



Monitoring Riverine Fish Communities in the North Coast and Cascades Network

2011 Annual Report

Natural Resource Data Series NPS/NCCN/NRDS—2013/463



ON THE COVER

Olympic National Park fisheries biologists count fish species in the Sol Duc River.
Photograph by: Phil Kennedy

Monitoring Riverine Fish Communities in the North Coast and Cascades Network

2011 Annual Report

Natural Resource Data Series NPS/NCCN/NRDS—2013/463

Samuel J. Brenkman, Lauren H. Kerr, John R. Boetsch, and Philip K. Kennedy

National Park Service
Olympic National Park
600 East Park Avenue
Port Angeles, Washington 98362

April 2013

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Data Series is intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received formal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data, and whose background and expertise put them on par technically and scientifically with the authors of the information. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available from North Coast and Cascades Network website (<http://science.nature.nps.gov/im/units/nccn/reportpubs.cfm>) and the Natural Resource Publications Management website (<http://www.nature.nps.gov/publications/nrpm/>).

Please cite this publication as:

Brenkman, S. J., L. H. Kerr, J. R. Boetsch, and P. K. Kennedy. 2013. Monitoring riverine fish communities in the North Coast and Cascades Network: 2011 annual report. Natural Resource Data Series NPS/NCCN/NRDS—2013/463. National Park Service, Fort Collins, Colorado.

Contents

	Page
Figures.....	v
Tables.....	vii
Abstract.....	ix
Acknowledgments.....	x
Introduction.....	1
Sampling Design.....	1
Study Area	2
Olympic National Park	2
Methods.....	5
Number and Location of Sampling Sites.....	5
Data Management.....	7
Results.....	9
Snorkel Survey Effort Within and Among Rivers.....	9
Comparisons of Seasonal Fish Species Composition Within and Among Rivers	11
Annual Abundances of Fish Species Within and Among Rivers	13
Proportions of Hatchery and Wild Fish in Rivers	15
Literature Cited	17

Figures

	Page
Figure 1. Location of reference sites for long-term monitoring of fish communities in Olympic National Park rivers.	3
Figure 2. Schematic diagram that depicts two divers snorkeling downstream to count fish species in the reference site in the North Fork Skokomish River, Olympic National Park.	7
Figure 3. Number of snorkel surveys in reference sites of Olympic National Park rivers in 2011 as part of the monitoring program for fish communities during summer months.....	9
Figure 4. Highest number of each fish species observed per river kilometer (km) for each river during 2011.	11
Figure 5. Mean monthly composition of primary fish species in the East Fork Quinault River, North Fork Quinault River, and South Fork Hoh River in 2011.	12
Figure 6. Mean monthly composition of primary fish species in the Bogachiel, North Fork Sol Duc, South Fork Calawah, and Sol Duc Rivers in 2011.....	13
Figure 7. Mean monthly composition of primary fish species in the North Fork Skokomish River in 2011.....	13
Figure 8. Annual peak counts of bull trout, mountain whitefish, and rainbow/cutthroat trout across eight Olympic National Park rivers in summer, 2011.	14
Figure 9. Annual peak counts of adult Chinook salmon and adult summer steelhead in seven rivers in summer, 2011.	15
Figure 10. Summary of the relative proportions of hatchery and wild Chinook salmon among Bogachiel, East and North Fork Quinault and South Fork Hoh in 2011.	16
Figure 11. Summary of the relative proportions of hatchery and wild adult steelhead among Bogachiel, East and North Fork Quinault, South Fork Hoh, and Sol Duc Rivers in 2011.	16

Tables

	Page
Table 1. Watershed characteristics of Olympic National Park rivers being monitored for seasonal and annual trends in fish communities.	4
Table 2a. Approximate drive time (round trip from Port Angeles), hiking duration, and duration of snorkel survey at each reference site.	5
Table 2b. Specific locations of river reference sites in Olympic National Park based on GPS.	6
Table 3. Fish species that were observed in Olympic National Park rivers during snorkel surveys.....	10
Table 4. Weekly distribution of snorkel surveys among eight Olympic National Park rivers from June to September, 2011.	11

Abstract

This report summarizes the monitoring of fish communities at Olympic National Park (OLYM) in 2011. Specific monitoring objectives were to determine seasonal trends in: 1) fish species composition; 2) relative abundance; and 3) the extent of non-native and hatchery fish among rivers during summer months.

Fish communities were monitored via intensive snorkel surveys within ~ five-km reference sites from May to December across eight park rivers. In 2011, 36 surveys occurred and biologists observed 18,226 individual fish and recorded 12 fish species. Seasonal trends in fish species composition were reported as the mean percent of each fish species per month in each river. In 2011, species compositions in west peninsula rivers exhibited similar patterns where mountain whitefish (*Prosopium williamsoni*) and cutthroat/rainbow trout (*Oncorhynchus clarkii*/*Oncorhynchus mykiss*) were the dominant fish species. No non-native fish were observed. Analysis of annual peak counts of fish species provided a gauge of relative productivity among rivers. Peak counts of mountain whitefish ((ranged from 52 to 359 per km) were orders of magnitude higher than those for other fish species in 2011. Adult summer steelhead (*Oncorhynchus mykiss*) and Chinook salmon (*Oncorhynchus tshawytscha*) were at critically low levels of abundance in all rivers within the five kilometer reference sites.

We reported in proportions of hatchery versus wild salmonids were determined at each reference site. In 2011, hatchery steelhead were detected in the Bogachiel (23%, n=74), North Fork Quinault (50%, n=4), and South Fork Hoh Rivers (50%, n=2) and hatchery Chinook were observed in the Bogachiel (14%, n=7) and North Fork Quinault Rivers (100%, n=1). No hatchery coho (*Oncorhynchus kisutch*) salmon were observed in any reference site in 2011. Only wild coho salmon were observed in the Sol Duc River.

Acknowledgments

We sincerely thank National Park Service employees K. Beirne, A. Geffre, J. Geffre, L. Grace, M. Huff, and H. Hugunin, for their assistance in various aspects of monitoring fish communities and report generation. We also thank B. Baccus and P. Crain for their constructive comments on an earlier version of this report.

Introduction

This annual report presents 2011 results from the monitoring of fish assemblages in Olympic National Park (OLYM), as part of the North Coast and Cascades Network (NCCN) Inventory and Monitoring Program. The Protocol for Monitoring Fish Assemblages in Pacific Northwest Parks was designed for rivers that have high water visibility and that are conducive to snorkel methods from June through September each year (Brenkman and Connolly 2008).

OLYM is the only national park in the lower 48 states that contains significant numbers of wild Pacific salmonids, with at least 70 populations in park rivers (Houston and Contor 1984). These salmonids are critical to ecosystem function, and link freshwater, marine, and terrestrial ecosystems. Pacific salmonids provide food for over 130 species of aquatic and terrestrial wildlife species (Cederholm et al. 2001), and studies have shown that 20 to 40% of the phosphorus, nitrogen, and carbon in freshwater systems may be marine-derived through carcasses of spawned salmon (Kline et al. 1990, 1994, Bilby et al. 1996).

In OLYM rivers, fishery resources are of high ecological and cultural importance, and contribute significantly to recreational, commercial, and tribal fisheries. Fish communities are focal resources of parks (see Jenkins et al. 2003) and represent critical components of biological integrity from ecosystem and public interest perspectives (Peck et al. 1999). Fish communities also serve as excellent indicators of ecological conditions because they integrate effects from lower trophic levels (e.g., fish being key predators and consumers in aquatic food webs); they integrate environmental variability at different spatial scales (Oberdorff et al. 2002); and they are reasonably easy to identify (Plafkin et al. 1989). At the temporal scale, the longevity of fishes helps to “register” environmental alterations across long time periods (Schmutz et al. 2000). The life histories of many fish species are well understood, and therefore the presence or absence of specific taxa or life stages can have large inferential meaning (Flotemersch et al. 2006). The decline in native fish species in western North America highlights the importance of understanding patterns observed in least-disturbed habitats such as rivers of OLYM.

OLYM rivers contain federally threatened fish populations (e.g. bull trout, *Salvelinus confluentus*) and non-commercial fish species such as mountain whitefish (*Prosopium williamsoni*). Mountain whitefish have received little research attention despite being one of the most abundant fish species in many river systems (Northcote and Ennis 1994). Cutthroat trout (*Oncorhynchus clarkii*) and summer steelhead (*Oncorhynchus mykiss*) also are important species targeted by recreational anglers. Prior to the inception of this monitoring project there were no existing monitoring programs for non-commercial (e.g., Pacific salmonids) fish species in Olympic Peninsula rivers.

Sampling Design

For this report, we rely on the sampling design that was established in the protocol for monitoring fish assemblages in NCCN rivers (Brenkman and Connolly 2008).

Study Area

Olympic National Park

Olympic National Park, located on the Olympic Peninsula, contains one of the largest contiguous areas of relatively pristine habitat throughout the range of several west coast fish species.

Olympic National Park protects 373,133 ha (922,000 acres) including the upper portions of 12 major river basins and 5,600 km of streams (Figure 1). The park is 96% designated wilderness, with roads, campgrounds, and structures comprising less than 1% of the total area of the park (Jenkins et al. 2003). The western portion of the park receives the greatest precipitation in the conterminous United States with annual precipitation that ranges from 180 to 250 cm to greater than 600 cm on Mount Olympus (Jenkins et al. 2003). Most of the precipitation occurs between November and April, falling as rain in lowland areas, and snowfall at higher elevations. In most rivers, discharge is strongly influenced by rainfall in winter and snowmelt in spring. Watersheds in the park are generally characterized as having steep slopes, short drainages, and high amounts of annual precipitation that cause river discharges to rise and decline rapidly with frequent high flows in the winter.

Watersheds that drain the west side of the park contain anadromous and non-anadromous species, whereas watersheds that drain the eastside of the park are inhabited strictly by potamodromous (e.g., migrate entirely within freshwater) fish species due to the existence of natural barriers and dams that prevent upstream migration of anadromous fish. A summary of watershed characteristics can be found in Table 1.

Fish fauna in OLYM consist primarily of coldwater species in the families Salmonidae and Cottidae. There are nine species of Pacific salmonids including at least 70 unique populations (Houston and Contor 1984, OLYM files). A total of 31 native and 5 non-native freshwater fish species from 11 different families have been documented in OLYM waters. Both native wild populations and hatchery stocks of Pacific salmonids occur in OLYM.

OLYM has exclusive federal jurisdiction of recreational fishing regulations in the park, where fishing is generally permitted throughout the year. Coastal rivers provide popular sport fisheries for Pacific salmonids throughout the year, with angler effort typically the highest during periods when salmon and steelhead are migrating upstream. The park offers diverse fishing opportunities with an emphasis on catch-and-release of wild fish species and retention of hatchery and non-native fish. Tribal gill-net fisheries occur in west side rivers most weeks of the year.

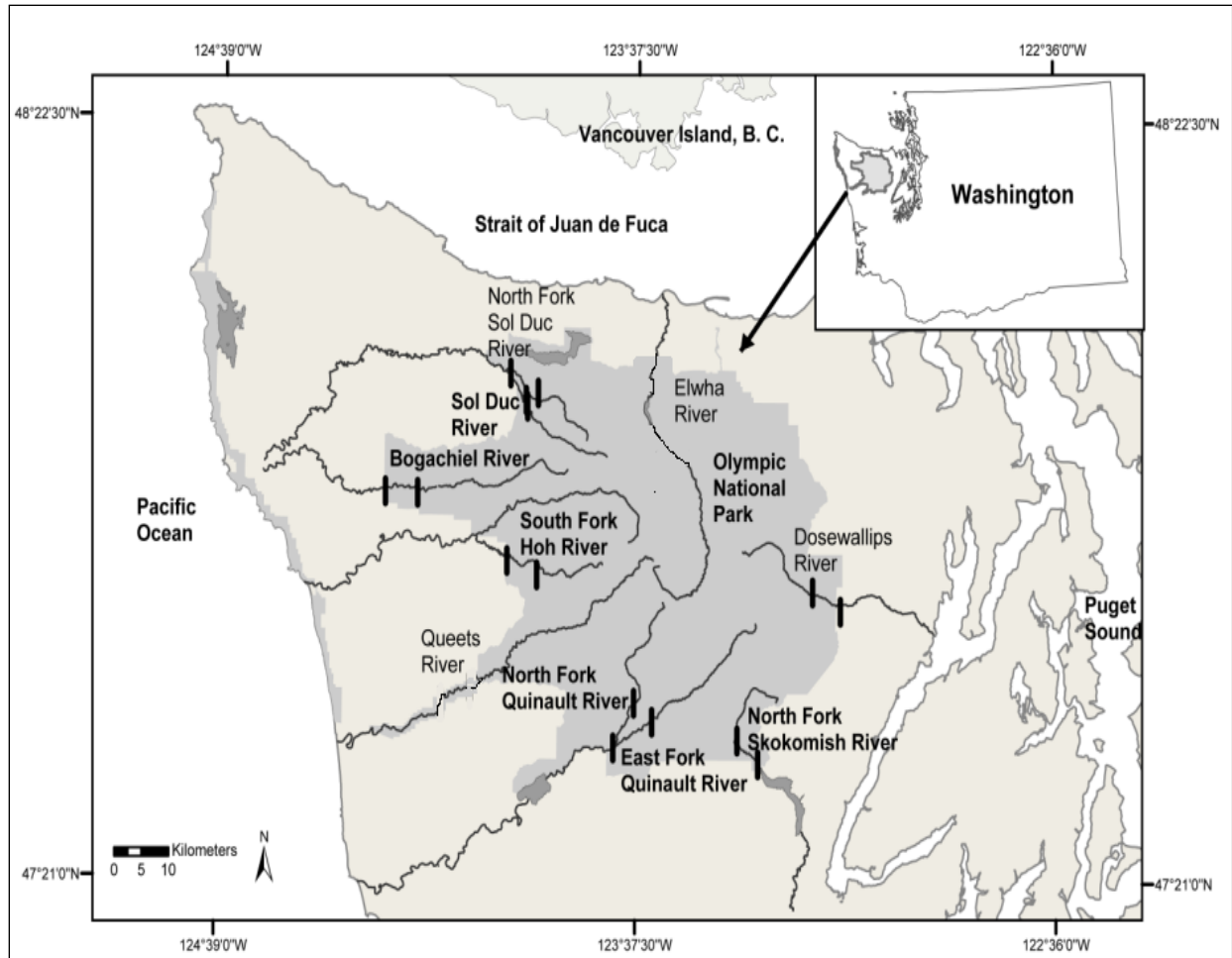


Figure 1. Location of reference sites for long-term monitoring of fish communities in Olympic National Park rivers. Bars depict start and end points of reference sites approximately 5km in length that extend upstream from the park boundary.

Table 1. Watershed characteristics of Olympic National Park rivers being monitored for seasonal and annual trends in fish communities. Mean summer flow was determined for gaged rivers by taking the average daily flow during the survey period. Flow information was available from the USGS: National Water Information website (<http://waterdata.usgs.gov/nwis/rt>) for all gaged rivers with the exception of the Sol Duc which was available from the Washington Department of Ecology: River and Streamflow monitoring (<https://fortress.wa.gov/ecy/wrx/wrx/flows/station.asp?sta=20A070>).

River	Watershed Area (ha)	% Watershed Area in Park	Elevation at Park Boundary/ Headwater (m)	Total River Length (km)	Total River Length in Park (km)	Mean Summer Flow (cfs)	Anadromous Fish/ Hatchery Present	Drains into Where
Bogachiel (BOGA)	32,849	64	103/1,288	75.3	42.1	193	Yes/Yes	Quillayute River
East Fork Quinault (EFQU)	23,278	100	117/2,245	21.4	21.4	Not gaged	Yes/Yes	Quinault River
North Fork Quinault (NFQU)	20,837	100	115/1,238	30.8	30.8	Not gaged	Yes/Yes	Quinault River
North Fork Skokomish (NFSK)	31,081	48	225/1,622	51.8 (includes reservoirs)	22.7	306	No/Yes	Lake Cushman
South Fork Hoh (SFHO)	11,338	79	244/1,318	31	24.3	287	Yes/No	Hoh River
Sol Duc (SOLD)	19,442	29	318/1,440	105.6	25.9	134	Yes/Yes	Quillayute River
North Fork Sol Duc (NFSO)	7,965	100	329/1,520	24.3	24.3	91	Yes/Yes	Sol Duc River
South Fork Calawah (SFCA)	35,215	19	125/1080	91	25	232	Yes/Yes	Bogachiel River

Methods

The seasonal movements, assemblage structure, and relative abundances of fish species were determined by intensive, weekly snorkel counts in reference sites of each river. The objective of repeated snorkel surveys in relatively long sample sites (2.6 to 5.7 km) was to examine seasonal and annual changes in abundances of each of the primary species. The general rationale for intensive sampling (e.g., up to 10 surveys per river per year) of reference sites was to account for the high seasonal variability in fish movements and abundances in rivers. To detect seasonal and annual trends in fish communities in reference sites, we relied on repeated (e.g. multiple surveys) and consistent annual sampling using the same methods at each monitoring location.

During the 2011 season, the goal of weekly snorkel counts was often missed due to high river flows that would have significantly reduced survey safety and accuracy. The Elwha River and the Dosewallips River which are typically sampled were unable to be sampled during the 2011 season. High flows and unsafe conditions prohibited the survey team from completing surveys thereby excluding these rivers from this summary. Limited numbers of surveys were conducted on the rivers in the Quinault system and the South Fork Hoh River for the same reason. These rivers are therefore not represented in the early months of the survey season. The high flows during the 2011 season can be attributed mainly to a late and prolonged snow melt.

Number and Location of Sampling Sites

Fish communities were monitored in reference sites located immediately upstream of the park boundary (Figure 1, Table 1). We monitored portions of rivers immediately upstream of the park boundary as these reference sites typically minimize challenges to access. Specific locations of reference sites, travel times and duration of surveys are included in Tables 2a-b. The reference sites were comprised of main-stem and side-channel habitats with multiple types of habitat units (e.g., pools, riffles, glides) throughout each reference site. Locating reference sites at the park boundary has the advantage of reflecting the integrated conditions of the watershed. These river reference sites were generally characterized as unconstrained, productive floodplains that are utilized by numerous fish species when compared to remote reaches of upper watersheds that are largely confined and where physical barriers and waterfalls prevent upstream movements of migratory fish.

Table 2a. Approximate drive time (round trip from Port Angeles), hiking duration, and duration of snorkel survey at each reference site.

River/Park Region	Drive Time (Hours)	Hike Time (Hours)	Snorkel Time (Hours)
Bogachiel, Quillayute System	3.0	2.0	2.0-3.5
East Fork Quinault, Pacific Coast	5.5	0.5	2.0-3.75
North Fork Quinault, Pacific Coast	5.5	0.5	2.0-3.75
North Fork Skokomish, Hood Canal	5.0	0.5	1.5-2.5
South Fork Calawah River, Quillayute System	1.5	0.3	3.0
South Fork Hoh, Pacific Coast	4.5	1.75	1.5-3.
Sol Duc, Quillayute System	2.0	0.75	2.25-3.5
North Fork. Sol Duc, Quillayute System	2.0	1.0	2.5-4.0

Table 2b. Specific locations of river reference sites in Olympic National Park based on GPS. River miles are used only to describe approximate locations; the actual length of each reference reach may vary from year to year and is determined using imagery in GIS.

River/Park Region	Downstream Boundary		Upstream Boundary		Location (river mile)
	Latitude	Longitude	Latitude	Longitude	
Bogachiel, Quillayute System	47.8788972	124.2472417	47.8830556	124.18972	25.0-22.0
South Fork Calawah, Quillayute System	47.9633333	124.2938889	47.9519444	124.244444	15.8-13.1
East Fork Quinault, Pacific Coast	47.5375	123.6708333	47.5575	123.61139	51.0-47.4
North Fork Quinault, Pacific Coast	47.5375	123.6708333	47.5689143	123.64873	2.7-0.0
North Fork Skokomish, Hood Canal	47.5022222	123.3175	47.5196182	123.33442	29.7-28.1
South Fork Calawah River, Quillayute System	47.9633333	124.2938889	47.9519444	124.24444	15.8-13.1
South Fork Hoh, Pacific Coast	47.7902778	123.9352778	47.7782956	123.90696	6.5-4.8
Sol Duc, Quillayute System	47.9872222	123.8938889	47.9669444	123.85972	62.7-60.4
North Fork Sol Duc, Quillayute System	48.025	123.9094444	48.007486	123.89154	4.2-2.2

Two experienced divers, one on each side of the river (Figure 2), proceeded downstream counting each species of fish greater than 15 cm in fork length. When fish were observed in large aggregations, divers commonly made two passes in their respective lanes and averaged the counts. Because of the difficulty in distinguishing between cutthroat trout and rainbow trout underwater, counts of these two species were combined as cutthroat/rainbow trout. Seasonal and annual trends of proportions of hatchery (e.g., fin clipped) versus wild salmonids were determined by observations of marked and unmarked fish along each reference site. The observations of marked fish provide a relative gauge of the extent of hatchery fish invasions in park rivers. These observations only apply to adult salmonids. Divers made frequent stops to compare and minimize duplication of counts. The sampling procedure of snorkel counts was consistent within and among years and consistent among rivers.

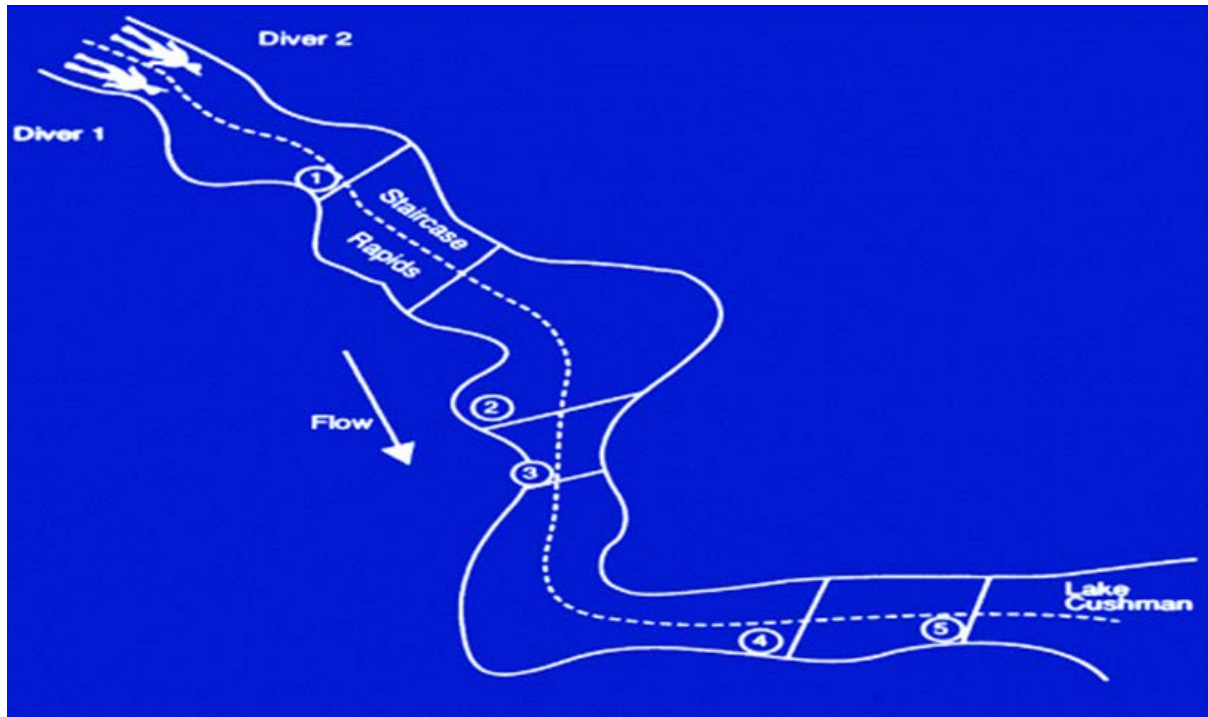


Figure 2. Schematic diagram that depicts two divers snorkeling downstream to count fish species in the reference site in the North Fork Skokomish River, Olympic National Park.

Annual trends in proportions of hatchery (fin clipped) versus wild salmonids were determined by observations of marked and unmarked fish at each reference site. Annual observations of hatchery and wild fish (for each species) in a given river were summed to determine the proportion of hatchery to wild salmonids in 2011 (Figures 10 and 11). These observations apply only to adult salmonids and do not include observations recorded as “unknown” where snorkelers failed to identify whether an individual fish was wild or hatchery. Annual peak counts were determined by calculating the largest number of each individual species counted during a survey in 2011. Survey lengths for each reference site were digitized from recent aerial photography to reflect current river morphology and to standardize reporting of peak count per river kilometer.

Data Management

Following each data collection event, data were entered into the project database. Database records were later verified for complete and accurate transcription by retrieving and visually comparing the data associated with each sampling event against the original forms. Once all data for the season were entered and verified, a rigorous quality review was conducted on the data set by running a set of pre-built validation queries to check for completeness, missing or out-of-range values, logical consistency, and structural integrity. Errors identified during this review were corrected where possible, and annotations related to specific issues raised by each query were stored within the project database as needed and appropriate. After data validation was complete, survey lengths were digitized from recent aerial imagery in a geographic information system (GIS), and added to the database. The data set was then certified as complete and ready for use. Output for this report was generated using standard summary queries in the project database.

Results

Snorkel Survey Effort Within and Among Rivers

Fisheries crews snorkeled approximately 185 river kilometers in eight rivers during 2011. The maximum number of surveys occurred in the Bogachiel (11 surveys) and the least number of surveys occurred in the East Fork Quinault, North Fork Quinault, North Fork Sol Duc, and South Fork Hoh Rivers (2 surveys at each site). Survey effort was lower in the coastal rivers due to prolonged periods of high flows from May through July (Figure 3). In total, we monitored 12 fish species across the eight rivers. Ten of the 12 fish species were in the family Salmonidae (Table 3).

In 2011, 36 surveys occurred from June to September (Table 4) and biologists made 18,226 individual fish observations. Mountain whitefish dominated the fish species in all rivers where they are present (not typically present in survey reaches of North Fork Sol Duc and Sol Duc). The North Fork Skokomish had the largest concentration of Mountain whitefish with a peak count 359 per river kilometer (Figure 4). The Sol Duc River had large numbers of coho salmon observed in 2011, with a peak count of 227 per river kilometer (Figure 4).



Figure 3. Number of snorkel surveys in reference sites of Olympic National Park rivers in 2011 as part of the monitoring program for fish communities during summer months. BOGA=Bogachiel; NFSK = North Fork Skokomish; SFCA = South Fork Calawah; SOLD = Sol Duc; EFQU = East Fork Quinault; NFQU=North Fork Quinault; NFSO = North Fork Sol Duc; SFHO = South Fork Hoh.

Table 3. Fish species that were observed in Olympic National Park rivers during snorkel surveys.

Common Name	Family	Genus species	River(s)
Largescale sucker	Catostomidae	<i>Catostomus macrocheilus</i>	EFQU
Dace	Cyprinidae	<i>Rhynchithys spp.</i>	BOGA
Pacific lamprey	Petromyzontidae	<i>Lampetra tridentata</i>	BOGA
Chinook salmon	Salmonidae	<i>Oncorhynchus tshawytscha</i>	NFSK ¹ ; BOGA; EFQU; NFQU; SOLD; SFHO
Pink salmon	Salmonidae	<i>O. gorbuscha</i>	BOGA
Chum salmon	Salmonidae	<i>O. keta</i>	BOGA; SFHO
Sockeye salmon	Salmonidae	<i>O. nerka</i>	BOGA; EFQU; SFHO
Coho salmon	Salmonidae	<i>O. kisutch</i>	BOGA; EFQU; NFQU; SOLD; NFSO; SFHO
Steelhead trout	Salmonidae	<i>O. mykiss</i>	BOGA; EFQU; NFQU; SOLD; NFSO; SFHO; SFCA
Rainbow trout ²	Salmonidae	<i>O. mykiss</i>	DOSE; ELWH; BOGA; EFQU; NFQU; SOLD; NFSO; SFHO; SFCA; NFSK
Cutthroat trout	Salmonidae	<i>O. clarkii</i>	ELWH; BOGA; EFQU; NFQU; SOLD; NFSO; SFHO; SFCA; NFSK
Bull trout	Salmonidae	<i>Salvelinus confluentus</i>	ELWH; EFQU; NFQU; SFHO; NFSK
Mountain whitefish	Salmonidae	<i>Prosopium williamsoni</i>	SFCA; BOGA; EFQU; NFQU; NFSO; SFHO; SFCA; NFSK

¹Landlocked Chinook salmon.²Landlocked rainbow trout.

Table 4. Weekly distribution of snorkel surveys among eight Olympic National Park rivers from June to September, 2011.

River	Jun 19	Jun 26	Jul 3	Jul 10	Jul 17	Jul 24	Jul 31	Aug 7	Aug 14	Aug 21	Aug 28	Sep 4	Sep 11	Sep 18
NF Skokomish									X	X	X	X		
Bogachiel	X	X	X		X	X	X		X		X			
Sol Duc		X	X		X		X		X	X			X	
EF Quinault											X		X	
NF Quinault												X	X	
SF Hoh									X		X			
NF Sol Duc		X				X								
SF Calawah		X	X	X	X	X	X	X		X				

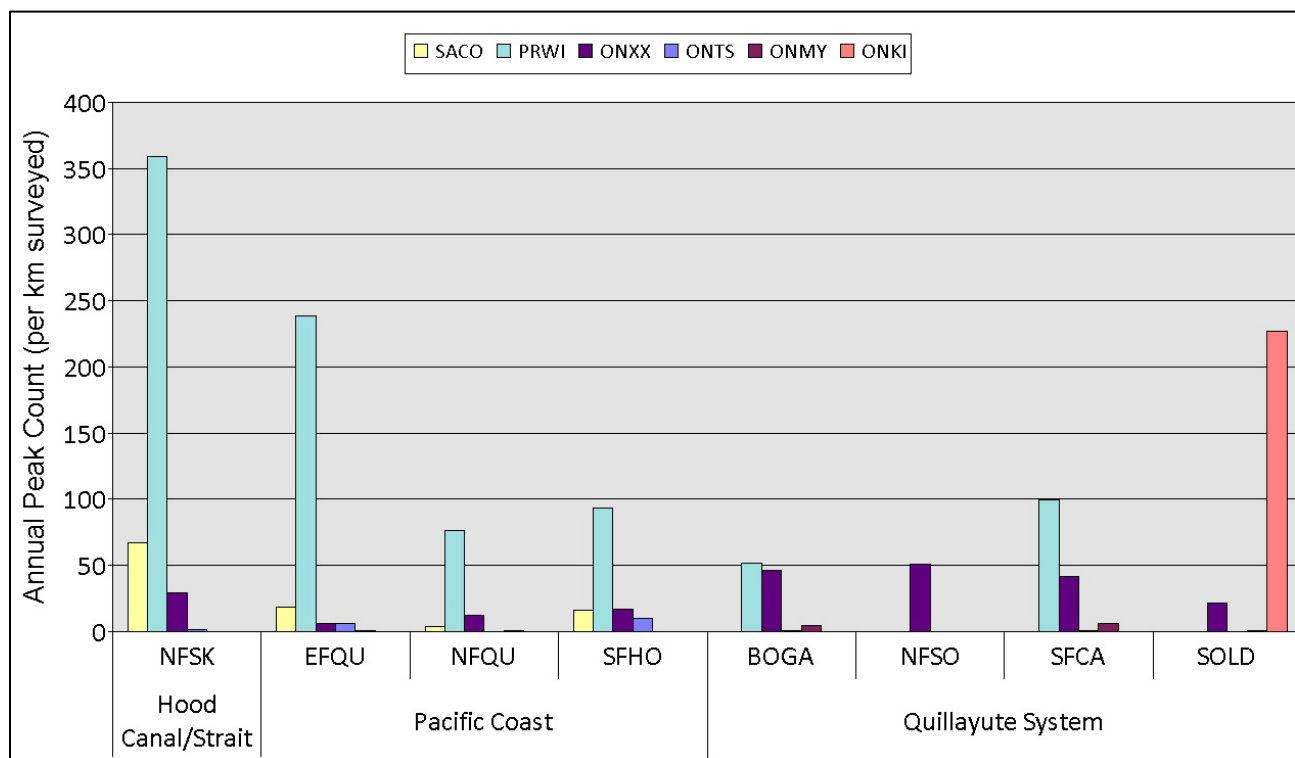


Figure 4. Highest number of each fish species observed per river kilometer (km) for each river during 2011. NFSK = North Fork Skokomish; EFQU=East Fork Quinault; NFQU=North Fork Quinault; SFHO=South Fork Hoh BOGA=Bogachiel; NFSO=North Fork Sol Duc; SFCA=South Fork Calawah; SOLD=Sol Duc. SACO=bull trout; PRWI=mountain whitefish; ONXX=cutthroat/rainbow trout; ONTS=adult Chinook salmon; ONMY=adult summer steelhead; and ONKI=coho salmon.

Comparisons of Seasonal Fish Species Composition Within and Among Rivers

The relative seasonal composition of fish species was determined within each river in 2011 (Figures 5 to 7). Seasonal trends in fish species composition were reported as the mean proportions for each fish species in a given month in each river.

Species compositions in the East Fork Quinault, North Fork Quinault, and South Fork Hoh Rivers exhibited similar patterns during summer months in 2011. Mountain whitefish, trout, and bull trout had the highest percentages, respectively in those rivers (Figure 5). The North Fork Sol Duc River was dominated by trout during the summer months in 2011 (Figure 6). Mountain whitefish and trout comprised a majority of the fish communities in the Bogachiel, South Fork Calawah, and North Fork Skokomish Rivers during the summer months (Figures 6 and 7). Adult Pacific salmon and steelhead trout comprised low percentages of reference sites among all rivers in 2011 except the Sol Duc River where high numbers of coho salmon were present.

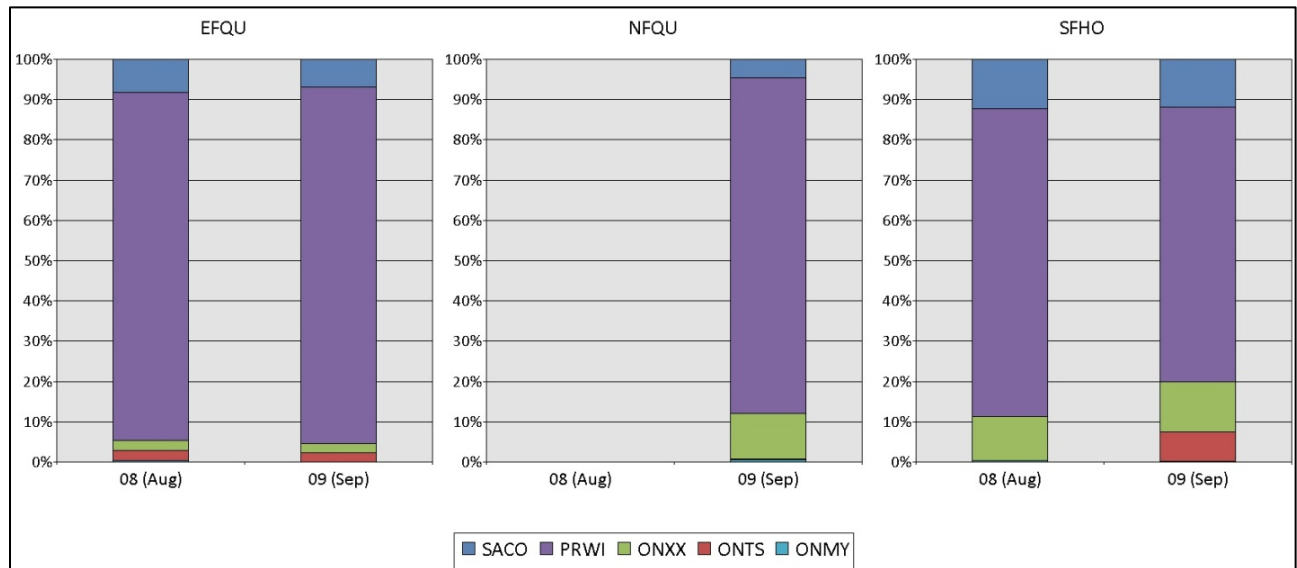


Figure 5. Mean monthly composition of primary fish species in the East Fork Quinault River (EFQU), North Fork Quinault River (NFQU), and South Fork Hoh River (SFHO) in 2011. Surveys were limited to August and September based on high riverflows in June and July. SACO=bull trout; PRWI=mountain whitefish; ONXX=cutthroat/rainbow trout; ONTS=adult Chinook salmon; and ONMY=adult summer steelhead.

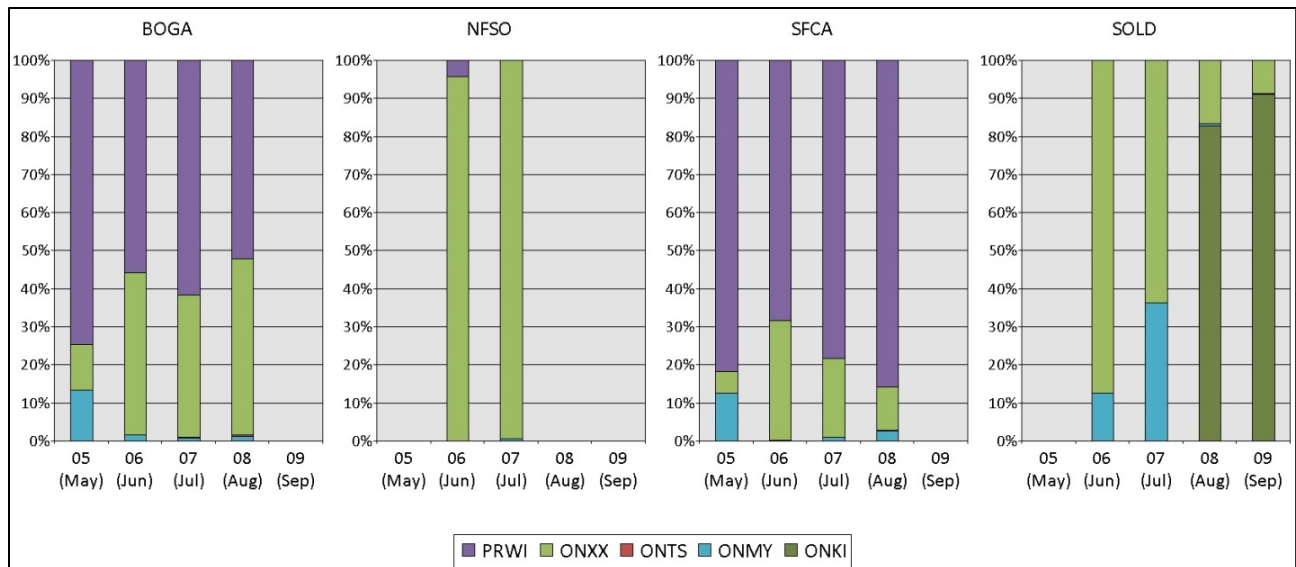


Figure 6. Mean monthly composition of primary fish species in the Bogachiel (BOGA), North Fork Sol Duc (NFSO), South Fork Calawah (SFCA), and Sol Duc Rivers (SOLD) in 2011. PRWI=mountain whitefish; ONXX=cutthroat/rainbow trout; ONTS=adult Chinook salmon; ONMY=adult summer steelhead; ONKI=coho salmon.

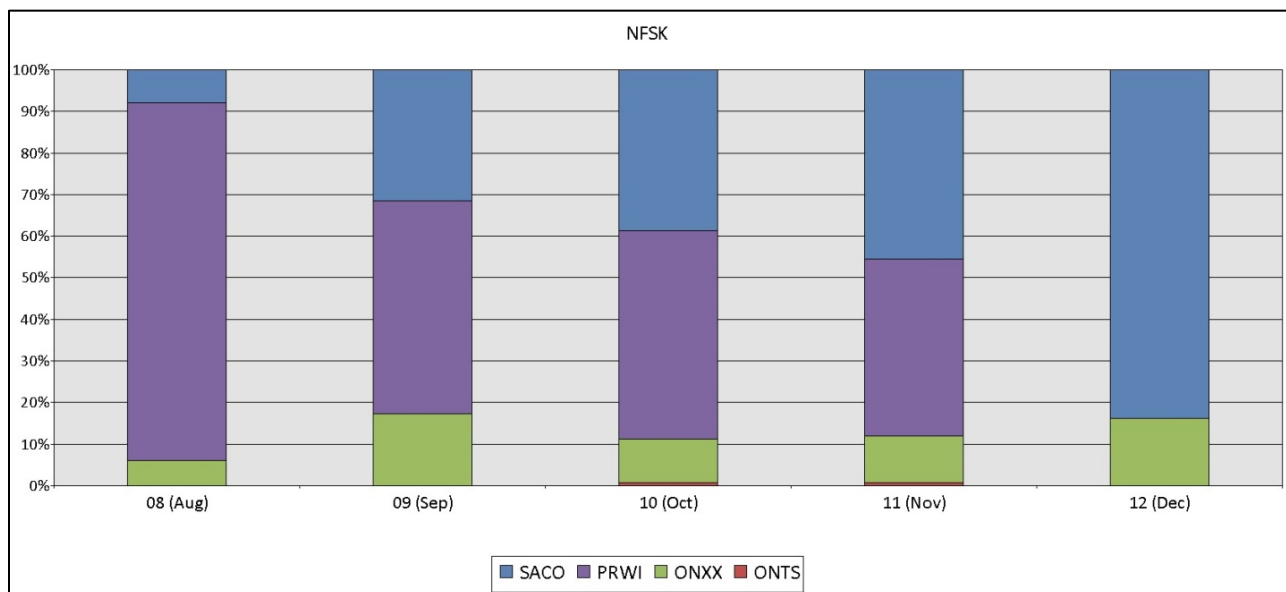


Figure 7. Mean monthly composition of primary fish species in the North Fork Skokomish River in 2011. SACO=bull trout; PRWI=mountain whitefish; ONXX=cutthroat/rainbow trout; and ONTS=adult Chinook salmon.

Annual Abundances of Fish Species Within and Among Rivers

We determined annual peak counts of primary fish species among rivers in 2011 (Figures 8 and 9) as a gauge of relative productivity for different species among park rivers. Annual peak counts of mountain whitefish were orders of magnitude greater than other fish species (ranged from 52 to 359 per kilometer, or 282-1,375 individuals observed), and were highest in the East Fork

Quinault and North Fork Skokomish Rivers (Figure 4, 8). Peak counts of rainbow/cutthroat trout were highest in the Sol Duc River (51 fish/km) and bull trout were highest in the North Fork Skokomish River (67.5 fish/km).

In 2011, peak counts of adult Chinook and summer steelhead were exceptionally low across rivers and ranged from 1 to 36 and 1 to 28 adults, respectively (Figure 9). The South Fork Calawah had the highest number of summer steelhead with a peak count of 6 steelhead per river kilometer and the South Fork Hoh contained the most adult Chinook salmon during a single survey in 2011, with 10 Chinook observed per river kilometer (Figure 4).

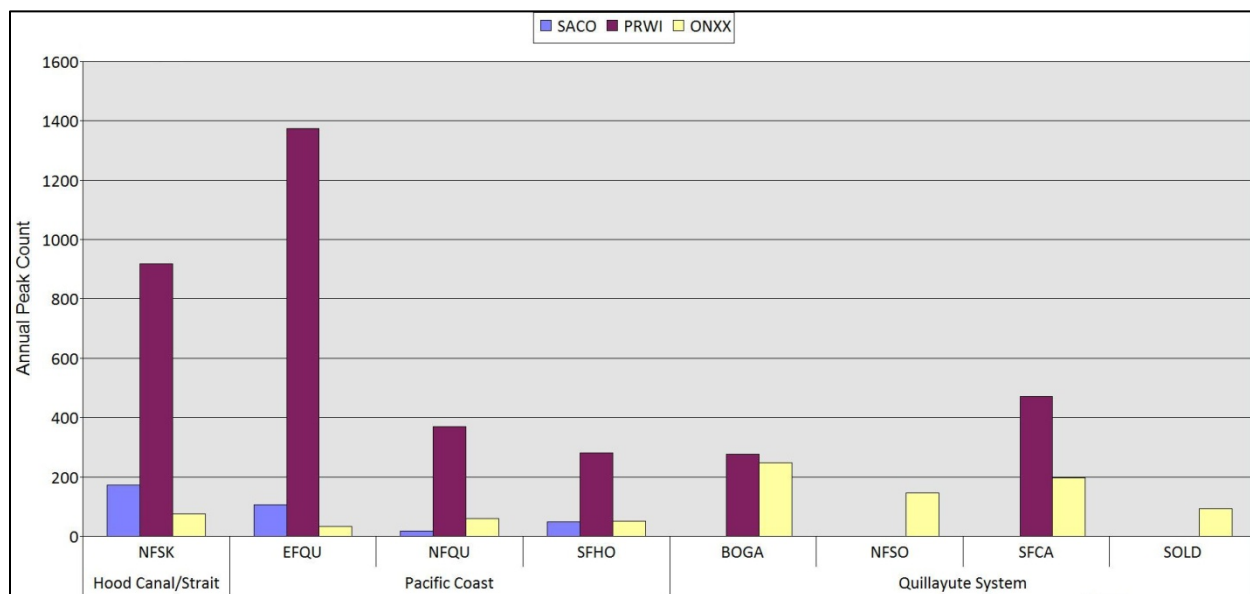


Figure 8. Annual peak counts of bull trout, mountain whitefish, and rainbow/cutthroat trout across eight Olympic National Park rivers in summer, 2011. SACO=bull trout; PRWI=mountain whitefish; ONXX=rainbow/cutthroat trout. NFSK=North Fork Skokomish; EFQU=East Fork Quinault; NFQU=North Fork Quinault; SFHO=South Fork Hoh; BOGA=Bogachiel; NFSO=North Fork Sol Duc; SFCA=South Fork Calawah; and SOLD=Sol Duc River.

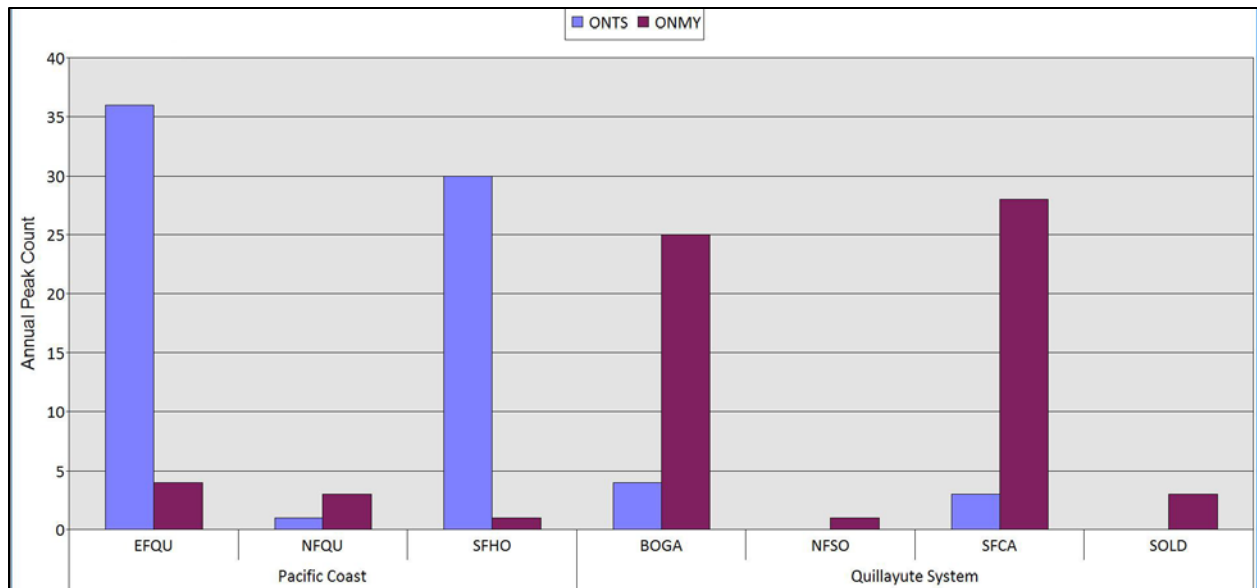


Figure 9. Annual peak counts of adult Chinook salmon (ONTS) and adult summer steelhead (ONMY) in seven rivers in summer, 2011. Chinook and steelhead do not occur in some rivers. EFQU=East Fork Quinault; NFQU=North Fork Quinault; SFHO=South Fork Hoh; BOGA=Bogachiel; NFSO=North Fork Sol Duc; SFCA=South Fork Calawah; and SOLD=Sol Duc River.

Proportions of Hatchery and Wild Fish in Rivers

In 2011, hatchery Chinook salmon were only detected in the Bogachiel and North Fork Quinault Rivers, albeit in low numbers (Figure 10). In 2011, hatchery, non-native summer steelhead were detected in the Bogachiel, North Fork Quinault, and South Fork Hoh Rivers (Figure 11). The South Fork Hoh and North Fork Quinault had the highest percentage of hatchery summer steelhead (50%) that year. We did not detect hatchery coho salmon in any reference site in 2011. These results indicated higher proportion of hatchery winter steelhead in the river populations than other recent estimates on natural spawning grounds in Olympic Peninsula rivers, ranging from 16% (Quillayute River) to 44% (Quinault River) (Busby et al. 1996).

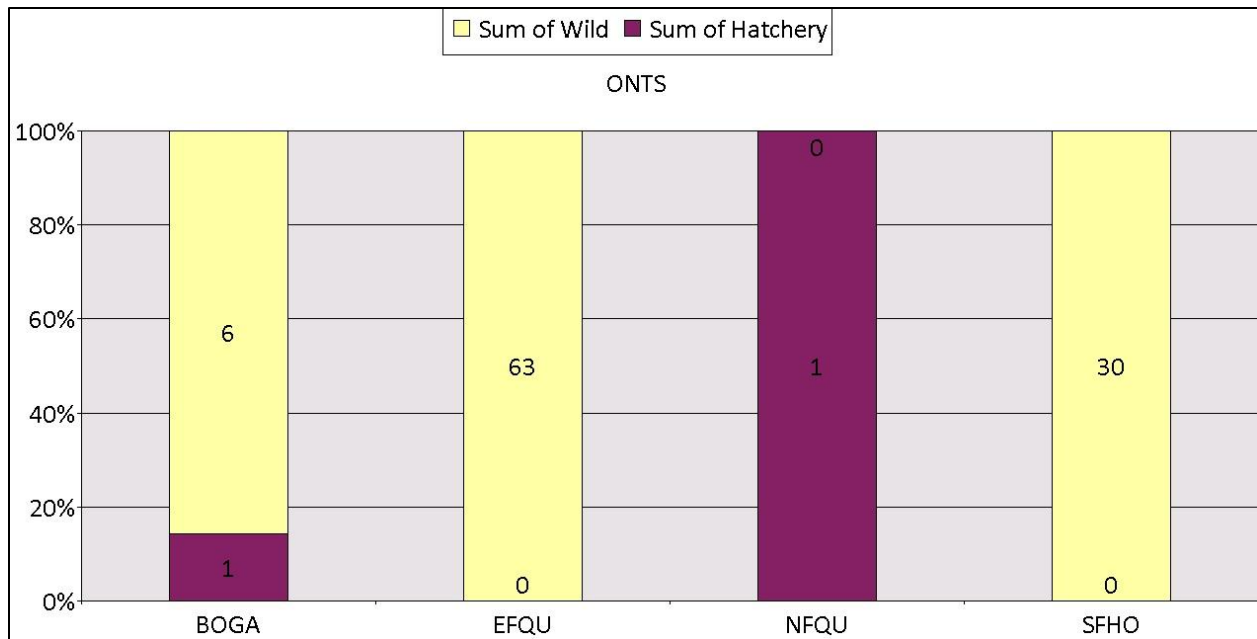


Figure 10. Summary of the relative proportions of hatchery (purple) and wild (yellow) Chinook salmon (ONTS) among Bogachiel (BOGA), East and North Fork Quinault (NFQU) and South Fork Hoh (SFHO) in 2011. The relative number of marked versus unmarked fish is based on the total number of observations during surveys conducted in 2011.

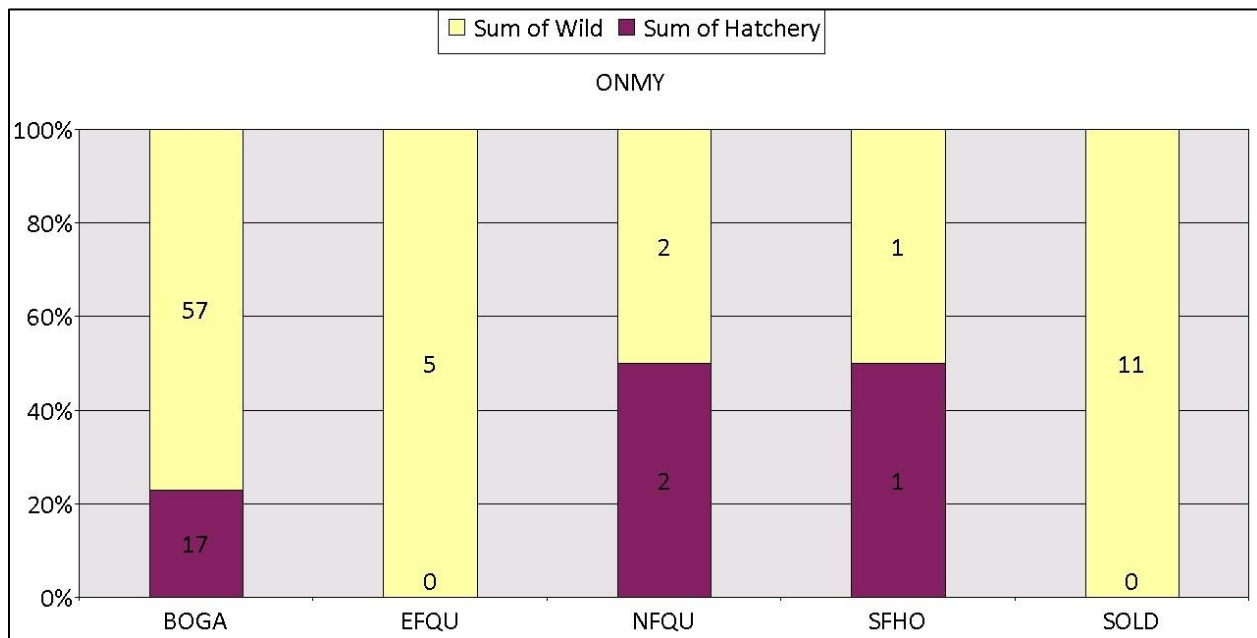


Figure 11. Summary of the relative proportions of hatchery (purple) and wild (yellow) adult steelhead (ONMY) among Bogachiel (BOGA), East and North Fork Quinault (EFQU, NFQU), South Fork Hoh (SFHO), and Sol Duc (SOLD) Rivers in 2011. The relative number of marked versus unmarked fish is based on the total number of observations during surveys conducted in 2011.

Literature Cited

- Bilby, R. E., B. R. Fransen, and P. A. Bisson. 1996. Incorporation of nitrogen and carbon from spawning coho salmon into the trophic systems of small streams: Evidence from stable isotopes. *Canadian Journal of Fisheries and Aquatic Sciences* 53:164-173.
- Brenkman, S. J., and P. J. Connolly. 2008. Protocol for monitoring fish assemblages in Pacific Northwest National Parks: U.S. Geological Survey Techniques and Methods 2-A7.
- Busby, P. J., T. C. Wainwright, G. J. Bryant, L. J. Lierheimer, R. S. Waples, F. W. Waknithz, and I. V. Lagomarsino. 1996. Status review of west coast steelhead from Washington, Idaho, Oregon, and California. U.S. Department of Commerce, NOAA Technical Memo. NMFS-NWFSC-27, 261 p.
- Cederholm, C. J., D. H. Johnson, R. E. Bilby, L. G. Dominguez, A. M. Garrett, W. H. Graeber, E. L. Greda, M. D. Kunze, B. G. Marcot, J. F. Palmisano, and others. 2001. Pacific salmon and wildlife: Ecological contexts, relationships, and implications for management. Pages 628-687 in D. H. Johnson, and T. A. O'Neil (Eds.). *Wildlife-habitat relationships in Oregon and Washington*. Oregon State University Press, Corvallis, Oregon.
- Chilcote, M. W., S. A. Leider, and J. J. Loch. 1986. Differential reproductive success of hatchery and wild summer-run steelhead under natural conditions. *Transactions of the American Fisheries Society* 115(5):726-735.
- Flotemersch, J. E., J. B. Stribling, and M. J. Paul. 2006. Concepts and approaches for the bioassessment of non-wadeable streams and rivers. EPA 600-R-06-127. U.S. Environmental Protection Agency, Cincinnati, Ohio.
- Houston, D. B., and R. J. Contor. 1984. Anadromous fish in Olympic National Park: Status and management considerations. Pages 97-111 in J. M. Walton, and D. B. Houston (Eds.). *Proceedings of the Olympic Wild Fish Conference*. (March 23-25, 1983). Fisheries Technology Program, Peninsula College, Port Angeles, Washington.
- Jenkins, K., A. Woodward, and E. Schreiner. 2003. A framework for long-term ecological monitoring in Olympic National Park: Prototype for the coniferous forest biome. U.S. Geological Survey, Biological Resources Discipline, Information and Technology Report, USGS/BRD/ITR-2003-0006.
- Kline, T. C., J. J. Goering, O. A. Mathisen, P. H. Poe, and P. L. Parker. 1990. Recycling of element transported upstream by runs of Pacific salmon: I. $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ evidence in Sashin Creek, southeastern Alaska. *Canadian Journal of Fisheries and Aquatic Science* 47:136-144.
- Kline, T. C., Jr., J. J. Goering, O. A. Mathisen, P. H. Poe, P. L. Parker, and R. S. Scanlan. 1994. Recycling of element transported upstream by runs of Pacific salmon: II. $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ evidence in the Kvichak River watershed, Bristol Bay southwestern Alaska. *Canadian Journal of Fisheries and Aquatic Science* 50:2350-2365.

- Northcote, T. G., and G. L. Ennis. 1994. Mountain whitefish biology and habitat use in relation to compensation and improvement possibilities. *Reviews in Fisheries Sciences* 2(4):347-371.
- Oberdorff, T., D. Pont, B. Hugueny, and J. Porchers. 2002. Development and validation of a fish-based index for the assessment of “river health” in France. *Freshwater Biology* 47:1720-1734.
- Peck, D. V., J. M. Lazorchak, and D. V. J. Klemm (Eds.). 1999. Unpublished draft. Environmental Monitoring and Assessment Program-surface waters: Western pilot study field operations manual for wadeable streams. U.S. Environmental Protection Agency, Washington, D.C.
- Plafkin, J. L., M. T. Barbour, K. D. Porter, S. K. Gross, and R. M. Hughes. 1989. Rapid bioassessment protocols for use in streams and rivers: benthic macroinvertebrates and fish. EPA/440/4-89/001. U.S. Environmental Protection Agency, Washington, D.C.
- Reisenbichler, R. R., and J. D. McIntyre. 1977. Genetic differences in growth and survival of juvenile hatchery and wild steelhead trout, *Salmo gairdneri*. *Journal of the Fisheries Research Board of Canada* 34:123-128.
- Schmutz, S., M. Kaufmann, B. Vogel, M. Jungwirth, and S. Muhar. 2000. A multi-level concept for fish-based, river-type-specific assessment of ecological integrity. *Hydrobiologia* 422/423:279-289.