Final Report

Washington Department of Fish and Wildlife's

High Lakes Fishery Management Program

Prepared for

Washington Department of Fish and Wildlife
Olympia, Washington

Prepared by

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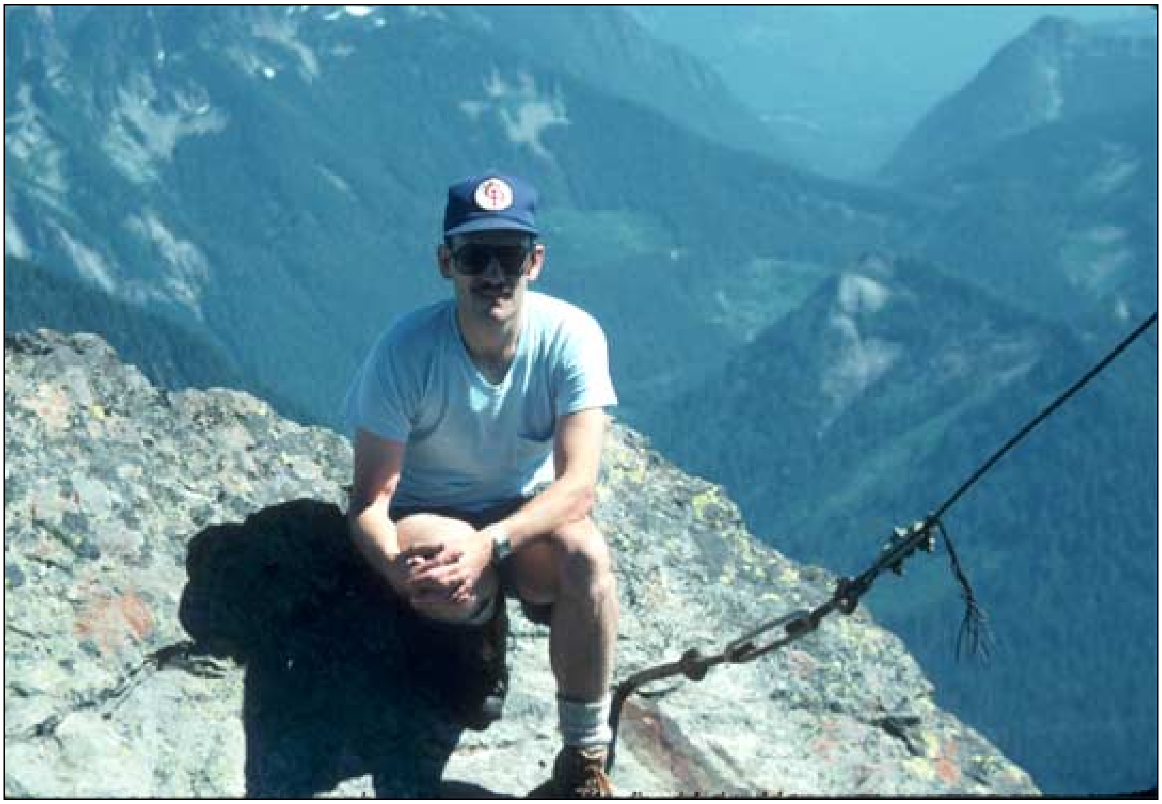

Bob Pfeifer was the District Fish Biologist in the greater Seattle area for the Washington Department of Fish and Wildlife between 1978 and 2000. Prior to this he was a habitat biologist for the same area between 1972 and 1978. Mr. Pfeifer's management district contained approximately 670 lakes and ponds on lands managed by the US Forest Service, the Washington Department of Natural Resources, three large municipal watersheds (Everett, Seattle and Tacoma), and major timber owners. In addition to managing this large and diverse number of waters, Bob hiked to and surveyed most of those that support fish – many of them multiple times. He worked closely with other WDFW managers and members of the Trail Blazers and Washington State Hi-Lakers to develop an improved system for monitoring the fishery, and collaborated on the development of databases both inside and outside the agency. Pfeifer guided the development of Washington's only golden trout captive brood stock. He was the High Lakes Program Coordinator in the Seattle (Region Four) regional office between 1980 and 1999, coordinating the volunteer stocking and fishery monitoring over a 10-county area. Bob's passions are mountaineering, high lake fishing, and outdoor photography. He was the President of the Washington State Hi-Lakers for two years, and is currently the Treasurer of the Trail Blazers. (Bob is here seen in 1989 reveling in the awesome views from the summit of Three Fingers Mountain in Washington's North Cascades. The view is to the east over the Squire and Clear Creeks drainages.)

Mike Swayne has been a member of Trail Blazers, Inc. since 1958. An avid climber in his youth, Mike made a number of notable first ascents in the central and north Cascades. He has been a passionate and active hiker/mountaineer for over 40 years. Mike manages an environmental consulting business that develops databases for environmental projects specializing in the identification and remediation of hazardous and toxic chemicals at municipal, industrial, military and mining sites. As the long-time Librarian of the Trail Blazers, Mike has led the development of an extensive, comprehensive database on Washington's high lakes and fishery that would be the envy of most other state fishery agencies. The database identifies 3,837 high lakes and ponds in Washington with an associated 12,352 fish introductions and 11,403 fish observations. Mike acknowledges the assistance of the following agencies and organizations in developing this database: Trail Blazer library stocking and survey records; Hi-Laker library survey records; Snohomish County Sportsmen stocking and survey records; WDFW lake identification and stocking records in Olympia; WDFW regional biologist stocking and survey records; North Cascade National Park lake identification; biological and chemical survey records; Forest Service fish, wildlife, vegetation, and camp records; USGS chemistry records, StreamNet surface water topology records; and EPA chemistry records. (Mike is here seen in 1992 atop unnamed Peak 7722 in the Charlotte Alplands in the British Columbia Coast Range. The view is to the northwest.)

Brian Curtis has a degree in fisheries management, and has been a member of Trail Blazers, Inc. since 1987, and the Washington State Hi-Lakers since 1973. Like Mike Swayne, Brian maintains a powerful database on Washington's high lakes fishery, with an emphasis on trip survey reports. Brian and his father, Walt Curtis, are leaders in the development of lightweight backpacking and fishing equipment, some of which was indispensable in the collection of information presented in this report. (Their remarkable 20-oz pack raft is shown in its stuff sack in Plate 4, and in use in Plates 6, 11, 26, and 33.) Brian was the President of the Trail Blazers in 1994 and has served as the communications point of contact between the Trail Blazers and WDFW since 1997. (Brian is seen here on a recent [August 2001] trip to the Great Bear Wilderness in Montana. The view is over the Spotted Bear River towards the Bob Marshall Wilderness from Gunsight Peak.)

ACKNOWLEDGMENTS

This report is the result of the combined efforts of many people, spanning nearly three decades. The primary author's role was largely one of synthesizing the collective experience of others. Past and present WDFW fish biologists provided technical information contained within the report.

It would have been impossible to produce the report within the allotted time frame and budget without the *pro bono* contribution of time and database analysis by Dr. Mike Swayne of the Trail Blazers, Inc., and Mr. Brian Curtis of the Trail Blazers and the Washington State Hi-Lakers. The majority of the database information on the number of lakes, their size, stocking statistics, and volunteered angler reports was provided by these individuals. Their assistance and friendship is greatly appreciated. The Trail Blazer library was started by "Honest" Charlie Yadon soon after the club was formed in 1933. Charlie acquired his nickname due to his attention to detail and meticulous record keeping in log books, journals, annual reports, minutes, and notes from coordination meetings with the early Department of Game. Without his fine work much of the early years of Trail Blazer stocking efforts would have been lost to history. In more recent years the Trail Blazer library has been coordinated with Brian Curtis, the Washington State Hi-Lakers Librarian.

Figures 1 through 5, 6b through 7b, 14, 17, and Appendix K Plates 1 through 13 were prepared by Mike Swayne. All photographs were taken by the primary author unless otherwise noted. Many photographs or transparencies were freely given to the author over the years, and this was, again, sincerely appreciated. Individuals who were particularly helpful for this report include Gerry Ring Erickson, Jim Cummins, Larry Hirni, and Bill Henkel.

The first draft of this report received review from many WDFW area fish biologists, many of whom provided valuable feedback. The author gives credit to Jim Uehara and Bob Gibbons, WDFW program managers, for the contractual arrangements that made this report a reality. Preparation of this program summary had been a career goal of his for many years. Bob Gibbons' extensive comments on the first draft and discussion with the primary author were essential to the report's completeness and relevance.

Bob Pfeifer
September 16, 2001
Kirkland, Washington

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ACRONYMS

GPOs	Goals, Policies, and Objectives
HLS	High Lake System (Trail Blazer database)
NCNP	North Cascades National Park
NPS	National Park Service
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
WDFW	Washington Department of Fish and Wildlife
WDG	Washington Department of Game
WDW	Washington Department of Wildlife
WSP	Washington Salmonid Policy

EXECUTIVE SUMMARY

Report Purpose

This is the first comprehensive review and summary of the management of the high lake fishery in Washington State. Its purpose is to document the history, goals, and unique aspects of this program, as well as angler participation in, and economic value of the fishery. It identifies the number and general characteristics of the lakes that are managed for a fishery, as opposed to the many waters that are left in a natural state. The report provides documentation of the Washington Department of Fish and Wildlife's (WDFW's) current high lake management practices. WDFW seeks to increase public awareness and understanding of the high lake fishery program; this report documents how WDFW meets the public's need and desire for this form of recreation, while protecting other wildlife and wilderness values. Finally, the report is the first comprehensive preparation of recommendations on how to improve WDFW's high lake management program.

History

Most of Washington's high lakes were naturally fishless following the last glaciation. Native Americans may have placed some fish in some lakes, but early settlers, miners, and loggers carried trout fry into numerous lakes in the late 19th century. Prior to the creation of the Washington Department of Game by public initiative in 1933, management of fisheries in Washington's high lakes was conducted by the federal government (principally the Forest Service) and local county governments. Many lakes that currently contain problem (excessively abundant) fish populations received their initial introductions from these agencies and individuals, not the State of Washington. WDFW's progress in development and management of the fishery closely paralleled that seen in other states for the next 35-40 years. The performance of various strains and species of trout and char were empirically tested in waters of varying productivity and setting. Methods were developed and refined for stocking fry using backpack and aircraft to replace the old USFS pack strings or miners lugging milk cans. More rigorous methods were developed for surveying the lakes and their fisheries beginning in the early 1970s. Initial chemical treatments were made on high lakes to replace stunted, excessively abundant char with a controlled population of trout that is compatible with the alpine lake ecosystem. Methods were developed for more complete and error-free data collection, monitoring, database management, and reports.

Program Goals

WDFW's mission is Sound Stewardship of Fish and Wildlife; one of its goals in pursuit of this mission is "Maximum fishing, hunting and non-consumptive recreational opportunities compatible with healthy, diverse fish and wildlife populations". In general, conservative utilization is the objective for naturally-produced, native fish and wildlife populations. The high lake fishery is entirely artificial, created by stocking programs to provide a unique recreational fishing experience in Washington's subalpine and alpine environments. The goal of maximum recreational fishing opportunity is not inconsistent with the agency mission since management of the fishery is sensitive and responsive to issues such as genetic integrity of native fish populations, and irreversibly adverse ecological interactions with native vertebrates and invertebrates in and near stocked lakes.

Value of the Program

Only a handful of states in the coterminous United States have the diversity of landscape to offer recreational opportunity at thousands of lakes in subalpine and alpine environments, much of which is protected as designated wilderness. Washington has a rich glacial and legislative legacy of wilderness settings that challenge the hiking angler, and provide a huge diversity of opportunity for angling of the highest quality. Users can choose destination lakes that range from the end of a road, to the most challenging remote locations that require a high degree of mountaineering skill to access. The fisheries include lakes that have supported family-oriented recreation for many decades. Depending on the lake setting and the individual, alpine lake fishing in Washington is often truly a unique experience.

The 1995 Angler Survey conducted by WDFW determined that more than 175,000 license-buying anglers fish Washington's high lakes annually. These anglers are in addition to children or others who, for one reason or another, do not purchase a license. About 1,400,000 fishing trips were made in 1994 by these individuals, based on an average of 7.7 trips per angler. Using an average figure of $49.79 per trip yields an annual fishery value of over $67 million. Because many of the high lakes support self-sustaining fish populations, and the cost of small fry used in stocking programs is very low, the program has a phenomenally high benefit to cost ratio of between 1000:1 and 1600:1. The high lake fishery is almost certainly the most cost-effective program administered by WDFW.

Lakes in the Program

Slightly over 4700 high lakes occur in Washington, based on a definition of their occurring above 2500 ft (mean sea level) west of, and 3500 ft east of the Cascades. Only 1777 (38%) of these support fish; of these, about 800 (17%) are periodically stocked. The balance, or about 1000 waters, have self-sustaining fish populations. Nearly two thirds (62%) of Washington's high lakes and ponds are fishless, and are broadly distributed across the landscape. Lake size and depth is highly variable, ranging in size from tiny ponds at about 0.1 acre, to very large lakes of over 300 acres. The majority are between 0.2 and 50 acres. The smallest lakes and ponds are usually at least 3 feet deep at their deepest point. Maximum depth increases continuously with lake size up to about 160 acres. A typical 10-acre lake would have a maximum depth of about 40 feet. There is great diversity in average depths, shoreline shape and slope, setting, exposure, soil development, and bedrock type, resulting in a wide range of potential productivity.

Many of the lakes contain excessively abundant populations of eastern brook or cutthroat that are known to have adverse effects on native biota in or near the lakes. Determining an accurate list of these lakes, the problem species, the lake locations, and the most practicable treatment for each water was beyond the scope of this report, but is a very important next step. Local WDFW fishery managers are, for the most part, well aware of most of these lakes, but some field reconnaissance may be necessary to derive a fully complete list since not all lakes have been surveyed in a few locations.

Current Management

Great progress has been made by WDFW biologists in performing "baseline" surveys on waters under their responsibility, but the task is not yet complete. Physical, chemical, and biological survey methods were developed primarily in the early 1970s, but a formal state-of-the-art Methodology, or Methods Manual for high lake surveys has not been prepared. This should be considered a high priority, as well as providing the human and other resources needed to implement it, and complete the surveys. This report describes some of the major elements of such a Methodology.

A large amount of data has been collected on the lakes (physical and chemical characteristics), and on the biology of the fish and invertebrates within them. Work was initiated on developing a model of trout growth or lake productivity in a subset of Washington high lakes. This work should be completed by adding the data collected by WDFW biologists in other geographic areas. The results of this analysis should not, and probably cannot provide a cookbook or prescription for individual lake management, but would be of great value by increasing technical understanding of the production capabilities of lakes or lake types in Washington.

Local WDFW biologists visit their lakes on a time-available basis, but monitoring of the fishery is largely volunteer-based. This is developed to an usual degree in Washington, particularly with two key sports clubs in the Seattle area. The Trail Blazers, Inc., founded in 1933, and the Washington State Hi-Lakers were leaders in the development of data forms and methods to systematically collect and organize information on fishery performance at the remote lakes. WDFW has worked closely with these groups for many years, and relies heavily on their input to track program success. WDFW needs to allocate additional local staff time to maintain this feedback mechanism. Use of the Internet should be explored as a way to expand the sources of angler information, but there is no substitute for the experience of the local professional fishery manager in filtering and managing volunteer-based information.

While data management has improved greatly since 1972, some staff time (temporary or permanent) needs to be devoted to closing data gaps and correcting (relatively minor) data flow problems. The most important need is to develop a consistent approach to collecting and managing volunteered monitoring data, and producing periodic report summaries to enable routine management decisions.

The discipline in Washington's stocking program is its hallmark. Knowledge of fish reproductive status in each lake under management is critical information. WDFW managers have determined this for most, but not all lakes under management. Stocking schedules are generally not set on any lake for which fish reproductive status is not known. Resources need to be directed at lakes and counties where this information in most needed (e.g. Chelan County). An even higher level of discipline could be achieved if measures of natural and angling mortality of trout were available. These measures should be obtained for several fish species, in a variety of settings, and under a range of fishing pressure. This information would be an extremely valuable adjunct to the volunteer-based monitoring program.

Recreational overuse at lakes, particularly in wilderness areas, is usually not caused solely by anglers. Angling is rarely the primary activity at lakes where overuse is a serious problem. WDFW should continue to work cooperatively with land managers on overuse issues, but not terminate stocking as a means of controlling human numbers at lakes. Controls on access (e.g. limited entry, or the distance people must walk) are a far more equitable and effective means of reducing use levels.

Experience and research has shown that most high lakes in Washington need not, and should not be stocked at densities greater than 50 to 100 fish per surface acre. WDFW managers became aware of this fact years before issues surrounding the decline of amphibians came to light. To prevent excessive fish numbers in a lake, trout or char species and strains should be, and are chosen that have a demonstrated inability to successfully reproduce in a given lake environment. Research on the use of sterile hybrid crosses and strains proceeds on the basis of time and financial resources availability. Overall stocking has been declining for 20 years, as well as the average density of fish stocked. Most lakes that require stocking are on low-density maintenance programs.

New fish species or strains are not stocked into waters they have not been stocked into previously without appropriate review of the biological effects. At the same time, WDFW managers need to be given the freedom to use special strains under carefully prescribed circumstances. An example is the use of top predators such as tiger muskellunge as a biological control of stunted eastern brook trout. WDFW local managers give full consideration to the potential effects of fish introductions on downstream native fish resources, and this will continue.

As a general rule, species should be, and are stocked that are native to the lake's drainage basin. However, to meet the program goal of providing diversity in the fishery, strains that are not having a negative effect on native biota should continue to be stocked (e.g. golden trout). Other strains or species should be stocked where it makes sound biological sense to do so, such as where biological controls are used to control excessive fish abundance, rather than the use of piscicides.

WDFW is aware of the need to practice ecologically responsible stocking in the high lakes. To this end, the prioritized research topics identified in the literature review conducted concurrent with this report preparation should be implemented as budgets allow. Fish should be removed from lakes where they are documented to have an unacceptable impact on native species. However, the results of studies in other states should not be categorically applied to Washington where invertebrate and amphibian communities and ecological relationships often differ from those of the states where other research occurred.

Earlier mistakes made by individuals and agencies that resulted in self-sustaining, excessively abundant trout or char populations in some Washington high lakes can be rectified in many cases. A list of prioritized lakes needing fish population control should be prepared. The extremely high benefit to cost ratio of this program should be balanced against the cost of a long term program of lake reclamations. Annual conversion of several high lakes to quality, low-density trout fisheries will go far towards meeting future recreational demand, will increase angler satisfaction, and will systematically reduce the impacts of overabundant fish on native biota. The most practical control option for each lake should be identified. To date only chemical treatment has been shown to eliminate stunted, overabundant fish in Washington high lakes. Biological controls show considerable potential for reducing fish abundance; further testing in Washington is warranted on lakes where other methods are impractical. Spawning area exclosures and intensive netting or fishing may have some potential in a limited number of lakes.

The demand for recreational fishing continues to rise as the population of Washington increases. WDFW local managers have learned through painful experience that when historic fish populations are allowed to die out in lakes, unscrupulous publics will sometimes reintroduce fish. The illegal re-introduction may not be a suitable species, and may cause irreversible harm. The number of lakes being managed for low-density, high quality fisheries should not be allowed to drop below current levels in order to satisfy recreational fishing demand, and to demonstrate active, responsible management.

Periodic angler use surveys such as was conducted in 1995 should continue. Given the value and cost-effectiveness of the high lake fishery, it should be given special attention in future surveys.

WDFW has a long history of cooperation with major state, private, and federal land managers. Periodic or annual meetings to discuss mutual management issues should be encouraged. The 1988 Supplemental Agreement to the memorandum of Understanding between WDFW and the National Park Service should be renegotiated. It should take advantage of the best current science, this report, the concurrent literature review, and the corporate experience of groups such as Trail Blazers, Inc.

Public outreach and education can be increased by broad publication of this report and other media explaining the high lake program. This report and the associated literature review should be made available on the agency website. Local WDFW managers need to be given the time to maintain, or increase their communication with publics and groups that supply needed feedback and fishery monitoring.

What Have We Learned

WDFW understanding of management of the state's high lake fishery can be summarized as follows:

- Continue to not stock all available waters. Balance ecological issues with fishery values. Maintain a network of barren lakes and ponds across the landscape.
- Stock only at low densities.
- Avoid species and strains that may reproduce excessively.
- Remove or reduce problem fish populations wherever it is feasible to do so. Replace excessively abundant species with a controlled fish community to meet the public demand for this form of recreation.
- Stock native species primarily. Contain stocked fish to the target lake by use of appropriate stocking methods.
- Maintain close coordination with other land managers.

Research

Studies specific to Washington would be valuable that addressed subjects investigated in other regions, such as identification of the stocking densities and intervals that have significant, or irreversible impacts on native invertebrates. More complete information is needed on the basin life history and abundance of amphibians in Washington's high country; to date there is no evidence that any species native to this life zone is severely depressed or endangered.

More definitive information is also needed on the degree to which stocks used by WDFW emigrate or drop out of lakes in which they are stocked.

1. INTRODUCTION

1.1 REPORT BACKGROUND AND PURPOSE

Many people do not understand the high lake fishery program that has been managed by the State of Washington since 1933. Ignorance and misunderstanding has resulted in published misinformation, even by fisheries professionals. Few people understand that nowhere near all mountain lakes in Washington are being stocked, or even contain fish, and that the number of lakes being stocked, as well as trout stocking densities, have been steadily dropping for years. Many do not know that the stocking program is now basically one of low-level maintenance of quality trout fisheries, wherever possible. Many, perhaps most license-buying angler-hikers do not know how trout came to exist in mountain lakes, or how they are managed. Members of some groups whose mission is to protect wilderness areas and wilderness values believe trout have no place in wilderness lakes. Many do not know of, or understand the effort Washington Department of Fish and Wildlife (WDFW) fishery managers take to coordinate the high lake trout program with other land and wilderness management agencies.

This report, along with a comprehensive scientific literature review (Divens et al. 2001), was prepared as one mechanism to dispel myths and misunderstandings related to WDFW's trout management in high lakes. It will better educate the public on the methods WDFW uses to manage the fishery, and to co-manage aquatic habitats in a way that is beneficial to recreational users, yet has minimal impact on the natural environment. It describes the major economic and recreational benefits of the fishery in perspective relative to its ecological impact.

The need for a written, standardized methodology for the survey and management of high lake trout fisheries has been recognized by WDFW biologists for years. This report is a step towards that goal, although it is not intended to be a thorough technical reference document for current and future field and office management biologists. The primary purpose and objective of this report is to describe WDFW's current approach to high lake fishery management statewide. Management methods vary somewhat around the state, as do geography, geology, climate, lake environments, and angler use levels. This report identifies and explains the overall management approach, and the reasons for differences among WDFW administrative regions.

This report is not a future Management Plan for Washington high lakes. It is not intended to be a prescription of the methods and policies that will shape these fisheries in the future, however it does identify management principles which have shown success or promise in recent years. The purposes of this report are as follows:

- Document the history, goals, objectives, and unique aspects of the high lake program in Washington State;
- Document angler participation and economic value of the fishery;
- Identify the number and general characteristics of high lakes managed for a fishery;
- Document WDFW's current high lake management practices;
- Inform and educate the public on the high lake program, and the steps being taken to balance mandates; and

- Recommend modifications to improve the high lake management program in Washington.

1.2 REPORT PREPARATION METHODS

For the purposes of management and this report, WDFW fishery managers have defined a high lake in western Washington as one situated above 2500 feet (762 m) mean sea level (msl), and above 3500 feet (1,067 m) msl in eastern Washington (Figure 1). These elevations are not wholly arbitrary, but take into account the location of the sub-alpine and alpine zones, as well as other attributes. Since the alpine zone lies well above 2500 ft msl in western Washington, the term "high" lake is preferred over "alpine" lake, as the former is more inclusive.

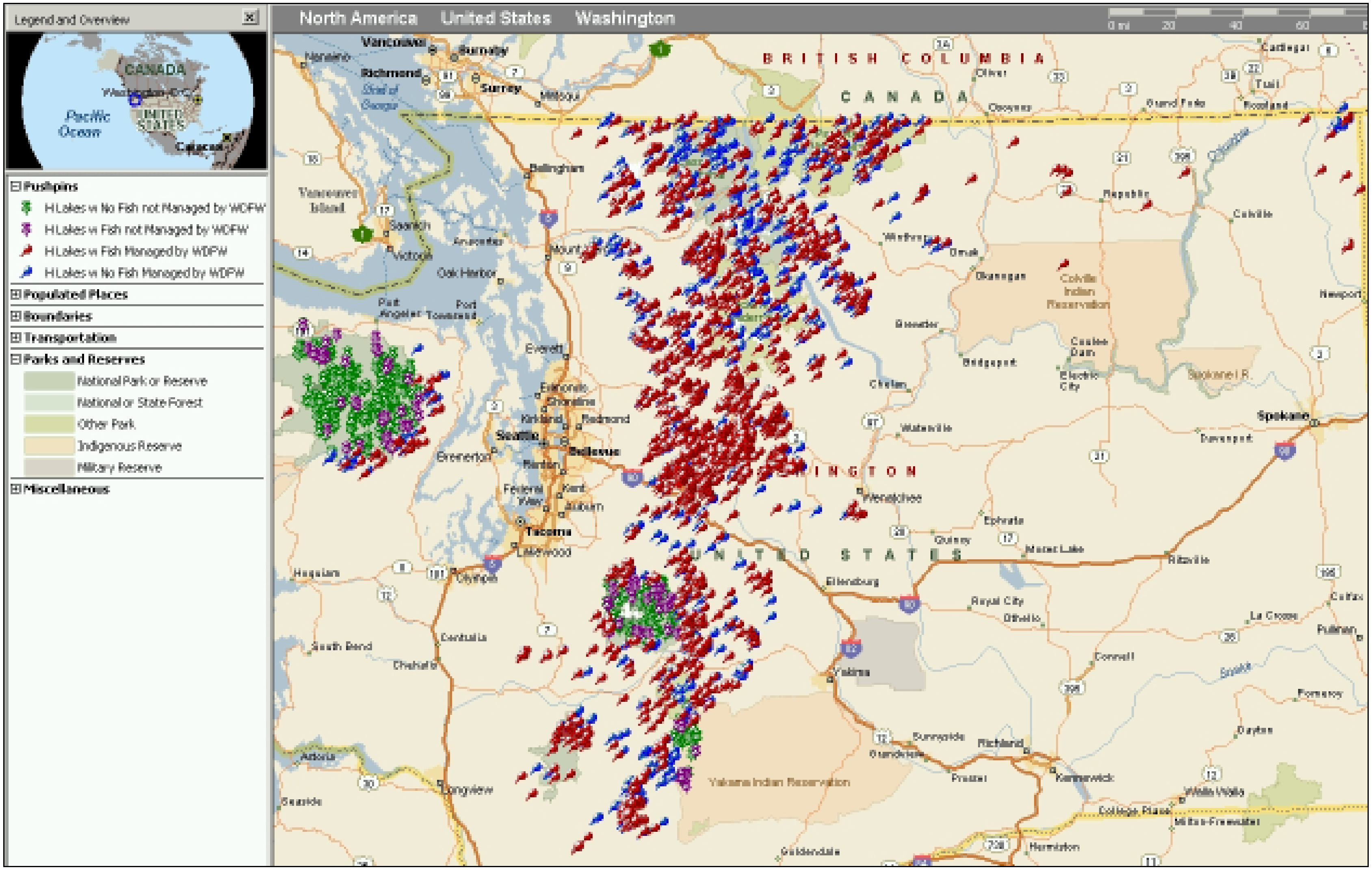
Most "high" lake fisheries, as defined, are managed much differently than lowland lake fisheries. The actual difference in management approach is more pertinent than strict elevation in many cases. Some, perhaps most local WDFW fishery managers pay little or no attention to lake elevation, but set stocking frequency and density, and make fish species selections based more on factors such as access, lake productivity, and anticipated angler use levels. "High lake" fisheries are generally managed for low fish density, low angler use levels, and higher "quality" fishing opportunity than most lowland lakes.

Definition of a high lake "universe" was required to prepare this report. The initial data set was prepared using the 2500 ft / 3500 ft breakout for western and eastern Washington, respectively, and subset files were distributed to each WDFW local manager for an accuracy check. A few lakes located below these elevations were added due to their management approach and local environmental conditions. Conversely, a very small number of waters above these elevations were removed from the sets for various reasons. The agreed upon files for each district were used to generate the statistics used in this report, and were closely coordinated with the Trail Blazer High Lake System (HLS) database (below).

Much of this report's content is based on the primary author's 20+ years of experience in managing high lakes in the central and north Cascades, and intimate familiarity with the program's internal processes of lake surveys, trout culture, stocking, monitoring, and database management. An important step in the coordination and collection of statewide information occurred during a 2-day meeting in Wenatchee on January 17-18, 2001 of current and recently-retired district fish biologists. A comprehensive questionnaire was prepared to guide discussion and collection of information (Parametrix 2001). Detailed discussion of the questionnaire's content occurred at the January workshop. Later, all attendees, plus several who could not make the workshop, completed the questionnaire, giving concise, and often frank answers. These were subsequently compiled within the questionnaire format, with individual local management biologist comments listed below each question.

The importance and value of the 2-day workshop was critical in development of this report. Subtle differences in regional program implementation that may be suggested by dry stocking records from a central database often have sound reasons, based on local conditions. Many of the management biologists who attended the workshop or completed the questionnaire had, or have 20-27 years of practical field experience in managing high lake fisheries (Appendix A). As a group, the respondents represent more than 150 years of field experience with high lake fisheries in Washington's Cascades and Olympic Mountains. This report seeks to capture the value of that extensive field and management experience. Much of the commentary in succeeding report sections follows directly from the workshop and compiled managers' responses.

Figure 1 The Distribution of High Lakes and Ponds in Washington State. Blue lakes are those WDFW-managed waters >.1 acres without fish stocked or seen. Red lakes are those WDFW-managed waters where fish have been stocked or seen.



Some of the most critical statistics in this report that appear in charts and tables were prepared using the Trail Blazer HLS database. This database has been developed over the last 20 years by combining data from several sources including: Trail Blazer library stocking and survey records; Washington State Hi-Laker library survey records; Snohomish County Sportsmen stocking and survey records; WDFW lake identification and stocking records in Olympia; WDFW regional biologist stocking and survey records; North Cascade National Park lake identification; biological and chemical survey records; US Forest Service fish, wildlife, vegetation, and camp records; USGS chemistry records, StreamNet surface water topology records; and EPA chemistry records.

The HLS contains 4,718 high lakes and ponds, and contains essentially all the high lakes and ponds shown on USGS 1:24,000 scale topographic maps in Washington. These maps show essentially all lakes and ponds greater than about 0.2 acre. Coverage in the North Cascades National Park is more complete and includes several lakes and ponds identified from aerial and ground surveys in the 0.1-0.2 acre size range, with a few identified down to the 0.03 acre size. The HLS contains 12,140 high lake fish stocking records and is considered reasonably complete from the early 1930's to 2000, with some records going back to 1914, and a few back to 1899. It also contains 11,400 fish survey and observation records and is considered reasonably complete for WDFW Region 4.

2. HISTORY

2.1 PRE-1933

Most high lakes in Washington's Cascades and Olympics were created following the last glaciation, roughly 10,000 years ago (Bretz 1913, 1915; Booth 1987). Whether lakes were created by glacial plucking of the bedrock, or by other processes such as avalanche damming of stream valleys (Hutchinson 1975), the newly-created lake basins would be barren of fish unless fish had access from the sea or streams draining the landscape as the ice masses retreated. Most high lakes have steep gradient outlets or outlet falls which are total barriers to upstream movements of fish into the lake. However, a few high lakes in Washington did retain native fish populations following the Pleistocene glaciation. These are very few in number, and are located in headwater areas of 2nd or 3rd-order streams (e.g., Waptus Lake in Kittitas County).

Since a search for isolated documentation of fish presence in high lakes at the time of European colonization of the Pacific Northwest was beyond the scope of this report, the actual extent of natural fish presence in high lakes of Washington is largely a matter of speculation. Early trappers, miners, loggers, and outdoorsmen would be expected to carry a few trout fry (juvenile fish up to 1.0 inch [Lagler 1952]) from local streams to stock lakes near their cabins or workings to provide a ready source of protein or recreation. Regardless of how or why the practice began, stocking of high lakes by the packing of fry was well underway, even officially sanctioned, by the early 20th century. Rief (1906) describes fish caught from Lake Calligan, near North Bend, in King County – a lake that was created by damming of a steep tributary of the North Fork Snoqualmie River by the moraine of a valley glacier. Rief (1906) makes note of trout up to 10 pounds in Calligan, as well as the presence of a single miner's cabin on the lake. Many lakes throughout Washington were stocked with U.S. Forest Service (USFS) mule pack trains. WDFW file records document USFS introductions of kokanee salmon (*Oncorhynchus nerka*), eastern brook trout (*Salvelinus fontinalis*), and cutthroat trout (*O. clarki*) into Seattle-area high lakes as early as 1914. This practice was not unique to the United States (Donald 1987).

Local fish and wildlife resources were managed by the various counties prior to 1933. For example, King County wildlife officials managed fish traps on local streams, including the outlets of some high lakes, to collect spawn for supplementation purposes. Dorothy Lake, a high lake located near Skykomish, in King County, was stocked with eastern brook trout in 1921 and 1922 (Piper and Taft, Inc. 1925). Spawn was collected from this lake, as well as Lake Hancock, near North Bend prior to creation of the Washington Department of Game by public Initiative in 1933. Many lakes in the Cascades and Olympics had already received their initial fish introductions prior to the creation of the agency which has had the responsibility of their management since 1933.

Significant ecological impacts associated with excessive trout abundance in some high lakes are the direct result of unknowing mistakes made by early non-governmental parties, as well as federal and county agency staff. Many of the stunted eastern brook trout populations in Washington high lakes were created by introductions that occurred in this early era.

2.2 1933 TO 1971

From its inception in 1933, the Washington Department of Game (WDG) continued the stocking programs begun by the USFS and the counties. However, no detailed documentation exists of the guidelines (if any) used by state inland fisheries biologists in making species or stocking density decisions. Examination of the historical stocking record (Section 5.3.1) shows that relatively high stocking densities were the rule more than the exception, with levels of more than 1000 trout per surface acre occurring frequently.

At about the same time as the creation of the WDG, a group of sportsmen keenly interested in Washington's high lake fishery was organized in Seattle (Yadon et al. 1993). While sports club coordination with the new agency was, and still is commonplace, the Trail Blazers, Inc. were unique in their focus on the development of the high lake fishery. Stocking by the club and interaction with agency biologists tended to be focused on lakes in the west central Cascades initially, but later expanded to most counties with high lakes (Appendix I). Close coordination occurred in the development of new stocking methods, which has continued to this day. Agency fish biologists worked with the club to design biological survey techniques and data forms. Work parties were organized in the 1930s and 1940s to conduct first-time biological surveys of some high lakes, prior to any fish introductions. This level of coordination still continues.

Organized angler interest led to the stocking of some trout species or strains exotic to Washington. These include golden trout (*Oncorhynchus aguabonita*) from California, and Kamloops rainbow (*O. mykiss*) from British Columbia. The earliest golden introductions occurred in King County in 1936 in several lakes in the current Alpine Lakes Wilderness Area. The earliest recorded stocking of Kamloops rainbow occurred in Chelan County in 1932. There have been no biological problems associated with the low-density stocking of golden trout, but Kamloops rainbow are often successful at reproducing in Washington's high lakes. A number of stunted rainbow populations have developed from these early Kamloops introductions.

Scientific understanding of the limnology of Washington's high lakes, and the ecological effects of the trout program on the lake communities made very slow progress in these four decades. Biologist managers, who were very low in number and had very large districts, devoted what time they could to the fishery, but little in-depth analysis occurred, or could occur, given staff and equipment constraints. Most lakes were stocked for the sole purpose of providing recreational fishing opportunity, and little detailed attention was paid to the fine points of lake and fish population management. Most stocking programs were developed through trial-and-error. Species or strains later found to reproduce excessively continued to be stocked in some lakes, but by the 1950s it was recognized that some species, such as eastern brook trout, could overpopulate lakes and create stunted, low-quality fish populations.

A number of very significant developments occurred in the post-War era. The first of these was the development and broad use of High Lake Report cards in about 1955 - franked postcards on which anglers could provide postage-paid feedback to the agency management staff on conditions observed at lakes they visited (see Section 5.2 and 5.3.2). A second was the development shortly after WWII of fry stocking methods using fixed-wing aircraft. A high degree of piloting skill was acquired by one or two tenured agency pilots who had a keen interest in this stocking technique (Clayton Barnes, Tom Wilson). Third, agency staff biologists, and groups such as the Trail Blazers, began to realize that higher quality trout populations and greater success in stocking (fry survival) could be achieved through reduced stocking densities and stocking frequencies.

For much of this era the Trail Blazers were a *de facto* right arm of the WDG Fisheries Management Division for management of the high lake fishery. Stocking recommendations proffered by the club were usually approved without much discussion, and the club made material progress in evaluating the relative performance of several trout species and strains, and reduced stocking densities. The benefits of their experience were conveyed to the agency staff through frequent written communications, and during the coordination of annual stocking plans. Although this club's activities did not blanket the Cascades and Olympics, they were active in a large percentage of this area (Figure 1; Appendix I), and their findings and recommendations affected management decisions made in other areas of the state. For the most part, the WDG approved stocking requests made by sports groups during this era.

The incremental addition of lakes to the list of those being stocked for recreational fishing occurred slowly at first due to access difficulty. As road construction for logging and other purposes increased in the 1940s and 1950s, the number of lakes added per year also increased (Figure 2). The number of new lakes being stocked peaked in 1940, and has since been in general decline. Most "new" waters stocked in the late 1970s and throughout the 1980s were almost universally small, remote waters that may have actually held fish in the past, but for which no disciplined stocking history had been initiated. Since 1991 few to no lakes that had no previous stocking history have been added to the list of lakes being stocked.

The annual number of high lakes stocked (disregarding whether they have been stocked in the past) is shown in Figure 3. This number peaked in 1988, and has also been in general decline for the past 12 years. Reasons for removing lakes from the stocking program are discussed in Section 5.4.2.3.

The use of mule or horse pack trains to stock high lakes diminished in this period, being largely supplanted by back packing of fry, and the use of aircraft, both fixed-wing and helicopter. The agency only recently discontinued horse packing in the Methow River basin in north central Washington, but low-level recreational horse packing of trout fry continues in several areas of the central and south Cascades. This is usually accomplished by members of the Backcountry Horsemen, but the USFS continues this tradition in some areas in Washington. As with the Trail Blazers, these volunteer-based activities were closely coordinated with the agency in the development of annual fry stocking allotments.

2.3 1972 TO DATE

The following section, which describes Washington's high lake fishery management since 1972, is a concise summary of the principal developments in the management of this fishery in the last 29 years.

Lake Surveys

The most significant milestone in the history of high lake management in Washington was the hiring of a group of fish biologists around 1970 who took a keen, active interest in the scientific development of the management of this fishery (Appendix Plate 1). 1972 was chosen as a break point in time since that was the year when the first technical reports were prepared that led directly to significant changes in management approaches. Unusual freedom and support was given to several of these district biologists, who devoted the summers of up to 3 or 4 years of their early careers to the relatively intense survey of lakes within their geographic areas of responsibility. (The late Cliff Millenbach, Chief of the Fisheries Management Division of WDG, is gratefully acknowledged for his support and encouragement of these directed studies.) A number of technical reports were produced (Cummins 1972, 1973, 1974, 1975; Johnston 1972, 1973; Williams 1972, 1975, 1976). These reports, along with workshop-like discussion at annual WDG biologist meetings, led to further refinement of data collection and lake survey methods, as well as a general reduction in stocking densities (Figure 4) and stocking frequency (Figure 5). Contrary to published misinformation (e.g., Bahls 1992), Washington fishery managers have been well aware of the need to control trout abundance in high lakes for at least 25 years.

Figure 2. The Number of New Washington High Lakes Stocked, by Year, 1914 – 2000.

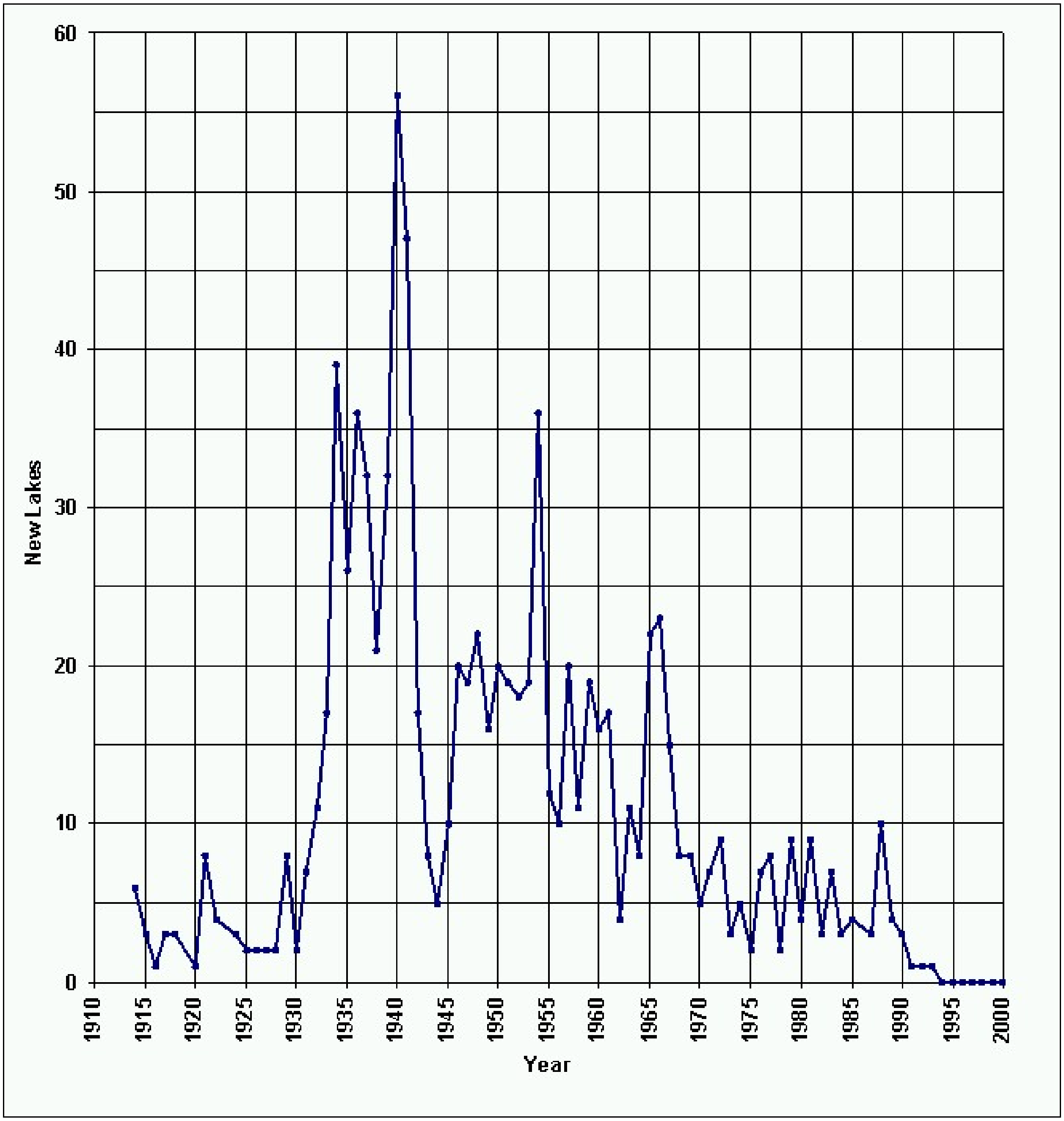


Figure 3. **The Annual Number of High Lakes Stocked in Washington, by Year, 1909-2000.** (Not the same as the number of lakes on a stocking cycle – see Table 2.)

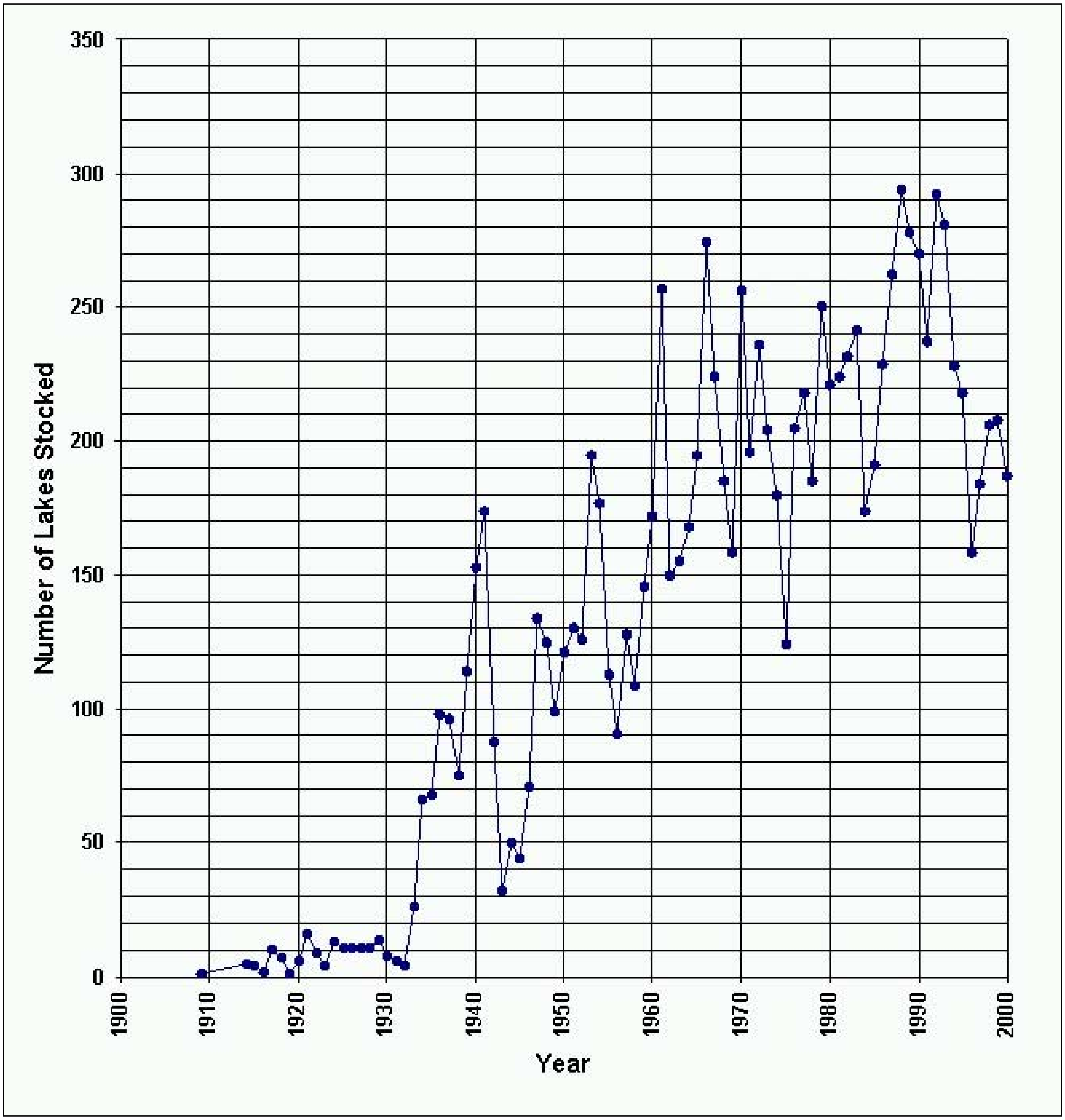


Figure 4. Mean Number of Fry Stocked Per Acre in Washington High Lakes, 1909 – 2000.

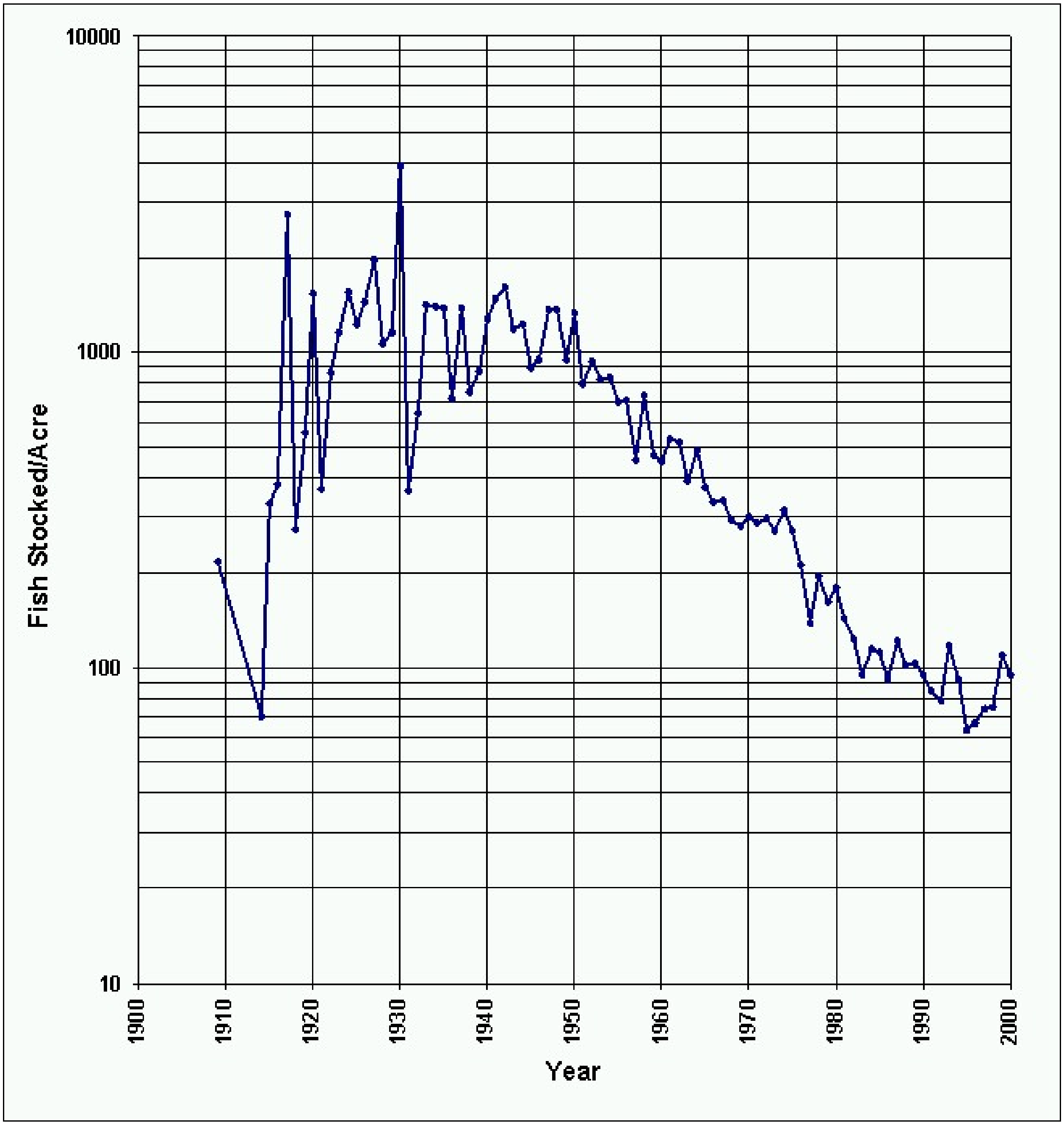
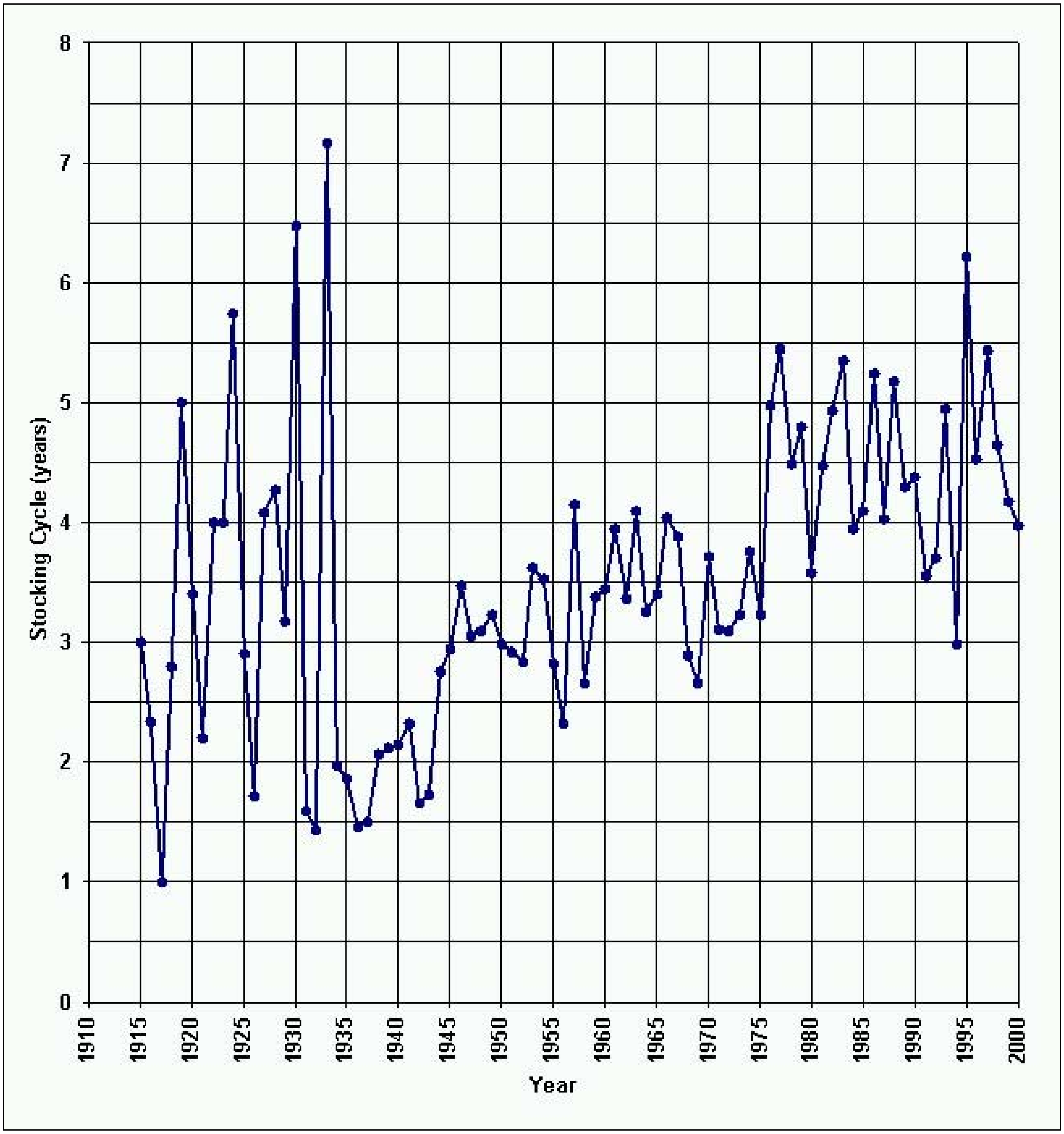


Figure 5. The Mean Number of Years Between Fry Introductions Among All Washington High Lakes Stocked Per Year, 1916 – 2000.



Other WDG district biologists have made comprehensive district surveys since these landmark reports, some of which have been similarly summarized in a technical report (Lucas 1989). An additional 32 lakes in the east central Cascades were surveyed and published under USFS contract (Deleray and Barbee 1992). Hundreds of high lake surveys have been made on the west side of the Cascades in WDFW administrative Region Four by Jim Johnston and Bob Pfeifer. Jim Cummins, Eric Anderson, and others have similarly made hundreds of surveys in the Chelan/Kittitas/Yakima Counties region. The data have not been published from most of these surveys, but the technical information has been used to develop individual lake by lake management plans. See Section 5.1 and Appendix C.

Development of Monitoring Procedures

A more focused approach to collection of angler trip report data began in the late 1970s. District fishery biologists prepared annual lists of lakes from which information was desired. These "survey lists" are still annually coordinated with sports clubs, particularly the Trail Blazers and Washington State Hi-Lakers (both based in Seattle). The High Lake Report card, initiated in the mid-1950s, was thoroughly revised in the mid-1980s, and the information collected is now entered into permanent databases (Section 5.2.1).

Database Development

Cooperative work over 10-15 years between the Trail Blazers, Inc., and WDG staff biologists has resulted in a high degree of knowledge of the historical stocking record of all managed lakes and their current stocking and trout reproductive status. Statewide cataloguing has also determined the relative number of lakes being actively managed for trout, or as fishless refugia for native flora and fauna (see Section 5.1, and the definition of a lake).

Some district managers have further organized their information on fishery monitoring, physical, chemical, and biological lake attributes, and trout age and growth into electronic databases (e.g., WDFW Fish Management Program 1994). The initial development of electronic databases for the high lake fishery program was accomplished by district fishery biologist Larry Brown in Wenatchee in the mid-1980s. (See Section 5.3.)

Stocking Procedures

Since 1972, techniques used to stock trout fry remained truck transport, backpacking, air drops by fixed-wing aircraft or helicopter, and horse packing. Only refinements in methods occurred, as described in Section 5.4.5. Use of oxygen in backpack and horse pack stocking significantly reduced hauling losses, and improved stocking precision with respect to managing for given fish densities. (Average losses in backpack containers documented by Trail Blazers, Inc. dropped from an average of 5.2% with 5-gallon cans to 2.3% with small, oxygenated containers.) Much greater attention to quality control was given to the number of fry actually stocked, and accuracy of final stocking records. This emphasis began in the early 1980s. A majority of high lakes are stocked using backpack methods (Section 5.4.5), most of which is conducted by the Trail Blazers. This club backpack stocks an average of 49.6 percent of the total number of high lakes stocked <u>statewide</u>.

Ecological Concern

Recognition of basic principles of lake carrying capacity and the effects of overstocking appear in Johnston (1973) and Williams (1972). These reports, and ensuing professional discussion within the agency, led to a general reduction in stocking rates and frequencies (Figures 4 and 5), depending on local lake conditions. Lakes occurring in alpine zones, with little soil development, difficult angler access, etc., were the lakes where stocking rates and frequencies were most commonly adjusted downward.

Experimentation on Biological Controls of Stunted Trout

The need to control overpopulation of trout or char in Washington's high lakes has long been recognized (WDG 1981). Limited experimentation with top predators and hybrid trout strains has occurred by local fishery managers since 1979 on a time-available basis. Much of this work has been in cooperation with Trail Blazers, Inc. Results to date, while promising in a few cases, remain unpublished. (See Section 5.7.2.)

Interagency Coordination

Meetings with land managers such as the US Forest Service and National Park Service became commonplace (annual events in some WDFW administrative regions) by the early 1980s. Issues of mutual concern were discussed, and largely resolved. WDFW coordinated and cooperated with the North Cascades National Park (NCNP) and its contracted researchers through all phases of studies on the effects of trout stocking in that park (see Section 5.9). Cooperative research on high lake stocking issues continues through the University of Washington.

Public Education

Articles of general interest relating to the high lake fishery were periodically published in the Department of Game's bi-monthly magazine. Recognition by the late 1980s of the need to address perceived public misunderstandings, and to direct mounting angler pressure to lakes and lake basins that could support higher use, led to cooperative development of an agency brochure on the high lake fishery (see Section 5.10.1). A concerted and successful effort was made to coordinate the brochure's content with US Forest Service wilderness managers, prior to its publication. Closely-related articles, radio programs, and agency website information were developed, largely through volunteered effort (see Section 5.10).

3. POLICIES, GOALS, AND OBJECTIVES

The Washington Fish and Wildlife Commission received its authority from the passage of Referendum 45 by the 1995 Legislature and public at the 1995 general election. The Commission is the supervising authority for the Department of Fish and Wildlife. With the 1994 merger of the former Department of Fisheries and Department of Wildlife, the Commission has comprehensive species authority as well.

While the Commission has several responsibilities, its primary role is to establish policy and direction for fish and wildlife species and their habitats in Washington, and to monitor the Department's implementation of the goals, policies and objectives established by the Commission. The Commission also classifies wildlife and establishes the basic rules and regulations governing the time, place, manner, and methods used to utilize or enjoy fish and wildlife. The current Goals, Policies, and Objectives (GPOs) of the Fish and Wildlife Commission have been published (WDFW 1995a; Appendix L).

The Department's mission is Sound Stewardship of Fish and Wildlife; one of its goals in pursuit of this mission is "Maximum fishing, hunting and non-consumptive recreational opportunities compatible with healthy, diverse fish and wildlife populations". In general, conservative utilization is the objective for naturally-produced, native fish and wildlife populations.

Additional guidance for the high lake program has been provided by the publication of the Wild Salmonid Policy (WSP) in 1997. The Commission GPOs and the WSP are largely directed at the stewardship and management of the state's native wildlife (reproducing vertebrate and invertebrate populations). The high lake fishery is almost entirely artificial, created for the sole purpose of providing recreational fishing opportunity in generally highly scenic, uncrowded surroundings. However, an explicit Goal of the Commission for its own activities is to "Maximize recreational opportunity for fish and wildlife constituents consistent with the preservation, protection, and perpetuation of the fish and wildlife resources" (WDFW 1995a). Goals specific to fish management include "providing for significant recreation opportunities through artificial propagation programs", and "maximiz(ing) fish recreation opportunities". Current WDFW high lake fishery management is consistent with these goals since it is designed to provide recreational fishing opportunity in ways that do not have significant negative impacts on native fish or other biota. This is explained in greater detail in subsequent sections of this report.

Commission Objectives under the Goal of maximizing fish recreation opportunities included implementing "balanced management strategies that provide for a variety of recreational activities including unique fishing opportunities (and) optimum harvest", among other elements. Most people would agree that catching or viewing high quality trout in a pristine alpine lake environment is a unique fishing experience. A related Objective directed the agency to "maintain maximum recreation through population manipulations with the use of stocked fish, partial treatments with rotenone, and other strategies in appropriate waters".

An additional Objective was to "conduct surveys to gather information on angler needs, desires, motivations and satisfactions". The most recent angler survey (WDFW 1996a) reaffirmed the large number of license-buyers who utilize the high lake fishery (see Section 4.0).

The published Wild Salmonid Policy, adopted by the Washington Fish and Wildlife Commission on December 5, 1997, makes no mention of the high lake stocking program (WDFW 1997). The bulk of the policy is directed at fishery, hatchery, and habitat programs and procedures that affect wild salmon and trout in streams, rivers, and estuaries. The only potential interaction between the high lake stocking program and wild, native salmonids in streams is addressed in the WSP under Ecological Interactions, Performance Standard 4: "All recommended guidelines for genetic diversity and ecological interactions should apply in aquaculture programs where there is a likelihood of adverse interactions with wild populations". Management of the current high lake program is sensitive to these potential interactions and guidelines (see Sections 5.4, 5.5, and 5.6).

4. FISHERY VALUE

"*I learned these fishing skills almost entirely in the high Cascades. Up in that wild and remote country two or three of us would have whole lakes and streams to ourselves. It's the most ideal place to learn trout fishing that I know. Having learned the secrets of the trout, I acquired new confidence in my ability to survive in the mountains. My food supply was surely obtainable from the creeks and lakes; hence the fear of being lost and starving was not a factor in these trips*." -- William O. Douglas - Of Men and Mountains (1950).

More than 175,000 license-buying anglers use Washington's high lakes annually (see Section 4.3 below). This figure does not include children and family members who fish high lakes, but do not purchase fishing licenses. For thousands of people, including several, if not all of the authors of this report, early fishing experiences in Washington's mountains were the first step in lifelong appreciation of wilderness and wildlife values (Plate 1). To quote a line from a recent public speech by co-author Mike Swayne, "there is something basic that connects a parent and a kid and a fish hitting a lure, and dancing on the end of the line, and then into the frying pan. Fish started me on a lifelong love affair with the lakes and the mountains that has affected my whole life for the better." For the authors of this report, as well as thousands of others, these experiences create future active defenders (Plate 2) of our land and wildlife heritage.

While much could be written on the incalculable values of Washington's high lake fishery, the following section provides more traditional measurable statistics on its economic value. In both cases, with proper management, both measurable and intangible values of this fishery can be maintained long into the future, without unacceptable or irreversible harm to other biological resources.

4.1 PROGRAMMATIC HATCHERY COST COMPARISON

The stocking component of the WDFW inland trout program consists primarily of "catchable" (9 to 12 inch) yearlings (usually rainbow), rainbow and cutthroat fry, and kokanee fry (Table 1). (In recent years purchased triploid trout weighing a pound or more have been added to the traditional program. The cost of these highly cultured trout accentuates the difference between lowland lake trout costs and high lake trout costs in the table of 1988 data below.) About $3,615,000 was spent to culture trout for the inland trout program in 1988. Because of a year's hatchery care, catchable trout were most costly at $0.52 apiece. Small, briefly-reared kokanee and trout fry released into lowland lakes averaged about ten cents apiece. Fry stocked into high lakes, which have the briefest period of care and feeding, cost about 1.3 cents apiece when averaged across all statewide hatcheries producing fry for the high lake program.

Table 1. Washington Department of Wildlife 1988* Statewide Trout Culture Costs by Fish Size Class

Size Group	Number Stocked	Total Cost	Cost per Fish
Catchable Trout	3,500,000	$1,820,000	$0.520
Low Lake Kokanee	8,700,000	$817,800	$0.094
Low Lake Trout Fry	10,400,000	$977,600	$0.094
High Lake Trout Fry	300,000	$3,900	$0.013

* Comparable statistics from recent years were not available when this report was prepared.

Plate 1. Quality wildlife experiences early in life enhance family relationships, and foster lifelong appreciation of natural resource values. Upper Greider Lake, Snohomish County, Washington.

Plate 2. A young angler holds a fish for a biologist surveyor to document unusual cryptic coloration of rainbow found in a high, clear, shallow lake in Snohomish County, Washington.

4.2 RELATIVE COST TO PROVIDE TROUT ANGLING OPPORTUNITY

The cost to administer high lake trout or char fisheries that are based on naturally-reproducing fish is almost zero. Some staff time is required to maintain file records on lakes with these populations, coordinate with landowners and other agencies on access to them, etc. This tends to be minimal when averaged across all such lakes. Most high lake administration costs are related to implementing the stocking program (which includes the cost of fish culture and stocking), coordinating monitoring of the overall fishery, and conducting baseline surveys on the few lakes that have not been surveyed.

It is instructive to compare the cost of providing an equal density of catchable (10 to 12 inch) trout in a typical lowland lake and a typical high lake. The cultural costs presented in the previous section are used in the example illustrated in Table 2. An initial stocking density of 280 trout per surface acre is used in this example to yield 125 fish per acre after two years in the lake. This stocking density is not often used in Washington high lakes today (Section 5.4.2), except in exceptionally rich lakes. However, experience has shown that this density of catchable trout is typically required in lowland lakes in western Washington in order to meet minimal early season catch rate objectives (WDFW 1994). Other assumptions in the example are 50 percent mortality of the fry stocked in the high lake in the first year (Donald and Alger 1986; Nelson 1987), and 10 percent in the second (Johnston 1973). In 1994 it cost $74.38 to provide 125 catchable trout per acre, but a typical high lake can grow these same fish to beautiful condition (Plate 3) for $1.29, or 1.7 percent of the cost for a lowland lake.

Table 2. Relative Cost to Stock 125 Catchable Trout Per Surface Acre of a Lowland Lake and a High Lake in Washington (1994 Values). Mortality Is Assumed To Be 50% To Age 1, And 10% To Age 2 In The High Lake

Lake Type	Density in (Year)	Cost per Fish	Total Stocking Cost
Lowland	125/ac (Year 0)	$0.595	$74.38
High	280/ac (Year 0) 140/ac (Year 1) 126/ac (Year 2)	$0.0046	$1.29

4.3 PARTICIPATION AND FISHERY VALUE

As mentioned above, an estimated 175,324 anglers fished Washington high lakes in 1994 (WDFW 1996a). This level of use leads to phenomenal overall fishery values, since high lake anglers made an average of 7.7 trips each, based on the 1995 angler survey (WDFW 1996a). No studies could be found that used the contingent value (willingness-to-pay) method of economic valuation to ask high lake anglers what they would be willing to pay to partake of this fishery. Most studies of freshwater angling arrive at values ranging from $23 to $60 for a day's "trout" fishing; this report uses an average of three recent studies on lowland lake and stream fisheries.

Plate 3. Phenomenal growth and condition was observed in Mount Whitney rainbow stocked at low density in a lake in the Wallace River (Skykomish River) drainage. The lake has been managed for a trout fishery since 1954. (22 August 1995) Mike Swayne photo.

The high lake fishery in Washington is worth an estimated $67 to $70 million annually (Table 3). An estimate of program costs and benefits was made in 1992 with the cooperation and assistance of Consulting Scientist Dr. Gerry Ring Erickson of the Washington State Hi-Lakers. Annual cost of labor, trout culture, and aircraft use in 1992 was about $39,000 (Appendix G). Assuming an annual rate of inflation of 3.1 percent yields a program cost of $41,455 in 1994, and a benefit / cost ratio of 1621:1. (If the 1997 purchase of a $23,000 drop tank for the agency Beaver (see Section 5.4.5.3) is included in the cost and not amortized over its expected 30-year life, the ratio drops to 1043:1.)

Table 3. Washington High Lake Angler Effort Levels and Fishery Value, 1994 and 2001

	1994	2001
High Lake Anglers	175,324	182,666[1]
Fishing Trips @ 7.7 days/angler[2]	1,349,995	1,406,528
Value @ $49.79/trip[3]	$67,216,251	$70,031,029

[1] Assumes an annual increase of 4.19%; see Section 5.8.

[2] Source: WDFW (1996).

[3] Arithmetic mean of three Contingency Valuation Method sources: Demirelli (1988); The Research Group (1991); Dalton et al. (1998).

It is clear from these values that the high lake fishery is one of, if not the most cost-effective fishery program administered by the WDFW. High lake fisheries that take advantage of the natural productivity of mountain lakes have long been recognized as being economical, as noted by Lindsey (1959): “Good fishing means good business; the dollar value of the airplane stocking program goes far beyond the fish in the creel.”

4.4 ASSESSMENT AND RECOMMENDATIONS

The high lake fishery is phenomenally cost-effective. It provides some of the finest quality trout fishing opportunity in the state for a startlingly small amount of money. In 1992, the estimated cost to administer the program was 0.07 percent of the agency’s $53,593,000 biannual budget (Appendix G). While the cost of providing trout fishing opportunity in lowland lakes has risen significantly due to the general inability to maintain lowland lakes in an economical trout monoculture in western Washington (Fletcher 1976; Bradbury 1986; WDFW 1994), and due to the need to purchase even more costly triploid trout, the costs to maintain the high lake program have probably risen very little since 1994.

Johnston (1973) reported a total cost of $400 to rehabilitate a 9 acre high lake on the Olympic National Forest. Even allowing for a 3 percent annual rate of inflation over 30 years, which results in a cost of $943 per lake, a statewide program of just five lakes per year (one per district biologist, costing a total of about $5000) would still result in a program benefit / cost ratio of 968:1, based on the 1994 program costs ($67,216,251 / [$41,455 + $23,000 + $5000].)

Recommendation #1: An updated and more detailed cost analysis of the high lake program in Year 2000 dollars should be conducted. Cost of staff labor and administration, fish culture, and stocking should be included.

Recommendation #2: A detailed cost estimate to conduct a typical high lake rehabilitation using both rotenone and Antimycin should be prepared. A technical memorandum should be prepared that can be used as a model by local managers to plan annual, or periodic high lake rehabilitations.

Recommendation #3: An annual program of rehabilitation of several high lakes should be implemented. A target of one lake per biologist per year is initially suggested. (See also Sections 5.7 and 5.8 Recommendations.) If the cost to rehab a high lake were ten times what it cost in 1973, the program would still be extremely cost-effective.

Recommendation #4: The agency should publish information on the cost-effectiveness of the high lake program as a form of outreach (Section 5.10).

5. CURRENT MANAGEMENT

All pertinent administrative and technical aspects of WDFW's current management of the high lake fishery in Washington are briefly summarized in the following chapter. At the end of each major section, an assessment is made of current policies and practices. These are followed by recommendations, as appropriate.

Many believe the WDFW is stocking all, or a majority of the "lakes" in the mountains. Nothing could be further from the truth. Of the more than 4700 high lakes and ponds in Washington, at least 2940 (62%) are fishless (see Section 5.4.6), and only about 800 (17%) are periodically stocked. In order to address this unfounded concern about excessive stocking, it is useful to begin with a definition of a lake. As Anderson (1971) pointed out, the terms "lake" and "pond" or "tarn" defy precise definition, therefore he "arbitrarily" categorized his study waters according to a graph similar to Figure 6a. We have adopted this approach as being convenient and reasonable, based on extensive experience with the size and shape of managed waters in Washington. From the figure it is seen that waters with a maximum depth of 3 feet, but an area of about 8 acres would still be considered ponds. Conversely, waters as small as 1 or 2 acres, if at least 12 to 16 feet deep at their deepest point, would still be considered lakes.

The very small ponds and tarns still tend to have maximum depths of 3 to 5 feet (Figure 6b). Maximum depth increases continuously with lake size up to about 160 acres (n=1207). A 2, 5, 10, and 20 acre high lake in Washington tends to have a maximum depth of about 13, 28, 41, and 73 feet, respectively.

The overwhelming majority of alpine and subalpine waters being maintained for trout fisheries in Washington are not only lakes by this definition, but are at least large enough to appear on standard 7.5 minute U.S. Geological Survey (USGS) topographic maps. Waters less than 0.1 to 0.2 acre tend to be omitted from these 1:24,000 scale maps. However, recent work in NCNP documents what experienced high lake fishery management biologists already knew: there are thousands of small ponds and tarns scattered across the landscape that do not appear on 1:24,000 scale topographic maps. Most of these do not support fish, but do provide important, or critical habitat for amphibians and invertebrates (Kezer and Farner 1955; Anderson 1967; Fukumoto and Herrero 1998).

Figure 7a plots the size distribution of lakes and ponds larger than 0.02 acre. This figure includes all waters, with or without fish. Most waters in the current lake and pond database range from 0.2 to 50 acres, but there are a few high lakes that exceed 300 acres (Figure 7a). The size distribution of the waters being managed for fisheries is similar (Figure 7b). Most of these waters have self-sustaining fish populations and are not stocked. The arithmetic mean area of waters in the HLS database is 6.1 acres, however the geometric mean is only 1.5 acres, indicating the vast majority of lakes and ponds are small. About two thirds to three quarters of all waters in the HLS database are less than 3 acres in size (Figure 7a).

5.1 INVENTORY METHODS

Cummins (1972), Johnston (1972, 1973) and Williams (1972) presented methods they had found practical to obtain information deemed essential for fishery management at that time. To date, no "standardized" methodology for high lake surveys has been prepared for use in Washington. A report such as Bahls (1989) might serve as an example. There are many similarities between Bahls' methods, and those used by most WDFW management biologists. Bahls (1989) even cited both of Johnston's 1972 and 1973 reports. A truly standardized methodology is probably not possible as long as district biologists must survey their lakes on their own, given differences in personal hiking ability, if nothing else. It would

Figure 6a. Suggested Curve to be used to Designate Lakes Versus Ponds in Washington High Country.

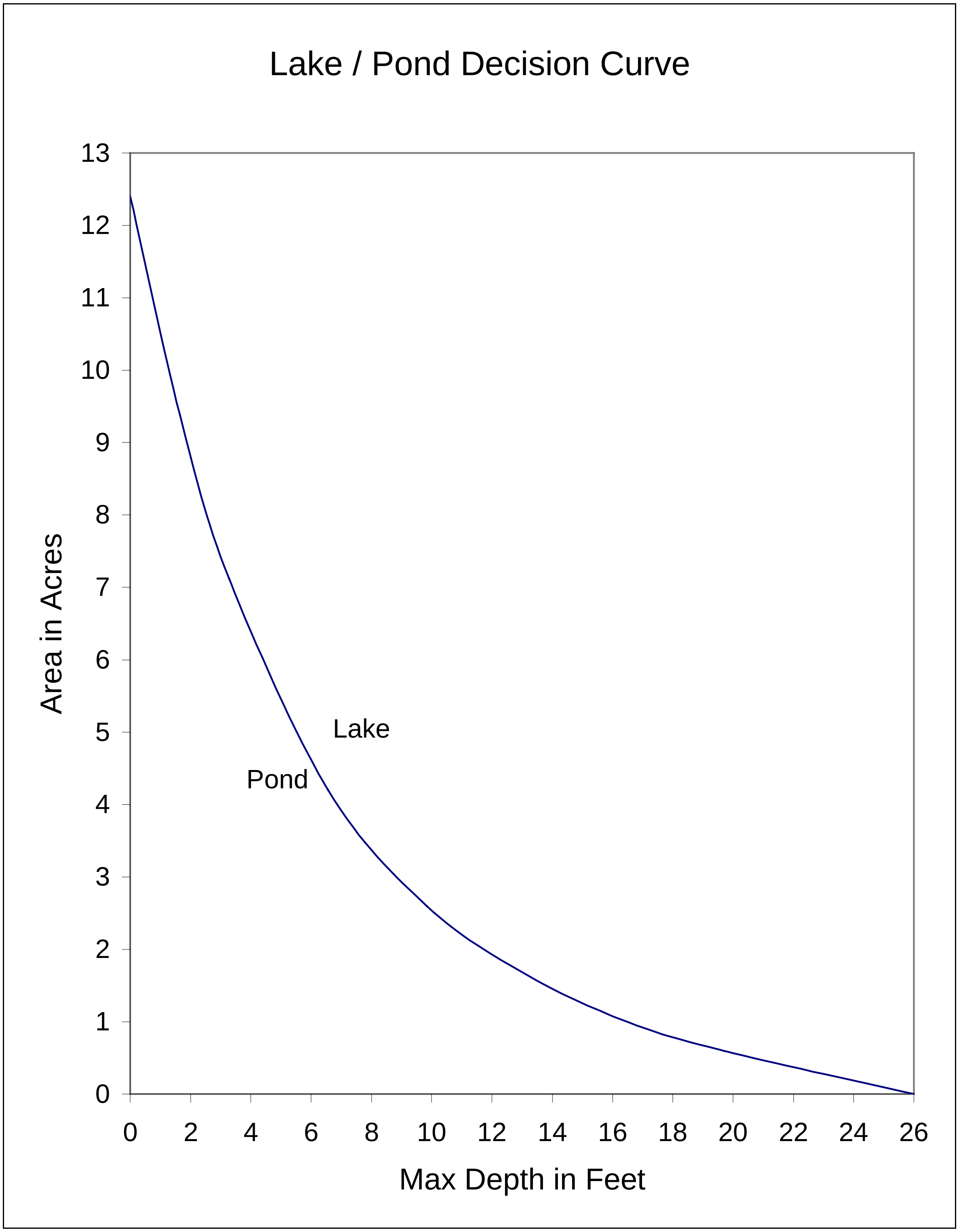


Figure 6b. The Relationship Between Maximum Depth and Area of Washington High Lakes. The number of lakes in each size category is shown.

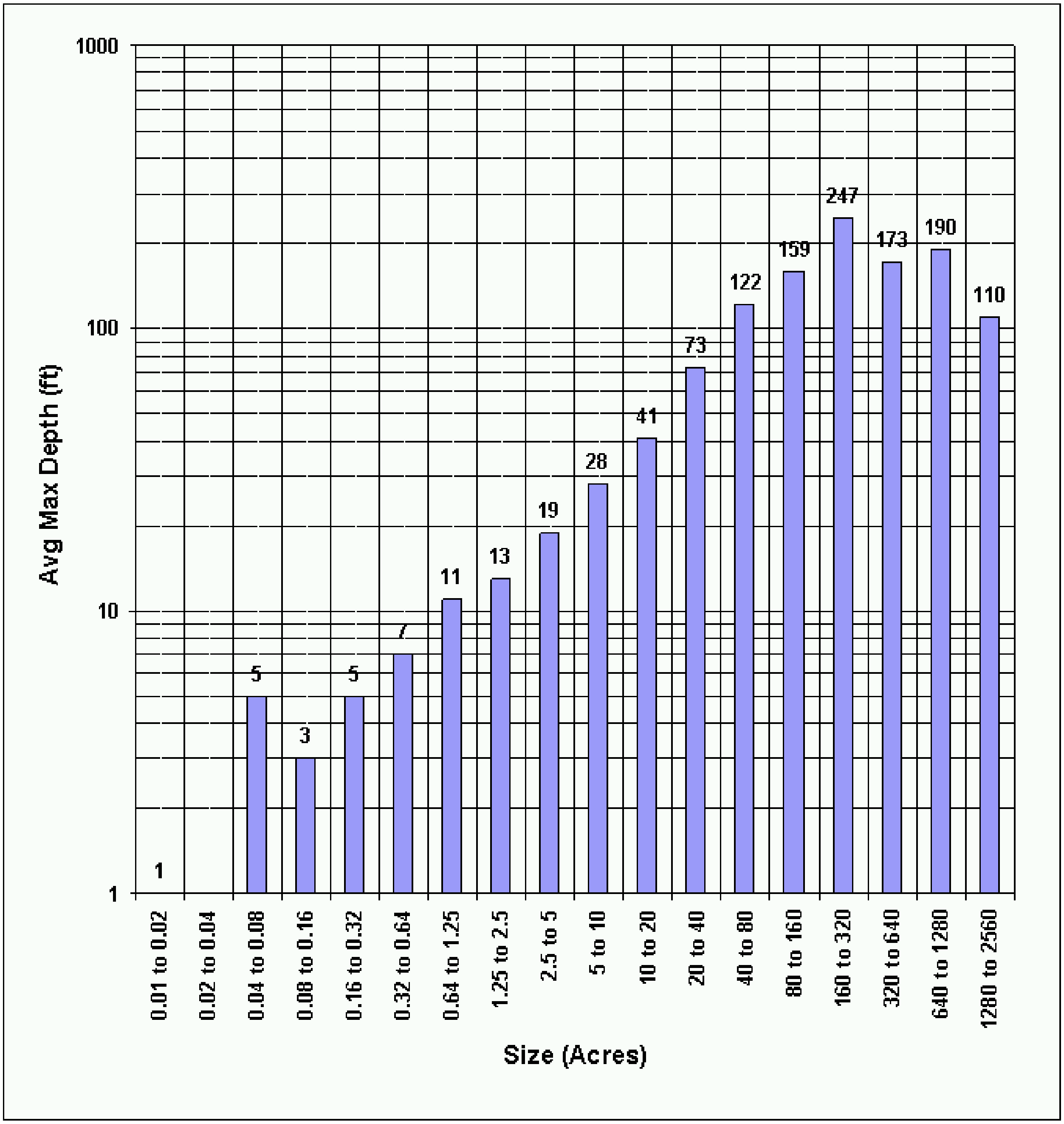


Figure 7a. The Size Distribution of High Lakes and Ponds in Washington (with and without fish).

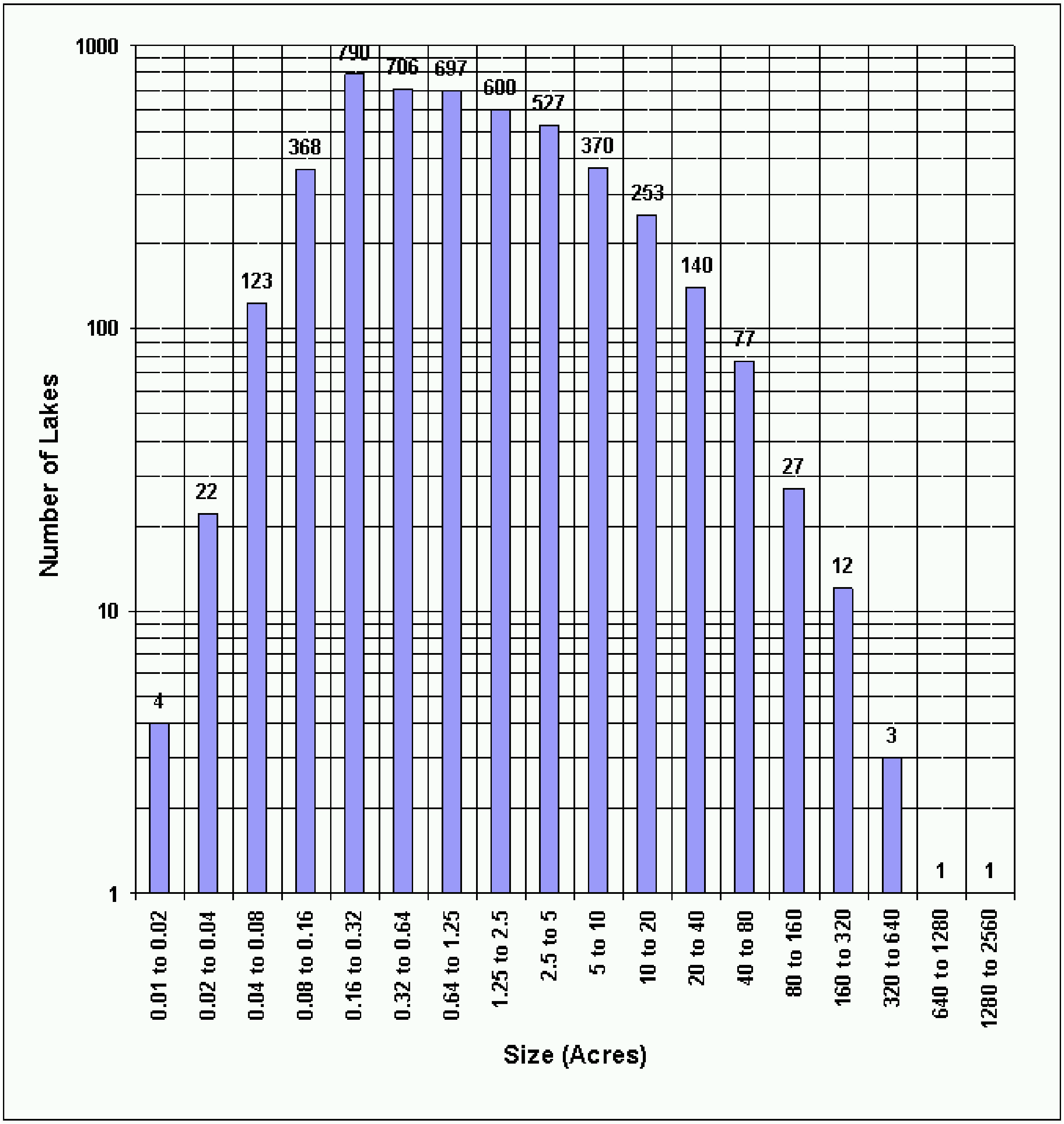
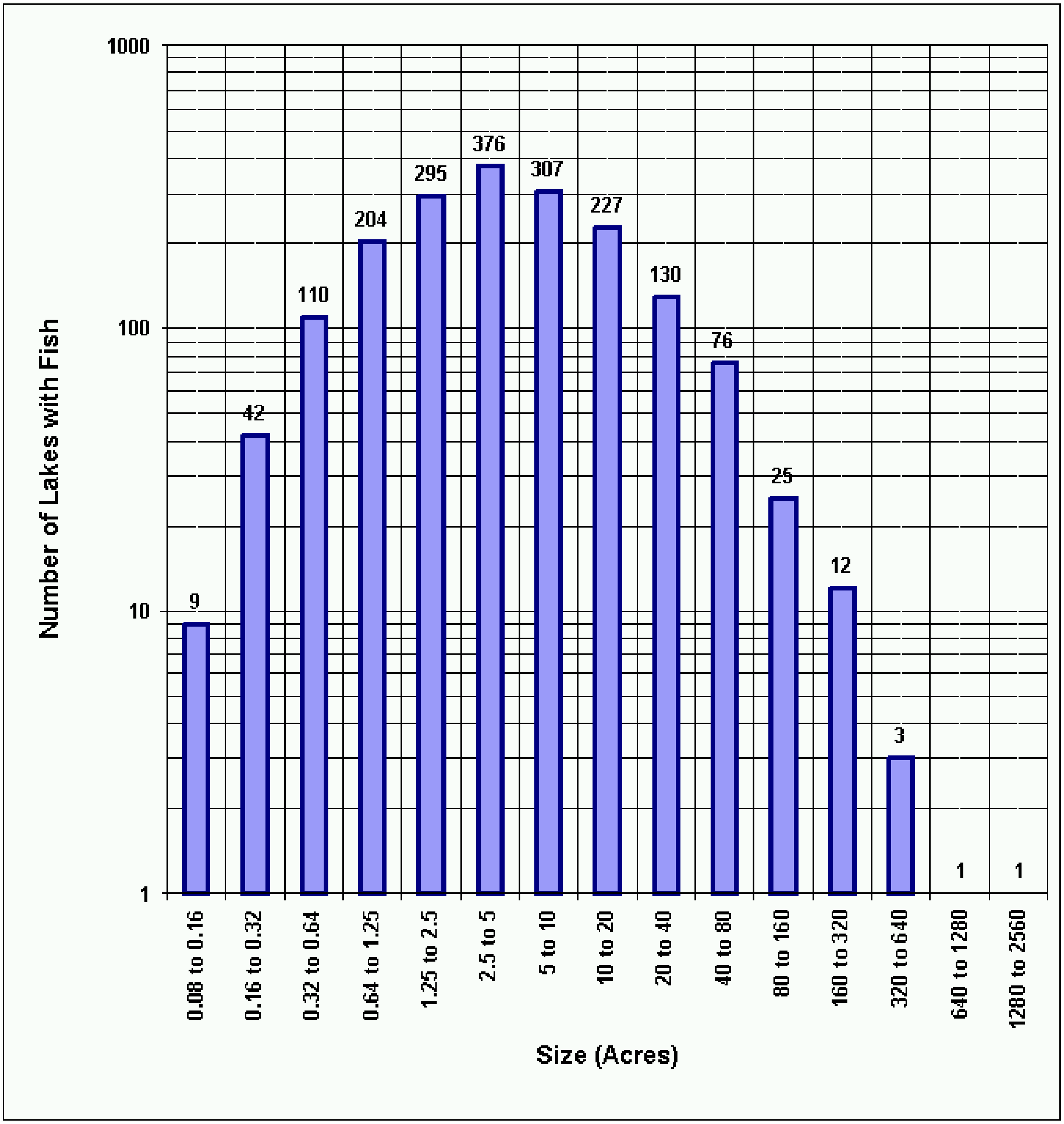


Figure 7b. The Size Distribution of High Lakes And Ponds Managed for Trout Fisheries in Washington. A majority of the waters have self-sustaining fish populations.



certainly be possible to agree on a minimum amount of information, and this has, by and large, been obtained on many lakes. A "minimum" high lake survey methodology for Washington high lakes, perhaps stratified for western and eastern Washington districts, would be a valuable reference, particularly for future district fishery biologists. However, the first step, literally, is to get to the lakes.

5.1.1 Getting There

The first requirement of a successful, or at least productive high lake fishery manager in Washington is to take the long view. With the biota associated with literally thousands of ponds and lakes under WDFW's purview, surveying and cataloguing all of them seemed like an overwhelming task 30 years ago. Fortunately, a number of individuals were willing to take that first step, even if it was up a very steep, brushy slope. Much of the terrain that supports high lakes in Washington is very rugged and geologically youthful. Complicating the task of inventory and surveying is the fact that a majority of the lakes lie within designated wilderness, which limits access in most cases to hiking.

The pack of a solo biologist/hiker, loaded with the minimum gear for one to several nights, may weigh 65 pounds or more. With experience, surveyors can minimize bulk and weight, yet bring a variety of surveying equipment for work on and around the water (Plates 4 to 6). Apart from safety concerns, most WDFW high lake biologists also hiked to their lakes with experienced backcountry hiker/anglers who assisted in the gear toting task, as well as fish collections and biological workup (e.g. Lucas 1989).

To date, the majority of lakes have been accessed on foot or horseback. In some areas outside of wilderness it is possible to utilize helicopters (Plate 7), which, although expensive, have a number of advantages. Careful helicopter trip planning can place one to several surveyors in a strategic location for surveying multiple lakes, and save substantial hiking time, thus defraying the cost of the lease. Some WDFW biologists were also able to obtain donated helicopter air time from a variety of sources. Helicopters of the size shown in Plate 7 can land in an opening as narrow as 35 feet.

As useful as a helicopter is in reducing the effort and time to access remote lakes, it has one serious drawback. One of the most essential indices of angler effort of remote lakes is the time and effort required to get to them. The fishery manager cannot even begin to appreciate this if he/she does not hike to the lake. Personal experience on the route is one of the most important ways a manager can "get a feel" for annual recreational effort, and gauge probable angling mortality (see Section 5.4.2).

5.1.2 The Concept of Survey "Level"

Experience has shown that information on certain physical, chemical, and biological parameters is essential to development of any management plan for high lakes or ponds supporting trout fisheries. The minimum "level" would be that which collects this essential information. Physical information includes lake area and maximum depth; an estimate (or calculation) of mean depth; location and character of tributaries and outlet/s, length accessible to trout, and the amount of spawnable habitat; and the nature of the nearshore lake bottom (littoral zone). Chemical parameters include pH, hardness, total alkalinity, and the presence of any toxic elements, such as heavy metals. Biological information includes presence or absence of fish; the age structure of any population found; growth and condition of fish; and any evidence of successful reproduction, such as fry in spawning areas, or a population age structure that does not correlate with the water's stocking history. Additional biological information is the diversity and relative abundance of invertebrate food resources, and the presence of rooted aquatic plants. Other valuable information that does not fit neatly into these three categories includes access difficulty, and evidence of the level of human use of the lake vicinity.

Plate 4. Light, compact fishing equipment is a pre-requisite for surveying remote backcountry lakes. The blue bag contains a folded nylon raft. Together, the raft and inflating bag weigh 19 ounces. The breakdown rod doubles as a spinning or fly rod.

Plate 5. An assortment of bait, spinning lures, wet flies, and dry flies helps assure success in sampling by hook and line.

Plate 6. An inflatable sleeping pad, placed in the raft, provides back support, and enables comfortable work for hours, even in frigid water. Goat Lake, Middle Fork Snoqualmie River drainage, (27 September 1991).

Plate 7. Smaller helicopters can land in a space no wider than 35 feet, and can transport three men with heavy packs to a strategic jumpoff point. Nine Hour Lake, Middle Fork Snoqualmie River drainage, (8 September 1982). G. Ring Erickson photo.

This basic information can enable a determination as to whether the water needs to be stocked, whether it should be stocked, what fish species may be appropriate, and a preliminary estimate of an appropriate stocking density and frequency. Note, however, that these basic surveys have already been completed on most high lakes or ponds supporting fisheries (Table 4). Additional detail is given in the following sections on the techniques used by local management biologists since 1970.

Table 4. Percentage of Washington High Lakes Supporting Fisheries That Have Received a Baseline Physical, Chemical, and Biological Survey, by County, as of 2001.

(Excluding Lakes in Olympic and Mt. Rainier National Parks and Yakama Indian Nation)

County	Number of Fish-Bearing Lakes	Number Surveyed	Percent Surveyed
Jefferson	15	15	100
Grays Harbor	6	3	19
Mason	16	(ND)[1]	
Whatcom	121	47	39
Skagit	140	55	39
Snohomish	217	80+	37
King	360	323	90
Pierce	57	31	54
Cowlitz	7	7	100
Lewis	74	74	100
Skamania	118	118	100
Yakima	117	32[2]	27
Kittitas	111	0[2]	0
Chelan	223	0[2]	0
Okanogan	108	108	100
Pend Oreille	3	3	100

[1] Information unavailable at time of report preparation.

[2] Most fish-bearing waters have received limited survey, but not a full "baseline" survey of all variables.

5.1.3 Physical Description

The questionnaire survey of most of the biologists who managed Washington's high lakes for the past 25-30 years revealed some diversity of methods. The initial surveys reported by Cummins, Johnston, Lucas, and Williams were fairly thorough. Interested readers should review their reports for specifics, but the various techniques most commonly used are summarized below. A few biologists have not had the time or resources to develop much detailed physical information on their lakes on their own, but some lakes on their districts have been surveyed by the US Forest Service using their Region 6 protocol (Hann and Wall 1992).

Field data forms and explicit procedures were developed and used on surveys on the Olympic National Forest (Johnston 1972), and in the following counties: Whatcom, Skagit, Snohomish, King (WDFW Region Four file data); King and Pierce Counties (Cummins 1973); Cowlitz and Lewis Counties (Lucas 1989); and Okanogan County (Williams 1972). An example of the primary field data form used in King and Snohomish Counties appears in Appendix C.

The field sketch map of the lake or pond is the most important and fundamental information collected on the water's habitat. Most, if not all local biologists retain their baseline survey data in lake by lake files. Information on lake shape, location of inlets and seeps, fish access, location of campsites, soundings and transects, and more are noted on the base map. This is usually transferred to a more refined database or management plan format (Appendix C), or may be prepared as figures in reports such as Lucas (1989), or Deleray and Barbee (1992).

Lake Area

All local management biologists use surface area as a fundamental metric in setting trout stocking rates. Some managers used surface area estimates provided in Wolcott (1965), although a few of Wolcott's areas are known to contain errors, some of which are quite significant. Most of Wolcott's acreage estimates were derived from aerial photographs and use of a polar planimeter. The area of others, particularly "small" lakes, was derived using scaled grids. Wolcott (1965) noted that aerial photos often showed water areas that differed considerably from that shown on some maps. Other WDFW local managers (Johnston, Pfeifer) used aerial photos and/or scaled grids and 1:24,000 topographic maps to determine lake area. These methods are described in basic texts such as Welch (1948). Pfeifer also used a stereo analytical plotter and aerial photographs to digitize lake polygons on most of the lakes in the Snoqualmie, Cedar, and Green River watersheds (WDFW 1994; Reutebuch et al. ND; Plate 8). (All high lakes and ponds shown on 1:24,000 USGS topographic maps of Washington were recently digitized into a GIS layer. This information could be used to update acreage information used by some local managers, although errors in Wolcott (1965) are usually not significant from a fish management perspective.)

Personal experience of the author has repeatedly shown that there is often no substitute for an on-the-ground survey (Plate 9). Lake shape and actual size is often different from that shown on topographic maps, particularly for small water bodies. In most cases, however, a quality aerial photograph of suitable scale (Plate 10) is nearly as good as a ground survey for determining lake area. A number of biologists reported they prepare a lake outline from a topographic map or aerial photo, then make in-field adjustments to correct inadequacies in the preliminary shoreline outline. The ideal approach is to prepare a field map of the lake or pond, and mate that with use of a pair of stereo aerial photographs (Plate 8).

Plate 8. A stereo analytical plotter utilizes two adjacent aerial photos that have been corrected for parallax, and which are controlled, or linked to known GPS coordinates. The system has a high degree of precision; a white dot viewed through the optics corresponds to about 30 feet on the ground. Digitized lake polygons, or attributes such as islands, are logged in files created on the linked computer to enable calculation of metrics such as lake surface area, shoreline length, etc.

Plate 9. Whenever possible, the field sketch map of the lake should be truthed and edited from a vantage above the lake. Prepared lake outlines from sources such as USGS topographic maps make excellent baseline maps to build on. Upper Wildcat Lake with the rugged Melakwa Pass area beyond, Middle Fork Snoqualmie River drainage, (15 September 1984). G. Ring Erickson photo.

Shoreline Development

Shore development refers to the ratio of the actual length of shoreline of a lake to the length of the circumference of a circle the area of which is equal to that of the lake. Although this standard physical measure (Welch 1948) has not yet been shown to be important in setting fishery management objectives in Washington, it is intuitively appealing to believe that lakes with highly irregular shorelines and extensive littoral zone development relative to total lake volume would be more productive. Information to calculate shoreline development was collected on scores of lakes in King and Snohomish Counties, but the relevant data have not yet been analyzed to answer this question. Most local biologists do not determine this measure.

Maximum Depth and Lake Bathymetry

Most biologists obtained depth and bottom shape information on their lake surveys, either by a series of sounding line plumbs, or by running echo sounder transects (Johnston 1972; Plates 10 & 11). At least two of the biologists used both, taking a series of soundings from a raft on the small lakes or ponds, and limiting sounder use to the larger waters. Individual soundings are located on the base field map, which can then be used to estimate the location of depth isopleths for the bathymetric map (Lucas 1989; Deleray and Barbee 1992).

A few of the biologists have had the luxury of time and equipment to develop full maps of the bottom contours of many of, or all of their surveyed lakes (Johnston 1972; Lucas 1989; Deleray and Barbee 1992). Pfeifer produced sounder chart records of transects taken on 98 lakes on the North Bend and Skykomish Ranger Districts (Plate 10; WDFW 1994). All of the strip data have been entered into spreadsheets, but the final step of plotting the data to produce bathymetric maps has not yet been taken. Previous bathymetric survey maps prepared by the USGS (e.g., Bortleson et al. 1976; Dethier et al. 1979) have also been made part of individual lake management files in many of the administrative districts.

High lake bathymetric maps are frequently requested by anglers, but have not been produced for that purpose. Their principal value, apart from giving a better sense of the overall depth, shape, and bottom conditions in the lakes, is to enable calculation of lake volume and mean depth (Welch 1948). Mean depth may have application in models of high lake trout production (Moyle 1949; Northcote and Larkin 1956; Ryder 1982; Prepas 1983). Lake volume is certainly needed if a whole-lake chemical treatment is contemplated (see Section 5.7.1).

Plate 10. Essential components for bathymetric mapping using a chart recorder include a transducer that can be towed behind the raft, a pair of 6-volt batteries that can be wired in series to produce 12 volts, a high quality aerial photo of the area, and the base map outline to establish transect end points. Snoqualmie Lake in the Middle Fork Snoqualmie River drainage is shown on the base map.

Plate 11. A bicyclist's rear view mirror attached to sunglasses allows the surveyor to watch the chart recorder and still maintain a straight course between transect end points, even on large, wide lakes. A constant speed is maintained from one end of the transect to the other. Lower Blethen Lake, Taylor River drainage, (24 June 1992). Laurie Wyatt photo.

Nearshore Area and Bottom Composition

Collection of detail on nearshore area and composition (Johnston 1972; 1973) has largely been limited to lakes surveyed by Cummins, Johnston, and Pfeifer (Appendix A). However, their work represents surveys of hundreds of ponds and lakes, mostly in western Washington. Johnston (1973) and Bahls (1989) originally described the technique, wherein the overall average substrate composition is determined from the water's edge to a depth of about 10 feet (Plate 12). The predominant substrate shoreward of the 10 foot contour is categorized as detritus, woody debris, silt, sand, gravel, rubble, boulders, or bedrock (Appendix C).

The amount of total lake surface area in this zone, as well as from the water's edge to a depth of about 20 feet is also of interest. Although not yet statistically tested from the data collected in Washington, the percent of lake surface area shoreward of the 20 ft or 10 ft contours may correlate with trout growth rates. Adding the nature of the substrate within these zones may also contribute significantly to such a model.

The littoral zone is defined as that portion of the shoreward profile occupied by autotrophic plants (Ruttner 1973). The littoral zone is the outer rim of the lake's euphotic zone, which is defined as the depth at which light intensity is one percent of that incident to the surface (Woods and Falter 1982). Photosynthesis is restricted to the euphotic zone, and the phytoplankton and crustacean zooplankton are most dense in this zone (Reid 1961). The 10 ft and 20 ft depth isopleths chosen by Johnston (1973) are somewhat arbitrary, and almost always include the true littoral in most high lakes due to their high transparency. In many lakes, all of the surface area is over water that is less than 20 feet deep, or even 10 feet deep (Plate 13). It is no surprise that these shallower high lakes and ponds are typically the most productive in terms of trout growth rates, particularly at the lower elevations of the subalpine zone (WDFW file data).

Lake Elevation

Virtually all of the biologists use a combination of published information to obtain lake elevation, such as Wolcott (1965) or USGS topographic maps. High quality altimeters are sometimes used in the field to obtain more precise elevations where interpolation on topographic maps is sometimes required, or difficult. WDFW biologist Bob Pfeifer also used GIS-controlled aerial photographs to determine precise elevations on many lakes in King County (Reutebuch et al. ND).

Plate 12. Littoral zone survey includes mapping of bottom materials and vegetation types, and noting the relative abundance of macroinvertebrates. Lunker Lake, Middle Fork Snoqualmie River drainage, (26 August 1993).

Plate 13. A vantage above the lake allows preparation of an accurate map, showing the nature of the substrate that can often be seen throughout smaller, clear, shallow lakes. Polarized sunglasses greatly facilitate this task. Unnamed lake in the Deception Creek and Skykomish River drainage. Mount Daniel is on the horizon (22 September 1999).

Lake Exposure

Biologists who have collected this information most consistently include Johnston, Lucas, Pfeifer, and Williams. It is reported in compass degrees by first orienting a 7.5 minute topographic map to the magnetic field, then aligning a compass edge to a line running from the center of the lake to the direction of least blockage by mountain or ridge slopes surrounding the lake (often directly opposite the direction of glacial headwalls) (Plate 14). Some of the biologists reported the exposure in non-numeric terms such as "northerly", or a series of directions, such as "north through northeast". Exposure is another physical variable which may not have obvious management applications, but may be an important variable in productivity modeling. Exposure is almost certainly correlated with the open-water season, particularly in western Washington and at the higher elevations, based on empirical observations, and 20+ years of data on snow pack and degree of lake clearance in the 3rd week of July (WDFW file data).

Geomorphic Lake Type

Since there is no obvious and urgent fishery management application of this classification, few biologists have determined it for their lakes. Those who did so on a lake by lake basis were Johnston and Pfeifer. Lucas (1989) gave a generalized description of the geology of his work area, and noted groups of lakes that fell within geomorphic categories.

Watershed Area and Basin Gradient

Most biologists did not determine this for their lake basins. Johnston and Pfeifer did so for lakes in King, Snohomish, Skagit, and Whatcom Counties. Basin areas were determined from planimetric measurement of the lake hydrographic boundary determined from a topographic map. Pfeifer also calculated the basin gradient, defined as the elevation difference (ft) between the lake edge and the highest point in the basin, divided by the horizontal distance (ft) between these same points.

Average Water Level Fluctuation

The average water level fluctuation may be defined as the distance in feet between the lake surface in late summer or fall of an average rainfall year, and the change in vegetation (lichens or brush) seen circumscribed about the lake due to the effects of ice, snow, or high water (Plate 15). After the initial work of Johnston (1973), this measurement was collected by Cummins, Pfeifer, Lucas, and Williams; other biologists whose field data were not prepared in technical reports; and Deleray and Barbee (1992). The value could be biased low if the lake is surveyed before it has reached its late summer low point. However, it is the primary author's experience, based on many repeat surveys to lakes spanning the entire summer, that many lakes attain their ultimate fall low level relatively quickly, and either stabilize, or drop much more slowly after a fairly rapid drop soon after iceout. There are, of course, numerous exceptions.

A management application of this measure occurs in those unusual cases where a lake or pond loses a substantial portion of its surface area or rearing volume by late summer, usually due to subsurface drainage. Stocking densities are based on the average late-season, low-volume surface area. A good example is Hi-Low Lake in King County which drops 5-8 feet annually (Plate 16). Its reduced area, determined from a late season aerial photograph coupled with multiple field surveys, serves as the basis for its fry stocking rate.

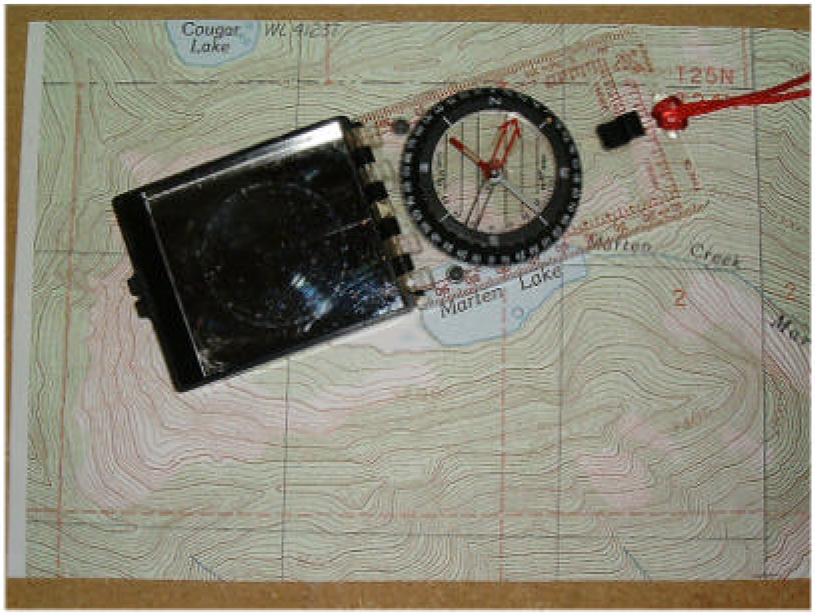


Plate 14. Principal exposure direction is generally along the lake's long axis, oriented away from the glacial headwall.

Plate 15. Lakes that have a significant annual change in surface elevation typically leave distinct marks on the shoreline vegetation that are clearly seen. Nazanne Lake, with Malachite Peak beyond, Foss River and Skykomish River drainage (7 September 1998).

Spawning Area

Most biologists have made physical measurements of the inlets and outlet/s of their lakes, including the lineal distance accessible to trout. The exact manner in which spawning area is reported has varied between the investigators. There is, as yet, no standardized approach. Johnston and Pfeifer measured accessible lengths and mean stream width, and estimated the actual area of spawning habitat by inspection of the substrates (Plate 17). For large or long inlets, Pfeifer approximated spawning area by estimating the percentage of instream habitat that was spawnable, and applying this decimal fraction to the measured total instream area. Others simply reported accessible length, and gave qualitative remarks about the amount of spawning habitat. In essentially all of the technical reports, however, some assessment is made of current or potential reproduction by trout or char. The lake surveys often have both quantitative measurements of spawning habitat, and the biologist's subjective appraisal of its quality, or potential for successful trout reproduction ("None, Poor, Little, Medium, High", etc.).

This assessment is probably the most important one made in the baseline survey of every lake. Contrary to published misinformation (Bahls 1992), WDFW biologists have made this determination on a high percentage of their lakes (Table 5). (See also Section 5.1.2.)

Table 5. Percentage of Washington High Lakes Managed for a Trout Fishery that are Stocked, and in Which a Determination of Fish Reproductive Status has Been Made, by WDFW Administrative Region, as of 2001. ("Lakes" May Include Some Ponds, Per Figure 6a.)

Administrative Region	Number of High Lakes Managed[1] for a Trout Fishery	Number of Lakes Periodically Stocked[2]	Number of These Lakes Where Trout Reproductive Status[3] is Known (%)
1	2	1	2 (100)
2	301	301	260 (86)
3	158	108	158 (100)
4	776	225[4]	535 (69)
5	206	95	206 (100)
6	44	44	44 (100)
All Regions	1,487	-----	1205 (81)

[1] A management decision is often to allow reproducing fish to remain in a lake; in that case it is being managed for a fishery, even though stocking does not occur.
[2] From Parametrix (2001), and estimated for Chelan County from Larry Brown database.
[3] Reproductive status includes: no fish present; fish present but not reproducing; or some level of reproduction.
[4] King and southern Snohomish Counties only; information was unavailable from the north half of Region Four when this report was prepared.

Many of the management biologists have baseline survey maps of most, or all of their managed high lakes. Exceptions are lakes in Chelan, Yakima, Kittitas, and northern Snohomish Counties, where a relatively high percentage have not yet been physically surveyed at the appropriate professional level. (It is important to note that even in these counties, angler reports have often enabled deduction of the presence of reproduction.) The line drawings are stored in lake-by-lake folders or binders of various kinds. The basic maps include the location and orientation of inlets and outlets, and the location of barrier falls.

Plate 16. Lakes like aptly-named Hi-Low, in the Middle Fork Snoqualmie River drainage, can lose a significant amount of surface area over the course of the summer and fall. The high water mark was clearly seen on (26 August 1993).

Plate 17. Many lakes can have extensive inlet systems such as this at Elbow Lake in the Middle Fork Snoqualmie River drainage. Sediment from coarse sand to large gravel may be spawnable, but most smaller trout and char prefer material of the general size range seen here (8 September 1982).

Several of the biologists have used a finer scale in mapping their inlets, differentiating "seeps" from inlets having better-defined channels, or perennial flow. Seeps may be defined as having a bank width of less than 4 inches, or an undefined channel (Plate 18).

Attention paid to in-lake spawning habitat has varied among the field biologists, and underscores the need for an agreed-to standardized approach to baseline lake surveys. While the presence of trout or char reproduction can almost always be deduced by comparing the fish population age structure with the water's stocking history, it is very important to know where the spawning is occurring. This information is critical if reproduction control measures are contemplated. If the only spawning area is a small patch of gravel in one inlet, for example, it may be possible to greatly diminish reproductive success by constructing a fish migratory barrier out of natural materials readily at hand (talus pieces, large woody debris, etc.).

Locating the site/s of spawning is often challenging, especially if it is occurring within the lake. Effective, or even excessive fry seeding can occur from as little as a few square feet of spawning area. These sites are often scree or alluvial fan deposits at the base of steep slopes or inlets (Plates 19, 20). The inlets need not be perennial, since redds are often constructed within the lake proper. A great deal of precision in the measurement of such habitat is not essential; what is essential is some estimate of in-lake spawning area, usually made visually, to account for its existence (Appendix B, C). Documentation of its existence can prevent future stocking mistakes (wrong species or strain) that can lead to virtually irreversible fish reproduction problems (see Section 5.4).

Water Temperature

Lake water temperature is another measure which has not been collected in a standardized manner in Washington. Most biologists collect surface temperature, but the point of collection may be from shore, or offshore, as from a raft. Some also take readings midway in the water column, or near the bottom at the lake's deepest point. Although thousands of readings have been collected over the years, the data have not been analyzed in ways that identify the most valuable or appropriate manner of collection. From a management standpoint, an estimate of the mean summer water temperature has potential value as it has been correlated with trout growth. Donald et al. (1980) found a significant correlation between the weight of Age-5 eastern brook trout and midsummer water temperature, defined as the mean for the 2 to 10 meter depth zone, collected between mid-July and the end of August.

Sufficient "random" surface water temperature values have been collected to give managers a general idea of when lakes will warm to a point where transport water temperatures and temperature shock may be a concern for air-dropped trout fry. In-season monitoring of the time of iceout and weather patterns are part of the "tools" needed by experienced fishery managers to avoid unnecessary stocking mortality, and imprecision in population management. (This concern is somewhat assuaged by observations made on air-dropped fish into Kelcema Lake, in Snohomish County (Pfeifer 1986a). Although the lake surface water temperature was 70^{o} F, fry had sounded from the surface within 15 seconds, and there was no evidence of temperature shock, or apparent delayed mortality in the first 30 minutes. More of these kinds of observations should be made.)

Plate 18. Seeps may be seasonally dry, or may range from damp to carrying a very small flow. The flow volume is too small, and the depth is too shallow to support even small spawners.

Plate 19. Large, long talus-filled chutes or rockslides that support snowfields late into the summer often produce subtle springs or upwelling at their base (see Plate 20). Porous, coarse-grained sediments beneath the larger talus blocks can effectively convey considerable water volume to the lake with no emergent surface flow. Big Snow Lake, Middle Fork Snoqualmie River drainage, (14 August 1994).

Lake surface water temperatures should always be collected offshore, and well away from the influence of inlets. The ideal is a top to bottom temperature profile, but secondary goals are to identify the depth of the epilimnion, or minimally, to take readings 2 inches below the surface, and 3-5 feet below the surface. (Surveys conducted by the USGS in the 1970s provide excellent temperature profile data (Figures 8a,b) on many waters that were subsequently incorporated into wilderness areas (Bortleson et al. 1976; Dethier et al. 1979). Most WDFW biologists have incorporated this kind of high quality information, obtained by others, into their lake files.)

5.1.4 Chemical Description

Parameter lists and collection methods are even less standardized for chemical survey data than physical data. Several management biologists noted they do not need the information to make routine management decisions (e.g.,, stocking rates), and do not obtain the information unless there is some potential problem with water chemistry that needs attention (e.g., Pfeifer and Peacock 1987). The management uses of chemical data from high lakes fall into three general areas:

- Explanation of a water's inability to support fish;
- Monitoring of parameters sensitive to anthropogenic sources of acidification; or
- Classification or scaling of waters as to their potential for trout production.

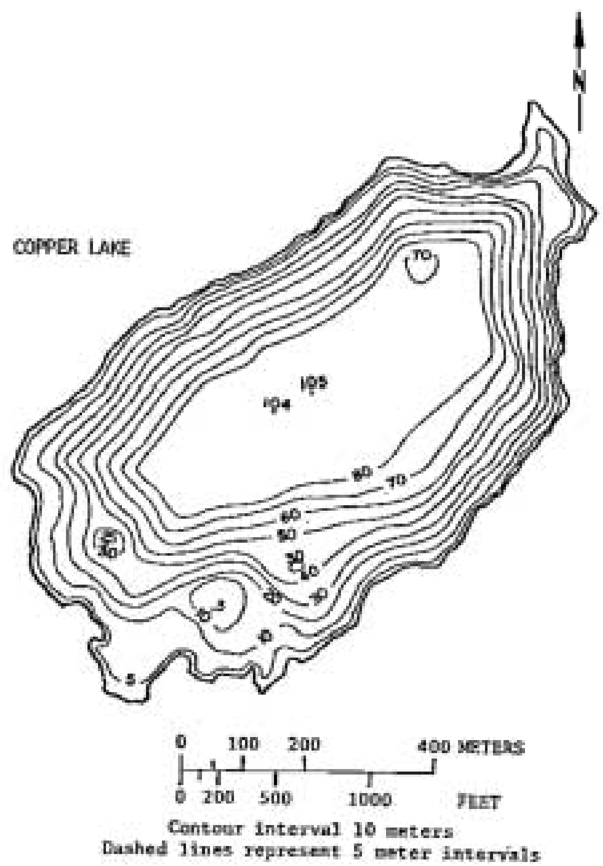
5.1.4.1 *Chemical Limitations*

There is very little need for this type of information in Washington for high lake fishery management. Most biologists have information in regional files that explains why certain lakes cannot support fish. These lakes are often located in mining districts, or lie in basins with naturally high levels of mineralization (Pfeifer and Peacock 1987). Heavy metals are the chemical constituent that most often limit fish survival in these cases.

5.1.4.2 *Acidification*

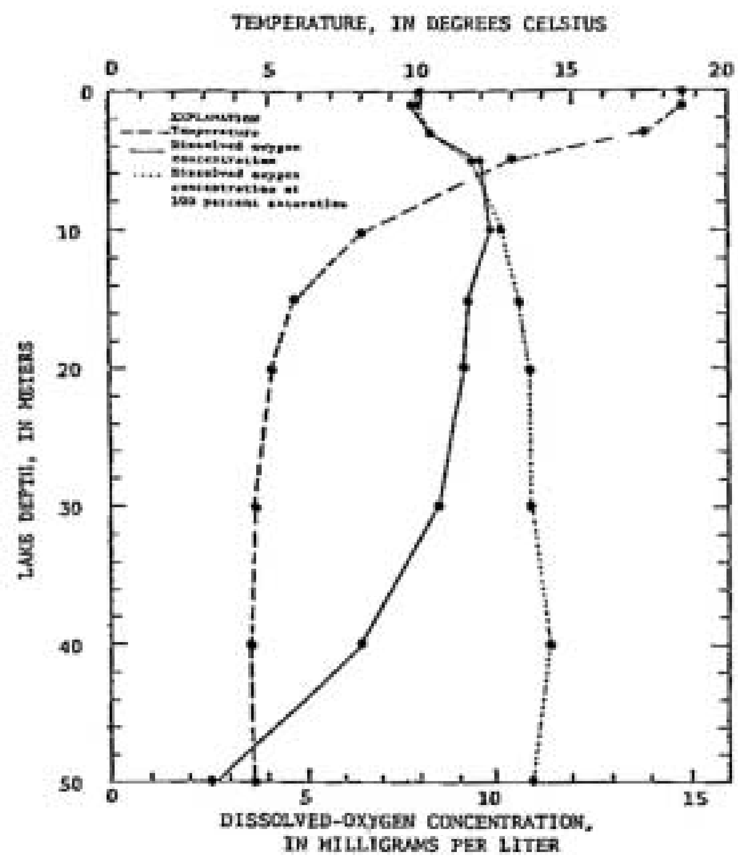
There is great concern by federal land and water managers over the potential for many lakes in Washington's Cascade Mountains to become acidified due to their extremely low acid neutralizing capacity. Considerable field research has occurred on this subject (Haines 1981; Logan and Duncan 1981; Lindstrom et al. 1984; Welch and Spyridakis 1984; Welch et al. 1984; Melack et al. 1985; Welch et al. 1986; Roberts et al. 1986; Welch et al. 1991). Unfortunately, collection of reliably precise information on parameters such as pH has been a challenge, even using sophisticated field equipment (Gall 1998). Most WDFW biologists have collected pH readings for less-demanding purposes, using drop titration and colorimeter methods which are only accurate to 0.25 pH unit, and require visual interpolation to reach that level. While this is precise enough for fishery management, it may not be for more rigorous analyses or early warning detection of changes (Boyd 1980). Very few biologists have the pack space or lab analysis budgets to pack out water samples. However, given these limitations, the many baseline readings of pH, taken *in situ* by biologists in the last 30 years, may still provide a valuable benchmark for detecting relatively gross changes in pH over extended time periods. A few lakes have been sampled which exhibit remarkably low or high pH values that at least partially explain their inability to support trout, but these are likely natural conditions.

Figure 8a. Bathymetric map of Copper Lake, King County, Washington, prepared by the U.S. Geological Survey, 1978.



Copper Lake, King County. From
U.S. Geological Survey, August 4, 1978.

Figure 8b. Dissolved oxygen and temperature profiles of Copper Lake, King County, Washington, prepared by the U.S. Geological Survey, 1978.



Copper Lake, King County. From
U.S. Geological Survey, August 4, 1978.

5.1.4.3 *Lake Productivity Evaluation*

Despite questions of utility, and sometimes inconsistent collection, several parameters have been collected in a great many high lakes in Washington, and quite consistently in some districts. These include pH, total alkalinity, hardness, and conductivity. As with temperature, studies conducted by others (Bortleson et al. 1976; Welch et al. 1986) are often incorporated into WDFW lake files. Johnston (1973) and Pfeifer have amassed a large amount of spot sample information on a lengthy list of lake chemical constituents, either by their own collections and in-field processing, by bringing samples from the field for lab processing, or by accumulating information published by others. This data set has not been analyzed to determine whether any parameters, or some subset, are correlated with trout or char growth in Washington's high lakes, although this has been attempted by others in other areas (Donald et al. 1980).

Jones and Hoyer (1982) found chlorophyll-*a* to be a stronger correlate with sport fish harvest (kg/ha) than total phosphorus, alkalinity, or the morphoedaphic index. However, their data was taken from lowland lakes and reservoirs, not high lakes. Determination of chlorophyll-*a* concentrations requires collection of a field sample in a rigorous manner, and subsequent lab processing. While it may be a useful correlate with trout growth, its collection and cost of processing makes it an unlikely tool for routine classification of high lakes by field biologists. Wagner and Parker (1973) reported similar logistical and sampling problems with primary nutrients, and stated: "The energy pathways involved (in lake fertilization) are very complex, and this complexity may make it impossible to always find any direct relationship (to) fish yield".

Individual chemical constituent measurements may have little or no utility for classifying Washington high lakes in terms of trout production capability. However, they may have considerable value as part of a suite of variables analyzed using techniques such as multiple regression (Donald et al. 1980), or multivariate analysis (ter Braak 1986; Infometrix, Inc. 1994). Total dissolved solids, or its correlate conductivity, seem to have the most potential as individual metrics, but they may be even more useful if combined with several other known correlates with trout growth (Donald et al. 1980). Conductivity is easily measured in the field, and may be most valuable as an index of potential trout growth in lakes where their numbers can be controlled. Conductivity can be measured *in situ* with sufficient accuracy and precision with an easily portable instrument (Plate 21). Conductivity can be substituted for total dissolved solids in the morphoedaphic index (MEI; Ryder 1982). The MEI may be an equally, or more powerful index of potential trout production than chlorophyll-*a* or TDS alone, but its derivation requires a measure of the lake's mean depth. It is for this reason that many lakes were re-surveyed for total volume, area, and mean depth by Pfeifer in King and Snohomish Counties. Analysis has not yet occurred on the large amount of field data already collected by Pfeifer and Johnston on trout growth from lakes where stocked trout densities were known, and conductivity (and other variables) is also known. Completion of this data analysis may provide a very useful index of potential trout growth in lakes throughout the Cascades and Olympics where trout or char reproduction is not a problem.

General Field Chemical Methods

Methods most commonly used by WDFW fish biologists to collect water chemistry data are described below.

pH

Biologists who have been able to conduct baseline surveys on their high lakes collect a surface water sample from near shore, or from a raft, and analyze pH with a wide range indicator solution and a color comparator (Plate 22). In some cases, where equipment is available or may be borrowed, a Hydrolab

Plate 20. The sediment and scree slope at the base of the rockslide seen in Plate 19 provides pocket gravel and coarse sand that is spawned by west slope cutthroat. The size of the material is scaled by the black and white mechanical pencil at the water's edge, bottom center. The sediment slopes into deeper water at upper right. Big Snow Lake, Middle Fork Snoqualmie River drainage, (14 August 1994).

Plate 21. Conductivity readings of adequate precision can be taken with a light-weight, portable unit that is easily packed. The unit is calibrated at the beginning of each season with a highly buffered stock solution of known conductivity.

(Plate 23) has been used for pH, as well as other parameters. Due to its size and weight, no WDFW field biologists have packed a Hydrolab into wilderness waters on a routine basis. Lacking regular assistants, most biologists are not willing to substitute other packed gear or supplies to gain the precision it provides.

Baseline pH readings should be standardized as to method of collection, and time of year. Detailed studies of acidification pulses have shown that samples aimed at detecting acid input pulses should be collected at the time of iceout to sample the waters entering the lake from the surrounding snow pack (Welch et al. 1984; Gall 1998). Otherwise, samples may be collected at most any time during the ice-free season. Bahls (1989) recommended a near-surface shallow water sample, and one from near the bottom at the lake's deepest point. From a fishery management perspective, a mid-lake (or well offshore) sample from near the surface should be adequate. Sampling near inlets should be avoided, as well as during rainstorms.

Alkalinity and Hardness

Most WDFW biologists have used the popular Hach Chemical Company Model AL-36B field water chemistry kit components to analyze for alkalinity and hardness (Plate 22). The kit's precision for these parameters is 7 and 14 mg/L, respectively. This may be suitable for broad categorization of lakes, but the data collected to date have not been analyzed for this purpose. Water samples have generally been collected in the same manner and place as for pH (surface water, near shore or offshore). While Johnston (1972) used both the Hach AL 36-B kit and the more precise DR-EL portable laboratory (Midkiff et al. 1972; Boyd 1980), the latter kit's components are generally too bulky and heavy for lakes that must be surveyed using backpack methods.

Conductivity

While some Washington high lakes have been sampled at both the surface and at depth for conductivity (Bortleson et al. 1976; Dethier et al. 1979; Deleray and Barbee 1992), most WDFW biologists (primarily Johnston and Pfeifer) have taken readings in the lake's surface water near shore, or from a raft. In most cases conductivity readings have only been taken on one date at each lake.

Plate 22. Components of several Hach Chemical Company test kits can be packaged in waterproof containers in the backpack. The reagents and methods are not highly precise, but are accurate, and are suitable for general baseline determinations and fishery management. The wide range pH indicator solution is replaced annually to assure accuracy. Reagent solutions can be taken in small quantities to hold pack weight down.

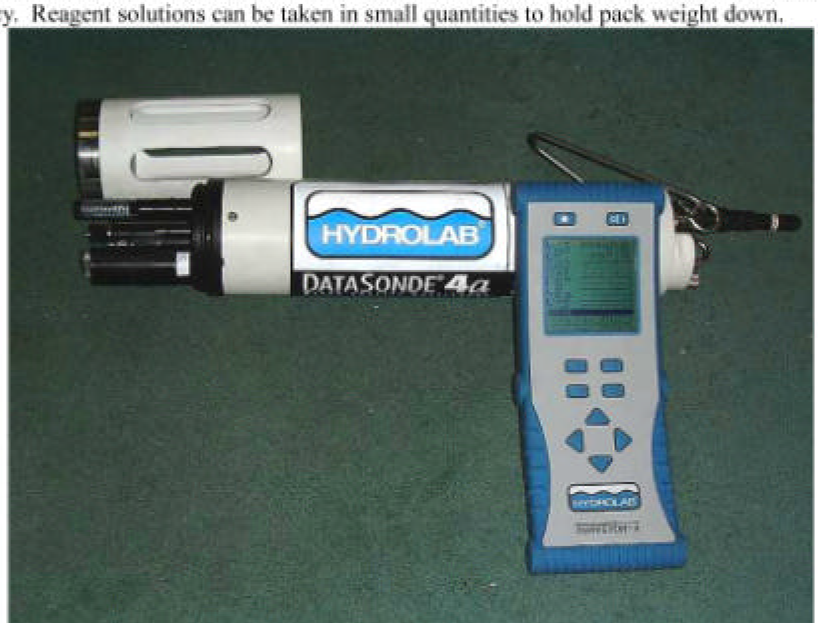


Plate 23. When necessary, greater precision can be obtained on various parameters through use of a high quality instrument, such as a Hydrolab. Packing gear of this volume and weight is generally not practical for single individuals, unless water quality information is the primary objective.

5.1.5 Biological Description

Biological data collected at Washington high lakes can be categorized as relating to nearshore vegetation; lake invertebrates; evidence of fish reproduction; fish age, growth, and condition; fish diet; general fish abundance; evidence of amphibian use; and notes or comments on wildlife use of the lake basin.

Nearshore Vegetation

Some biologists have collected and mapped this information, and some have not. Vegetation was mapped or verbally described for all lakes in the Olympic National Forest (Johnston 1972, 1973). Williams provided verbal descriptions of vegetation for lakes in the Okanogan region. Cummins has taken notes on vegetation on lakes surveyed in Yakima and Kittitas Counties. Limited amounts of this information have been collected in Skamania or Chelan Counties. Biologists working the west side of the Cascades (Lucas, Cummins, Pfeifer, Johnston) have obtained this information for a very large percentage of the lakes supporting fish, and many lakes that do not.

The named westside biologists estimated areas covered, or percentages of lake surface area or littoral area that supported emergent vegetation. Some also mapped their distribution on a field map of the lakes. Species typically seen and noted include freshwater mosses, sedges, aquatic grass, water shield, and lilies (Plates 24, 25).

Most biologists have not noted or mapped the terrestrial nearshore vegetation. Pfeifer and Johnston have developed this information for many lakes in King, Snohomish, Skagit, and Whatcom Counties from aerial photographs and field surveys. Its pertinence to fishery management decisions has not yet been determined, but the information may play a role in analysis of factors that may affect trout production (Wissmar et al. 1977).

Lake Invertebrates

Again, methods used by the various biologists have varied significantly, and no standardized methods have been established agency-wide. Table 6 shows the kinds of invertebrate information available from Washington high lakes, by county, and relevant references or data sources. This is followed by a general description and discussion of the methods that have been used to obtain information on each type of invertebrate.

Plate 24. Some relatively shallow, lower elevation subalpine lakes develop diverse plant communities. These commonly support a relatively luxuriant invertebrate community. It is important to map these plant beds accurately. Shallow plant beds are known to serve as refuge for amphibian larvae, as well as adults. Stocked trout and salamanders have coexisted in this lake for many decades. (There is no reproduction by the trout.) Merlin Lake, Middle Fork Snoqualmie River drainage, (3 September 1984).

Plate 25. Extensive areas of emergent rushes, such as seen here at the inlet end of Myrtle Lake, are also very important as refuge and habitat for amphibians and fish food organisms. Big Snow Mountain rises beyond. Middle Fork Snoqualmie River drainage, (2 September 1984).

Table 6. Types Of Invertebrate Data Collected on Washington High Lakes, by County

County	Zooplankton	Benthic Macroinvertebrates	Amphibian Eggs or Larvae	Quantitative Collections
Whatcom	Yes [1,2,3]	Yes [1,2,3]	Yes [1,3]	Yes (a)
Skagit	Yes [1,2,3]	Yes [1,2,3]	Yes [1,3]	Yes (a)
Snohomish	Yes [1,2]	Yes[1,2]	Yes [1]	Yes (b,c)
King	Yes [1,2]	Yes[1,2]	Yes [1]	Yes (c,d)
Pierce	No	Yes[1,2]	No	No
Yakima	Yes [1,3]	Yes[1,3]	A few observations and notes	No
Kittitas	No	Yes (few)	A few observations and notes	No
Chelan	No	No	No	No
Okanogan	Yes[1]	Yes[1]	No	No

[1] Qualitative assessment of general abundance; notes on taxa present.
[2] Samples collected by consultant or USFS.
[3] Surveyed as part of academic or ecological studies
[3] Deleray and Barbee (1991), selected lakes in Yakima Co.
[a] Liss et al. (1995).
[b] WATER (1993) – in cooperation with USFS..
[c] ZP's Taxonomic Services (1999) – in cooperation with USFS.
[d] Rowe-Krumdick and Matthews (1991)

Zooplankton

Biologists responsible for lakes in most counties made at least qualitative observations on macrozooplankton abundance during their baseline lake surveys. An effective technique is to hold a white raft paddle in the lee of a raft, and slowly extend its position to arm's length (Plate 26). The white surface makes an excellent reflective surface over which even relatively small copepods and cladocerans are visible. Large, red calanoid copepods such as *Hesperodiaptomus* are readily apparent, and general abundance can be gauged (particularly after some experience). Some biologists made vertical hauls with plankton nets in deep water, and horizontal hauls in nearshore areas (Lucas 1989; Deleray and Barbee 1992). It is recognized that even these methods are not quantitative (Edmondson and Winberg 1971).

Semi-quantitative samples of zooplankton have been made in recent years at numerous lakes on various national forests in Washington, using the Region 6 protocol (Hann and Wall 1992). In some cases collections have been made by private consultants (WATER Environmental Services Inc. 1993, 1994; ZP's Taxonomic Services 1999). In-depth studies have been accomplished on many lakes in North Cascades National Park, affecting waters in Whatcom, Skagit, and Chelan Counties (Liss et al. 1995). WDFW biologists obtain this information, and incorporate into their lake files. The relevant application of this information is exemplified by the observation that low-density trout stocking does not result in elimination of large, conspicuous zooplankton forms in Washington high lakes (Divens et al. 2001).

Littoral Macroinvertebrates and Gammarus

Biologists in most areas have made at least some qualitative appraisal of macroinvertebrate presence in their lakes (Table 6). Methods used differ somewhat, but most investigators visually searched the shoreline areas, and took notes on taxa seen, and relative abundance (Plate 12). Some (Johnston, Cummins, Pfeifer) mechanically disturbed the substrate and used a dip net or screen to augment the visual substrate scanning. Their results are reported or maintained as office records in various forms; see Appendix D for a typical example.

Deleray and Barbee (1992) used nets to sweep a minimum of six shoreline areas at each of 32 lakes in Yakima County. Lakes in four national forests in Washington have received more detailed sampling under the USFS Region 6 protocol (Hann and Wall 1992). Liss et al. (1995) applied rigorous sampling techniques to many lakes in North Cascades National Park. WDFW biologists have acquired this information, and make it a part of their lake files.

Invertebrates that are in low abundance, and are therefore difficult to collect (e.g., *Pisidium*) are sometimes observed in trout stomach contents. These observations augment the findings of the shoreline searches.

Evidence of Fish Reproduction

Most, if not all of the district fish biologists determine the presence of natural reproduction through one or more of the following means:

- Reconciliation of the observed age or size composition of the population with the stocking record;*
- Observation of fry in the lake or in spawning areas;
- Angler reports of the above kinds of information (preferably with follow-up field verification).

*Note: In many cases a determination of reproduction hinges on the accuracy of the stocking record. Multiple age groups in the fish population, and equivocal information on spawning habitat shift the evidentiary dependence to the stocking record. This is probably the most important reason for rigorous accuracy in annual stocking records, and the need to ferret out errors from the historical record as much as possible (see Section 5.5.1). It is easy to see how bootleg (illegal, unauthorized) stocking by ignorant or unlawful members of the public can make the determination of reproduction more difficult. The presence of young fish, or fish whose age does not jibe with the official stocking record, can lead an inexperienced biologist to assume they were the result of reproduction.

It is relatively easy to make a determination of active reproduction, discounting for the moment difficulty in accessing remote lakes, or being unable to obtain a fish sample on an individual sampling trip. The latter two circumstances, significant time commitments to access and survey remote lakes, and the frequent need to make repeated trips to obtain confirmation of a fishless condition, are the difficult aspects of this task. However, if a gill net set or two, and multiple hours of lake observation and angling fail to produce any sign of fish, especially on a second or third trip, it is a fairly safe conclusion that if any reproduction exists, it is at a very low level. This can be supported by a habitat survey that shows little or no available spawning habitat.

Most of the lakes being managed for trout fisheries have long stocking histories, and many years of angler reports (see Sections 5.5.1 and 5.2.1). These often provide sufficient information to verify active reproduction, or are a strong reference to augment one to several sampling trips for those few remaining managed lakes or ponds where this question has not been answered (Table 4).

Fish Age, Growth, and Condition

All WDFW biologists routinely collect length information, either directly during their own surveys (e.g., Johnston 1973; Cummins 1973), or from angler reports (Section 5.2.1). The manner in which the information is stored, however, varies among the districts. Some maintain the information in spreadsheets, paper files, data notebooks, or annual Dingel-Johnson reports. Age and growth information from lakes in Chelan, King, and Snohomish Counties has been logged into electronic databases (Section 5.3.3). Most lengths collected are total lengths, but this has not been set as a statewide standard. Units (English versus metric) have also not been standardized, although some biologists prefer metric for its greater precision, and the values are easily converted to English units later, if needed. (See also Section 5.2.1.)

Fish age and growth determinations are made based on scale or otolith samples, unless the age of the fish is known based on the stocking history. Storage of these data varies among the districts, similar to length data. There has been very little in-depth analysis of age and growth characteristics among species, strains, or geographic lake districts. Technical reports (e.g., Johnston 1973; Deleray and Barbee 1992) generally report means and ranges of lengths observed, sometimes by age group, in a tabular format.

Wet whole weight is collected from fish by some biologists, but not all, or inconsistently by some. The availability of suitably precise scales that could fit in a stuffed backpack prevented broad collection of fish weights until the mid- to late 1980s. Deleray and Barbee (1992) used lightweight Pesola spring scales (Plate 27), which were also noted by Bahls (1989). All fish collected by Pfeifer in King and Snohomish County lakes since 1991 were measured to the nearest gram using these scales, resulting in a database with 1747 records for fish lengths and weights in that district (Section 5.3.3). These scales have recently been adopted by the Washington State Hi-Lakers as an integral part of their mission-oriented volunteer high lake survey program (Section 5.2.1).

Strict condition factors (Anderson and Neumann 1996) have been calculated in some districts (Johnston 1973; Deleray and Barbee 1992). Johnston and Pfeifer have large databases of length and weight data from King, Snohomish, Skagit, and Whatcom County high lakes that could (or will) be utilized to calculate these indices. (Also see Section 5.2.1.)

Most WDFW biologists have used qualitative indices of fish condition since 1970 (Cummins 1975; Lucas 1989; Williams 1972). These have generally included a subjective appraisal of overall plumpness or robustness, plus inspection for internal visceral fat reserves (Plates 28, 29). While these are useful yardsticks for professional angler/biologists, they should be augmented with a standardized, accepted approach to measuring fish condition, mindful of the fact that most indices vary with the season (Anderson and Neumann 1996).

All WDFW inland fishery biologists are quite familiar with "stunted" fish populations, whether they are of eastern brook trout (most common), Kamloops rainbow, or westslope cutthroat. Calculation of condition indices is largely an academic exercise for these populations, where fish have been termed "pin-headed" or "snakey" or "emaciated" (Plate 30). However, Pfeifer has collected length and weight data in

Plate 26. Large, conspicuous zooplankton are often very patchy in distribution in large, very clear lakes such as Caroline. Their relative abundance in the lake's top layer can be checked, as hook and line sampling and shoreline mapping proceeds, by extending a white raft paddle into the lake on the lee side of the raft. The checks are made at many points around the lake. Middle Fork Snoqualmie River drainage (16 September 1984). G. Ring Erickson photo.

Plate 27. Precise measurements of fish weight can be obtained with light, easily packed spring scales. The blue scale, about 9 inches long, can be read to one gram.

Plate 28. A west slope (Twin Lakes) cutthroat from a small lake in the Pratt River drainage exhibits moderate to heavy internal fat reserves, and a light orange flesh color. (14 August 1991)

Plate 29. A golden trout with light visceral fat deposits has a deep orange to red flesh color, and had been feeding exclusively on large calanoid copepods. The female would have been sexually mature the following spring. (1 August 1984) C. Kraemer photo.

a standardized manner on numerous stunted populations in King and Snohomish Counties to establish baseline conditions. Reduction in fish abundance through biological controls, spawning area blockage, or other means can then be evaluated in terms of improved fish condition, as well as other measures, such as catch per unit effort (see Section 5.7.2).

Fish Diet

Nearly all information on trout or char diets in Washington high lakes is qualitative. Most biologists take field notes on the relative abundance of food organisms seen in fish collected by hook-and-line, or by gill net (Cummins 1972; Williams 1972; Lucas 1989). No information on fish diet was reported by Deleray and Barbee (1992). Most of the biologists maintain notes on diet in individual lake files, or in spreadsheets. Pfeifer has logged all diet information from the field forms (Appendix B) to an electronic database for King and Snohomish County lakes (n=1747). Some biologists (Cummins, Pfeifer) have also noted relative degrees of stomach fullness, but of course this can vary greatly, especially at times of certain insect hatches. Dietary items are typically identified to the lowest taxon identifiable in-hand, which is generally not lower than the Family level.

A common phenomenon observed in Washington high lakes is dietary prey resource partitioning, or fish selectively feeding on one prey item, while other fish feed selectively on another. This is most easily observed in the flesh color when time is not available to make iterative samples of the diet over days or weeks. Fish which are feeding fairly exclusively on crustaceans, most commonly large calanoid copepods such as *Hesperodiaptomus*, or on *Gammarus*, develop a rich orange to red flesh color due to the carotenoid pigments these organisms carry (Andre' 1926; Miki 1991). Trout which are feeding on insects have a characteristic flesh-colored or very pale yellow hue (Plate 31). Flesh color is very highly correlated with stomach contents in trout from Washington high lakes (WDFW file data). (This relationship is not as clear-cut with char such as eastern brook since the lining (peritoneum) of the body cavity has a yellow to light orange tint which somewhat masks the underlying flesh color.)

General Fish Abundance

This is one of the most difficult and challenging pieces of information to obtain from high lakes, especially wilderness lakes. Very few district biologists have the time or resources to perform classic mark-recapture type population estimates such as reported by Nelson (1987) and Gresswell et al. (1997). However, this would be extremely valuable information, if collected in a systematic fashion, and would answer a number of very important management questions. These include:

- Average annual mortality of stocked, single-age fish communities;
- Average annual mortality of moderate to high-density, reproducing fish populations;
- Average annual angling mortality, if linked to creel survey;
- Fry recruitment from varying quantity and quality of spawning habitat area; and
- Calibration of indirect, less-precise measures of abundance, such as the number of fish seen rising or cruising, for which a large amount of data has been collected (Section 5.2.1).

Plate 30. An eastern brook trout from Unnamed Lake in the Skykomish River drainage exhibits very poor condition. July, 1993. J. Ledbetter photo.

Plate 31. The fish on the left (surveyor's right hand) had been feeding on insects, while the other had been feeding on crustaceans. Both fish were caught from the same lake. (September 1979). G. Ring Erickson photo.

Most of the biologists have qualitatively appraised fish abundance based on knowledge of the stocking history, the probability, or knowledge of reproduction, their visual observations at the lakes, and catch per unit effort (cpue) from hook and line (h/l) sampling or set gill nets (Plates 32, 33). Fish abundance has usually been classified as Low, Moderate, or High (Appendix B), along with comments made at the time of the survey. Some biologists have calculated cpue for their h/l sampling and net sets. An overnight set of a standardized gill net has the advantage of being less biased than angling, where angling skill varies among biologists. The small mesh sizes of a set net are also better able to sample small fish than h/l sampling. Pfeifer calculated cpue for both h/l sampling and net sets, and noted both the set/pull times and the period of darkness for two calculations of net set cpue (Appendix B).

Johnston (1999) recommended summarizing reproduction in four general categories (None, Low, Moderate, High) based on the number of small fish (10-150 mm) seen rising or cruising within a standardized amount of time, or along a standardized reach of shoreline. Although this method is largely subjective, it offers a prototype that can be further refined when joined with classic mark-recapture measures of abundance. The reproduction categories would correspond to seeing 0, 1-5, 6-20, or 20-100+ small fish, respectively. The critical management information is a) whether the fish are reproducing or not; and b) to what degree of success. Management biologists need to be able to reliably gauge whether fish density is at or above some threshold level, such as 200 fish/acre. While most of the experienced biologists have developed a "feel" for this level based on surveys of lakes where the number of fish stocked was known, there is a need for a somewhat more quantitative index or measure. Broad application of mark-recapture population estimation is highly unlikely to occur in Washington wilderness areas, or any time soon on the hundreds of lakes where abundance monitoring is an on-going need.

Since sports groups such as the Washington State Hi-Lakers and Trail Blazers, Inc. are the extended eyes of the small agency staff, simple, yet effective indices of fish abundance that are based on observations already made by club members would be of extreme value (see Section 5.2.1).

Evidence of Amphibian Use

Amphibian Life Stages

Most WDFW fishery management biologists have not made directed collections, or extensive visual searches for amphibian adults, larvae, or egg masses as part of their baseline lake surveys. Williams (2001) emphasized that he "never" saw amphibians of any sort in Okanogan County lakes, and opined that they may not have suitable habitat in that part of Washington. Others indicated they were not collecting that type of information, usually because of a lack of time and resources. Some (Cummins, Johnston, Lucas, Pfeifer) have noted their presence in trout diets, or in surveyed lake or pond environments (Johnston 1972, 1973). Beginning in the mid- to late-1980s, Pfeifer routinely made notes on the field lake sketch map of the general abundance of egg masses (almost always *Ambystoma gracile*), larvae seen in the lakes or trout stomachs, and the presence of adult salamanders or newts in the water column (Table 7). Frogs and tadpoles were also noted, and occasionally photographed (Plates 34, 35), but they were not keyed to species. Johnston made similar observations and notes on waters he surveyed in Skagit and Whatcom Counties in the late 1980s and 1990s, but detailed studies on this subject were already on-going in this same geographic area (Liss et al. 1995). (See additional discussion of this key topic in Section 5.6.1.)

There has been little in-depth discussion of, and no agreement on the best methods fishery management biologists should use to survey for amphibians in high lakes managed for fisheries. The local managers are comfortable that if trout numbers are kept low, and stocking is infrequent, there is not apparent impact on amphibians. All evidence to date indicates the current program of cyclic, low-density fry stocking is compatible with native amphibians (Divens et al. 2001). There is no evidence that any amphibian native to Washington's sub-alpine and alpine zones is in danger of extinction at a basin-level scale. Therefore, most local fishery managers, already limited by time and resources, are generally unable to add labor-intensive amphibian surveys to their list of priority information to be collected at high lakes that have not yet received baseline surveys. Additional information on the basin-scale distribution and ecology of salamanders was identified as a high priority research topic in Divens et al. (2001).

Biological data from Washington high lakes are routinely collected by volunteers (Section 5.2.1). Two of the most active of these sport groups have recently solicited training materials and seminars from local experts on amphibian biology and identification. The goal of these anglers is to assist the WDFW in obtaining relevant information on the distribution of amphibians in Washington's high country, and in fish-bearing high lakes. As information is obtained from these volunteers, it will be entered into the HLS database (see Section 5.3.2).

Table 7. Table of Stocking Frequency, Fry Density, and the Occurrence of Northwestern Salamander Egg Masses and the Copepod *Hesperodiaptomus kenai* In A Sample of Surveyed Lakes in King County, 1982-1999 (WDFW Region 4 File Data).

Lake	Elevation (ft msl)	Year First Stocked	Stocking Frequency (yrs)	Fish Reproduction	Stocked Fry Density (number/ac)	Salamander Egg Mass Relative Abundance	*H. kenai* Relative Abundance
Blazer	4060	1929	5	None	87	Mod	Mod
Blethen	3198	1952	4	None	40	Many	Mod
Cougar	4123	1947	9	None	41	Note 1	Mod
Deer	3630	1918	5	Light	50	Low	Scarce
Elbow	3900	1969	0	Mod	0	Note 2	Scarce
Hardscrabble	4800	1947	0	Mod	0	Note 1	Scarce
Hester	4050	1931	6	Low	78	Low	Scarce
Horseshoe	3500	1929	6	None	61	Mod	Low
Isabella	3510	1954	4	None	60	Note 3	Mod - High
Little Kulla	3870	1936	4	None	115	High	High
Olallie	3780	1914	0	High	0	Scarce	Scarce
Pratt	3385	1914	0	High	0	Note 3	Scarce
Little Pratt	4080	1953	6	Low	58	Mod	Low
Thompson	3650	1929	5	Low	64	Note 3	Low
Upper Tuscohatchie	4020	1918	0	Mod	0	Note 3	Mod
Windy	4186	1969	6	None	70	Note 1	High

1. Surveyed in late summer - too late to expect to see egg masses.
2. Surveyed in late summer. Frog tadpoles numerous in shallows.
3. None seen.

Notes on Wildlife Use

Some fishery biologists note the occurrence and activities of wildlife at or near high lakes, in part to assist other WDFW staff, and to document the interactions of wildlife with the artificially-created high lake fishery. These notes have been made to field notebooks, the lake sketch map, or a Comments field on a data form (Appendix B). See Section 5.6.3.

Plate 32. The blue cork line of a 60-ft sinking horizontal gill net can be seen at left center of the photo. Sets are made with the smaller mesh afixed to an object on shore, preferably where there is at least 3 feet of depth at the lake's edge. The net is set perpendicular to shore, avoiding large woody debris on the bottom. Rock Lake, Taylor River drainage (25 August 1993).

Plate 33. With some practice, even 120-ft floating gill nets can be set from a small inflatable raft. (Floating nets must be anchored at their distal end.) The net may be fed into a plastic bag between the surveyor's knees upon retrieval. Unnamed Lake, Skykomish River drainage (27 September 1996). G. Ring Erickson photo.

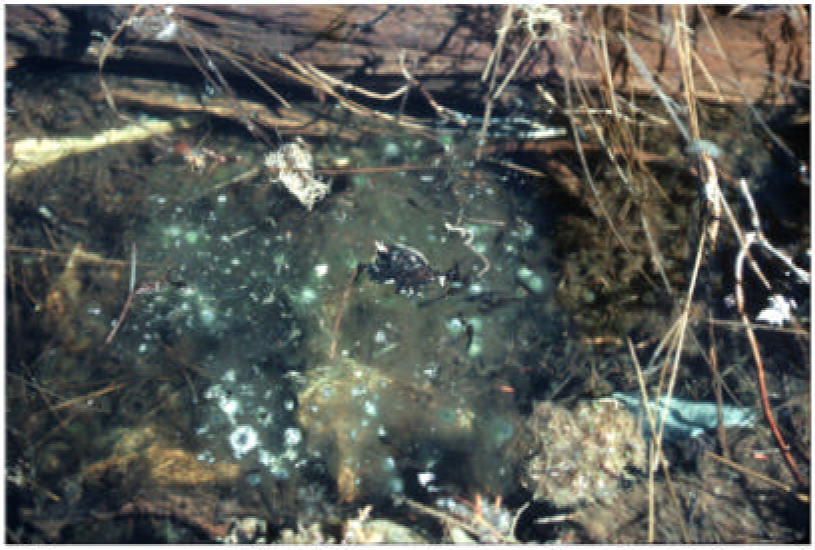


Plate 34. Eggs or egg masses of Cascade frog, northwestern salamander, and other species are commonly seen along the edges of ponds and lakes of all sizes in the west central Cascade Mountains. Egg masses may be at the extreme edge, or in several feet of water, depending on the species. Amphibians coexist with trout in this periodically stocked lake. Upper Snow Lake Pothole, Middle Fork Snoqualmie River drainage. (25 July 1988).

Plate 35. Smaller, shallow tarns such as this one which lies within 100 feet of a larger lake that has a reproducing population of cutthroat often support amphibians. Many hundreds of frog tadpoles were seen between the aquatic grass and the water's edge in this pot near Trico Mountain Lake in the Deception Creek and Skykomish River drainage. (8 September 1996)

5.1.6 Assessment and Recommendations

Extensive personal experience by the primary author has conclusively shown that there is no substitute for a professional-level survey on each high lake and pond being managed. Fortunately, much of this very large task has been accomplished over the past 67 years, especially in the last 30 years. The minimum amount of information should be obtained by a professional biologist, or under his/her close supervision. District biologists lacking at least four years of experience in managing high lakes should not delegate this work, but must obtain their expertise first-hand. The exact nature of the "basic survey" information, and methods used to obtain it, has not been standardized, or agreed-to for the varying geographic districts with high lakes.

> **Recommendation #1a:** The economic benefits of the high lake fishery (Section 4.0) should be borne in mind, and a greater amount of staff time allocated to completing baseline surveys on all districts. There is a particularly acute need for this in Chelan County. A standardized Methodology for completing baseline surveys should be prepared by or with current staff, and be published (internally or externally) for current, and by far most important, future staff use. Summary reports based on these surveys should include the information contained in the samples provided in Appendix C.

> **Recommendation #1b**: Staff agreement should be reached on the types of information, and level of detail obtained in a "baseline", or "Level 1" survey. The data form in Appendix B may serve as an example, or basis for in-depth discussion. Similar definition should be developed for any higher level surveys deemed necessary for management or research purposes.

More complete information on spawning habitat and the current level of fish reproduction is needed for many lakes. This can be considered a subset of the assessment and recommendation above. This information is critical for addressing potential impacts of the program on native invertebrates and amphibians. While much is already known (Table 5), the remaining information gap should be filled as soon as possible.

> **Recommendation #2a**: This recommendation is closely related to #1. If staff time or geographic work areas must be prioritized, new baseline surveys or collection of information on spawning area and fish density should be focused in Chelan and Kittitas Counties.

> **Recommendation #2b**: Mark-recapture population estimates should be made in a carefully-chosen set of lakes in an attempt to calibrate commonly-used indirect measures of fish abundance (numbers seen rising, cruising, etc.). Counts of fish obtained by snorkeling shoreline reaches should be a part of this evaluation. A related question is whether cpue reported by high lake volunteers is correlated with actual fish abundance (Richards and Schnute 1986).

There is usually little need for physical and chemical data to make routine management decisions on high lakes with long management histories, apart from surface area. However, two major benefits could come from analysis of existing data for the purpose of developing a model of the relationship between habitat variables and trout growth in Cascades and Olympics high lakes:

- Existing and future fishery managers (in Washington and elsewhere) would gain an increased understanding of the relationships between sub-alpine and alpine aquatic habitat in this ecoregion, and trout growth rates. Since the model/s would be developed from lakes where trout densities are known, and controlled through stocking, the information would lend much scientific credibility to the current WDFW assertion that low density stocking not only leads to quality trout, but is ecologically compatible with the natural aquatic environment.

- Trial and error over many years has established appropriate stocking rates and frequencies for most lakes under active management. The greatest benefit of a model to managers would be for the setting of stocking levels for lakes that are either currently barren, or that have had all of their fish removed. (Habitat assessment and re-stocking should occur after a period of recovery for the invertebrate community in cases where a chemical treatment is used.)

Recommendation #3: Existing data collected by Johnston and Pfeifer from lakes in Clallam, Jefferson, Mason, Whatcom, Skagit, Snohomish, and King Counties should be analyzed with the objective of developing one or more models of trout growth in relation to habitat variables in Olympics and Cascades high lakes. Preliminary analysis of a subset of this data by Johnston suggests the model/s would consist of a relatively low number of easily-measured parameters.

There has been much speculation of, but little proof of the impacts of low-level trout stocking on native amphibians in Washington. Given the high demand for quality trout fishing in Washington (WDFW 1996a), and the great cost-effectiveness of the high lake trout program (Section 4.0), efforts should be made to address questions that remain.

Recommendation #4: The prioritized research studies listed at the end of Divens et al. (2001) should be methodically implemented. They should occur in the sequence noted, since information obtained from the higher-priority topics may obviate the need for some of the lower-priority ones.

5.2 FISHERY MONITORING

For the purposes of this report, monitoring is taken to mean the periodic or annual collection of information on trout growth rates, angler use, angler catch success, quality of fishing (angler satisfaction), and environmental impacts at lakes for which a fishery has been established. Monitoring typically occurs on lakes which have long histories of fish presence and angler use, but also includes waters that are visited by only a few individuals annually. It does not include the data collection required to catalogue the existing habitat and fish population conditions when a "baseline" survey is first completed. (There are still numerous fish-bearing high lakes in Washington that have not yet received a baseline survey.)

5.2.1 Professional and Volunteered Survey Reports

WDFW Monitoring

Most WDFW district fish biologists perform monitoring, or "follow-up" surveys on some of their lakes each year. The number surveyed varies substantially among the districts, due to varying demands of other programs during the summer and fall. A goal of 10 to 15 lakes per year has been established for each region. Some biologists with high anadromous fish time demands and few high lakes may survey two or three lakes annually; others with hundreds of high lakes on their district and less competing demands on their time have surveyed as many as 20 to 25 annually.

Some biologists use the form found in Appendix B, or a close facsimile. Some simply log notes to a waterproof notebook. However, the form in Appendix B is intended for baseline surveys. The type of data collected for routine monitoring is much closer to that requested on the revised High Lake Fishing Report Form (Appendix D). Key information includes the survival of the previous fish introduction (relative abundance and catch rates), fish growth and condition, evidence of reproduction, the number of anglers and other users at the lake, use/campsite impacts, and access conditions.

Monitoring by Volunteers

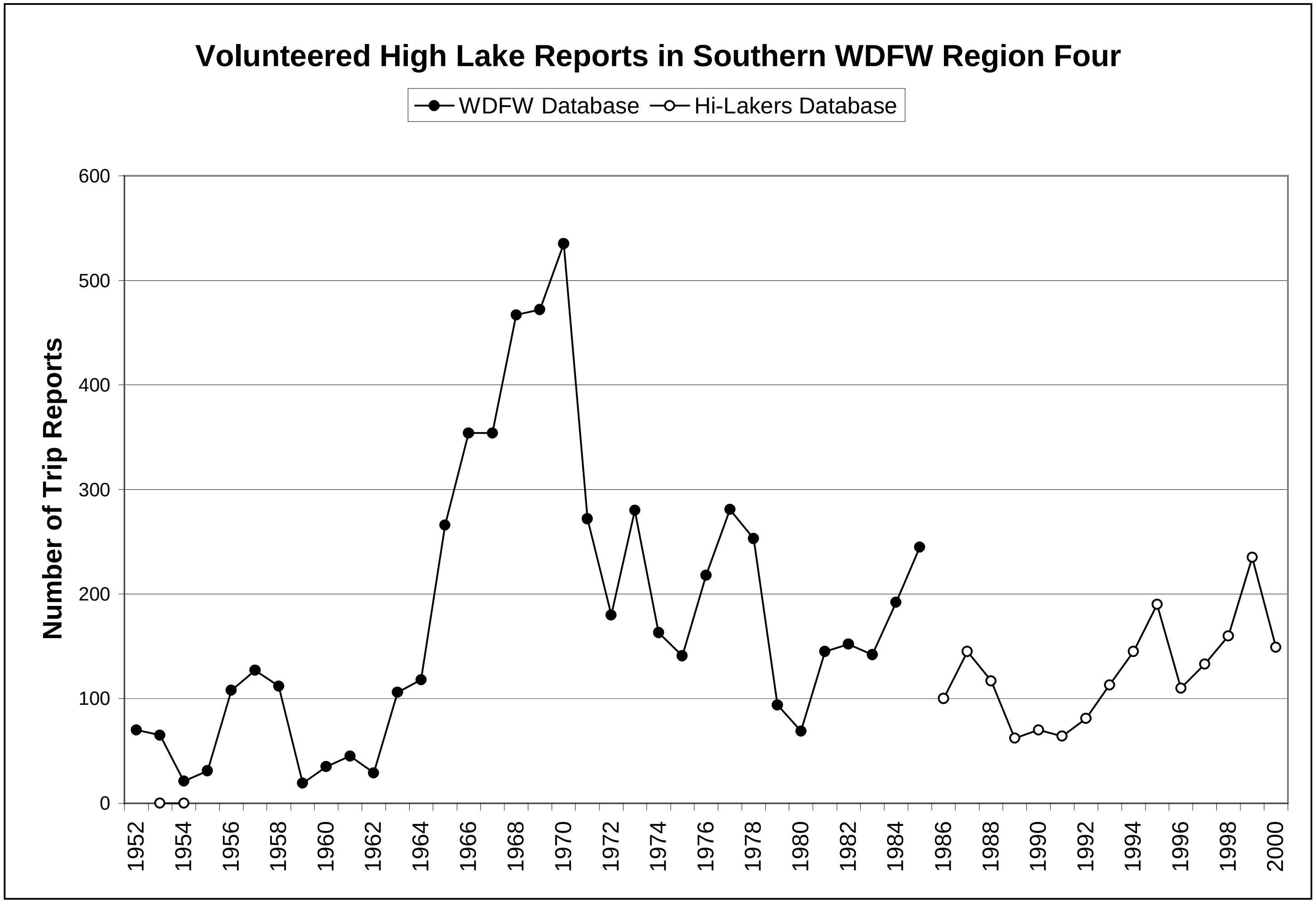
A unique high lake fishery monitoring situation may exist in the State of Washington. While the use of angler diaries by fishery managers is not new (Anderson and Thompson 1991), very few volunteered creel data programs date back to the mid-1950s, especially for remote high lake fisheries. As described in Section 2.0, High Lake Fishing Report cards were instituted in Washington in about 1955. The Washington Department of Game distributed thousands of the cards through regional offices and Forest Service district offices, and many hundreds were returned. The cards were promoted in Washington Wildlife magazine, on radio spots, and in mailings to sports clubs. However, returns of the cards dropped continuously in the late 1970s and early 1980s for reasons that are now obscure.

The old WDG High Lake Report card was revised and updated in late 1985, and was first used in 1986 (Appendix D). This form has almost completely supplanted the earlier form, particularly in WDFW Region Four. The use of this form was promoted with the Washington State Hi-Lakers and Trail Blazers, Inc., the two major high-lake oriented fishing clubs in Washington, both located in Seattle. Walt and Brian Curtis of the Washington State Hi-Lakers were particularly instrumental in developing the revised form with WDFW district fishery biologist Bob Pfeifer. The form was revised to allow entry of all contributed information into an electronic database.

Figure 9 shows the number of angler reports received for southern Snohomish County, and all of King County since 1952. Reports received through 1985 were obtained primarily by public distribution and publication of the original WDG-designed High Lake Report Card. An annual peak of around 500 trip reports obtained by use of this card occurred in 1971. The number of reports then quickly dropped, and varied between 150 and 250 reports per year through 1985. In recent years the number of trip reports received with the new form has similarly ranged from 110 to 235, and has averaged about 154 since 1993 for this district

.

Figure 9. Volunteered high lake angler trip reports submitted for lakes in southern Snohomish County, and in King County, 1952-2000.



Since the mid-1970s WDFW district fishery biologists have provided the Washington State Hi-Lakers and Trail Blazers, Inc. annually updated lists of high lakes that they would like surveyed. In about 1998, the Washington State Hi-Lakers initiated a more rigorous survey program. While stocking of the high lakes is the principal objective of the Trail Blazers (Yadon et al. 1993), the Washington State Hi-Lakers made lake surveys their principal objective.

WDFW management biologists meet or communicate with these clubs at least annually to discuss and coordinate the list of lakes to be surveyed in the upcoming year. The lake list will often specify the types of information sought from individual lakes, such as survival of previous introductions, or the presence of natural reproduction. Presentations to the club/s by biologists help assure that information obtained is accurate. Programs have been presented on amphibian life stage identification, as well as ways to gather data on trout age, growth, diet, and condition. Reports received from the club members are compiled, and a data summary is provided to the individual WDFW management biologists a few months after each hiking season.

While the Trail Blazers and Hi-Lakers contribute many trip reports to management biologists in several WDFW administrative regions (Table 8 and Figure 10), their number of trips and annual report submittals naturally diminish in more or less direct proportion to the trailhead distance from the Seattle area (Appendix I). Nevertheless, the groups do perform surveys in all areas of the Cascades, and to a limited degree in the Olympics. Management biologists in other districts have established feedback relationships with other groups such as the Backcountry Horsemen, or key local anglers, but none of these rival the scope or effectiveness of the program based in Seattle, which has been growing steadily (Figure 11).

Table 8. The Number of High Lake Fishing Reports Submitted to WDFW by Administrative Region, 1986 through 2000.

WDFW Region	Hi-Lakers Reports	Trail Blazers Reports	Total Reports[1]
2	594	134	681
3	529	185	640
4	2028	1002	2487
5	134	48	154
6	137	37	160

1 The total does not equal the sum of the two clubs since numerous individuals are members of both clubs.

Figure 10. The Number of High Lake Fishing Reports Submitted to WDFW by Year and WDFW Administrative Region, 1986 to 2000

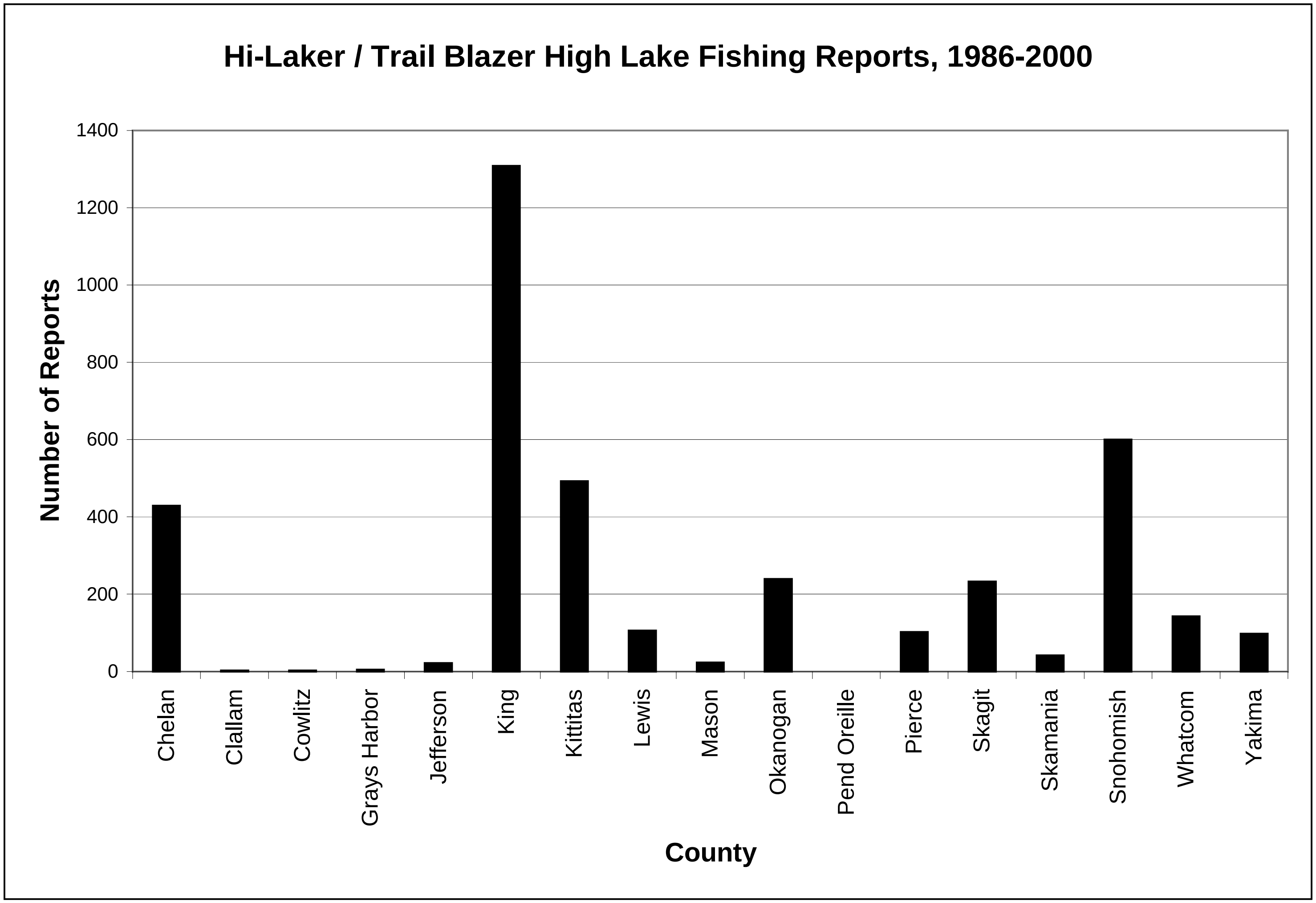
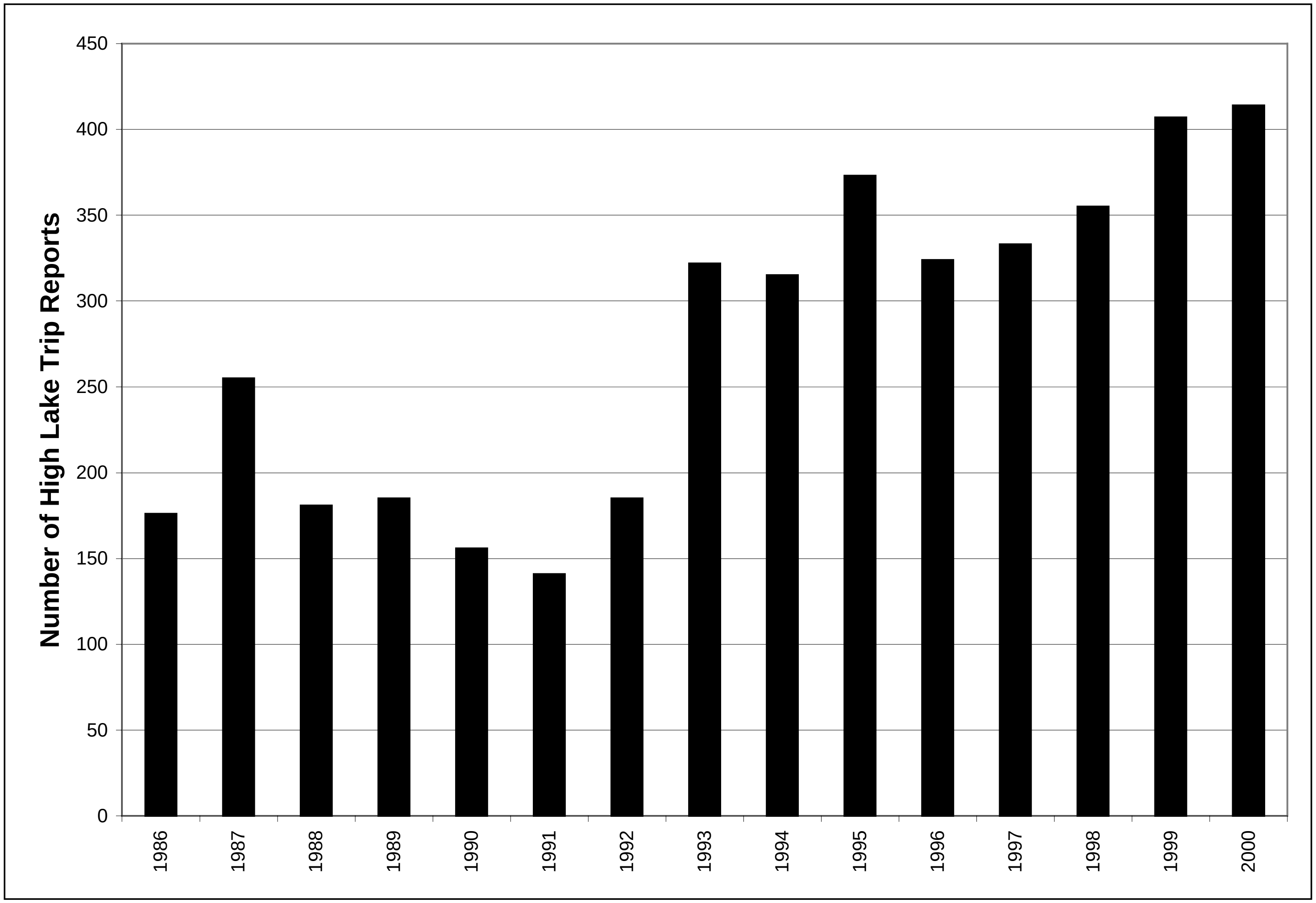


Figure 11. **The number of High Lake Fishing Reports entered into the Washington State Hi-Lakers database by year, 1986-2000.**



The statistical problems of creel survey in general (Carlander et al. 1958; Radford 1973), and volunteered information (Tarrant et al. 1993; Fisher 1996) are recognized. However, WDFW fish biologists have held recurring training sessions with members of the Trail Blazers and Hi-Lakers. The most active surveyors have many years of experience in the high country, and understand the data needs of the agency. This tends to minimize, but does not eliminate problems with data quality. Data collection biases associated with particular surveyors are also recognized by biologists who have long professional and social relationships with many of the surveyors. There is no substitute for the "filtering" function an experienced manager must perform with this type of data. This quality control can only be fully developed through experience, but a detailed description of the procedures and potential statistical pitfalls should be written. Despite the shortcomings, surveys performed by volunteers greatly increase the amount of information that can be collected for managers who have up to 600 high lakes on their districts.

The most valuable and reliable feedback provided by volunteered surveys include:

- Current access conditions; road closures, locked gates, trail washouts, access policy changes, etc.
- Presence of fish; success of preceding fry introductions.
- Size ranges of fish caught, and general fish condition.
- Number of other anglers and non-anglers at the lake/s during the survey.
- Number of, and condition of campsites.
- Verification of natural reproduction, if fry are noted that do not jibe with stocking record.
- Date of iceout.
- Observations of dead fish.
- Use of fish by other forms of wildlife.

Other valuable information, but less reliable, and needing strict quality control by the local management biologist, includes:

- Catch rates for fish present, by species.
- Relative abundance of fish.
- Absence of fish.
- Fish stomach contents.
- Presence of salamanders, by species.
- Presence of conspicuous zooplankton or macroinvertebrates.

A sample of the type and quantity of information available from the database of High Lake Fishing Reports is provided in Table 9. Close to 4000 trip reports have been logged since 1986. The data show that the party size of the type of high lake anglers found in the two Seattle clubs is generally one or two individuals, and that usually less than one other angler is present at the lakes visited. This is largely due to the fact that lakes for which a survey has been requested, or that these avid high lake anglers visit, tend to be small and remote. Selective queries of the database would yield much different information on larger, more popular lakes.

Table 9. Summary Statistics by County From Volunteered High Lake Fishing Trip Reports (Washington State Hi-Lakers and Trail Blazers, Inc. databases)[1].

County	No. of Lakes Surveyed[2]	Reports Submitted[3] Since 1986	Mean No. of Anglers in Party	Mean No. of Other Anglers at Lake	Mean Number of Hours Fished	Number of Reports Where Fish Caught	Percent of Trips Where Some Fish Caught
Chelan	164	429	2.0	0.9	1.3	253	59.0
Clallam	3	3	1.0	1.0	0.7	1	33.3
Cowlitz	3	3	1.0	0.0	0.8	0	0.0
Grays Harbor	3	5	1.7	0.4	1.7	4	80.0
Jefferson	15	22	1.6	0.0	0.9	14	63.6
King	303	1308	2.1	0.8	1.6	631	48.2
Kittitas	98	492	1.7	0.4	1.1	215	43.7
Lewis	51	106	1.8	0.4	1.1	42	39.6
Mason	12	23	1.7	0.4	1.2	14	60.9
Okanogan	118	239	1.9	1.8	1.5	137	57.3
Pend Oreille	0	0					
Pierce	56	102	1.9	0.7	1.0	39	38.2
Skagit	92	233	2.2	0.5	1.6	125	53.6
Skamania	29	42	1.8	0.2	1.1	16	38.1
Snohomish	163	600	1.9	0.6	1.6	273	45.5
Whatcom	62	143	1.8	0.3	1.4	69	48.3
Yakima	50	98	1.8	0.4	1.2	49	50.0
Total or Mean	1222	3848	1.74	0.56	1.23	1882	47.5

[1] There are numerous other data categories which are not shown in this table.

[2] The number of unique lakes in the county for which there is at least one volunteered trip report.

[3] The total number of trip reports for all lakes, including repeat reports on individual lakes.

Not all trip reports logged into WDFW district fish biologist databases or lake files are provided by organized sports club members. Numerous reports are annotated from unsolicited calls made by interested anglers to the local biologist. Relevant information (usually on non-fish related issues such as access) have been gleaned from chat group or trip report postings on web sites maintained by groups such as the Washington Trails Association (http://www.wta.org/scripts/wta/cgi-pvt/web9.pl?tr+fr+date) or Washingtonlakes.com (http://www.washingtonlakes.com). The popularity of these web sites suggests the Internet may be an effective way to solicit input from a larger segment of the high lake fishing public.

5.2.2 Assessment and Recommendations

Most of the local fishery managers are pleased with the quality and quantity of angler-based feedback they receive. Annual development by the biologists of lists of lakes to be surveyed results in the highest quality of feedback, given the limitations inherent in volunteer-based data collection. In the past few years, competing program demands have prevented some district biologists from preparing updated lists of lakes to be surveyed, which has diminished the effectiveness of the process.

Recommendation #1: Given the high overall value of the high lake fishery (Section 4.0), a greater amount of staff time should be allocated to restore full coordination with volunteers and organized sports groups on high lake fishery monitoring.

Recommendation #2: As staff time and resources allow, use of the Internet or the agency web site should be explored as a means to augment the volunteered information obtained from organized sports groups.

Recommendation #3: The Trail Blazers, Inc. and Washington State Hi-Lakers databases should be considered a resource to draw upon by WDFW fishery managers, even if on a contractual basis. This report has only touched upon the potential value of the statistical information contained within them.

Recommendation #4: The High Lake Fishing Report form (Appendix D) should be the basic form used to collect information from volunteers. It can be easily modified as needed for special purposes. Information from the form is logged to a database, which can be queried for various reports. Summary information can be readily prepared for inclusion in individual lake management summaries (Appendix C).

5.3 DATA MANAGEMENT

5.3.1 Stocking History

Purpose

There are several reasons to prepare an accurate and complete stocking record for the high lakes of each district. These include:

- Knowledge of past species and strain introductions to determine application of the Exotic Species Policy when "new" introductions are contemplated;
- To enable interpretation of differences in species and stock (strain) performance in individual lakes, or regionally;
- To be able to map the previous, or current distribution of species or strains across the landscape (Williams 1999), and interpret genetic information from wild fish in receiving waters;
- If historic "hard" agency records are lost or destroyed, they are often irreplaceable.

Historic and Existing Conditions

Records of fish introductions into lowland and high lakes between 1933 and the mid- to late 1990s were maintained in both regional and headquarters offices of the Washington Department of Game (WDG; later WDW, then WDFW). The majority of the records were hand-logged or typed onto a standardized "Record of Planting" card (Appendix E). Broad use of this card did not begin until the mid-1950s. Introductions made prior to about 1955 (for both high and low waters) were recorded on hatchery stocking sheets and other media, and were not always transferred to the new cards. Most of these early, pre-1955 records were archived in one or more locations in the WDG Olympia headquarters, or in regional offices.

Miscellaneous (far from complete) records of stocking performed by the various counties, as well as by the U.S. Forest Service, were deposited in individual lake files in the WDG headquarters warehouse.

Some WDFW fish biologists accessed these historical records (Pfeifer, Johnston) and incorporated them into the regional/district stocking databases. Other documentation, although somewhat less reliable by being unofficial, occurred in sportsmen's guides such as Piper & Taft, Inc. (1925). In at least one instance, these non-WDFW historical stocking records proved to be invaluable in explaining the "appearance" of a fish species not seen in a high lake in King County in many decades (see Section 5.7.2).

Concurrent stocking records were maintained by the Trail Blazers, Inc., based in Seattle. These consisted of introductions made by the club, as well as stocking performed by the WDG. They included trout stocked into lowland lakes, ponds, and streams as well as high lakes and ponds. Paper records, largely in the form of letter correspondence and copies of agency fry allotments and stocking summaries, were later converted to electronic databases by Mike Swayne, Trail Blazer Librarian.

The current WDFW stocking data recording procedure is a 5-step process beginning with preparation of a stocking allotment by the local fishery management biologist:

1) District fish biologists prepare their annual allotment for high lakes (or lowland waters) on their district.

2) Regional fish biologists combine the requests of all local biologists into a regional allotment, which is routed to the agency headquarters for approval.

3) When approved, allotments are forwarded to the affected hatcheries, whose staffs conduct the actual stocking. (Local biologists or volunteers may or may not assist in the stocking process. However, Trail Blazer implementation of much of the high lake stocking has occurred since 1933. See Section 5.4.5.)

4) As stocking is accomplished, monthly hatchery reports are distributed to the regional and/or headquarters offices. Introductions are entered into the headquarters databases as they occur, i.e., when monthly stocking reports are received. Regional office staff processes may vary; some regional staff elect to maintain their own local databases, and either enter stocking data as they receive it from the hatcheries, similar to the central database, or accumulate the information, and enter it at the end of the stocking season. (With respect to the high lake program, this latter approach has important quality control implications. See Section 5.4.5.)

5) Regional offices have an opportunity to perform a quality control check on the central stocking database when an annual summary of the previous year's introductions is mailed or emailed to the regional staffs for review. Not all regional biological staff apply rigorous quality control to the stocking data submitted by the hatcheries, but base their management decisions on previous allotments.

An important step affecting this process, but not strictly related to the management of high lake stocking data, is the preparation of egg allotments by the local fishery biologists roughly one year in advance of the actual stocking season. Biologists project their probable fry stocking needs about a year in advance so hatchery staffs can plan on collection of spawn from captive broodstock, or from semi-wild populations in broodstock lakes (see Section 5.5.3). This step would occur just before #1, above. Hard copies of egg allotments have been maintained in agency files, similar to fry allotments and stocking records.

5.3.1.1 *Historical Accuracy*

Some of the current and recently-retired WDFW district fishery biologists (Appendix A, Table 1) have taken pains to perform quality control on the historic stocking records for their districts (Parametrix 2001). The number of previous years where biologists feel they have successfully reconstructed the stocking history, or where they feel errors have been corrected, varies among the districts. Bob Pfeifer and Jim Johnston did a thorough review on the available information for high lakes in King, Snohomish, Skagit, and Whatcom Counties, and feel they may have successfully reconstructed the record of official high lake introductions back to 1933 and agency founding. Larry Brown also made a concerted effort to assemble a complete and accurate record for Chelan and Kittitas County high lakes. Ken Williams felt he had successfully reconstructed the record for Okanogan County lakes back to about 1966. Prior to that WDG Game Warden Dick Chandler and USFS employee Francis Lufkin had "stocked large numbers of fry" beginning in about 1961, but records of these introductions were unavailable (Parametrix 2001). It may be assumed that current records prior to the mid-1950s for other counties are incomplete, and to some unknown degree, inaccurate. No rigorous, standardized quality control process has been applied statewide to all high lake stocking records.

Bob Pfeifer found in his effort to minimize errors and omissions in the stocking record for King and Snohomish Counties that comparison of several sources of information was essential to identify errors. In a very small percentage of the overall individual stocking events, inconsistencies could not be resolved. (These were typically which unnamed pothole among a group of proximal pots was stocked, not whether a stocking event occurred.) The information sources included:

- Trail Blazer stocking histories and hard copies of records of their own, plus WDG;
- WDG/WDW/WDFW stocking allotments;
- WDG/WDW/WDFW hatchery stocking records;
- WDG/WDW/WDFW "Record of Planting" cards;
- WDG stocking data summaries for individual lakes or counties, located in regional and headquarters files; and
- Corroborating, but unofficial information in published angler guidebooks.

A general problem with the historic stocking database, even into the 1980s, was failure to note the strain, or sub-species of fish stocked (e.g., listing "cutthroat" and not noting 'Twin Lakes' or 'westslope', or 'Tokul Creek' (coastal)). However, in many cases the strain stocked could be inferred by the size of the fry and date of the release, where intimate knowledge is known of the production characteristics of individual hatcheries (e.g., coastal versus westslope cutthroat from the Tokul Creek Hatchery).

5.3.1.2 *Central and Regional Databases*

Central

All statewide inland fish stocking records back to about 1981 have been entered into a Unix-based Paradox database in WDFW's Olympia headquarters. New stocking information is entered into the database on a monthly basis as the hatcheries submit their stocking summaries at the end of the month. High lake stocking generally begins in June, and ends in October, although some unusual introductions have occurred as late as mid-December. Most high lake stocking data entry occurs from June through November.

Regional

High lake stocking data management varies among the regional offices. Some district biologists maintain records in databases or spreadsheets on their office PCs. Some regions continue to update the "Record of Planting" cards. A general problem is lack of a consistent, standardized approach to management of these data among the regions, and between the regions and agency headquarters. Some regions rely on the Hatchery Program (which dispenses the fish to volunteers and sponsors) to follow the allotments, and to track and make an accurate accounting of what gets stocked. This is then recorded in the central database, an updated electronic copy of which is annually sent to the regions for review. Other regions check stocking data accuracy earlier in the process by reviewing hatchery stocking sheets which are submitted to the central database.

Database Coordination

Most of the biologists polled in Wenatchee (Parametrix 2001) stated they had data inconsistency problems between their local records, and those logged to the central database. While the inconsistencies are not large (affecting many records, or involving large value errors), they are chronic. Most relate to problems of identification of the specific lake or pond actually stocked. This problem is almost always limited to small, unnamed lakes or potholes where a location descriptor such as a quarter Section is insufficiently precise to eliminate confusion with a nearby water body. The second most frequent problem is confusion over the name of a stocked water.

Both of these problems can be corrected by local fishery managers if they review the hatchery stocking sheets. Headquarters data entry staff do not have the intimate knowledge of the lakes, or the regional fry stocking allotments, to catch errors of naming or location that occasionally occur on the monthly hatchery stocking summary. These data entry errors can be caught and corrected when the annual stocking summary is mailed to the regions for review. An alternative approach would be for the local fishery managers to enter the stocking data into the central database. They have the best ability to identify errors in the data, particularly for high lakes. These problems are far less significant for lowland lakes and streams for which legal descriptions of stocking locations are generally adequate to prevent any confusion as to which water or stream reach was actually stocked.

An additional quality control check on high lake stocking data occurs when volunteers, notably Trail Blazers, notify the agency of the number of fry that were lost in transit, or during the stocking process. This results in small, but occasionally significant differences in the number of fry reported by the hatchery as having been "stocked", based on what left the hatchery, and what should be entered into the formal database. Most regions have set up procedures so that the number of fry lost in transit is deducted before the monthly hatchery stocking summary is submitted. Again, there are exceptions to this, and continual diligence by the local fishery manager, in coordination with any volunteers, is required to maintain the highest level of data quality. This has been a regular process with the Trail Blazer program since at least 1978.

5.3.2 Fishery Reports Databases

Volunteered angler trip reports have been submitted on High Lake Report Cards, and its updated version (Appendix D; see Section 5.2.1). Most biologists have retained the old cards in metal or manila files, and continue to access them from those repositories. The newer report form is distributed by the Washington State Hi-Lakers to the district fishery biologists either as single sheets as submitted by the reporting individual/s, or more recently, in a summary, stapled hard copy printout form. At this point local managers either separate the forms and file them in the relevant individual lake files, or convert the hard copies into electronic records.

Bob Pfeifer built upon a dBASE framework originally developed by Larry Brown in the mid-1980s (Appendix Table 1) to produce a concise summary output of all relevant management information for individual lakes in King County and portions of Snohomish County (Appendix F). This has been accomplished for about 600 waters in that geographic area, although only about 390 of these waters are actively managed for a fishery. This has the great advantage of presenting the historic, as well as the most recent trip report (monitoring) information alongside the stocking history and management prescription for each lake. This relational database system is the most efficient and valuable way local managers can utilize the continually evolving and growing information base on each managed water.

5.3.3 Management of Inventory Data, Cataloguing Data, & Permanent Files

All of the local WDFW high lake management biologists retain the original field data forms, lake sketch maps, and notebooks from baseline surveys in manila files and/or 3-ring notebooks. A few biologists (Larry Brown, Bob Pfeifer) have converted much of the field data to electronic databases (dBASE), although the original field notes have been retained. Several (Bob Lucas, Bob Pfeifer, Jim Johnston) have developed lake by lake summaries, or management plans (Appendix C) in electronic word processed files (PC-Write, Word Perfect, MS-Word). These files tend to be more complete than recent technical reports (Deleray and Barbee 1992), but are similar in many ways to the seminal works published in the early 1970s (e.g., Cummins 1973; Johnston 1973). This approach is most complete for high lakes in King, Snohomish, Skagit, and Whatcom Counties (1,514 waters), but has not been published in the form of the earlier technical reports. The degree to which these summary files, or lake by lake management plans have been completed varies from region to region (Table 10). Most of the other biologists are using spreadsheets to catalogue lake by lake data and brief management recommendations (Parametrix 2001).

Electronic files of basic field data and the lake by lake management plans have been backed up and stored in a safe deposit box for King and Snohomish County waters. Similar electronic files from other districts should receive similar care.

An electronic file listing the lakes defined as high lakes and used as the source for several figures and tables in this report is included as Appendix N. This file was assembled from several sources and includes lake names, identifications, sizes, elevations and locations. The file also includes a cross reference between various lake identifiers that have been used.

Table 10. Percent of Managed[1] Washington High Lakes (Exclusive of Olympic and Mt. Rainier National Parks and Yakama Indian Nation) for Which a Summary File or Management Plan[2] Has Been Developed as of 2001.

County	Number of Managed High Lakes	Number with Summary File or Management Plan (Percent)
Jefferson	38	38 (100)
Grays Harbor	6	6 (100)
Mason	24	24 (100)
Whatcom, Skagit, No. Snohomish	187	103 (55)
Southern Snohomish	143	80 (56)
King	532	532 (100)
Pierce	98	32 (33)
Cowlitz	11	11 (100)
Lewis	136	136 (100)
Skamania	254	254 (100)
Yakima	154	154 (100)
Kittitas	167	167 (100)
Chelan	302	217 (72)
Okanogan	240	108 (45)
Pend Oreille	15	15 (100)

[1] "Managed" means a decision has been made to maintain the water as fishless or with a fish population, whether or not a complete "baseline" survey has been made.
[2] "Plan" as used in this table consists of one or more surveys, and some sort of management prescription or recommendations (see Appendix C). Many local high lake management plans are not yet at the level or in the format set out as a goal by Fish Program leadership in the mid-1990s.

5.3.4 Assessment and Recommendations

Not all district fishery managers have done a thorough quality control check on their historic high lake stocking data. Counties in which a fairly complete check or reconstruction has occurred (e.g., back to 1955 or earlier) include Cowlitz, Lewis, King, Snohomish, Skagit, Whatcom, and Chelan Counties. Those for which data back to the late 1960s have been reviewed include Clallam, Jefferson, Mason, Pierce, and Okanogan Counties.

Recommendation #1: Temporary, student, or intern help should be obtained to complete reconstruction and quality control checks on the historic high lake stocking data in those counties for which it has not been completed. A one or two-page summary memo should be prepared giving an evaluation of the completeness and accuracy of the task, by region, and be made part of the permanent regional files (or part of an annual report).

Some confusion and lack of consistency still exists in the management of stocking information between regions, and between the regions and the central office. Example: the steps taken to document the number of fry that actually leave a hatchery and are stocked into a high lake (accounting for losses) differs between WDFW Region 3 and Region 4.

Recommendation #2: A workshop should be held between headquarters database managers and selected regional fishery managers. A consistent approach to the handling of stocking data should be agreed upon, from the preparation of allotments to the logging of final, end-of-season fry introduction numbers. Lakes should be identified at each step in the process by the code used in a central data management system. Simply identifying a lake by county and name or in the case of small ponds by Township, Range and Section often leads to confusion. The initial quality control screen of the hatchery stocking reports should be done by the district fishery management biologist. This could be facilitated and enhanced by their having the ability to query, enter, and edit the central stocking database.

Use of volunteered angler reports by management biologists varies considerably among the districts. For biologists with a small number of lakes and low numbers of monitoring reports, their management is not a significant issue. For biologists with hundreds of high lakes with managed fisheries, and who garner dozens of monitoring reports annually, a standardized report management system would be valuable.

Recommendation #3: A report management system should be agreed upon for those districts that have large numbers of historic reports, or which receive significant numbers of new reports annually. Staff time, or temporary help should be made available to develop this capability, and to train local fishery managers in its use. It should be built upon the model originally developed by Larry Brown for this expressed purpose, or a close facsimile.

5.4 STOCKING CONSIDERATIONS

The following section describes the managerial, biological, and logistical considerations that WDFW district fishery biologists assess when making first-time, or annual decisions to stock high lakes in Washington.

5.4.1 Assessment of Existing Trout Reproduction

Contrary to published misinformation (Bahls 1992), WDFW management biologists are unanimous in stating that the presence of existing reproduction is their foremost consideration in deciding whether to stock their high lakes (Parametrix 2001). The manner in which reproduction is assessed is described in Section 5.1.5. Most lakes under long term management have had an assessment of fish reproduction made (Table 5), but there are significant data gaps, such as in Chelan County.

A more subtle determination is whether natural reproduction is sufficient to maintain a quality fishery, or whether it is excessive, and harmful to invertebrates or amphibians. Fewer of the managers have developed this level of understanding of their lakes and fish populations. Managers who have made first-pass assessment of the <u>level</u> of reproduction in most of their current or previously-managed waters include Anderson and Cummins, Johnston, Pfeifer, and Williams. Most of the other managers have developed a “feel” for this through many years of stocking trial and error, including that of their predecessor managers, coupled with fishery monitoring. Most of the managers have lakes with low-level reproduction which they supplement at low levels on a periodic basis. No manager knowingly adds fish on top of populations of stunted trout or char.

Some district managers have adopted a strict “policy” of not stocking any lake for which reliable information on reproduction was unavailable. (In the case of King and Snohomish County high lakes, a delayed stocking decision primarily occurred for lakes on a cyclical stocking program that were “due”, but for which a reproduction assessment was lacking. These lakes were the first to receive baseline, or Level 1 surveys, prioritized on the basis of ease of access, and potential or documented ability to provide a fishery. In a very few cases, mostly in the mid- to late 1980s, truly new, first-time fish introductions were made, but only after a thorough baseline survey had occurred.).

5.4.2 Stocking Frequency and Density

5.4.2.1 *Frequency and Density*

Although these are two of the most important aspects of high lake fisheries management, there has been relatively little rigorous research in Washington on the underlying factors which determine them, such as natural and angling mortality of trout in high lakes, or angling effort (trips or cumulative hours spent fishing). This lack of detailed investigation is due to factors such as lake access difficulties, low agency staff resources, and dispersed angling recreation, particularly in remote wilderness lakes.

Very limited research-based information on natural and angling mortality of trout in high lakes has been developed, particularly in Washington. In his study of Olympic National Forest lakes in Washington, Johnston (1973) assumed a 10% annual natural mortality rate, and constructed a matrix to estimate trout production to Ages I through V at three different angling mortality rates. Lucas (1989) developed similar trout production tables for lakes in Cowlitz and Lewis Counties, but he assumed higher angler mortality rates than Johnston (1973). This is reasonable, since many of the lakes in Lucas' district are more accessible than the lakes in Johnston's (1973) study area. Working in Colorado between 1967 and 1987, Nelson (1987) calculated annual mortality rates ranging from 40 to 60% for rainbow in Lower Agnes Lake over nine survey years, and 58 to 79% in Summit Lake over four survey years. Nelson also found that brown trout (*Salmo trutta*) had much lower mortality (25%). Nelson's mortality estimates were calculated from gill net catch curves, and therefore are the sum of both natural and angling mortality.

Apart from accepting the stocking rates and frequencies proposed by Johnston's (1972, 1973) initial estimates of trout survival and production in Washington high lakes, most local WDFW biologists have had to use professional judgment, and trial-and-error in establishing stocking rates and frequencies on their lakes. This approach suffers from several limitations:

- Assumed trout mortality rates in broad regional models are insensitive to variability between lakes, or between years; and
- Assumed angler effort and catch success levels are insensitive to changes in access, either between years for individual lakes, or among groups of lakes with naturally varying access difficulty.

There may be no practical way to monitor angler effort with sufficient precision to make small adjustments in stocking rates or frequency to account for rises and falls in angling mortality. The best approach is to obtain some good estimates of natural and angling mortality from lakes that fall into ranges of productivity and angler use, and make general application of the results. Marked fish studies with annual sampling to develop catch curves on fish of known age for the purpose of estimating annual mortality have not been accomplished in Washington.

Lucas (1989) built upon the approach originally suggested by Johnston (1973), and developed a series of production models for varying levels of angling pressure. He recommended choosing the model that best fit the angling pressure and potential lake productivity conditions.

Despite the lack of detailed studies on mortality and angling effort, the average length of time between re-stocking of Washington high lakes has increased substantially since 1970, while the number of fish stocked per surface acre has dropped as well (Figure 4). The statistics plotted in Figure 4 are for lakes that have very little or no natural reproduction occurring in the trout or char populations. Lakes in the latter category are usually not stocked at all. Most biologists endeavor to match stocking frequency and fish density with some assessment of angling effort, so as to provide a reasonable expectation of catch success on quality trout, while allowing the fish populations to dwindle to a low level before re-stocking. The vast majority of lakes are stocked at levels below 100-150 fry /acre. Stocking frequencies range from annually on lakes that are accessible by roads, or are easily accessible and heavily fished, to once in 10 or more years on remote, seldom-visited wilderness lakes. The statewide mean number of years between stocking is currently about 4 years (Figure 5), although this varies between regions, and is largely dictated by lake access and fishing pressure.

Most WDFW local managers adjust their stocking frequencies (cycles) and fish densities to provide "quality" fish in those lakes where they have the ability to do so (little or no natural reproduction is occurring). Trout or char reproduction in many lakes provides opportunity for "fast" fishing on smaller fish, and thereby offer a consistent fishery for those users who expect to find fish in the lakes. These are often categorized as "family" type waters. While management objectives definitely vary among lakes, with remote wilderness lakes often being managed differently than high lakes that are heavily visited, most WDFW managers try to strike a balance between consistent opportunity (a minimum average catch rate) and overstocking, with the latter's resultant impacts on fish size.

Table 11 illustrates the impact on fish growth that can occur when reproduction is excessive, versus the growth potential of some trout stocks in lakes where fish numbers can be controlled. Two lakes illustrate high and low growth rates that are likely at the extreme ends of the observed spectrum; data from two other lakes are provided for comparison. Fish from stunted growth and fast growth lakes are shown in Plates 36 and 37, respectively.

Table 11. A Comparison of Low (Disciplined Stocking) Density, and High (Reproducing) Density With Trout or Char Length at Age in Six Western Washington High Lakes.

			Mean Total Length at Age (in)			
Lake	**Density**	**Stocked Fry / acre**	**Age 1**	**Age 2**	**Age 3**	**Age 4**
Little Kulla (CT)	Low	64	4.7	7.5		
Thompson (RB)	Low	115	5.4	9.8		
Unnamed[1] (RB)	Low	83	3.9	9.1	12.7	16.2
Elochoman (EB)	Low	125		9.75	11.5	
Hatchet (CT)	High		3.4	5.3	7.3	8.6
Blanca (RB)	High		2.4	3.5	4.8	6.1
Joan (EB)	High					7.4[2]

1 Lake not named due to sensitivity to overfishing.

2 Could not read scales; length at age from otoliths.

Plate 36. Late fall casts a harsh shadow behind stunted eastern brook trout from Joan Lake in the Rapid (Skykomish) River drainage. The fish, 6 to 8 inches long, were 3 to 5 years old. (20 October 1998)

Plate 37. Mount Whitney rainbow exhibit superb condition and fast growth in a lake that is stocked every 4 to 5 years at relatively low density. Skagit River drainage (19 October 1986).

5.4.2.2 *Continuity of Fish Presence*

There has been considerable debate both within WDFW, and between WDFW and sports group members on the relative merits of stocking lakes to maintain a constant presence of fish (albeit at low density), or whether lakes should be allowed to go fallow for a year or two before restocking. Arguments against allowing all fish to die out include:

1) Hiker/anglers who go to the very considerable trouble of arduous back country travel to a lake which has a history of supporting trout should be rewarded by finding at least some in the lake;

2) Stocking a single allotment of Age 0 fry, then allowing that group to age and die from angler harvest or natural causes before restocking creates "boom and bust" fisheries, mostly on fish of Age 2 to 4;

3) Allowing a lake to go fishless may increase the probability of its being illegally stocked, with potentially disastrous results (see Section 5.4.2.4); and

4) Maintenance of a low-density trout population, where one to several year classes of fish are present, does not have an excessive impact on, or eliminate native invertebrates or amphibians.

Arguments for allowing all fish to die out for 1 or 2 years before restocking include:

5) Having fish continually present in a lake, particularly one that can produce "quality" trout, may tend to incrementally increase angler utilization, and may increase shoreline or general environmental overuse impacts. This is a particularly compelling argument for lakes that are currently seldom-visited, or that currently receive only light use;

6) The converse is believed to be equally true – that managing for very low fish density, or fish absence for 1 or 2 years tends to prevent development of a general public expectation that fish and fishing opportunity will always be present at a given lake; and

7) Allowing all or nearly all fish to die out before restocking greatly reduces predation on invertebrates and amphibians for a few years, allowing them to return to pre-stocking levels. The next group of fry stocked then has an optimum food supply to produce the next fishable trout population. This management approach maximizes trout growth rates and flesh table quality.

Although the frequency of stocking, or stocking "cycle" is a fundamental aspect of the management of lakes that require stocking, there is little rigorously-obtained information on these pro and con arguments. As a consequence, opinions vary among both WDFW fishery managers and the sport fishing public on the relative accuracy or relevance of each argument. Variability in lake access, angler use, lake productivity, and other attributes make it even more difficult to determine which of the arguments or paradigms are most often true. In reality and practice, some lakes can or should be managed for periodic fish absence, while in others it makes better sense to maintain at least some fish all of the time. Some additional discussion of the pro and con arguments follows.

Con #1: WDFW managers strive to maximize sport fishing opportunity, while at the same time protecting the subalpine and alpine lake ecosystem, per Fish and Wildlife Commission mandate (see Section 3.0). Having at least some trout in a particular lake at all times should be permissible if it does not eliminate other species, or create intractable management problems for other land and resource managers. Striking this balance requires an understanding of each lake's basic productivity potential and average annual angler harvest or effort level; frequent monitoring; and flexibility by the local, professional fishery manager. As noted by the Commission, the goal of management is to provide opportunity, and opportunity to catch fish still exists even when their numbers are low.

Con #2: There is no question that on average, angler catch rates and catch success are highest the second or third year after fry are stocked in a barren high lake if fish are not stocked annually. The theoretical abundance of fish from year to year following stocking, assuming certain levels of natural and angling mortality, are explored in production model tables presented by Johnston (1973) and Lucas (1989). However, these tables also show that fish are available for up to six or seven years, depending on angling mortality. If angler pressure is high, the remaining fish density can drop fairly rapidly, depending on the initial stocking density, leading to the "boom and bust" phenomenon.

Table 12 shows how the presence of fish over 7 inches can vary, depending on stocking frequency. Given certain assumptions about average natural and angling mortality, the number of years in a decade that fish of this size or larger are present varies from 6 for a 5-year stocking frequency, to 8 for a 4-year cycle (not shown), to continuously for stocking at a 3-year interval or less. The challenge for the local fishery manager is to weigh the relative benefits of providing frequent or continuous fishing opportunity against the potential for ecological impacts at the higher fish densities and stocking frequencies. Even where a 3-year stocking cycle begins with a barren lake, three year classes are continuously present by the 6th year. The model presented in Table 12 is generalized, and certainly does not apply to remote lakes that are seldom visited, or, for lakes that are very productive.

Table 12. Theoretical Comparison 0f Number Of Fish >7" Per Surface Acre Under Differing Stocking Strategies

(5-Year Stocking Cycle and Stocking Rate Of 30 To 100 Fish/Ac in a Lake of Average Productivity). Stocking Years Are Emboldened. Years Where 7" or Larger Fish Exceed 10 Fish/Ac Are Shaded. Adapted From a Table Originally Produced by WDFW Fish Biologist Jim Johnston.

Year:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Fish Size at Age	2-3"	7"	9"	11"	12"	13"	14"	15"		
Natural Mortality in Year (%)	5	10	10	25	35	35	45	55		
Total Mortality in Year (%)	5	20	30	50	70	70	70	80		
5-Yr Cycle	1	2	3	4	5	6	7	8	9	10
30/ac	0	23	16	8	2	29	23	16	8	3
50/ac	0	38	27	13	4	49	39	27	14	4
70/ac	0	53	37	19	6	68	55	38	19	6
100/ac	0	76	53	27	8	97	78	65	27	8
3-Yr Cycle	1	2	3	4	5	6	7	8	9	10
30/ac	0	23	16	37	25	17	37	25	17	8
50/ac	0	38	27	61	42	28	61	42	28	14
70/ac	0	53	37	85	59	39	85	59	39	19
100/ac	0	76	53	122	84	56	122	84	56	27

Assumptions: The lake is barren in Year 1. 5% stocking mortality; angling mortality includes catch and release mortality; fish rarely live longer than 7 years.

In summary, WDFW has not prepared a thorough analysis or theoretical model which would effectively prescribe stocking levels and frequencies on individual lakes. Although this would be a valuable management tool, it is questionable whether this is even feasible, given the changes that occur in angler use levels, access conditions, and climate, all of which affect trout survival in lakes, even if a lake's basic productivity potential is fairly constant. The principal value of further development of the mortality analyses prepared by Johnston (1973) and Lucas (1989) may be to further general understanding of the probable range in annual trout mortality. Year to year decisions on stocking density and frequency should be based primarily on the historic stocking record on each lake, subsequent trout growth and condition, evidence of survival of vulnerable trout prey, and the most up-to-date angler reports from the monitoring program.

Con #4: Work conducted by Oregon State University in North Cascades National Park for the National Park Service illustrates that WDFW's low-density trout stocking program does not result in elimination of invertebrate or amphibian taxa (Liss et al. 1995). Abiotic factors may be more important in determining the presence or abundance of salamander larvae (Tyler et al. 1998). Tyler et al. (1998) noted that "the detection of differences in larval densities between fishless lakes and lakes with trout was related to the reproductive status of trout populations, which likely was indicative of trout density and age and the size structure of trout populations". Table 13 provides trout density information on a sample of NCNP lakes that were found to be compatible with native biota. (Larval abundance ranged from zero to nearly 170 per 100 meters of surveyed shoreline in their entire lake sample. More complete information than that presented in Table 10 is currently being prepared by OSU.) Bahls (1990) studied 91 lakes in 1986 and 1987 in the Selway-Bitterroot Wilderness, and found that seven fishless lakes stocked more than 10 years prior to the time of survey showed "no obvious differences from 'pristine' fishless lakes". These studies are taken as good evidence that periodic stocking, particularly when done at low densities, does not lead to invertebrate species extinction. However, Bahls (1990) did not provide data from his study lakes that would indicate whether they supported more than one age class of fish at any point in time. Since invertebrates were not eliminated from lakes where more than one age class was present, fish density appears to be the more important factor leading to severe overgrazing on invertebrates. These results tend to support the argument that periodic stocking leading to the maintenance of multi-aged trout populations in high lakes does not impact native biota unduly, as long as overall fish density is kept low.

Table 13. Empirical Relationship Between Stocking Density and Observed Presence and Abundance of Salamanders and Invertebrates in North Cascades National Park.

Lake	Density of Trout Present (Number / ac)	Salamander Larvae Abundance (No. / 100 m)	Observed Range of Larval Abundance (all lakes)
LS-1	243	20.93	0.0 – 169.7
LS-2	293	0.79	
Upper Panther	243	23.00	
Lower Panther	158	8.71	

Pro #5 & #6: No published information was found that directly supports or refutes the hypothesis that providing fishing opportunity on a consistent basis generates more recreational use on a high lake in Washington than when fish are periodically absent. A practical argument against more frequent stocking (while still keeping fish densities low) is the logistical one of not having sufficient trained personnel available to carry out a significantly larger annual stocking program (a higher number of lakes due to more frequent stocking). This does not directly address the question, however, since in <u>theory</u> a larger stocking workforce could be developed. A rigorous test of the hypothesis would call for selection of a sample of stocked lakes, and altering their treatments, with some being stocked less frequently such that fish die out or become scarce. Recreational angling use of each lake would need to be carefully monitored, probably in conjunction with a user survey to correct for normal year to year variation in use, such as caused by changes in weather or access. The difficulty of monitoring angler use on many wilderness lakes has prevented a suitable test of this hypothesis.

Although Hendee et al. (1977) did not address this hypothesis directly either, their data did show that in moderate to high-use areas, limitations on fishing (i.e., not maintaining a fishable population through stocking) would not have an appreciable effect on user impacts since fishing was either an incidental activity, or anglers were far outnumbered by other users. For virtually all wilderness high lake users, the focal point is the lake (Plates 38, 39, 40). Hendee et al. (1977) note that “modifying the fishery to modify visitation at high lakes is, at best, a partial solution” to overuse problems.

WDFW managers with many years of experience have accumulated considerable anecdotal evidence that in some cases allowing fish to become scarce or absent results in fewer annual visitations, particularly at very remote or difficult to access lakes. Some evidence for large fluctuations in angler use can be found in volunteered angler reports (see Section 5.2.1), but at least some of these are related to the presence of unusually attractive species, such as golden trout. Overall, there has been little or no scientific evaluation in Washington of the numerical response of human visitors to lakes in relation to the abundance or presence of stocked trout. On many wilderness lakes, the number of angling visitors is a small fraction of the total use at or near the lake (Wenatchee and Mt. Baker-Snoqualmie National Forests 1993). Angling is very often an incidental activity for wilderness users, with numerous other aspects of the wilderness experience (e.g., solitude and aesthetics) assuming a much higher value (Hendee et al. 1968). Only 3 percent of users of the Enchantment Lakes area of the Alpine lakes Wilderness listed fishing as their primary activity (Shelby et al. 1989).

(As a side note, a study of “a high influx of backpackers” on two series of lakes in the Sierra Nevada of California concluded that the use did not have a negative effect on alpine lake water quality (Silverman and Erman 1979). The authors also opined that the presence of users at the lakes probably resulted in some reduction in bacterial contamination due to reduced wildlife use of the immediate lake environs.)

Pro #7: There have been no scientific studies in Washington directed specifically at the question of whether allowing fish to die out or become scarce allows complete recovery of a grazed invertebrate or salamander population. Bahls’ (1990) survey of over 90 previously-stocked lakes in Idaho strongly suggests allowing a cohort of trout to die out will allow a lake’s invertebrate community to recover to its mean annual abundance. What is not known is whether this same recovery would occur even if some small residuum of fish remained in the lake towards the end of a stocking cycle. These points will probably remain largely academic due to the inability of WDFW managers to manage or monitor their lakes at this level of precision.

Empirical observations made by WDFW high lake fishery managers show maintenance of large, conspicuous invertebrates such as *Hesperodiaptomus kenai* in lakes where periodic stocking occurs at moderate levels, such as 50 to 100 fry/acre (Table 7). The managers have also noted that when *H. kenai* is relatively abundant, stocked trout often utilize it as a primary dietary item, resulting in deep orange to red flesh color from astaxanthin and carotenoid pigments (Andre 1926; Miki 1991; Bjerkeng 1997)(Plates 29, 31). Trout which have an abundant macro-zooplankton food supply often exhibit exceptional condition (Galbraith 1975) in Washington high lakes. The high lakes in Washington where this condition exists (high quality trout at low density in sympatry with conspicuous macro-zooplankton) are too numerous to list.

A summary conclusion on the subject of continuity of fish presence cannot be based on hard science from Washington. Studies on the effects of trout presence and abundance on invertebrates (Divens et al. 2001), coupled with the many decades of experience of WDFW high lake fishery managers (Appendix A,

Table1), lead to the general conclusion that in most cases, continual presence of trout, as long as they are not excessively abundant, does not result in overuse of the lake or lakeshore environment, or result in extirpation of invertebrate food supplies. See Section 5.9 for discussion of possible exceptions, particularly with respect to human overuse.

Plate 38. The impact of social trails and heavy recreational use is clearly evident, even from afar, in this view over Silver Lake near Monte Cristo in the Silver Creek and North Fork Skykomish River drainage. Silver Lake has never supported fish due to high mineral content, which illustrates the fact that the aesthetics of the lake and surrounding environment is often the overriding factor driving use levels. Eight people are crowded into a thin space 20 feet wide along the lakeshore on (1 August 1996) (bottom of photo).

Plate 39. Heavy camping and wandering have left large areas of bare mineral soil at Silver Lake (1 August 1996).

Plate 40. Heavy recreational use at fishless Silver Lake has prompted the Skykomish Ranger District to attempt vegetation recovery. (1 August 1996)

5.4.2.3 *Termination of Stocking in Individual Lakes*

Lakes with a history of trout stocking are occasionally removed from the stocking program. Reasons to terminate stocking include:

- Initiation of, or an increase in natural reproduction by trout or char in the lake (see Section 5.6.1);
- New knowledge that natural reproduction is occurring in the lake, and is sufficient to support the fishery;
- Complete loss of angler access;
- As part of a coordinated regional approach to managing the high lake fishery, in cooperation with other land managers (USFS, NPS), where new fisheries are created to replace those eliminated.

The decline in the number of lakes being stocked (Figure 3) is almost wholly due to changes in fish reproductive status – either trout or char have begun to spawn in lakes where they did not in the past, or recent surveys have documented spawning that had previously not been discerned or reported. Most of the few remaining lakes that have been dropped from the stocking program are on lands administered by the USFS or NPS. However, it is important to note that no new lakes on federal lands were added to the program to offset those that were lost due to the creation of the North Cascades National Park (see Section 5.9.2).

5.4.2.4 *Termination of a Managed Stocking Program*

Large numbers of the sport fishing public desire lake fishing opportunity in Washington's back country and wilderness areas (WDFW 1996a). The experience of long-tenured district fishery biologists (Appendix A, Table 1) has clearly shown that some members of the angling public are perfectly willing and able to pack fish into their favorite lake, despite this being illegal (RCW 77.15.250; RCW 77.15.290). In rare instances anglers have contacted a local WDFW biologist before taking this drastic step (e.g., a documented case involving Joe and Edds Lakes on either side of the Pacific Crest Trail [WDFW Mill Creek regional office files]). Recently, lakes in Mount Rainier National Park and in the Mount St. Helens National Volcanic Monument in which fish have been removed or died out have been illegally re-stocked by members of the public. Bootleg stocking of miscellaneous small lakes has been a problem for many years, but has been reduced to a very low level in the past 10 to 15 years.

Much of the perceived reduction in illegal stocking is probably due to the more disciplined (higher quality) nature of the WDFW high lake fishery management program that has developed in the last 25 years. Elimination of a controlled, professionally-managed stocking program in wilderness or backcountry areas runs the very real risk of spurring an increase in illegal stocking. In many cases, probably a majority, readily-available species from lakes already overrun with reproducing fish would be chosen as sources of fry. Thus, eastern brook trout or westslope cutthroat would probably be the most common species illegally transferred to lakes that were dropped from their historic stocking regimes. This would have the definite effect of creating additional spawning populations and excessive fish abundance in some of, perhaps most of the lakes, rather than maintaining quality fisheries based on low-density, periodic stocking of species and strains which cannot or do not reproduce. In most cases illegal introduction of these "volatile" species would simply increase the number of lakes impacted by excessive numbers of trout or char, rather than maintaining a fish density which has been shown to be compatible with native invertebrates and amphibians in Washington (Divens et al. 2001).

It is also very important to note that creation of new, self-sustaining fish populations would be essentially irreversible in some lakes due to the physical impossibility of totally removing all fish, chemically or otherwise. WDFW has been experimenting with biological controls in lakes such as these, with very limited positive results (see Section 5.7.2).

5.4.3 Species and Stock Selection

See Crawford (1979) for a partial description of the individual species stocks and strains used in the historic and current WDFW high lake program. Crawford did not review all strains that have been used in Washington in the latter 20th century, but limited his review to those brood stocks maintained by the State of Washington. Numerous other strains and species have been used or tested since 1970. WDFW local managers choose species to stock based on the following considerations:

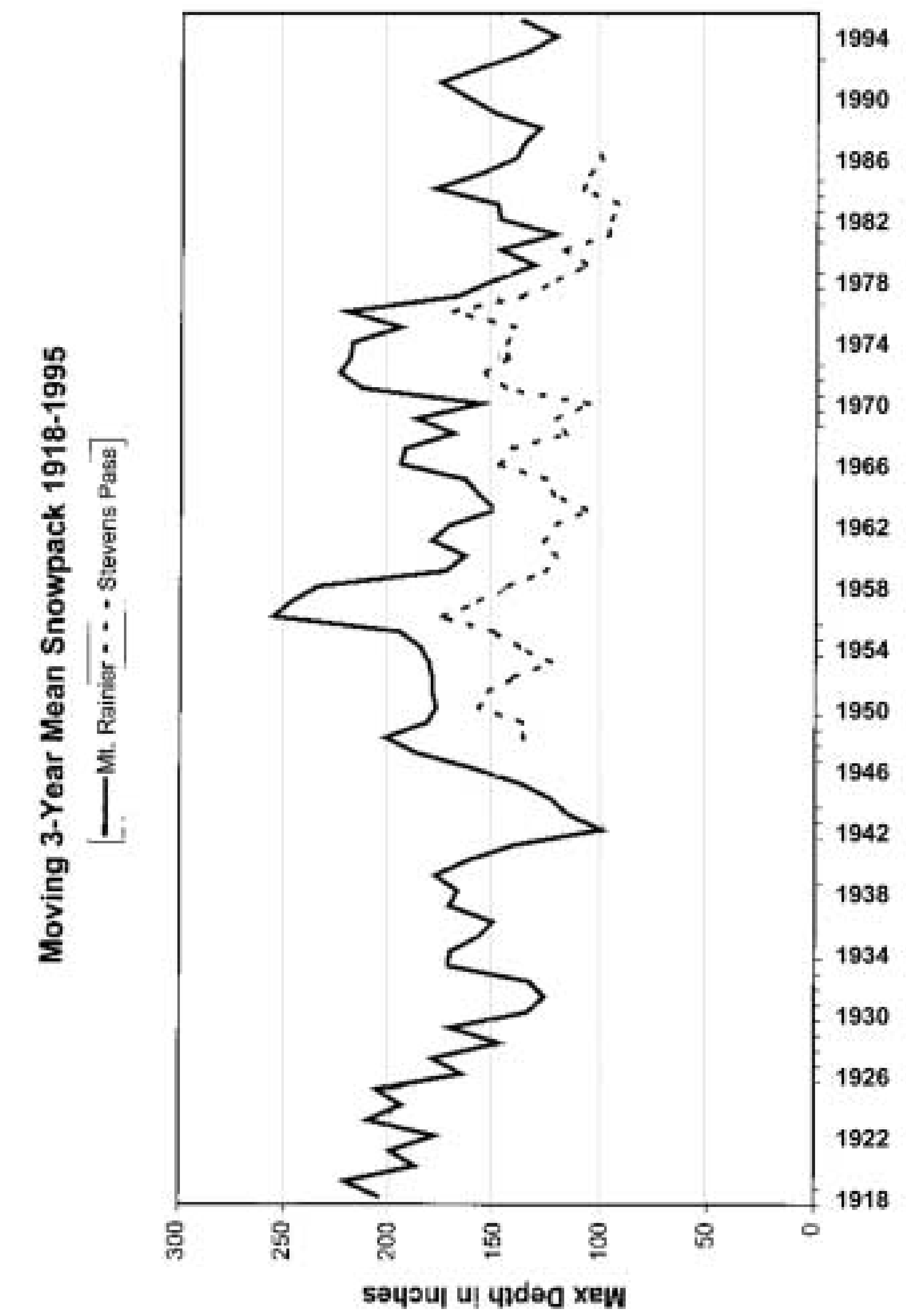
- The current species present in the lake, and its past performance;
- Whether greater program diversity is needed or desirable on a local regional basis (WDG 1981);
- As part of on-going evaluations of potential apex predators (biological controls) in lakes with stunted trout or char populations (see Section 5.7.2);
- Whether emigration or fallout and downstream genetic impacts are a current or potential problem; and
- To assess the performance (sporting qualities, growth characteristics, etc.) of a new strain.

In general, if the species is or are performing well in a lake that requires periodic stocking, the species or strain/s will continue to be stocked. Monitoring of the fishery in individual lakes is, therefore, a critical management element, and serves to alert the manager of changes in species or stock performance. A perfect example is the development of successfully reproducing populations of Twin Lakes (westslope) cutthroat in lakes where they did not reproduce in the past. Use of this stock has nearly ceased in most areas of western Washington as a result, but the strain is still used extensively in eastern Washington.

(The cause/s of the remarkable increase in spawning success of Twin Lakes cutthroat in western Washington lakes where they did not formerly reproduce remain a mystery, and the subject of considerable conjecture. Mechanisms suggested include inadvertent selection of more beach or alluvial fan spawners from the Twin Lakes, or longer open water periods due to climate change. The latter theory seems more likely since spawner collection methods have changed very little at the Twin Lakes in recent decades. Earlier clearing of lakes and longer open-water periods in stocked lakes could allow more temperature units to be accumulated by incubating eggs laid in tributaries, resulting in either successful fry emergence before winter, or earlier fry entry into the lake and longer feeding before winter conditions set in. Either of these scenarios could result in the observed increased survival of naturally-spawned westslope cutthroat fry. Support for the longer open-water theory is found in Figure 12, which suggest a declining trend in peak snow pack from the early 1970s, particularly in the north central Cascades as indexed by depths taken at Stevens Pass.

Providing a diversity of species and strains within management districts has varied among the WDFW local managers. Some have used one or two species almost exclusively (e.g., Twin Lakes cutthroat in Okanogan County lakes). The greatest level of experimentation and use of diverse strains has been in King, Snohomish, Skagit, and Whatcom County lakes, where up to 16 strains of trout and char have been available within a 75 mile radius of Seattle (Curtis and Erickson 1992; Mottram 1994). See Section 5.5.4

Figure 12. Moving 3-Year Mean Maximum Snow Pack Depth at Mt. Rainier And Stevens Pass, 1918-1995.



for a list of the species and strains that have been used. Notable past species tests included atlantic salmon (*Salmo salar*), which have exhibited superior sporting qualities and growth where tested, except when in competition with rainbow (Plates 41 and 42). Brown trout have attained large size and excellent condition in a number of lakes where they have been introduced to serve as top predators on stunted fish (see Section 5.7.2).

Although some of the most regrettable early introductions involved eastern brook trout, this species provides excellent diversity, sporting characteristics, and table quality where its numbers can be controlled (Plate 43). Use of eastern brook trout is most common in the southern Cascades (Cowlitz, Lewis and Skamania Counties) where it has performed well in many lakes for many years, and where hybridization issues with native char are not a concern (e.g., in lakes with no surface outlet).

Arctic grayling (*Thymallus arcticus*) were stocked in three or four disparate locations in western Washington in the mid-1940s, but only survived in one high lake in the Skagit River drainage. They continue to be a very popular draw for serious anglers interested in experiencing this species in Washington. Although a number of local managers are still interested in utilizing this species in a very limited number of other lakes, there is no readily available source of fry.

Lake trout (*Salvelinus namaycush*; Plate 44) were stocked very early in the 20th century in a small number of lakes (Piper & Taft, Inc. 1925). Self-sustaining populations occur in only two or three high lakes statewide. New introductions are rare, and have been limited to lakes where they have been introduced in the past, or as a test of their ability to control stunted eastern brook trout (Section 5.7.2).

A variety of rainbow and cutthroat strains have been tested by the Trail Blazers, Inc. with WDFW permission (see Section 5.5.4). Anecdotal information, some of which is documented in volunteered angler reports (Section 5.2.1), indicates sport quality and growth was exceptional for most of the varieties, particularly when they did not have to compete with reproducing fish. However, some strains seemed to compete better with stunted species than the traditional strains used by WDFW. Hybrid crosses, notably steelhead x golden trout, have been reported to exhibit many of these same characteristics (hard fighting, fast growth, exceptional appearance, etc.). Limited evaluation of the use of these hybrids to control stunted fish is currently underway (WDFW 1995b).

5.4.4 Genetic Impacts & Ecological Interaction

Since virtually all high lakes in Washington were originally fishless, genetic impacts from trout or char stocked into high lakes, if any, would generally be limited to native fish that exist downstream from the stocked lake. (See Section 5.6.2.) WDFW local managers are aware of the need to consider the potential for dropout or emigration from stocked lakes, and possible interbreeding with native salmonids. Native stocks used on the eastside of the Cascades include Twin Lakes (west slope) cutthroat (Plate 45). In western Washington Tokul Creek (coastal) cutthroat (see Section 5.5.2) have been used, and their use is being expanded as a substitute for Twin Lakes cutthroat. Rainbow in the Skagit River above Gorge, Diablo, and Ross Dams are being considered for development as a native stock that can be used as a substitute for Mount Whitney rainbow, where appropriate.

Native bull trout or Dolly Varden are currently being considered as apex predators in lakes where biological control of excessively abundant char or trout is desired. No brood collections or fry introductions have been made, but char stocks native to the river basin would be used in test lakes located in the same watershed from which the brood fish were obtained.

Plate 41. Two atlantic salmon (outer fish) and one Mount Whitney rainbow from Nine Hour Lake in the Middle Fork Snoqualmie River drainage, (4 September 1985). The salmon are 4 years old.

Plate 42. Four Atlantic salmon from Lake Serene, Skykomish River drainage (11 July 1978). Although the fish fought well, they exhibited slow growth when in competition with rainbow in this lake. The salmon were 3 years old

Plate 43. Eastern brook trout commonly grow well and exhibit fine condition in lakes in the southern Cascades and Indian Heaven wilderness. Stunted populations are far less common in this geographic region. John Thomas photo.

Plate 44. Lake trout from Eightmile Lake, Icicle Creek and Wenatchee River drainage. G. Ring Erickson photo.

Plate 45. Twin Lakes (west slope) cutthroat exhibit classic spotting and fine coloration in Little Cougar Lake, North Fork Snoqualmie River drainage. (25 September 1991)

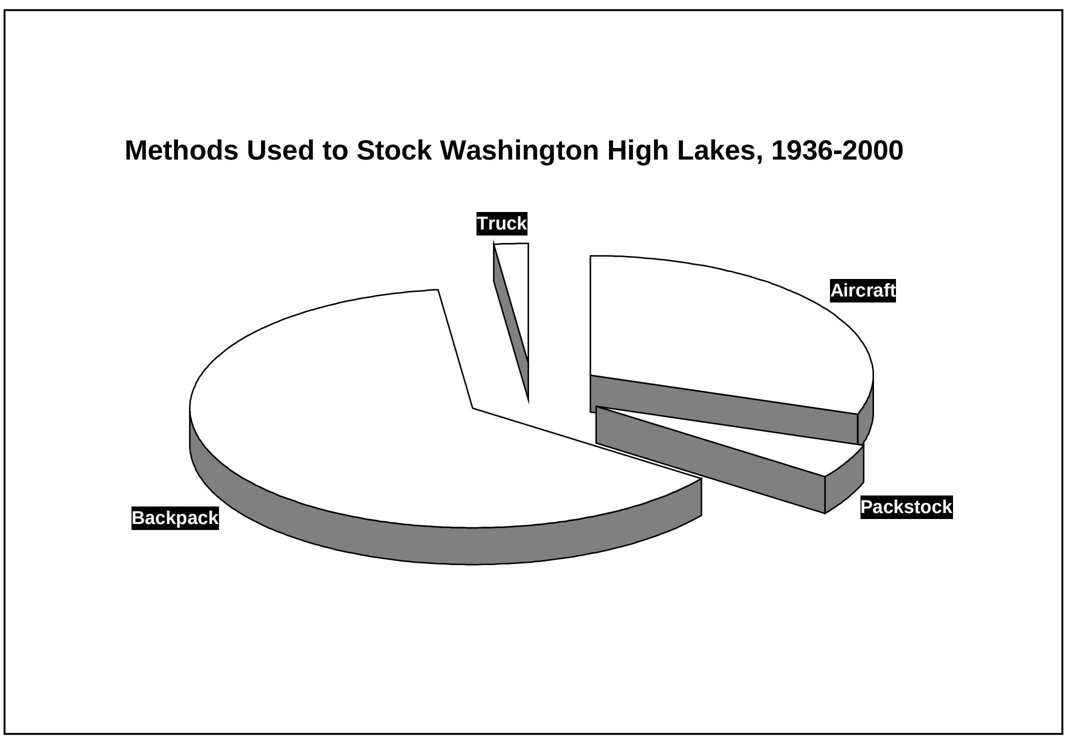
Ecological interaction considerations are primarily limited to stocking densities (see Section 5.4.2). WDFW local managers were essentially unanimous in noting that where problems are known to exist with dropout of non-native species, they are in systems where non-native fish were stocked in the distant past (Parametrix 2001; Table 19). Although wildlife benefits are rarely, if ever a consideration in species selection or other decisions regarding stocking, some wildlife considerations (ecological interactions) affect the stocking program or the fishing season (see Sections 5.6.3 and 5.9.2).

5.4.5 Stocking Methods and Quality Control

Like most of the western states, the WDFW stocks its high lakes by a variety of methods (Figure 13; n=5756 introductions). Lakes are stocked both from the ground and from the air, using one of the following methods:

- Standard hatchery tank truck and hose;
- Pickup truck or flatbed, generally with a small tank, from which fry are packed a short distance;
- Backpacking of small containers;
- Horse packing of medium-sized containers (panniers);
- Air drops from fixed-wing aircraft; and
- Air drops or shore-based hand release of fish from helicopters.

Figure 13. Distribution of methods used to stock trout fry into Washington high lakes, 1936-2000.



Two actions are accomplished in all methods where fish are released by hand directly into the lake. These are tempering (gradual equilibration of the transport water temperature to that of the receiving water), and careful observation of fry behavior. Tempering can be, and is accomplished as necessary in all but direct dumps from a large truck tank, from fixed wing aircraft, and from helicopters if they cannot land. Tempering is advisable if water temperatures differ by 10 degrees Fahrenheit or more, particularly if the lake is warmer than the transport water. If fish exhibit erratic behavior or loss of equilibrium even after water tempering, they are observed for up to one half hour to judge the extent of hauling loss. Careful observation of fry behavior and condition is common to all release methods where fish are released by hand. Therefore, short pack from a truck, backpack, horse pack, and landed helicopter are the preferred methods since they allow a much more accurate gauging of the actual number of fry that survive the stocking operation.

5.4.5.1 *Truck Methods*

Road access allows standard truck stocking at a very small percentage of high lakes. Although in some cases it is possible to literally back a truck up to the lake and dispense fry with a hose, it is usually more convenient to contain the fry allotment in a screened fry bucket suspended within the larger truck tank (Plate 46). The fry are hand-stocked from this bucket into the lake, and note taken of any hauling or handling stress or loss.

A more common situation is logging road access to near, but not all the way to a lake. At this point fry are transferred from a fry bucket to a container that can be conveniently carried or backpacked to the lake.

Note is taken of any fish loss upon release, as noted above. The only significant differences between this "truck method" and "backpacking", below, are the distance the fish must be hauled to the lake/s, the condition of the access road, and the number of fry that must be stocked. Agency hatchery trucks with their larger 200 to 500 gallon tanks are only used where road conditions allow, and it is practical to hand pack or backpack the fish to the lake/s. For large numbers or poundage of fish, it is usually more cost-effective to use aircraft.

Data quality control is generally very good with truck stocking since trained and experienced hatchery personnel observe the condition and behavior of released fish. Hatchery stocking reports are adjusted to account for any observed losses.

Plate 46. Individual lake fry allotments are kept separate in screened buckets sealed with small-mesh netting material. (The tank aerators are turned off.) Arlington airport tarmac, (20 August 1986).

5.4.5.2 *Backpack and Horse Pack Methods*

At the hatchery, relatively small numbers of fry are loaded into lightweight containers (Plate 47) that are cooled in an ice chest (or facsimile) en route to the trailhead. The containers are wrapped in suitable insulation for transport in a pannier, or in a backpack. Water sloshing en route serves to maintain aeration and dissolved oxygen levels in the container water, but volunteers and agency personnel are trained and experienced to be aware of the time limitations under which fish can be transported in a sealed container (Gebhards 1965). If necessary, water is exchanged en route to the lake/s. At the lake, the container is opened to the atmosphere, and dissolved gases are allowed to equilibrate, particularly blood gases in the fish. If necessary, the container is placed into the lake as part of the tempering process. Fish are released slowly into shoreline areas (Plate 48) where refuge from predators (birds, mammals, large fish, even adult salamanders) is available (talus interstices, complex woody debris, etc.). Notes are taken on the container and lake water temperatures, and any relevant observations on fish behavior, particularly mortalities.

Stocking data quality control is generally good, often excellent with backpack or horse pack methods since experienced volunteers or agency staff generally have the time and opportunity to carefully observe the fish they release. Special forms and procedures have been established wherein the Trail Blazers adjust the allotment number noted at the hatchery at trip departure by the number of fry lost en route or at the lake, if any. This quality control check is not possible with fixed wing stocking, or helicopter stocking if the helicopter cannot land to allow hand release of the fish.

5.4.5.3 *Fixed Wing Aircraft*

The earliest air stocking of salmonid fry may have been by Prevost (1935) in the early 1930s in the Quebec region of Canada (Gaub and Hodges 1996). Similar methods were soon emulated in Montana in “the 1930s”, where methods were tested and developed which are still in use today: direct dumping of fry and their transport water from heights of 100 to 1000 feet (Gaub and Hodges 1996). Other states, such as New York (Lindsey 1959), similarly began air stocking in the 1930s, and developed their own aircraft-based stocking program. Initial air releases in Washington occurred at about this same time; Otter Lake in the current Alpine Lakes Wilderness Area was stocked in 1938 with containers to which small parachutes were attached (Yadon et al. 1993). California also experimented with cans hung from parachutes, making such drops in 1946 (Leitritz 1951).

Extensive experimentation in California and Washington in the first years after World War II (1946 and 1947) determined the optimum size of fish that could be dropped without significant mortality, and from what heights (Leitritz 1951). Although the 1946-47 California experiments found that the “most suitable height” was 300 to 800 feet, and that trout up to 4 inches could be dropped without mortality, instantaneous mortality became significant beyond that size, and was 100 percent for 15 inch trout (Leitritz 1951).

Fry dropped from fixed-wing aircraft appear to fare well and behave normally upon hitting the lake (Leitritz 1951; Pfeifer 1986a), and fry can be dropped quite accurately from fixed-wing aircraft into lakes as small as 2 to 3 acres (Leitritz 1951). These short-term results tend to give confidence that small to large mountain lakes can be successfully stocked from the air, and that the number of surviving fish is known. However, sampling of Ontario lakes with gill nets 2 to 4 months after air stocking suggested delayed mortality can occur (Fraser 1968). Fraser (1968) found that backpacking and hand stocking of fish that had received similar culture resulted in higher survival than that seen in air-dropped fish.

Plate 47. Plastic containers that hold up to 2.5 gallons are ideal for packing small quantities of trout fry. A good deal of experience and technical know-how is required to transport this many fry to a remote lake without mortality. (9 September 1979)

Plate 48. Fry are released into an areas where they have some cover from predators. Tempering of the transport water, and collection of lake water temperature are routine tasks. Careful observation of fry behavior after release yields high reliability in the stocking record. Round Lake, Whitechuck River drainage (9 September 1979).

Typical equipment used to carry fish in fixed-wing aircraft has been described by Leitritz (1951) and Loftus (1956). The water used to carry the fry is kept cool and aerated en route to the lakes, but atomizes into a cloud immediately upon release (Plate 49). The fry “float like feathers to the water” (Gaub and Hodges 1996), as they achieve a terminal velocity of about 50 feet per second, or approximately 28 mph (Leitritz 1951). The fish have a trajectory of about 200 feet from an aircraft traveling at 120 mph, and then fall straight down unless drifted by the wind. “The accuracy with which the target area can be hit is most surprising” (Leitritz 1951). Although Leitritz (1951) was enthusiastic about drop accuracy, WDFW experience has shown that the fry dimple pattern clearly seen on the lake after the drop (Garlick 1950) can sometimes extend into shoreline areas of very small lakes unless wind conditions and pilot judgment are ideal. Therefore, lakes smaller than 5 acres generally are not stocked with fixed-wing aircraft. (Note that should some fry be dropped into shoreline areas, the lake is effectively understocked, not overstocked, and the principal adverse effect is poor record-keeping, and perhaps a lessened ability to correlate stocking density with other variables of interest, such as fish growth.)

A modern, multi-chambered drop tank (described and depicted at http://www.soloy.com) has been custom-designed for one of WDFW’s de Havilland Beavers (Plates 50, 51). Its function is similar to equipment described by Garlick (1950), Leitritz (1951), and Loftus (1956), but is enhanced by the ability to load up to nine tanks with fry aliquots for up to nine lakes while still on the tarmac. There is no need to transfer fry from one container to another once underway. A pilot checklist correlates tank numbers with the target lakes, and each tank’s drop solenoid switch (Plate 52).

The WDFW Beavers are equipped with Global Positioning System (GPS) instrumentation that allows the latitude and longitude coordinates of target lakes to be keyed into onboard avionics. Flight time is minimized as the pilot can follow a displayed bearing directly to the lake/s. If the target lake is the only one in the general area, there is virtually no chance that the wrong lake would be stocked. However, lakes are frequently closely clustered in the Cascades. Stocking of the correct lakes is virtually assured if an observer who is familiar with the target lakes and terrain accompanies the pilot. This has been a common practice in the WDFW fixed-wing stocking program for many years.

Stocking data quality control consists of the pilot coordinating closely with the hatchery staff when the fry are loaded (Plate 53), and reporting any fry losses due to equipment failure (rare). In virtually all cases, the number of fry loaded by the hatchery staff at the airfield is the number that is effectively stocked into the correct lake. The potential for stocking the wrong lake has been eliminated, but occasional problems with aeration equipment can lead to fish being dropped that are not in ideal condition. Some delayed mortality can occur under these circumstances (Fraser 1968), but the number of fish lost is never known.

This is the most significant drawback to fixed wing stocking, but this error source is minimized by flying when weather conditions are good or ideal, stocking only healthy fish, not stocking small lakes, and using skilled, experienced personnel.

Fish survival and the accuracy of stocking data is further optimized by stocking the lakes as early in the season as possible. This tends to minimize the difference between lake surface water temperature and that of the water in the drop tank containers. For certain species that must be stocked late in the summer due to spawning timing, potential temperature shock can be minimized by transporting fry to the airfield in a tank that has been allowed to sit out overnight for 12 to 18 hours. Some states have had success in stocking small fingerlings up to 4 inches long in the fall, when ponds and lakes have cooled to temperatures closer to that of the hatchery water supply (Lindsey 1959). While survival of fall-stocked 4 inch eastern brook trout was excellent in New York, fish stocks used in Washington are far smaller in the fall, and their survival is sharply reduced if fry cannot acclimate to the lake and its food supply before winter. Thus, fall stocking to avoid temperature shock is generally not an option in Washington.

Plate 49. The 4 to 5 gallons of transport water quickly atomizes upon release, but the fry fall nearly straight down several hundred feet to the target lake. Kelcema Lake, Stillaguamish River drainage, (21 August 1986).

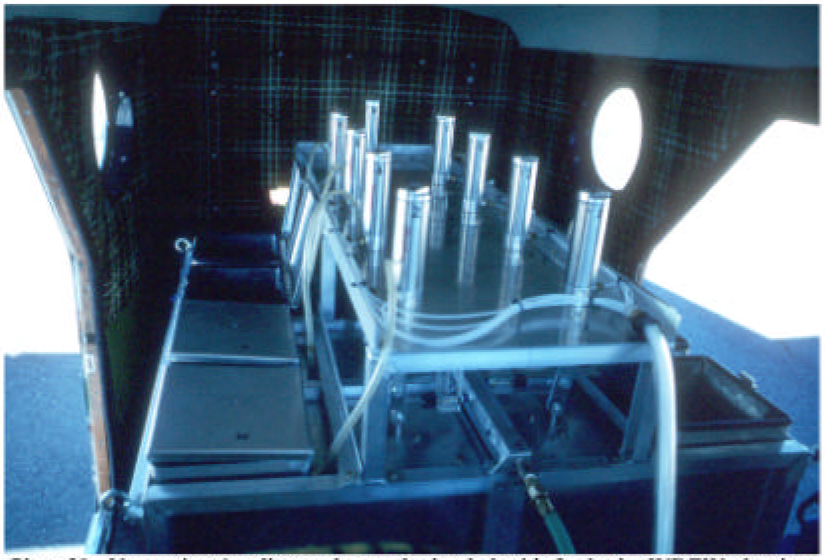


Plate 50. Up to nine 6-gallon tanks can be loaded with fry in the WDFW planting tank built by Soloy Corporation. Compressed oxygen can be metered at individual rates to each tank, and flow is automatically shut off when the fish are released. Nine release valve solenoids are visible, and are controlled remotely by the pilot. Each tank and solenoid is numbered, which coincides with numbering on the release toggle panel.

Plate 51. The drop tank was designed for the deHavilland Beaver. The drop tube is seen exiting the camera port to the left of the step, and below the fuselage port-hole. The individual tanks are loaded from both sides of the plane. Darrington airfield, (30 September 1998)

Plate 52. Release of tanks 1 through 8 places fry and water in the 9th tank, which is controlled by the far left toggle switch. The 9th, or posterior "ready" tank is dumped when in position over the target lake. Photo by Soloy Corporation.

Plate 53. The hatchery Manager (with clipboard) carefully discusses the fry stocking allotment with the pilot for all lakes to be stocked on an individual flight. Arlington airport, (20 August 1986).

5.4.5.4 *Helicopter Stocking*

Helicopters have been used to stock high lakes in Washington since the Korean War. They were used in cooperative stocking programs between the U.S. Fish and Wildlife Service and the National Park Service to stock high lakes in Olympic National Park (Garlick 1950). More recently, WDFW local managers have used helicopters leased from private operators (Plate 54), and in cooperative, no-cost arrangements with private helicopter owners, major timber owners, the Washington Air National Guard (Plates 55, 56), and the U.S. Forest Service.

Helicopters are more costly to operate on an hourly basis than the agency's Beaver, but have several distinct advantages:

- Leased, or volunteered/cooperative helicopters are generally available on short notice, whereas the agency Beaver may be down for service, or being used for other agency business;

- Helicopters can access virtually any lake, but geographic setting and lake size are distinct limitations on whether they can be stocked using fixed wing;

- The ability to hover over a lake or land nearby allows much greater flexibility in assuring all fry are placed into the lake, and allows slow hand tempering under unusual circumstances. Both hovering close to the lake and shore-based tempering increase the probability of fry survival, and more accurate stocking records.

- Apart from a brief noise intrusion, helicopter stocking avoids all other impacts on the surrounding environment that may be associated with a stocking crew or pack stock.

Since helicopter stocking essentially replaces human backpacking or horse packing labor to reach the lake, it is used either for waters that require a large number of fry, or in areas where agency staff, volunteer labor, or the agency Beaver are not available. It is possible to land at most non-wilderness lakes, which allows hand-stocking and tempering of fry from small containers that have been prepared before the flight in the same manner as for backpacking. Otherwise, the container of fry is simply poured into the lake from the hovering ship. The local WDFW management biologist usually accompanies the pilot on all helicopter stocking, assuring that the correct lakes are stocked.

Plate 54. Under some special circumstances it is desirable to have high confidence in the number of fish surviving an introduction, such as under research conditions. It is often feasible to land a small helicopter near a lake to be stocked. The fish can then be hand released with care, in the same manner as those brought in by backpack. Small helicopters can also ferry supplies for chemical treatments (see Section 5.7.1) with little or no impact on the general lake environment.

Plate 55. National Guard personnel gain valuable air time in mountainous terrain when assisting WDFW with fish stocking. Bags of fry are in the black 5-gallon buckets. The Regional Fish Biologist discusses the fry allotment with a crew member. Private airstrip near the Tokul Creek Hatchery at Snoqualmie, (Fall 1976).

Plate 56. The bags of fry can be dumped directly from the hovering ship, or be carried to the lake if the ship lands. (Heather Lake, 29 August 1978.)

Lake Management Approaches

The department generally manages each high lake with one of four basic approaches, or objectives (WDFW 1996b). These are:

1) Maximum sustainable yield fishery – recreation emphasis (“Flexible Management Waters”);

2) Optimum sustainable yield fishery – recreation emphasis (may include “Sustainable Wild Production Waters”);

3) Larger waters purposefully managed as fishless – “Special Protection” (ecological / scientific reserve emphasis); and

4) Small, fishless waters – “Special Protection” (ecological / scientific reserve emphasis).

The first category includes, by default, all lakes that have naturally-reproducing trout or char populations where fish are excessively abundant. Other lakes managed with approach 1 could include those having all of the following characteristics: periodically stocked, high angler use levels, and easy access. “Flexible Management Waters” are lakes (or streams) with no native species preservation concerns.

Lakes managed with approach 2 are the many lakes where the local manager regulates fish stocking frequency and density to produce fish of high quality, usually not quantity (see Section 5.4.2). Fishing may range from fast to slow, depending on factors such as weather, insect hatches, etc. Most waters in this class are on a periodic stocking cycle, so fish abundance is low in some years, leading to slow fishing (see Section 5.4.2). This is offset by the important objectives of preservation of all invertebrate taxa in the lake, and production of consistently high quality trout. “Sustainable Wild Production Waters” is a classification that has better application to streams with native fish species than high lakes with fish introduced for the purpose of providing recreation. There are a very few high lakes in this classification that have naturally-reproducing native fish that provide a recreational fishery.

Approach 3 lakes occur most frequently in designated wilderness, or in one of the state’s national parks. “Special Protection Waters” includes lakes or streams that are managed for native species only, with no supplemental trout stocking. These waters may or may not have historically contained fish.

With the exception of a subset of lakes in North Cascades National Park, no trout stocking occurs in lakes and ponds in the state’s national parks (Olympic, Mt. Rainier, North Cascades), or in a number of waters in Natural Resource Conservation Areas managed by the Washington Department of Natural Resources (Class 3 and 4 waters). This results in literally thousands of lakes and small tarns that can be managed and studied for their natural condition and ecological communities Tables 12, 14). This management approach also provides many lakes and ponds across the landscape that can serve as habitat or refugia for various species of invertebrates or amphibians (Appendix Plate K-2). Although the percentages vary from region to region, an average of 62 percent of ponds and lakes larger than 0.1 acre are managed for a fishless condition (below). These include lakes that are over 10 to 20 feet deep, which are preferred by some invertebrate and amphibian species. Table 14 gives the physical characteristics of some lakes in WDFW Region Four that are capable of being managed for a fishery, but which are purposefully left fishless. These lakes represent a range in elevation, size, and depth, and are only a very small subsample of the many fishless waters.

Table 14. Physical Characteristics of 10 Lakes Managed for a Fishless Condition in or Near the Western Half of The Alpine Lakes Wilderness, Washington

Lake	Elevation (ft msl)	Surface Area (ac)	Max Depth (ft)	Mean Depth (ft)
Gem	4857	14.9	148	50
Chair Peak	4950	5.0	105	80
Findley	3710	22.3	55	26
Lower Sutton	3610	1.3	9	6.5
Bear	4180	2.8	16	6
Quartz	4800	1.0	9.5	7
Lower Tank	5800	4.0	16	10
S.M.C.	3702	40.7	180	81
Nadeau	3722	18.9	77	32
Moolock	3903	45.4	150	57

Information on the number of lakes and ponds present in a geographic area, and the number of these supporting fish, is available in most areas of Washington. The number and percentage of all Washington high lakes that are left in their natural condition can be approximated by an indirect approach. The most recent mapping of "high" lakes and ponds in Washington's Cascades and Olympics yields a total of 4718 waters 0.1 acre or larger (Trail Blazers, Inc. HLS database). A total of 1777 waters are currently under some sort of stocking regime, or are known to have self-sustaining fish populations. Discounting the very small percentage of unsurveyed waters that may have wild fish populations, about 62 percent of Washington high lakes and ponds 0.1 acre or larger are known or presumed to be fishless. Table 15 presents data from districts where all waters over 0.1 acre have been catalogued for fish presence. One may safely assume that few to none of the unsurveyed ponds less than 0.1 acre contain self-sustaining fish.

Table 15. The Total Number of Lakes and Ponds 0.1 Acre and Larger With and Without Fish (as of 2001) Mapped (USGS) at the 1:24,000 Scale, by WDFW Administrative Region[1]

Administrative Region	Number of High Lakes and Ponds	Number of High Lakes and Ponds With Fish[2] (%)	Number of High Lakes and Ponds Lacking Fish (%)
1	31	3 (10)	28 (90)
2	723	331 (46)	392 (54)
3	588	227 (39)	361 (61)
4	1638	838 (51)	810 (49)
5	710	206 (29)	504 (71)
6	1028	182 (18)	846 (82)
All Regions	4718	1777 (38)	2941 (62)

[1] Includes waters in all national parks, plus the Yakama Nation.
[2] Waters with stocking record, or in which fish have been seen.

Designated wilderness areas in Washington typically have examples of all four of these management approaches. Table 16 gives representative statistics for two wilderness areas in the southern half of WDFW Region Four (Region Four includes all or portions of six wilderness areas, plus two national parks).

Table 16. The Number and Percent of Wilderness High Lakes and Ponds in Southern WDFW Region Four in Each of Four Management Approaches as of 2001.

Wilderness	Management Approach	Number of Lakes/Ponds (%)
Alpine Lakes (west side)	1	49 (13)
(385)	2	81 (21)
	3	8 (2)
	4	247 (64)
Henry M. Jackson (west side)	1	6 (17)
(35)	2	6 (17)
	3	2 (6)
	4	21 (60)

Table 17 was prepared to give perspective on the number of managed high lakes in Washington wilderness areas.

Table 17. The Number of Stocked[1] Fish-Bearing Lakes, and Non-Stocked Fishless Lakes and Ponds In Wilderness Areas of Washington By WDFW Administrative Region as of 2001.

Region	Total Waters	Number of Lakes and Ponds in Wilderness[2] (%)	Stocked or Fish-Bearing Wilderness Waters (%)		Non-Stocked, Fishless Wilderness Waters (%)
			All Plants	Since 1970	
1	31	10 (32)	3 (30)	3 (30)	7 (70)
2	723	536 (74)	223 (42)	186 (35)	313 (58)
3	588	383 (65)	137 (36)	120 (31)	246 (64)
4	1638	737 (45)	396 (54)	355 (48)	341 (46)
5	710	392 (55)	72 (18)	66 (17)	320 (82)
6	1028	104 (10)	37 (36)	27 (26)	67 (64)
All	4718	2162 (46)	868 (40)	757 (35)	1294 (60)

[1] Many lakes that were stocked in the past developed reproducing fish populations, and are no longer stocked.
[2] Excludes waters in national parks and the Yakama Indian Nation.

Management of many lakes and ponds for a fishless condition is not unique to Washington. Gaub and Hodges (1996) noted that in Montana "Lakes are usually stocked every 3 to 6 years. Not all high mountain lakes are stocked; many are intentionally left fishless to preserve their unique biological characteristics".

5.4.6 Assessment and Recommendations

Local WDFW management biologists unanimously agree that knowledge of the reproduction status of trout populations in their high lakes is a foremost concern in setting stocking rates and frequencies. However, a few districts still have significant numbers of lakes where this information has not been obtained due to the number of lakes present, and lack of human resources.

Recommendation #1: Resources should be focused on obtaining critical information on fish reproductive status from the remaining lakes where it is lacking (primarily Skamania, Klickitat, Yakima, and Chelan Counties). Reproduction must be determined by on-lake surveys. The information should be obtained from WDFW staff, experienced consultants, trained graduate students, or trained volunteers, in that order of priority. Anecdotal information should never be relied on when making a reproduction status determination.

There is a general lack of well-researched information on natural and angling mortality of trout and char in Washington high lakes. Managers have used mortality estimates based on personal experience, with some guidance from published information from other states or provinces. Stocking frequency decisions would benefit from a better understanding of the range of natural and angling mortality seen, particularly if assessed from lakes stratified on the basis of geographic location, and annual level of angler effort. The information would also need to be stratified by fish species.

Recommendation #2: Specific research should be directed at obtaining estimates of natural and angling mortality for trout and char in Washington high lakes. This would be an excellent cooperative project with the Forest Service and/or North Cascades National Park.

Arguments can be made both pro and con for maintaining a continuous presence of fish in high lakes through periodic stocking (as opposed to the presence of reproducing populations, which tend to be too dense). Recent studies have shown that invertebrate and amphibian taxa can co-exist with trout as long as trout densities are kept low (Divens et al. 2001). These studies have generally not evaluated whether *continual* fish presence, even if low, has unacceptable impacts on other biota. There have also been no studies to test the hypothesis that allowing fish abundance to drop to very low levels for 1 or 2 years results in reduced recreational pressure at a lake. Despite the lack of rigorous studies and testing, empirical observations and extensive experience by WDFW local managers indicate vulnerable native biota is preserved when fish densities are kept low, even when fish are continually present. Some managers also believe allowing fish abundance to drop helps prevent overuse or overfishing, particularly on remote, small lakes that receive little general recreational use, or in areas that are not close to high density urban population centers. Selection of fish species to stock is of paramount importance due to the differing potential for natural reproduction between species and strains, and the nullifying effect of excessive reproduction on a manager's ability to control continuous fish presence or density.

Recommendation #3a: If human overuse is a problem at some lakes, WDFW local managers should continue to coordinate with USFS or other land managers to devise methods or approaches that limit human use without singling out recreational anglers. (In most lakes that receive moderate to heavy recreational use, fishing is an incidental activity, and fish absence would make little difference in overall use impacts.) Where angling use levels are demonstrated to be excessive (e.g., causing significant resource damage), managing for fluctuating fish density should be given serious consideration. This should only be considered where angling is the primary recreational use of the lake.

Recommendation #3b: As a general guideline, high lakes should be managed for a total standing trout density of no more than 50 to 100 fish per surface acre. It is recognized that this varies greatly, with target densities ranging from 10/ac to several hundred/ac. Local managers should never stock at more than 100/ac unless the lake has received a complete survey, and its physical, chemical, and biological characteristics indicate it can support higher densities without long term ecological harm.

Recommendation #3c: As a general rule, fish species and strains should be stocked which have a demonstrated **in**ability to successfully reproduce in Washington's high lakes. New species or strains should never be stocked into a lake that has not received a complete survey (see #3b, above). Exceptions to this rule could include lakes which do not have surface outlets and have no spawning habitat, or lakes where limited reproduction by a top predator may be desired for long term biological control (see Section 5.7.2).

WDFW local managers have experienced numerous incidents where the public has illegally stocked lakes that had a history of supporting fish, but were fishless for varying lengths of time, and for various reasons. Most experienced managers, when polled, agreed that allowing a large percentage of lakes to return to a fishless condition would lead to a marked increase in illegal stocking. Much of this stocking would likely be with fish species that would establish reproducing populations, thus extending the geographic extent of conditions that impact native biota.

Recommendation #4: The number of lakes being managed for quality, low-density trout fisheries should not be allowed to drop below current levels in order to meet the ever-increasing demand for back country angling recreation. Lakes which currently support excessively abundant fish species should be given chemical or biological treatments to reduce fish abundance. Some problem lakes should be restored to a fishless condition, and others should be managed for low-density, quality fisheries. Outreach and public education efforts should be directed to address public perception problems regarding the ecology of fish in Washington high lakes; an important theme would be the often-irreversible damage illegal stocking can cause.

Fish species and strain diversity is felt to be a very important attribute of the WDFW high lake program, not only by local managers, but also by the sport fishing public (Curtis and Erickson 1992). Diversity in the program was identified as a goal in earlier planning (WDG 1981). Recent use of exotic species and strains in carefully selected lakes has not been shown to have adverse effects, but on the contrary, have either added diversity to the catch, or had varying levels of effectiveness in controlling stunted fish populations (see Section 5.7.2).

Recommendation #5: Use of fish species and strains that are not native to Washington or specific drainages should be allowed for special and specific management objectives under circumstances where the fish cannot emigrate from, or be washed from the lake.

Genetic impacts on native fish from trout or char stocked into high lakes have not been demonstrated in Washington. (There has, however, been much speculation on the subject.) The presence of some species (eastern brook trout) or strains (westslope cutthroat) in streams below stocked high lakes may be evidence of dropout. The long history of stocking of various species and strains into headwater streams in the early part of the 20th century makes this determination problematic in most cases. Nevertheless, WDFW managers do not want stocked fish interacting with downstream native fish populations.

Recommendation #6: *WDFW local managers should practice continued diligence when preparing stocking allotments to be certain that species and strains stocked do not pose a significant risk of interbreeding with native fish in downstream areas*. Species that pose the most risk (e.g., eastern brook trout or westslope cutthroat) should be stocked only in lakes where they are currently present in low numbers, or where they physically cannot migrate or be washed out of the lake.

Local biologist managers have generally determined the stocking methods that provide the best fry survival, and that are most cost-effective for their areas. The most significant remaining problem is quality control of the stocking database. Most, if not all local managers maintain accurate records; minor problems occur when data entry is made in the Olympia headquarters, and quality control checks by the local management staff on the central database are inefficient or non-existent.

Recommendation #7: Regional office staff should have the ability to query and edit the central stocking database. All hatchery stocking reports should be reviewed by the local managing biologist for accuracy before they are forwarded to Olympia for entry into the central database.

Although the agency Beaver has avionics that can be programmed to place the airplane over the lake/s to be stocked, an experienced passenger should accompany the pilot on those trips where there is even a slight chance that the wrong lake could be stocked. These are usually instances where several small lakes lie in a tight cluster. An "expert passenger" policy would essentially eliminate the risk of stocking the wrong lake.

Recommendation #8: The district fish biologist, or other individual thoroughly familiar with the water/s to be stocked, should accompany the fixed wing or helicopter pilot on stocking runs where there is any potential for an inability to correctly identify the target water.

5.5 HATCHERY PRODUCTION PROGRAM

As mentioned in Section 2.0, trout culture and subsequent stocking into Washington high lakes preceded the establishment of the Washington Department of Game in 1933 by many years. A partial history of stocking by other agencies is given in Table 18 to illustrate this point. The following section will broadly review the WDFW cultural program over the past 20 to 30 years, and provide an emphasis on current practices.

Table 18. Early Stocking of Washington High Lakes by the United States Forest Service, National Park Service, and the U.S. Fish And Wildlife Service.

Years	Agency	Number of Lakes Stocked	Fish Species	Number of Fry Stocked
1914 -	USFS*	53+	EB, KO, RB, CT	720,175
1918 – 1973	NPS	50	EB, RB, CT	429,620
1956	USFWS	4	EB	45,430

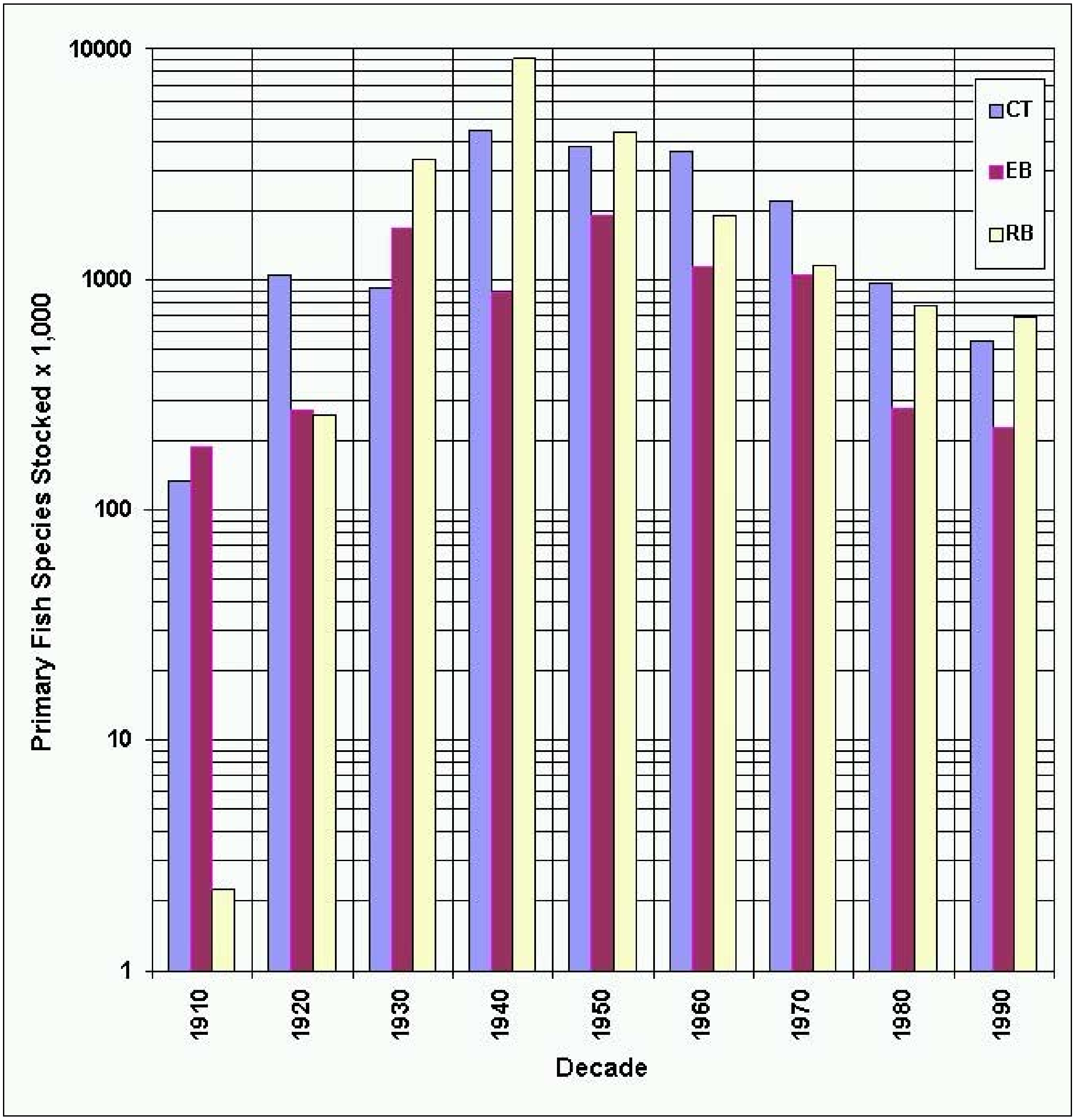
* The US Forest Service continues to stock high lakes in cooperation with WDFW.
Sources of data are archival stocking records from WDFW and NPS.

Fry stocked into Washington's high lakes are produced from either captive brood stocks, or semi-wild fish from broodstock lakes. Exceptions are exotic species such as lake trout or golden trout that are periodically imported from other western states, and test introductions of unusual species or hybrid strains (e.g., atlantic salmon, steelhead x golden hybrids, etc.).

5.5.1 Stocking Statistics

Early recognition of the need to maintain low-density fish populations in Washington high lakes is reflected in a plot of the total number of fry stocked annually (Figure 14). The sharpest declines are with species that are known to reproduce, creating conditions that are adverse for native invertebrate and amphibian biota.

Figure 14. Total Number of Eastern Brook, Rainbow, and Cutthroat Trout Fry Stocked into Washington High Lakes by decade, 1909 to 2000.



5.5.2 Species and Strains Historically Used

A lengthy list of species and strains has been introduced into Washington high lakes since the early 1900s (Table 19). The earliest introductions used the most commonly-available salmonid game species. Since many of the earliest introductions were made by federal agencies (Table 18), fish were commonly obtained from federal hatcheries. Eastern brook trout may have been the first species officially stocked, but cutthroat and kokanee were also available between 1911 and 1915 from early local hatcheries such as Lake Whatcom (near Acme), Tokul Creek (near Snoqualmie), and Twin Lakes (near Leavenworth)(Crawford 1979).

Table 19. Earliest Introduction of Fish Species and Strains Stocked into Washington High Lakes Per Available Documentation

Species	Strain	Year Introduced	Sponsoring Agency
Eastern Brook	Unknown	1914	USFS
Rainbow	Unknown	1917	USFS
Rainbow	Kamloops	1932	Unknown
Rainbow	Mount Whitney	1946	WDG
Kokanee	(Lake Whatcom presumed)	1917	USFS
Cutthroat	Unknown	1909	NPS
Cutthroat	Coastal	1965	WDG
Cutthroat	Westslope (Twin Lakes)	1915	USFS
Cutthroat	Yellowstone (MBS)	1914	USFS
Lake Trout	Unknown	1920	Unknown[1]
Golden Trout	(California)	1936	WDG
Grayling	Unknown	1945	WDG
Steelhead	Coastal / Puget Sound	1916	Unknown[2]
Atlantic Salmon	Unknown	1975	WDG
Brown Trout	Unknown	1935	WDG
Coho Salmon	(Coastal/P. Snd. presumed)	1918	USFS
Chinook Salmon	Wallace (Skykomish) River	1999	WDFW

[1] Source: Piper & Taft (1925); probably USFS.
[2] Source: Trail Blazers, Inc. database; probably USFS.

A wide variety of rainbow trout, including winter-run steelhead, have been stocked. Only the Kamloops variety is known to reproduce in Washington high lakes. Several other varieties (Entiat, Shasta) were obtained from federal hatcheries between 1970 and 1990, and were experimentally stocked to evaluate their growth and performance in an extremely limited number of lakes.

Millions of cutthroat fry have been stocked into scores of different high lakes, most of which were of the Twin Lakes (westslope) variety (Plate 57). As a result, the range of this strain has been artificially extended in Washington (Behnke 1992; Williams 1999). Coastal cutthroat (Plate 57), generally of the Tokul Creek variety (originally from Lake Whatcom), are the second most-stocked variety. A small number of lakes have received Yellowstone Lake and Henry's Lake cutthroat; a few lakes have developed naturalized populations of this strain.

Plate 57. Coastal cutthroat (top fish) and a west slope cutthroat (bottom, flipping fish) illustrate the difference in spotting pattern between these varieties. (23 October 1977) Gerry Ring Erickson photo.

Brown trout have been stocked on a very limited, experimental basis, primarily to test their ability to serve as a top predator, and control stunted fish populations (see Section 5.7.2). The Ford Hatchery stock (Scottish Loch Levan variety) is believed to be the only one that has been used.

Lake trout were introduced into Washington high lakes very early, with the first introduction to Lake Isobell (sic) in Snohomish County apparently occurring in 1920 (Piper & Taft, Inc. 1925). Another naturalized population exists in Eightmile Lake in Chelan County. They have been tested on an extremely limited basis (two lakes) since 1980 for biological control purposes.

Grayling were stocked in Washington in a number of locations as early as the 1920s, but only survive in one (high) lake in Skagit County. Attempts were made in the late 1980s to develop a high lake near North Bend as a grayling brood stock lake, and several fry introductions were made. The effort failed due to predation by the wild rainbow reproducing in the lake. There is currently no brood stock in Washington, nor plans to develop one.

Kokanee were stocked in numerous high lakes in the early 20th century, but their use essentially ceased by 1950. They established reproducing populations in many lakes (see Section 5.7.2). They are only occasionally stocked now, primarily to augment forage for lake trout in one or two lakes.

Atlantic salmon have been tested in a number of high lakes. Results have either been spectacular, or dismal failures. When stocked into barren waters, they exhibit excellent growth, and superb sporting qualities. However, when forced to compete with other species, particularly rainbow, they tend to do very poorly (Plate 42; Williams 1974).

Golden trout (Plate 58) have been stocked intermittently since 1938 (Figure 15). Inconsistent availability of eggs from other western states, particularly after 1970, was recognized as a major problem with this species. When eggs were available, up to 27 lakes were stocked (Figure 16) in as many as 10 counties.

Early efforts by WDG biologist Jim Cummins in the late 1970s to develop a broodstock led to some success in the early to mid-1980s (Pfeifer 1986b). Most of the credit for this measured success was due to the care, attention, and problem-solving of Manager Larry Klube and the staff of the Tokul Creek Hatchery, near Snoqualmie, Washington. A statewide survey of WDG district biologists by Cummins led to the development of an annual statewide fry production goal of 12 to 15,000 fry. Golden trout successfully reproduce in less than five high lakes in Washington. One is stocked with a low number of fry annually to serve as a potential backup source of gametes in case of failure of the captive broodstock, and an inability to import eyed eggs. Gametes have been collected from ripening goldens in a Washington high lake on several occasions.

Figure 15. Number of Golden Trout Stocked into Washington High Lakes and the Number of Counties Receiving Golden Trout, by Year, 1938 to 2000.

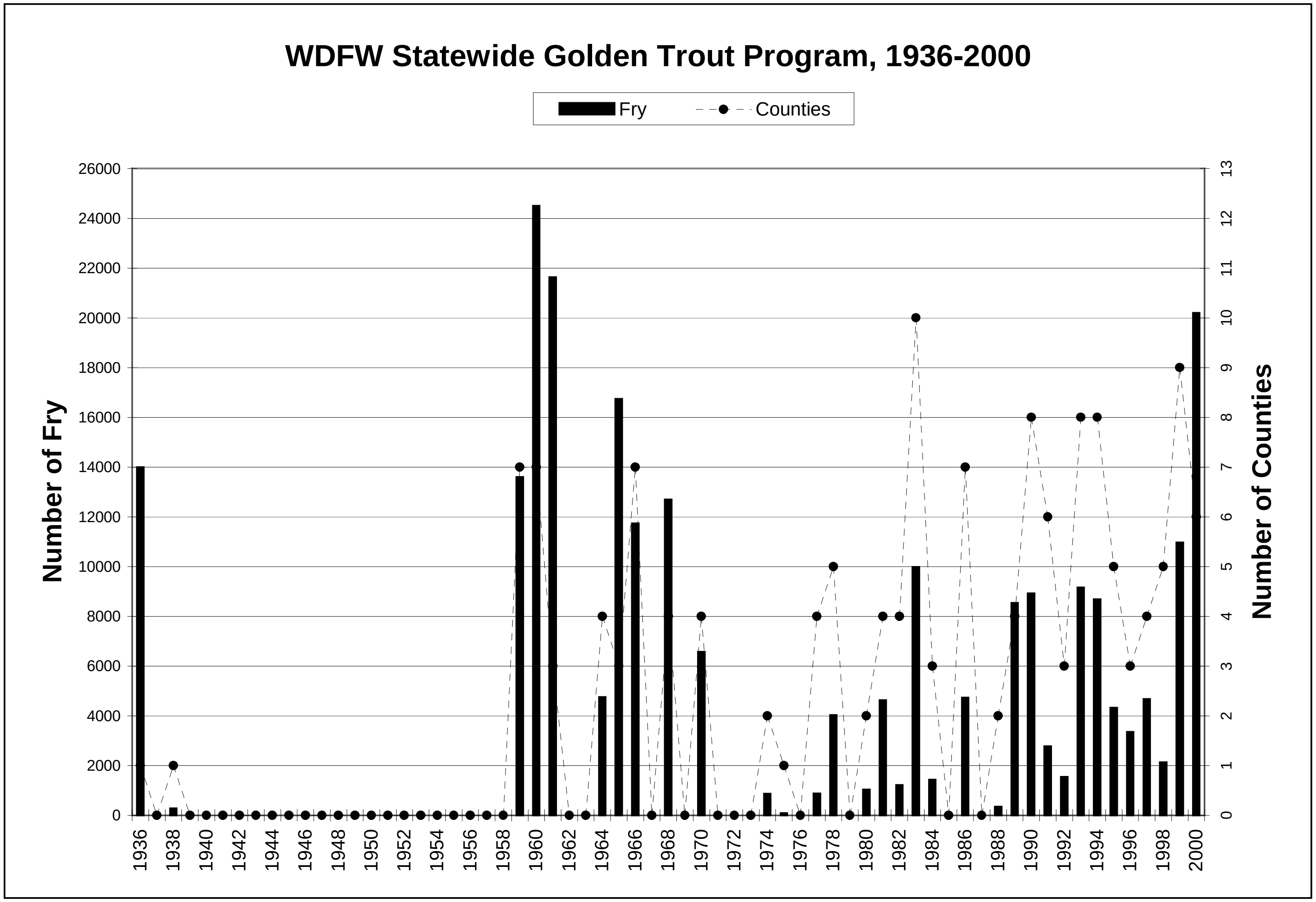
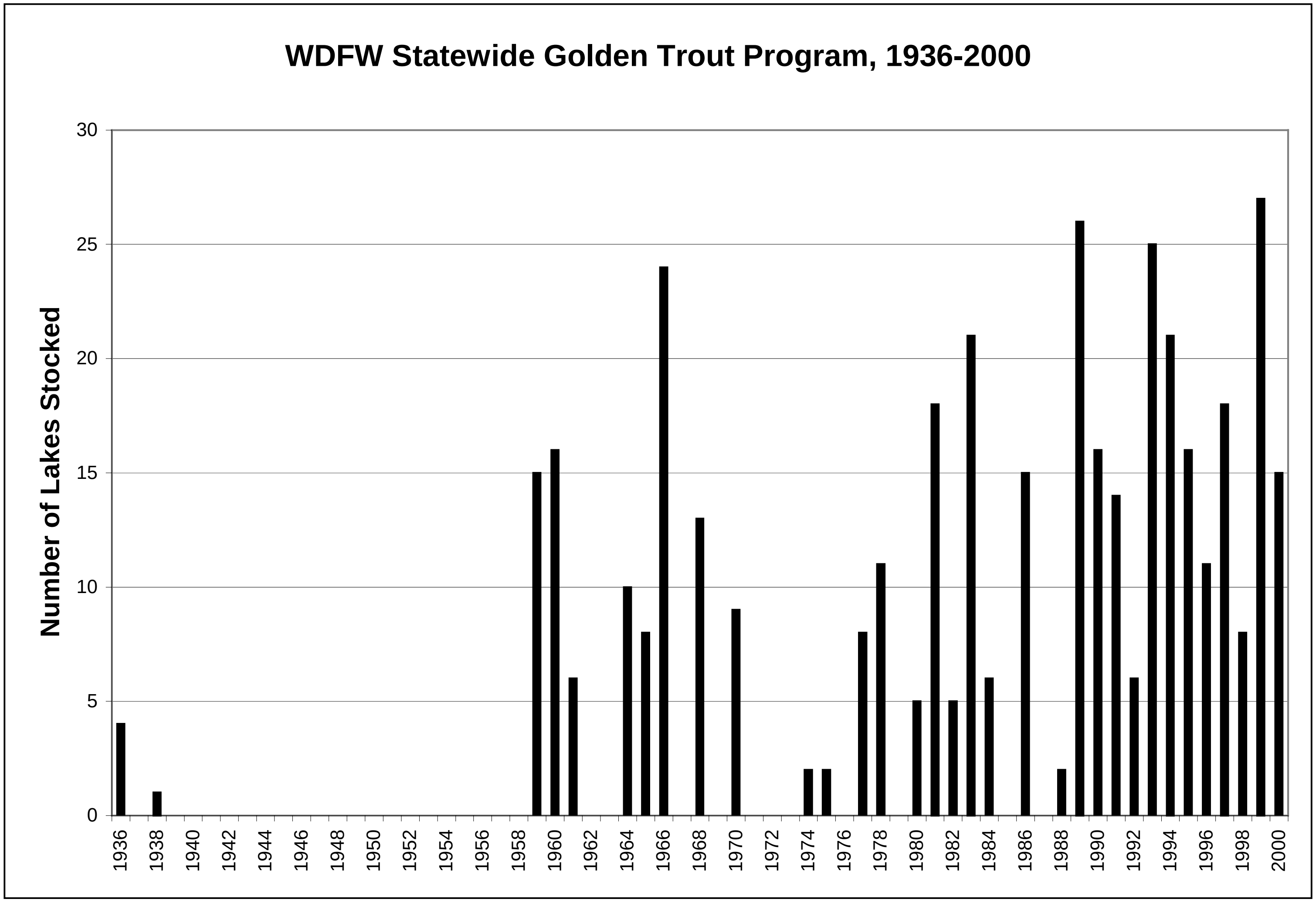


Figure 16. The Number of Washington High Lakes Receiving Golden Trout, by Year, 1936 to 2000.



Chinook salmon are currently being tested as a potential top predator on stunted eastern brook trout in one lake in the Skykomish River drainage. The chinook stock being used is native to the lake's watershed.

5.5.3 Broodstocks and Broodstock Lakes

Native kokanee have been cultured at Lake Whatcom, near Acme, Washington since 1915 (Crawford 1979), and this stock was subsequently introduced to many Washington high lakes. This stock is still occasionally used (previous section), although it was not developed expressly for use in high lakes.

The Mount Whitney rainbow (Crawford 1979) has been a mainstay of the Washington high lake stocking program since the 1960s. Its December to March, but primarily January maturation timing is ideal for producing fry of a size suitable for back packing early in the stocking season. Of greatest importance is the fact that the stock shows very little tendency to successfully reproduce in the high lake environment (Crawford [1979] was in error on this point). The stock is currently maintained at the WDFW Eells Springs Hatchery, near Shelton, Washington.

One of the earliest, and still operating wilderness egg-taking stations was developed on Upper Twin Lake, near Leavenworth (Plate 59 and Figure 17). Westslope cutthroat, native to Lake Chelan, if not the Twin Lakes themselves (Behnke 1992; Crawford 1979), have been spawned at this station since 1915 (Plates 60 to 62). The Twin Lakes have been closed to fishing for decades, and remain one of the few true broodstock lakes in the Washington inland trout program. Recent westslope cutthroat supplementation efforts in the Lake Chelan drainage emphasize the importance of this station and this stock, whose genetic purity has been maintained for 86 years.

The Tokul Creek cutthroat, derived in the mid-1940s from native cutthroat in Lake Whatcom (Crawford 1979), was held at the Tokul Creek Hatchery for about 50 years. The broodstock was moved to the Eells Springs Hatchery along with the Mount Whitney rainbow due to pathological concerns with the water supply at Tokul Creek. The coastal variety (Plate 57) has had limited use in Washington's high lakes, primarily because of its mid-winter spawn timing which produces fry that are generally too large for backpack stocking. Concerns about the use of westslope cutthroat in western Washington will likely result in increased use of the Tokul Creek stock, although neither are genetically identical to cutthroat that may be found in individual streams to which the lakes drain (Campton 1982).

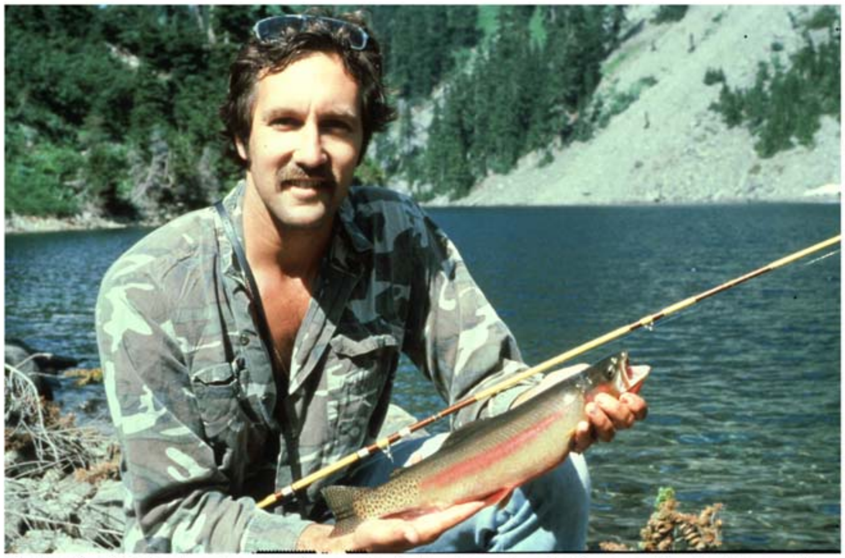


Plate 58. Golden trout engender angler interest well out of proportion to the number of lakes they are found in. This classic example of the strain is from a lake in the Middle Fork Snoqualmie River drainage. (August 1979) Jim Cummins photo.

Plate 59. The original work cabin situated between the Twin Lakes was rebuilt in 1949. The facility is operated soon after the lakes clear, usually in mid-May to early June, until the completion of egg takes roughly one month later. (June 1982)

Figure 17. Location of the WDFW Twin Lakes Eyeing Station Near Leavenworth, Washington.

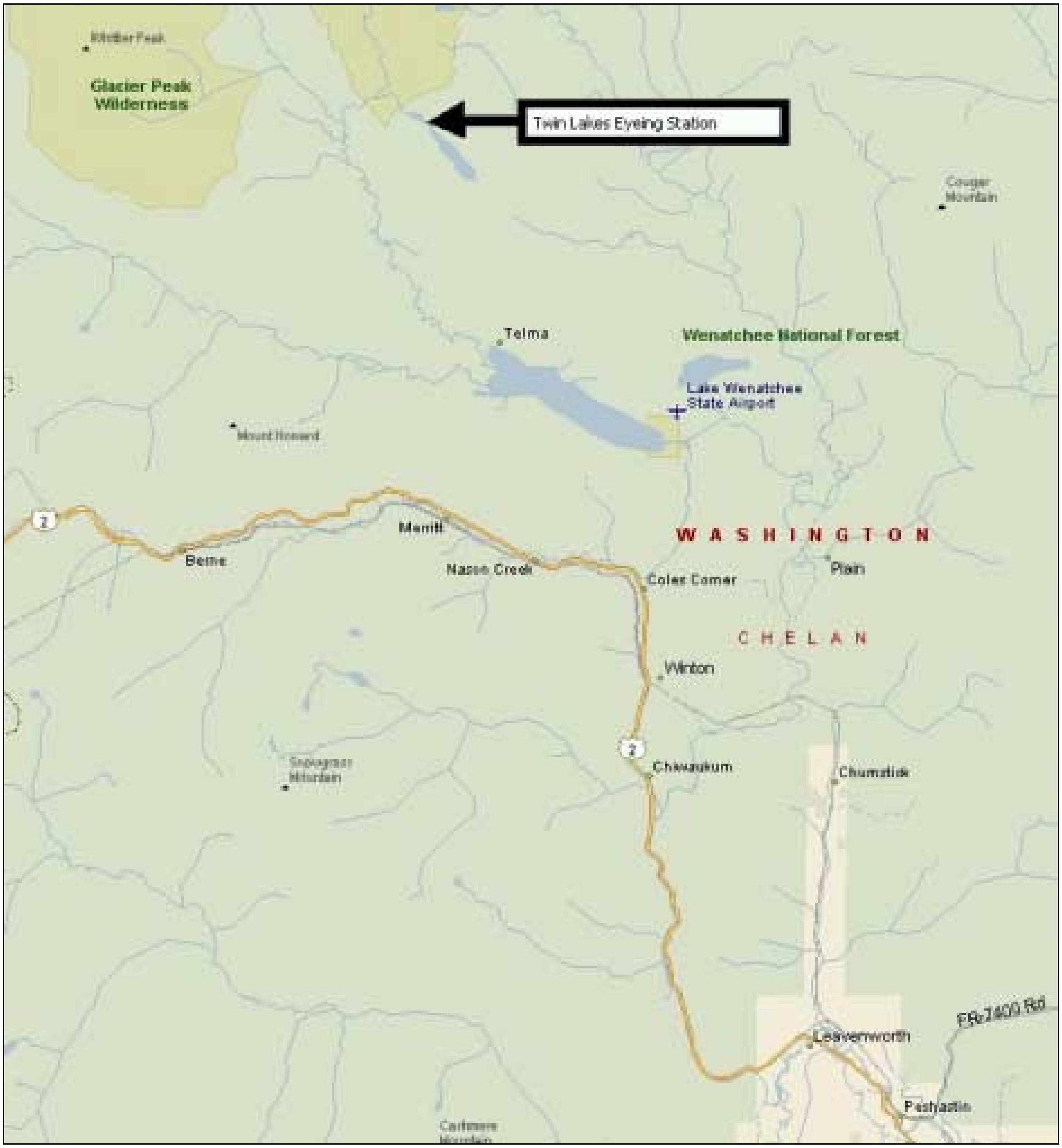


Plate 60. A weir and fyke trap (plus holding box) is situated on the outlet of the upper lake (that forms a low gradient, interconnecting stream to the lower lake). Fish from the upper lake that attempt to spawn in the outlet are collected in the fyke trap. The Welsh corgi sits on the lid of the fyke trap. A biologist transfers fish to the holding box that have been brought from one of the upper lake tributary traps. Fish are spawned about twice a week. (23 May 1993) G. Ring Erickson photo.

Plate 61. The Lynx Creek trap is one of two tributary traps on Upper, or Big Twin Lake. Migrants are ferried in a sedating anesthetic solution to the outlet holding box, where they are checked for ripeness, and ultimately spawned. (23 May 1993) G. Ring Erickson photo.

Plate 62. The District Fish Biologist (left) and local Fish Pathologist spawn Twin Lakes cutthroat from the holding box on one of the two spawning days during the week. This venerable procedure has been conducted at this site since 1915 (Crawford 1979). (June 1982)

5.5.4 Exotic Species

Strictly speaking, virtually all fish stocked into Washington's high lakes are exotic to the lakes themselves since the vast majority of the lakes were fishless since the last glaciation (see Section 2.0). The next level of concern is whether the fish stocked are native to the lake basin, or watershed to which it drains. Again, all stocks used are non-native, except when Twin Lakes cutthroat are stocked into lakes that drain to the mid- to upper Columbia River. These concerns are largely academic unless there is reason to believe the fish will either find their way out of the lakes into which they are stocked, or careless individuals transfer them into other systems supporting native fish.

Diversity of angling opportunity is a goal of the high lake fishery program, and local WDFW managers abide by the agency's Exotic Species Policy. This policy dictates that no species be introduced into waters in which it has not been stocked before unless the State Environmental Policy Act (SEPA) is followed (submittal of Environmental Checklist and biological justifications). WDFW is generally not introducing new species into the high lakes. Where new species introductions are proposed, SEPA guidelines are followed. In general, and as a practical matter, no species is introduced that has the potential of hybridizing or competing with native fish in downstream receiving waters. Stocking non-native species or strains into remote lakes with no surface outlet poses little or no risk to native fish of Washington. And, the history of exotic species stocking in the high lakes is one of very low numbers in a relatively small number of lakes (Table 20).

Table 20. Counties and Number of Lakes Where Unusual Fish Species or Strains Have Been Introduced to Washington High Lakes as of 2001 (Documented Introductions, Only).

Species	Counties	Year/s of Introductions	Number of Lakes Receiving Species or Strain
Eastern brook	Clallam, Jefferson, Mason, Whatcom, Skagit, Snohomish, King, Pierce, Cowlitz, Lewis, Skamania, Yakima, Kittitas, Chelan, Okanogan	1914 - 2000	1399
Yellowstone Cutthroat	King, Kittitas, Lewis, Okanogan, Pierce, Skagit, Snohomish, Whatcom	1914 - 1976	148[1]
Lake Trout	Chelan, King, Snohomish	1920 - 1999	5
Golden Trout	Chelan, Kittitas, King, Lewis, Okanogan, Snohomish, Skagit, Whatcom, Yakima, Mason, Skamania, Jefferson	1936 - 2000	231
Grayling	King, Skagit	1945 - 1986	14
Atlantic salmon	Jefferson, Snohomish, Yakima	1975 – 1985	10
Brown Trout	King, Chelan, Cowlitz, Lewis, Pierce, Skamania, Yakima, Whatcom	1935 – 2000	143
Kokanee	King, Skagit, Snohomish	1917 - 1998	3
Coho Salmon	King, Okanogan, Skamania, Yakima	1918 - 1997	8
Chinook Salmon	King	1999	1

[1] Includes Henry Lake cutthroat.

For the purpose of this report section, rainbow and cutthroat are considered native species. It is generally recognized that Twin Lakes (westslope) cutthroat are genetically dissimilar from coastal cutthroat in western Washington. Similarly, Mount Whitney rainbow can be genetically distinguished from virtually all native rainbow and steelhead in Washington. The balance of this section discusses species that are either not naturally found in Washington, are not found in the lake's watershed, or both.

Experimentation with brown trout as a biological control of stunted fish continues in a very small number of high lakes. No new lakes are currently being proposed to receive this species. (Biological control of stunted fish is a major area of interest [see Section 5.7.2]. Reports of success with tiger muskies (a hybrid cross between muskellunge and northern pike) as a control of stunted eastern brook trout in Idaho high lakes are extremely encouraging (see Section 5.7.2.3), and may lead to some similar testing with this sterile hybrid in Washington.)

Interest in the use of arctic grayling in a few lakes remains high among WDFW local managers (Parametrix 2001). The managers continue to receive calls from the public asking about the singular population, and whether WDFW will expand use of this species. Any new introductions will require a full SEPA review.

Although there are no current plans to stock atlantic salmon, their spectacular performance in at least one Olympic Peninsula Lake in the 1970s makes them a good candidate for very limited use in selected lakes lacking a surface outlet. Their unusual appearance (Plates 41, 42), not to mention their tendency to repeatedly leap clear of the water, often generates calls to the local management biologist when they are encountered in the high country.

5.5.5 Assessment and Recommendations

Overall stocking has been declining for the past 20 years. Most lakes are on low-density, maintenance stocking programs. Recent concern about potential genetic impacts on native fish in streams below high lakes is well-intentioned. However, with rare exceptions, the concern has not been validated by any evidence that significant competition or hybridization is occurring anywhere in Washington with native fish below stocked lakes. The source of exotic species or strains in outlet systems is usually made obscure by historic stocking practices or long histories of both legal and illegal stocking affecting both streams and lakes. Diversity and maximization of recreational angling opportunity are goals of the high lake fishery program (WDG 1981; WDFW 1995a). Species are generally not being stocked into lakes where they have not been stocked before; new introductions are subject to a full SEPA review process.

> **Recommendation #1:** Exotic species such as brown trout, lake trout, atlantic salmon, tiger muskies, and grayling should be stocked where special circumstances make sound biological sense to do so. Many lakes with stunted trout and char populations cannot be treated with piscicides. They must either remain as is, or potentially receive benefits from a biological control such as a top predator. Unusual species which attract high angler interest (golden trout, grayling) should be expanded to a low number of lakes lacking surface outlets if their introduction does not result in unacceptable impacts from increased recreational use.

> **Recommendation #2:** As a general rule, species should be stocked that are native to the lake's drainage basin (e.g. rainbow, cutthroat). To maintain program diversity, strains that are not having a negative effect on native biota (e.g. golden trout) should continue to be stocked.

5.6 ECOLOGICAL CONSIDERATIONS

WDFW fishery managers are aware of the need to consider the ecological effects of the high lake stocking program. As noted in earlier sections, the overall number of lakes being stocked is dropping (Figure 3), as is the general density of fry stocked (Figure 4). The Fish and Wildlife Commission mandate is to "Maximize recreational opportunity for fish and wildlife constituents consistent with the preservation, protection, and perpetuation of the fish and **wildlife** resources" (WDFW 1995a). The native invertebrate and amphibian members of the communities associated with sub-alpine and alpine lakes are classified as **wildlife** (RCW 77.08.010 (16)), therefore their protection and preservation is explicitly directed in Commission policy.

5.6.1 Amphibian and Invertebrate Impacts

There is substantial international concern over the loss of amphibian species, and the possible causes (Barinaga 1990; Pechmann and Wilbur 1994; Blaustein and Wake 1995; Koch et al. 1997). (The stocking of trout into mountain lakes has been suggested as a mode of transfer of *Saprolegnia spp*., a ubiquitous fungus found in virtually all open, natural waters. It has been further suggested that such transfers have lead to amphibian mortality from *Saprolegnia*. This is a specious hypothesis; see Appendix H.) Some of the most recent research suggests a variety of factors, linked to the recent changes in climate, may be responsible for amphibian die-offs (Kiesecker et al. 2001). WDFW fishery managers are equally concerned about the possible effect of stocked trout on native amphibians and invertebrates in Washington, and conducted a detailed review of the literature on the subject (Divens et al. 2001). What follows is a concise summary of that review; readers with a strong interest in the ecological effects of fish in high lakes are urged to read the full report, as well as many of the papers reviewed, in order to gain a full understanding of this complex subject.

5.6.1.1 *Amphibians*

There is no evidence that any amphibian native to the subalpine and alpine zone in Washington has suffered substantial population declines, or is in danger of extinction. Most concern expressed about the effects of Washington's high lake program on amphibians is based on research conducted in other states. The only published research on the interaction of fish and amphibians in Washington high lakes is that which has been conducted in the North Cascades National Park (Liss et al. 1995). That study did not provide any evidence that stocked trout have eliminated amphibians over any significant portion of their natural range. The study did, however, reaffirm findings common to studies from other states. The most important of these is the observed negative correlation between salmonid density and amphibian larval density within their study lakes.

The effects of trout or char on amphibians are species-specific and life history dependant, and vary depending on the species of fish, fish density, and the reproductive capability of the fish species introduced. Important abiotic factors affecting amphibian larval survival include lake morphometry and habitat characteristics, and amphibian habitat that is unavailable to trout within the same drainage basin. In plain terms, some amphibian species are more vulnerable to trout or char predation than others; in Washington, long-toed salamander (*Ambystoma macrodactylum*) appears to be most vulnerable (Divens et al. 2001). Amphibian larvae become difficult or impossible to find or collect when fish densities exceed about 250 fish per surface acre (Hoffman and Pilliod 1999; Divens et al. 2001). This negative relationship tends to weaken when lakes are more productive (higher nutrient levels)(Tyler et al. 1998), or when there is in-lake refugia in the form of shallow edges, or abundant woody debris or talus interstices to serve as cover for larval salamanders (Liss et al. 1995). Ponds and wetlands proximal to lakes supporting trout or char can serve as alternate breeding and overwintering habitat, preserving a nucleus of vulnerable species (e.g., *A. macrodactylum*) in lake basins where fish are excessively abundant.

Seven salamander species occur in Washington's high mountain areas. Three species, northwestern salamander (*Ambystoma gracile)*, long-toed salamander, and roughskin newt (*Taricha granulosa*), breed in lakes or ponds. The roughskin newt and northwestern salamander possess protective secretions, and co-exist with trout and char in Washington's high lakes (Table 7). Long-toed salamander is likely more susceptible to predation, as indirectly shown by studies in Washington (Liss et al. 1995). However, long-toed salamanders are widespread throughout many habitat types in Washington, from western coastal lowlands, to eastern shrub-steppe, to high mountain areas. While their density can be significantly lower in lakes with high density trout or char populations, the effects of trout stocking on their abundance and distribution on a basin or regional scale remain unknown (Divens et al. 2001).

Of six frog and toad species found in Washington's high country, only one, the Columbia spotted frog (*Rana luteiventris*), may potentially be more vulnerable to trout predation in stocked high lakes than other Washington frogs. Unlike Washington's other high mountain anurans, tadpoles of this species may overwinter in deeper lakes or ponds at high elevations and metamorphose the following spring (Nussbaum *et al.* 1983; Corkran and Thoms 1996). However, Columbia spotted frogs have been found to coexist with trout in basins and even lakes with stocked trout as they typically utilize littoral and wetland habitat inaccessible to trout. In Washington, this species occurs in eastern parts of the Cascade Mountains and in low elevation areas of eastern Washington (Green et al. 1997). Koch et al. (1997) reported that the Columbia spotted frog appears to be widespread and common in the main portion of its range, including eastern Washington.

Despite examining the contents of thousands of stomachs from trout collected from Washington high lakes, none of the WDFW fish biologists have seen evidence of frogs or tadpoles in trout diets. On the other hand, larvae and adults of some salamanders, particularly *A. gracile*, are commonly eaten. Empirical observations suggest that larger larvae and adults are not preyed upon by trout until they reach about 12 inches in total length, or an age of about 3 years (WDFW file data). Thus, in lakes where single age classes of fish mature and die from introductions as fry, there are periods of up to several years where amphibians are presumably able to co-exist with younger trout, experiencing little or no predation. This is supported by research in other states that clearly shows co-existence of salamanders with trout, usually under conditions of low trout density (Divens et al. 2001).

After surveying scores of subalpine and alpine lakes in King and Snohomish County over 15 or more years, WDFW Area Biologist Bob Pfeifer noted the common co-existence of *A. gracile* with trout in lakes that have been managed on a cyclic, low-density stocking regime for many years, or decades (Table 7). Similar information was not obtained for long-toed salamander (*A. macrodactylum*) in this district, although this species is significantly more difficult to observe and survey (Divens et al. 2001).

A general conclusion of a thorough review of the literature on the subject of trout and salamander interactions in Washington high lakes (Divens et al. 2001) is that trout and salamanders are able to co-exist when trout or char numbers are kept low. Unfortunately, most researchers investigating these interactions failed to note fish densities in their study lakes. A general trend gleaned from the studies is that salamanders are able to co-exist with trout and char when the fish populations are maintained by periodic stocking, and at levels at or below 100 fish per surface acre (Divens et al. 2001). Most of the studies that exhibited significant impacts to salamanders came from waters that held fish at levels well above this density.

5.6.1.2 *Invertebrates*

There is little doubt that introduced trout can alter both the abundance and community structure of zooplankton and macroinvertebrates in stocked high mountain lakes, especially if the fish population is dense. However, population densities of even vulnerable invertebrate species have often been reported to rebound in lakes as fish abundance declines, or when fish are eliminated (Bahls 1990). Mechanisms facilitating the rebound process are not always clear, but likely involve either immigration (Maguire 1963; McNaught et al. 1999), reproduction by individuals that escaped predation and detection during sampling (Kiser et al. 1963; Nilsson and Pejler 1973), or a combination of both. Recolonization, the ability of zooplankton to utilize fishless lakes, refuge habitat within stocked lakes, and lakes with low density fish populations, apparently allow these species to persist in geographic areas with stocked trout. In some extreme instances, recolonization may not occur due to the biotic and abiotic changes which can arise following the introduction of trout to a previously fishless high mountain lake. Based on recent data, in zooplankton communities in Washington high lakes managed for fisheries, extirpations, if any, are most likely to occur in lakes with reproducing trout or char, resulting in high fish densities. It is unknown whether trout stocked in Washington have eliminated any zooplankton species. However, if such a situation were identified in Washington, there is reported evidence that once an undesirable fish population is eliminated by management action, a zooplankton community can probably be restored by re-introduction of those species which fail to re-appear (McNaught et al. 1999).

5.6.1.3 *Summary*

Washington fishery managers are aware of the problems associated with excessively abundant trout and char in high lakes, and began experiments with biological controls as early as 1979 (see Section 5.7.2). Whole-lake chemical treatment with rotenone was used on a stunted eastern brook trout population in Olympic National Forest in 1973 (Johnston 1973). A two-lake fish removal project was proposed in the Henry M. Jackson Wilderness in 1983 (Weinheimer and Kearney 1983), but was not carried out due to funding difficulties. Federal and state land and fishery managers are using both rotenone and Antimycin piscicides in stunted char removal projects in western states, including Washington (Mottram 1995; Fraley 1996; Drake and Naiman 2001). WDFW fishery managers are wholly supportive of efforts to restore balance to the many aquatic communities in Washington’s high country that have been impacted by excessively reproducing fish populations. One option to restore quality fisheries and ecological balance is by removing problem species or strains and replacing them with species or strains that can be maintained at low density through disciplined stocking.

Research reviewed by Divens et al. (2001) indicates that the degree of impact stocked trout may have on native biota inhabiting high lakes can vary widely. To date, no research has focused on determining the impact of various trout species or stocking rates typically used in high lake stocking. Although some researchers have reported that stocked trout caused a decline in the abundance of some native species, other research suggests that there may be little effect using certain management strategies (i.e., certain trout species or stocking rates and cycles). Studies on the impacts on non-fish species have tended to lump fish species, and rarely provided detailed information on the actual density of fish present in study lakes.

Some researchers have recommended halting high lakes stocking and leaving only “wild” fish populations that can sustain themselves through natural reproduction (Bahls 1990; Murray and Boyd 1996; Munger et al. 1997). Following this recommendation, WDFW fishery managers could offer only lakes with introduced self-reproducing fish populations. Lakes with reproducing fish populations have been reported most likely to have an impact on native biota. Additionally, these lakes often offer less desirable trout populations for anglers because of their tendency to over-populate and stunt. Elimination of the more desirable fisheries will also increase the tendency of unscrupulous or ignorant publics to transfer problem trout or char species from these lakes to other waters, thereby exacerbating and extending the potential impacts of such reproducing populations.

The WDFW literature review (Divens et al. 2001) shows that the high lake fisheries likely to have the least impact on the native biota and offer “quality” fishing opportunities are put, grow and take populations maintained by stocking select species of trout at low densities on a schedule that keeps the number of fish in the lake below that which threatens native biota. Long term experience by local WDFW fishery managers suggests stocking rates of 100 fish per surface acre or less are compatible with native amphibians and conspicuous macrozooplankton (Table 7). Research is needed to determine with more rigor which stocking density should be used to provide diverse recreational fishing opportunities, while at the same time ensuring the persistence of native lake fauna. Specific research along these lines is suggested in Divens et al. (2001).

5.6.2 Native Fish Impacts

Introduced fish can impact native fish species in many ways including genetic, inter- and intra-specific competition, and predation (Krueger and May 1991; Philipp et al. 1993; Kitano et al. 1994). Because most high lakes in Washington were historically fishless, there have been few sites where stocked trout have interacted directly with native fishes. However, emigration of trout from high lakes into connected streams can occur. Most problems with dropout from high lakes and competition or hybridization with downstream native fish seem to involve brook trout. Brook trout stocked directly into lakes and streams inhabited by bull trout have competed with, or hybridized with, bull trout populations in Washington and other western states (Leary et al. 1983; Leary and Allendorf 1991; Buktenica 1997). In Colorado, native greenback cutthroat trout (*Oncorhynchus clarki stomias*) inhabiting streams below stocked high lakes were displaced by naturally reproducing brook trout (Windell and Foster 1982). Considering the downstream barrier to fish passage, Windell and Foster (1982) believed the brook trout originated in the high lakes upstream. Following their stocking in Beaver Lake, in north central Washington, brook trout colonized Beaver Creek below, resulting in the extirpation of native bull trout in at least the south fork (Ken Williams, WDFW District Fish Biologist, unpublished data).

Although introduced fish can displace native fish species in streams through hybridization and/or competition, the extent of emigration of stocked trout from high lakes in Washington to streams above and below stocked lakes is unknown. Nevertheless, many local WDFW fish managers are cognizant of these risks, and either use native fish stocks in their high lake program, or consciously avoid use of species known to contribute to this problem (Parametrix 2001). There is currently a virtual moratorium on the stocking of eastern brook trout into Washington high lakes. Most WDFW local managers would also like to have the resources to begin a systematic program of removing reproducing eastern brook trout (and certain westslope cutthroat) populations – the ones most likely to be emigrating from high lakes and interacting with downstream native fish. Finally, the use of exotic fish species in Washington high lakes is generally limited to those with no surface outlet, or where experience with low density populations in the lakes has not revealed an emigration problem.

5.6.3 Wildlife Benefits

Carnivorous wildlife benefit from fish introductions into formerly barren lakes, although the evidence of this is mostly anecdotal. WDFW local fish biologists and high lake anglers have seen fish taken from high lakes by mergansers and ospreys (Curtis and Erickson 1992). An active osprey nest was observed by WDFW biologist Bob Pfeifer adjacent Upper Tuscohatchie Lake in King County, while surveying it in 1991. It is reasonable to expect species such as raccoon, coyote, otter, fisher, marten, and black bear to take fish either from the lakes directly, or more likely from spawning tributaries, particularly when the fish are exhausted after spawning. This food source may be increasingly important as their foraging range outside designated wilderness continues to shrink due to an ever-increasing human population, particularly in the western Cascades.

5.6.4 Habitat Protection

WDFW Fishery and Habitat Biologists have very limited control or influence over actions taken by major timber owners, or federal land managers. An estimated 46% of “high” waters >0.1 acre in Washington are located in designated wilderness (Table 17), and upland habitat around the lake is generally well-protected, except for the incidental impact of recreational users. In some areas high lakes occur on lands owned by major timber companies, or on state land administered by the Washington Department of Natural Resources (DNR). Coordination between WDFW biologists and timber/land managers from DNR and private owners can sometimes protect nearshore habitat through elements of the Washington Forest Practices Act (RCW 76.09).

Unfortunately, state law has often been inadequate to protect the natural forest or meadow environment surrounding some high lakes (Plates 63 through 68). The impact of clear-cutting around a 19-acre lake is not limited to aesthetics (Plate 63), but can affect the lake’s thermal regime, particularly for shallow lakes (Plates 65, 66). Altered rates of snow accumulation and snowmelt due to removal of the forest in the lakebasin may also alter the annual water budget (Rothacher 1970). Again, the impact would be expected to be greatest on small, shallow lakes. The ecological effects of these perturbations have not been extensively studied in Washington high lakes. However, research in a natural, uncut subalpine lake ecosystem showed that needle drop and other allochthonous sources of carbon can be a major part of the lake’s carbon budget, much of which supports the invertebrate (fish food) community (Wissmar et al. (1977). These authors stated that their “study illustrates the probable dependence of many lakes in coniferous forests upon allochthonous inputs and their sensitivity to land-based perturbations”.

Plate 63. Almost no trees were left standing when clearcut logging occurred around 19-acre Nadeau Lake, near North Bend in the early 1980s. The old growth forest had shaded out most understory. Three outstanding fisheries were lost when three large lakes within a square-mile Section received this treatment and access was gated off. It will be many decades before the original aesthetics and local carbon pathways are restored. (28 May 1983)

Plate 64. A "buffer strip" one or two trees wide was left along 5-acre Rachor Lake, near North Bend. However, such strips commonly blow down, eliminating all shade benefits, and effectively extinguish normal allochthonous carbon input from needle drop. Trees which topple into the lake offer some substrate value for invertebrates, but often inhibit fishing. (28 May 1986)

Plate 65. Small lakes such as Upper Mine Creek Pothole (South Fork Snoqualmie River drainage) are exposed to unusual rates of heating when forest cover is removed. Exposure to ultraviolet radiation and lake heating may also affect amphibian reproductive success. (26 June 1990)

Plate 66. Broad, shallow meadow lakes such as Airplane Lake in the lower Skykomish River drainage are also vulnerable to heating when the large cedars that occurred around the lake are removed. Manipulations of the woody debris at the lake's outlet by users of the logging road that crosses it has resulted in a serious drop in lake elevation. It can no longer support a fishery due to exposure and shallowness. (23 May 1995)

Plate 67. Removal of a beaver dam on the outlet of Lower Duffey Lake (lower Skykomish River drainage) lowered the lake several feet. Former productive, shallow, rush-filled bays are now exposed, and the lake's overall area has been substantially reduced. Fish, amphibian, and wildlife habitat has been lost. Logging is currently occurring around both Lower and Upper Duffey Lakes. (20 July 1998).

Plate 68. Logging roads near lakes often provide irresistible temptation to off-road vehicle users. This chronic muddy mess extends to the edge of Rockdale Lake, near Snoqualmie Pass, as well as to its principal inlet. (2 July 1998)

5.6.5 ESA Coordination

There has been very little application of the Endangered Species Act (ESA) to the WDFW high lake program to date. As mentioned in Section 5.6.3, the presence of fish in many high lakes probably provides a potential additional food source for species such as bald eagle, gray wolf, and grizzly bear. Human interactions with spotted owl and marbled murrelet may be problematic in nesting areas, but fishing is rarely the sole reason people go to high lakes (Hendee et al. 1977). WDFW fishery managers have worked cooperatively with wildlife and recreation managers in instances where backcountry users conflict with sensitive species such as wolves or loons. Adjustment of access and fishing season opening dates are one method used to minimize conflicts in certain locales.

Dropout of eastern brook trout from high lakes into streams with native bull trout is an obvious ESA issue, and was discussed in Section 5.6.2. WDFW does not stock eastern brook trout into high lakes with surface outlets that drain to basins that currently or historically supported bull trout. WDFW would like to have the time and resources to begin a systematic program of removing (and in most cases, replacing with an appropriate substitute fish species or sterile strain) eastern brook populations from high lakes that drain to bull trout habitat.

Apart from eastern brook trout fallout, there is no known problem or potential problem with the high lake program and other listed fish species, such as Puget Sound chinook, or mid-Columbia River salmon and steelhead.

Use of bull trout as an apex predator to control stunted brook trout, Kamloops rainbow, or westslope cutthroat (see Section 5.7.2) may provide an opportunity to restore bull trout presence in basins from which they have been extirpated, or to simply extend their range and overall numbers (Pister 1990).

5.6.6 Assessment and Recommendations

WDFW fishery managers are cognizant of the ecological interaction issues surrounding the historic high lake fishery, and future stocking. Stocking rates and cycles have been adjusted downward for nearly 30 years, with the largest adjustment occurring in the early 1970s. A detailed literature review confirmed that WDFW's program of maintaining low-density, quality-oriented fish populations in a limited number of waters is consistent with the protection of native amphibians and invertebrates. Positive steps have been taken in the past to remove problem fish populations, and this program should be expanded to one of reclamation of at least several lakes annually. This would have two major benefits:

- Positive progress in removing fish populations known or likely to have ill effects on native fish, amphibians, or invertebrates; and
- Assurance that WDFW maintains a fisheries management field staff experienced and expert in the chemical or biological treatment of lakes having problem fish populations.

Impacts of the historic and current high lake stocking program on native fish are poorly documented. Better information is needed on the rate and extent of fish dropout from high lake – which species, what age or sizes, and under what conditions. Problem lakes with eastern brook (or other species) that threaten native species such as bull trout should be prioritized for chemical or biological control treatments.

Recommendation #1: The prioritized research topics listed in Divens et al. (2001) should be implemented as budgets allow. Fish should be removed from lakes where they are documented to have an unacceptable impact on native species. Conversely, fish should be allowed to remain in lakes where they have historically provided a valuable recreational fishery and potential wildlife benefits, and where they are not having an unacceptable impact on native species.

Recommendation #2: For ecological as well as angling quality reasons, lakes that require stocking should be stocked at low densities, and on an infrequent basis to keep overall fish abundance low. In general, native fish species that do not reproduce should be used (see Section 5.4.7).

Recommendation #3: A list should be prepared of all known Washington high lakes that contain excessively abundant fish populations (most are known, and local WDFW file data should enable this). The lakes should be prioritized for treatment (partial or complete fish removal, or biological controls), and the suggested treatment/s noted for each lake. Criteria for prioritization are social (recreation benefits), physical (logistics and site-specific conditions; costs), and ecological (degree of current impacts, fish species involved, etc.). For each lake, fish removal or numbers reduction actions that are feasible should be identified.

5.7 POPULATION CONTROL METHODS

To date, WDFW has primarily used chemical methods (rotenone) to control or eliminate excessively abundant fish populations in Washington high lakes. Although this should probably occur on scores of high lakes statewide, it has only been attempted (and successfully accomplished) on one lake in the Olympic Mountains (Johnston 1973). Local fishery managers, often in cooperation with sports groups, have conducted very limited experimentation with hybrid trout and top predators, but none of these tests have (yet) resulted in major reductions in fish abundance that are needed to assure native invertebrate communities are not significantly less diverse than the natural, fishless condition. Neither liberalized regulations nor intensive fishing have been tested by WDFW. These options are further discussed, below.

5.7.1 Chemical Methods

Unfortunately, the prospect of use of any chemicals in the seemingly "pristine" environments that typically surround high lakes often elicits strong emotions from publics who are not familiar with the specific properties of the piscicides. Erroneous, misleading, and fear-promoting misinformation as to alleged properties of chemicals such as rotenone often require professional organizations and agencies to publish reports and articles in an attempt to correct the damage (Bradbury 1986; Task Force on Fishery Chemicals 2001). Rarely, if ever, are the short term effects of rotenone or Antimycin publicly balanced against the benefits of removing excessively abundant fish that are exerting a continuous predatory and competitive force on native biota. (The economic and recreational benefits are well-published [Ball 1945; Trimberger 1975; Stockbridge 1977; WDG 1979; Christenson et al. 1982; Bradbury 1986], even if not publicly well-known.)

Public awareness needs to be raised of the benefits to be gained by removing problem fish populations. These benefits include restoration of the native invertebrate community (Kiser et al. 1963; Anderson 1970), and replacement of a stunted, unattractive fish population with a healthy, fast-growing population in balance with its environment (Johnston 1973; Walters and Vincent 1973; Fraley 1996). The common fear of "chemicals in the water" needs to be balanced with facts; rotenone has commonly been used to control problem fish in public drinking water supplies (Cohen et al. 1960).

Chemical treatment options are limited to rotenone, or Antimycin (Schnick et al. 1986). While rotenone has been used very successfully in high lakes (Fraley 1996), even in Washington (Johnston 1973), its impact on non-target species (i.e., invertebrates) is longer-lasting and more severe than Antimycin. (However, its use still does not result in extinctions [Bradbury 1986].) In fact, when Antimycin is used at the levels needed to eradicate fish, “generally there were no discernible effects on invertebrates” (Schnick 1974). Antimycin is almost certainly the chemical of choice, particularly if the lake has a flowing outlet. Applied in parts per billion, much smaller quantities of active ingredient are required to treat a given volume of water. Its toxicity is measured in hours or days (Gresswell 1991), rather than weeks, or even months (Anderson 1970; Engstrom-Heg and Colesante 1979). Its greatest value lies in the fact that it is extremely rapidly degraded when in contact with sunlight and strong oxygenation. Therefore, high lakes with steep, dashing outlets do not require chemical treatment (Pfeifer 1985) to detoxify the chemical before it reaches downstream fish populations (Tiffan and Bergersen 1996). Rosenlund and Stevens (1992) removed eastern brook from 26 lakes and streams in Colorado, including waters in Rocky Mountain National Park, and verified the “natural degradation of Antimycin in stream habitats with an elevation loss of 260 to 490 feet”. These authors reported case histories where eastern brook have been eliminated for over 15 years.

Federal land managers have used piscicides to remove unwanted fish populations for years (Gresswell 1991; Rosenlund and Stevens 1992), including lakes in Washington (Mottram 1995). WDFW fishery managers have decades of experience in application of piscicides (Bradbury 1986). Only a lack of resources has prevented WDFW biologists from extending their experience to problem populations in more high lakes (Johnston 1973; Weinheimer and Kearney 1983).

5.7.2 Biological Controls

Use of top predators to control smaller prey species, yet provide angling opportunity is a common tool in warmwater fisheries (McCammon and von Geldern, Jr. 1979). Generally, use of non-native species should be approached with extreme caution; use of sterile hybrids or neutered fish are safer approaches (Everhart et al. 1975). Since it was obvious that rotenone could not be used in all high lakes having stunted eastern brook populations, WDFW high lake fishery managers became interested in top predators as an alternative control method in the mid- to late 1970s. While top predators and hybrid trout competitors have been tested in numerous high lakes in both western and eastern Washington (Pfeifer 1995), data were only available from the following three lakes, and serve as examples of the range of results that may be expected. (The results of the experiments in these three lakes will be the subject of separate, more detailed technical reports. These results are purposefully reported without customary statistical analysis.)

It is useful to establish some measures of success where the fishery management goal is to improve on adverse conditions in a fish population, rather than eliminate the population and start over. The paramount goal is to reduce problem fish numbers. Incidental benefits include improved growth rates and fish condition. Since WDFW local managers rarely have the resources to perform mark-recapture studies to obtain fairly accurate population estimates (Gresswell et al. 1997), reduced fish abundance in the three experimental lakes can be inferred if catch per unit effort (cpue) from a standardized gill net set drops appreciably, and consistently. Corroborating evidence of reduced fish density includes increased length at age, and increased relative weight, a standardized measure (Anderson and Nuemann 1996), and internal body fat (a subjective measure). Finally, in most cases, the management “bottom line”, assuming a fish population is to be retained in a lake, is to improve the quality of the fishery. Improved quality can take the form of increased diversity, such as when a new species is introduced for control purposes, but which can also be caught (Tipping 1996). Most anglers also are interested in catching and keeping a few fish of nice size and condition (Braaten 1970; Moeller and Engelken 1972). These indices were used to evaluate the success of top predator introductions in the three test lakes.

5.7.2.1 *Top Predators*

Unnamed Lake

In 1979, 200 Age 1 brown trout were stocked by helicopter with a fire bucket into a 23-acre lake located at 4500-ft in the Skykomish River drainage (Plates 69, 70), resulting in a density of 8.7 brown trout per surface acre. (The lake is not named herein because of the likely publicity this report will receive, and the potential increased impact on the lake environment due to notoriety.) The purpose of this introduction was to attempt to reduce the abundance of the severely stunted, naturally-reproducing eastern brook trout population (Plate 71). Periodic monitoring in 1980 and later years indicated the brown trout, which had been reared in a hatchery raceway for over a year, had difficulty adapting to the natural environment. Many grew slowly, if at all (Plates 72, 73), and some became emaciated. Some fish were presumably able to successfully switch to a diet of fish, as they grew to large size and maintained good to excellent condition (Plate 74). Most of these survivors were difficult to catch, and lived for 8 to 10 years.

The high mortality and poor condition seen in the brown trout stocked as yearlings led to a change in the stocking strategy to one of backpack stocking advanced fry, or small fingerlings. Two supplemental brown trout introductions into Unnamed Lake occurred in 1990 (500 at 60/lb) and 1994 (300 at 150/lb). If a mortality rate of 50 percent is assumed in the first year after stocking (Donald and Alger 1986), a density of 10.8 browns per acre existed in 1991, and approximately 15 per acre in 1995.

Table 21 summarize most of the success indices following WDG biologist Jim Cummins' pioneering introductions in 1979. In 1977, Jim described the fish as "extremely thin", and "severely stunted" (Plate 71). In 1996, two remarkable fish were collected. An 18 inch specimen was in excellent condition (Wr = 96.6), and had heavy internal fat. A second 11.6 inch fish was also in good condition. These were the largest brook trout reported from this lake in nearly 50 years of angler reports. Discounting the obviously faster-growing fish in 1996 (Table 21), the maximum size observed in all eastern brook samples increased slightly by 1998, adding one half inch since 1977. Length at age in 1998 was slightly higher than in 1977 for Age 3 fish, and 0.8 inch greater for Age 4 brook trout. Unfortunately, weights were not taken on the char before the brown trout were added in 1979. However, relative weight showed an increase between 1996 and 1998 for fish collected at the same time of year (fall), again excepting the unusually large specimen.

Plate 69. Unnamed Lake (shaded, at photo bottom) in the Skykomish River drainage. The frozen lake at left center does not drain to Unnamed Lake. (18 July 1995)

Plate 70. Unnamed Lake has long been popular with local hiker/campers. Heavy use was probably driven more by the aesthetics of the area then the opportunity to fish the stunted eastern brook trout population. (26 July 1980)

Table 21. Matrix of Eastern Brook Population Indices in Three Western Washington High Lakes Stocked with Top Predators, 1977-1999

Lake	Year	Overnight Gill Net Set cpue	Relative Weight	Maximum Length (in)	Length at Age 2	Length at Age 3	Length at Age 4
Unnamed	1977		ND	9.25		7.0	7.5
Unnamed	1996		96.6	18.0	8.6	10.0	11.8
Unnamed	1996	1.49	80.6	9.9			
Unnamed	1998	0.88	83.8	9.8	5.4	7.2	8.3
Talapus	1981			10.4			
Talapus	1984	2.875	84.4	13.3			7.0
Talapus	1988	0.765	90.1	9.3			
Talapus	1989	2.625	86.3	9.8	6.2	8.1	8.7
Talapus	1991	1.600	89.5	10.3	5.5	8.0	9.3
Talapus	1999	0.750	86.3	10.2			
Pratt	1984	2.471	87.7	9.5			
Pratt[1]	1992	0.583	88.2	9.8			8.8
Pratt[1]	1997	0.700	90.6	10.2	5.6	7.1	9.0
Pratt[1]	1998	0.479	83.1	10.3		7.6	9.7
Pratt	1999		86.0	10.2			
Pratt	2001		86.6	11.4			

[1] Length at age estimated; total ages from otoliths only.

Plate 71. This emaciated eastern brook trout from Unnamed Lake looks more like a deep-sea swallower (Family Eurypharyngidae) than a healthy char. Large numbers of starving fish can be expected to reduce many members of the lake's native invertebrate community to undetectable levels. (26 July 1980) Jim Cummins photo.

Plate 72. Two-year old brown trout that had been stocked as yearlings into Unnamed Lake in 1979 were in relatively poor condition the following year. (26 July 1980) Jim Cummins photo.

Plate 73. Although the brown trout were by no means prime in 1980, some anglers were nevertheless thrilled at the opportunity to find fish of even this size and condition in Unnamed Lake after decades of stunted brook trout. (26 July 1980) Jim Cummins photo.

Plate 74. Some brown trout stocked into Unnamed Lake in 1990 were 25 inches long in 1998, and weighed almost 8 pounds. The fish was in excellent condition. (7 October 1998)

A large majority of the brook trout in Unnamed Lake now have trace or light amounts of internal fat (Table 22), whereas in 1977 none of the 20 fish sampled by Cummins had any internal fat. Conditions continued to improve in 1998, where over one quarter of the fish sampled had moderate amounts of internal fat.

Although the same gear was set at the same time of year in the same locations, gill net cpue for brook trout dropped 41% between 1996 and 1998 (Table 21). Finally, the general size distribution and maximum length of the brook trout in Unnamed Lake changed for the better between 1977 and 1996 (Figure 18).

These indices all suggest brook trout abundance has dropped in Unnamed Lake since the brown trout stocking program began. Predation on smaller brook trout is presumed to be a major factor, since all brown trout collected during sampling in 1996 had small brook trout remains in their stomachs (Plate 75). While the brown trout have obviously not eliminated brook trout in Unnamed Lake, they have added a definite element of diversity and quality to the catch (Plates 74, 75). However, improvements in the brook trout population are slow, and measured. As recently as 1993 some of the char were still thin (Plate 30), but none of the fish sampled in 1996 or 1998 had this appearance (Plate 75).

Table 22. Subjective Ratings of Internal Body Fat in Eastern Brook Trout From Talapus and Pratt Lakes, Washington, 1977- 2000

			Subjective Internal Fat Content (%)			
Lake	**Year**	**Number of Eastern Brook**	**None**	**Light**	**Moderate**	**Heavy**
Unnamed	1977	20	20 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)
Unnamed	1996	18	2 (11.1)	15 (83.3)	0 (0.0)	1 (5.6)
Unnamed	1998	15	2 (13.3)	9 (60.0)	4 (26.7)	0 (0.0)
Talapus	1988	10	0 (0.0)	8 (80.0)	2 (20.0)	0 (0.0)
Talapus	1989	20	1 (5.0)	17 (85.0)	2 (10.0)	0 (0.0)
Talapus	1991	8	3 (37.5)	4 (50.0)	1 (12.5)	0 (0.0)
Talapus	1999	9	2 (22.2)	6 (66.7)	1 (11.1)	0 (0.0)
Pratt	1981	4	4 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)
Pratt	1992	8	1 (12.5)	5 (62.5)	2 (25.0)	0 (0.0)
Pratt	1997	25	2 (8.0)	19 (76.0)	4 (16.0)	0 (0.0)
Pratt	1998	30	1 (3.3)	29 (96.7)	0 (0.0)	0 (0.0)
Pratt	2000	8	0 (0.0)	7 (87.5)	1 (12.5)	0 (0.0)

Light = Fat in continuous streaks, but of minimal depth (< 1 mm).

Moderate = Fat continuous, depths ranging from 1 to 2 mm; organs, stomach, and intestine generally visible.

Heavy = Fat generally > 2 mm in thickness; organs, stomach and intestine generally occluded, and only visible by teasing apart fat accumulations.

Figure 18. Length Frequency of Unnamed Lake Eastern Brook Trout, 1977 – 1998.

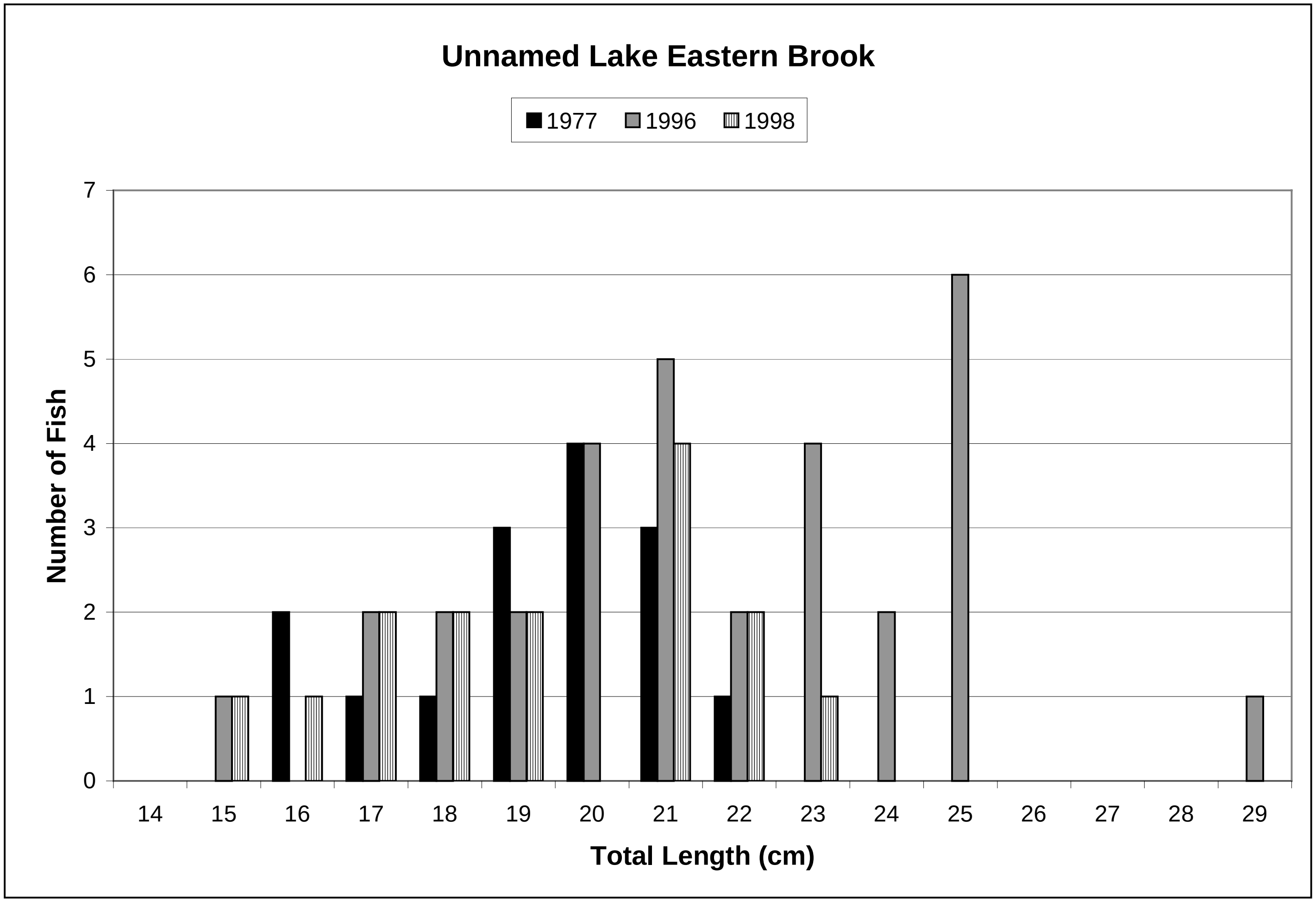


Plate 75. Mixed eastern brook and brown trout from Unnamed Lake, September 27, 1996. All of the brown trout, which were running about 11.5 inches, had eastern brook fry in their stomachs. All of the eastern brook were in good condition.

The Unnamed Lake brown trout experiment can be viewed as a partial success in that it improved several measures of the fishery (quality and diversity of both fish species). A major unknown is the condition of the lake's invertebrate community before and after the putative reduction in char density. The Unnamed Lake experience may be only slightly better than that seen in other lakes where they have been tested; one WDFW high lake manager reported he "got big browns and lots of eastern brook" (Parametrix 2001).

Talapus Lake

A similar test was conducted in 18-acre, 3270-ft Talapus Lake (Plates 76 to 78), a subalpine lake that supports reproducing brook and cutthroat trout. Sub-yearling brown trout running 30 to 40 per pound were backpack stocked at 9 to 11 fish per acre in 1983 and 1984. Supplemental stockings occurred at the same density in 1988, 1989, and 1990. The fish population was sampled with sinking gill nets at the same time of year (early summer), and in the same locations in 1984, 1988, 1989, 1991, and 1999. Results in Talapus were mixed, and certainly not conclusive, except it is clear that the brook trout were not eliminated. The initial condition of the brook trout in Talapus (Plate 79) was also much better than that seen in Unnamed Lake (Plate 71).

There was considerable variability seen in brook trout relative weight between 1984 and 1999 (Table 23), however the relative weight data must be interpreted with caution. Fish condition factors are known to vary with the season and state of sexual maturation (Carlander 1969), and this was certainly observed in Talapus Lake. An attempt was made when sampling all of the test lakes to sample at the same time of year, and when the lakes had been clear of ice for approximately the same amount of time. It was obvious when mid-June samples were collected in 1991 and 1999 that the lake had not been open an equivalent amount of time as the mid-July samples taken in 1984 and 1988. Additional net sets were therefore made in mid-July to coincide with sets made in 1984 and 1988. Brook trout condition improved between mid-June and mid-July in both 1991 and 1999, but especially in 1991. It is interesting to note that the condition of the char was relatively good (Wr = 85.2) even when the lake had just cleared (40^o F) in mid-June of 1999. They were in much better condition than a larger fish sample on nearly the same date in 1991, even after one of the heaviest snow packs in many years. Overall, relative weight increased only very slightly between 1984 and 1999 for fish collected in the third week of July (Table 23).

There was no appreciable change in the amount of internal body fat seen between 1988 and 1999, although sample sizes were low (Table 22). The maximum length seen in the brook trout actually occurred in 1984, when a 13.3 inch fish was collected. The largest subsequent fish was 10.2 inches (Table 21 and Figure 19). Gill net cpue was quite variable, but if the low cpue in 1988 is not included, the 11 year series may represent a declining trend from the high value of 2.875 in 1984 to the low of 0.750 in 1999 (Table 21).

The test of top predators in Talapus Lake was confounded by a change in the amount of char spawning habitat due to inlet flooding by new beaver activity (Plate 76). Thus, any change in the condition and abundance of the char could not be ascribed solely to predation since it could also have been associated with reduced fry recruitment. The brook trout population in Talapus was also not in acutely poor condition at the start of the test (Plate 79), unlike Unnamed, and other lakes. Talapus Lake brook trout had an average relative weight of 84.4 in 1984, higher than that seen in Unnamed Lake in 1998, after Unnamed Lake char had improved considerably (Table 23). (By way of perspective, the severely stunted brook char in Tye and Joan Lakes (Plates 80 and 36) had relative weights of 76.6 and 74.7, respectively.)

Plate 76. The inlet system just west of Talapus Lake had flooded a sizable area, and consisted of multiple slow channels due to beaver activity in the mid-1980s. The view is to the northwest just west of the lake. The amount of former spawning habitat that had been flooded is unknown. (16 July 1991)

Plate 77. The main inlet of Talapus Lake forms a peninsula at the lake's west end. (16 July 1991)

Plate 78. View northeasterly of the main body of Talapus Lake in the South Fork Snoqualmie River drainage. There are several very small trickle tributaries on the north shore, but they offer very little spawning habitat. (16 July 1991)

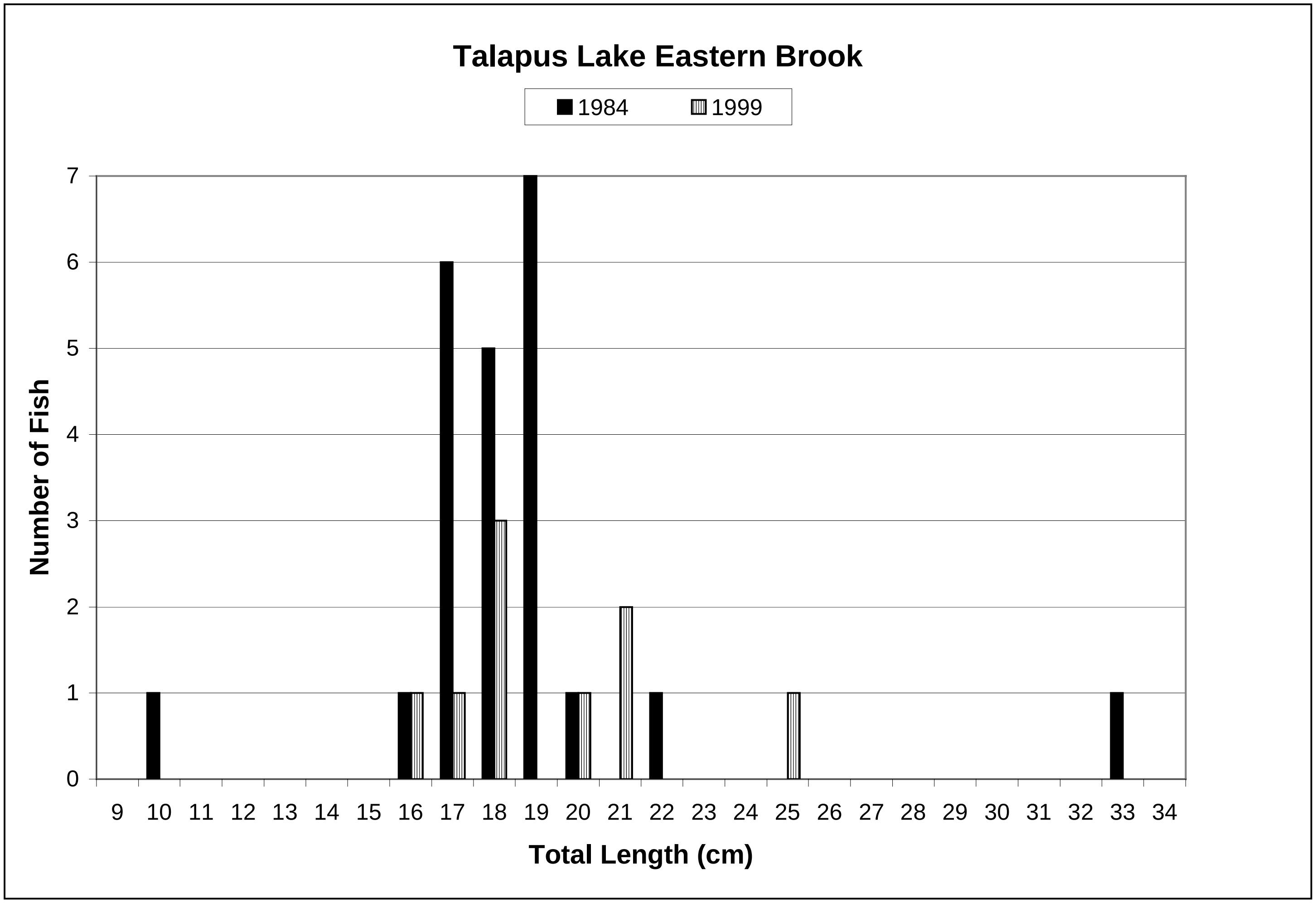
Plate 79. Seven eastern brook, one cutthroat, and four brown trout collected from Talapus Lake on June 20, 1991 (counterclockwise from top left). The length and age of the brown trout were 7.5 inches, Age 2; 8.25 inches, Age 3; and 11.6 inches, Age 8.

Plate 80. Eastern brook trout collected from Tye Lake on September 13, 1995. Note the very poor condition of the top and fifth fish. The fish were 3 to 6 years old.

Table 23. Relative Weights of Eastern Brook from Three Washington High Lakes with Stunted Populations Treated with Top Predator Biological Controls, 1984-2000

Lake	Year	Date	Sample Size	Lake Temperature (F)	Relative Weight (Wr)
Unnamed	1996	9/27	33	50	81.1
Unnamed	1998	10/7	15	55	83.8
Talapus	1984	7/19	22	60	84.4
Talapus	1988	7/15	10	54	90.1
Talapus	1989	6/16	26	50	86.3
Talapus	1991	6/20	19	50	74.6
Talapus	1991	7/16	5	60	89.5
Talapus	1999	6/26	3	40	85.2
Talapus	1999	7/16	6	54	86.3
Pratt	1984	7/19	20	66	87.7
Pratt	1992	7/3	12	64	88.2
Pratt	1997	7/5	31	62	90.6
Pratt	1998	6/5	30	54	83.1
Pratt	1999	7/13	13	56	86.0
Pratt	2000	6/26	8	61	85.2
Pratt	2001	6/28	7	54	86.6

Figure 19. Length Frequency of Talapus Lake Eastern Brook Trout, 1984 – 1999.



Pratt Lake

A long term experiment with a lake trout introduction has yielded interesting and limited, but positive results. Pratt Lake is a 125-foot deep, glacially-carved lake in the west-central Cascades (Plate 81). Inlet and shoreline-spawning brook trout were thin, with large heads in 1984 in the 43.5 acre lake. Lake trout averaging 45 per pound were backpack stocked in 1985 in a long-term test of their ability to improve the condition and size of the eastern brook. The initial introduction was 15.1 lake trout per surface acre.

Eastern brook relative weights from Pratt Lake must be interpreted with caution, just as in Talapus Lake, since the length of time the lake had been clear of ice when the population was sampled varied from year to year. A slight increasing trend in relative weight is seen between the years 1984 and 1997 when all of the net sets were made in early to mid-July (Table 23). Sampling in 1998, 1999, 2000, and 2001 was consciously arranged to try to be at the lake as soon after iceout as possible in order to increase the chances of sampling the lake trout. The lake was still fairly cold, and had not been open long in 1998, 1999, and 2001. The year 2000 represents an intermediate condition. More detailed analysis of these data may show that none of the changes in relative weight are statistically significant.

None of the few brook trout caught on hook and line in 1981 had any internal body fat, but this could have been partly due to the low sample size. By 1992, over 87 percent of the 25 sampled char had light to moderate internal fat deposits (Table 22). A more substantial sample in 1997 verified that a majority of the eastern brook now came through the winter with at least light to moderate fat reserves. This trend continued through 2000. (Fish were not sampled for internal fat in 2001.)

Growth rate (length at age) was not available from the 1981 or 1984 brook trout samples (the scales from these fish are also very difficult to read). Length at age increased annually between 1992 and 1998, and represents some of the higher growth rates among the three experimental lakes (Table 21). The average length of age 4 brook trout from Pratt Lake (9.7 inches) is now the highest value seen in these populations, with the exception of the unusually large fish collected from Unnamed Lake in 1996. The maximum size observed in the brook trout has increased from 9.5 inches in 1984 to 11.4 inches in 2001 (Table 21 and Figure 20).

Growth rates observed in Pratt Lake are intermediate in the range seen among Washington high lakes. Eastern brook thrive in many high lakes of the southern Cascades, where stunting is not as ubiquitous (Plate 43). A good example of excellent brook trout growth is seen in Elochoman Lake in Cowlitz County (Table 24). At the other extreme are lakes such as Tye, Mazama, and Upper Twin, which typify the classic stunted fish that plague many of our high lakes in Washington. These fish continue to live and exert predatory pressure on a lake's invertebrate food resources for many years, sometimes to an almost unbelievable extent (Reimers 1979).

There are two fairly strong lines of evidence that overall fish abundance is reduced in Pratt Lake following the lake trout introduction. Eastern brook catch per unit effort from a standardized net set dropped from 2.50 in 1984 to 0.875 in 1997, and 0.75 in 1998. Second, and most interesting, is the fact that kokanee, which were initially introduced into Pratt Lake by the U.S. Forest Service in 1918, were not being caught by anglers, and were totally absent from the angler catch report record which began in 1968 for this lake. No kokanee were taken in four floating and sinking gill net sets in three separate years (1981, 1984, 1992). These sets yielded a total of 38 brook trout. However, sampling by both gill net and hook-and-line in 1997 found kokanee readily catchable; subsequent high lake anglers who visited the lake out of curiosity about this turn of events also had no difficulty catching kokanee along with the brook trout. The lake has been monitored annually since 1997, and both kokanee and brook trout can now be caught from shore or raft.

Plate 81. Pratt Lake in the Pratt River (Middle Fork Snoqualmie River) drainage, looking north. (August 1976) Jim Cummins photo.

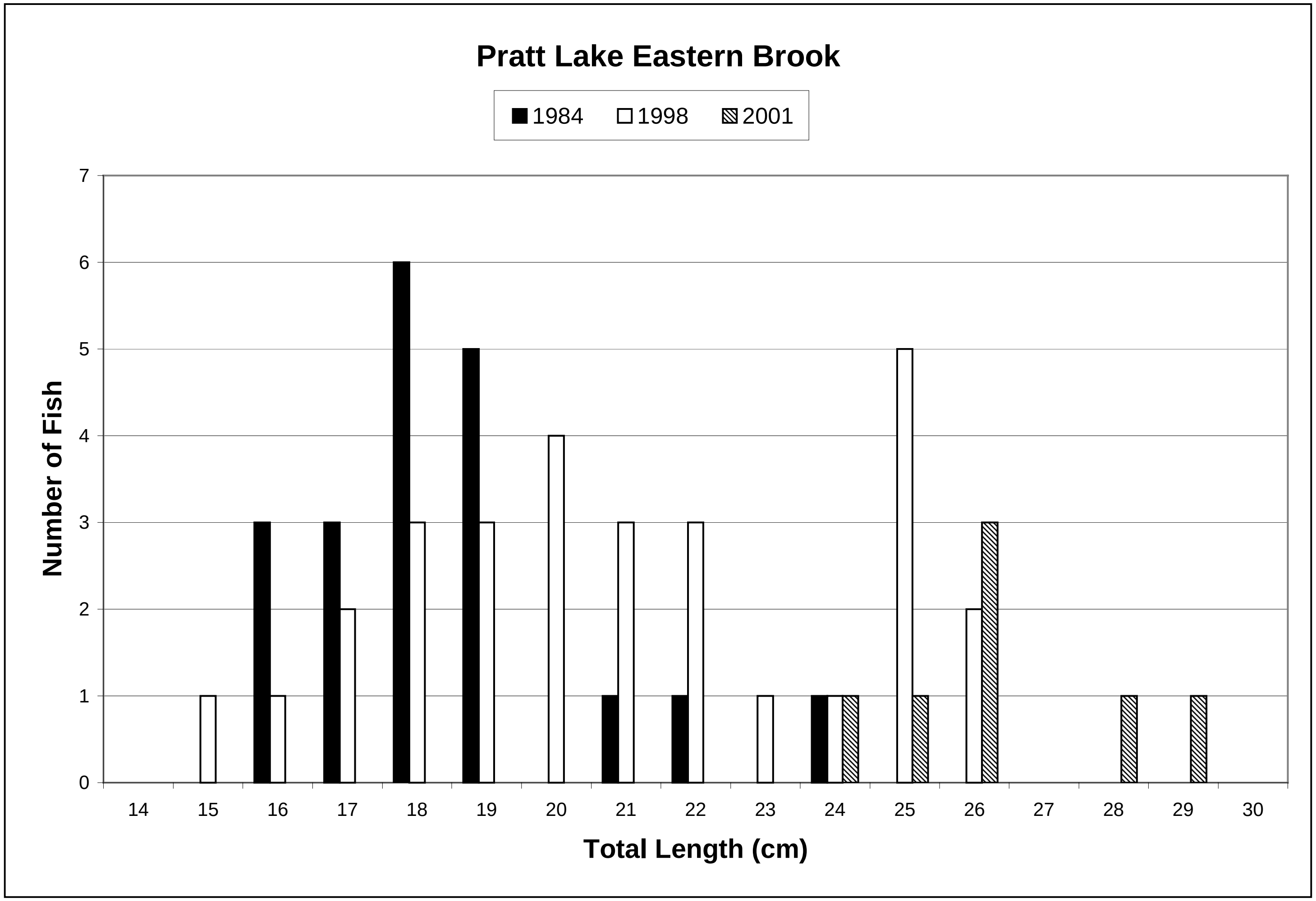


Figure 20. Length Frequency of Pratt Lake Eastern Brook Trout, 1984 – 2001

Table 24. Comparison of Pratt Lake Eastern Brook Mean Total Length (Mm) at Age with Other Washington High Lake Brook Trout Populations Of Greater Or Lesser Growth Rate.

			Mean Total Length at Age				
Growth Rate	**Lake**	**County**	**Age 2**	**Age 3**	**Age 4**	**Age 5**	**Age 6**
Fast	Elochoman	Cowlitz	9.8	11.5			
Intermediate	Pratt ('81)	King			8.4	9.7	
Intermediate	Pratt ('98)	King		7.6	9.7		
Intermediate	Iceberg	Whatcom		7.9	10.4		
Intermediate	Granite	Lewis	7.4	8.5	11.0		
Slow	Tye	King		6.6	6.7	7.4	7.6
Slow	Mazama	Whatcom			5.6		
Slow	Upper Twin	Whatcom		5.5	6.1		

Perhaps the most significant change in the Pratt Lake fishery, apart from being able to catch three species now instead of one, and for fish which are no longer stunted and in poor condition, is the ability to catch fish up to at least 19 inches (Plate 82). This fish, plus one other lake trout taken in 1997, both aged to the 1985 brood year. This fishery is now significantly improved over one where angler reports referred to "small", "scrawny and lifeless", and "skinny" fish (Plate 83). However, like Unnamed Lake, there is insufficient information to judge whether the putative reduction in overall fish density has resulted in recovered diversity or abundance in the lake's zooplankton and invertebrates.

Plate 82. Age 14+, 19 inch lake trout from Pratt Lake, taken on July 13, 1999. Bill Henkel photo.

Plate 83. Eastern brook (two left columns), a 13" lake trout, and kokanee (above lake trout) from Pratt Lake on July 5, 1997. The lake trout was 12+ years old. None of the fish are in poor condition. Bill Henkel photo.

Summary

Table 25 summarizes the eastern brook trout population status indices for Unnamed, Talapus, and Pratt Lakes as of 1999. All indicators showed improvement in Unnamed Lake, but none did in Talapus Lake. In Pratt Lake, all indicators except relative weight improved following the introduction of lake trout in 1984. Talapus Lake brook trout were not in very poor condition at the start of the experiment (Plate 79), and the heavy fishing pressure the lake receives probably resulted in many of the brown trout being caught before they could have much of an effect on the char population. The fisheries in both Unnamed and Pratt Lakes are now significantly improved over what they were in 1979, at almost no cost, apart from the special monitoring which occurred with these tests.

The fisheries in Unnamed and Pratt Lakes should continue to be monitored, and top predators periodically added as needed. (Bull trout would be an excellent alternate predator to test; see next section.) The quality of the brook trout may continue to improve, as well as the size and effectiveness of the top predators.

Table 25. Matrix of eastern brook population indices in three Washington high lakes supplemented with top predators.

	INDICATOR					
Lake	**Faster Growth**	**Increased Relative Weight**	**Reduced CPUE in Standard Gill Net Set**	**Improved Internal Fat Content**	**Increased Length or Growth Rate**	**Increased Fishing Diversity / Quality**
Unnamed	YES	YES	YES	YES	YES	YES
Talapus	NO	NO	NO	NO	NO	NO
Pratt	YES	NO	YES	YES	YES	YES

5.7.2.2 *Other Species*

WDFW managers are interested in experimenting with bull trout or Dolly Varden in high lakes with stunted trout or char. The piscivorous nature of bull trout and Dolly Varden is well-documented in lowland lakes and streams (Thompson and Tufts 1967; Willamette National Forest 1989). Based on limited studies of bull trout ecology in high lakes elsewhere, this species appears to be a potential candidate for experimental use in the role of a top predator (Wilhelm et al. 1999). Use of these native fish for biological control would, in most cases, eliminate concern about dropout or washout into downstream waters, particularly if a stock was used that is native to the lake's watershed. Wilhelm et al. (1999) found that typically vulnerable macroinvertebrates such as *Gammarus,* and large, conspicuous zooplankton such as *Daphnia* were able to coexist with reproducing bull trout up to 21.25 inches in size in Harrison Lake (3.4 acres, max depth 35 feet) in Banff National Park. (Bull trout is the only fish species in the lake.) *Gammarus* and chironomids were the main dietary items, which emphasizes the importance of low fish density and differential diets of young and old fish in maintaining invertebrate communities. The bull trout were piscivorous to only a very limited degree, feeding almost exclusively on the native aquatic invertebrate community. The authors speculated that cannibalism could occur during winter under ice cover when the thick ice and snow cap would displace small fish from the shallow-water refugia.

Limnetic *Daphnia* escaped intense predation because larger bull trout are limnetic in Harrison Lake, and do not choose zooplankton, while younger, smaller bull trout remain in shoreline areas.

5.7.2.3 *Sterile Hybrids*

Although used with significant success in a large lowland reservoir in Washington to control northern pikeminnow (Tipping 1996), tiger muskies, a sterile hybrid, have not been used in Washington high lakes. However, biologists with the Idaho Department of Fish and Game have preliminarily reported a high degree of success in dramatically reducing the abundance of stunted brook trout in a high lake (Ice Lake). A muskie introduction in 1998 has reportedly reduced the brook trout population to the point where they are now difficult to catch with either hook and line or gill net.

Trail Blazers, Inc., with WDFW approval, have experimented with female rainbow and male golden trout in 14 high lake in western and eastern Washington (Pfeifer 1995). Earlier *ad hoc* experiments by the National Marine Fisheries Service with these and similar hybrids in a larger number of lakes suggested that some obscure interspecific behavioral mechanism can lead to dramatic reductions in density of the problem fish species. Follow-up surveys from test introductions made in 1993 and 1995 are being completed in 2001. Data analysis and a technical report are scheduled to follow the third and final follow-up surveys on these 14 lakes.

5.7.3 Intensive Fishing / Regulations

Liberalized regulations have been tested in a few lakes and regions in Washington to control or ameliorate the ill effects of excessively abundant trout or char in high lakes (Merritt and Schaefer Lakes in Chelan County; Spectacle Lake in Kittitas County; Indian Heaven Wilderness in Skamania County). The success or failure of these regulations has not yet been evaluated.

Low-key experiments are underway using volunteers to test for perceptible effects from liberal angling in a few lakes. Evidence of success, if any, would be expected to appear as reduced catch per unit effort and improved fish condition. Preliminary results are not encouraging. Given the reproductive potential of a fish population, assuming good egg-to-fry survival in spawning areas, fishing gear or methods far more efficient than angling are required to effectively reduce the total fish population, particularly where angler access is limited (Le Cren 1965; McFadden et al. 1967; Everhart et al. 1975; Donald and Alger 1986).

Gill nets have sometimes been successfully used to remove all fish from a small lake. Intensive netting would certainly substantially reduce the overall density of a trout or char population, but the effort would need to be repeated periodically to maintain a low population. The effort involved to attain a complete removal is suggested by Kelso and Shuter (1989) who desired to remove about 135 fish which were accidentally released to a 29 acre lake. The fish, a mixture of rainbow trout, brook trout, and lake trout, were not reproducing, ranged in size from 6.3 inches to 24.5 inches, and ranged in age from 1 to 4 years. Three multi-panel gill nets, each 210 feet long, were fished on the lake bottom, with daily changes in location. Twenty eight overnight sets of the three nets were made in the first year, and not all fish were removed. The last of the fish were removed after 12 more sets in the second year. (The netting results were particularly instructive in that no fish were caught on four consecutive nights after the first 20 days of netting, suggesting major depletion. One fish was caught on the 25th night, then 16 were taken on the 26th. Thus, netting efforts would need to continue well beyond the first "null sets" to be sure all fish were removed.)

While intensive netting or trapping may have potential for partial control, or even complete fish removal in lakes where such effort is a high priority, the thousands of man-hours involved to apply this technique to scores of lakes with excessively-abundant, reproducing fish populations is a significant management obstacle. This is particularly true for the many wilderness lakes where access involves arduous cross-country hiking. WDFW has not tested this control option since corporate experience indicates it would only make economic sense for an extremely limited number of relatively small lakes where fish removal was a high priority, and other more economical methods could not be used. The use of volunteers to intensively net a prioritized list of lakes has not been pursued.

5.7.4 Assessment and Recommendations

Only chemical treatment (rotenone) has been shown to eliminate stunted, excessively abundant fish in Washington high lakes. Antimycin is much less toxic to non-target species such as invertebrates and zooplankton, and should be used in lieu of rotenone whenever possible. However, many lakes will remain that for one reason or another cannot be treated with piscicides. While work in an Idaho high lake with tiger muskellunge has shown great promise in dramatically reducing the abundance of brook trout, no top predator has done so in Washington. There is indirect evidence that brown trout and lake trout have some potential to improve the condition of formerly stunted brook trout in two Washington test lakes. These species have shown the ability to grow to relatively large size, and add an important element of diversity and excitement to fisheries that were formerly largely shunned. However, it has not been demonstrated that a fish population reduction caused by top predators has resulted in improved conditions in the zooplankton or invertebrate community. Sterile hybrids have so far not been documented as having an ability to reduce excessively abundant char or trout in Washington.

Recommendation #1: A list of prioritized lakes needing control of excessive fish populations should be prepared (see Section 5.6.6). For each lake, one or more potential control methods should be identified; potential control methods include chemical treatment (Antimycin or rotenone), top predators, spawning habitat exclosure (barriers), or intensive netting or trapping.

Recommendation #2: The use of non-sterile exotic top predators should be limited to lakes where they have no potential for having negative interactions with native fish, and where they may have measured success in improving the overall condition and quality of stunted trout or char. Brown trout and lake trout should not be expected to effect significant changes in stunted fish abundance in less than 10 years (or more). Monitoring should continue on the lakes where test introductions have been made, and where initial results show potential for further measurable improvements. Final monitoring data collection and report preparation should occur on the lakes that have received sterile hybrids.

Recommendation #3: An annual program of high lake rehabilitation is long overdue. The extremely high benefit to cost ratio of this fishery (see Section 4) should be balanced against the cost of fishery recoveries. Annual conversion of several high lakes to quality, low ecological impact fisheries will go far to increase angler satisfaction, and to a lesser degree, angler participation. Rotenone and Antimycin should be used, as appropriate, to effect complete eradication of problem fish populations. Intensive netting or trapping is not likely to be an effective tool except for small, easily accessed lakes. A volunteer work force would likely be needed to implement any significant intensive netting or trapping program.

Recommendation #4: Spawning area exclosure should be tested in a few lakes where the spawning habitat is limited to a few inlets where natural materials can be placed that create barriers to the only effective spawning substrate. In general, this option would be used only if other methods, particularly chemical methods, could not be used, or would likely be ineffective.

Recommendation #5: Liberalized regulations should not be relied upon to make any significant or lasting reduction in overabundant or stunted fish populations.

Recommendation #6: Limnological data should be gathered on lakes that have received test introductions of top predators. Although the pre-test conditions are not known, current or final invertebrate species diversity and abundance can be compared to data from other similar vicinity lakes which do not have excessive fish populations. Lakes proposed for new top predator introductions should have their invertebrate communities thoroughly surveyed prior to the predator introduction to enable a better evaluation of the potential benefits of this technique.

5.8 USER PARTICIPATION & SATISFACTION

WDFW local fishery managers generally do not have access to good data on use levels of their high lakes, whether anglers or users. Usually only regional summaries are available, and they tend to be infrequent, and lacking of specifics on angling use (Wenatchee National Forest and Mt. Baker-Snoqualmie National Forest 1990). Statewide statistics on high lake use are, again, typically broad in nature, and infrequent (WDFW 1996a). An estimated 175,324 anglers fished Washington's high lakes in 1994 (WDFW 1996a). This is a 33.5 percent increase over the pervious use estimate in 1986 (Mongillo and Hahn 1988). A similar 4.19% per annum increase in the last 7 years would translate into 182,666 high lake anglers in Washington in 2001. The 1995 survey also found that the average number of days spent fishing high lakes increased from 6 in 1986, to 7.7 in 1995. If the number of days fished remained at 7.7 in 2001, 182,666 anglers would spend 1,406,528 days enjoying the state's high lake fishery. Even if there were no increase over the 1995 estimate of the number of high lake anglers, about 1,350,000 angler days are being spent at the mountain lakes <u>every</u> <u>year</u>.

There is almost no focusing of survey information beyond the statewide level, however the 1995 survey did find that there was very little difference between eastern and western Washington anglers in the percent of their fishing time spent at high lakes (7.3 and 7.9 percent, respectively). A slightly higher percentage of western Washington anglers (18.6 percent) preferred to fish high lakes than eastern Washington anglers (16.2 percent)(WDFW 1996a).

5.8.1 Catch, Harvest, and Effort Statistics

Most WDFW local managers have to manage with the barest of statistics on catch and angler effort from high lakes on their districts (Parametrix 2001). Occasionally US Forest Service or DNR recreation staffs will develop statistics on specific lakes or trailheads, but even then, anglers are rarely, if ever factored out of the general user population. Earlier studies such as Hendee et al. (1968) are now dated, were based on a very limited number of geographic areas, and did not provide quantitative measures or guidelines to apportion use to individual lakes or watersheds.

Some WDFW local managers have ranked annual angler effort as low, moderate, or high (Lucas 1989; Deleray and Barbee 1992). Others have estimated use on an individual lake basis by personally hiking to them, assessing the access difficulty, enumerating the number of anglers seen at the lake, differentiating weekday effort from weekend and holiday effort, using personal judgment based on past experience, and arriving at an approximation of the number of annual trips made to the lake (Cummins, Johnston, Pfeifer, Williams). This semi-quantitative approach can be calibrated to a very limited degree by making comparisons of the personal use estimates with more quantitative figures obtained by a trailhead survey, or by analysis of the High Lake Fishing Report database. Neither of these approaches has been pursued due to lack of time and resources, and an estimate of angler effort on individual lakes remains one of the most, if not the most serious data gap for local managers.

The revised High Lake Fishing Report form (Appendix D), if filled out properly, can be used to generate catch, effort, cpue, and harvest statistics. The database developed from this form, begun in 1986, now stands at 3848 records, and will be higher by the time this report is published. Table 9 shows the number of records, by county, that have been logged that can generate these statistics. To date this database has not been queried to generate statistics on individual lakes for use by local WDFW managers. The database is maintained by members of the Washington State Hi-Lakers, and Trail Blazers, Inc.

5.8.2 Trip and Fish Goals and Objectives (Quantity, Quality)

Most WDFW local managers have developed, or say they are developing goals and objectives that are tailored to each lake. Most feel this is an important thing to do (Parametrix 2001). This is generally manifested as a list of "management considerations" in lake by lake plans that often lack explicit, measurable objectives, such as a minimum catch success rate (Appendix C). There is general recognition that access and biological conditions at lakes vary too greatly to have single, prescriptive fishery management objectives for all. However, WDFW has not developed agreed-upon general, quantifiable fishery performance goals and objectives for the high lake program overall.

The 1981 Strategic Plan (WDG 1981) stated that "Alpine lakes are generally managed as more of a quality or "blue ribbon" fishery than are lowland lakes or reservoirs". The Goal for the program at that time was "…to increase the diversity and quality of angling opportunity. Emphasis will be on improving those qualitative aspects of diversity that make alpine angling a special outdoor experience". Most managers have addressed this goal by adjusting stocking rates and frequencies downward (see Section 5.4.2). Some managers have implicit, or program-wide objectives such as "managing for a target condition where most trip reports from a lake give 'good' to 'excellent' ratings on trip and fish quality, and most anglers catch at least a few trout" (Parametrix 2001). Some managers have also added species or strains in lakes where it is ecologically safe to do so in order to offer greater program diversity (see Section 5.4.3).

One seasoned manager noted that it is often impossible to control the factors that impact the quality of a fishing experience. Examples are crowding, excessive fish reproduction, and the behavior of other anglers. He sagely noted that "we could do more if we can remove or control stunted populations".

Achieving "quality" or "blue-ribbon" performance from a fishery obviously depends on a person's definition of quality. There are, and probably always will be many high lakes in Washington with reproducing trout or char that provide fast fishing action for small fish. Many users find these perfectly acceptable, if not preferable conditions for "family" outings where children get their first mountain fishing experience. WDFW managers recognize the need to provide this aspect of the fishery, as long as it is not harmful to the general aquatic ecology of an area.

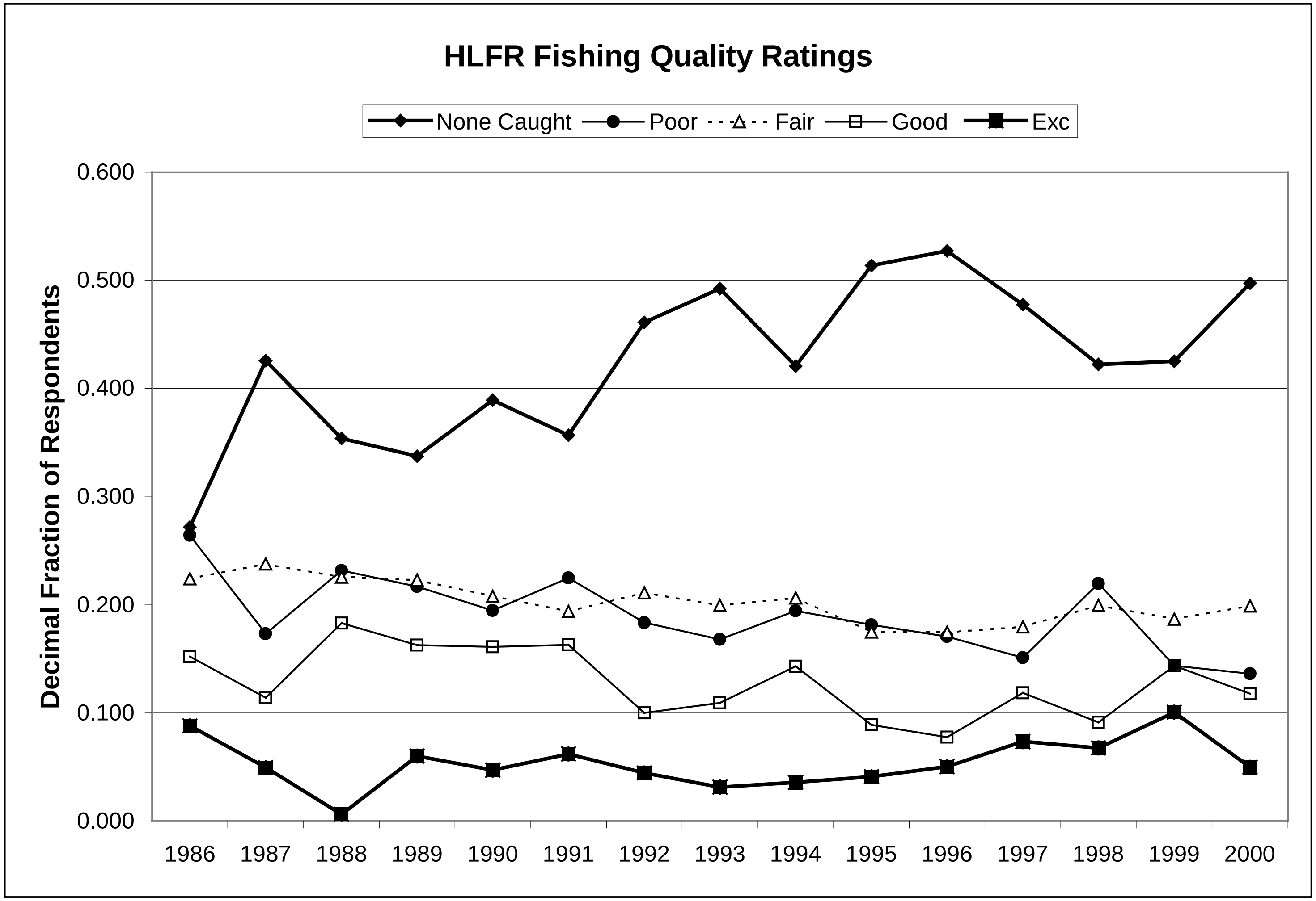
5.8.3 Measures of Satisfaction

Angler satisfaction with the high lake program was nearly identical in the 1986 and 1995 statewide angler surveys. About 44 percent of the survey respondents rated high lake angling "good to excellent" in Washington (WDFW 1996a; Plate 84). This survey result can be compared to the statistics gathered on angler satisfaction through the volunteer-based High Lake Fishing Report (see Section 5.2.1 and Appendix D). Statistics have been generated from this form since the summer of 1986, but from a far smaller user group than fishing license-buyers at large. Also, the volunteers filling this form out tend to be members of organized high lake fishing clubs, and probably have very different (e.g., more demanding) attitudes and expectations concerning a high lake fishing experience than the public at large.

There is no statewide, standardized approach to gauging angler satisfaction with the high lake fishery, with the exception of the 1995 angler survey (WDFW 1996a). However, the High Lake Fishing Report form (Appendix D) could serve this purpose as is, or with slight modification. It currently asks anglers to rate the "Quality of Fishing" they experienced on an individual outing. Admittedly, this is not exactly the same as asking an angler if he/she had a satisfactory outing (Moeller and Engelken 1972), but is probably close enough for fishery management purposes. The High Lake Fishing Report form gives ratings feedback to the manager on an individual lake basis, which is critical. By contrast, statewide assessments of license buyer satisfaction with the overall high lake program have only occurred every 9 to 10 years, or more.

Figure 21 plots the percent (decimal fraction) of each year's High Lake Fishing Reports (HLFR), by rating, from the HLFR database for each year since 1986. The number of reports per year ranged from 125 in 1986 to 382 in 2000, and averaged 230. These results are quite different from what was reported in the 1995 statewide angler survey (WDFW 1996a), probably because the data in Figure 21 were from more sophisticated high lake anglers. On average since 1986, 18 percent of anglers submitting HLFRs rated the quality of their fishing either good or excellent. An average of nearly 43 percent caught no fish (50 percent in 2000). It is clear that current fishing quality is not meeting at least one manager's objective of "most trip reports from a lake (giving) 'good' to 'excellent' ratings on trip and fish quality". The results plotted in Figure 21 are so far from that standard it may be asked whether it is a realistic objective. If the standard is realistic, Figure 21 indicates WDFW needs to apply more work to the high lake fishery product it is providing. Systematic elimination of stunted, low-quality fish populations would be an excellent next step.

Figure 21. Ratings of Washington High Lake Fishing Quality by Anglers Who Submitted High Lake Fishing Reports, 1986 to 2000.



The results from the HLFR database may be biased downward by virtue of the fact that many of the surveys being reported on are surveys requested by WDFW biologists. These are often requests to obtain information on a lake that has received little attention, has not been stocked in many years, needs a baseline survey, etc. At a minimum the HLFR database should not be considered an unbiased measure of the satisfaction of the high lake angling public at large. A better sample may be to query the database for the most recent 8 to 10 reports from each lake, rather than all reports for each year.

5.8.4 Appreciative Viewing / Non-Consumptive Uses

Since fish are not native to most high lakes in Washington, they are expressly stocked to provide a consumptive recreational fishery. However, there are many lakes with reproducing trout, char, or grayling that provide unusually good opportunities for viewing salmonids in their natural environment. Many high lakes have exceptional water quality and transparency, enhancing the ability to view fish. This unquestionably adds to the enjoyment, wilderness experience, and wildlife appreciation of many users, particularly children. Stocks used in the Washington high lake fishery program often attain their most dramatic coloration or condition in well-managed high lakes (Plates 44, 45, 58, 84, 85, 86).

5.8.5 Assessment and Recommendations

There is no evidence or expectation that the number of users of Washington's high lake fishery is going anywhere but up. "People management" is in many ways a larger issue than fish or fishery management, particularly with respect to meeting the terms and intent of the Wilderness Act of 1964 (Public Law 88-577). Many lakes, particularly those that are off-trail destinations, are largely self-limiting on use, depending on access difficulty. WDFW local managers face the dual challenge of balancing angler effort with trout abundance, growth rates, and ecological impact, while at the same time considering the effect of the fishery on the land and wilderness values (see Section 5.9).

Better measures of angler use on a lake by lake basis would help managers refine their decisions on stocking density and frequency. Expansion of the use of the High Lake Fishing Report form, and analysis of the existing HLFR database, may help further these local refinements. Closer coordination with, or cooperation from land managers such as the Forest Service or DNR could lead to acquisition of much valuable data on local angler use. Additional human resources are needed to accomplish either of these management objectives in a timely manner.

Managers have the ability, and typically try to manage for higher quality in lakes that do not have reproducing trout or char, especially in lakes that are off-trail, or that receive only moderate or lower use. Their ability to do this would be greatly extended if a program were initiated to annually rehabilitate several high lakes having excessive fish.

Relatively low angler satisfaction ("fishing quality") levels in the High Lake Fishing Report database suggest a review should be made of the sampled angler population to see if it is representative of the public at large. In any case the causes of the low quality ratings should be determined.

Plate 84. This angler appears to be satisfied with the Twin Lakes cutthroat he took from a lake that has been stocked at about 70 fish/ac every 6 or 7 years since 1953. The lake is in the Skykomish River drainage, and is unusual in that it supports good numbers of Gammarus. This macroinvertebrate has not suffered any obvious depletion despite many years of coexistence with trout.

Plate 85. WDFW Biologist Jim Cummins enjoys a 19. 25 inch Twin Lakes cutthroat from a lake in the Henry M. Jackson Wilderness. (July 1977) Gerry Ring Erickson photo.

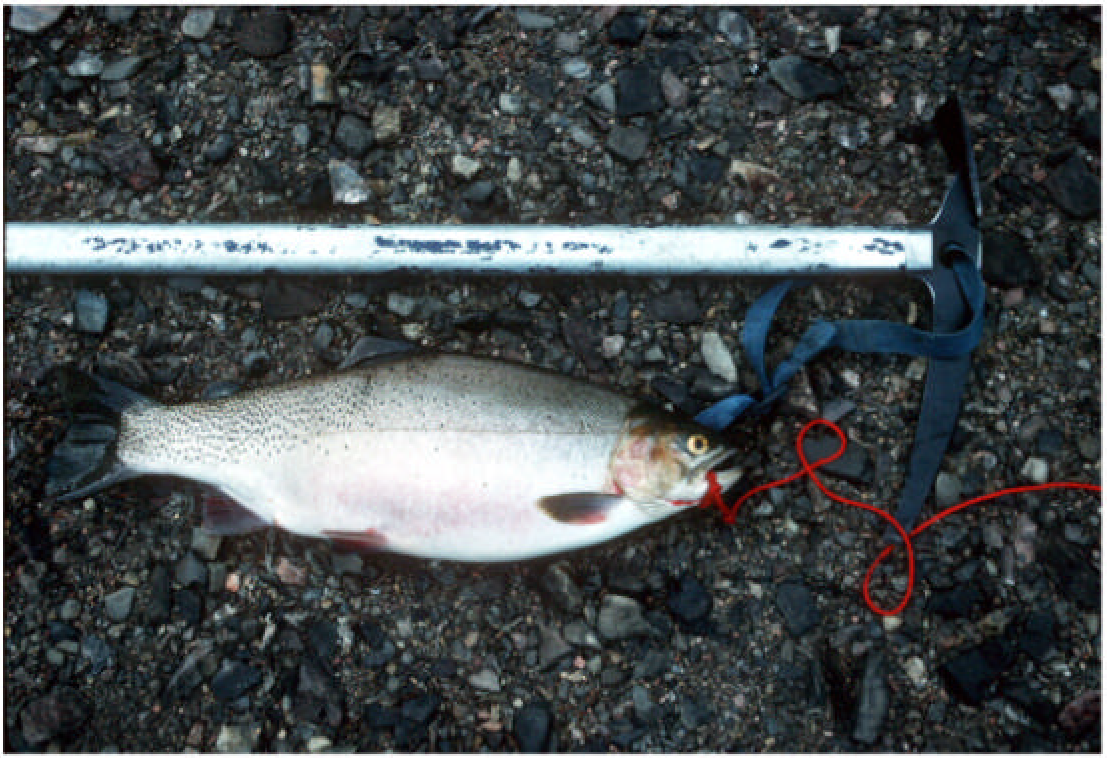


Plate 86. Twin Lake cutthroat can obtain exceptional condition when growing conditions are right. The high lake that produced this fish is stocked at low density on an annual basis. (October 1988)

Although the high lake fishery is primarily consumptive, managers need to be mindful of its non-consumptive benefits. These values should be quantified, if possible, so that all legitimate aspects of the fishery are considered in decisions that affect maintenance of individual lakes, or the collective fishery.

Recommendation #1: Local managers should be allocated the time to annually coordinate with volunteers to assure that the High Lake Fishing Report form and volunteer-based monitoring (Section 5.2.1) are utilized. This is a highly cost-effective way for WDFW to obtain needed information. Time or monies should be devoted to working with the Washington State Hi-Lakers or Trail Blazers, Inc. in preparing lake by lake catch, harvest, and effort statistics from the existing HLFR database for use by local managers.

Recommendation #2: WDFW should finalize earlier efforts to define statewide Goals and Objectives for the high lake fishery program. These should be general, allowing the essential flexibility needed to tailor objectives to individual lakes. Their principal purpose and value would be to publicize and memorialize the agency's overall direction for this fishery with more specificity than that published in 1981. Objectives should be quantifiable, to the degree possible, so that statewide or regional statistics can be used to measure overall program success.

Recommendation #3: Periodic surveys of angler preferences and use levels need to continue. Future surveys should pay special attention to the high lake fishery since it is one of the most cost-effective the agency manages.

5.9 INTERAGENCY AND LANDOWNER COORDINATION

The WDFW does not manage the high lake fishery in a vacuum. Coordination with major private timber owners, state agencies, and federal land managers has been an integral part of the program for decades. While WDFW retains the primary authority and responsibility for management of all fish and wildlife within the state (Title 77 Revised Code of Washington; RCW 77.04.012; RCW 77.04.020), other landowners and agencies control access and land management activities on the majority of lands that contain the high lakes. Coordination with these other owners and managers is essential, and on-going.

5.9.1 US Forest Service

U.S. Forest Service management of high lake fisheries in Washington pre-dates the creation of the Washington Department of Game by many years (see Section 2). Since the State assumed this responsibility in 1933, the respective roles have been primarily that of fishery managers (State), and land base, access, and human use managers (USFS). Designation of extensive areas as wilderness beginning in the 1960s has intensified the need for coordination of these management roles.

Most local WDFW fishery managers have worked with local Ranger Districts or regional national forest staff to develop individual lake surveys and management plans (Williams 1972; Cummins 1973; Johnston 1973; Pfeifer and Peacock 1987; Lucas 1989). Recent cooperative high lake surveys have been funded by the Forest Service (Deleray and Barbee 1992). A great deal of cooperative survey work has been coordinated with USFS districts that has not been reduced to published reports (WDFW 1994). Much of the high lake survey work conducted in King, Snohomish, Skagit, and Whatcom Counties, involving hundreds of lakes, has been closely coordinated with scientists and managers of the Mt. Baker-Snoqualmie National Forest. The same is true of most other areas that have not yet had summary technical reports prepared (e.g., Gifford Pinchot and Wenatchee National Forests).

The manner in which lakes that occur in wilderness areas may be stocked is dictated by USFS policy and rules developed after passage of the Wilderness Act (IAFWA 1986). In general, those methods that were in use at the time of wilderness designation may continue to be used. However, WDFW managers are well aware of the shattering effect helicopter stocking can have on an individual's wilderness experience. It is important to keep in mind that aircraft stocking only occurs on a very small percentage of lakes that lie within wilderness. A fixed-wing fly-over typically occurs on one day in a 3 to 6 year time interval, and lasts less than one minute. These events are scheduled for weekdays during seasons when the probability of disturbing users is minimized. Most stocking of lakes in wilderness is accomplished using backpack or aircraft methods (92%); 56 percent of all stocking is done by backpack (Table 26).

Table 26. Methods Used to Stock High Lakes in Designated Wilderness Areas in Washington.[1]

	Number of Introductions by Stocking Method (Percent)				
Wilderness	Number of Stocking Trips	Truck	Aircraft	Backpack	Horse Pack
Mt. Baker	174	66 (38)	43 (25)	38 (22)	27 (16)
Noisy-Diobsud	23	0 (0)	18 (78)	5 (22)	0 (0)
North Cascades NP	142	0 (0)	57 (40)	82 (58)	3 (2)
Glacier Peak	438	0 (0)	177 (40)	229 (52)	32 (7)
Lk. Chelan / Sawtooth	27	0 (0)	11 (41)	15 (56)	1 (4)
Henry M. Jackson	213	0 (0)	90 (42)	99 (46)	24 (11)
Alpine Lakes	2112	0 (0)	679 (32)	1321 (63)	112 (5)
Boulder River	23	0 (0)	15 (65)	8 (35)	0 (0)
Norse Peak	26	0 (0)	11 (42)	11 (42)	4 (15)
William O. Douglas	154	0 (0)	83 (54)	53 (34)	18 (12)
Clearwater	26	0 (0)	0 (0)	20 (77)	6 (23)
Goat Rocks	39	0 (0)	4 (10)	34 (87)	1 (3)
Pasayten	86	0 (0)	68 (79)	18 (21)	0 (0)
The Brothers	13	0 (0)	5 (38)	8 (62)	0 (0)
Indian Heaven	13	0 (0)	5 (38)	8 (62)	0 (0)
Totals:	**3509**	**66 (2%)**	**1266 (36%)**	**1949 (56%)**	**228 (6%)**

[1] Based on available information in the Trail Blazers database. Wildernesses only listed if 10 or more introductions were logged.

In keeping with the 1986 IAFWA Guidelines, and a Master Memorandum of Understanding between the State of Washington and the USFS signed in 1988 (Appendix M), periodic meetings are held between local USFS district staff and WDFW staff. Matters of mutual interest are discussed, and management problems resolved. The annual statewide alpine lake stocking program is coordinated with several forests through local meetings in a few key geographic locations.

Sharing of data and resources is a common occurrence at the local level. Technical documents that have been prepared almost universally acknowledge the contributions of counterpart agencies (e.g., Johnston 1973; Lucas 1989; USFS 1997). Previous planning efforts to initiate rehabilitation of lakes with stunted eastern brook have required close coordination between WDFW and the USFS (Weinheimer and Kearney 1983), as will future efforts along this line.

Overuse of wilderness areas is a matter of great mutual concern. Most high lake anglers consider crowding an impact on their wilderness fishing experience (Hendee et al. 1977). However, fishing alone is rarely the primary cause of overuse at specific lakes (Hendee et al. 1968). WDFW local fishery managers do, nevertheless, coordinate closely with USFS recreation staff to design fishery management plans that meet the needs of both agencies, to the greatest extent possible. A few lakes in areas where recreational use is grossly out of compliance with wilderness management standards (Wenatchee National Forest and Mt. Baker-Snoqualmie National Forest 1990) have been purposefully left barren to assist local USFS staff. Some of these lakes have a prior history of stocking. Concessions have been made in rare instances to reduce impacts on unusually fragile areas, even though it is recognized that users would flock to most of these lakes because of their extreme scenic beauty (Plate 87), whether or not they contained fish. WDFW considers these overuse problems people management challenges in the majority of cases, not fish stocking issues.

5.9.2 National Park Service

Active management of fisheries in high lakes that occur within a national park by the State of Washington only occurs in North Cascades National Park (NCNP). Maintenance of fisheries in this park is based on understandings that occurred at the time the park was founded. Current stocking and individual lake management is authorized and coordinated by the terms of a Supplemental Agreement to a Memorandum of Understanding between the National Park Service (NPS) and WDFW, signed in 1988. The 1988 Supplemental Agreement supplements the original Agreement, No. MU-9000-5-0004 dated August 15, 1985. The Supplemental Agreement establishes a mutually agreed to list of lakes in which continued stocking will be allowed.

WDFW has coordinated closely with NPS staff on the issues surrounding fish stocking in NCNP. WDFW scientists have served a peer review role on studies that have occurred (Liss et al. 1995), both on the early research designs, and on final report drafts. WDFW's most experienced high lake biologists (Johnston, Pfeifer) have worked closely with NCNP staff over the past 15 years in conducting lake surveys, coordinating stocking with research activities, and working to resolve disagreement on matters of policy.

WDFW also coordinates with NPS staff on wildlife management issues. These occasionally overlap with high lake fisheries management. WDFW staff worked closely with NCNP staff in reducing fishery season length by adjusting published regulations in order to protect nesting loons and denning wolves in areas near the north end of Ross Lake (reservoir).

Plate 87. Aptly-named Gem Lake, in the Snoqualmie Pass group of peaks, actually drains to the Middle Fork Snoqualmie River. It receives heavy hiking and camping use, and has held fish in the past. It has not been stocked since 1963, although it is recognized that the presence of fish in the lake would probably not have much effect on nearshore use (see Plate 35). Background peaks are Chair Peak, Kaleetan Peak, and Mt. Roosevelt. (12 September 1991)

5.9.3 Washington Department of Natural Resources; Major Timberlands Managers

There is generally a clear separation of management authority between WDFW and the Washington Department of Natural Resources (DNR), particularly in areas supporting high lakes. Staff of the sister agencies meet periodically, particularly at the local level, to coordinate on matters of mutual interest. These commonly involve land management activities under the purview of DNR, such as road and trail access, development, or maintenance. WDFW Habitat Biologists work with DNR on the design and permitting of timber sales to minimize the impacts of cutting units on nearby lakes and ponds.

Region 3 biologists have been working with DNR to reduce domestic cattle and sheep grazing impacts on stream environments in the forested zones of the Ahtanum drainage (South Central Cascades). Also working with timberland managers/private landowners in the same drainage to continue to allow anglers access to Blue and Green Lakes.

Most local WDFW fishery managers state they have little control over management actions taken by large private timber owners. Several west side managers agreed that loss of road access in the past decade has had a significant impact on their high lake program (Parametrix 2001)

5.9.4 Interagency/Academic Cooperative Projects

Interagency or academic co-op projects are a relatively rare occurrence in the high lake program. Their infrequency is largely due to WDFW staff workloads and resources. Where cooperative projects have occurred, they have been highly beneficial.

Deleray and Barbee (1992) expanded the number of high lake surveys in Yakima County by 32 lakes in the summer of 1991. Their work provided useful, if not essential information for managers of both the USFS and WDFW.

Pfeifer and Peacock (1987) ascertained the cause of Williams Lake's inability to support trout. Williams Lake lies in a broad meadow area in the headwaters of the Middle Fork Snoqualmie River (Plates 88, 89). The lake basin collects drainage from a mineralized plateau sprinkled with tarns ("Chain Lakes") on the shoulder of 6585-ft La Bohn Peak (Plate 90). Exploratory mining dating to early in the 20^{th} century exposed mineralized tailings in the area draining to Williams Lake (Plate 91). Water quality sampling (Plate 92) and a lake bioassay (Plate 93) determined that high copper levels were the cause of fish mortality, and not a lack of dissolved oxygen in late winter (Plate 94). They obtained information on heavy metals in the Chain Lakes mining district in the watershed above Williams Lake and in Williams Lake itself (Plate 92) which supported the North Bend Ranger District's negotiations over purchase of a controversial mine inholding.

One of the most beneficial academic projects supported by WDFW was the thorough study of the life history of arctic grayling in the single Washington high lake where they occur (Beauchamp 1982). Apart from being a superb piece of scientific work, this study was of great value to local managers in determining whether the grayling could co-exist with westslope cutthroat.

Plate 88. Tracks emanate from an old mine adit near Williams Lake in the headwaters of the Middle Fork Snoqualmie River. Several inlets enter on the north (right) shore, draining the rugged Chain Lakes mining area. An arrow shows the spot where a late winter water sample was collected to ascertain dissolved oxygen content. (18 August 1987)

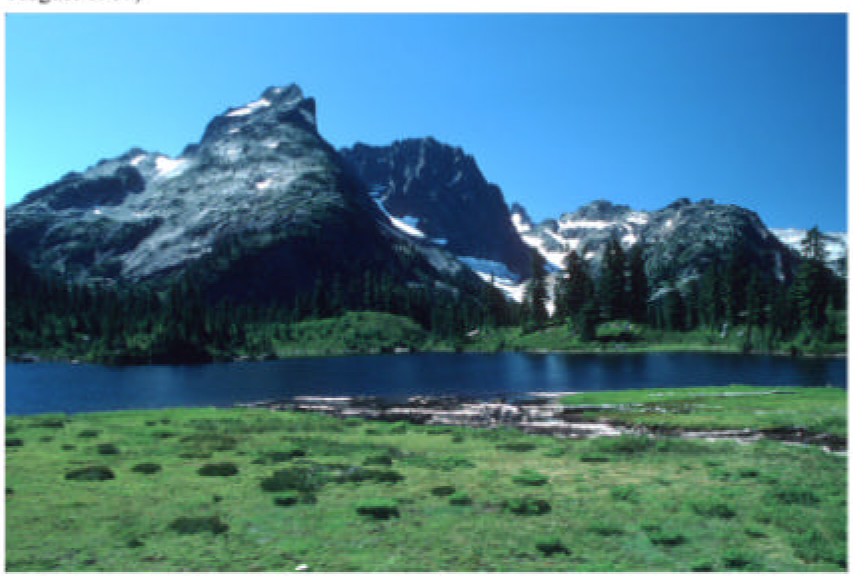


Plate 89. The principal inlet of Williams Lake faces Summit Chief Mountain. Although Williams Lake cannot support trout due to high copper content, cutthroat thrive in its outlet about one mile downstream, at Pedro Camp. Williams Lake
receives moderately heavy recreational use despite its lack of a fishery. (18 August 1987)

Plate 90. A sharp, or trained eye can pick out most of the 10 Chain Lakes in the lower right quarter of this photo. The wing tip points northwest, and touches 6585-ft La Bohn Peak. Williams Lake is just out of the photo at lower left. The arrow shows mine tailings that are also plainly visible in Plate 91. (13 July 1987)

Plate 91. The largest of the Chain Lakes lies below two mine shafts, one of which contributes tailings and leachate to this, and lower lakes. The left arrow indicates the location of a vertical shaft; the right arrow shows tailings at same location as in Plate 90. (18 August 1987)

Plate 92. USFS hydrologist Kathi Peacock collects water samples and conductivity readings near the mouth of one of the small inlets at Williams Lake. (18 August 1987)

Plate 93. Trout survived less than 12 hours in this minnow trap that was positioned where there was adequate exchange of water. (24 September 1987)

Plate 94. An early May field trip found the lake still fully covered with snow at its inlets. Mid-lake and near-bottom water samples were saturated with oxygen, ruling out winterkill as a limiting factor for trout survival. The lake was sampled at its deepest point. (10 May 1988) Jim Jewell photo.

5.9.5 Assessment and Recommendations

WDFW has a long history of coordination and cooperation with other land managers. Cooperative projects have yielded many highly beneficial work products. Most of the problems in recent years stem from the burgeoning human population in Washington, and difficulty in meeting the terms of earlier legislation. Inconsiderate dumping and vandalism on state and private timberlands from a small minority has prompted DNR and private timber growers to erect gates on roads that lead to high lakes. USFS wilderness managers have greater and greater difficulty in meeting the standards set forth in the Wilderness Act due to ever-increasing levels of use. Special interest groups, ignorant of understandings and communications that occurred at the time the North Cascades National Park was created, exert pressure on NPS administrators to eliminate historic high lake fishing in NCNP.

Recommendation #1: WDFW should continue to coordinate and cooperate with other land managers and agencies. The frequency of meetings with some agencies has slipped in recent years; this should be rectified, if possible. Annual or biannual workshops with federal land managers have historically been the most productive, and significantly increased communication and understanding.

Recommendation #2: The 1988 Supplemental Agreement to the Memorandum of Understanding between the National Park Service and WDFW should be renegotiated. The negotiation should take advantage of the most current science available, this report, Divens et al. (2001), the extensive experience and library of the Trail Blazers, Inc., as well as relevant information that may be held by other parties or groups.

5.10 OUTREACH

Because of the misunderstanding of biological and ecological issues surrounding the high lake fishery in Washington**,** it is essential that the public be better informed and educated about the benefits and impacts of the program. That is one of the primary purposes of this report.

Numerous articles have appeared in newspaper, magazine, and special interest group newsletters in recent years that suggest that trout stocking in high lakes leads, *ipso facto*, to amphibian declines (Wilderness Watch 1992a; Forstenzer 1998, 2000). Differing points of view or hypotheses (Recer 1997; Cone 2000; Schoch 2001) are rarely, if ever mentioned by those who would ban trout stocking. The most recent research has, in fact, revealed that the situation is far from simple, and that amphibian declines may be the result of complex environmental interactions (Kiesecker et al. 2001). Only rarely is a differing point of view published (Johnston 1998).

Some groups believe trout should be banned from wilderness areas in which they are not native (Wilderness Watch 1992b). How many people know that the Alpine Lakes Wilderness Area was only created after President Ford was taken there on a fishing trip so he could view its near-pristine lakes, rivers, and mountains (Wright 1993)? Fishing is a permitted activity in wilderness areas, as is fish stocking (IAFWA 1986).

Apart from these policy issues, there is always a need for basic education of the public about how the agency manages its high lake fishery resource. The fishery has unique safety issues associated with backcountry and off-trail hiking. And, since trout are put into high lakes primarily to be harvested, many users benefit from a guide on where to go to enjoy this resource.

5.10.1 High Lake Fishing Guide

Local WDFW managers routinely get seasonal calls from the public asking where they can go to fish a high lake; often a majority of these are asking about specific species, such as golden trout. In part to meet this information need, a "Primer" on the high lake fishery was written by Washington State Hi-Lakers member Gerry Ring Erickson, and WDFW Fish Biologist Bob Pfeifer in the mid-1980s.

The "Primer" had a modest beginning, being no more than a stapled series of pages. It included sections on the fish found in the fishery, fishing gear and techniques successful in high lakes, back country safety, a list of suggested lakes to visit to begin to learn about the fishery, and perhaps most important, a section on the Leave No Trace wilderness ethic.

The authors of the "Primer" recognized the sensitive nature of the high country, and the potential conflict with wilderness management by USFS staff. Therefore, a carefully selected list of lakes was chosen for the "Suggested Lakes" section. The list was drafted with the help of the two major high lake fishing clubs in the Seattle area (Washington State Hi-Lakers, and Trail Blazers, Inc.). The lake list was also edited by all affected local WDFW fishery managers. An agreed-to list of lakes was then mailed to each of the affected Forest Service district offices to obtain their feedback. A few lakes were removed from the list, and a few were added. In general, the lakes are ones which have had high numbers of users for many years, have well-maintained trails and camping areas, and are large lakes, with fish populations that can withstand fairly heavy fishing pressure.

The Primer was initially published in 1986 in *Signpost For Outdoor Trails* magazine. For years the stapled sheets version of the Primer was copied by WDFW regional office staffs for distribution. In the mid-1990s it was given a more professional appearance by the agency's publications department. It has been distributed to WDFW regional offices where demand typically quickly outruns annual supply. It was revised slightly in the late 1990s, and now appears renamed on the agency website as a Fishing Guide entitled "Trout Fishing in Washington's High Lakes" (below).

5.10.2 Agency Website

WDFW, like all modern agencies, has an Internet website for broad dissemination of information. The former High Lake Fishing Primer can now be found at the following website address: http://www.wa.gov/wdfw/outreach/fishing/highlake.htm. It is one of 11 features in the "Fishing Guides and Tips" section accessed by the "Fishing & Shellfishing" tab on the home page.

5.10.3 Sport Club Coordination

Coordination with hunting and fishing clubs is, of course, standard procedure with WDFW, like all fish and wildlife agencies. Local fishery management biologists regularly meet with constituent groups to present programs, discuss issues, or simply attend to maintain communication. Many clubs receive regular mailings of information from the agency. Close agency coordination with the Trail Blazers is a long tradition (Yadon et al. 1993) – longer than with the Washington State Hi-Lakers only because the Trail Blazers' founding in 1933 preceded the Hi-Lakers by 25 years. Regular contact is maintained with the Back Country Horsemen as well, although generally through one or two contact individuals, rather than by attendance at club meetings.

The special coordination that occurs with the Washington State Hi-Lakers was discussed in Section 5.2.1 because of this club's focus on high lake surveys. Aspects of Trail Blazer coordination were covered in Sections 5.4.5 because of this club's major role in assisting WDFW with stocking the many small, remote wilderness waters, and their exceptionally valuable historical databases.

5.10.4 Assessment and Recommendations

The agency's outreach effectiveness has probably been greatly extended in recent years with the development of its website. However, while the "runs" on the High Lakes Fishing Primer were tangible evidence of public contact, the number of times the website's *Trout Fishing in Washington High Lakes* page is accessed is less apparent to WDFW fishery managers. In the last year or two there has been a significant drop in WDFW local biologist contact with the two key high lake fishing clubs in the Seattle area. This is particularly troubling as it may result in diminished monitoring, or reduced quality or usefulness of the data collected.

Recommendation #1: The agency webmaster should perform an annual "page analysis" on the *Trout Fishing in Washington High Lakes* feature to monitor the approximate number of new individuals who obtain this information. The annual summary statistics of this analysis should be circulated within WDFW. The guide also needs to be updated to reflect changes in access, and better local understanding of individual fisheries since the original publication.

Recommendation #2: This report should be made available to the public at large on the agency website.

Recommendation #3: The benefits and values generated by the high lake fishery needs to be widely distributed to the public and internal and external policy makers.

Recommendation #4: Because of the key role the two Seattle high lake fishing clubs and the Back Country Horsemen play in WDFW's high lake stocking and monitoring programs, time should be made available to local fishery management biologists to maintain an adequate amount of coordination communication.

6. RESEARCH

Apart from the studies mentioned in Section 5.9.4, very little research in support of management has been done on Washington's high lakes by WDFW. This begs the definition of research, since WDFW staff biologists have surveyed hundreds of the lakes, and collected a great deal of information. Only a fraction of this information is published, and virtually all of it is in the gray literature. Local managers obtain and retain in their libraries work done by others, which in itself is a form of research (literature review). A very few examples of information obtained through literature review are Larson (1972) for Pratt Lake, near Seattle, and Rowe-Krumdick and Matthews (1991) for a cluster of high lakes in the western Alpine Lakes Wilderness.

Divens et al. (2001) identified five prioritized research needs on the subject of wildlife diversity and species protection. Initial field activity occurred on one of the tasks in the summer of 1999, but work was discontinued due to lack of funding. The topics were:

- Investigate which trout species, stocking rates and stocking intervals can provide quality trout fishing opportunities and do not significantly impact native biota;

- Evaluate the extent of emigration and fallout following high lake stocking;

- Investigate the effects of trout stocking on a landscape scale; experimentally evaluate if Washington's current high lakes management practices can eliminate, significantly reduce the abundance of, or significantly affect the general distribution of any native invertebrate, amphibian, or fish species in high lakes.

- Further investigate basic life histories of Washington's native amphibians; and

- Develop an evaluation procedure which can be used to identify any high mountain lake fish populations which may threaten native biota and test management techniques to decrease or eliminate the threat.

7. LITERATURE CITED

Anderson, J. D. 1967. A comparison of the life histories of coastal and montane populations of *Ambystoma macrodactylum* in California. American Midland Naturalist 77:323-354.

Anderson, L. E. and P. C. Thompson. 1991. Development and implementation of the angler diary monitoring program for Great Bear Lake, Northwest Territories. Pages 457-475 IN: D. Guthrie + 7 coeditors. Creel and angler surveys in fisheries management. Amer. Fisher. Soc., Symposium 12, Bethesda, Maryland.

Anderson, R. Stewart. 1970. Effects of rotenone on zooplankton communities and a study of their recovery patterns in two mountain lakes in Alberta. J. Fish. Res. Bd. Can. 27: 1335-1356.

Anderson, R. Stewart. 1971. Crustacean plankton of 146 alpine and subalpine lakes and ponds in western Canada. J. Fish. Res. Bd. Can. 28: 311-321.

Anderson, Richard O. and Robert M. Neumann. 1996. Length, weight, and associated structural indices. Pages 447-482 *IN*: Brian R. Murphy and David W. Willis (eds.). Fisheries Techniques. Second Edition. American Fisheries Society, Bethesda, Maryland. 732 pages.

Andre, E. 1926. Influence de l'alimentation sur la pigmentation cutanee' des salmonides. Revue Suisse de Zoolgie 33: 659-666.

Bahls, Peter. 1989. Preliminary report of a survey methodology for high mountain lakes. High lake fisheries project. Nez Perce National Forest and Idaho Fish and Game. 50 pages.

___________. 1990. Report of the high lake fisheries project. Nez Perce National Forest. September, 1990. Nez Perce National Forest and Idaho Fish and Game.

___________. 1992. The status of fish populations and management of high mountain lakes in the western United States. Northwest Science 66(3): 183-193.

Ball, Robert C. 1945. A summary of experiments in Michigan lakes on the elimination of fish populations with rotenone, 1934-1942. Trans. Amer. Fish. Soc. 75: 139-146.

Barinaga, M. 1990. Where have all the froggies gone? Science 247:1033-1034.

Beauchamp, David A. 1982. The life history, spawning behavior, and interspecific interactions of the arctic grayling (*Thymallus acticus*) in Upper Granite Lake. Master of Science thesis. University of Washington, Seattle, Washington.

Behnke, Robert J. 1992. Native Trout of Western North America. American Fisheries Society Monograph 6. AFS, Bethesda, Maryland. 275 pages.

Bjerkeng, Bjorn. 1997. Chromatographic analysis of synthesized astaxanthin – a handy tool for the ecologist and the forensic chemist? Progr. Fish Cult. 59(2): 129-140.

Blaustein, A. R. and D. B. Wake. 1995. The puzzle of declining amphibian populations. Scientific American 272(4):52-57.

Booth, Derek B. 1987. Timing and processes of deglaciation along the southern margin of the Cordilleran ice sheet. Pages 71-90 *IN*: Ruddiman, W. F. and H. E. Wright, Jr. (eds.). The Geology of North America. Vol. K-3, North America and adjacent oceans during the last glaciation. The Geol. Soc. of America, Boulder, Colorado.

Bortleson, G. C., N. P. Dion, J. B. McConnell, and L. M. Nelson. 1976. Reconnaissance data on lakes in Washington. Water Supply Bulletin 43. Washington State Department of Ecology, in cooperation with USDI – Geological Survey.

Boyd, Claude E. 1980. Reliability of water analysis kits. Trans. Amer. Fish. Soc. 109(2): 239-243.

Braaten, Duane Ole. 1970. Characteristics and angling desires of western Washington trout anglers, and a simulation of the fishery management system so as to optimize angler enjoyment. PhD Diss. University of Washington, Seattle, Washington.

Bradbury, Alex. 1986. Rotenone and trout stocking. A literature review with special reference to Washington Department of Game's lake rehabilitation program. Fisher. Mgmt. Report 86-2. Washington Department of Game, Olympia, Washington.

Bretz, J. Harlan. 1913. Glaciation of the Puget Sound region. Washington Geological Survey. Bulletin No. 8.

_________. 1915. Pleistocene of Western Washington. Geological Society of America. Bulletin 26: 131.

Buktenica, Mark W. 1997. Bull trout restoration and brook trout eradication at Crater Lake National Park, Oregon. Pages 127-135 IN: W. C. Mackay, M. K. Brewin, and M. Monita (eds.). Friends of the Bull Trout Conference Proceedings. Calgary, Alberta.

Campton, Donald E. 1982. Genetic structure of sea-run cutthroat trout (*Salmo clarki clarki*) populations in the Puget Sound area. Master of Science Thesis, University of Washington, Seattle, Washington.

Carlander, Kenneth D. 1969. Handbook of Freshwater Fishery Biology. Volume One. The Iowa State University Press, Ames, Iowa. 752 pages.

Carlander, Kenneth D., Charles J. DiCostanzo, and Raymond J. Jessen. 1958. Sampling problems in creel census. Progr. Fish Cult. (1958) 20: 73-81.

Christenson, L. M., A. M. Forbes, and J. J. Kempinger. 1982. Improved angling quality following chemical treatment of Nebish Lake and reintroduction of smallmouth bass and yellow perch. Wisc.Dept. Nat. Res. Res. Report 115.

Cohen, J. M., L. J. Kamphake, A. E. Lemke, C. Henderson, and R. L. Woodward. 1960. Effect of fish poisons on water supplies. Part 1. Removal of toxic materials. J. Amer. Water Works Ass. 52(2): 1551-1566.

Cone, Marla. 2000. Scientists call pesticides a factor in lower mountain-frog numbers. Los Angeles Times. December 9, 2000.

Corkran C. C. and C. Thoms. 1996. Amphibians of Oregon, Washington, and British Columbia. Lone Pine Publishing, Vancouver, British Columbia.

Crawford, Bruce A. 1979. The origin and history of the trout brood stocks of the Washington Department of Game. Washington State Game Department. Fishery Research Report. 76 pages.

Cummins, James L. 1972. High lake survey report. Region 8. Washington State Game Department. 49 pages.

_________. 1973. High lake survey report. Gifford Pinchot and Snoqualmie National Forests. 1973. Washington State Game Department. 178 pages.

_________. 1974. High lake survey report. Pierce County. 1974. Washington State Game Department. 78 pages.

_________. 1975. High lake survey – 1975. King & Pierce Counties. Washington State Game Department. Fishery Management Report. 81 pages.

Curtis, Brian and Gerry Erickson. 1992. Washington's high lake recreational fishery: should it be stocked? Signpost for Northwest Trails. November (1992): 35-37.

Dalton, R. S., C. T. Bastian, J. J. Jacobs, and T. A. Wesche. 1998. Estimating the economic value of improved trout fishing on Wyoming streams. No. Amer. J. Fish. Mgmt. 18(4): 786-797.

Deleray, Mark and Cindra Barbee. 1992. Alpine lakes survey. Yakima County. Washington Department of Wildlife. Fisheries Management Division. Report # 92-3. 194 pages.

Demirelli, Lawrence K. 1988. The economic value of recreational steelhead fishing in Washington. Master of Arts in Agric. Econ. Washington State University, Pullman, Washington.

Dethier, D. P., P. L. Heller, and S. A. Safioles. 1979. Reconnaissance data on lakes in the Alpine Lakes Wilderness Area, Washington. USDI-Geological Survey. Open File Report 79-1465.

Divens, Mark, Scott Bonar, and Bob Pfeifer. 2001. Trout stocking in high lakes: reported impacts and implications for Washington State. Washington Department of Fish and Wildlife, Olympia, Washington.

Donald, D. B. 1987. Assessment of the outcome of eight decades of trout stocking in the mountain national parks, Canada. No. Amer. J. Fish. Mgmt. 7(4): 545-553.

Donald, D. B. and D. J. Alger. 1986. Dynamics of unexploited and lightly exploited populations of rainbow trout (Salmo gairdneri) from coastal, montane, and subalpine lakes in western Canada. Can. J. Fish. Aquat. Sci. 43: 1733-1741.

Donald, D. B., R. S. Anderson, and D. W. Mayhood. 1980. Correlations between brook trout growth and environmental variables for mountain lakes in Alberta. Trans. Amer. Fish. Soc. 109(6): 603-610.

Drake, Deanne C. and Robert J. Naiman. 2000. An evaluation of restoration efforts in fishless lakes stocked with exotic trout. Conserv. Biol. 14(6): 1807-1820.

Edmondson, W. T. and G. G. Winberg (eds.). 1971. A Manual on Methods for the Assessment of Secondary Productivity in Fresh Waters. IBP Handbook No. 17. Blackwell Scientific Publ. Oxford, UK. 358 pages.

Engstrom-Heg, R. and R. T. Colesante. 1979. Predicting rotenone degradation in lakes and ponds. New York Fish & Game Journal 26(1): 22-36.

Everhart, W. H., A. W. Eipper, and W. D. Youngs. Principles of Fishery Science. Cornell University Press, Ithaca, New York. 288 pages.

Fisher, Mark R. 1996. Estimating the effect of nonresponse bias on angler surveys. Trans. Amer. Fish. Soc. 125(1): 118-126.

Fletcher, Douglas H. 1976. Facts about Washington State Game Department's lake rehabilitation program in Region Four. Fisheries Management Division. Washington Department of Game, Olympia, Washington. Unpublished Technical Memorandum.

Forstenzer, Martin. 1998. When trout move in, frogs move out. Fish blamed for amphibians' decline. Science. The Seattle Times, January 6, 1998.

____________. 2000. When the trout arrive, the amphibian exodus begins. Science. The New York Times. November 28, 2000.

Fraley, John. 1996. Cooperation and controversy in wilderness fisheries management. Fisheries 21(5): 16-21.

Fraser, J. M. 1968. Differential recovery of brook trout planted by hand and by air drop. Trans. Amer. Fish. Soc. 91(1): 32-36.

Fukumoto, J. and S. Herrero. 1998. Observations of the long-toed salamander, *Ambystoma macrodactylum*, in Waterton Lakes National Park, Alberta. The Canadian Field-Naturalist. 112 (4):579-585.

Galbraith, Merle G., Jr. 1975. The use of large *Daphnia* as indices of fishing quality for rainbow trout in small lakes. Verh. Internat. Verein. Limnol. (1975): 19: 2485-2492.

Gall, Barry. 1998. Aquatic Scientist, Mt. Baker-Snoqualmie National Forest. Multiple communications with Bob Pfeifer in the mid- to late 1990s.

Garlick, Lewis R. 1950. The helicopter in fish-planting operations in Olympic National Park. Progr. Fish Cult. 12(2): 73-76.

Gaub, Mark and Daryl Hodges. 1996. Trout that fly. Montana Outdoors July/August 1996: 19-22.

Gebhards, Stacy V. 1965. Transport of juvenile trout in sealed containers. Progr. Fish Cult. January (1965): 31-36.

Green, D. M., H. Kaiser, T. F. Sharbel, J. Kearsley, and K. R. McAllister. 1997. Cryptic species of spotted frogs, *Rana pretiosa* complex, in western North America. Copeia 1:1-8.

Gresswell, Robert E. 1991. Use of Antimycin for removal of brook trout from a tributary of Yellowstone Lake. Nor. Amer. J. Fish. Mgmt. 11(1): 83-90.

Gresswell, R. E., W. J. Liss, G. A. Lomnicky, E. K. Deimling, R. L. Hoffman, and T. Tyler. 1997. Using mark-recapture methods to estimate fish abundance in small mountain lakes. Northwest Science 71(1): 39-44.

Haines, T. A. 1981. Acidic precipitation and its consequences for aquatic ecosystems: a review. Trans. Amer. Fish. Soc. 110(6): 669-707.

Hann, Denise and Bill Wall. 1992. United States Forest Service. Region 6. Lake Inventory Handbook. Version 1.1. Prepared for the Pacific Northwest Region Fisheries, Watershed, Recreation, and Air Quality Programs.

Hendee, John C., W. R. Catton, Jr., L. D. Marlow, and C. F. Brockman. 1968. Wilderness users in the Pacific Northwest – their characteristics, values, and management preferences. USDA-Forest Service. Pacific Northwest Range and Experiment Station, Portland, Oregon. Research Paper PNW-61.

Hendee, John C., Roger N. Clark, and Thomas E. Dailey. 1977. Fishing and other recreation behavior at high-mountain lakes in Washington State. USDA Forest Service Research Note PNW-304. Northwest Forest and Range Experiment Station. Portland, Oregon.

Hoffman, R.L., and D.S. Pilliod. 1999. The ecological effects of fish stocking on amphibian populations in high-mountain wilderness lakes. United States Geological Survey, Biological Resources Division, Forest and Rangeland Ecosystem Science Center, Corvallis, OR.

Hutchinson, G. E. 1975. A Treatise on Limnology. Volume 1. Geography, Physics, and Chemistry. John Wiley & Sons, New York. 137 pages.

IAFWA (International Association of Fish and Wildlife Agencies). 1986. Policies and guidelines for fish and wildlife management in national forest and Bureau of Land Management wilderness. (Revised version of original 1976 document.)

Infometrix, Inc. 1994. Statistical and pattern recognition multivariate analysis of winter steelhead passage rate, environmental and operational variables at the Lake Washington Ship Canal / Ballard Locks fishway. Prepared for Washington Department of Fish and Wildlife. Final Report. 16 June 1994.

Johnston, Greg. 1998. Trout Fishing Enhances Wilderness. Western Outdoors. January(1998):10,60.

Johnston, James M. 1972. High lake and stream survey report. Olympic National Forest. 1972. Washington Department of Game. Fisheries Management Division. 175 pages.

__________. 1973. High lake survey report. Olympic National Forest. Part II. 1973. Washington State Game Department. 362 pages.

__________. 1999. Fishery Management of High Lakes in the North Cascades: Findings and Evaluations. (Notes on high lake survey techniques distributed to WDFW fishery management biologists in Lacey, Washington, 10 February 1999).

Jones, John R. and Mark V. Hoyer. 1982. Sportfish harvest predicted by summer chlorophyll-*a* concentration in midwestern lakes and reservoirs. Trans. Amer. Fish. Soc. 111(2): 176-179.

Kelso, J. R. M. and B. J. Shuter. 1989. Validity of the removal method for fish population estimation in a small lake. No. Amer. J. Fish. Mgmt. 9(4): 471-476.

Kezer J. and D. S. Farner. 1955. Life history patterns of the salamander *Ambystoma macrodactylum* in the high cascade mountains of southern Oregon. Copeia 2:127-131.

Kiesecker, J. M., A. R. Blaustein, and L. K. Belden. 2001. Complex causes of amphibian population declines. Nature 410: 681-684.

Kiser, R. W., J. R. Donaldson, and P. R. Olson. 1963. The effect of rotenone on zooplankton populations in freshwater lakes. Trans. Amer. Fish. Soc. 92(1): 17-24.

Kitano, S., K. Maekawa, S. Nakano, and K. D. Fausch. 1994. Spawning behavior of bull trout in the Upper Flathead Drainage, Montana, with special reference to hybridization with brook trout. Transactions of the American Fisheries Society 123:988-992.

Koch, E. D., G. Wood, C. R. Peterson, and P. S. Corn. 1997. A summary of the conference on declining and sensitive amphibians in the Rocky Mountains and the Pacific Northwest. Idaho Herpetological Society and U. S. Fish and Wildlife Service, Snake River Basin Office Report, Boise, Idaho.

Krueger, C. C. and B. May. 1991. Ecological and genetic effects of salmonid introductions in North America. Canadian Journal of Fisheries and Aquatic Sciences 48(Supplement 1):66-77.

Lagler, Karl F. 1952. Freshwater Fishery Biology. 2nd Edition. Wm. C. Brown Co., Dubuque, Iowa. 421 pages.

Larson, Gary L. 1972. Gonad maturation of brook trout (*Salvelinus fontinalis*) in a high mountain lake under a modified photoperiod. J. Fish. Res. Bd. Can. 29: 1209-1211.

Leary, Robb F. and Fred W. Allendorf. 1991. Population genetic structure of bull trout in the Columbia and upper Klamath River drainages. Div. of Biol. Sciences, Univ. of Montana, Missoula, MT. Draft manuscript; Lewis and Clark Conservation Laboratory Report 91/2.

Leary, R. F., F. W. Allendorf, and K. L. Knudsen. 1983. Consistently high meristic counts in natural hybrids between brook trout and bull trout. Systematic Zoology 32: 369-376.

Le Cren, E. D. 1965. Some factors regulating the size of populations of freshwater fish. Mitt. Internat. Verein. Limnol. 13:88-105.

Leitritz, Earl. 1951. Raining fish: planting by plane. Progr. Fish Cult. 13(1): 31-35.

Lindstrom, T., W. Dickson, and G. Anderson. 1984. Reclaiming acid high mountain lakes by liming: a progress report. Inst. Freshw. Res. Drottningholm. Report No. 61.

Lindsey, James J. 1959. New York's flying trout. The New York State Conservationist. April-May (1959): 12-13.

Liss, William J. + 10 coauthors. 1995. Ecological effects of stocked trout in naturally fishless high mountain lakes, North Cascades National Park Service Complex, WA, USA. Technical Report NPS/PNROSU/NRTR-95-03. USDI-NPS-Pacific Northwest Region. 285 pages.

Loftus, K. H. 1956. Equipment for dropping fish. Progr. Fish Cult. 18(4): 181-184.

Logan, R. and L. C. Duncan. 1981. Acid precipitation and lake susceptibility in the central Washington Cascades. Draft manuscipt. Central Washington University, Ellensburg, Washington.

Lucas, Bob. 1989. Southwestern Washington high lake surveys. Washington Department of Wildlife. Fishery Management Report 89-1. 230 pages.

Maguire, Bassett, Jr. 1963. The passive dispersal of small aquatic organisms and their colonization of isolated bodies of water. Ecological Monographs 33: 161-185.

McCammon, George W. and Charles von Geldern, Jr. 1979. Predator-prey systems in large reservoirs. Pages 431-442 *IN*: Robert H. Stroud and H. Clepper (eds.). Predator-Prey Systems in Fishery Management. Sport Fishing Institute, Washington, D.C.

McFadden, J. T., G. R. Alexander, and D. S. Shetter. 1967. Numerical changes and population regulation in brook trout *Salvelinus fontinalis*. J. Fish. Res. Bd. Can. 24(7): 1425-1459.

McNaught, A.S., D.W. Schindler, B.R. Parker, A.J. Paul, R.S. Anderson, D.B. Donald, M. Agbeti. 1999. Restoration of the food web of an alpine lake following fish stocking. Limnology and Oceanography 44(1):127-136.

Melack, John M., John L. Stoddard, and Cliff A. Ochs. 1985. Major ion chemistry and sensitivity to acid precipitation of Sierra Nevada lakes. Water Resources Research 21(1): 27-32.

Midkiff, W. S., F. Cadena-Cepeda, E. T. Davison, and P. E. McGinnis. 1972. Laboratory evaluation of the Hach DR-EL “Direct Reading” portable engineer’s laboratory. Civil Engineering Dept., New Mexico State Univ. Tech. Rep. No. 77, NMSU-EES-77-72.

Miki, Wataru. 1991. Biological functions and activities of animal carotenoids. Pure & Appl. Chem. 63(1): 141-146.

Moeller, George H. and John H. Engelken. 1972. What fishermen look for in a fishing experience. J. Wildl. Mgmt. 36(4): 1253-1257.

Mongillo, Paul E. and Peter K. J. Hahn. 1988. A survey of resident game fish anglers in Washington. Final Report submitted to the U.S. Fish and Wildlife Service. Project F-90-R, Job No. 1. Washington Department of Wildlife. Fisheries Management Report 88-9. 128 pages.

Mottram, Bob. 1994. High lakes fishing varies wildly with type of trout. The News Tribune Outdoors writer. The News Tribune, July 20, 1994.

____________. 1995. Mount Rainier tests no-fish strategy in “feasibility study”. The News Tribune Outdoors writer. The News Tribune, September, 1995.

Moyle, John R. 1949. Some indices of lake productivity. Trans. Amer. Fish. Soc. 76: 322-334.

Munger, M. C., B. R. Barnett, and A. Ames. 1997. 1996 Sawtooth Wilderness amphibian survey. A challenge cost share agreement between the Sawtooth National Forest, USDA Forest Service, and Boise State University. Boise State University, Idaho.

Murray, M. P. and A. W. Boyd. 1996. Selway-Bitterroot Wilderness lakes and streams naturalization plan: an analysis and proposal. Ecocentric Wildlands Management Institute, Moscow, Idaho.

Nelson, Wesley C. 1987. Survival and growth of fingerling trout planted in high lakes of Colorado. Tech. Publ. No. 36. Colo. Div. Wildlife. March, 1987. DOW-R-T-36-87. 51 pages.

Nilsson, N. A. and B. Pejler. 1973. On the relation between fish fauna and zooplankton composition in north Swedish lakes. Institute of Freshwater Research, Drottingholm 53:51-77.

Northcote, T. G. and P. A. Larkin. 1956. Indices of productivity in British Columbia lakes. J. Fish. Res. Bd. Can. 13(4): 515-521.

Nussbaum, R. A., E. D. Brodie, Jr., and R. M. Storm. 1983. Amphibians and reptiles of the Pacific Northwest. University of Idaho Press, Moscow.

Parametrix, Inc. 2001. Special Appendix. Questionnaire Survey of WDFW Biologists to Support a Report on the Washington Department of Fish and Wildlife's High Lakes Fishery Management Program. Prepared for Washington Department of Fish and Wildlife. Parametrix, Inc., Kirkland, Washington. June 2001.

Pechmann, J. H. and Henry M. Wilbur. 1994. Putting declining amphibian populations in perspective: natural fluctuations and human impacts. Herpetologica 50(1): 65-84.

Pfeifer, Bob. 1985. Potassium permanganate detoxification following lake rehabilitation. Procedures, costs, and two case histories. Wash. Dept. Game. Fish. Mgmt. Report 85-5. Washington Department of Game, Olympia, Washington.

Pfeifer, Bob. 1986a. Air stocking of Kelcema Lake – 21 August 1986. Wash. Dept. Game. Fisheries Mgmt. Div. Unpublished 7 page mimeo.

Pfeifer, Bob. 1986b. Golden trout at Tokul Creek. Broodstock development progress. Wash. Dept. Game. Fisheries Management Division. Report 86-5.

Pfeifer, Bob and Kathi Peacock. 1987. Preliminary investigations of suspected mining impacts on Williams Lake. North Bend Ranger District. Mt. Baker-Snoqualmie National Forest. Washington Department of Wildlife and USDA-Forest Service.

Pfeifer, Bob. 1995. Evaluation of hybrid trout introductions to control stunted trout populations in selected Washington State alpine lakes. 1995-96 research plan. Fish Management Program. Wash. Dept. Fish and Wildl. July 1995.

Phillipp, D. P., J. M. Epifanio, and M. J. Jennings. 1993. Conservation genetics and current stocking practices - are they compatible? Fisheries 18(12):14-16.

Piper & Taft, Inc. 1925. Taft's Sportsman's Guide and Handbook. Fishing Edition. Western Washington State. Piper & Taft, Inc., Seattle, Washington.

Pister, Phil. 1990. Pure Colorado trout saved by California. Outdoor California. Jan-Feb.: 12-15.

Prepas, E. E. 1983. Total dissolved solids as a predictor of lake biomass and productivity. Can. J. Fish. Aquat. Sci. 40(1): 92-95.

Prevost, Gustave. 1935. Experimental stocking of speckled trout from the air. Trans. Amer. Fish. Soc. 65: 277-278.

Prevost, Gustave and Lucien Piche'. 1938. Observations on the respiration of trout fingerlings and a new method of transporting speckled trout (*Salvelinus fontinalis*). Trans. Amer. Fish. Soc. 68 (1938): 344-353.

Radford, D. S. 1973. A comparison between actual and reported angling times. Trans. Amer. Fish. Soc. 102(3): 641-645.

Recer, Paul. 1997. Study: excess UV deadly for amphibians. Times Focus. Science. The Seattle Times, December 9, 1997.

Reid, George K. 1961. Ecology of Inland Waters and Estuaries. Van Nostrand Co., New York. 375 pages.

Reimers, Norman. 1979. A history of a stunted brook trout population in an alpine lake: a lifespan of 24 years. California Fish and Game 65(4): 196-215.

Reutebuch, S. E., J. L. Taylor, and D. K. Kaneko. (No Date). Utilizing previously controlled photos in PC-based analytical stereoplotters. USDA Forest Service. Unpublished 8 page mimeo.

Richards, Laura J. and Jon T. Schnute. 1986. An experimental and statistical approach to the question: is CPUE an index of abundance? Can. J. Fish. Aquat. Sci. 43: 1214-1227.

Rief, H. 1906. How a new kind of trout was found. Pacific Sportsman 3(8): 273.

Roberts, David, C. M. Spens, M. Ruckelshaus, and T. L. Myers. 1986. Acid rain program. Technical Report. 1986. Prepared for the Washington State Legislature. Wash. St. Dept. Ecology.

Rosenlund, Bruce D. and David R. Stevens. 1992. Application of Antimycin (Fintrol) to alpine lakes and streams in Rocky Mountain National Park and the headwaters of Leadville National Fish Hatchery to establish populations of greenback and Colorado River cutthroat trout. Draft manuscript, 17 April 1992. US Fish and Wildl. Serv. (primary author).

Rothacher, Jack. 1970. Increases in water yield following clear-cut logging in the Pacific Northwest. Water Resour. Res. 6(2): 653-658.

Rowe-Krumdick, Stephen and Robin Matthews. 1991. Amphibian monitoring project 1990. Project Report. Instit. For Watershed Studies. Western Washington University, Bellingham, Washington.

Ruttner, Franz. 1973. Fundamentals of Limnology. 3rd Edition. Univ. of Toronto Press, Toronto. 295 pages.

Ryder, Richard A. 1982. The morphoedaphic index—use, abuse, and fundamental concepts. Trans. Amer. Fish. Soc. 111(2): 154-164.

Schnick, Rosalie A. 1974. A review of the literature on the use of Antimycin in fisheries. USDI Fish and Wildlife Service. Fish Control Laboratory, La Crosse, WI. April 1974.

Schnick, R. A., F. P. Meyer, and D. L. Gray. 1986. A guide to approved chemicals in fish production and fishery resource management. Univ. of Arkansas Coop. Ext. Serv. And U.S. Fish and Wildl. Serv.

Schoch, Deborah. 2001. Key to missing-toad mystery uncovered. Los Angeles Times. April 8, 2001.

Shelby, Bo, Jay Goodwin, Mark Brunson, and Dave Anderson. 1989. Impacts of recreation use limits in the Alpine Lakes Wilderness. Dept. of Forest Resources, Oregon State University, Corvallis, Oregon. Coop. Agreement PNW 87-423 with USDA-Forest Service Pac. NW Rge. Exp. Sta., Portland, Oregon.

Silverman, G. and D. C. Erman. 1979. Alpine lakes in Kings Canyon National Park, California: baseline conditions and possible effects of visitor use. Jour. Environ. Mgmt. (1979) 8: 73-87.

Stockbridge, Jay. 1977. Lake rehabilitation. Washington Wildlife 29(1): 2-5.

Tarrant, M. A., M. J. Manfredo, P. B. Bayley, and R. Hess. 1993. Effects of recall bias and nonresponse bias on self-report estimates of angling participation. No. Amer. J. Fish. Mgmt. 13(2): 217-222.

Task Force on Fishery Chemicals of the American Fisheries Society. 2001. Relationship between rotenone use in fisheries management and Parkinson’s disease. Fisheries 26(3): 36-37.

ter Braak, C. J. F. 1986. Canonical correspondence analysis: a new eigenvector technique for multivariate direct gradient analysis. Ecology 67(5): 1167-1179.

The Research Group. 1991. Oregon angler survey and economic study. Final Report. Prepared for Oregon Department of Fish and Wildlife.

Thompson, R. B. and D. F. Tufts. 1967. Predation by the Dolly Varden and northern squawfish on hatchery-reared sockeye salmon in Lake Wenatchee, Washington. Trans. Amer. Fish. Soc. 96(4): 424-427.

Tiffan, K. F. and E. P. Bergersen. 1996. Performance of Antimycin in high-gradient streams. No. Amer. J. Fish. Mgmt. 16(2): 465-468.

Tipping, Jack M. 1996. Mayfield Lake tiger muskie progress report for 1995. Wash. Dept. Fish and Wildlife. Hatcheries Program. Assessment and Development. Report H96-01.

Trimberger, E. J. 1975. Evaluation of angler-use benefits from chemical reclamation of lakes and streams in Michigan. Pages 60-65 *IN*: P. H. Eschemeyer (ed.). Rehabilitation of Fish Populations With Toxicants: A Symposium. North. Central Div., Amer. Fish. Soc. Special Publ. No. 4. May 1975.

Tyler, T., W. J. Liss, L. M. Ganio, G. L. Larson, R. Hoffman, E. Deimling, and G. Lomnicky. 1998. Interaction between introduced trout and larval salamanders (*Ambystoma macrodactylum*) in high-elevation lakes. Conserv. Biol. 12(1): 94-105.

USDA Forest Service. 1997. Watershed Analysis – Skykomish forks. Skykomish Ranger District. USFS – Mt. Baker-Snoqualmie National Forest.

Wenatchee and Mt. Baker-Snoqualmie National Forests. 1993. Environmental Assessment. Alpine Lakes Wilderness Recreation Use. USDA. Forest Service. Pacific Northwest Region.

Wagner, John F. and Michael Parker. 1973. Primary production and limiting nutrients in a small, subalpine Wyoming lake. Trans. Amer. Fish. Soc. 102(4): 698-706.

Walters, C. J. and R. E. Vincent. 1973. Potential productivity of an alpine lake as indicated by removal and reintroduction of fish. Trans. Amer. Fish. Soc. 102: 675-697.

WATER Environmental Services, Inc. 1993. Olympic National Forest wilderness lake survey. Goat Lake phytoplankton-zooplankton community analysis. Prepared for Olympic National Forest, USDA Forest Service.

____________. 1994. Mt. Baker-Snoqualmie National Forest. 1993 Skykomish wilderness lakes survey. Lake plankton – water quality analysis. Prepared for MBSNF, USDA Forest Service. Skykomish Ranger District. 49 pages.

WDFW (Washington Department of Fish and Wildlife) Fish Management Program. Inland Division. 1994. Native resident fish management. Federal Aid Project F-105-R. Segment 3. Annual Report. July 1, 1993-June 30, 1994.

WDFW. 1995a. Goals, Policies, and Objectives by the Washington Fish and Wildlife Commission. February 2, 1995.

___________. 1995b. Evaluation of hybrid trout introductions to control stunted trout populations in selected Washington State alpine lakes. 1995-96 research plan. WDFW Fisheries Management Division. Nine pages plus tables.

___________. 1996a. A 1995 survey of resident game fish anglers in Washington State. Wash. Dept. Fish and Wildl. Inland Fish Division. Technical Report IF96-04.

___________. 1996b. Draft Inland Fish Division Plan (12/06/96). Washington Department of Fish and Wildlife, Olympia, Washington.

___________. 1997. Policy of Washington Department of Fish and Wildlife and Western Washington Treaty Tribes Concerning Wild Salmonids. Adopted by Washington Fish and Wildlife Commission December 5, 1997.

WDG (Washington Department of Game). 1979. Supplemental Draft EIS. Lake rehabilitation program. 1979-1980.

WDG (Washington Department of Game). 1981. Draft Strategic Plan. A comprehensive framework for the management of Washington's wildlife and game fish resources until 1995. July 1981. 123 pages.

Weinheimer, John and Marsha Kearney. 1983. Environmental Assessment. Lake Rehabilitation of Cup and Saucer Lakes. USDA-Forest Service. Skykomish Ranger District.

Welch, Eugene B. and Dimitris E. Spyridakis. 1984. Acidification potential in high mountain lakes in Washington. Final Report. Wash. Dept. Ecology Research Contract C-84039.

Welch, Eugene B., W. H. Chamberlain, and D. E. Spyridakis. 1984. Chemical content of snow and effect of melting on Cascade Mountain lakes. Northwest Science 58(2): 85-93.

Welch, E. B., D. E. Spyridakis, and T. Smayda. 1986. Temporal chemical variability in acid sensitive high elevation lakes. Water, Air, and Soil Pollution 31: 35-44.

Welch, E. B., D. E. Spyridakis, K. B. Easthouse, T. J. Smayda, and L. C. Duncan. 1991. Response to a smelter closure in Cascade Mountain lakes. Water, Air, and Soil Pollution 61: 325-338.

Welch, Paul S. 1948. Limnological Methods. McGraw-Hill Book Co., New York. 381 pages.

Wenatchee National Forest and Mt. Baker-Snoqualmie National Forest. 1990. Alpine Lakes Wilderness Recreation Visitor Use Monitoring Report. October 1990.

Wilderness Watch. 1992a. Aquatic ecosystems threatened by fish stocking programs. Wilderness Watcher 3(1): 5.

Wilderness Watch. 1992b. Foreign objects: trout fishing in (primitive) America. Wilderness Watcher 3(1): 4.

Wilhelm, F. M., B. R. Parker, D. W. Schindler, and D. B. Donald. 1999. Seasonal food habits of bull trout from a small alpine lake in the Canadian Rocky Mountains. Trans. Amer. Fish. Soc. 128(6): 1176-1192.

Willamette National Forest. 1989. Biology of the bull trout *Salvelinus confluentus*. A literature review. Willamette National Forest. Eugene, Oregon. (Frequently cited as Goetz, Fred A. 1989.)

Williams, Ken. 1972. High lake survey report. Okanogan County. 1972. Washington State Game Department. 233 pages.

___________. 1974. An evaluation of the introduction of atlantic salmon into Chopaka Lake. Progress Report. D-J Federal Aid Project F-62-R-1-2. March 31, 1973 to December 31, 1973. Washington State Game Deaprtment.

___________. 1975. A survey of Okanogan County alpine lakes. Progress Report. Project No. F-62-R-3, Job No. 7, Contract 14-16-0001-5813. Submitted to U.S. Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife. March 15, 1975. 60 pages.

___________. 1976. Alpine lake investigations. Progress Report. Project No. F-62-R-4, Job No. 2, Contract 14-16-0001-5813. Submitted to U.S. Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife.

___________. 1999. Westlope cutthroat status report for Washington. (Draft) Wash. Dept. Fish and Wildl. Unpublished manuscipt.

___________. 2001. WDFW inland fishery management biologist (recently retired). Personal communication with Bob Pfeifer (and others) on January 18, 2001 at the WDFW biologists' workshop, Wenatchee, Washington.

Windell, J. T. and S. Q. Foster. 1982. The status of unexploited fish populations in the Green Lakes Valley, and alpine watershed, Colorado trout range. Occasional paper - Institute of Arctic and Alpine Research, University of Colorado 37:133-137.

Wissmar, R. C., J. E. Richey, and D. E. Spyridakis. 1977. The importance of allochthonous particulate carbon pathways in a subalpine lake. J. Fish. Res. Bd. Can. 34: 1410-1418.

Wolcott, Ernest E. 1965a. Lakes of Washington. Volume I. Western Washington. Second Edition. Water Supply Bulletin No. 14. Washington Department of Conservation. Division of Water Resources. Olympia, Washington. 619 pages.

___________. 1965b. Lakes of Washington. Volume II. Eastern Washington. Second Edition. Water Supply Bulletin No. 14. Washington Department of Conservation. Division of Water Resources. Olympia, Washington. 650 pages.

Woods, Paul F. and C. Michael Falter. 1982. Limnological investigations: Lake Koocanusa, Montana. Part 4: factors controlling primary productivity. Special Report 82-15. US Army Corps of Engineers, Washington, D.C.

Wright, Daniel A. 1993. Letter to the Editor. Seattle Post-Intelligencer, June 27, 1993.

Yadon, Charles M., Mike Swayne, and Virg Harder. 1993. Trail Blazer Histories. Trail Blazers, Inc., Seattle, Washington.

ZP's Taxonomic Services. 1999. Report on the 1998 zooplankton samples. Unpublished narrative report by Allan Vogel, PhD, plus data tables, to staff of the Skykomish Ranger District, Mt. Baker-Snoqualmie National Forest, Washington.

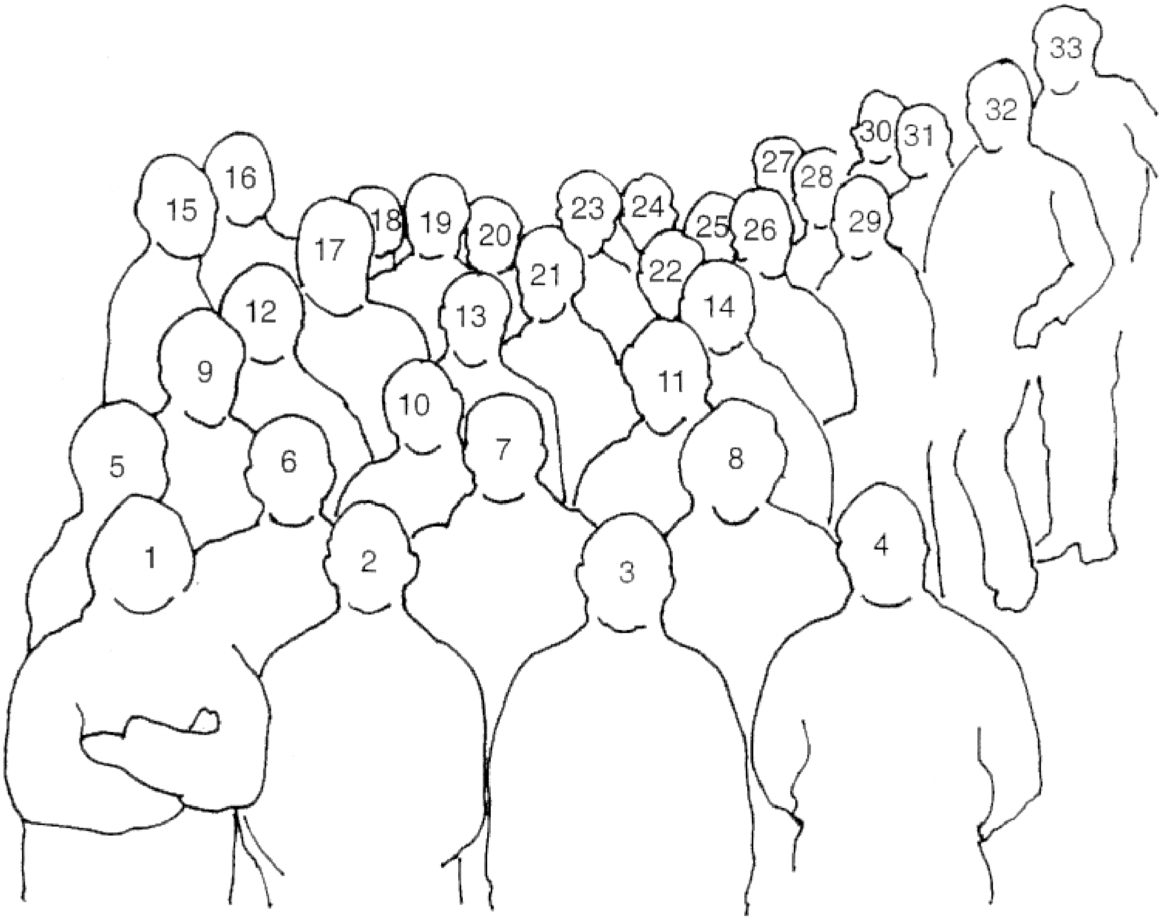
APPENDIX A

Tenure Table of WDFW Inland Fishery Management Biologists

Appendix A Table 1.
Tenure of WDFW Inland Fishery Management Biologists, by County, 1970- 2000.

Managed Counties	Biologists	Years as Local Manager
Pend Oreille	Tom Cropp	1974 – 1980
	Curt Vail	1981 – 2000
Clallam, Jefferson, Grays Harbor, Mason	Bob Watson	1970 – 1971
	Jim Johnston	1972 – 1973
	Tom Cropp	1974 – 1978
	Jay Hunter	1979 – 1998
	Dan Collins	1980 – 2000
Whatcom, Skagit; northern Snohomish	Louis Lund	1970 – 1977[a]
	Tom Williams	1978 – 1982[b]
	Jim Johnston	1984 – 2000
Southern Snohomish, King	Jim DeShazo & Bruce Crawford	1970 – 1974
	Jim Cummins	1975 – 1977
	Bob Pfeifer	1978 – 1999
	Mark Downen	1999 – 2000
Pierce	Jim Cummins	1970 – 1980
	Tom Cropp	1981 – 1996
	Steve Jackson	1997 – 1999
	Jay Hunter	1999 – 2000
Cowlitz, Lewis	Dory Lavier	1970 – 1971
	Jim Cummins	1972 – 1975
	?	1976 - 1977
	Bob Lucas	1978 – 2000
Skamania, Klickitat	Fred Holm	1970 – 1979
	Bruce Crawford	1980 - 1983
	Mark Chilcote	1984 - 1987
	John Weinheimer	1988 – 2000
Yakima, Kittitas	Bob Rennie	1970 – 1976
	Jim Cummins	1981 – 1987 Yakima County
	Larry Brown	1977 – 1980 Yakima County
	Larry Brown	1977 – 1993 Kittitas County
	Eric Anderson	1988 – 2000 Yakima County
	Eric Anderson	1994 – 2000 Kittitas County
Chelan	Fred Holm	1970 – 1972
	Lou Lund	1973 - 1980[a]
	Jim Cummins	1981 - 1982[a]
	Larry Brown	1983 – 1998
	Art Viola	1999 - 2000
Okanogan	Fred Holm	1970 – 1972
	Ken Williams	1972 – 1998
	Heather Bartlett	1999 - 2000

[a] Year is estimated.
[b] Tim Quinn filled in for one year when Tom Williams passed away.



1. Bill Young
2. Wayne Brunson
3. Freddie Holm
4. Ray Duff
5. Doug Fletcher
6. Jerry Smith
7. Dan Collins
8. John Hisata
9. Rod Woodin
10. Jim Nielson
11. Jay Hunter
12. Tom Cropp
13. Tom Williams
14. Dick Simons
15. Ted Muller
16. Ken Williams
17. Tony Oppermann
18. Jim DeShazo
19. Jim Cummins
20. Jack Ayerst
21. Bob Pfeifer
22. Curt Kraemer
23. Cliff Millenbach
24. Merrill Spence
25. Larry Brown
26. Dorie Lavier
27. Jim Morrow
28. John Ward
29. Dave Burns
30. Lou Lund
31. Roy Banner
32. Jim Johnston
33. Bob Watson

APPENDIX B

Sample WDFW High Lake Survey Data Form

Alpine Lake Field Survey Form

Available in Hard-Copy Version Only

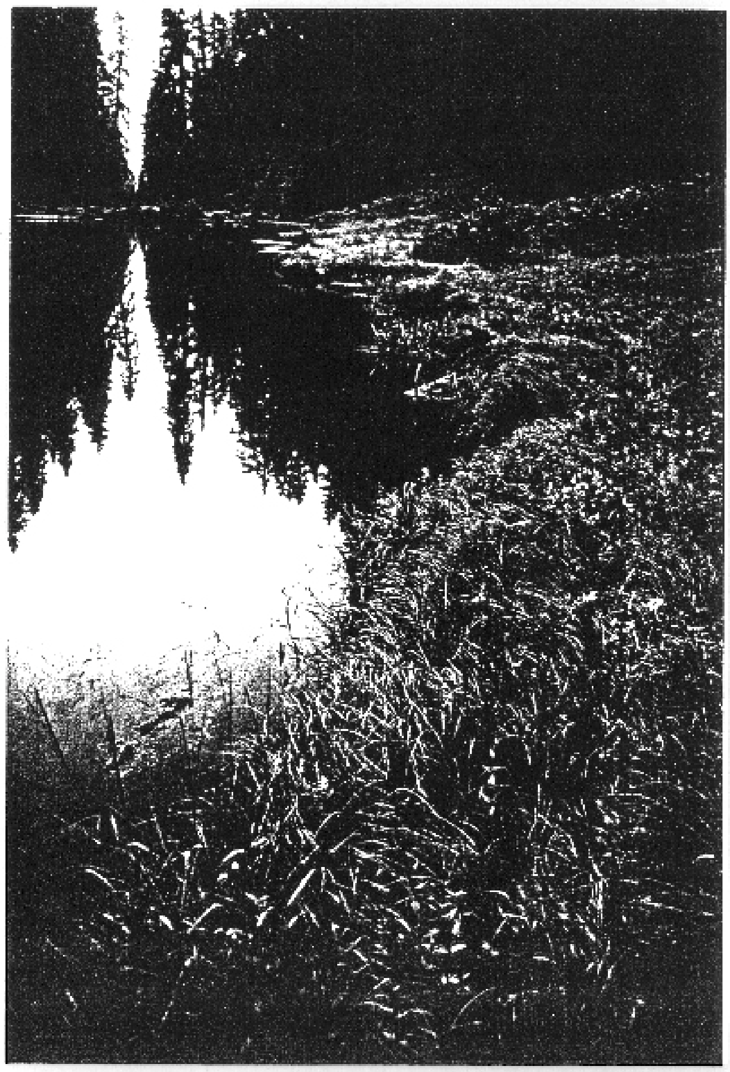
APPENDIX C

Sample WDFW High Lake Management Data Summaries

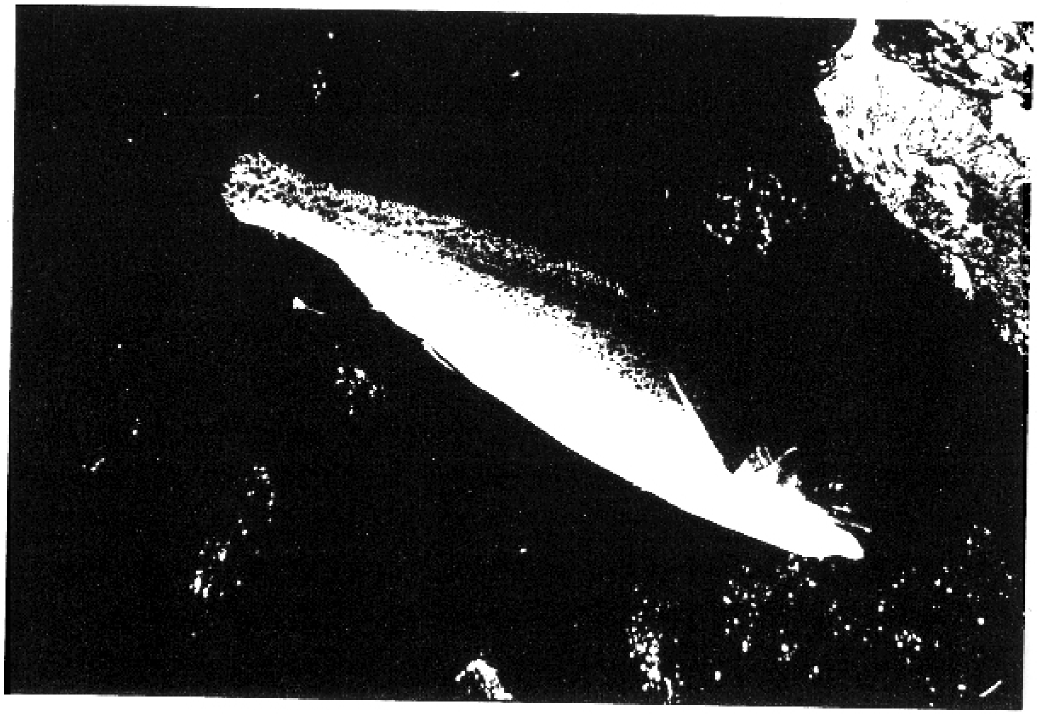
LAKE NAME: DOREEN

ELEVATION (FT): 3389 LOCATION: SECTION 09M T 37 N R 07 E COUNTY: WHATCOM SURVEY DATE: 08-21-90

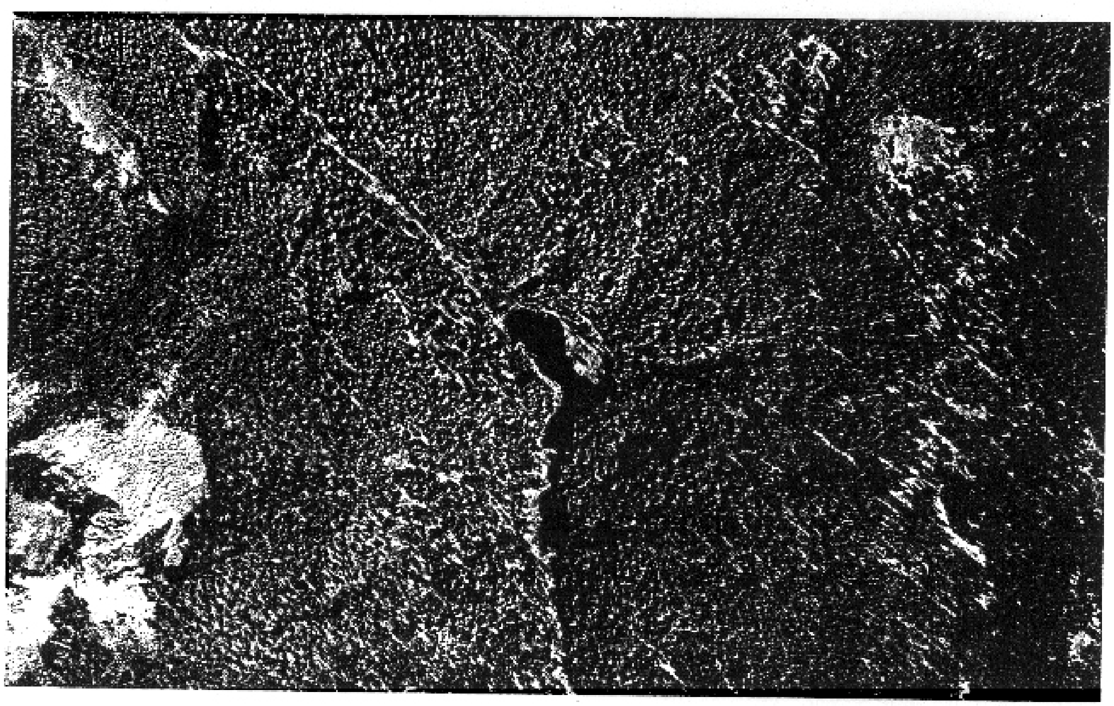
LAKE OUTLET DRAINAGE: TO HWTRS SF NOOKSACK R WATER IDENTIFICATION CODE (WACODE): 01 30 3753408L LK



LAKE PHOTO: LOOKING TOWARD OUTLET FROM WEST SIDE OF INLET



DOREEN LAKE RAINBOW: AGE 3, 185 MM IMMATURE FEMALE



USFS AERIAL PHOTOGRAPH: PHOTO DATE 08-02-86 PHOTO SCALE 1" = 1000' MARKER INDICATES LAKE LOCATION

DRAINAGE BASIN

MAP SCALE: 1" = 2000'

USGS MAP: TWIN SISTERS MTN, WA 1989

CONTOUR INTERVALS (FT): 40

LAND CLASSIFICATION: 82: USFS WILDERNESS

LAKE WATERSHED AREA (ACRES): 280

RATIO OF LAKE AREA TO WATERSHED AREA: 1:187

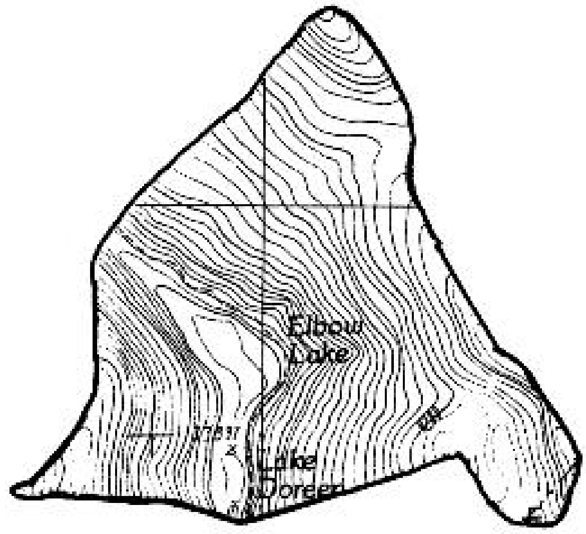
LAKE BASIN EXPOSURE DIRECTION AXIS: 200°

LAKE GEOMORPHIC TYPE: KETTLE

GEOLOGY (PARENT ROCK): CODE 6: GNEISS, DIORITE, GREENSTONE AND POSSIBLE DUNITE PRESENCE

SOIL DEVELOPMENT: 3-6 FT DEPTH AROUND PERIMETER OF LAKE AND 60% OF BASIN; REST OF BASIN (WEST SIDE) O-3 FT DEPTH

BASIN VEGETATION COVER: 90% VEGETATION COVER WITH 80% CONIFER CANOPY



LAKE SURFACE AREA AND DEPTH

MAP SCALE: 1" = 400'

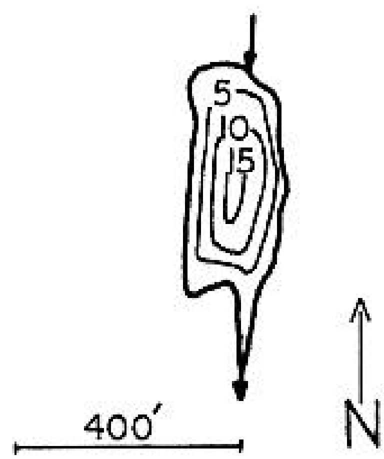
LAKE SURFACE AREA (ACRES): 1.5

ANNUAL WATER LEVEL FLUCTUATION (FT): 1

MAXIMUM DEPTH RECORDED (FT): 15

PERCENT LAKE SURFACE AREA OVER 0 - 10 FT BOTTOM CONTOURS: 73

PERCENT LAKE SURFACE AREA OVER 10 - 20 FT BOTTOM CONTOURS: 27



LAKE WATER CHEMISTRY

pH	CONDUCTIVITY (MICROMHOS/CM)	TOTAL ALKALINITY (PPM HCO_3)	TOTAL HARDNESS (PPM $CaCO_3$)	WATER COLOR/CLARITY
7.7	82	44	43	LT GREEN/CLEAR (10')

SUBSTRATE COMPOSITION OF LAKE BOTTOM SHOREWARD OF THE 10-FOOT CONTOUR LINE (PERCENT OF THAT AREA)

BEDROCK	(SOLID ROCK OUTCROP)	0
BOULDER	(ROCK GREATER THAN 10 INCHES IN DIAMETER)	0
RUBBLE	(ANGULAR BROKEN ROCK LESS THAN 10 INCHES IN DIAMETER - INCLUDE ROUNDED ROCK 3 - 10 INCHES IN DIAMETER)	1
GRAVEL	(ROUNDED MATERIAL LARGER THAN SAND BUT LESS THAN 3 INCHES IN DIAMETER)	1
SAND	(PARTICLES 0.06 MM TO 2.0 MM DIAMETER; FEELS ROUGH BETWEEN FINGERS)	1
SILT	(PARTICLES 0.004 MM TO 0.06 MM DIAMETER; FEELS GREASY BETWEEN FINGERS)	62
DETRITUS	(DEAD ORGANIC MATTER INCLUDING TREE TRUNKS, BRANCHES AND LEAVES THAT ARE UNDERWATER)	35

INLET STREAMS (DRY OR FLOWING), ACCESSIBLE TO FISH DURING SPAWNING SEASON, THAT CONTAIN SPAWNING HABITAT

INLET NUMBER	LOW FLOW WIDTH(FT)	LOW FLOW AVG DEPTH(IN)	CUBIC FEET PER SECOND	LENGTH ACCESSIBLE TO SPAWNERS(FT)	ACCESSIBLE SUBSTRATE AREA WITH GRAVEL < 1.5 INCH DIAMETER (FT^2)	OBSERVED SPAWNERS ADULTS	OBSERVED SPAWNERS SPECIES	OBSERVED SPAWNERS REDDS	OBSERVED FRY (AGE 0)
FM ELBOW	6	4	0.5	TO ELBOW	20	0	--	2	8

ALLUVIAL FAN OR NEAR-SHORE SPRING AREAS THAT PROVIDE SUITABLE SPAWNING HABITAT

NONE WITH SUITABLE SPAWNING GRAVEL

OUTLET STREAM CONDITIONS

LOW FLOW WIDTH(FT)	LOW FLOW AVG DEPTH(IN)	CUBIC FEET PER SECOND	LENGTH ACCESSIBLE TO SPAWNERS(FT)	ACCESSIBLE SUBSTRATE WITH GRAVEL < 1.5 INCH IN DIAMETER (FT^2)	OBSERVED SPAWNERS ADULTS	OBSERVED SPAWNERS SPECIES	OBSERVED SPAWNERS REDDS	OBSERVED FRY (AGE 0)
8	7	0.5	300+	30 (IN 300')	11	RB	7	100+

NOTE: 200+ IMMATURE AGE 1 TO 3 FISH IN OUTLET STREAM.

AQUATIC VEGETATION AND SEDGE GRASS INCIDENCE AND AREA COVERAGE

TYPE	COMMON NAME	AREA COVERAGE (FT^2)
SUBMERGED	MOSS	200
SEDGE GRASS	SEDGE	600

AQUATIC INVERTEBRATE ABUNDANCE RELATIVE TO OTHER NORTH CASCADE MOUNTAIN LAKES

COMMON NAME	TAXONOMY	RELATIVE ABUNDANCE
ZOOPLANKTON	(PRIMARILY DIAPTOMUS KENAI):	MEDIUM
SHRIMP	(GAMMARUS)	NONE SEEN BUT REPORTED IN 1982
CADDISFLIES	(TRICOPTERA):	HIGH
MAYFLIES	(EPHEMEROPTERA):	MEDIUM
MIDGES	(PRIMARILY FAMILY CHIRONOMIDAE):	MEDIUM
BEETLES	(HEMIPTERA AND COLEOPTERA):	MEDIUM
DRAGONFLIES AND DAMSELFLIES	(ODONATA):	MEDIUM
FW SNAILS	(MOLUSCA)	MEDIUM

HUMAN IMPACTS NOTED DURING SURVEY

TRAIL CONDITIONS: USFS CONSTRUCTED, SIGNED TRAIL TO THE LAKE

HIKING TIME TO LAKE FROM NEAREST LOGGING ROAD APPROACH (IN 1992): 20 MIN

NUMBER OF FIRE RINGS NEAR THE LAKE: 1

ESTIMATED AREA OF TRAMPLED CAMPGROUNDS NEAR THE LAKE (IN SQUARE FEET): 50

IS THERE A TRAIL CIRCLING THE LAKE? NO, ONLY ON EAST SIDE

ARE THE CAMPSITES OR SHORELINE TRAIL IN AREAS OF SENSITIVE VEGETATION? NO

LITTER PROBLEMS: NONE

ESTIMATE OF NUMBER OF ANGLERS FISHING THE LAKE EACH YEAR: 150

ESTIMATE OF NUMBER OF NON-ANGLERS VISITING THE LAKE EACH YEAR: 300

FISH MANAGEMENT

FISH PLANTING HISTORY

MONTH/YEAR	SPECIES	NUMBER	SIZE (NUMBER/POUND)	PLANTING RATE (NUMBER/ACRE)	PLANTING METHOD	ORGANIZATION	REMARKS
/16	STH	UKN	FRY	UKN	HORSE	U.S. BUREAU FISH	SKAGIT R STEELHEAD
9/53	CT(TL)	3014	831	2009	AIR	WDG	--

ANGLER REPORT HISTORY

MONTH/YEAR	SPECIES CAUGHT	NUMBER CAUGHT	HOURS FISHED	SIZE (INCHES) AVERAGE	SIZE (INCHES) RANGE	OTHER FISH OBSERVED	TOTAL ANGLERS	TOTAL NON-ANGLERS	FIRE RINGS	LITTER	REMARKS
6/68	RB	2	--	--	11-19.5	SPAWNERS IN CR	--	--	--	--	PART FROZEN
	CT	2	--	11	11-11	& MOST 9-13"	--	--	--	--	& ELBOW FROZEN
7/68	RB	12	--	11	9-12	--	--	--	--	--	--
7/70	RB	2	--	8	8-8	MANY RISES	--	--	--	--	--
6/71	RB	5	--	8	7-8.5	--	--	--	--	--	60% FROZEN
7/71	RB	5	--	10	9-11	--	--	--	--	--	FISH FAT
9/71	RB	4	--	8	7-9	NUMEROUS	--	--	--	--	FISH FAT
7/80	--	0	--	--	--	FISH RISING	--	--	--	--	--
8/82	RB	3	--	9	8-10	SAW FISH 4-16"; FISH SPAWNING IN INLET & OUTLET;					FISH FAT
7/84		0	--	--	--	SAW 10-11" RB	--	--	--	--	--
9/90	RB	7	0.5	8	7-9	--	1	--	--	--	--

FISH SPECIES IN THE LAKE ON DATE SURVEYED: RAINBOW (STEELHEAD-ORIGIN)

SOURCE OF FISH CURRENTLY IN THE LAKE (NATURAL REPRODUCTION, HATCHERY PLANT OR BOTH): NATURAL REPRODUCTION

ESTIMATE OF FISH ABUNDANCE: MORE THAN 75/SURFACE ACRE

FISH SAMPLE TAKEN DURING 08/90 SURVEY AND 9/92 ELECTROSHOCKER COLLECTION

SPECIES	AGE	FORK LENGTH MILLIMETERS	FORK LENGTH INCHES	SEX	SEXUAL MATURITY	CONDITION	STOMACH CONTENTS	FLESH COLOR
08/90								
RB	3	154	6.1	F	IMMATURE	FAT	SNAIL, CADDIS(L)	WHITE
RB	3	157	6.2	F	IMMATURE	FAT	CADDIS(L,P)	WHITE
RB	3	160	6.3	M	MATURE	FAT	SNAILS, CADDIS(L)	WHITE
RB	3	161	6.3	M	MATURE	FAT	SNAILS, CADDIS(L)	WHITE
RB	3	172	6.8	F	IMMATURE	FAT	SNAILS	WHITE
RB	3	176	6.9	M	MATURE	FAT	CADDIS(L)	WHITE
RB	3	181	7.1	F	MATURE	FAT	CADDIS(L)	WHITE
RB	3	183	7.2	M	MATURE	FAT	SNAIL, CADDIS(L)	WHITE
RB	3	185	7.3	F	IMMATURE	FAT	SNAIL, CADDIS(L)	LT PINK
RB	3	185	7.3	M	MATURE	FAT	CADDIS(L)	WHITE
RB	3	187	7.4	M	MATURE	FAT	CADDIS(L)	WHITE
RB	4	203	8.0	F	MATURE	FAT	CADDIS(L)	WHITE
RB	4	220	8.7	M	MATURE	FAT	CADDIS(L)	WHITE
RB	4	220	8.7	F	IMMATURE	FAT	CADDIS(L)	WHITE
RB	4	233	9.2	F	MATURE	FAT	CADDIS(L)	WHITE
RB	4	235	9.3	F	MATURE	FAT	CADDIS(A)	WHITE
RB	5	235	9.3	M	MATURE	FAT	SNAILS, CADDIS(L)	WHITE
RB	5	242	9.5	F	MATURE	FAT	CADDIS(L)	WHITE

9/92 ELECTRO-SHOCKER COLLECTION FROM OUTLET FOR TRANSPLANT TO WISEMAN (BIG AND LITTLE) LAKES AND TO UNNAMED LAKE SOUTH OF MCGINNIS (T36N R7E S5K) INCLUDED 260 TOTAL FISH FROM AGE 0 TO AGE 5. THE FOLLOWING WERE AGED.

SPECIES	AGE	MILLIMETERS
RB	1	76
RB	1	77
RB	1	77
RB	1	79
RB	1	80
RB	1	80
RB	1	84
RB	1	85
RB	2	116
RB	2	118
RB	2	120
RB	2	121
RB	2	124
RB	2	126
RB	2	127

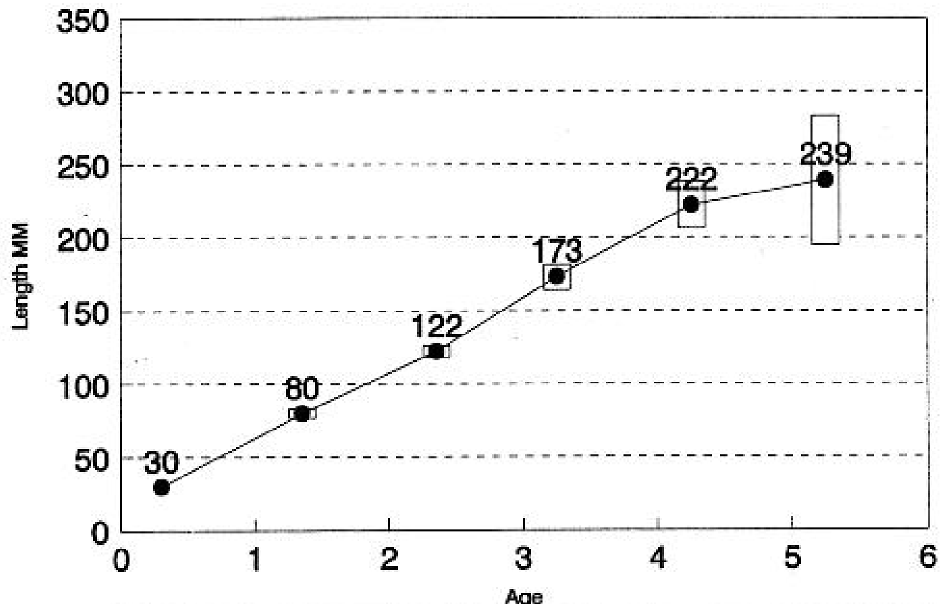
AGE VERSUS LENGTH(MM) DATA FROM BIOLOGICAL SURVEY

SPECIES: RAINBOW (SKAGIT RIVER STEELHEAD ORIGIN)

AGE	1	2	3	4	5
N OF CASES	8	7	11	5	2
MINIMUM	76.00	116.00	154.00	203.00	235.00
MAXIMUM	85.00	127.00	187.00	235.00	242.00
RANGE	9.00	11.00	33.00	32.00	7.00
MEAN	79.75	121.71	172.82	222.20	238.50
VARIANCE	10.79	16.90	158.76	164.70	24.50
STANDARD DEV.	3.28	4.11	12.60	12.83	4.95
STD. ERROR	1.16	1.55	3.80	5.74	3.50
95% CONF. INTERVAL +/-	2.70	3.80	8.50	15.90	44.50
95% CI RANGE	77-83	118-126	164-181	206-238	194-283

Doreen Lk Rainbow Age/Lgth Data

Mean Length & 95% C.I. By Age



	0.3	1.35	2.35	3.25	4.25	5.25
95% Conf. Interval		77	118	164	206	194
		83	126	181	238	283
Mean Length	30	80	122	173	222	239

□95% Conf. Interval —●— Mean Length

FISHERY MANAGEMENT CONSIDERATIONS

DOREEN'S RAINBOW, WHICH ORIGINATED FROM A PLANT OF SKAGIT RIVER STEELHEAD HAVE ADAPTED TO THE LAKE'S ENVIRONMENT AND ARE SUSTAINED BY NATURAL REPRODUCTION. PART OF THE WATER SOURCE FOR THIS LAKE ORIGINATES FROM AREAS OF DUNITE ROCK, WHICH CONTAINS HEAVY METALS CAPABLE OF KILLING PLANTED FISH BY AGE 3. BECAUSE DOREEN'S TROUT HAVE ADAPTED TO THESE METALS OVER SEVERAL GENERATIONS THEY SHOULD CONTINUE TO BE TESTED IN OTHER TWIN SISTERS MOUNTAIN RANGE LAKES AS A POTENTIAL DONATOR STOCK. THE HIGH RATE OF NATURAL REPRODUCTION SHOULD ALLOW REMOVAL OF UP TO 500 AGE 0 RAIBOW EACH YEAR WITHOUT REDUCING RECRUITMENT TO DOREEN TO A LEVEL THE CATCH RATE SUFFERS. THE REMOVAL SHOULD HAVE A POSITIVE EFFECT ON THE AVERAGE SIZE OF FISH REMAINING IN DOREEN LAKE.

APPENDIX D

High Lake Fishing Report Form

HIGH LAKE FISHING REPORT

Please fill in the blanks, check all appropriate boxes that apply, and add comments when necessary. This information is used by the Department of Wildlife to help obtain quality fishing in the high lakes.

Name of lake________________________ **Date of trip**____________

County______________ **Township**_____ **Range**_____ **Section**_____ **Subsection**______

Latitude__________________ **Longitude**____________________

Name of reporter______________________ Hi-Laker☐ Trail Blazer☐

	RAINBOW	CUTTHROAT	GOLDEN	E BROOK	BROWN	ATL SALMON	GRAYLING	MACKINAW	
QUANTITY									
SIZE RANGE									
AVERAGE SIZE									

QUALITY OF FISHING: Zilch☐ Poor☐ Fair☐ Good☐ Excellent☐

FISH ACTIVITY: **Rising** None☐ Few☐ Lots☐ **Cruising** None☐ Few☐ Lots☐

FISH CONDITION: Fat☐ Normal☐ Thin☐ Big head☐ Spawning☐ Dead fish seen☐ Fry seen☐

Other/Comments____

SUCCESSFUL LURES: Bait☐ Dry Flies☐ Wet Flies☐ Spoons☐ Spinners☐ Flatfish☐

Other____

STOMACH CONTENTS: Empty☐ Copepods☐ Shrimp☐ Snails☐ Larvae☐ Surface Insects☐ Debris☐

Other____

SENSITIVE SPECIES: Red copepods☐ Gammarus☐ Large Aquatic Insects☐ Salamanders (NW☐, LT☐)

Other____

TIME AT LAKE: Days____ Hours_____ **TIME FISHING:** (Nearest 1/4 Hour)______

#Anglers in party_____ #Other anglers at lake______ #Non-Anglers at lake______

LAKE CONDITION: Clear☐ Glacial☐ Dark☐ % Frozen______

Comments____

CAMP USAGE: Heavy☐ Moderate☐ Light☐ #of camp sites______

WEATHER: Partly Cloudy☐ Cloudy☐ Clear☐ Cold☐ Warm☐ Hot☐ Windy☐ Calm☐ Snowing☐ Raining☐ Foggy☐ Other____________________

COMMENTS:____

____

____

____

If confidential, check all boxes indicating who may see this report, check no boxes if all right to put in summary report:

Co-reporters☐ Hi-Lakers☐ Trail Blazers☐ Department of Wildlife☐

List Co-reporters here:____

WEIGHT LENGTH DATA: As a general guideline, take weights only on fish that have been killed to take home, are part of a sample to be worked up for biological management purposes, or died for some other reason. Please be as accurate as possible.

Species	Weight	Length

Indicate units used

weight
- ☐ pounds
- ☐ ounces
- ☐ lb, oz
- ☐ grams

length
- ☐ inches
- ☐ centimeters

Species	Weight	Length

APPENDIX E

Washington Department of Fish and Wildlife Fish Planting Card

WASHINGTON DEPARTMENT OF FISH AND WILDLIFE FISH PLANTING CARD AVAILABLE IN HARD-COPY ONLY

APPENDIX F

Sample Region Four High Lake Database Output

KING COUNTY HIGH LAKE DATA SUMMARY

WACODE:	NAME:	ALTNAME:	WRI:	BAS:	SEC:	PART:	TWP:	RNG:
1711402L	MASON LAKE	BIG MASON; SHORT LAKE	07	80	05	A/B	22	10

ELEV:	AREA:	DEP:	WITHFISH:	STOCKED:
4180	32.60	49	T	T

ACCESS:	LAND:	FSRD:	LOCATION:	TOPO:
T	45	NBRD	12 mi SE North Bend; 1800' S Kulla Kulla L; dr SF Snoq. R.	BANDERA

REPROD:	HISTPL:	PLSP:	NOPERAC:	CYCLE:	BASEYR:	PLMETH:	YRASSN:	TBMAIN:
NONE	RB SH	MW RB	24	3	1992	PLANE	1990	F

NAME	DATE	YEAR	SP	BROOD	STERILE	HYBRID	SIZE	NUMBER	SOURCE	METHOD
MASON LAKE		1921	EB		False	False		20000		USFS
MASON LAKE		1921	RB		False	False		60000		USFS
MASON LAKE	08/09	1935	RB		False	False		10000		PACK - TB
MASON LAKE	08/26	1936	SH		False	False		10000		PACK - TB
MASON LAKE	06/25	1939	SH		False	False	2000	10000		PACK - TB
MASON LAKE		1945	RB		False	False		11790		PACK - TB
MASON LAKE		1952	RB		False	False		10000		PACK - TB
MASON LAKE	06/19	1958	RB		False	False	350	4000	TOKUL CREEK H	WDG FW
MASON LAKE	07/12	1961	MW RB	303	False	False	90	1800	ARLINGTON H	WDG FW
MASON LAKE	07/13	1961	MW RB	303	False	False	240	1200	ARLINGTON H	WDG FW
MASON LAKE	10/10	1968	RB		False	False	470	1000	ARLINGTON H	PACK - TB
MASON LAKE	08/08	1972	RB		False	False	270	3240	TOKUL CREEK H	WDG FW
MASON LAKE	08/18	1976	MW RB	303	False	False	100	2500	ARLINGTON H	HELO
MASON LAKE	08/24	1979	MW RB	303	False	False	135	2498	ARLINGTON H	WDG FW
MASON LAKE	07/16	1981	MW RB	303	False	False	305	2450	ARLINGTON H	WDG FW
MASON LAKE	08/21	1986	MW RB	303	False	False	150	1695	ARLINGTON H	WDG FW
MASON LAKE	08/07	1989	MW RB	303	False	False	400	1300	ARLINGTON H	WDG FW
MASON LAKE	09/10	1992	MW RB	303	False	False	530	975	ARLINGTON H	WDG FW
MASON LAKE	09/11	1995	MW RB	303	False	False	420	785	ARLINGTON H	WDFW - FW
MASON LAKE	09/30	1998	MW RB	303	False	False	205	820	ARLINGTON H	WDFW - FW

NAME	REPYR	REPDATE	ANNOT

NAME	REPYR	REPDATE	ANNOT
MASON LAKE	1956	07/15	Con Mattson had poor f'g; blanked. Lk 3/4 open. Way tr poor cond on RH side outlet (N.B.!). 2.25hrs, 2mis fr end "abandnd but passable lggng rd." (more)
MASON LAKE	1956	07/15	No shltrs. Lk just opening. Many periwinkles crawling on bottom. Needs re-stocking. No one had caught a fish. A couple rises in center of lake.
MASON LAKE	1963	08/25	Fm had poor f'g; none caught. A few 6" fish seen. Bait/lures. Heavy pressure. Trails good.
MASON LAKE	1965	06/03	The lake was completely frozen. Sno cvrd last haf of trail. 1.25hrs, 1.5mis fr High Valley. 1 set of trax in. 6' drifts arnd lake.
MASON LAKE	1965	07/01	Clarence Pautzke (!) had poor f'g; skunked. Only saw 5 rises in evening. No snow. Good tr, 4.5hrs, 7.5mis fr Sunset Hiway. Many people. Fished out.
MASON LAKE	1965	07/02	Fm found none. Lk open. Good tr, 1.5hrs, 1.5 mis from "Hi Valley Logging Rd." 7fm seen on a FRI. Lots litter, 2 yrs ago good f'g. Now appears barren.
MASON LAKE	1965	08/21	Al Odmark had poor f'g; none caught. No sign of any fish. Good tr, but vry steep. 1.75 hrs, 2.5 mis. 15fm, 35 scouts. Needs stocking badly; much fishing pressure.
MASON LAKE	1965	08/21	John Kelly had poor f'g; said "couldn't even get a strike." Good tr off lggng rd where xes outlet; 1.5hrs, 3 mis. BSA troop + 4 parties. Pretty clean of litter. No raft
MASON LAKE	1966	06/18	Fm said ice was just coming off. No fish evident.
MASON LAKE	1966	08/05	Con Mattson had poor f'g. Full of 3" fish; f'd only 1 hr w/eggs. 1fm rep'd taking 16" Rb. Gets hvy f'g press. USFS should dig a garbage pit @ main camp spot.
MASON LAKE	1967	07/28	Bill Longwell said "On a clear day you can see forever." Had fair f'g for 5 Rb ave 7", lrgst 8". Active; f'd nr outl for 0.5 hr w/lures. Loved view fr Mt. Defiance top.
MASON LAKE	1968	06/02	Fm had fair f'g for 5 Ct ave 9", lrgst 10". Ice just off and 1 school swmmng arnd perim. Took 1 fish on evry circuit of 40mins. 3fm, 1non. Exc Ct lake - best type seen.
MASON LAKE	1968	06/09	Fm did not fish; grp of Rb seen mvng arnd lk edge in evening tkng flies. 2fm seen; prob'y hvy press later judging fr amt of litter.
MASON LAKE	1968	06/22	Fm had fair f'g for 6 Rb or Ct ave 8.5", lrgst 11". Active. In exc cond., well fed. Vry active. No fry seen. 4fm, 2non. Fair tr, hrd to follow.
MASON LAKE	1968	09/15	Fm had poor f'g; none caught. 1 fm took 2 Ct 12"; "b'ful fish, fat w/full bellies." 4fm, 0non. Area in good cond. & well kept.
MASON LAKE	1968	09/15	Fm took 2 Ct 12-14". Well fed. Poor f'g compared to earlier trip on 22 June.
MASON LAKE	1968	10/27	Charlie Lund had poor f'g for 1 11" Ct. Vry little evdnce fish-appears abt f'd out. 8fm, 0non. Lots use, but litter no worse than when last visited.
MASON LAKE	1969	08/02	Fm had poor f'g for lrgst fish 4". (Unk # taken) Water quite warm. Sm fish numerous & active in shallows; saw 2 legal fish caught. 6fm, 3non.
MASON LAKE	1970	07/21	Bill Longwell had poor f'g; blanked. So foggy couldn't see end of line; sum action nr shor by sm trout. 2fm, 0non.
MASON LAKE	1970	07/21	Fm had poor f'g; none caught. Saw no activity @ 0900. Foggy-could not see across lk. 0 else. Tr good; amazingly clean for use it gets.
MASON LAKE	1970	08/27	Ed Lebert had poor f'g; none caught. Saw svrl rises, and Rb @ 8". Didn't fish vry long. 5fm, 2non. Hordes been here earlier. Good tr. Pckd out much litter.
MASON LAKE	1970	09/10	Al Odmark had poor f'g; none caught. Only 2 fish seen. Lures. 3 othr fm.

APPENDIX G

High Lake Fishery Cost: Benefit Technical Addendum

NOTES AND LOGIC ON HIGH LAKE FISHERY PARTICIPATION LEVELS, COSTS, BENEFITS AND ENVIRONMENTAL CONSIDERATIONS

PARTICIPATION LEVELS, HIKING AND HIGH LAKE FISHING

The Interagency Committee for Outdoor Recreation (IAC) published a 1987 survey in the Seattle Times listing recreational activities, with estimated household participations (x1000) and % growth rates for the state. Selected activities are listed below:

Rank	Activity	Participation (x1000)	%Growth Rate
1	Jogging	11,604	35%
2	Walking	8,756	44%
12	Dayhiking	3,218	37%
15	Fresh-water fishing	3,124	19%
26	Backpacking	1,273	30%
35	Off-road 4-Wheeling	737	35%
37	Off-road Motorcycling	691	32%
42	ATV driving	467	28%
48	Climbing/mountaineering	254	35%
50	Off-trail backpacking	198	31%

Jogging was most popular, followed by walking. Dayhiking (12^{th}), fresh-water fishing (15^{th}) and backpacking (26^{th}) were also high on the list. Climbing/mountaineering (48^{th}) and off-trail backpacking (50^{th}) had participation levels about 7% of dayhiking and 2% of jogging and walking, a reflection of the greater skil level demanded by those activities. The IAC survey also indicated that non-motorized recreation (dayhiking, backpacking, climbing and off-trail backpacking) had over 2.5 times the participation level of motorized recreation (off-road 4-wheeling, off-road motorcycling and ATV driving).

The 1988 edition of 100 Hikes in the Glacier Peak Region estimated that Washington had a population of about 350,000 hikers (approximately 7.2% of the state's total population of 4.867 million and 9.7% of the over-18 population of 3.605 million). In a 1985 member survey by REI, a multiple-response question on regular activity participation showed hiking 59%, camping 58%, backpacking 43%, walking 41%, bicycling 40%, XC skiing 36%, jogging 35%, nature photography 31%, downhill skiing 31%, fishing 30%, swimming 29% and racquet sports 22% as most popular. Participation levels less than 20% were recorded for archery, bird watching, climbing, hunting, kayaking, power boating, rafting, sailboarding, sailing, scuba diving, team sports and canoeing. Of primary interest are the REI hiking and fishing participation rates, which taken together imply that 30% of hikers fish and 17.7% of REI customers are hiking anglers.

The number of fishing licenses sold by the State Department of Wildlife was 588,700 adult annual licenses in 1991 corresponding to about 16% of the state's adult population of 3.6 million. In addition, about 12,000 licenses were sold to non-resident visitors. Applying the REI angler participation percentages to the total number of hikers would lead to an estimate of 105,000 hiking anglers, amounting to about 18% of the licenses sold. The WDW surveyed license holders in 1988 and found that 65.4% were primarily lowland lake anglers, 23.6% were primarily stream anglers and 11.0% were primarily high lake anglers. The 7% difference between the estimate based on REI participation level and the surveyed primary interest would correspond to the cross-over interest among those who list streams or lowland lakes as primary, but who do some high lake fishing.

HIGH LAKE PROGRAM COSTS AND ECONOMICS

Hatchery costs to raise trout were estimated by John Kerwin to be $5.35/lb @ 50/lb = $0,094/fingerling and $2.10/lb @ 4/lb = $0.52/legal. High lake trout are stocked as fry, with a weighted mean size of all fish stocked in 1988 at 518.7/lb, which would correspond to $0.013/fry for hatchery costs. In 1988, 298,809 fry were stocked statewide in the Alpine Lakes program. Annual high lake stocks of 300,000 fry would entail costs of $3,900 while lowland lakes stocking of 3.5 million legals (=$1,820,000) plus 10.4 million fingerlings (=$977,600) plus 8.7 million Kokanee (=$817,800) would entail hatchery costs of $3.615 million, implying high lake hatchery costs are 0.08% of lowland costs.

In addition to hatchery costs, Bob Pfeifer estimated that he spent about 165 hours/year on the Alpine Lakes program, corresponding to salary/benefit costs of $4,610/yr. He estimated that the other regional and area biologists spent about 80% of the time that he does on the program, corresponding to additional salary/benefit costs of about $28,000. WDW Administrative charges the Fisheries Management Division at $55/hour for fixed wing airplane time. Alpine Lakes airdrops were estimated at 5 days per year, 5 hours per day for divisional costs of $1,375. Occasional helicopter use was estimated at 4 hours/year at $425/hr. for $1,700.

Total Alpine Lakes program costs are thus estimated at $39,000. In fiscal year 1991-92, the WDW budget was reported to be $53,592,000 (Report of the Budget & Review Committee, 6 August 1991). Thus the Alpine Lakes trout program represents 0.07% of the total WDW budget.

While the authors have not seen an economic evaluation of the recreational trout fishing program for the state, a chapter on "Economic Considerations in Managing Salmonid Habitats" showed recreational value estimates for trout fishing ranging from $13-20 per angler per day (willingness to pay) for Idaho and California. Averaging these figures for our state assuming 100,000 high lake anglers making 6 trips per year would indicate a perceived recreational value of the high lake fishery of $9,600,000 per year. Gear and equipment expenditures for high lakes fishing would be hard to separate from expenditures for hiking and lowland fishing as they will satisfy those combined interests, but they could be estimated as proportional to those license holders who indicated high lake fishing as their primary interest. Combined trip, gear and equipment expenditures could be approximated by the annual perceived recreation values as they are based on willingness to pay to participate.

APPENDIX H

Literature Review Relating to *Saprolegnia*

A LITERATURE REVIEW ON *SAPROLEGNIA* AND ITS RELATIONSHIP TO FISH STOCKING AND AMPHIBIAN MORTALITY

BACKGROUND

No one has identified a short list of one or two key factors leading to the declines seen in a variety of amphibian species, worldwide. The list of potential factors is long (Blaustein and Wake (1990, 1995), and it is very difficult, in many cases, to separate natural from anthropogenic causes (Pechmann and Wilbur 1994; Kiesecker et al. 2001). However, one proposed mechanism, introduction of the water mold *Saprolegnia*, deserves special treatment here, as it has been suggested that trout stocking could somehow be related to amphibian mortality caused by this fungus (Blaustein *et al*. 1994).

"The Saprolegniales, or water molds, occur most commonly in fresh water, but many of them inhabit moist soil. They are saprophytes living on dead plant or animal remains, or they are facultative or obligate parasites of algae, fish, and various small aquatic animals, or occasionally they are parasites of the roots of vascular plants" (Cronquist 1961).

Saprolegnia is just one of numerous genera in the Saprolegniales (Seymour 1970), a number of which are pathogenic to fish (Srivastava and Srivastava 1978; Pickering and Willloughby 1982). Srivastava and Srivastava (1978) found *S. ferax* to be as lethal as *S. parasitica* on their test fish (*Colisa lalia* and *Puntius sophore*), which were not salmonids. *S. ferax* was identified as the species involved in Blaustein *et al.*'s (1994) report of amphibian mortality. Pickering and Willloughby (1982) list nine species among three genera (*Achlya*, *Dictyuchus*, and *Saprolegnia*) as being "potential fish pathogens of the Family Saprolegniaceae" in their Table 1. It is important to identify *Saprolegnia* to below the generic level since not all *S.* species are pathological to trout (Willoughby 1978).

DISTRIBUTION OF *SAPROLEGNIA*

How broadly is *Saprolegnia* distributed? Apparently it's ubiquitous around the globe, as indicated by the following quotations, arranged alphabetically by author. Any emphasis added to the text is via emboldening or underlining:

Blaustein, A. R. and D. B. Wake. 1995: "It turns out that since the late 1980s, increasing numbers of amphibians in Oregon have been sickened by the fungus *Saprolegnia*, <u>which is found naturally in lakes and ponds.</u>

Blaustein, A. R., D. G. Hokit, R. K. O'Hara, and R. A. Holt. 1994: "Moreover, the fungus we identify is <u>worldwide in distribution</u>...."

Bly *et al*. 1996: "Winter saprolegniosus in channel catfish *Ictalurus punctatus* is associated with low temperature induced immunosuppression and invasion by a <u>ubiquitous, opportunistic water mold</u>, identified as a *Saprolegnia* sp."

Kanouse, Bessie B. 1932: "The species of water mold that is found commonly on fish and fish eggs in fish hatcheries <u>and in the fresh water lakes and streams</u> belongs to the genus *Saprolegnia*." "The fungus <u>is widespread not only in America but also in Europe</u>." "The extermination of the fungus in hatcheries and in the fresh water lakes and streams is, of course, utterly impossible."

Massachusetts CZM (1995): "<u>*Saprolegnia* is a ubiquitous fungus and inhabits all freshwater</u>."

Pickering, A. D. and L. G. Willoughby. 1982.: "However, one subject that has not yet been considered is the relative abundance of pathogenic *Saprolegnia* spores or propagules in the environment. Reliable methods for quantitative estimation of propagules in fresh water are usually labour-intensive and tedious to operate. This, together with the fact that fungal identification may take several weeks, or even months, is responsible for the paucity of information on the abundance of pathogenic *Saprolegnia* propagules in natural water bodies." "The species *Saprolegnia* implicated in fish pathology are probably best considered as facultative necrotrophs, forms which are normally saprophytic but which can also exist as parasites. It follows, therefore, that **their natural distribution in fresh water need have no correlation with the presence of fish**." (Emphasis added.) "It would seem likely that pathogenic *Saprolegnia* spores or propagules are ubiquitous components of the microbial flora of most natural water bodies...."

PATHOGENICITY

While the previous extracts argue strongly for *Saprolegnia* likely being present even in "pristine" wilderness waters, or in the soil or wetland environments near lakes and ponds, conclusive demonstration of presence or absence is subject to the difficulties noted by Pickering and Willoughby (1982). The following extracts suggest that infection is associated with some level of stress or pathology in the organism prior to *S*. infection, and that the number of infecting agents (zoospores) in the environment need not be high. However, once an organism is infected, the number of propagules generated increases markedly. Again, listing authors alphabetically:

Massachusetts Coastal Zone Management (1995): "(*Saprolegnia*) invades most species of fish that have been subjected to some type of stress. It is also capable of infecting insects and amphibians. There is potential for infection whenever fungal zoospores are present in excess of 23,000 spores/liter."

Richards and Pickering 1978: "Under hatchery conditions the background spore count may rise to over 20,000 spores/liter whereas the normal spore count does not exceed 5000/liter in Windermere and 4000/liter in Loch Leven."

Pickering and Willoughby 1982: "Mucus removed from the surface of the fish triggers encystment of zoospores of the pathogenic strains and mycelial growth ensues rapidly." "It would seem likely that pathogenic *Saprolegnia* spores or propagules are ubiquitous components of the microbial flora of most natural water bodies and that potential hosts are constantly challenged by the pathogen. Under these circumstances, changes in the host and in the environment may be at least as important as changes in the pathogen load of the water in determining the outbreak of fungal infections. Once an outbreak occurs, the presence of infected fish ensures that the spore count in the water rises dramatically." "Based on his work with Pacific salmon, Neish (1977) emphasized the role of stress in initiating *Saprolegnia* infections."

Willoughby, L. G. 1962: “At Windermere lake margin total Saprolegniales estimation figures ranged from <25 to 5200/liter. At Windermere lake center total Saprolegniales estimation figures were never more than 100 per liter and a mean figure of 11 per liter was derived for this situation. At Wraymires Fish Hatchery total Saprolegniales estimation figures ranged from 400 to 4600 per liter.” “In the waters investigated, *Saprolegnia* was easily the most conspicuous genus, followed by *Achlya* and *Aphanomyces*.”

INTERPRETATION

Wraymires Hatchery obtains its water untreated from adjacent Lake Windermere. (Windermere and Loch Leven support numerous fish species.) Willoughby found that water from the edge of Windermere carried higher zoospore levels (25-5200/L), but water in the lake’s center had far fewer. Pumping of nearshore lake water into the hatchery environment resulted in an intermediate count of propagules, as would be expected (400-4600/L). This is more than adequate to initiate infection in fish which are compromised in some way. In the natural environment, stress may be more important in initiating fungal infection than a prior infection or injury (Neish 1977).

Blaustein *et al.* (1997) provided strong evidence of the susceptibility of long-toed salamander eggs to mortality from UV-B radiation. Earlier, Blaustein and Wake (1995) stated: “Because ultraviolet rays can impair immune function in many animals, it seems reasonable to guess that some amount of egg damage in amphibians is caused by an ultraviolet-induced breakdown in the ability of amphibian embryos to resist infection by the fungus.” We totally agree!! They also stated that eggs of Cascade frog and western toad are similarly vulnerable. *Saprolegnia* is ubiquitous in the freshwater environment. It is probably found at very low levels in wilderness lakes, whether or not they contain fish. Given the long list of environmental insults to which amphibians are subject, we do not believe one can infer from Blaustein *et al.* (1997) that *Saprolegnia* is, or has been introduced to wilderness waters where it did not previously exist. We believe it is much more likely that the populations which succumbed to *Saprolegnia* in Blaustein *et al.*’s (1997) study suffered infections by a previously-present fungus after having been compromised in some way by UV-B radiation.

Comment and Relationship to Washington High Lake Management:

Washington’s high lake stocking program is one of maintenance, not expansion (Figures 2, 3). In fact, the number of lakes being stocked is decreasing (Figure 3) due to a recent trend of some fish stocks to successfully reproduce (thought to be related to climate change and length of growing season). Therefore, the potential of introducing *Saprolegnia* into waters where it does not currently exist via trout fry stocking is near zero. If the fungus has been introduced into any lakes through trout stocking, it probably occurred in the distant past, well before anyone took notice of amphibians suffering massive *Saprolegnia* infections (see Section 5.5 and Table 17).

COMMENTS ON SPECIFIC REFERENCES

Blaustein, A. R., D. G. Hokit, R. K. O'Hara, and R. A. Holt. 1994. Pathogenic fungus contributes to amphibian losses in the Pacific Northwest. Biological Conservation 67:251-254.

Comment/s and Relationship to Washington High Lake Management:

The authors state: "*Saprolegnia* is an important worldwide pathogen of fishes, especially those species reared in hatcheries (refs.)." This is an egregious error in syntax. What they probably meant to say, based on reality, is: ...especially ***when*** those species ***are*** reared in hatcheries (emphasis added, but even then the sentence is not universally true). Their sentence, as published, infers that fish species which are cultured in hatcheries, are subject, *ipso facto*, to *Saprolegnia* infection. This is untrue, and implies that all trout reared in hatcheries are likely to be carrying *Saprolegnia* infections. While there is no doubt that hatchery culture can, under some circumstances, greatly increase the count of *S*. zoospores in the rearing water and thereby increase the chance of infection in compromised fish, it does not necessarily follow that fish which have received proper prophylactic care are stocked carrying *Saprolegnia* infections.

These authors cite a number of other studies where various amphibian species (*Rana*, *Bufo*, etc.) succumbed to *Saprolegnia* **in temporary pools** (emphasis added). Unless these same ephemeral ponds were stocked with fungus-bearing trout at the same time the amphibians spawned, it requires a leap of logic to connect trout stocking to those frog die-offs. Sympatry with stocked trout was presumably not a pre-requisite in those mortality studies. However, the authors also "hypothesize that individual amphibians may transmit the pathogen to other populations as they migrate or disperse." Hypotheses are not the same as fact.

REFERENCES

Blaustein, A. R. and D. B. Wake. 1990. Declining amphibian populations: a global phenomenon? Trends in Ecology and Evolution 5:203-204.

Blaustein, A. R. and D. B. Wake. 1995. The Puzzle of declining amphibian populations. Scientific American 272(4):52-57.

Blaustein, A. R., D. G. Hokit, R. K. O'Hara, and R. A. Holt. 1994. Pathogenic fungus contributes to amphibian losses in the Pacific Northwest. Biological Conservation 67:251-254.

Blaustein, A. R., J. M. Kiesecker, D. P. Chivers, and R. G. Anthony. 1997. Ambient UV-B radiation causes deformities in amphibian embryos. Proceedings of the National Academy of Science 94:13735-13737.

Bly, J. E., S. M. A. Quiniou, L. A. Lawson, and L. W. Clem. 1996. Therapeutic and prophylactic measures for winter Saprolegniosus in channel catfish. Diseases of Aquatic Organisms 24: 25-33.

Cronquist, Arthur. 1961. Introductory Botany. Harper & Row. New York. 902 pages.

Kanouse, Bessie B. 1932. A physiological and morphological study of *Saprolegnia parasitica*. Mycologia 24: 431-452.

Kiesecker, J. M., A. R. Blaustein, and L. K. Belden. 2001. Complex causes of amphibian population declines. Nature 410: 681-684.

Massachusetts Coastal Zone Management. 1995. Massachusetts Aquaculture White Paper. (On the worldwide web at: http://www.magnet.state.ma.us/czm/wptoc.htm.

Neish, G. A. 1977. Observations on saprolegniasis of adult sockeye salmon, *Oncorhynchus nerka* (Walbaum). J. Fish Biology 10:513-522.

Parametrix, Inc. 2001. Questionnaire survey of WDFW Biologists to support a report on the Washington Department of Fish and Wildlife's high lakes fishery management program. Special Appendix. 74 pages.

Pickering, A. D. and L. G. Willoughby. 1982. *Saprolegnia* infections of salmonid fish. Pages 271-297 *IN*: R. J. Roberts, ed. Microbial Diseases of Fish. Spec. Publs. of the Society for General Microbiology. Academic Press. London.

Richards, R. H. and A. D. Pickering. 1978. Frequency and distribution patterns of *Saprolegnia* infections in wild and hatchery-reared brown trout *Salmo trutta* L. and char *Salvelinus alpinus* (L.). Jour. of Fish Diseases. 1(1): 69-82.

Seymour, R. L. 1970. The genus *Saprolegnia*. Nova Hedwigia 30: 1-124.

Srivastava, R. C. and G. C. Srivastava. 1978. Fungi associated with the diseases of freshwater fishes. Mycopathologia 63(2): 121-126.

Willoughby, L. G. 1962. The occurrence and distribution of reproductive spores of Saprolegniales in fresh water. The Journal of Ecology 50(3): 733-759.

_____________. 1978. Saprolegnia of salmonid fish in Windermere: a critical analysis. Jour. of Fish Diseases 1(1): 51-67.

______________, A. D. Pickering, and Hilary G. Johnson. 1984. Polycell-gel assay of water for spores of Saprolegniaceae (fungi), especially those of the *Saprolegnia* pathogen of fish. Hydrobiologia 114: 237-248.

Wood, S. E. and L. G. Willoughby. 1986. Ecological observations on the fungal colonization of fish by Saprolgeniaceae in Windermere. Jour. Appl. Ecol. 23: 737-749.

APPENDIX I

Historic Trail Blazer Stocking, by County

Appendix Table I. Trail Blazers, Inc. stocking trips, by county and decade, in Washington State.

County	1930s	1940s	1950s	1960s	1970s	1980s	1990s	2000s
Chelan	6	3	13	18	30	91	121	3
Cowlitz						1	4	
Jefferson				8	1			
King	83	102	118	184	208	283	314	36
Kittitas		13	11	38	50	107	134	14
Lewis			1	8	6	21	86	1
Okanogan				6	5	3	7	4
Pierce				1	17	18	20	1
Skagit			18	60	40	74	119	5
Skamania					9		9	
Snohomish	3	18	54	85	117	202	275	17
Whatcom			1	32	13	57	55	6
Yakima			4	3	1	12	11	2

APPENDIX J

Summary Management Statistics by WDFW Manager

Appendix Table J. Washington high lake management statistics by county and WDFW management biologist.

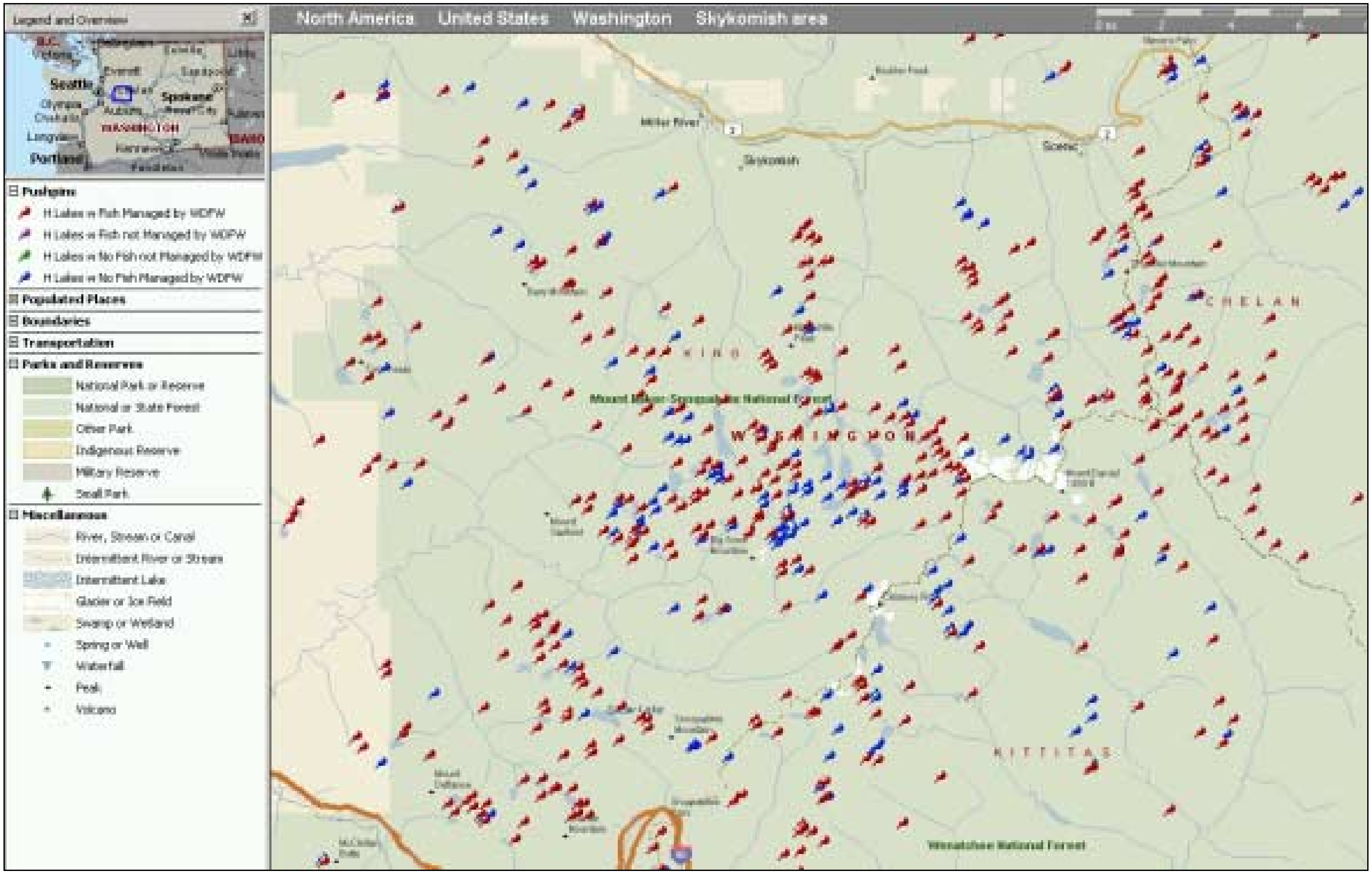
Region	Manager	County	Number of Lakes	Number in Park	Number Surveyed	Number w/Plan	Number Managed	Number in Region w/Fish	Percent w/Fish	Repro Status Deter'd	Percent
1	Vail	Pend Oreille	31		15	15	15	3	10	15	100
2	Bartlett	Okanogan	321		108	108	240			89	36
2	Viola	Chelan	402	28			302	331	46	171	57
		Kittitas	221			167	167			167	100
3	Anderson	Yakima	367			154	154	227	39	154	100
5	Weinheime	Skamania	382		250	250	250	206	29	250	100
		Cowlitz	13		11	11	11			11	100
5	Lucas	Lewis	315	35	171	171	171			171	100
		Pierce	277	166			51				
6	Hunter	Mason	93				24	182	18		
		Grays Harbc	25	2	3	3	5			3	60
		Jefferson	543	366	17	17	19			17	89
6	Collins	Clallam	90	75	0	0	0				
		King	572		323	323	532			346	79
4	Jackson	So.Snohomish	143		80	80	143			86	74
		No.Snohomish	252								
		Skagit	311	52						56	
		Whatcom	360	200						47	
4	Downen	Aggregate	(837)		98	98	187	828	51		
		Total:	4718					Mean:	38	Mean:	83

APPENDIX K

Distribution Maps of Washington High Lakes

Appendix Plate K-1. Density of high lakes by county in Washington State.

Appendix Plate K-2. Distribution of high lakes with and without fish between SR 2 and I-90 in the central Cascades. Note the presence of fishless lakes throughout the area, and in most sub-basins of the upper Snoqualmie, Skykomish, and Yakima River Basins.



APPENDIX L

Goals, Policies, and Objectives by the Washington Fish and Wildlife Commission. February 2, 1995

Goals, Policies, and Objectives by the Washington Fish and Wildlife Commission. February 2, 1995 Available in Hard Copy Version Only

APPENDIX M

Agency Guidelines and Memoranda of Understanding

Agency Guidelines and Memoranda of Understanding Availble in Hard-Copy Version Only

APPENDIX N

High Lakes File

The attached High Lakes File was used as the basis for several figures and tables in this report. Not all the detailed data used for the report is included in the file. However, the lake names, identification numbers, size, location, administrative areas are included. The lakes are ordered by County, Township, Range, Section and Lake Name in memory of Ernest Wolcott who used that ordering in his Lakes of Washington volumes.

HIGH LAKE TABLE FIELD DEFINITIONS

Field Name	Type	Comment
CountyName	Text	County name
Township	Text	Public Land Survey Township
Range	Text	Public Land Survey Range
PSection	Long Integer	Public Land Survey Section
PSectionSuffix	Text	Section subdivision using Wolcott method
Lake Name	Text	Primary lake name. Unnamed lakes use Unnamed-Elevation for a name
Other Names	Text	Other lake names in use
HighLakeFlagWDFW	Yes/No	Flag identifying a high lake or pond based on WDFW criteria
HighLakeException	Yes/No	Flag identifying lake that does not meet WDFW high lake criteria but is being managed as a high lake by regional biologist.
FishStocked	Yes/No	Flag identifying that the lake has ever been stocked with fish
FishSeen	Yes/No	Flag identifying that a fish has ever been observed in the lake
Organization	Text	The organization managing or owning lake property
Admin	Text	Administrative area name if any
CU	Text	USGS basin (hydrologic unit) code
FSWatershed	Text	Forest Service 5th and 6th level watershed code
LakeBasin(Acres)	Single	Lake basin drainage area (acres)
Reach	Text	Reach identifier imported form USGS/EPA Reach File or assigned by Mike Swayne Trail Blazer Librarian using Reach File identification methodology
DownReach	Text	Downstream lake or stream name
RDOWCode	Text	Regional WDFW biologist lake code
SDOWCode	Text	State WDFW lake MUCODE
Lake2k	Long Integer	State WDFW GIS lake code
NPSCode	Text	North Cascade National Park lake code
Wolcode	Text	Wolcott code (Volume.Page.Item.subitem)

CurtisID	Integer	Lake code developed by Walt and Brian Curtis used in Hi-Laker High Lake database
Location	Text	Lake location description, distance and direction from named feature
SurfaceArea	Single	Lake area (acres)
AvgDepth	Single	Average lake depth (feet)
MaxDepth	Single	Maximum lake depth (feet)
MaxDepthQual	Text	Maximum depth qualifier
Outlet	Yes/No	Outlet exists flag
Shoreline	Single	Shoreline length (miles)
Elevation	Integer	Elevation above mean sea level (feet)
DLat	Double	Latitude decimal degrees NAD27
DLong	Double	Longitude decimal degrees NAD27
LLPosition	Text	Lat/Long position (Center, drainage outlet)
MapCode	Text	USGS Map code
MapName	Text	USGS Map name