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The Status of Fish Populations and Management of High Mountain Lakes in the Western United States

Abstract

Fish stocking of mountain lakes in the western contiguous United States is a topic of increasing ecological concern and public debate. A synthesis of available information is needed to assess the diversity of stocking programs employed and their large-scale ecological implications. The purpose of this report is to provide an overview of the status of fish populations and management of high mountain lakes in the western U.S. based on interviews of state fishery managers in each of 43 regions in 11 states. The managers estimated that more than 95 percent of about 16,000 lakes were naturally fishless prior to stocking. Presently, about 60 percent of the total number of lakes and 95 percent of the deeper lakes (>3 m) and larger (>2 ha) lakes contain trout. Seventy-five percent of the lakes with fish are regularly stocked, including an estimated one-third that may have wild (self-sustaining) fish populations. Most regions manage mountain lakes fisheries with little survey or research data on which to base stocking programs. Few managers consider the health of indigenous trout populations, other aquatic species, lake ecosystems or the concerns of affected recreational users when conducting stocking programs. Intensive, on-going and largely indiscriminate stocking of lakes in most mountainous regions in the western U.S. may be causing large-scale degradation to aquatic ecosystems, indigenous fish, invertebrates, amphibian fauna and potential quality fisheries. Some management regions have expanded lake surveys and reduced stocking efforts to protect native and wild trout populations, quality fisheries, and pristine fishless lakes.

Introduction

Stocking fish in high mountain lakes has long been a source of concern and controversy (Hendee 1976). Although mountain lakes are typically small (<30 ha surface area) and remote, collectively they represent an important national resource, including most of the pristine aquatic systems and undamaged watersheds remaining in the country. Most recreation in National Parks, Wilderness and roadless areas centers on mountain lakes, although most research shows that only about half of the visitors to Wilderness high lakes actually fish (Hendee 1976). Controversy over high lake stocking has revolved around state fishery agencies and fishing groups concerned with maintaining and expanding fishery opportunities and Wilderness and National Park managers concerned with maintaining and restoring natural ecosystems (Nicola 1976, Pister 1977). Ecological concerns are increasingly supported by research findings. Recent studies in the Sierra Nevada, Rocky Mountains and North Cascades suggest that the ecological impacts of alien fish species on indigenous aquatic communities may indeed be severe, long lasting and widespread throughout the western U.S. (Reimers 1958, 1979; Bahls 1990a, 1990b, Liss and Larson 1991).

Since the late 1940's, the use of aircraft to stock trout in high mountain lakes has facilitated widespread and intensive introduction of non-native species throughout the mountain ranges of the western United States. However, the improvement in technology that has permitted fish introductions on a massive scale has far out-paced an understanding of the ecological consequences and basic knowledge of the types and extent of stocking programs conducted nation-wide. The potential for large-scale ecological impacts of stocked fish and the increased national concern for the protection and maintenance of biodiversity suggests that a high priority will need to be given to revising the goals and strategies of high lake management programs.

The purpose of this report is to provide an overview of the status of high mountain lakes in the contiguous western United States relative to fish populations and current fishery management methods and policies. The goal of the study is to provide a broader perspective of current management practices and their large-scale ecological implications in order to stimulate discussion and improvement of state and regional approaches to high lake fishery management.

Methodology

Study Area

The study area encompasses the mountainous regions of the contiguous western United States, comprising 43 state fisheries management regions in 11 states: Washington, Oregon, California, Idaho, Montana, Wyoming, Utah, Colorado, Nevada, Arizona and New Mexico. Lakes included

in this study represent specific regional or state definitions for what constitutes a "high" or "mountain" lake. In general, the lakes included in this study represent naturally formed lakes occurring above 800 meters in elevation.

Methods

Telephone interviews were conducted between 10 October and 25 November 1988 with the 43 regional fishery managers or biologists working for state fish and wildlife agencies in 11 states. In addition, district fishery managers within each region in Oregon and parts of California were interviewed. High lake research and management summary reports also were obtained from some regions. The interview consisted of a standard series of questions on the status of lake fisheries, type of survey methods employed, stocking criteria used, coordination with land management agencies, level of recreational use, type of angling regulations, ecological considerations given to stocking programs and current research activities.

Results and Discussion

Fishery status

About 16,000 high mountain lakes exist in the western contiguous United States (Table 1). However, the total numbers of lakes is approximate, since managers did not know the precise numbers of lakes, particularly fishless lakes, in their region. The largest concentrations of lakes are located in the Oregon and Washington Cascade Mountains, the Sierra Nevada Range of California and the Rocky Mountains of Idaho, Montana, Colorado, and Wyoming (Figure 1).

Mountain lakes in the western U.S. typically occur in glacial cirque basins and are ultra-oligotrophic owing to their occurrence at high elevations and within nutrient poor geological zones. Watersheds and lakeshore areas are highly sensitive to disturbance and exhibit slow recovery. Fisheries are characterized by low productivity owing to the cold, nutrient-poor waters and the short growing season.

About 40 percent of the lakes within the 11 western states are fishless (Table 1). Most of these fishless lakes are predominantly shallow (< 3 m) and small (< 2 ha) lakes which were either judged or proven to be incapable of supporting fish due to winter-kill or summer drought conditions. However, even many small, shallow lakes contain fish and are periodically stocked in Washington, Oregon, California, Colorado and Arizona. Most fishery managers estimated that less than five percent of the larger (> 2 ha surface area), deeper (> 3 m max. depth) lakes considered suitable as trout habitat remain in a pristine, fishless condition. The few areas where more than ten percent of the large lakes are maintained in a fishless condition include the National Parks, where stocking has been largely phased out, the remote Absaroka-Beartooth mountains in southwestern Montana and the state of Wyoming.

Fisheries managers estimated that probably less than five percent of the lakes contained fish populations prior to introductions of trout which began about 100 years ago. Most lakes remained fishless until the advent of aerial stocking and improved hatchery technologies in the 1940s. With passage of the Wilderness Act of 1964, stocking was limited by Federal guidelines to lakes that had been

TABLE 1. Approximate total number and percent of mountain lakes in each state within each fishery type.

	State											
Fishery Status	AZ	CA	CO	ID	MT	NV	NM	OR	UT	WA	WY	TOTAL
Total no. lakes	60	4131	1446	1791	1650	36	50	877	1080	2700	2000	15891
% lakes with fish	50	63	76	58	47	58	64	84	66	56	40	59
% lakes without fish	50	37	24	42	53	42	36	16	34	44	60	41
% large, fishless lakes	0	3	3	3	8	0	0	0	0	4	10	4
% lakes stocked	50	52	59	46	24	22	64	76	50	44	20	45
% unstocked wild trout lakes	0	11	17	13	24	36	0	8	16	11	20	14
% salmonid lakes	50	38	52	43	29	17	58	13	26	30	9	32
% brook trout lakes	0	21	20	12	17	42	6	70	38	22	21	23
% other fish lakes	0	4	4	3	1	0	0	1	2	4	10	4

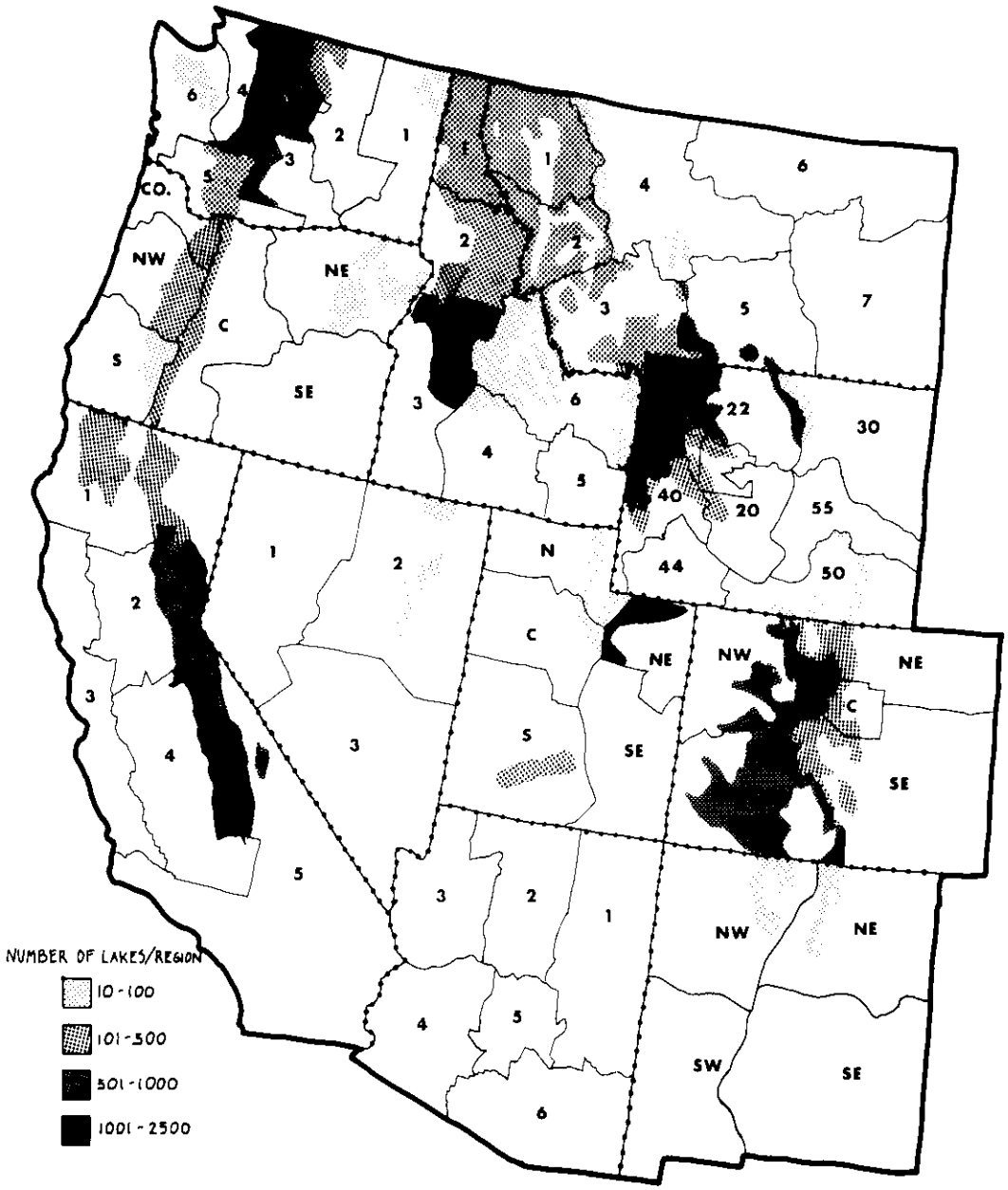

Figure 1. Number of lakes in mountainous areas of each state fishery management region in the western U.S.

stocked previous to Wilderness designation, providing at least some protection of naturally fishless lakes from state agency stocking programs (Figure 2).

The three primary fish species occurring in mountain lakes are rainbow trout (*Oncorhynchus mykiss*), cutthroat trout (*O. clarki*) and brook trout (*Salvelinus fontinalis*). Lesser numbers of golden trout (*O. aquabonita*), arctic grayling (*Thymallus arcticus*), lake trout (*Salvelinus namaycush*), brown trout (*Salmo trutta*), splake (brook-lake hybrid), rainbow-cutthroat hybrid, kokanee salmon (*O. nerka*), Atlantic salmon (*Salmo salar*) and several species of sucker, whitefish and minnow also occur. Although managers knew little about the

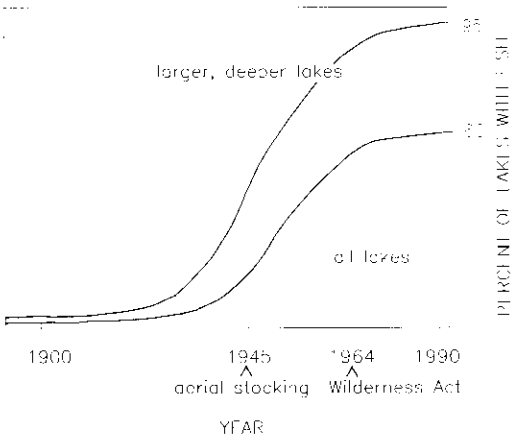

Figure 2. Hypothetical history of fish stocking for high mountain lakes in the western U.S. showing percentage of lakes containing fish for all lakes and larger (>2 ha surface area) and deeper (>3 m max. depth) lakes.

historical or current distribution of indigenous trout in lakes of most regions, they suggested that most lakes with indigenous trout have probably been subsequently stocked, leaving perhaps one percent of the lakes with relatively pure strains of native trout.

In most states, lakes originally planted with brook trout contain self-sustaining populations, usually with abundant numbers of small or stunted individuals. Notable exceptions include the Oregon Cascade mountains, where the majority of lakes continue to be stocked with brook trout every other year with few perceived over-population problems, and the highly productive lakes in the Boulder Mountain region of Utah which produce brook trout weighing 700 to 1000 grams within two years from the time of stocking.

Purpose of High Lake Fishery Programs

Regional managers stated that maximizing a diversity of fishery recreation opportunities (including "quality" fisheries) was the purpose of their high lake fishery program. Quality fisheries were generally defined as smaller populations of larger sized fish (>30 cm) supported within the carrying capacity of the lakes. Native and wild trout (self-sustaining by natural reproduction) populations are given high priority as "quality" fisheries in Colorado and Montana. Several regions, discussed later, have taken various steps to ensure that high lake stocking is consistent within the broader goal of protecting and enhancing indigenous trout, aquatic biodiversity and the ecological integrity of high lake regions.

Survey Methods

Most regions consider high lake management to be a low priority. Consequently, although stocking efforts are intensive and widespread, survey and research efforts have been minimal in most states (Table 2). Many lakes in the large wilderness and roadless areas of Montana and Idaho have never been surveyed, although they have been regularly stocked with fish for over 40 years. Most regions have an informal survey method of gill netting to obtain samples of fish for weight and length measurements. Some water quality samples and lake bathymetric measurements are taken as well. In some regions, fishery biologists and other personnel spend one to two weeks a year surveying lakes in an attempt to visit each lake in the region every five to ten years. Snorkeling instead of gill-net sampling is used by several districts in Oregon and California to estimate fish population and prey base characteristics of selected lakes.

The states of Wyoming, Colorado and Utah initiated long-term standardized fishery survey programs that included most of the mountain lakes in each state. In Colorado and Wyoming, most lakes were surveyed once to determine the status of the existing fish populations and the suitability for future stocking. Utah recently completed a second phase of surveys on about 600 lakes in the High Uinta Mountains in order to revise stocking rates established after the initial surveys, which were conducted 10-20 years ago. In the only systematic survey conducted in Montana, Pat Marcuson (1980) surveyed over 1000 lakes in the Absaroka-Beartooth region over a period of ten years.

More comprehensive limnological surveys have been conducted on 87 lakes in Colorado (Nelson 1988), 10 lakes in the Sierra Nevada (Reimers *et al.* 1955), 30 lakes in the Gospel Hump Wilderness (Espinosa 1976) and 189 lakes in the Nez Perce National Forest of Idaho (Bahls 1990a, 1987). Work in Washington includes surveys of 60 lakes on the Olympic Peninsula (Johnston 1973), 52 lakes in the North Cascades National Park (Liss and Larson 1991) and 30 lakes in Mt. Rainier National Park (G. L. Larson pers. comm., National Park Service, Oregon State University). In addition, Phase I of the Western Lakes Survey

TABLE 2. Percent of high lake fishery management regions in each state using various survey methods and management policies.

Survey methods and management policies	State											
No. of high lake mgt. regions	AZ 2	CA 4	CO 5	ID 5	MT 5	NV 2	NM 4	OR 5	UT 2	WA 6	WY 3	TOTAL %
Most lakes not surveyed	0	0	0	80	80	0	0	0	0	0	0	15
Infrequent fish status surveys	100	100	100	0	20	100	100	100	100	100	100	84
Comprehensive ecological surveys	0	0	0	20	0	0	0	0	0	34	0	5
Research studies	0	50	100	20	0	0	0	20	0	17	0	19
Active creel census program	0	25	40	40	0	0	0	40	0	83	0	21
No stock in native fish watershed	0	0	20	0	0	100	100	20	0	0	0	22
Stock only surveyed lakes	0	0	80	20	40	100	100	100	100	34	100	61
Stocking only with native strain	0	0	0	20	60	0	0	0	0	0	0	7
Stocking native and exotic strain	0	100	100	80	40	0	25	100	0	100	100	59
Stocking only exotic strain	100	0	0	0	0	100	75	0	100	0	0	34
Continued brook trout stocking	0	50	20	0	0	0	25	100	100	17	100	37
No supplemental stocking	100	25	0	80	60	0	50	0	0	17	0	30
No basis for stocking rates	0	25	0	80	60	0	0	0	0	0	0	15
Trial and error basis for rates	100	75	0	20	40	100	100	100	100	83	100	74
Quantitative index basis for rates	0	0	100	0	0	0	0	0	0	17	0	11
Stocking rotation period (years)	1	1-2	1-3	2-3	3-8	1-3	2-4	2	1-5	3-10	2-4	0
State-federal stocking plan	0	0	0	20	0	0	0	0	0	0	0	2
Concern with federal logging impact	0	25	0	60	0	0	0	60	50	17	0	14
Perceived recreation increase	100	100	100	100	100	100	0	100	100	100	100	91

was conducted in 1985 by the U.S. Environmental Protection Agency to determine the chemical status of 757 high mountain lakes considered to be at risk as a result of acidic deposition (EPA 1987).

A number of other methods have been used to obtain information on high lakes. Informal creel census, usually involving voluntary angler report cards available at the trail head, was used in many regions. Some states occasionally make use of state agency enforcement personnel to collect basic information (usually by angling) on the lake fishery. A few regions have cultivated high lake enthusiasts who give the state fishery agency information on the status of fish populations in high lakes that they visit. Washington has two user groups, the High Lakers and the Trail Blazers, which give stocking recommendations to the Department of Wildlife and, using backpacking methods, stock over 100 lakes a year.

Mountain lakes in the West have received little in-depth research compared with lowland aquatic systems (Goetze *et al.* 1989), but research activity seems to be on the increase. Current studies on high lakes include long term studies of the effects of fish stocking on the ecological communities of lakes in North Cascades National Park Service Complex, Washington (Liss and Larson 1991) and Wilderness Areas of the Nez Perce National Forest (Bahls 1990a). Nelson (1988) synthesized 20 years of research and survey data on high lakes in Colorado. Research has recently been completed on the population dynamics of stunted brook trout populations in response to density reduction in the Sierra Nevada mountains of California (Hall 1991). Work is in progress on developing a lake productivity index for use in estimating stocking rates in the northwestern Sierra Nevada (Morea pers. comm., California Department of Fish and Game).

Stocking Criteria

A. Lake habitat considerations

Few regions have active field investigations substantiating reasoning or results of stocking practices (Marcuson 1980). In terms of lakes considered suitable for stocking, most lakes in the West are assumed by managers to be able to support fish populations. Even many of the shallow, small lakes that provide marginal wintering habitat,

are stocked on a regular basis. Only one regional manager specifically stated that he would refrain from stocking a lake until it was surveyed. In Colorado and Wyoming, a small number of large, deep lakes at high elevations are not stocked due to their exceptionally low productivity. In addition, about 10 percent of the high lakes in Wyoming with suitable trout habitat are maintained in a pristine fishless condition.

B. Federal management considerations

Managers were aware of the "grandfather clause" of federal wilderness management guidelines that restrict stocking to lakes stocked previous to wilderness designation (USDA 1986). However, at least one region in Idaho continued to stock fishless lakes in wilderness areas until 1989. Considering that some managers assumed that most lakes have been stocked at one time or another, and the lack of state-federal planning coordination and limited survey data, rare fishless lakes are probably not adequately protected from stocking in some regions. However, the fishery management region encompassing the Absaroka-Beartooth Mountains of Montana maintains about 25 percent of 1000 lakes in a fishless condition as representative pristine lakes for baseline monitoring, research and wilderness values (Marcuson 1976).

National Park Service management policy adopted in 1977 (USNPS 1975) states in part that "The Service will. . . strive to maintain the natural abundance, behavior, diversity, and ecological integrity of native animals in natural portions of parks as part of the park ecosystem. . . No artificial stocking of fish species exotic to a park will occur; artificial stocking of fish may only be employed to reestablish native species. Naturally barren waters will not be stocked with either native or exotic fish species." However, sometimes heated controversies with the state fishery agency responsible for historical stocking of these lakes (Nicola 1976) have resulted in continuing stocking of a small percentage (< 10 percent) of lakes in most National Parks.

In a somewhat anomalous case, recent negotiations between the Washington Department of Wildlife and North Cascades National Park resulted in an agreement to continue stocking 50 percent of the lakes that would have reverted to a fishless condition with no stocking. In contrast, Rocky Mountain National Park allows no stocking of non-native trout species and initiated a native trout restoration program which has established self-sustaining native-strain greenback cutthroat and Colorado cutthroat in 11 lakes previously occupied by brook trout or other introduced trout (Rosenlund and Stevens 1988).

C. Fish species considerations

Several regions were taking steps to incorporate native trout protection and enhancement policies into their high lake management programs. New Mexico, Wyoming, and some regions of California have informal policies of not stocking lakes that drain into a stream system containing indigenous trout. Rocky Mountain National Park and a region encompassing the northeast Cascade mountains of Washington stock exclusively hatchery-reared trout originally indigenous to the region, while Colorado, Montana, Idaho, and New Mexico stock native-strain trout, while continuing to stock non-native trout species.

Most lakes in the West continue to be stocked with species, subspecies and stocks of trout not native to the watershed or region. Brook trout continue to be stocked in about 10 percent of the lakes stocked on a regular basis. However, most states have severely limited or discontinued brook trout stocking due to the observed tendency of the species to over-populate in most types of lakes. Brown trout and lake trout continue to be stocked occasionally to control over-populated brook trout lakes, although this method has met with mixed results and may actually compound the problem (Nelson 1988, Hall 1991).

D. Natural recruitment considerations

About 25 percent of the lakes containing fish in the West are not stocked owing to high levels of natural recruitment and self-sustaining fish populations (wild trout lakes). However, a variety of factors suggest that an additional 25 percent of the lakes with trout may not require further stocking to maintain fisheries. Most managers stated that stocking was conducted unless evidence of high natural recruitment was recorded for a lake. Given the lack of basic survey data in many regions and difficulty of identifying low to moderate levels of natural recruitment in the fish populations which are periodically stocked, the potential for unnecessary stocking is great. Also, intensive surveys of lakes in the Nez Perce National Forest indicated that 50 percent of the 130 lakes stocked on a regular

basis were probably capable of maintaining self-sustaining fisheries (Bahls 1990a). Likewise, National Park Service policy changes in the late 1960s which resulted in severe limitations on stocking, left self-sustaining trout populations in about 25 percent of the lakes previously stocked in national parks in California and Colorado (Wallis 1976, Rosenlund and Stevens 1988). The smaller percentage of wild trout lakes in the Parks may be due to the exceptionally marginal, high elevation spawning habitat and high angling pressure in these areas.

Only a few regions in Washington and Montana have a policy of not stocking lakes with any recognized natural recruitment. Montana, with a strong emphasis on maintaining wild and native fish populations in stream and river systems, appears to be the strongest supporter for maintaining wild trout populations in mountain lakes, shifting the burden of proof to permit stocking of only those lakes where it is clearly necessary to maintain fish populations. Supplemental stocking "when in doubt" is seen as an unnecessary risk to personnel involved in aerial stocking operations, a waste of management resources and potential cause of damage to quality wild trout fisheries and wilderness values (Marcuson 1976).

While most regions use supplemental stocking or an increase in stocking rates and frequencies to adjust to various levels of recruitment and angling pressure, several regions have adopted more restrictive angling regulations or are considering the implementation of such regulations to reduce the harvest and maintain a "quality" or wild trout fishery. In Rocky Mountain National Park, depletion of self-sustaining native-strain trout populations is prevented by a two fish per day bag limit. The Absaroka-Beartooth region of Montana has proposed a three fish limit. Colorado has long debated the idea of imposing slot limits, where trout within a specified size range would be released unharmed (Nelson 1988). On the other hand, in Colorado, Montana and Idaho, angling regulations allow the take of additional brook trout. According to Nelson (1988), the liberal regulation probably has little effect on reducing the abundant numbers of small and stunted fish that occur in most lakes containing this species, but probably does little harm either.

Stocking Rates and Frequencies

Most regions claim to manage high lakes by the "seat of the pants" method, presumably meaning in part that stocking rates and frequencies are based on limited or intuitive knowledge of the lakes in the absence of standardized or quantitative method for deriving appropriate stocking rates. Trial and error was the phrase most often heard, suggesting that stocking rates are based on past results in terms of the desired size, condition and relative abundance of fish. However, the past results upon which stocking rates are based varies considerably between regions. Montana and Idaho have relatively little data on which to estimate appropriate stocking rates, whereas in the Oregon Cascades, with fewer lakes per regional manager, higher fishing pressure and easier access to the lakes, there seems to have been more opportunity to evaluate stocking rates and make the necessary corrections.

Regions of Colorado rely primarily upon a stocking rate index based on research and surveys conducted by Nelson (1988) over a period of 20 years. The index incorporates lake elevation and estimated angling pressure (low, moderate, high) to derive appropriate annual stocking rates. For lakes in the Olympic Mountains of Washington, Johnston (1973) derived stocking rates from an "environmental parameter index" based on lake elevation, water alkalinity and food sources (shrimp and zooplankton) and other factors. Many regions, including those in Colorado, Utah, Washington and Wyoming, claim to have decreased stocking rates substantially since the 1940's and 1950's in response to lake surveys which indicated that existing stocking levels were resulting in populations of stunted and small fish.

Most regions stock at 62 to 620 fish/ha (25 to 250 fish/acre), depending upon the status of the existing fish population, perceived productivity and angling pressure at a lake. The frequency of stocking varies from one to eight years. Oregon plants mostly brook trout every other year and would stock every year if funding allowed. Most states stock fry or fingerlings on a set frequency of every two to five years for all lakes in the area, although some regions vary the frequency from two to eight years for specific lakes, depending on the perceived level of use, level of productivity and occurrence of other lakes in the area.

In the Absaroka-Beartooth region of Montana and the northeastern Cascades of Washington, the time period between fish plantings is between five to eight years and stocking cycles are staggered within a drainage basin (Marcuson 1980). The reasons given for such management are to:

1) provide a diversity of fishing opportunities—from abundant, small trout to lesser numbers of large, "trophy" trout in a lake over time and also between lakes in a drainage basin; 2) disperse recreational use among the lakes by varying the fishing opportunity available in a particular lake (from no fish present to trophy fish present) over time; 3) allow prey populations to replenish low productivity lakes during the period that trout populations are at a low level or not present in the lake; 4) increase the survival and growth rates of stocked fry due to lower predation associated with fewer large fish remaining in the lake and more abundant food resources available; 5) improve the cost-effectiveness of the stocking program by less frequent stocking and use of expensive helicopter time; and 6) lessen the impact of fish stocking on the lake ecosystem and associated wilderness values.

Stocking Methods

Use of fixed wing aircraft and helicopters are the major methods currently used to stock mountain lakes in the West. Backpacking and horse-packing trout fry into a lake are used rarely. In the Absaroka-Beartooth region, horse or backpacking methods are sometimes substituted for aerial stocking in the vicinity of a lake of special concern, such as a lake containing a pure stock of golden trout or native trout, to reduce the risk of stocking the lake accidentally while stocking lakes in the area (Marcuson 1980).

State and Federal Management Interactions

About 80 percent of the mountain lakes in the West are located in National Forests managed by the U.S. Forest Service, 15 percent in National Parks managed by the U.S. National Park Service and the remaining lakes fall under a variety of federal, state or private ownership. Most high lakes in the National Forests are located in designated Wilderness Areas, with the remainder mostly in roadless areas.

Management interaction between the federal and state agencies in regards to mountain lakes is limited, usually consisting of an annual notification from the state to the federal agency concerning the lakes to be stocked in that year. Few state fishery regions have formal "memorandums of understanding" listing the trout species or lakes which can and cannot continue to be stocked, although Federal Wilderness Management Guidelines recommend such action (USDA 1986). Based on baseline survey data collected and analyzed between 1986-1990, Nez Perce National Forest and the fishery management region of north-central Idaho are in the process of preparing a cooperative stocking plan for lakes in this National Forest. With the recent emphasis of the Forest Service on fishery programs, it seems likely that the cooperative funding and coordination between fishery and land management agencies to address mountain lake survey and management needs will increase.

In some regions, a major point of contention between state fishery and federal land managers is the building of new logging roads that increase accessibility to lakes and result in greatly increasing fishing pressure. Managers stated that the quality of the fishing experience is impaired by increased lakeshore impacts related to heavy recreational use and nearby logging operations and clear-cuts. Also, with increased fishing pressure on these relatively low productivity waters, fishery managers have not been able to sustain a "quality" trout fishery of large fish, but have switched to a "put and take" fishery of small catchable fish stocked more frequently into the lakes.

Recreational Use

Just as basic information is lacking on the fisheries resources of mountain lakes in most areas of the western United States, so too is an understanding of the people for whom stocking is conducted. No fishery region had conducted studies on the values or desires specific to high lake anglers or wilderness users. Managers' most commonly stated goals of providing a diversity of fishing opportunities and quality fisheries (in terms of larger fish in greater abundance) may have little relationship to the public's broader conception of a quality backcountry or wilderness experience.

Most regional managers perceived an increase in the recreational use of high lakes in recent years, with associated impacts on lakeshore vegetation and fish populations. The Sierra Nevada Mountains of California appear most heavily impacted, with most regions reporting a level of use far above that which fragile lakeshore areas can sustain. Fisheries consisting mainly of stunted and dense brook trout populations seem to be little affected by increased fishing pressure (Hall 1991). Staggering the stocking of lakes in a watershed, as discussed

above, is a standard method of trying to disperse use among a larger number of lakes, although only a few regions also use a lengthened time between stockings.

Long-term suspension of stocking at over-used lakes has been a matter of much debate (Cordone 1977, Wallis 1977, Nicola 1978). In some regions of Washington and California, suspension of stocking is considered a legitimate tool to disperse recreational users from heavily used areas. However, some regional fishery managers in Colorado are resisting requests by the Forest Service to discontinue stocking of over-used lakes, maintaining that use should be controlled by the land management agency through a special permit system, rather than indirectly, through a suspension of fish stocking.

Rather than discontinuing stocking to reduce impacts, Wyoming was seeking federal approval to stock additional pristine fishless lakes in Wilderness Areas as means to disperse use, but dropped the proposal due to ecological concerns and lack of U.S. Forest Service support. In general, most of the sociological research suggests that increasing fish stocking as a means of reducing recreational impacts may be counter-productive. Studies of backcountry users in many areas reveal that fishing is a relatively minor part of their overall visit. Manipulating the fishery would probably have a relatively small impact on the incentive of visitors to go to different places (Hendee 1976). Secondly, a highly curvilinear relationship exists between human use and impact, with relatively low levels of use producing high levels of impact and slow recovery in high elevation areas. Thus, a program to redistribute use would probably result in an increase in aggregate resource impact, ironically increasing the stress on high mountain fisheries and other values rather than reducing it (Stankey pers. comm., Oregon State University).

In Rocky Mountain National Park, pack animal use is restricted to areas below timberline and main trails. A permit system restricts camping to designated areas located at least .5 to 1 km from most lakes. The restrictions appear to keep lakeshore and fishery impacts at an acceptably low level, despite very high use of the Park overall (B. Rosenlund pers. comm. Fish and Wildlife Service).

Research Natural Areas

About 20 lakes in the western contiguous United States are designated as Research Natural Areas (RNA) under the U.S. Forest Service system. The majority of lakes with the RNA designation are located in the National Forests of Idaho, due largely to the efforts of Dr. Fred Rabe and others at the University of Idaho. Lakes proposed for RNA classification are usually managed as representative pristine ecosystems, with no fish stocking, road building or timber harvest permitted in the lake basin. Most regional fishery managers surveyed seemed amenable to the possibility of RNA designation of selected lakes in their regions for reasons of habitat protection and baseline study and monitoring, provided that a curtailment of fish stocking did not have significant impacts on fishery recreation.

Conclusion

Management of high lakes in the western contiguous United States can perhaps best be summarized as intensive, on-going and largely indiscriminate stocking of lakes in most mountainous areas. Most regions stock mountain lakes with non-native trout species and with limited or nonexistent survey data upon which to make basic stocking decisions, such as the identification of wild trout lakes (self-sustaining) that do not require further stocking. Most regions appear to have little concern for protection of native fish species in lakes or downstream systems, no evident concern for maintaining representative pristine lakes, and no consideration of the effects of trout stocking on indigenous fauna, aquatic ecosystems, and lakeshore recreational impacts. Furthermore, most regions appear to manage fisheries with little understanding of the high lake anglers whom they serve.

With virtually all mountain ranges in the contiguous western United States affected by more than 40 years of largely indiscriminate stocking practices, large-scale ecological disturbances and loss of biodiversity appear to be real possibilities. The elimination of many indigenous aquatic invertebrates following brook trout introduction to a lake in the Sierra Nevada was well documented by Reimers (1958, 1979). Recent research on 189 lakes of Nez Perce National Forest in Idaho (Bahls, 1990a and b) and 60 lakes in the North Cascades (Liss and Larson 1991) indicate significant differences in the biotic communities of lakes with and without fish, probably caused by fish predation on vulnerable invertebrates and amphibians. Degradation of potential quality fisheries throughout the

West by wasteful and unnecessary stocking also seems likely.

In the single-purpose drive of a fishery manager to make maximum use of fish stocking technology for the alleged purpose of providing for a small minority of the public that fish in remote mountain lakes, one might draw an analogy to the forest manager who strives to make as much timber available for harvest as soon as possible, irrespective of the losses to other resources or users. If fishery managers are to adequately serve the public as a whole, "optimum sustainable yield" must take the place of "maximum sustainable yield."

As Phil Pister (1977), regional fishery manager for the California Department of Fish and Game stated, "My obligation to provide and perpetuate a diverse and undisturbed invertebrate fauna is as great as it is to provide a creel full of trout; possibly greater, in that biological integrity dictates that I should give preference to endemic fauna. It is extremely important that we set aside a significant portion of the lake resource in as undisturbed a state as possible to provide for the generally unpredictable needs of future generations whose views and philosophies are likely to be completely different from our own."

Reform of high lake fish stocking programs to improve the condition of fisheries and wilderness ecosystems is largely the responsibility of regional fishery managers in each state. Reform necessitates shifting the burden of proof from favoring quantity fisheries to quality fisheries and ecosystem integrity, two compatible goals. As Aldo Leopold states in *A Sand County Almanac* (1966), "A thing is right when it tends to preserve the integrity, stability and beauty of the biotic community. It is wrong otherwise." A revised program would ensure that stocking would cease in lakes with no survey data or having the potential to maintain a self-sustaining fishery. Fishless lakes would not be stocked due to their rarity and value as representative pristine systems for long term scientific monitoring and research, maintaining biological diversity and protecting a prey base reservoir for colonizing lakes depleted by fish. The specific management recommendations that follow are based on management practices and policies currently in use by some fishery management regions in the West.

1) Increase lake survey efforts and discontinue stocking of unsurveyed lakes. Design surveys to obtain fishery and ecological data necessary for: a) long term biotic, human use and environmental monitoring, b) classification of lakes for fishery management purposes into four classes (I. Fishless, II. Self-sustaining [wild and native trout], III. Stockable [suitable and unsuitable habitat subclasses], and IV. Further study [questionable natural reproduction with re-survey after 8-10 year hold on stocking]).

2) Develop cooperative funding and support between state fishery agencies and the U.S. Forest Service for high lake survey work and management plans.

3) Stock only the species of trout indigenous to the drainage basin. Obtain native brood stock from sources as close to the actual lake drainage as possible.

4) Identify watersheds with native trout populations and cease stocking of any lakes located upstream.

5) Lengthen the number of years between stockings to 4-8 years and stagger stocking years within a watershed.

6) Check available lake survey data to identify lakes with naturally reproducing fish populations and suspend stocking in these lakes. Eight to ten years from the last stocking conduct a simple fish survey to determine if the fishery is sustainable without stocking.

7) The rarity of lakes with suitable fish habitat (>2 ha surface area and >3 m max. depth) which remain in a pristine condition in the West makes it imperative that no further stocking of "new" or currently fishless waters occur. As a guideline for management of wilderness lakes, at least 50% of the total number of lakes in the management region or Wilderness Area should remain fishless, including at least 10% of the larger, deeper lakes potentially suitable for a fishery. Consider discontinuing stocking in selected representative lakes to meet this objective.

8) Limit stocking to a list of lakes developed in coordination with the land management agency. Cease irregular stocking of beaver ponds and shallow lakes.

9) Encourage Research Natural Area designation to provide long-term protection of representative pristine lakes and watersheds on National Forest land, particularly areas with no protection by Wilderness designation.

10) Implement restricted bag limits or slot limits on an area-wide basis to maintain quality fisheries in lakes with low natural reproduction or high angling pressure, rather than using more frequent stocking or supplemental stocking of wild populations.

11) Experiment with not stocking over-used lakes to determine if it is an effective means of dispersing use.

12) Educate the public and involve them in high lake survey and planning efforts.

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