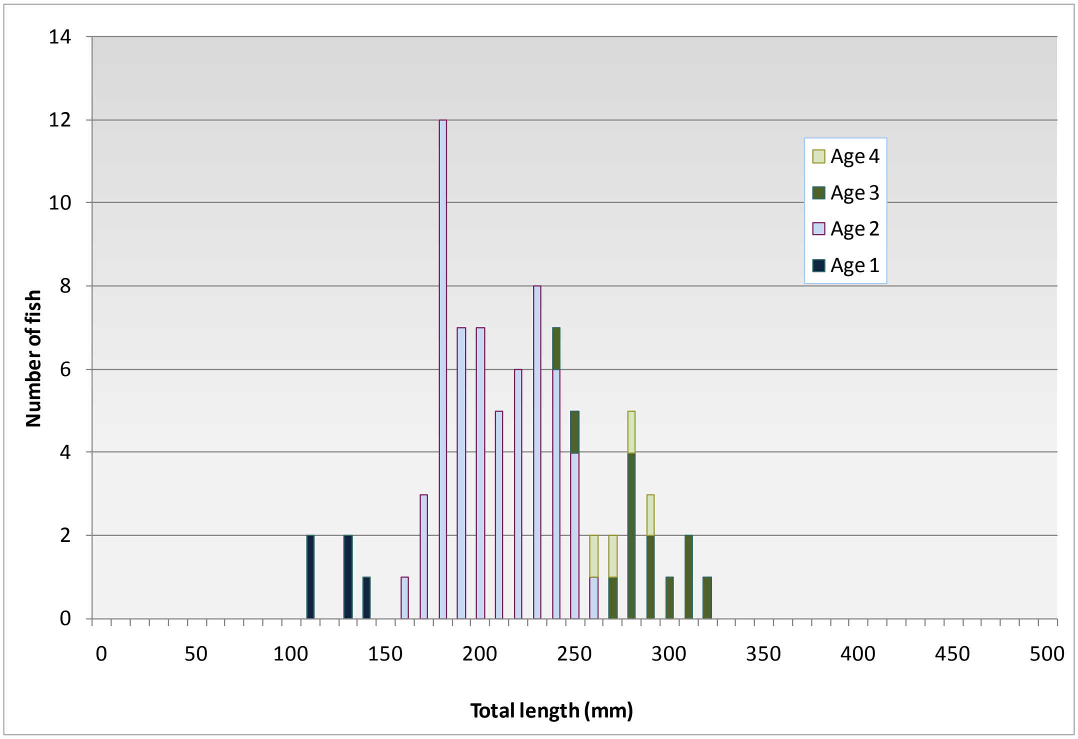

FIGURE 39. Length frequency distribution of rainbow trout sampled from Ross Lake in August 2006.

Condition of rainbow trout sampled from Ross Lake (**FIGURE 40**) was well below the 75th percentile compared with national standards, slightly below fish sampled from Diablo, and well below fish sampled from Gorge. Relative weight values showed a declining trend with respect to length, suggesting slow growth was related to age.

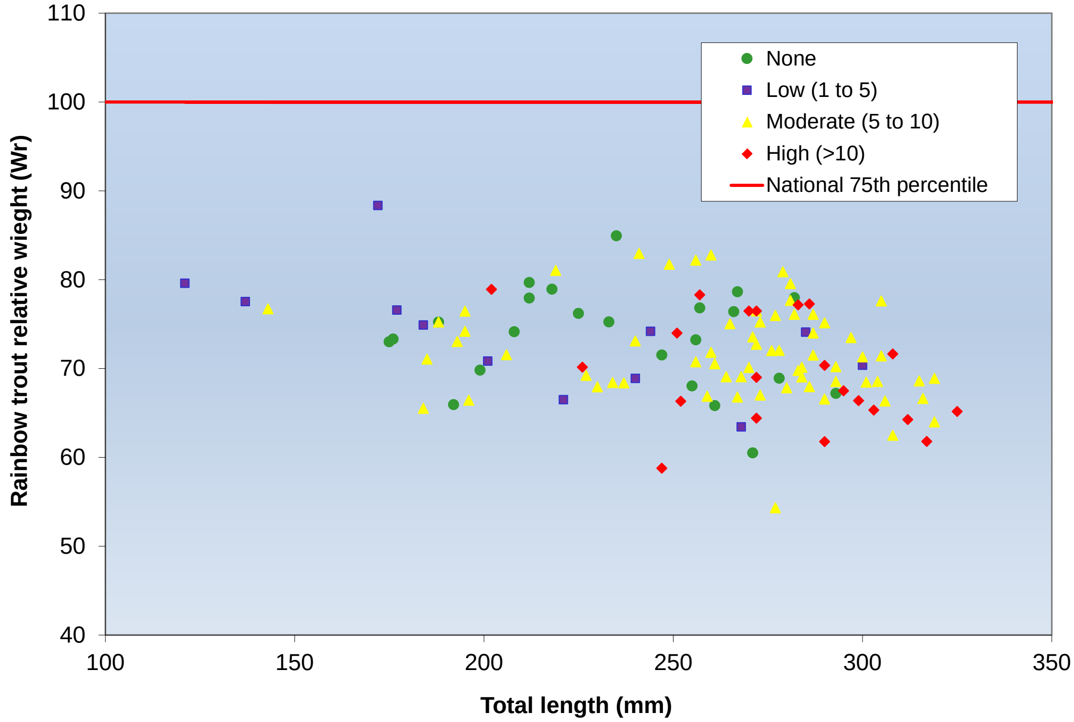

FIGURE 40. Relationship between relative weight and parasite load with respect to increasing length for rainbow trout sampled from Ross Lake in August 2006.

Field observations of small, poorly conditioned fish led to a systematic examination of the fish for internal parasites. The primary parasite identified in rainbow trout and native char was a cestode of the genus *Bothriocephalus*, common in *Salvelinus* and *Oncorhynchus* spp. The adult life stage inhabits the gut of adult fishes while the larvae are proceroid in copepods, a potentially important forage for rainbow trout. WDFW examined 121 rainbow trout in the field and found 80.9% were infected with the *Bothriocephalus* cestode (**FIGURE 41**). These rainbow trout lacked body fat and cysts and cestodes were observed on the exterior surface of the gut itself and around the pyloric caeca. The correlation between parasite load, age, and reduced growth suggest these parasites may be influencing the growth rates of rainbow trout in Ross Lake. However, the recent discovery of redside shiner in Ross Lake may have ecosystem-wide implications, including potential effects on growth and condition of rainbow trout.

Growth of rainbow trout in 2006 demonstrated a dramatic decline from rates observed from 2002 through 2004 in Ross Lake population. At age one, rainbow trout sampled from Ross were smaller than spawners sampled from Ross Lake tributaries, averaging only 7.6 mm less than Dry Creek fish (n = 3) and 7.4 mm less than Roland Creek fish (n = 7) in total length. However from age two through four, the 2006 fish trout averaged 38.7, 62.85, and 81.1 mm less than Dry Creek fish (n = 13, 34, and 4), and 26.87, 41.09, and 94.35 mm less than Roland Creek fish (n = 64, 98, and 8). These differences may be influenced by differences in spawning condition of sampled populations. But preliminary indications also point to declines in condition and growth due to parasite load. Declines in reservoir productivity predicted by the aging reservoir hypothesis may also be influencing these patterns.

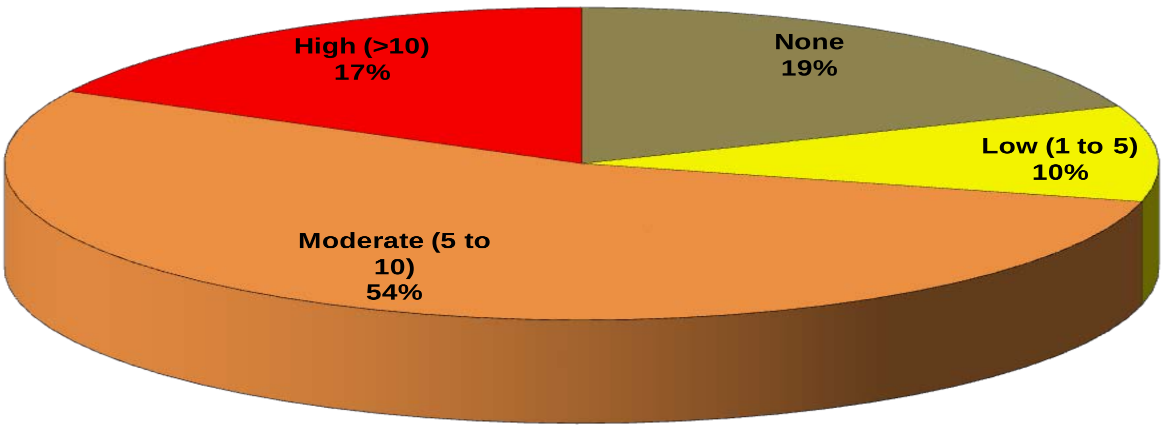

FIGURE 41. Percentages of the rainbow trout population of Ross Lake exhibiting various levels of parasite investation by the cestode of the genus Bothriocephalusin 2006.

Consistent differences in mean length between Ross rainbow trout and those sampled from Ross Lake tributaries for each of the four age classes do appear to be significant. However, unequal sample sizes, differences in dates of collection, differences in brood years and the possibility that Ross samples were biased by variability in maturity rates make further statistical analysis inappropriate. Differences in stream rearing and reservoir rearing life histories shaped by streams with differing hydrologic regimes may also influence these patterns.

Rainbow trout were present in the upper Skagit since the earliest fisheries survey was conducted by the University of Washington in 1919. The presence of both native bull trout and Dolly Varden has led to hypotheses that migratory char and steelhead ascended the Diablo gorge at some point and colonized the upper Skagit. Recent geological studies point to past connection of the upper watershed with the Fraser River basin. In either case these fish are currently assumed to be a primarily native stock with only minimal introductions of other rainbow stocks, ultimately derived from some combination of upper Skagit and introduced non-native stocks.

Most domesticated California stocks used historically by WDFW have not demonstrated high survival in western Washington wilderness lakes and have inconsistent spawn timing with native stocks. Some Canadian stocks have been planted in high lakes within North Cascades National Park (Downen 2003), and may contribute to the ancestry of the current population in Ross, but it is likely that the strongest genetic influence is that of upper Skagit rainbow. These samples should be included in future assessments of the Ross Lake rainbow trout stock, though they are unlikely to influence management decisions regarding the introduction of upper Skagit rainbow trout into Gorge and Diablo lakes.

Baseline Survey Comparisons among Reservoirs

Species composition in all three reservoirs was comprised of rainbow trout, eastern brook trout, and a native char complex of unknown proportions of Dolly Varden and bull trout (**FIGURE 42** and **FIGURE 43**). In Diablo rainbow trout were dominant in number and biomass, 47.1 and 51.9% respectively. Rainbow trout also dominated the species composition and Gorge and Ross by number, 68.5 and 40% respectively, while native char accounted for the majority of biomass in the catch. In addition to these species redside shiner was documented for the first time in Ross Lake where they were captured in small numbers in the fine mesh panels of horizontal gill nets and accounted for 2% by number and less than 1% and biomass.

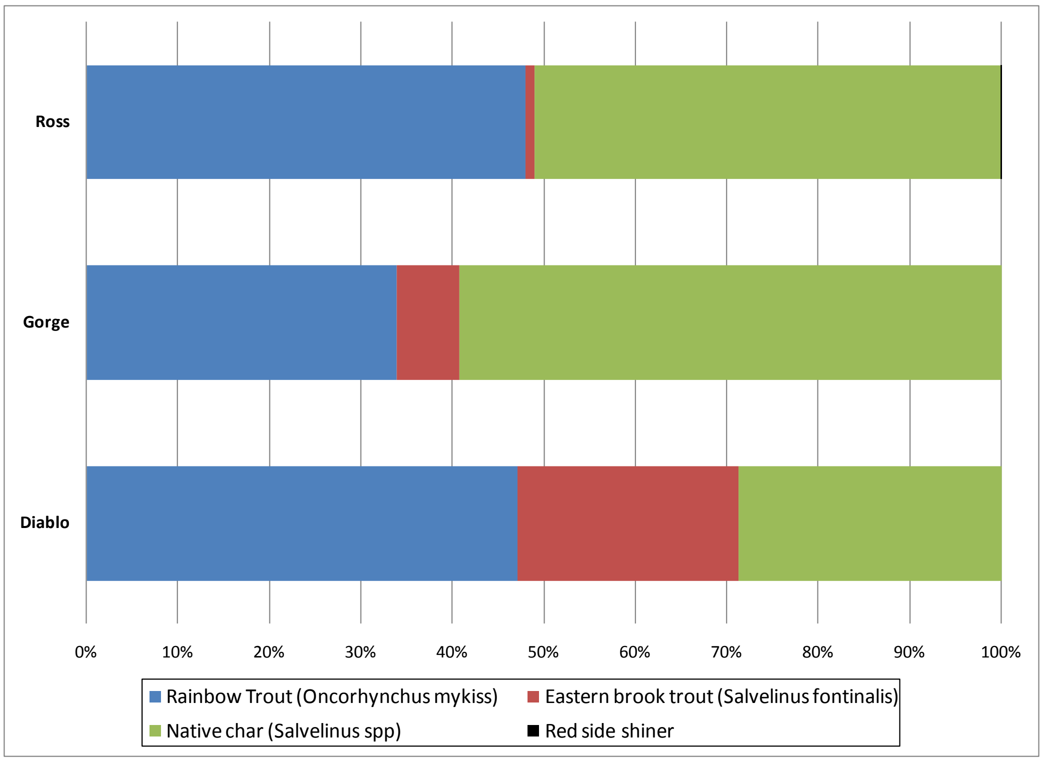

FIGURE 42. Species composition by biomass of fish sampled from Ross, Diablo, and Gorge reservoir in summer 2005 and 2006.

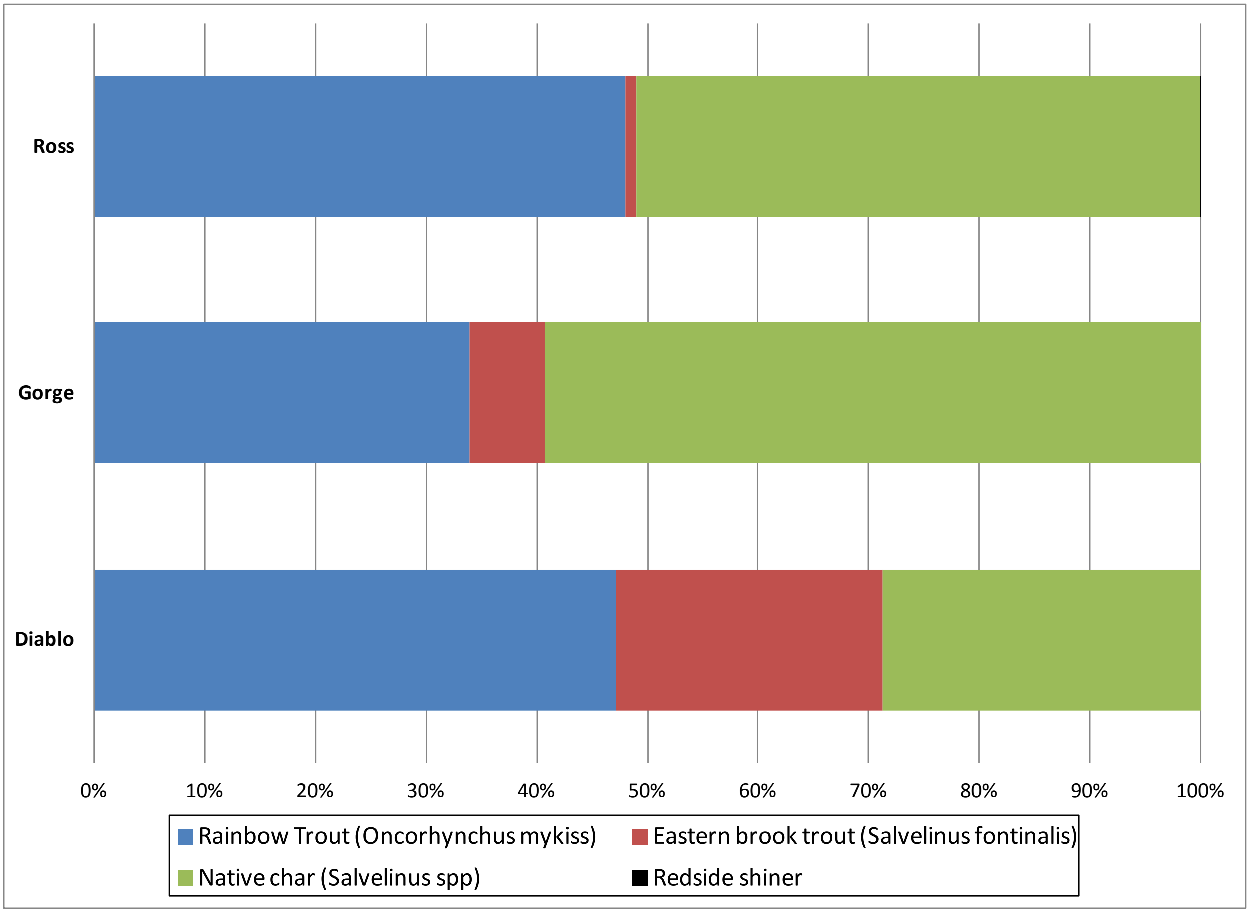

FIGURE 43. Species composition by number of fish sampled from Ross, Diablo, and Gorge reservoirs in summer 2005 and 2006.

Catch per unit effort for rainbow trout was highest in Ross Lake at 21.1 fish per night followed by Diablo at 13.4 fish per night and then Gorge at 8.9 fish per night implying lower abundances (**FIGURE 44**). Yet CPUE for both eastern brook trout and native char was highest in Diablo. However, sampling for Ross Lake was based on a different methodology for different purposes. WDFW sampled Ross Lake in 2006 specifically to examine declining growth rates of rainbow trout. To that end three locations with known presence of rainbow trout were selected with two replicates each.

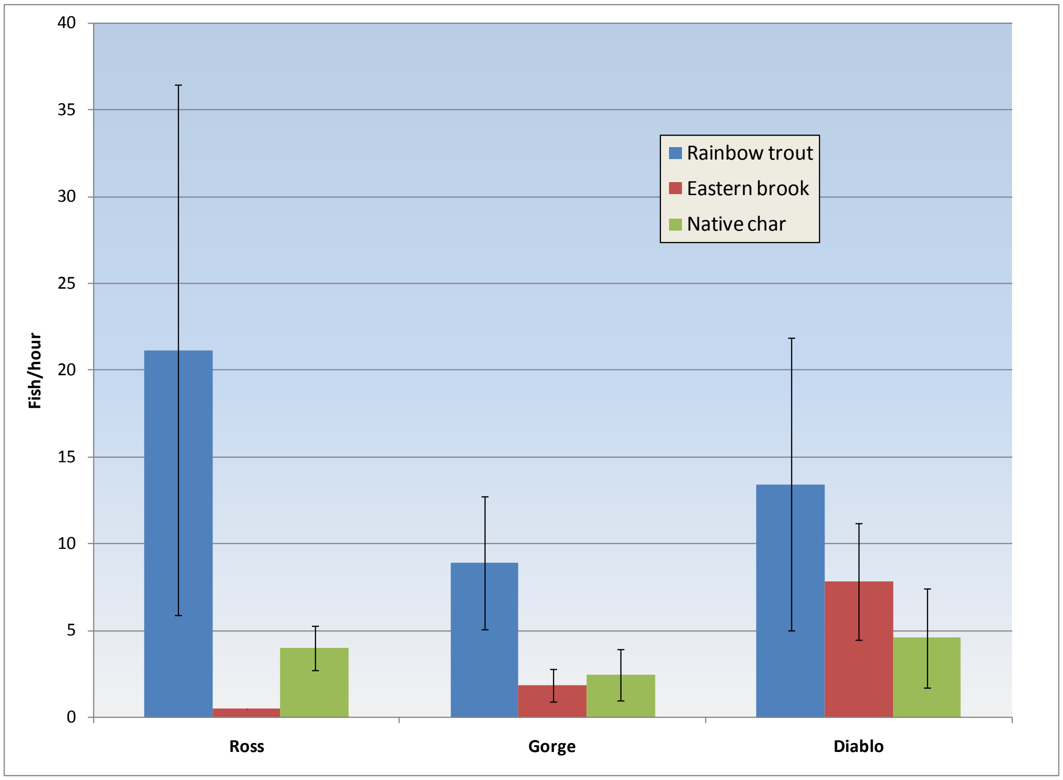

FIGURE 44. Catch per unit effort comparison of fish sampled from Ross, Diablo, and Gorge reservoirs in summer 2005 and 2006.

Proportional stock density comparisons for rainbow trout and eastern brook were not particularly useful due to the low sample sizes of stock-length and larger fish. Proportional stock density for native char, calculated based on values for bull trout, for Diablo, Gorge and Ross was 60 ± 28, 80 ± 22, 77 ± 17 respectively (**FIGURE 45**). While Age 1, 2, and 3 native char made up the majority of the catch, several Age 5 through Age 8 fish were also sampled.

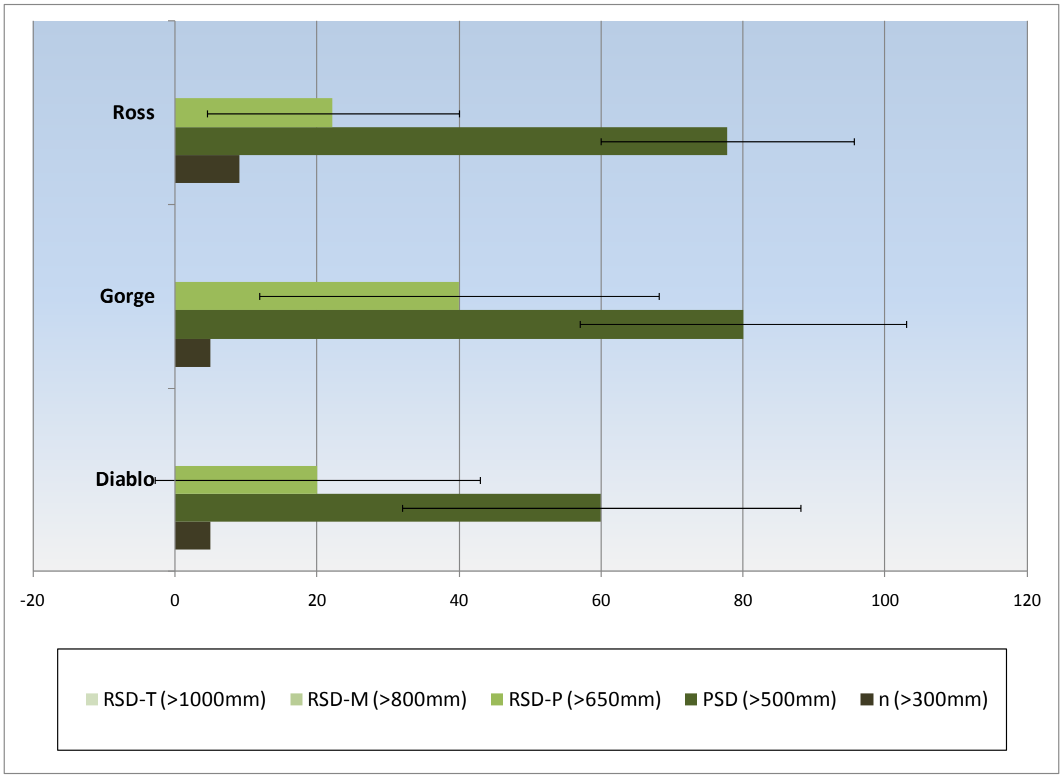

FIGURE 45. Comparison of proportional stock density indices for native char of fish sampled from Ross, Diablo, and Gorge reservoirs in summer 2005 and 2006.

Cumulative average growth rates for rainbow trout were highest in 2002 through 2004 spawners sampled in Ross Lake (**FIGURE 46**). The 2006 Ross Lake index sample indicated a decrease in cumulative growth rates and was consistent with angler reports of precipitately declining rainbow trout size in the fishery.

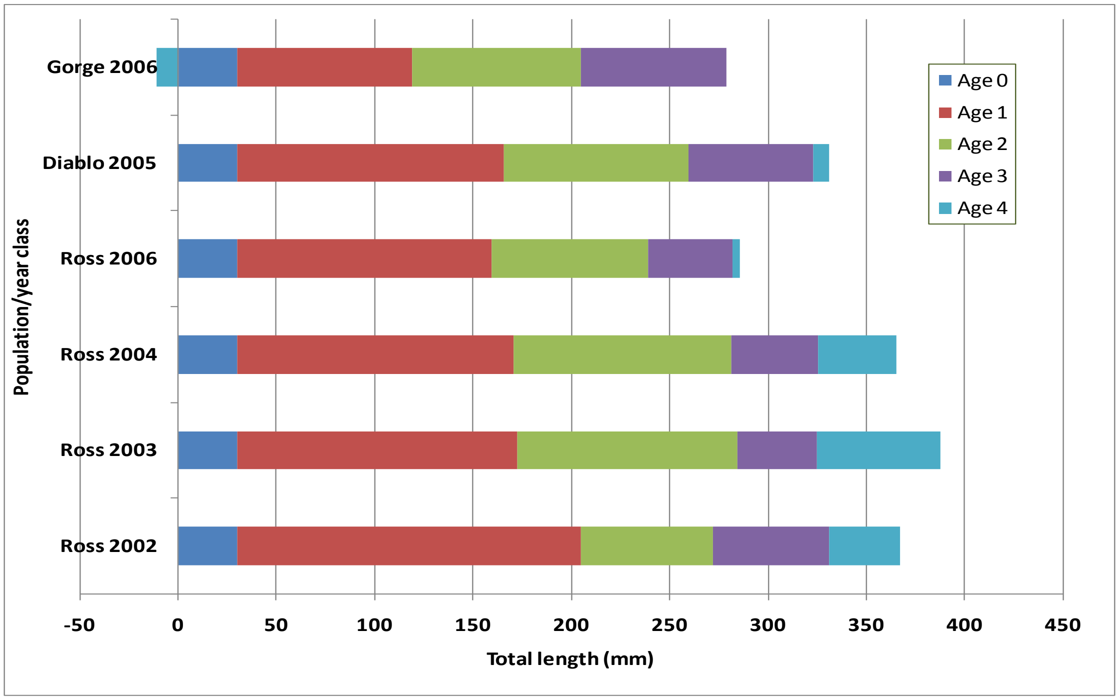

FIGURE 46. Comparison of average growth rates for upper Skagit rainbow trout populations sampled between 2002 and 2006. The apparent negative growth of Age 4 fish in Gorge is a reflection of smaller Age 4 fish than Age 3 fish sampled.

DIABLO AND GORGE RESERVOIR CREEL SURVEYS

Creel Survey Methods

WDFW conducted creel surveys on Gorge and Diablo Reservoirs from July 5 to September 17 in 2002 and 2003. Following methods adapted from Murphy and Willis, 1996, sampling intervals were determined by stratifying by morning/afternoon and weekday/weekend. One morning shift and one afternoon shift were randomly selected each week from weekdays and weekend days from each week.

Surveyors used standard Angler Fishery Database (AFD) forms to collect effort counts for boat, shore, and drift anglers each hour. Trip success and duration were determined through interviews of completed anglers. Anglers were asked for start time and end time, target species, gear type, and numbers of fish caught and released. Measurements for retained fish were also recorded on the AFD forms. In addition to recording whether anglers were adults of juveniles, boat, drift, or shore, we also recorded home zip codes for demographic analysis.

Creel Survey Results

Unexpanded catch rates indicated rainbow trout were the dominant species in the creel in Diablo reservoir while native char were caught in larger numbers in Gorge (**TABLE 31**).

TABLE 31. Unexpanded catch statistics of anglers interviewed during July, August and September of 2003 on Gorge and Diablo Reservoirs.

	Gorge		Diablo	
	2002	2003	2002	2003
Completed anglers	23	15	88	103
Hours fished	69	32.5	359.5	223.54
Average trip duration	3	2.25	4.1	2.13
RB caught	11	27	7	25
RB harvested	4	9	3	14
RB CPUE (fish/hr)	0.22	0.83	0.03	0.11
EB caught		3		10
EB harvested		1		1
EB CPUE (fish/hr)		0.09		0.04
NC caught	38	3	4	6
NC harvested	0	0	1	0
NC CPUE (fish/hr)	0.55	0.09	0.01	0.03

Angler counts were similar on both waters with low numbers of anglers throughout the season but highest in number around the fourth of July and Labor Day weekends (**FIGURE 47** through **FIGURE 50**). Most anglers were residents of western Washington (**FIGURE 51**). However, several anglers from eastern Washington and from out of State were interviewed as well. Catch rates were low for rainbow trout on both reservoirs but effort was substantially higher on Diablo (**TABLE 32**). However, many native char were caught and released by selective gear anglers on

Gorge Reservoir. Despite higher overall catch rates on Gorge there were no obvious differences in the levels of satisfaction among interviewed anglers. Reasons for this are not clear.

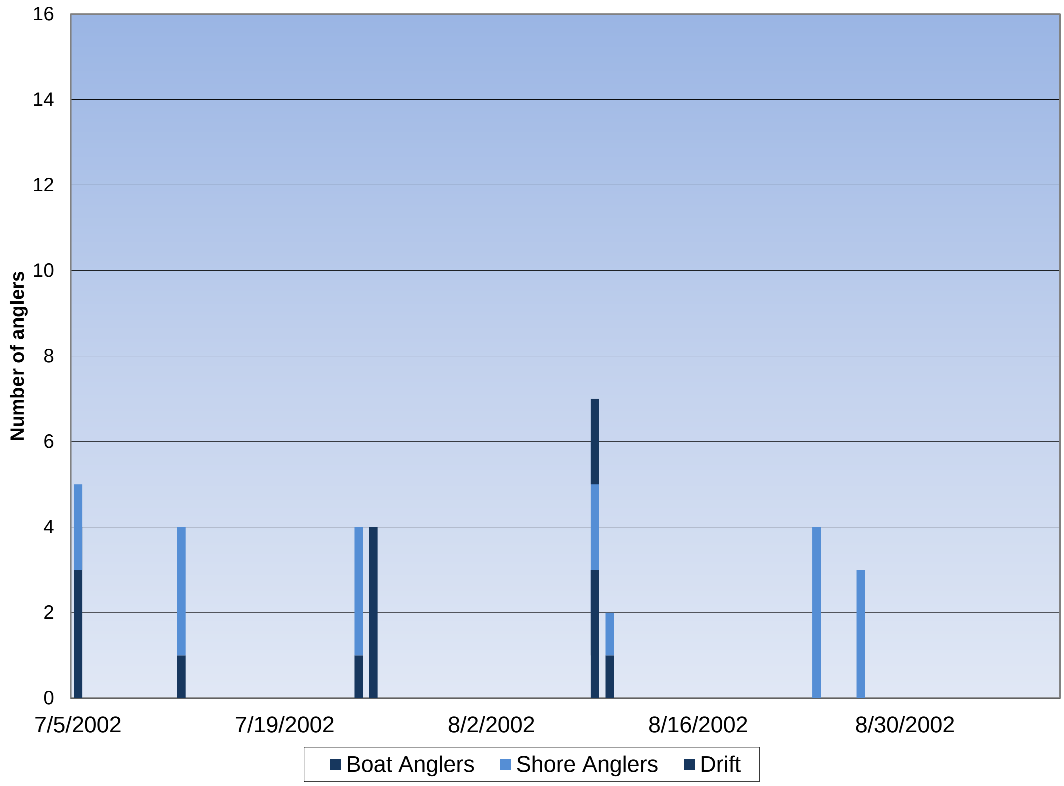

FIGURE 47. Angler counts for Gorge Reservoir from June 28 to September 9, 2002.

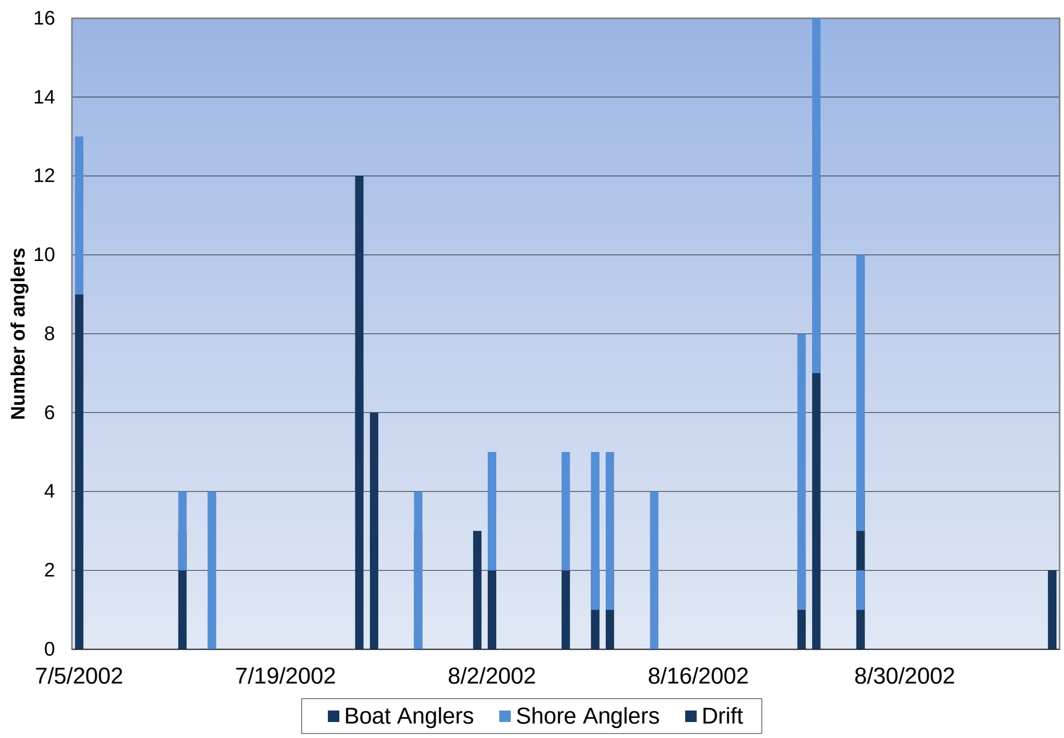

FIGURE 48. Angler counts for Gorge Reservoir from June 28 to September 9, 2002

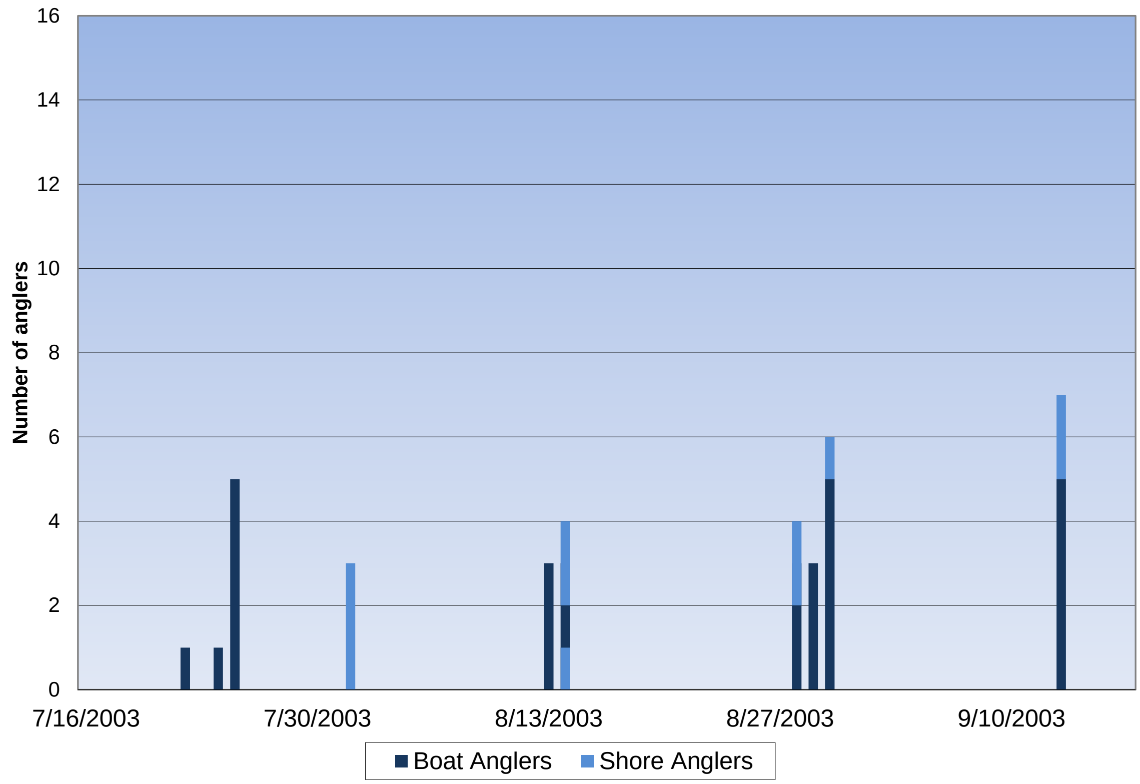

FIGURE 49. Angler counts for Gorge Reservoir from June 28 to September 16, 2003.

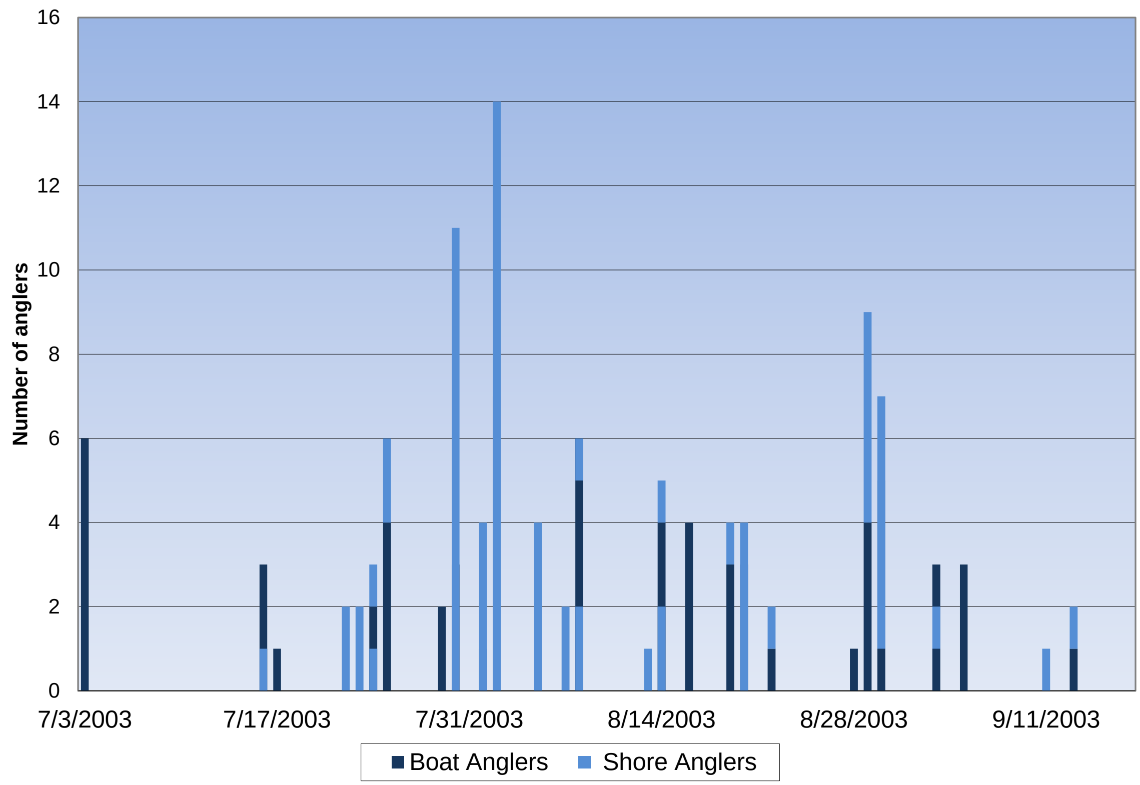

FIGURE 50. Angler counts for Diablo Reservoir from June 28 to September 16, 2003.

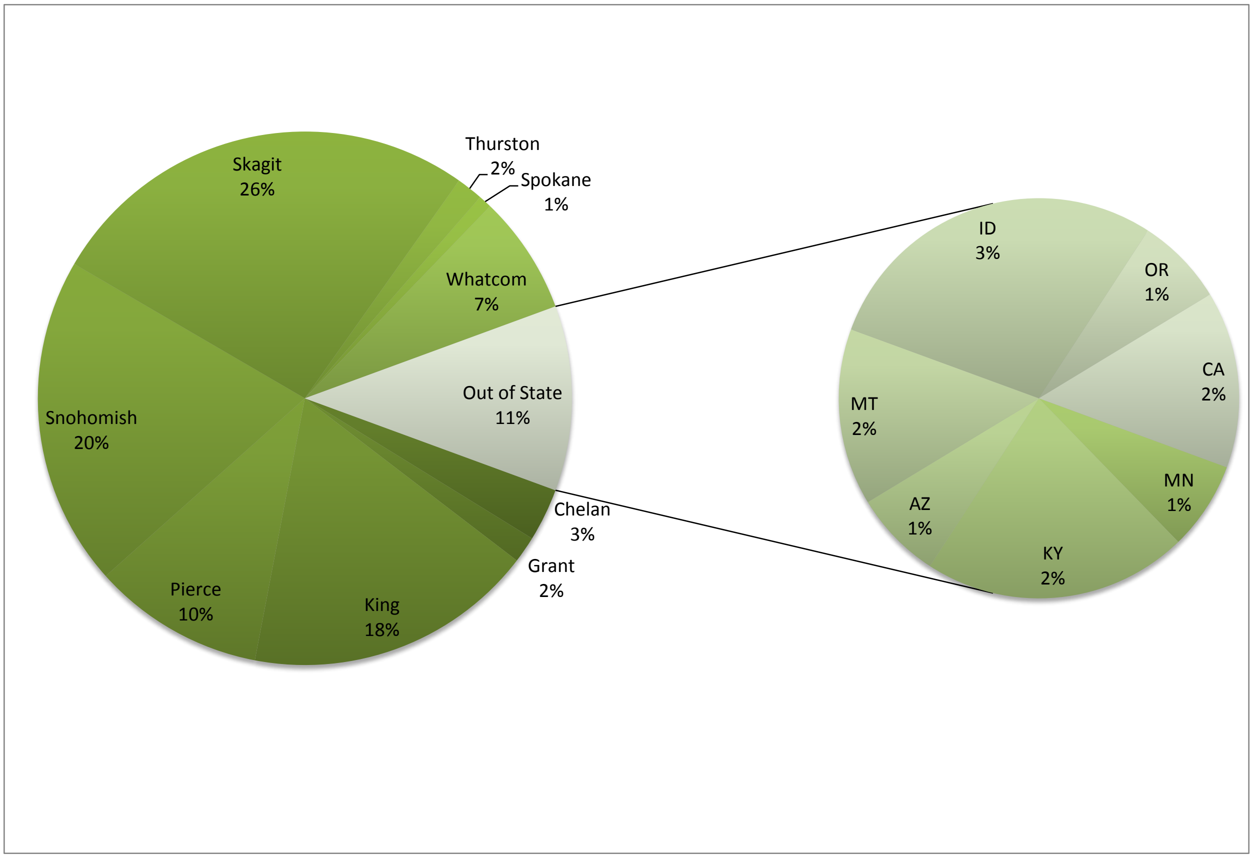

FIGURE 51. Geographic origin of anglers interviewed during July, August and September of 2003 on Gorge and Diablo Reservoirs.

TABLE 32. Characteristics of anglers interviewed during July, August and September of 2003 on Gorge and Diablo Reservoirs.

	Diablo		Gorge	
	Number	Proportion	Number	Proportion
Adults	79	0.64	15	0.58
Juveniles	44	0.36	11	0.42
Total Boat Anglers	53	0.43	4	0.15
Total Shore Anglers	63	0.51	22	0.85
Total Tube Anglers	7	0.06	0	0.00
Target Species				
Any	33	0.27	12	0.38
Trout	59	0.49	12	0.38
Rainbow	29	0.24	8	0.25
Gear Type				
Bait	38	0.31	0	0.00
Lure	15	0.12	4	0.15
Fly	7	0.06	5	0.19
Combination	63	0.51	17	0.65

MANAGEMENT CONSIDERATIONS

Historic annual stocking regimes in excess of 200,000 rainbow trout were common for Gorge and Diablo reservoirs, and the 1991 Settlement Agreement called for as many as 300,000 rainbow trout to be planted into Diablo and Gorge reservoirs annually. However, these densities were likely excessive. Growth rates of rainbow trout in the lower reservoirs do not support the premise that spawning habitat is the sole limiter of rainbow trout production. Granitic geology, the exhausted nutrient base of organic material inundated at reservoir formation, and rapid turnover of unproductive waters likely limit the potential forage base for zooplanktivorous fish species such as rainbow trout.

Initially, the Ross Lake rainbow stocking program began with a conservative rate of 80,000 rainbow fingerlings. This was derived from stocking densities applied to relatively unproductive alpine lakes but applied on an annual stocking cycle. Rearing fish at Marblemount Hatchery through the winter and planting larger fish in the spring was intended to confer competitive advantage over eastern brook and minimize predation by sub-adult native char. However, seven years of investigation on Ross Lake led to a more comprehensive understanding of what constitutes a robust native fish community under conditions imposed by the Skagit hydroelectric projects.

In the Ross drainage numerous streams of varying order produce a diversity of habitats and life history opportunities for rainbow trout and native char. Both species use the larger streams to rear for one to two years while rainbow trout also use smaller, snowmelt-driven streams and migrate to the lake in large numbers during their first summer. These early life history strategies result in the occupation of multiple ecological niches in the lacustrine environment, with Age 0 rainbow foraging along shorelines on early instars of macroinvertebrates and stream reared Age 1 and Age 2 rainbow drift feeding at stream mouths. As the summer progresses these fish move off shore to feed on zooplankton. Some rainbow trout subsequently turn to redside shiner. The more diverse the fish populations are temporally and geographically and with respect to size, the more stable the food web and the greater the likelihood rainbow will express a piscivorous life history.

In this context, the potential impacts of redside shiner introduction must also be considered. Redside shiner appeared in Ross Lake shortly before 2006 when they were first observed by fisheries biologists. Preliminary observations suggest they may contribute positively to growth of both rainbow trout and native char as a forage fish. Redside shiner began appearing in diet samples of both species and dramatic increases in growth became evident in rainbow trout by 2009. Cold water temperatures in the lower reservoirs are likely to suppress redside shiner life histories below Ross Lake. Their abundance, growth and distribution should be closely monitored in all of the reservoirs in concert with standardized stock assessment surveys.

The lack of spawning habitat in Gorge and Diablo is accompanied by a paucity of rearing habitat (Fisheries Research Institute, University of Washington. 1977). Daily spill regimes and low water residence time prevent normal limnogical conditions from forming, and limited access to stream habitats limits stream rearing opportunity. Lack of habitat diversity produces a perpetually constrained forage base for early life stages, as evidenced by low abundances and growth rates. Therefore a comprehensive stocking strategy should employ the use of both fry (minimally fed fish released soon after swim up) and fingerlings (fish fed through the first growing season and released at the onset of the second growing season). Initial stocking rates under this strategy should be approximately 160 fish/acre for 1,200 fish/pound fry in September and 80fish/acre for 200 fpp and fingerlings in May, resulting in 158,000 fry and 79,000 fingerlings for Diablo and 34,000 fry and 17,000 fingerlings for Gorge (**TABLE 33**). An additional 10,000 fry could be produced for the stocking of alpine lakes within the Skagit basin and 5,000 for broodstock replacement. Total production would be 303,000 rainbow trout for the program.

TABLE 33. Stocking recommendations for Ross Lake rainbow trout in the reservoirs and managed alpine lakes of the upper Skagit Basin.

Water	Area	Fish/pound	Fish/acre	Round number
Diablo	990	1,200	160	158,000
		200	80	79,000
Gorge	210	1,200	160	34,000
		200	80	17,000
High Lakes		700	60	10,000
Broodstock replacement				5,000
Total				303,000

The primary purpose of the reservoir surveys was to establish a baseline for abundance, distribution, growth, age class structure, and a genetic profile of rainbow trout in Ross, Diablo and Gorge reservoirs before implementing a stocking program with native Ross Lake rainbow trout. Proposed stocking densities should be adjusted based on growth and condition data collected under a regular monitoring program and harvest data collected through regular creel surveys.

Unbiased catch rates of rainbow trout in Diablo and Gorge support the premise of lower abundances of rainbow trout in the two lower reservoirs. Lower growth rates may be influenced by overall cooler water temperatures in the lower reservoirs but could also reflect lower system productivity. Diablo and Gorge reservoirs should be surveyed at least once every four years or one trout brood cycle. Systematic sampling to maximize independence of net set samples should be conducted with variable mesh, multi-panel experimental gill nets. Mesh sizes should range from half-inch stretched to 2 1/2 inches stretched and include at least three intermediate sizes. Calculations of species composition by number and biomass, species distribution, catch per unit effort, stock density indices, length frequency by age class developed from scale based age class analysis, and condition factor expressed in terms of relative weight will provide useful information on both community and population level variability and change over time. Effects on ESA-listed bull trout should also be monitored based on similar criteria. Adjustments to stocking strategies should be made if measurable reductions in growth or condition appear in rainbow trout. Monitoring of seasonal changes in condition, early summer versus late fall may also prove useful where evidence for competitive pressure arises.

Founded on a framework of adaptive management, the primary purpose of this program is to enhance recreational opportunity by increasing the numbers and quality of rainbow trout available to anglers in Gorge and Diablo reservoirs. Information gathered during standardized stock assessment surveys will provide metrics for abundance and quality as evidenced by increases in unbiased catch per unit effort estimates. Patterns of steady or increasing growth rates and condition will also support the goal on increasing densities without compromising the desirability of fish to anglers. However, direct fisheries measures should also be employed. Statistically valid creel surveys are expensive and labor intensive, and while they would be extremely useful in assessing effort and catch, they may not be feasible. Angling effort and catch per unit effort with meaningful confidence intervals would allow managers detect trends in the fishery. Yet, lacking the resources for such surveys, catch record reporting boxes and consistently applied effort counts could provide useful information as well. Applying trip lengths and catch rates from angler reports to independently collected effort data stratified by weekday versus weekend could be used to estimate angler trips and catch on a seasonal basis.

Specific targets for seasonal angler trips and catch per unit effort have yet to be developed for these fisheries. Pre-stocking catch rates of less than one fish per angler and one fish per hour could certainly be improved. Minimum target catch rates for year round lowland lakes of 2.5 fish/angler would be a meaningful goal for boat anglers on Gorge and Diablo reservoirs.

Re-introduction of Ross Lake rainbow trout into Gorge and Diablo reservoir will serve as an enhancement for the rainbow trout fishery. It will also reconnect the upper Skagit rainbow trout with resident rainbow trout in the lower Skagit. A recently completed geological history of the Skagit River (Reidel 2007), indicates the upper Skagit River was physically separated from the lower Skagit until the last part of the Pleistocene. Prior to this time, the upper Skagit was physically connected to the Frazer River system (Reidel 2007). However, from the end of the Pleistocene until the construction of Ross dam early in the twentieth century rainbow trout from the upper Skagit would have had unfettered opportunity to disperse downstream. Current management of Ross limits such connectivity since it is managed not to spill, and has only done so on rare occasions during anomalous high flows.

A recent analysis conducted by WDFW found that rainbow trout in Ross, Diablo, and Gorge were similar to each other, supporting their management as a single population. However, they are also genetically distinct from steelhead in the lower watershed and other headwater resident rainbow trout populations. All resident rainbow populations above anadromous barriers are distinct from each other as well as from the anadromous steelhead. Prior to the construction of Ross dam, genetic flow from the upper Skagit into the lower Skagit was likely only one-way (upstream to downstream) following the breaching of the Skagit divide approximately 15,000 years ago. Periodic sampling of resident rainbow trout below the project would be valuable for monitoring gene flow downstream.

Tissue samples were also collected from all char sampled from Diablo in 2005 for future identification of the relative contributions of Dolly Varden and bull trout to the presumed native char complex of Diablo Lake, and to investigate the potential for hybridization with eastern brook trout. Time and resources precluded similar collections in Gorge and Ross during the course of this project but it is strongly recommended that the char complexes throughout the upper Skagit be examined.

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