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North Cascades National Park High Lakes Fishery Management

Historic, Current, and Proposed Future Management of Sport Fish in High-Elevation Park Lakes

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EXECUTIVE SUMMARY

The National Park Service (NPS) has identified the need for an environmental impact statement (EIS) under the National Environmental Policy Act (NEPA) to develop a new fish management plan for North Cascades National Park (NCNP). The scope of the EIS and resulting fish management plan will include all high-elevation, natural lakes within the park and national recreation areas (NRA). The NPS invited the Washington Department of Fish and Wildlife (WDFW) to act as a cooperating agency in the development of fish management alternatives. The purpose of this document is to provide a summary of historical fish management activities for park waters, detail evolving fish management, outline current management of those fisheries by the state, and propose a management approach for the future that conserves biological integrity, minimizes impacts of fish management on native biota, and maintains sustainable quality fisheries in high lakes of the park.

The majority of high lakes within the current boundaries of the NCNP and NRAs appeared with the recession of the last glaciation, and due to topography, were not naturally colonized by fish. By the early 20th century, federal and county agencies were stocking many wilderness lakes, including high-elevation lakes within the current NCNP boundaries, with brook trout, rainbow trout, and cutthroat trout. By the time the Washington Department of Game was formed in 1933, several lakes within current park boundaries had already received fish introductions and harbored reproducing populations or were stocked periodically. Initially, fish stocking densities for lakes in the North Cascades were variable and high by current standards, and stocking frequencies were irregular since fish ecology in high-elevation lakes was poorly understood and fish management goals were largely undefined. Throughout the 1940's, 50's, and 60's, the high lake fishery resource within current park boundaries continued to expand.

By the time the federal government created NCNP and the Ross and Chelan NRAs in 1968, many lakes within the park boundaries had already been stocked with fish. Many had long fishery histories, and some harbored self-perpetuating populations. The state interpreted testimony from the Congressional hearings and specific provisions of the enabling legislation of NCNP as an endorsement of its historic fish management in the park. Thus, during subsequent decades, the state continued to manage fish within the park despite an independently evolving NPS management direction and subsequent disagreement over the practice of stocking.

A long history of interagency conflict unfolded from the date of the park's inception until the mid- 1980's as the NPS sought to phase out fish stocking and bring waters within its boundaries into compliance with evolving national park policy. This conflict climaxed in 1985 when the NPS and the state signed a Memorandum of Understanding (MOU) nullifying previous agreements, then proceeded to derive contradictory interpretations. Lack of specificity in the agreement led the NPS to conclude they now had the legal right to phase out fish stocking while the state maintained it still operated under a previously agreed-to variance until a new formal fishery management plan was developed. In 1986 the NPS issued a new fish management policy that recognized fishing as a valid recreational pursuit within the park, but maintained that activities related to fishing could not harm the natural integrity of park lakes. The policy also usurped fish management authority from the state and called for an assessment of fish impacts on native biota.

The state would not accept this policy because it excluded the state agency and sport fishing organizations from fish management of park waters. This led to a standoff until political intervention forced the park back into a position of "co-management" with the state, and ultimately resulted in the signing of a supplemental agreement to the earlier MOU. This new agreement, called the Fisheries Management Agreement, recognized the historical fishery as a valid recreational pursuit in the park, and granted power to the state to manage fish in 40 lakes within the north and south units of the park for the next 12 years while the NPS designed and implemented a research program to assess impacts of fish on lake environments. Lakes within the NRA boundaries were not subject to this agreement because fish stocking in the NRA's was not contrary to NPS policy, so the state continued to manage these waters under previous informal park agreements.

In addition to the constraints of the Fisheries Management Agreement, the state also implemented fishery management of park waters as it had within other designated wilderness areas. Only lakes managed prior to wilderness designation were managed for fisheries. Moreover, such waters were only stocked with species present prior to designation with methods used prior to designation. Generally, too, fixed wing stocking methods were only used where other less intrusive methods could not accomplish stocking goals.

In the early 1970's, state fisheries biologists had begun efforts to understand high lake ecology through biological assessment of their stocking efforts. Pioneering studies led to a better understanding of carrying capacity and the need to control trout density. Refinements in stocking methods coincided with these efforts and also contributed to stable programs. As a result, stocking frequency became more regular, and for lakes without fish reproduction, somewhat less frequent. In the next thirty years, stocking densities became consistent as regular stocking programs coalesced around non-reproducing waters based on increased understanding of the response of stocked fish to their forage base. By the early 1980's, some state biologists had developed carefully defined stocking densities and frequencies on a lake-by-lake basis. Others preferred to assign lakes into discrete management classes based on lake productivity and usage. Either way, the policy of not knowingly stocking fish on top of excessively reproducing populations and adopting conservative stocking rates became fairly universal among agency managers.

Future fish management in NCNP will be influenced by research conducted by Oregon State University (OSU) and the US Geological Survey (USGS) from 1989 through 2001 to describe high lake ecology, and demonstrate the impacts of non-native trout on native biota of mountain lakes in the park. The research found that observed densities of larval long-toed salamanders and of large-bodied copepods were significantly reduced by the presence of high densities of reproducing fish. However, effects of low densities of non-reproducing fish were only detectable in small, shallow, relatively warm, productive waters.

The researchers recommended not stocking any lake with total Kjeldahl nitrogen (TKN) > 0.045 mg/L or where water temperatures rise above $12^{o}C$. Should these guidelines be strictly followed, 23 of 27 lakes with fisheries maintained exclusively through stocking would no longer be stocked, and all lakes with reproducing populations would be considered at risk.

Before this approach is considered, some limitations to the research should be addressed including small sample size for high-productivity waters with non-reproducing fish (n = 4), the significant difference in surface area between waters with and without fish that are known to harbor long-toed salamanders, and lack of control for other factors limiting salamander abundance. Moreover, the lack of waters over 10 acres considered in the analysis, makes the extension of some statistical conclusions to the majority of fish-bearing lakes cautionary. Thresholds for where reductions in macroinvertebrate abundance constitute a significant risk to native species and processes in these lakes should also be more clearly defined.

Lingering uncertainty concerning potential risk to organisms outside the scope of research has emerged as an even greater concern with this approach. Researchers cannot assume that the relatively narrow guidelines, proposed to protect vulnerable long-toed salamanders, will maximize protection of taxonomic and ecological diversity throughout park high lakes. Managers cannot ignore the potential for unknown impacts to whole communities of aquatic organisms in larger, deeper, cooler nutrient-limited lakes, and should therefore manage for a diversity of fishless ecosystems. Finally, variable and collection-intensive water quality data should not be used to infer biological conditions when so much research has indicated the need to measure biological conditions as indicators of disturbance.

Despite these concerns, one conclusion of the research appeared robust, and consistent with other studies in Washington high lakes: the significance of fish density and impacts of excessively reproducing populations in high lake ecosystems. Conclusions on the effects of fish density and reproduction could be incorporated into a conceptual model of biological integrity that ensures that nearly pristine alpine ecosystems are not sufficiently disturbed by fish management activity that their species compositions and ecological processes deviate significantly from those expected in the absence of human disturbance. The OSU/USGS research could then be incorporated into the model with other alpine ecosystem research to conserve metapopulation dynamics of long-toed salamanders and other organisms, protect aquatic community structure and processes, and identify critical habitat and lake-specific vulnerability of native biota to fish impacts.

Such a model would consider risk factors for native biota in the context of fish presence, density and reproductive status, which can be ranked along a continuum of disturbance. Lakes in NCNP without any fish history or that have gone fishless for many years would be assumed to constitute nearly pristine ecosystems in the park, worthy of management for natural processes. These should represent a diversity of lake types to maximize protection for the greatest diversity of native biota, studied and unstudied. Based on NCNP research, lakes with low densities of stocked non-reproducing fish would be assumed, in general, to minimally impact the native biota, and be within the fish manager’s ability to control based on monitoring. In lakes with low densities and limited reproduction, fish would generally influence native biota in a manner similar to low densities of non-reproducing fish, but could occupy multiple trophic levels and persist over evolutionary time scales, largely outside the fish manager’s ability to control. Lakes stocked at high densities and frequencies would be within a fish manager’s ability to control, but would exert similar pressures on native biota as high densities of reproducing fish. At the extreme end of the fish impact continuum, the high-density, excessively reproducing populations of fish, non-native to downstream watersheds, would occupy and compete at multiple trophic levels, persist across evolutionary timescales, be outside manger's ability to control without major intervention, and potentially disperse and interact with native species downstream.

Lakes currently holding fish could then be classified into three management categories based on the reproductive status and resulting abundance of the fish inhabiting the lake: 1) lakes with trout populations reproducing at high levels; 2) lakes with trout populations reproducing at low levels; and 3) stocked assemblages of non-reproducing trout. Within these categories any of several management approaches should be pursued based on how fish reproduction influences trout density and how that density interacts with lake-specific risk factors, such as lake depth and size, habitat complexity, elevation, isolation, and presence of sensitive species. In addition to monitoring macroinvertebrate community structure and amphibian populations, growth and condition of fish would also be used as indicators of the biological condition of lake ecosystems. Finally, the potential for supporting quality fishing opportunity should also be considered before stocking fish.

Application of this model by WDFW would initially lead to the continuation of low-risk stocking programs in 14 of 26 lakes where fisheries are currently maintained exclusively through stocking. The majority of lakes dropped from stocking would be waters with marginal fish growing potential or where risk to native biota exists due to isolation. Two historic fish bearing waters have been identified with limited risk factors that could be added to offset losses due to ecological risks in other lakes, bringing the total number of stocked waters to 18. Of 35 waters with reproducing non-native fish populations, two larger, deeper lakes have such limited reproduction that they could be supplemented by stocking; 14 with excessive reproduction could be stocked after fish removal; four could be managed for continued wild production of species native to downstream waters; and four could be considered for density control where removal appears unfeasible; and at least two lakes should be evaluated for continued management of wild non-native fish. Before any fish removal project is implemented, there should be a sound biological basis for the removal. Where wild fish do not pose a significant threat to native biota, they should be allowed to continue to provide wilderness fishing opportunity.

Interagency coordination has been a reality in wilderness fish management since the 1970's. The most recent evidence for this has been WDFW's acceptance of the NPS invitation to participate in the environmental review of high lakes stocking and fish management in the NCNP. Interagency cooperation can lead toward achieving goals of both agencies in the future. The most important objective from an ecological perspective would clearly be the removal of problem populations of fish from impacted lakes rather than categorically terminating stocking programs for the sake of expedience. Continuing to provide angling opportunity through biologically-based stocking of non-reproducing fish at ecologically acceptable densities would reduce within-lake impacts, offer the option to terminate stocking should problems arise, and foster a positive relationship between NPS, WDFW, and the angling community. Ultimately, all stakeholders would benefit from practical, positive relationships, and the success of a future fish management plan will depend upon interagency cooperation.

INTRODUCTION

The North Cascades region extends from central Washington State northward into the Canadian province of British Columbia, and is characterized by such dramatic mountain relief as the El Dorado Complex, the Picket Range, and Mount Shuksan. A wet, temperate climate, dominated by coastal weather patterns characterizes the western slope of the Cascade Range while a dry, continental climate dominates the eastern slopes. These climatic zones give rise to forests dominated by Douglas fir, western red cedar, and hemlock at lower elevations on the west side and ponderosa pine, mixed conifers, and grasslands at lower elevations on the east side. Spruce-fir timberlines, alpine meadows, snowfields, numerous alpine lakes, and dramatic, glacially carved granite peaks and ranges characterize higher elevations.

The North Cascades National Park was designated by Congress in 1968 to include 505,000 acres, extending from the Canadian border southward into Whatcom, Skagit and Chelan counties of Washington State. An additional 179,000 acres of adjacent national recreation area (NRA) land was also designated around the Ross and Chelan Reservoirs. Enabling legislation clearly intended for preservation and protection of natural resources within the park, particularly scenic beauty, for future generations, while legislation for the recreation areas specifically mentioned the importance of providing recreational opportunity, including hunting and fishing. Public testimony prior to the creation of the park underscored the importance of a long-standing high lakes fishery that had been supported primarily through fish stocking since the early 1900's. However, enabling legislation did not mention the high lakes fishery specifically, or what the new park's role would be in perpetuating it.

Park waters support a number of native and introduced fish species in both riverine and lacustrine habitats. The park includes headwater reaches of the Chilliwak, Nooksack, Skagit, and Stehekin Rivers, associated tributaries, and numerous high-elevation wilderness lakes. The majority of high lakes within the current boundaries of the North Cascades National Park (NCNP) and National Recreation Areas (NRAs) appeared with the recession of the last glaciation some 10,000 years ago, and due to topography, were not naturally colonized by fish.

However, native populations of Dolly Varden (*Salvelinus malma*), bull trout (*Salvelinus confluentus*) and rainbow trout (*Oncorynchus mykiss*) inhabit various reaches of the Nooksack, upper Skagit, Cascade, and Baker Rivers and reservoirs within the Ross Lake NRA. Of these species, Dolly Varden are the least common, limited in their distribution to Canyon, Bell, and Wanlick Creeks in the Nooksack basin and Thunder Creek and various tributaries to the upper Skagit above Ross Reservoir. Of these, only the Thunder Creek population exists within park boundaries. Bull trout on the west side are widely distributed in park waters. Natal tributaries supporting bull trout spawning and rearing in the park include Bacon, Goodell, Newhalem, and Marble Creeks and the south fork of the Cascade River in the lower Skagit. In the upper Skagit, bull trout spawn in Big Beaver, Ruby, Lightning, Silver and Roland Creeks as well as tributaries to the upper Skagit above the reservoirs. Numerous other tributaries, including Thornton, Damnation, Lookout, and Sibley Creeks as well as the main-stems of the Skagit and Cascade Rivers provide extensive foraging opportunities for sub-adult and adult bull trout below the hydroelectric projects. Above the dams, bull trout exhibit fluvial and adfluvial life histories, foraging mainly in the reservoirs and rivers systems. Bull trout were also historically present in the Chelan drainage, and intermountain cutthroat trout (*O. clarki lewisi*) populations continue to reside there. Similar species assemblages occur in headwater streams in the park below migratory barriers. Some west side tributaries to the Skagit, including Bacon, Newhalem, and Goodell Creeks, and the Cascade River, support resident and anadromous coastal cutthroat trout (*O. clarki clarki*) and rainbow trout/steelhead (*O. mykiss*), as well as chinook salmon (*O. tshawytscha*), chum salmon (*O. keta*), coho salmon (*O. kisutch*), and pink salmon (*O. gorbuscha*) populations. The Chilliwack River also harbors native bull trout and sockeye salmon (*O. nerka*) populations.

The practice of stocking mountain lakes in the Pacific Northwest with fish began in the late 1800's and continues into the present time. Early stocking was originally practiced in order to turn "barren" waters into a food source for loggers, miners, trappers, settlers, and hunters. During the early 1900's, the US Forest Service, various county governments, and private individuals participated actively in the spread of various fish species including eastern brook trout (*Salvelinus fontinalis*), cutthroat trout, and rainbow trout throughout wilderness areas. In 1933, the state of Washington created the Washington Department of Game (WDG) by public initiative to manage game and freshwater game fish in the state of Washington. Over time, this agency developed and implemented fish stocking programs in Cascade mountain lakes directed at reducing unsanctioned and haphazard stocking efforts and promoting consistent fisheries. During the 20th century, fish introduction and stocking evolved into a method of creating and maintaining fisheries, primarily for sport anglers (Pfeifer et al. 2001).

By the time the federal government created the North Cascade National Park with a north and a south unit and the Ross and Chelan national recreation areas (Figure 1), many lakes within the park boundaries had already been stocked with fish. Several had long fishery histories, and some harbored persistent, self-perpetuating populations (Tables 1, 2 and 3). The requirement of possessing a valid Washington State fishing license was not explicitly included in the enabling legislation of the park and NRAs. However, the Washington Department of Game interpreted requirements in the enabling legislation for NPS consultation with the state on fish and wildlife management and for honoring previously issued licenses along with statements made in Congressional testimony as endorsement of historic fish management by the state in the park. So during subsequent decades, WDG continued to manage fish within the park in spite of an independently evolving NPS management direction and subsequent conflict over the practice of stocking.

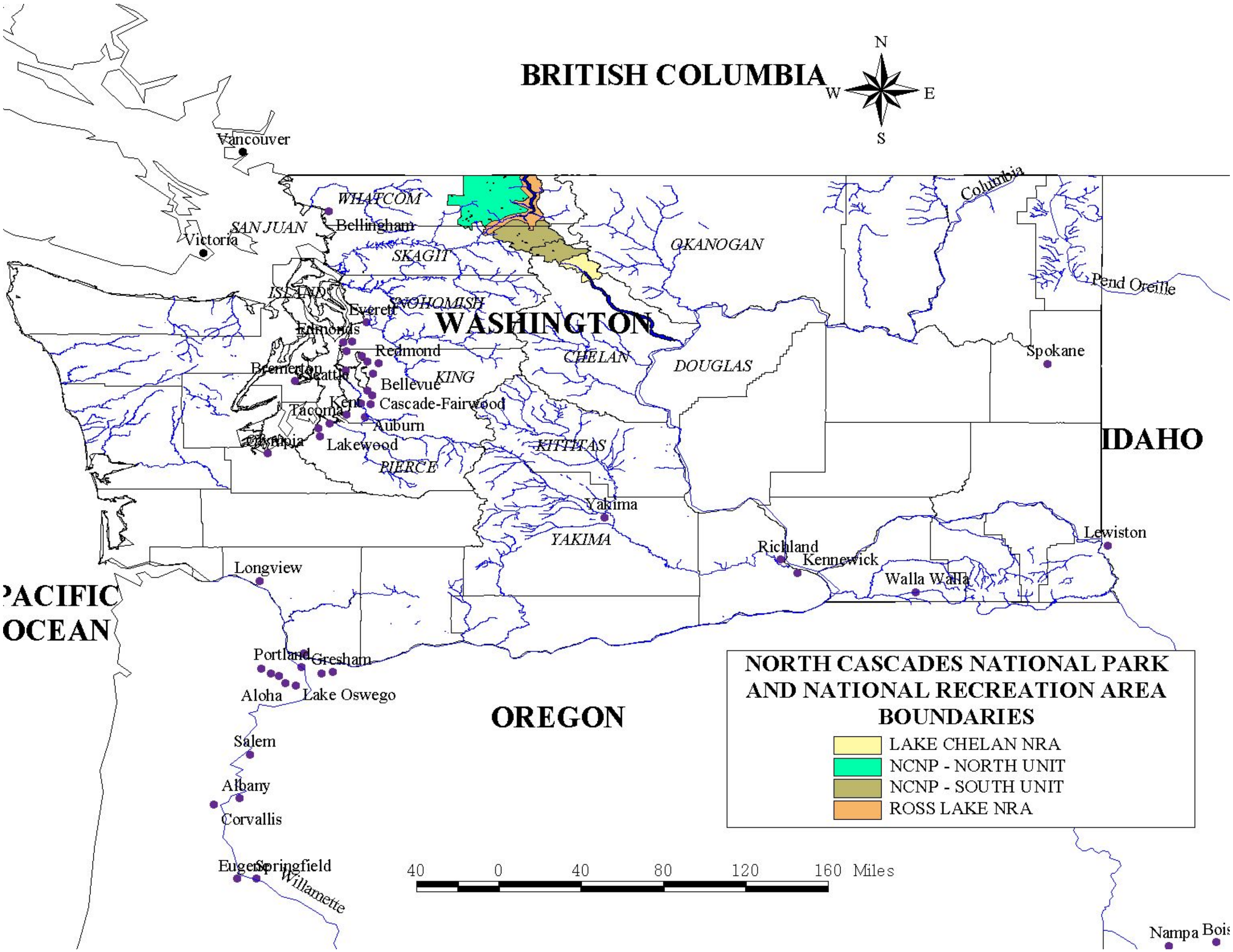
With the passage of time, pressure continued to build, both from within the Park Service and from elements of the public, to terminate fish stocking in the park since fish stocking within national parks had become contrary to new NPS policy derived from the Leopold Report, and due to assumed impacts of non-native fish species on native aquatic biota. During the 1980's a lawsuit brought by the North Cascades Conservation Council led to a consent decree where the NPS agreed to evaluate a number of human activities in the North Cascades National Park, including fish stocking and its impacts on native alpine ecosystems. In 1985 the director of the NPS issued a policy waiver that acknowledged historic fish stocking practices but also called for research concerning the ecological impacts of fish stocking on native biota.

In 1988 the Park Service and the Washington Department of Fish and Wildlife (then Washington Department of Wildlife, formerly Washington Department of Game) signed a Supplemental Agreement to the 1985 Memorandum of Understanding that resulted in a list of 40 lakes where the state would continue to manage fisheries within the north and south units of the park. The new agreement, termed the Fishery Management Agreement, was given a lifespan of 12 years, during which time, NPS was to design and implement a research plan to determine the ecological effects of non-native fish on natural aquatic ecosystems within the park. Most of the waters within the park that already harbored reproductive populations were included in the list of 40 lakes. Waters in the NRAs were not included in this agreement, presumably due to clear differences in enabling legislation of the park verses the recreation areas; general differences in park policies on fish stocking in recreation areas; and less restrictive attitudes toward managing recreational fisheries within recreation areas. Therefore, WDG continued to manage fisheries there in a manner consistent with recent historical practices.

In 1989 the US Geological Survey (USGS) and Oregon State University (OSU) began 12 years of research to demonstrate impacts of non-native fish on native biota. Those research efforts have ended and the National Park Service is preparing to fulfill its obligation under the consent decree to develop an environmental impact statement (EIS) under the National Environmental Policy Act (NEPA), and to use the research to develop a new fish management plan for the park. The scope of the EIS and resulting fishery management plan will include all high-elevation, natural lakes within the north and south units of the park, as well as similar lakes within the national recreation areas. Inclusion of NRA lakes is the result of several court precedents set for other parks determining that recreational activity cannot impair natural resources in park or recreation areas. However, reservoirs and associated pond complexes will not be included. Recognizing the potential benefit of collaborating in the development of a sustainable, long-term fisheries management plan for park lakes, the National Park Service invited the Washington Department of Fish and Wildlife (WDFW) to act as a cooperating agency in the EIS process.

The purpose of this document is to provide a summary of historical fish management activities, outline the current management of fisheries in the North Cascades National Park by WDFW, and propose a management approach for the future that conserves biological integrity, minimizes impacts of fish management on native biota, and maintains sustainable quality fisheries in high lakes of the park. Presentation of historic fish management is intended to demonstrate the evolution of fish management by WDFW in park waters and to serve as context for current and future fish species, stocking numbers and frequencies, regulation, and geographical extent of fisheries in the park and recreation areas. The scope of this report includes fisheries management of historically fishless, high-elevation lakes within the north and south units of the park and within the Ross and Chelan recreation areas, but not that of the rivers, streams, three reservoirs or lower pond complexes associated with tributaries to the reservoirs.

FIGURE 1. Location of North Cascades National Park Units and National Recreation Areas in northern Washington State.



HISTORICAL FISHERIES MANAGEMENT

Historic fish stocking activity and fish management goals

Fish introduction into wilderness lakes of Washington State is thought to have begun with early settlers around 1890. By the early 20th century, federal and county agencies were stocking many wilderness lakes, including some high-elevation lakes, with such species as eastern brook trout (*Salvelinus fontinalis*), and cutthroat trout (Pfeifer et al. 2001). By the time the Washington Department of Game (WDG) was formed by public Initiative in 1933, some lakes within current park boundaries had already received fish introductions and harbored reproducing populations or had been stocked, but were dependent on ongoing, periodic releases for long-term fish presence. Although records of these efforts are rare, some do exist. For example, Coon Lake (Chelan NRA) was stocked with cutthroat trout in 1915 and eastern brook in 1930, and Monogram Lake (NCNP South Unit) was stocked with cutthroat trout in 1932. A number of other lakes, including Blum #4, Green Lake, and Berdeen Lake also received fish prior to 1933, according to testimony of former US Forest Service employees and private individuals involved in those introductions. However, official records of these fish releases do not exist.

The WDG continued stocking practices begun by U. S. Forest Service (USFS) and county governments and worked closely with well-organized user groups, principally the Trail Blazers, Inc., and later, the Washington State Hi-Lakers (Pfeifer et al. 2001). These user groups not only aided in the distribution of fish into wilderness lakes but also provided essential information on fishery performance and kept comprehensive records. For a period beginning in 1915 and extending to the present, WDFW and the Trail Blazers accumulated stocking records for 84 of 561 waters in what is now North Cascades National Park and NRAs that include all state-sanctioned releases of fish into park waters.

From 1915 to 1960, sanctioned stocking ranged from zero to three lakes per year within future park boundaries (Figure 2). In the early 1960’s and during the years surrounding the creation of the park in 1968, stocking activity increased substantially, reaching upwards of 12 to 19 lakes annually. This increase reflected an expansion of the high lake fishery resource driven by growing public interest and the state’s desire to develop and enhance recreational fishing opportunity. Annual numbers of waters stocked during the 1970’s and early 1980’s ranged from five to nine lakes per year amidst strained, informal agreements between the NPS and WDG, then increased again in the mid- and late 1980’s to upwards of 12 to 15 lakes per year during a period of open interagency conflict over fish stocking.

Annual numbers of waters stocked for the first time remained at or below one lake/year from 1915 through 1935, then increased steadily from 1936 to 1946, to a rate of four new lakes/year. Stocking of new lakes then tapered off through the late 1940’s and 1950’s until 1960, when nine new lakes were stocked. This increase coincided with the overall increase in annual stocking activity that ebbed during the mid-1960’s before climbing to an all time high of 13 new lakes/year and 19 waters total, stocked in 1968. After the creation of the park, the stocking of new waters fell to a more or less flat range between zero and three lakes/year until 1994, when stocking of new waters ceased altogether (Figure 3). The cumulative increase in the number of waters receiving first-time stocking or fish introduction increased steadily until 1960, then increased steeply throughout the 1960's, slowing after the creation of the park and falling to zero shortly after the signing of the 1988 Supplemental Agreement to the 1985 Memorandum of Understanding between WDFW and NPS.

Little documentation exists concerning the goals and objectives of early stocking efforts of federal, county, and state agencies. Early on, a number of populations of eastern brook trout, cutthroat trout, and rainbow trout became established in lakes such as Hozomeen, Middle and Lower Blum, Monogram, Berdeen and Rainbow Lakes. In fact, this may have been the intended result since wilderness fish resources during this period were probably considered more as a renewable food source than for sport, and since the logistics of stocking was more difficult. Natural reproduction would also have provided greater consistency for early fisheries. Moreover, the performance of reproducing fish in high lake environments was poorly understood until after several populations had existed for multiple generations so the effects of excessive reproduction on the size and condition of fish was probably not known.

By the 1940's and 50's, fishery management goals had shifted toward providing recreation and in the 1970's and 1980's, management goals for wilderness and high lakes had begun to emphasize "quality" fishing opportunity by maximizing growth rates in fish while still fulfilling a reasonable expectation of catching fish in an aesthetic, untrammeled wilderness setting. During this period it became clear that fishery managers had to control trout density in order to balance fish growth and condition with the available forage base and overall productivity of the lake (Pfeifer et al. 2001).

Historic fish species, stocks, and strains

While the earliest stocking records exist for east side lakes, the majority of lake stocking activity in what is now the NCNP has occurred on the west side of the Cascade divide (Figure 4). This trend is largely a reflection of the fact that most of the lakes in the park are on the west side of the Cascade crest. Species composition of stocking activities on the west side included a few introductions of eastern brook trout in the first half of the 20th century, but was dominated by intermountain cutthroat trout, and to a lesser extent, rainbow trout throughout most of the century (Figure 5). Species composition for stocking programs on the east side of the Cascade Mountains was similar, though intermountain cutthroat trout (*O. clarki lewisi*) were even more dominant throughout most of the 20th century (Figure 6).

The earliest importation of eastern brook trout appears to have come from Pennsylvania around the turn of the last century (Crawford 1979). However, local populations became readily established and provided convenient sources for the majority of subsequent stocking efforts. Prior to the 1980's few records were kept on the sub-species or strains of fish used. Most stocking records listed generically as *Oncorhynchus clarki* were likely intermountain or Yellowstone cutthroat (*O. clarki bouvieri*). Washington State's domesticated rainbow stocks were mainly of California's McCloud River origin with some importation of fish from the Kamloops region of British Columbia, Canada (Crawford 1979).

The dominant use of intermountain cutthroat trout for stocking was largely the result of this species' propensity for survival and growth in high lake environments, as well as a later spawn-timing that resulted in fish small enough to pack or fly into high-elevation lakes after they became ice-free in July and August. These characteristics of intermountain cutthroat led to the development of a lake-run brood stock at Twin Lakes, Chelan County, Washington that continues to produce fish for use in some eastern Washington high lakes. Unfortunately, intermountain cutthroat trout adaptability to alpine lake environments, possible selection for shore-spawning behavior through lake-run brood stock management, and perhaps climate change have also enabled them to reproduce readily in many high lake environments where they were stocked (Pfeifer et al. 2001). Similarly to eastern brook trout, some intermountain cutthroat trout introductions resulted in over-abundance and poor growth over time, often due to this sub-species ability to spawn readily over groundwater intrusions along shorelines, then cumulatively outstrip and suppress limited forage bases, characteristic of high lake environments, over time.

Beginning in 1960, golden trout (*Oncorhynchus mykiss aguabonita* Behnke 1992) were stocked into a few lakes within the future boundaries of North Cascades National Park, mainly on the west side. This exotic sub-species of rainbow trout originated in California and has been stocked widely throughout the western United States. It has tended not to reproduce excessively nor disperse downstream in Washington State waters, and its performance in high lakes of Washington has led to it becoming one of the most sought-after species in the state's wilderness lakes.

Around 1990, a shift occurred in the North Cascades toward stocking fish species native to the watershed within which managed lakes drained, particularly where non-native species such as eastern brook trout or cutthroat trout had the potential to disperse downstream and interact with native fish populations. By 1991, rainbow trout and coastal cutthroat trout had become the dominant species stocked into west side waters. Chilling coastal cutthroat trout eggs during incubation at the hatchery and delaying hatching until late spring facilitated this change. Intermountain cutthroat continued to dominate stocking programs for the park lakes east of the Cascade crest throughout most of the twentieth century until about 1990, when they were largely replaced with non-reproducing Mt. Whitney rainbow trout, reflecting yet another shift toward favoring non-reproducing fish above even native species with strong reproductive potential.

The shift to rainbow trout occurred on both sides of the Cascade crest because of an apparent inability of the Mt. Whitney rainbow trout brood stock, used in high lakes since the 1970's, to reproduce in high lakes. This strain supported the emerging fish management strategy of controlling trout density in high lakes. Although widely used in high-elevation and wilderness lakes throughout the state, no reproducing populations have been documented (Pfeifer et al. 2001).

Historic stocking densities and frequencies

Fish stocking densities for lakes in the North Cascades were variable and high by current standards (Figure 7) and stocking frequencies were irregular (Figure 8). Early fisheries managers had little understanding of alpine lake productivity and carrying capacity, or the erratic nature of harvest rates in wilderness lakes. Generally, fish stocking density and frequency are related to the balance between fish survival and growth and annual mortality, including angling harvest. However, early stocking efforts did not benefit from extensive knowledge of such factors. It was not uncommon for stocking densities to reach upwards of 1,000 fish/acre for some waters. During the 1930's, 40's and 50's stocking rates ranged from 100 to 1,200 fish/acre and averaged about 500 fish/acre, and exhibited a declining trend over time. In the last twenty years, stocking densities have become more consistent at between 50 and 60 fish/acre since regular stocking programs coalesced around non-reproducing waters with increased understanding of the response of stocked fish to their forage base.

Erratic early fish stocking frequencies were often a reflection of undefined fish management goals and challenging logistics. Some stocking was haphazard or opportunistic. In some lakes the first stocking constituted an introduction where persistent reproducing populations were founded. In a number of cases where stocking frequencies were greater than ten years, reproductive populations had been founded, but new species were being stocked or reproductive success was unknown. If reproduction was limited or unsuccessful, then stocking frequency might hover near the lifespan of the fish but was more likely to occur on an annual basis, access permitting. A general trend of increasing stocking intervals appears for lakes under regular stocking programs (Figure 9). Continued stocking of waters with established reproducing populations was common throughout the early history of fish stocking in park waters, but after 1985, only in waters with limited reproduction or extensive pelagic zones were stocked, and only with non-reproducing fish. Trends in stocking intervals for lakes with reproducing fish were similar to those for non-reproducing waters (Figure 10).

In the early 1970's, WDG fisheries biologists began a concerted effort to understand high lake ecology through biological assessment of their stocking efforts. Pioneering studies of fish in Washington State high lakes by Johnston, Pfeifer, Williams and others led to a better understanding of carrying capacity and the need to control trout density. Refinements in stocking methods coincided with these efforts and also contributed to consistent programs. As a result, stocking densities declined and frequencies became more regular, and less frequent (Pfeifer et al. 2001). By the early 1980's, some WDG biologists had developed carefully defined stocking densities and frequencies on a lake-by-lake basis. Others preferred to assign lakes into discrete management classes based on lake productivity and usage. Either way, the policy of not knowingly stocking fish on top of excessively reproducing populations and adopting conservative stocking rates became fairly universal among agency managers (Pfeifer et al. 2001).

Resulting geographic distributions of fish

Historic fish stocking and founded fish populations in North Cascades National Park affected a wide diversity of aquatic ecosystem types with respect to surface area, depth, shoreline complexity and elevation, as well as geographic distribution. Examination of the 2003 NCNP geographic information system (GIS) statistics for polygons representing lakes yielded estimates of acreage and lineal shoreline distances for waters with various fish conditions within the park (Table 1). Mindful that the numbers and locations of smaller waters are not entirely static due to the discovery or formation of new ponds and errors in typing land cover from aerial photos, this was the most current version of such data. Acreages were estimated for waters whose locations were only identified with points as the smallest water visible on the 1:12,000 quadrangle, the majority of which were without fish histories.

Of 561 identified lakes and ponds within the NCNP, 84 have recorded stocking histories, 9 waters have fish presumed to be native, and 35 waters have naturally reproducing populations of introduced fish, 12 of which were established through undocumented introductions (Table 1, Appendix B). While 456 (81.3% by number) waters within the park are without any known fish history, these represent only 707.5 surface acres (31.8% by surface area). The 35 waters with introduced populations represent only 6.2% of park waters by number but 40.6% by surface area, reflecting the preponderance of larger waters that currently hold fish. Of 105 lakes with some fish history, 34 (6.1% by number and 17.2% by surface area) have reverted to a fishless state according to current WDFW and NPS lake survey data.

The WDFW currently manages waters within the park where fish and fishing opportunity exist, including native and wild fish populations where fishing regulation may be necessary, in addition to waters stocked for fishery enhancement. Waters in the park currently stocked, either as the sole means of fishery support or for enhancement where natural reproduction is low, total 40 and include 533.3 surface acres (7.1% by number and 23.9% by surface area). Total waters managed for fisheries number 65 (11.6% by number) and include 1,122.9 surface acres (50.4% by surface area).

Most of the 561 lakes and ponds are less than one acre with 166 being greater than one acre, 74 greater than 5 acres, 57 greater than 10 acres, and 12 greater than 50 acres. The vast majority of historically fishless waters by number are small (median surface area = 0.2 acres), shallow (median depth = 3.3 feet) waters ranging widely in altitude from 925 ft msl to 7,100 ft msl (Table 2). Despite their small size and lack of carrying capacity for fish, such waters provide critical habitat and geographic distribution for native amphibians and macroinvertebrates. Park waters with stocking histories, with naturally reproducing populations, and with stocking or mixed management programs tend to be considerably larger with median surface areas of 5.9, 9.4, 5.6, and 12.9 surface acres, respectively, and include all but two lakes over 50 acres in the park.

Graphic histogram analysis for waters of various fish status reinforces this point, but also reveals a number of fishless waters of different lakes classes by size (Figure 11). Though larger lakes are relatively few in the park and several currently harbor fish, Moraine and Price Lakes have remained historically fishless and Silver, Azure, and Pegasus Lakes held fish only briefly and are now fishless. Plotting surface area against elevation for lakes with various fish conditions reveals some variability for the lake types as categorized by these two parameters (Figure 12). One larger lake, Hozomeen, stands out with respect to elevation and represents a unique lake type due to its lower elevation (2,823 ft msl), size (97.4 acres) and overall productivity.

These data, when linked to WDFW stocking records not only yield estimates of the percentage of waters by surface area and lineal shoreline distance with given fish population and management characteristics, but also allow for examination of the spatial distribution of these waters (Figure 13). Generally, the distribution of fish stocking activities and the founding of populations correlates with the locations of larger waters.

Historic introductions resulted in 35 founded wild populations distributed throughout what is now North Cascades National Park (Figure 14). Intermountain cutthroat trout are the most widely distributed reproducing species, but several reproducing populations of rainbow trout and eastern brook trout also persist (Table 3). On the west side of the Cascade crest, intermountain cutthroat and eastern brook trout have been found in a few fish-bearing waters downstream, where they are not native, and have the potential to interact with native coastal cutthroat and char populations. Conversely, on the east side, rainbow trout may interact adversely with native intermountain cutthroat trout. Some of these lakes represent a dilemma for current fish managers. Intermountain cutthroat trout are occasionally observed in heavily surveyed tributaries to the Skagit, including Bacon Creek but no evidence has been found of established populations in any of the lower Skagit tributaries where bull trout are currently monitored. Eastern brook are limited in distribution to park waters in the upper Skagit basin, and are abundant in some tributaries to Ross and Diablo Reservoirs, including Hozomeen, Big Beaver, and Thunder Creeks. How these fish interact with fairly robust native char populations above the hydroelectric projects should receive closer examination. Despite a century of sympatry, bull trout populations in the upper Skagit appear healthy, suggesting interactions may be mediated by differences in spawning locations and timing due possibly to water temperature. Evidence does exist, however, for some degree of hybridization of rainbow trout with native intermountain cutthroat trout in the Stehekin drainage.

TABLE 1. Waters in various categories of fish history or fish management in the North Cascades National Park by number, surface area, and linear shoreline distance.

NCNP Waters	Number	Percent	SA (Acres)	Percent	P (km)	Percent
w/o fish history	456	81.3	707.5	31.8	94.1	52.1
with native fish	9	1.6	19.8	0.9	2.8	1.5
with undocumented fish intros	12	2.1	132.1	5.9	7.4	4.1
with stocking histories	84	15.0	1368.8	61.4	76.1	42.1
Total	561		2228.3		180.3	
Waters with fish reproduction	35	6.2	905.2	40.6	43.1	23.8
Fish in past	34	6.1	382.5	17.2	21.5	11.9
MOU Waters						
fishery supported by stocking	16	2.9	160.4	7.2	12.7	7.0
fishery supported by stocking and repro	11	2.0	302.7	13.6	15.3	8.5
fishery supported by wild population	13	2.3	429.0	19.3	17.2	9.6
NRA Waters						
fishery supported by stocking	11	2.0	57.1	2.6	6.4	3.5
fishery supported by stocking and repro	2	0.4	13.1	0.6	1.6	0.9
fishery supported by wild population	12	2.1	160.6	7.2	9.9	5.5
Total actively managed for fisheries	65	11.6	1122.9	50.4	63.1	35.0
total stocked for fisheries	40	7.1	533.3	23.9	36.0	20.0

TABLE 2. Morphometric medians, minima, and maxima for surface area, depth, and altitudes of waters in the North Cascades National Park in various categories of fish history or fish management.

	Surface area (acres)				Depth (ft)				Altitude (ft)			
Waters	median	min	max	n	median	min	max	n	median	min	max	n
w/o fish history	0.2	0.01	83.2	456	3.3	1.0	14.1	19	5020	925	7100	395
with native fish	0.6	0.01	13.5	9	ND	ND	ND	3	1663	1613	2625	9
with undocumented fish intros	0.9	0.01	97.4	12	22.0	2.2	62.3	4	5030	2823	6260	12
with stocking histories	5.9	0.20	162.2	84	26.7	3.3	258.2	42	5128	1350	6795	84
Waters with fish reproduction	9.4	0.47	147.2	39	19.5	1.2	258.0	32	4970	1350	6551	39
with fish in past	2.4	0.01	162.2	34	18.0	3.3	521.7	17	5240	2630	6763	34
Waters												
MOU fisheries supported by stocking	5.6	1.39	55.1	16	41.4	8.2	104.3	8	4967	3685	6795	16
MOU fisheries supported by reproduction	9.9	0.96	147.2	13	56.6	13.0	153.0	6	4940	3951	5795	13
MOU lakes under mixed mgmt	12.9	0.50	126.7	11	107.0	18.9	215.0	5	5000	4220	5733	11
currently stocked in NRAs	3.5	0.54	16.9	11	24.6	9.8	35.1	5	5900	2172	6495	11
managed for wild in NRAs	2.7	1.86	97.4	12	28.6	6.6	89.2	8	4679	1613	6551	5
NRA lakes under mixed mgmt	6.5	6.29	6.8	2	17.5	7.9	27.1	2	3345	1350	5340	2

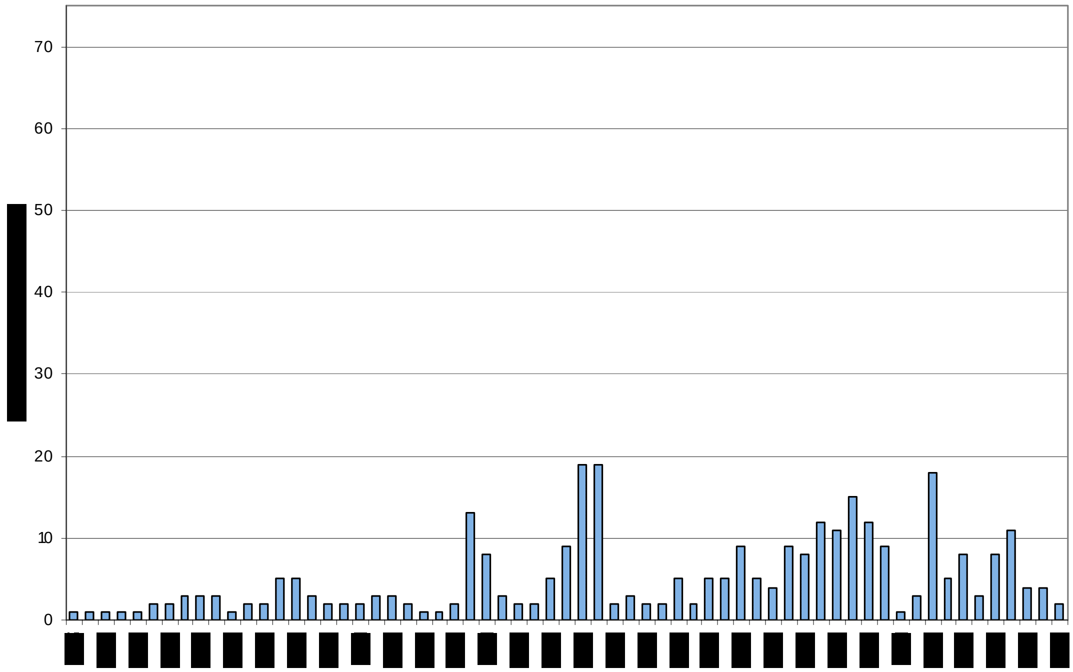


FIGURE 2. Annual number of lakes stocked with fish out of 561 lakes and ponds in the North Cascades National Park.

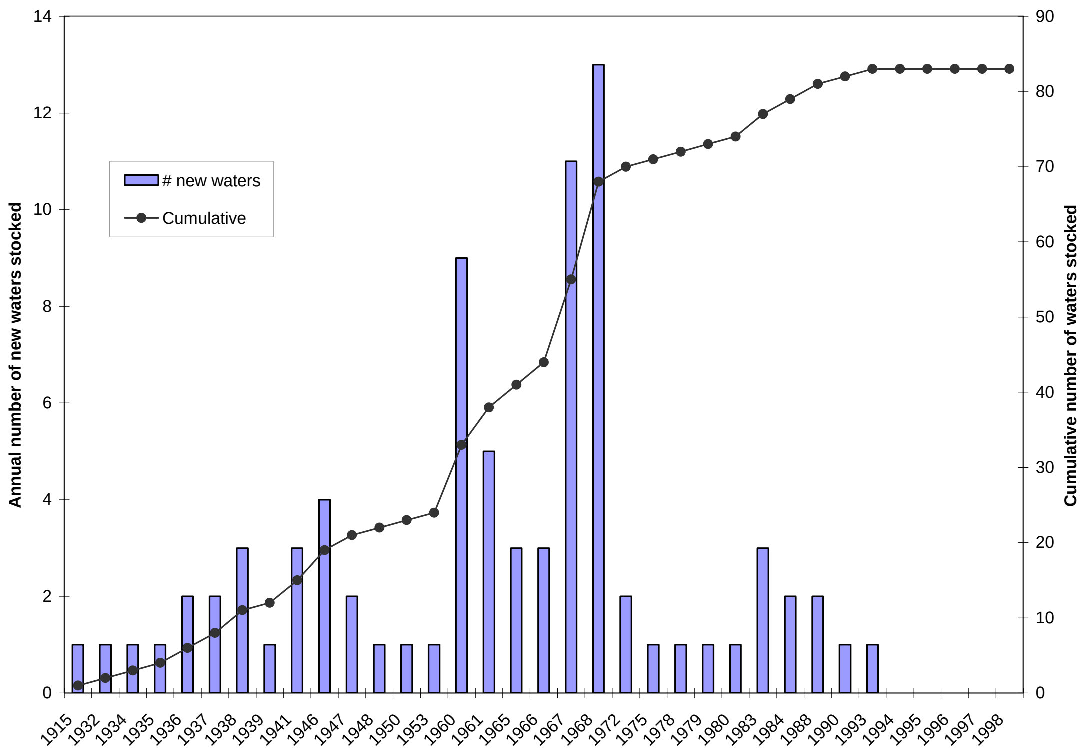


FIGURE 3. Number of waters receiving fish stockings or introductions for the first time in North Cascades National Park.

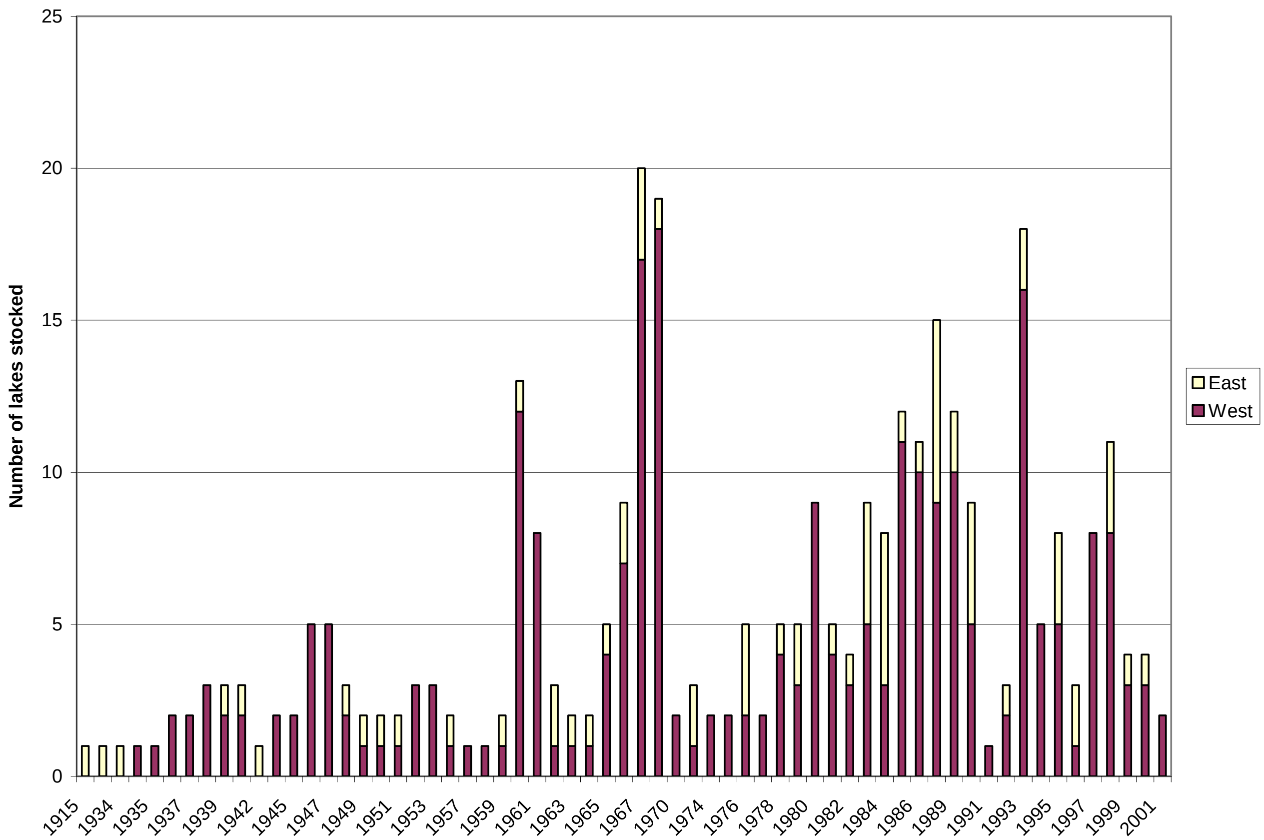


FIGURE 4. Distribution through time and by geographic region of annual fish stocking efforts in the North Cascades National Park.

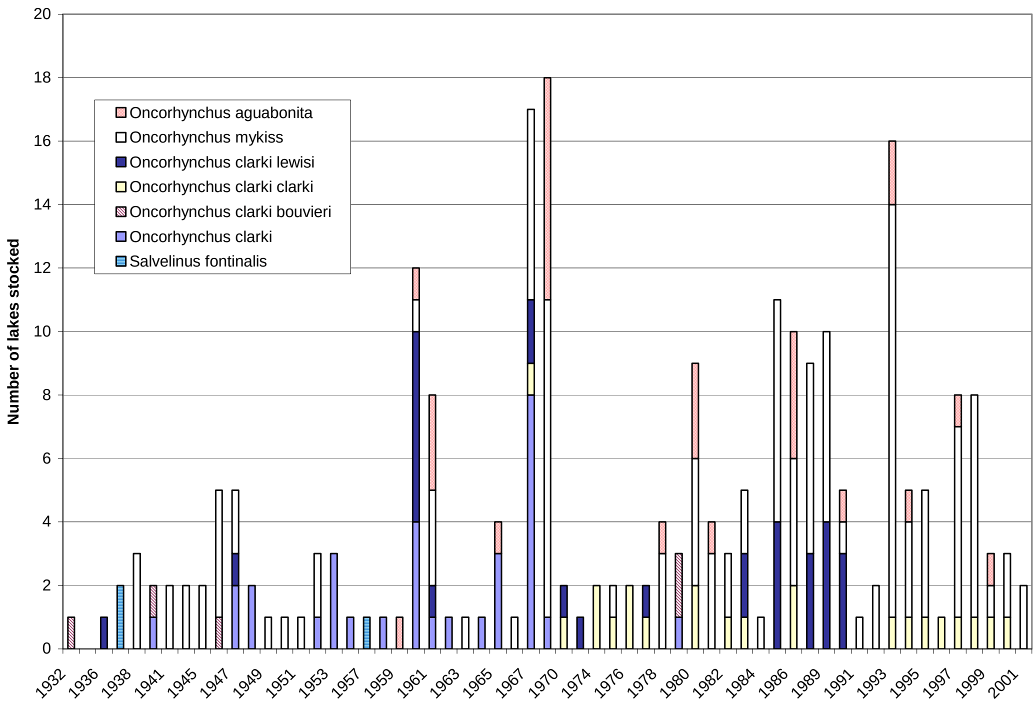


FIGURE 5. Distribution through time and species composition of lake stocking efforts in the western region of North Cascades National Park.

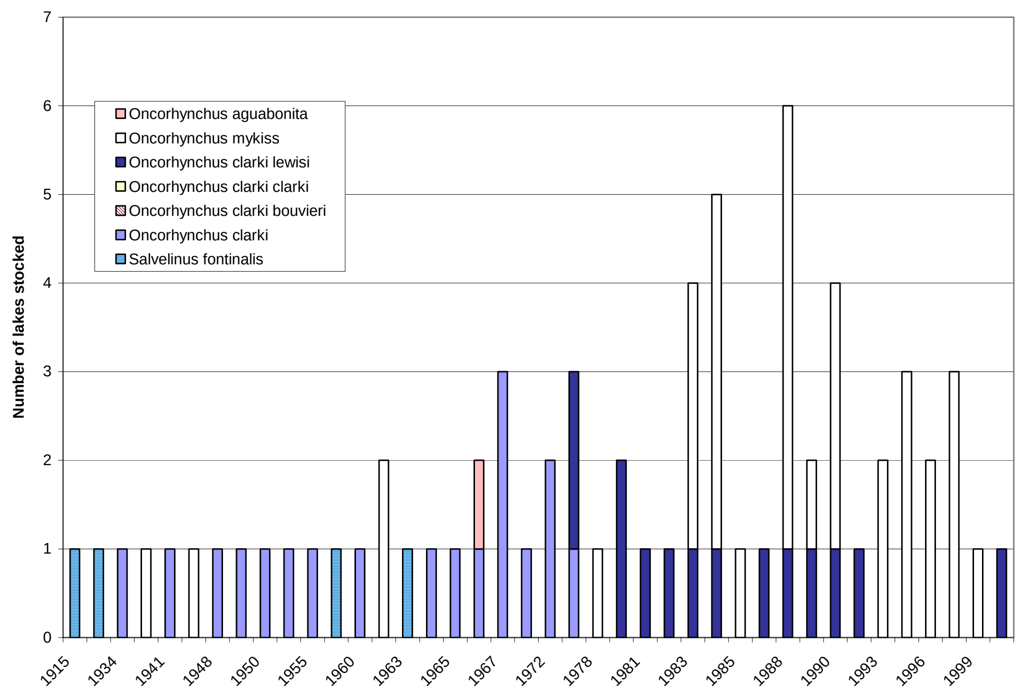


FIGURE 6. Distribution through time and species composition of lake stocking efforts in the eastern region of North Cascades National Park.

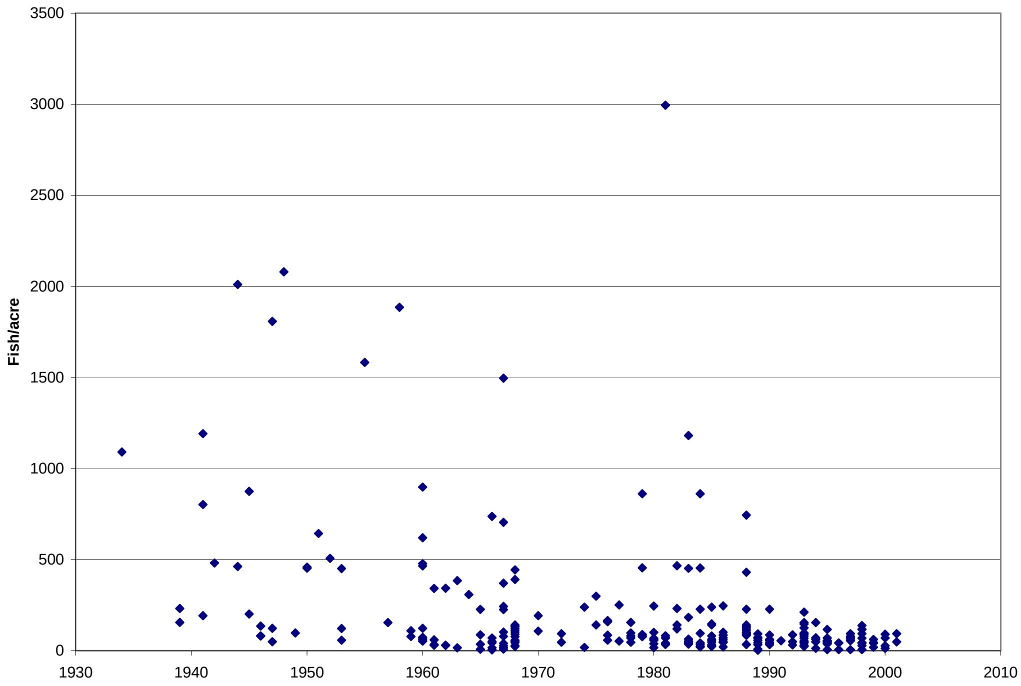


FIGURE 7. Fish stocking densities through time for lakes and ponds in the North Cascades National Park.

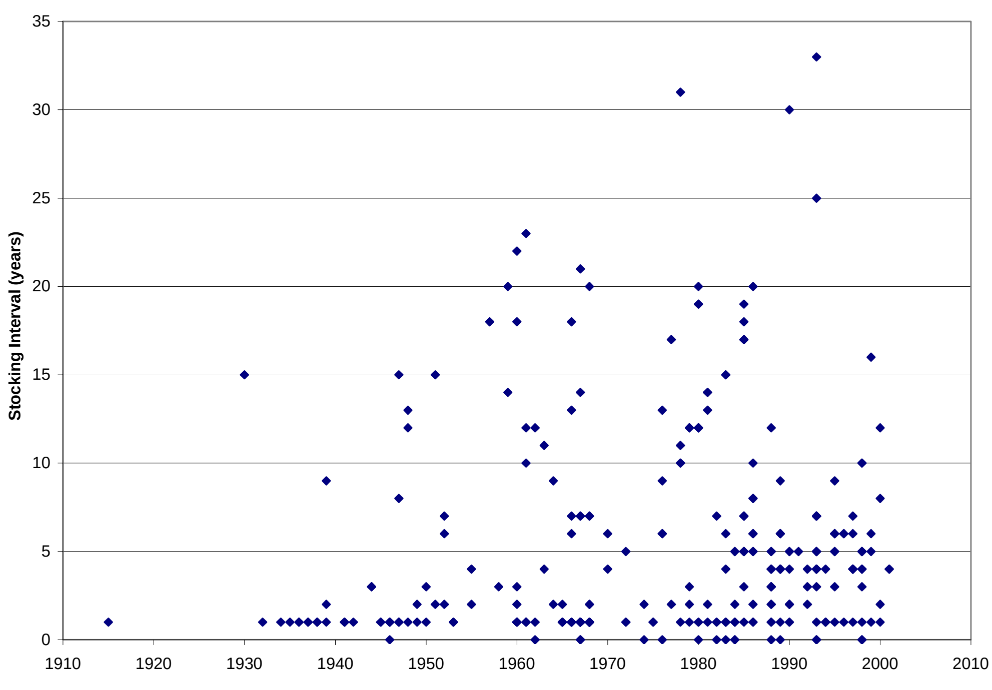


FIGURE 8. Fish stocking frequencies through time all recorded stocking events in lakes and ponds in the North Cascades National Park**.**

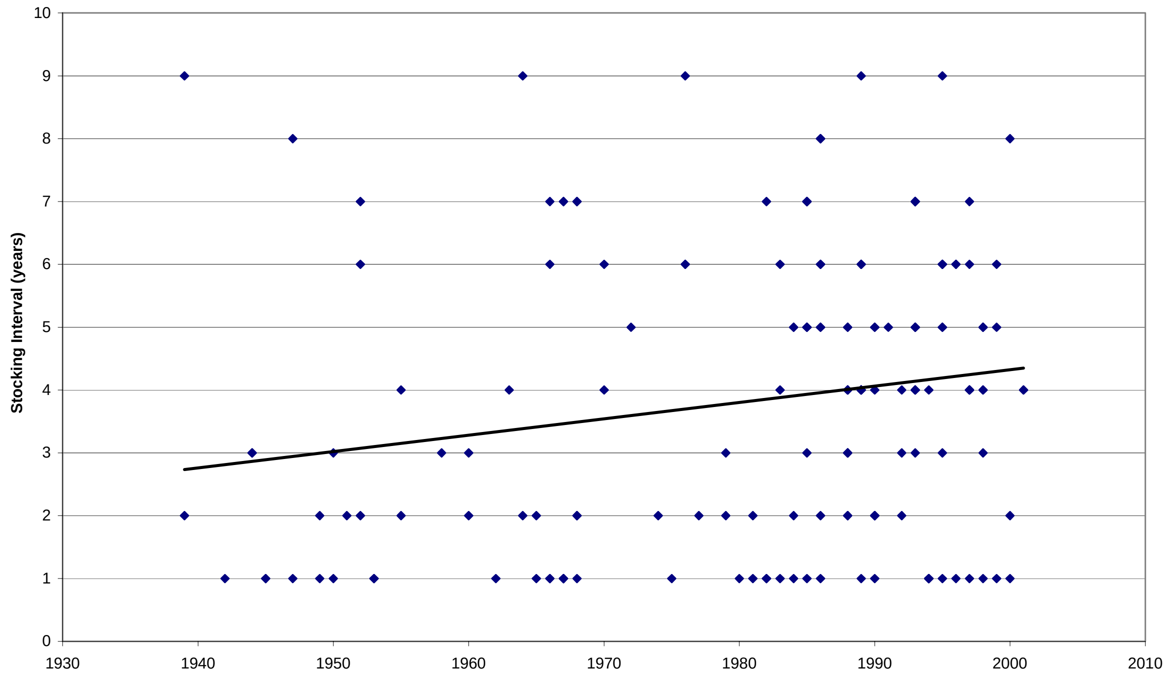


FIGURE 9. Fish stocking frequencies through time for lakes and ponds under regular stocking cycles (< 10 years) in the North Cascades National Park.

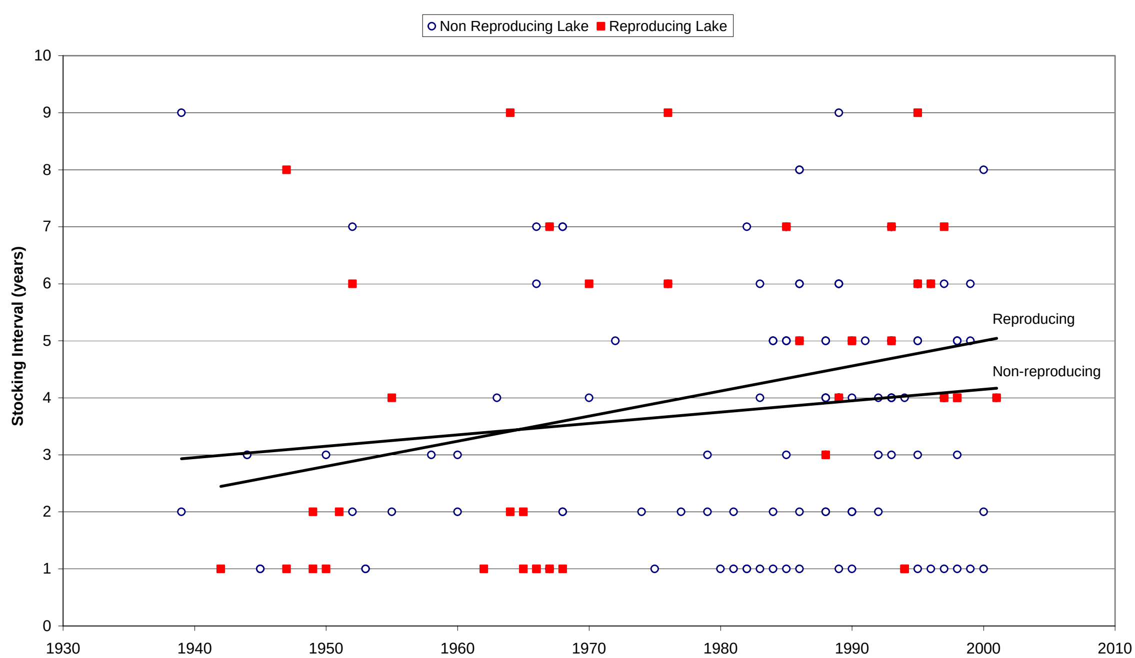


FIGURE 10. Fish stocking frequencies through time by reproductive status of lakes and ponds under regular stocking cycles (< 10 years) in the North Cascades National Park.

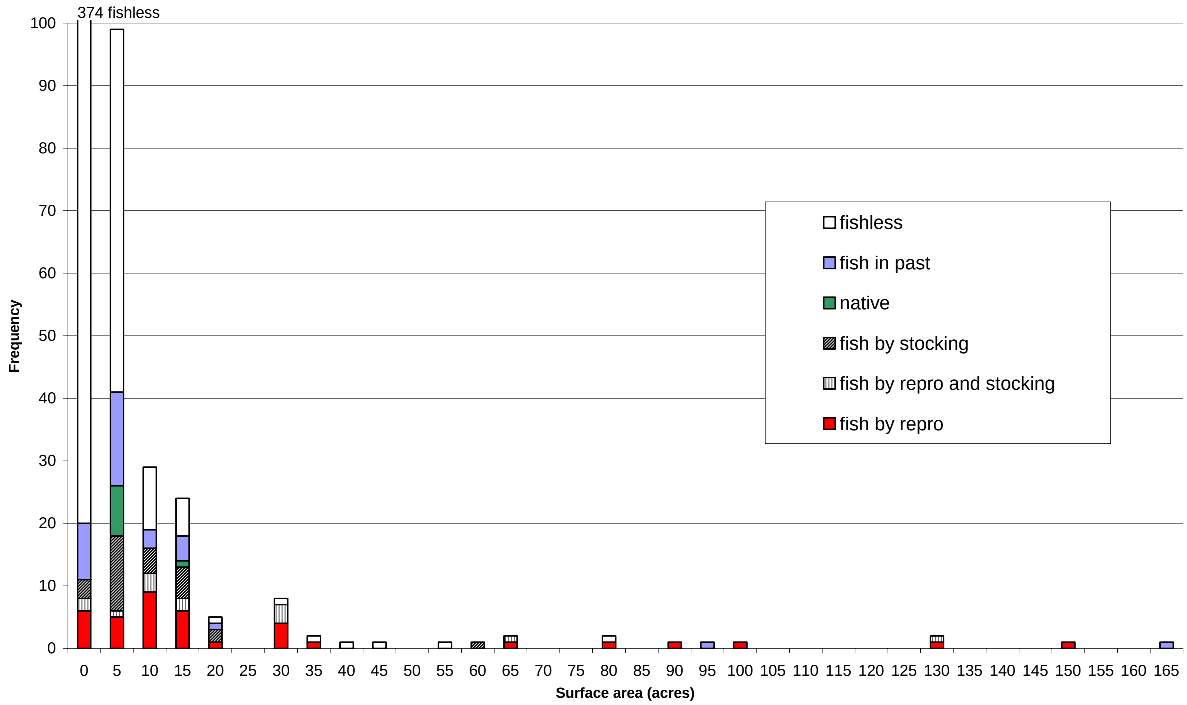


FIGURE 11. Frequency by surface area of North Cascades National Park and National Recreation Area lakes based on fish history or fish management status.

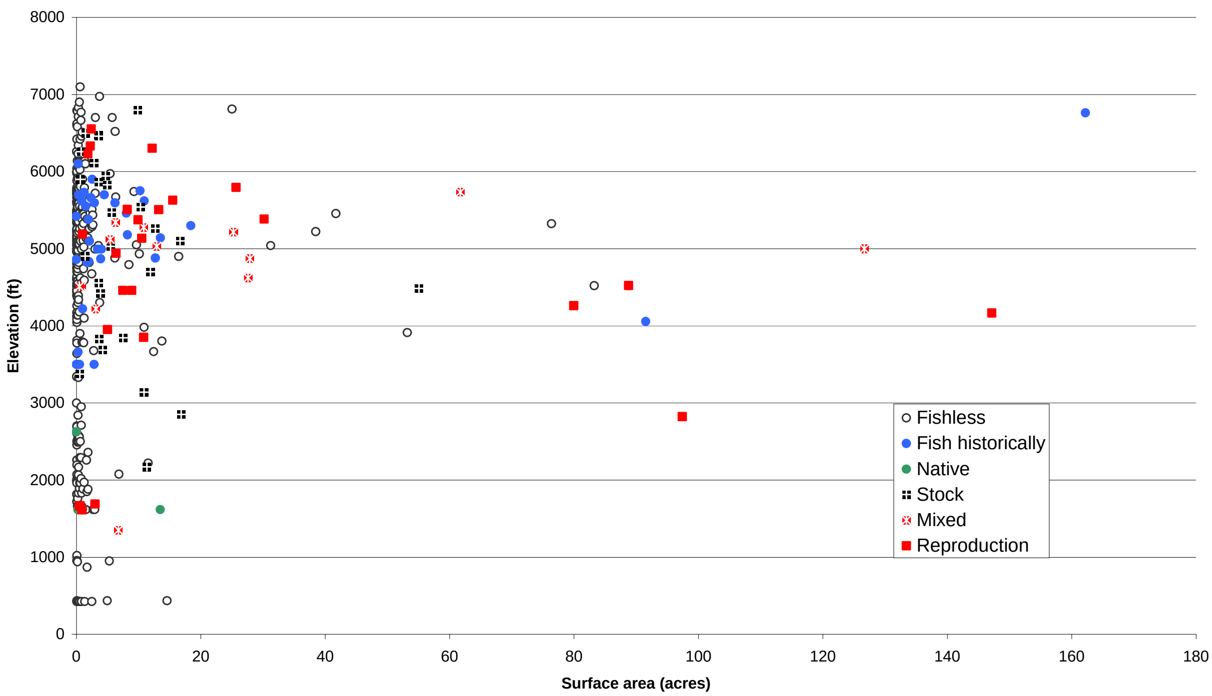


FIGURE 12. Surface area of lakes in the North Cascades National Park and National Recreation Area plotted against elevation based on fish history or fish management status.

FIGURE 13. Geographic distribution and fish history status of lakes and ponds in the North Cascades National Park.

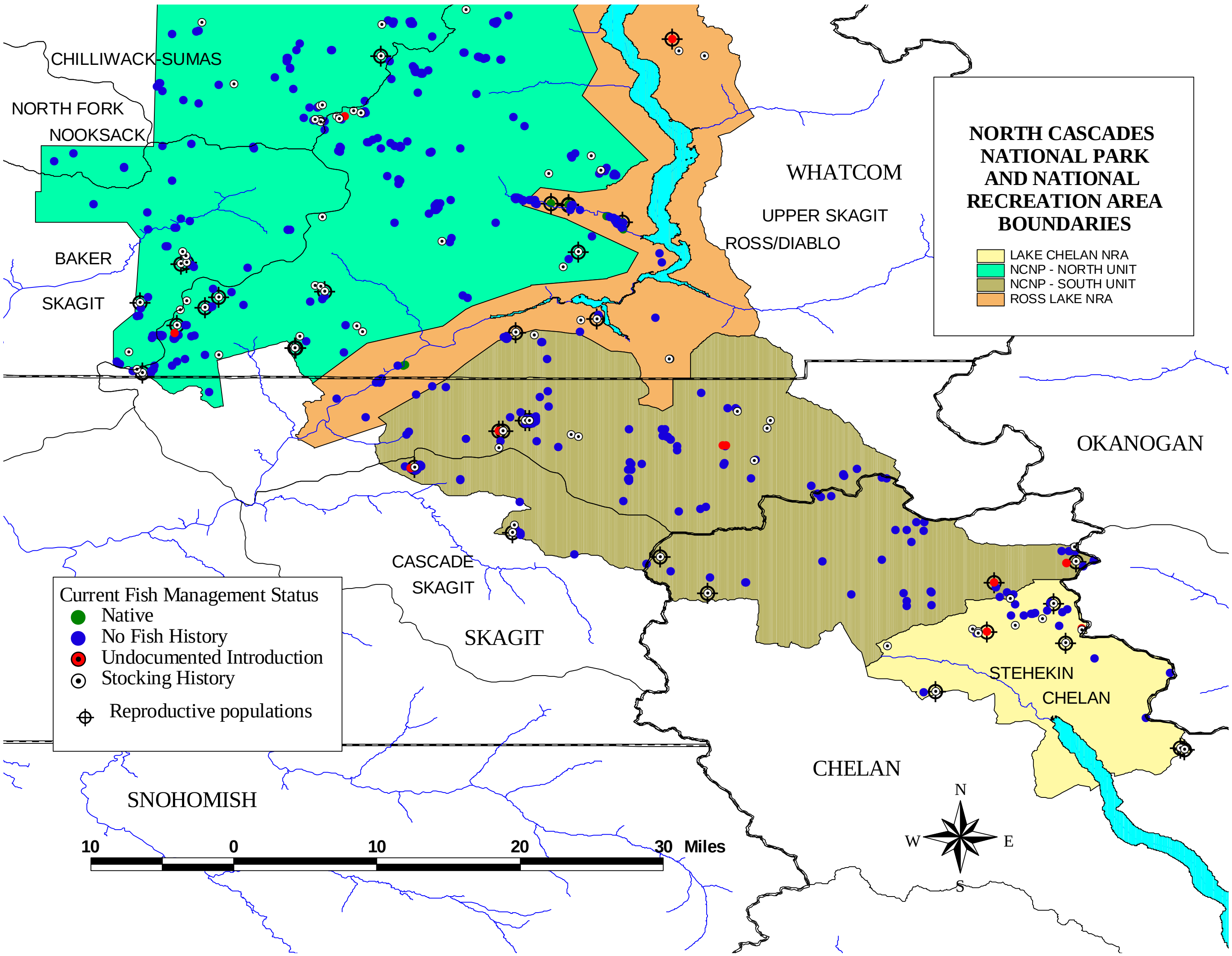


FIGURE 14. Geographic distribution and species composition of lakes in the North Cascades National Park with naturally reproducing non-native fish, excluding the reservoirs.

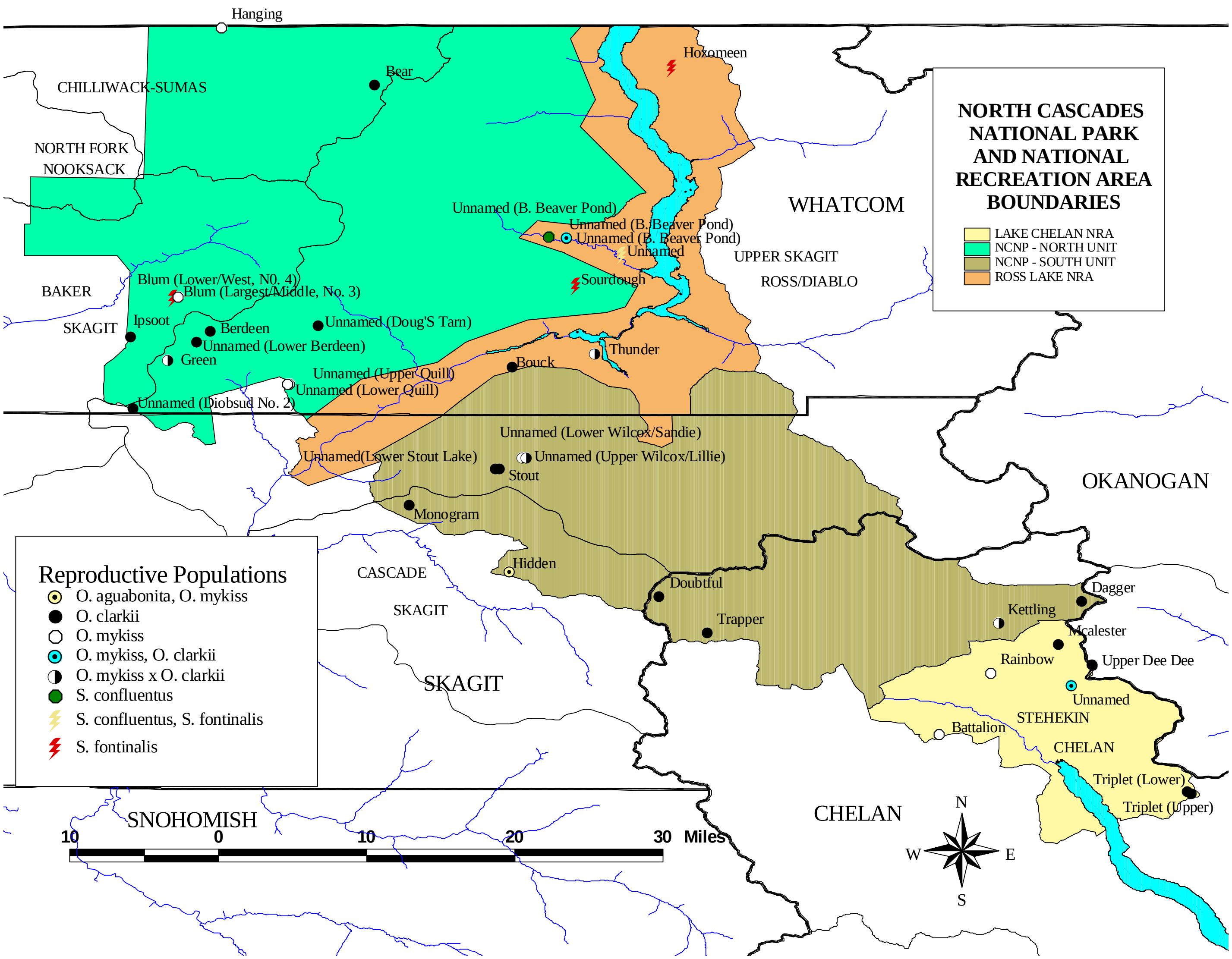


TABLE 3. Physical and biological data for lakes in the North Cascades National Park with naturally reproducing non-native fish.

NPScode	Official Water Name	Drainage	Side	MSL	Acres	Unit	MOU	SP	ASOF
CP-01-01	Doubtful	Stehekin	E	5385	30.2	South	Y	OC	1995
GM-01-01	Trapper	Stehekin	E	4165	147.2	South	Y	OC	1999
MLY-02-01	Battalion	Stehekin	E	5340	6.3	CNRA	N	OM	1991
MR-04-01	Dagger	Stehekin	E	5508	8.2	South	Y	OC	1997
MR-05-01	Kettling	Stehekin	E	5375	9.9	South	Y	OMxOC	1997
MR-10-01	McAlester	Stehekin	E	5507	13.2	CNRA	N	OC	1997
MR-14-01	Rainbow	Stehekin	E	5630	15.5	CNRA	N	OM	1997
MR-15-01	Upper Dee Dee	Stehekin	E	6303	12.1	CNRA	N	OC	2002
MR-16-01	Unnamed	Stehekin	E	6230	1.9	CNRA	N	OM,OC	1997
SM-02-01	Triplet (Lower)	Stehekin	E	6331	2.2	CNRA	N	OC	1997
SM-02-02	Triplet (Upper)	Stehekin	E	6551	2.4	CNRA	N	OC	1997
DD-04-01	Bouck	Skagit	W	3850	10.8	RNRA	N	OC	1999
EP-05-01	Unnamed (Lower Wilcox)	Skagit	W	5120	5.4	South	Y	OMxOC	
EP-06-01	Unnamed (Upper Wilcox)	Skagit	W	5136	10.5	South	Y	OMxOC	
EP-09-01	Stout	Skagit	W	5215	25.2	South	Y	OC	1988
EP-09-02	Unnamed(Lower Stout Lk)	Skagit	W	5190	1.0	South	Y	OC	1988
HM-02-01	Hozomeen	Ross Lk	W	2823	97.4	RNRA	N	SF	1979
LS-02-01	Unnamed (Diobsud No. 2)	Skagit	W	4220	3.1	North	Y	OC	1997
LS-06-01	Ipsoot	Baker	W	4460	8.9	North	Y	OC	1977
LS-07-01	Blum (Lower/West, N0. 4)	Baker	W	4940	6.4	North	Y	SF	1999
M-04-01	Green	Skagit	W	4261	80.0	North	Y	OMxOC	1977
M-07-01	Unnamed (Lower Berdeen)	Skagit	W	4460	7.5	North	Y	OC	1983
M-08-01	Berdeen	Skagit	W	5000	126.7	North	Y	OC	1995
M-11-01	Blum (Largest/Middle, #3)	Baker	W	5030	12.9	North	Y	OM	1994
M-20-01	Lower Thornton	Skagit	W	4486	55.1	North	Y	OCC	1990
M-21-01	Unnamed (Doug’s Tarn)	Skagit	W	3951	5.0	South	Y	OC	1986
M-23-01	Monogram	Skagit	W	4873	27.9	South	Y	OC	1998
M-24-01	Unnamed (Upper Quill)	Skagit	W	4510	0.9	South	Y	OM	2002
M-24-02	Unnamed (Lower Quill)	Skagit	W	4510	0.5	South	Y	OM	2002
MC-08-01	Hanging	Chilliwack	W	4522	88.8	North	Y	OM	1983
MC-12-01	Bear	Chilliwack	W	5795	25.7	South	Y	OC	1982
PM-08-01	Skymo	Ross Lk	W	5277	10.8	North	Y	OC	
PM-12-01	Sourdough	Ross Lk	W	4622	27.6	North	Y	SF	1998
RD-02-01	Thunder	Skagit	W	1350	6.8	RNRA	N	OMxOC	1998
SB-01-01	Hidden	Skagit	W	5733	61.7	South	Y	OM,OA	

CURRENT FISHERIES MANAGEMENT

Current interagency fish management agreement

A long history of interagency conflict unfolded from the date of the park's inception when fish stocking was not contrary to national park policy until the mid- 1980's as the NPS sought to phase out fish stocking within NCNP and bring waters within its boundaries into compliance with new policies, derived from the Leopold Report in the early 1970's (see Louter 2003 for a detailed review). This conflict climaxed in 1985 when the NPS and WDFW (then WDW) signed a Memorandum of Understanding that nullified previous agreements, then proceeded to derive contradictory interpretations of the new agreement. Lack of specificity in the agreement led the NPS to conclude they now had the legal right to phase out fish stocking while WDFW maintained it still operated under a previously agreed-to variance until a new formal fishery management plan was developed. In 1986 the National Park Service issued a new fish management policy that recognized fishing as valid recreational pursuit within the park, but maintained that activities related to fishing could not harm the natural integrity of park lakes. The policy also usurped fish management authority from the state and called for assessment of fish impacts on native biota.

The WDW would not accept this policy because it excluded the state agency and sport fishing associations from continued sport fish management of park waters. This led to a standoff where neither side was willing to give ground. Political intervention by Washington State's congressional delegation came in the form of a 1986 letter to NPS director, William Mott, forcing the park back into a position of "co-management" with the state, and ultimately resulting in the signing of a supplemental agreement to the earlier Memorandum of Understanding. This new agreement, called the Fisheries Management Agreement, recognized the historical high lakes fishery as a valid recreational pursuit in the park, and granted power to the state to implement stocking programs in 40 lakes within the north and south units of the park for the next 12 years while the NPS designed and implemented a research program to assess impacts of fish on lake environments. Moreover, the agreement dictated that WDFW would consult local NPS biologists on the numbers, species and specific lakes where fish stocking could occur (Tables 4 and 5). Lakes within the boundaries of the NRAs were not subject to this agreement because fish stocking was still allowed by park policy in recreation areas, so WDFW continued to manage these waters in accordance with previous informal agreements with NPS as it had in the past (Tables 6 and 7).

In addition to the constraints of the Fisheries Management Agreement, the WDFW also implemented fishery management of park waters as it had within other designated wilderness areas. Only lakes managed prior to wilderness designation were managed for fisheries. Moreover, those waters were only stocked with species present prior to designation with methods used prior to wilderness designation. Generally too, the method of fixed wing stocking was only used where other, less intrusive methods could not accomplish stocking goals, thus constituting a "minimum tool" for larger, more remote managed waters.

Current fish species, stocks, and strains

The Washington Department of Fish and Wildlife currently uses coastal cutthroat trout, intermountain cutthroat trout, golden trout, and non-reproducing Mt. Whitney rainbow trout in its high lakes stocking program. These fish species are used in the current high lakes fish stocking program within the park as well.

The WDFW currently stocks coastal cutthroat trout in a few western Washington park lakes. These fish are currently produced from a captive brood stock kept at the Eells Springs Hatchery in Shelton, Washington. Wild brood stock for this strain was initially collected from Lake Whatcom, in Whatcom County, Washington in the 1940's and fish were collected there again in the 1970's (Crawford 1979). This stock has been referred to in the past as Tokul Creek cutthroat because the brood stock was once kept at the Tokul Creek hatchery prior to its transfer to Eells Springs. However, it would be more accurate to refer to the stock as Lake Whatcom cutthroat since these fish are unique to the Lake Whatcom watershed and do not originate from Tokul Creek. Chilling the eggs at the Arlington Hatchery allow fry to be hatched later and kept smaller for August and September stocking. The WDFW also continues to maintain a lake-run brood stock of intermountain cutthroat trout at Twin Lakes in Chelan County, Washington that are used for stocking certain eastern Washington lakes, including some in North Cascades National Park.

Until 2001, WDFW maintained its own captive golden trout brood stock at Reiter rearing ponds (for a detailed account of the history of this program see Pfeifer et al. 2001). However, cultural difficulties, budget constraints, and assurances from California Department of Fish and Game concerning the stability of an annual egg supply led to the termination of the state's captive brood stock program. Currently, the golden trout program is supported through intermittent importation of eggs from the Mt. Whitney Hatchery in California to the Chelan Hatchery in Chelan County, Washington.

Mt. Whitney rainbow trout continue to be cultured at the Eells Springs Hatchery in Shelton Washington. This captive brood stock supplies fish throughout the state for wilderness fisheries on both the west and east side of the Cascade Mountains, and has become the dominant strain and species stocked within the North Cascades National Park and national recreation areas in recent years. Mt. Whitney rainbow trout produced by the state captive brood stock program, also at the Eells Springs Hatchery, are assumed to be unable to reproduce in high lakes since no reproducing populations have ever become established in Washington State despite widespread stocking (Pfeifer et al. 2001). This may be a result of hatchery spawning practices or genetic inbreeding that has resulted in extremely low sperm counts in males. Spawn timing of these fish may also reduce their reproductive compatibility with high-elevation lakes in Washington State.

Fish species, densities, and frequencies for specific park lakes

While 13 lakes are managed primarily through wild production of intermountain or Yellowstone cutthroat trout, rainbow trout, and eastern brook trout, 16 of the MOU waters within the north and south units of the park have no reproducing fish and are on 4- to 7-year stocking cycles for non-reproducing rainbow trout or golden trout (Table 5). Lake Jeanita, Hidden Lake Tarn, Middle Thornton, and Sweet Pea are on slightly longer stocking frequencies than other non-reproducing lakes to maintain optimum growth rates and limit fishing pressure.

Eleven large lakes, including Berdeen, Skymo, and Sourdough Lakes are stocked with low densities of non-reproducing rainbow trout on 4- and 5-year cycles in addition to established cutthroat trout or, in the case of Sourdough, eastern brook trout populations. These stocking efforts have been employed in order to utilize productive pelagic zones and further diversify the fishing opportunity there. In these mixed-managed waters (waters with fisheries supported and diversified through a combination of natural reproduction and limited stocking), stocking cycles of five years are standard due to the presence of reproducing fish that dominate the littoral zones to varying degrees. Stout Lake receives coastal cutthroat trout in an effort to supplant an existing intermountain cutthroat trout population over time. Marginal reproduction of golden trout may occur in Hidden Lake but the level is very low and cannot sustain a population or fishery. Lower Thornton also has a very low number of cutthroat reproducing at very low density. Therefore, Hidden and Lower Thornton are managed as stocked lakes despite their formal designation as a mixed-managed waters. Upper and Lower Quill currently need evaluations of fish reproduction since park surveys found juvenile fish in 2002 outside the official stocking cycle.

In the national recreation areas WDFW currently manages 11 lakes exclusively through stocking and supplements naturally reproducing populations in two lakes through stocking while fisheries for seven lakes are supported exclusively by natural reproduction (Tables 6 and 7). Stocking densities and frequencies are similar to those for lakes managed in the north and south units of the park. Ridley and Willow Lakes are stocked at higher frequencies and lower densities, every three years with 50 fish/acre and every year with 25 fish/acre, respectively, because low elevation and high lake productivity grow quality fish quickly and sustain more consistent fisheries. Moreover, these lakes receive more fishing pressure in response to rapid recruitment (Table 8).

Growth rates for stocked, non-reproducing fish in these lakes as well as Washington high lakes in general, indicate fish do not compromise their forage base at conservative stocking densities and recruit rapidly into the fishery (Pfeifer et al. 2001). Upper Rainbow is currently on a 10-year stocking cycle, presumably to allow the forage base recover sufficiently to maintain maximum growth rates for stocked fish. The remaining lakes with fisheries supported by stocking receive between 50 and 125 non-reproducing rainbow trout/acre every four to six years with the exception of Lower Panther Pot, which receives 100 coastal cutthroat every four years.

Battalion and Thunder Lakes are listed as mixed-managed waters, but both need prompt fish surveys to determine their exact reproductive status. Five populations of intermountain cutthroat trout, two populations of rainbow trout, and one population of brook trout currently support fisheries in the recreation areas, and all would benefit from fish removal and replacement with non-reproducing fish. However, Hozomeen may be the highest priority for fish removal due to the fact that it drains into ESA-listed bull trout waters, and due to its unique status as the only larger, lower elevation lake in the park. Bouck Lake on the west side with intermountain cutthroat trout, and Rainbow Lake on the east side with coastal rainbow trout, may also be dispersing fish, non–native to their respective watersheds, into waters supporting native fish.

These lakes are also of particular concern for careful evaluation and possible removal programs and subsequent stocking with sterile fish or with species native to their respective watersheds.

Management status of lakes with excessively reproducing fish populations

Currently, 35 lakes throughout the park and NRA units are known to harbor reproducing populations of fish (Table 3, Figure 14) and 24 of these are currently managed under the 1988 Supplemental Agreement to the 1986 MOU. All excessively reproducing, non-native fish populations in the park complex are considered undesirable in the context of fisheries management. Excessive natural reproduction occurs when the reproductive success of fish results in outstripping a lake's forage base, which, in turn, leads to overpopulation and poor growth. While strongly related to fish density in the lake, this condition also depends on the overall productivity of the lake and mortality in the population. This makes measurement of fish growth an excellent indicator of this ecological condition as opposed to setting a numerical density value for lakes in general. Reproduction tends to reduce fisheries managers' ability to control the species, density, and the very presence of fish in historically fishless lakes and excessively reproducing populations often recruit rapidly and deplete the limited resource base in high-elevation lakes. Moreover, natural reproduction can be a potential problem where species, non-native to the drainage, become established in high lakes and subsequently disperse downstream into historically fishless streams or fish-bearing inland or anadromous salmonid rivers where they may then compete with, hybridize with, or prey upon native fish species.

Within the park, populations of eastern brook trout have become established in lower Blum Lake, which drains into the Baker River, as well as Sourdough and Hozomeen Lakes, which drain into Ross Reservoir. Eastern brook fry are commonly present in the tributaries draining to the Baker and Ross Reservoirs and in the reservoirs themselves. Populations of intermountain cutthroat trout have also become established in 16 other lakes on the west side of the Cascade divide in sub-basins draining into the Skagit River. Intermountain cutthroat trout have been found in some headwater streams in the Nooksack, Skagit, and Stillaguamish drainages where bull trout and native coastal rainbow trout were once the only species present. Because these drainages harbor populations of native bull trout, which is federally listed as threatened under the Endangered Species Act (ESA), downstream-dispersal from populations of introduced eastern brook and intermountain cutthroat trout constitute an unknown risk to bull trout as well as to native coastal rainbow and cutthroat trout.

In the Chelan River drainage on the east side of the Cascade crest, non-native rainbow trout populations established in Rainbow Lake, and possibly Battalion Lake, may be dispersing into the Stehekin River and hybridizing with native intermountain cutthroat trout populations. The Washington Department of Fish and Wildlife has already curtailed past rainbow trout stocking programs in the Chelan Reservoir itself and only stocks non-reproducing Mt. Whitney rainbow trout in high lakes in the Stehekin drainage in order to reduce hybridization risk.

Geographic distribution of current fishery

Currently managed waters within the park generally lie near its boundaries in clusters with numerous fishless waters toward the interior of both the north and south units of the park (Figure 15). Several important managed waters are also distributed throughout the Ross and Chelan recreation areas, including Ridley and Willow Lakes on the west side and Triplet Lakes on the east side (Figure 16). A cluster of lakes near the center of the north unit received rainbow and intermountain cutthroat trout in the late 1960's, but subsequent surveys suggest these waters no longer hold fish. These lakes include Middle Lakes, Tapto Lakes and Reveille Lakes. Perhaps the most important waters currently believed to be fishless are Silver Lake (166 acres, 6763 msl) and Azure Lake (91 acres, 4055 msl). Silver Lake was stocked in 1961 with golden trout. Azure was stocked with rainbow trout in 1938 and golden trout in 1961. However, none of these stocking efforts appear to have resulted in the founding of populations. Since many of the larger lakes do have some level of reproduction, Silver and Azure Lakes represent a class of lakes that may require protection from future stocking efforts in order to maintain a diversity of fishless aquatic ecosystems within the park.

Current fishery monitoring

Fisheries managers currently rely on high lake angler report cards and/or periodic surveys with gill nets for fishery monitoring information. Most angler reports come from Washington State Hi-Laker and Trail Blazer, Inc. club members. Anglers volunteer to collect information in an organized manner that yields estimates of fish abundance, growth, and species composition as well as angler effort, success, and lake usage (Pfeifer et al. 2001). From 1968 to 2001, 133 anglers filed 90 reports for 32 lakes within the North Cascades National Park (Table 8). During this period 343 fish were reported with an overall catch per unit effort of 3.4 fish/hour and 2.5 fish per angler. Weighted means for fish/hour and fish/angler were 2.3 and 2.9, respectively. Lakes with reproducing fish such as the Berdeen, Bouck, Dagger, Stout, Hozomeen, and Sourdough Lakes were generally characterized by higher catch rates and smaller fish, while waters with fisheries supported with controlled stocking regimes such as Ridley, Willow, and Hidden were characterized by lower catch rates and larger fish.

While catch rates are suggestive of a successful fishery, lack of regular reporting (or any reporting) for many lakes is one obvious weakness in this type of data. Due to the level of effort by park staff over the years conducting fish surveys, WDFW biologists have not surveyed park lakes with nets in recent years. The National Park Service currently has a great deal of data from net sets which would be a valuable addition to what is currently being collected through angler report cards.

TABLE 4. Waters currently managed by Washington Department of Fish and Wildlife under the 1988 supplemental agreement to the Memorandum of Understanding with National Park Service.

NPScode	Water	MOU	Drainage	CO	MSL	SA (ac)	Dmax (ft)	Unit
DD-01-01	Jeanita	Stock	Skagit	W	4904	1.4	8.2	North
DD-05-01	Unnamed (U Bouck)	Stock	Skagit	W	5030	5.5		South
EP-14-01	Unnamed (Hidden Lk Tarn)	Stock	Skagit	W	5830	4.9		South
LS-03-01	Unnamed (Diobsud # 3)	Stock	Skagit	W	4420	3.9		North
M-01-01	Unnamed (Hi-Yu)	Stock	Skagit	W	3830	3.6		North
M-05-01	Unnamed (Nert)	Stock	Baker	W	4556	3.6	27.7	North
M-17-01	Unnamed (Triumph)	Stock	Skagit	W	3685	4.3		North
M-19-01	Thornton (Middle)	Stock	Skagit	W	4700	11.9		North
MC-06-01	Copper	Stock	Chilliwack	W	5263	12.7	67.2	North
MC-07-01	Unnamed (Kwahnesum)	Stock	Chilliwack	W	5102	16.7	104	North
ML-02-01	Unnamed (Sweet Pea)	Stock	Ross	W	5540	10.3		South
ML-03-01	Unnamed (Torment)	Stock	Ross	W	6460	3.6	45	South
MP-02-01	Unnamed (Firn)	Stock	Ross	W	5472	5.7	37.7	North
MR-01-01	Unnamed (Stiletto)	Stock	Stehekin	E	6795	9.9	84	South
PM-01-01	No Name	Stock	Ross	W	3843	7.5	31.2	North
EP-05-01	Unnamed (L Wilcox)	Mixed	Skagit	W	5120	5.4	18.9	South
EP-09-02	Stout	Mixed	Skagit	W	5215	25.2	176	South
LS-02-01	Unnamed (Diobsud # 2)	Mixed	Skagit	W	4220	3.1		North
M-08-01	Berdeen	Mixed	Skagit	W	5000	126.7	215	North
M-11-01	Blum (Largest/Middle, # 3)	Mixed	Baker	W	5030	12.9		North
M-23-01	Monogram	Mixed	Skagit	W	4873	27.9	37	South
M-20-01	Thornton (Lower)	Mixed	Skagit	W	4486	55.1		North
M-24-01	Unnamed (U Quill)	Mixed	Skagit	W	4510	0.9		South
M-24-02	Unnamed (L Quill)	Mixed	Skagit	W	4510	0.5		South
PM-03-01	Skymo	Mixed	Ross	W	5277	10.8		North
PM-12-01	Sourdough	Mixed	Ross	W	4623	27.6	107	North
SB-01-01	Hidden	Mixed	Skagit	W	5733	61.7		South
CP-01-01	Doubtful	Wild	Stehekin	E	5385	30.2	62.4	South
EP-06-01	Unnamed (U Wilcox)	Wild	Skagit	W	5136	10.5	65.9	South
EP-09-01	Unnamed (L Stout Lk)	Wild	Skagit	W	5190	1.0		South
GM-01-01	Trapper	Wild	Stehekin	E	4165	147.2		South
LS-06-01	Ipsoot	Wild	Baker	W	4460	8.9	50.8	North
LS-07-01	Blum (L/West, # 4)	Wild	Baker	W	4940	6.4		North
M-04-01	Green	Wild	Skagit	W	4261	80.0	153	North
M-07-01	Unnamed (L Berdeen)	Wild	Skagit	W	4460	7.5		North
M-21-01	Unnamed (Doug’s Tarn)	Wild	Skagit	W	3951	5.0		North
MC-08-01	Hanging	Wild	Chilliwack	W	4522	88.8		North
MC-12-01	Bear	Wild	Chilliwack	W	5795	25.7		North
MR-04-01	Dagger	Wild	Stehekin	E	5508	8.2	13	South
MR-05-01	Kettling	Wild	Stehekin	E	5375	9.9	2.2	South

TABLE 5. Current Washington Department of Fish and Wildlife management programs for North Cascade National Park lakes named in 1986 Memorandum of Understanding between WDFW and NPS.

NPScode	Water	MOU	Species	Frequency	Density	Comments
DD-01-01	Jeanita	Stock	OA	7	75	Sensitive shoreline
DD-05-01	Unnamed (U Bouck)	Stock	OA	4	60	
EP-14-01	Unnamed (Hidden Lk Tarn)	Stock	OM	6	40	
LS-03-01	Unnamed (Diobsud # 3)	Stock	OM	4	80	
M-01-01	Unnamed (Hi-Yu)	Stock	OM	4	50	
M-05-01	Unnamed (Nert)	Stock	OM	4	50	
M-17-01	Unnamed (Triumph)	Stock	OA,OM	4	20, 40	
M-19-01	Thornton (Middle)	Stock	OA, OM	4	50	
MC-06-01	Copper	Stock	OM, OCC	4	65	Needs survey
MC-07-01	Unnamed (Kwahnesum)	Stock	OM	5	100	Needs survey
ML-02-01	Unnamed (Sweet Pea)	Stock	OM	6	40	
ML-03-01	Unnamed (Torment)	Stock	OM	5	40	
MP-02-01	Unnamed (Firn)	Stock	OM	5	50	
MR-01-01	Unnamed (Stiletto)	Stock	OCL	6	50	
PM-01-01	No Name	Stock	OM	4	70	
EP-05-01	Unnamed (L Wilcox)	Mixed	OM	4	70	
EP-09-02	Stout	Mixed	OCC	NR 1967, 5	100	Replace OCL
LS-02-01	Unnamed (Diobsud # 2)	Mixed	OC, OM	NR 1990, 5	70	Suppl Stock of non-repro RB
M-08-01	Berdeen	Mixed	OCL, OM	NR 1990, 5	50	Suppl Stock of non-repro RB
M-11-01	Blum (Largest/Middle, # 3)	Mixed	OM	NR 1938, 5	50	Suppl Stock of non-repro RB
M-20-01	Thornton (Lower)	Stock	OM, OCC, OA	6	50	
M-23-01	Monogram	Mixed	OCL, OM	NR 1976, 5	70	Suppl Stock of non-repro RB
M-24-01	Unnamed (U Quill)	Mixed	OM	5	25	Needs repro evaluation
M-24-02	Unnamed (L Quill)	Mixed	OM	5	25	Needs repro evaluation
PM-03-01	Skymo	Mixed	OC, OM	NR 1968, 4	50	Suppl Stock of non-repro RB
PM-12-01	Sourdough	Mixed	OM	4	100	Suppl Stock of non-repro RB
SB-01-01	Hidden	Mixed	OA,OM	4	20, 40	
CP-01-01	Doubtful	Wild	OC,OM	NR 1967		
EP-06-01	Unnamed (U Wilcox)	Wild	OC	NR 1967		
EP-09-01	Unnamed (L Stout Lk)	Wild	OL	NR UNDOC		Rehab Candidate
GM-01-01	Trapper	Wild	OC	NR 1968		
LS-06-01	Ipsoot	Wild	OCB	NR 1961		
LS-07-01	Blum (L/West, # 4)	Wild	SF	NR 1934		Rehab Candidate
M-04-01	Green	Wild	OCL	NR 1947		
M-07-01	Unnamed (L Berdeen)	Wild	OM	NR 1946		
M-21-01	Unnamed (Doug’s Tarn)	Wild	OC	NR 1965		Rehab Candidate
MC-08-01	Hanging	Wild	OM	NR 1983		Canadian Intro
MC-12-01	Bear	Wild	OCL	NR 1967		
MR-04-01	Dagger	Wild	OC	NR 1934		
MR-05-01	Kettling	Wild	OMxOC	UnDoc		

FIGURE 15. Geographic distribution of lakes currently managed within the North and South Units of the North Cascades National Park according to a 1986 Memorandum of Understanding between NPS and WDFW.

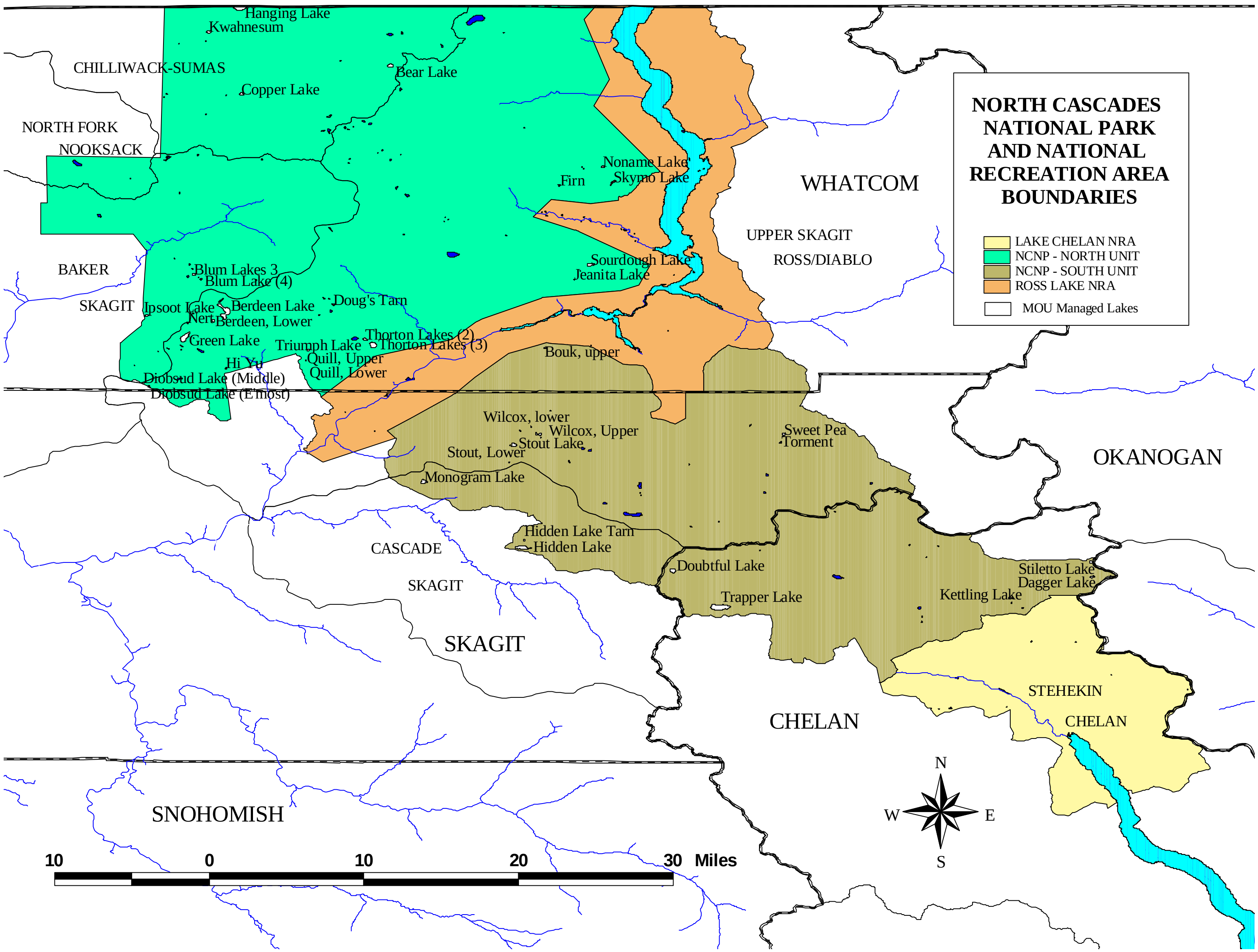


TABLE 6. Waters currently managed for fisheries by the Washington Department of Fish and Wildlife in the Ross and Chelan National Recreation Areas.

NPScode	Water	Mgt	Drainage	Reg	MSL	SA (ac)	Dmax	NRA
HM-03-01	Ridley	Stock	Ross	W	3140	10.9	35.1	Ross
HM-04-01	Willow	Stock	Ross	W	2853	16.9	24.6	Ross
MM-10-01	Coon	Stock	Stehekin	E	2172	11.3	17.2	Chelan
MM-11-01	Unnamed (U Rainbow, W)	Stock	Stehekin	E	6473	3.5		Chelan
MR-09-01	Unnamed (SE OF Kettling Lks)	Stock	Stehekin	E	5945	4.7		Chelan
MR-11-01	Unnamed	Stock	Stehekin	E	6111	2.9	27.5	Chelan
MR-12-01	Unnamed	Stock	Stehekin	E	6495	1.5		Chelan
MR-13-01	Unnamed (U Rainbow, N)	Stock	Stehekin	E	5900	0.6		Chelan
MR-13-02	Unnamed (U Rainbow, S)	Stock	Stehekin	E	5865	3.6		Chelan
MR-15-02	Unnamed (L Dee Dee)	Stock	Stehekin	E	6260	0.8	9.8	Chelan
RD-05-02	Panther Pots (L)	Stock	Skagit	W	3375	0.5		Ross
MLY-02-01	Battalion	Mixed	Stehekin	E	5340	6.3		Chelan
RD-02-01	Thunder	Mixed	Skagit	W	1350	6.8	27.1	Ross
DD-04-01	Bouck	Wild	Skagit	W	3850	10.8	63.14	Ross
HM-02-01	Hozomeen	Wild	Ross	W	2823	97.4	62.32	Ross
MR-10-01	McAlester	Wild	Stehekin	E	5507	13.2	23	Chelan
MR-14-01	Rainbow	Wild	Stehekin	E	5630	15.5	0	Chelan
MR-15-01	Unnamed (U Dee Dee)	Wild	Stehekin	E	6303	12.2	89.2	Chelan
MR-16-01	Unnamed	Wild	Stehekin	E	6230	1.9	0	Chelan
SM-02-01	Triplet (L)	Wild	Stehekin	E	6331	2.2	7.2	Chelan
SM-02-02	Triplet (U)	Wild	Stehekin	E	6551	2.3	12.5	Chelan

TABLE 7. Fisheries management of waters within the Ross Lake and Lake Chelan National Recreation Areas.

NPScode	Water	Mgt	Species	Freq	Density	Comments
HM-03-01	Ridley	Stock	OM	3	50	
HM-04-01	Willow	Stock	OCC	1	25	
MM-10-01	Coon	Stock	OCL	5	90	
MM-11-01	Unnamed (U Rainbow, W)	Stock	OM	5	50	
MR-09-01	Unnamed (SE of Kettling Lks)	Stock	OM	5	50	
MR-11-01	Unnamed	Stock	OM	5	50	
MR-12-01	Unnamed	Stock	OM	6	125	
MR-13-01	Unnamed (U Rainbow, N)	Stock	OM	4	50	Last stocked 1988
MR-13-02	Unnamed (U Rainbow, S)	Stock	OM	6	70	
MR-15-02	Unnamed (L Dee Dee)	Stock	OM, OCL	10	50	Seeded from U Dee
RD-05-02	Panther Pots (L)	Stock	OCC	4	100	
MLY-02-01	Battalion	Mixed	OM	ONE ST	50	Repro origin unknown
RD-02-01	Thunder	Mixed	OM, OCC	3,5	50	Replace OCL
DD-04-01	Bouck	Wild	OCL			Last stocked 1947
HM-02-01	Hozomeen	Wild	SF			Rehab Cand
MR-10-01	McAlester	Wild	OCL			Last stocked 1976
MR-14-01	Rainbow	Wild	OM			Repro origin unkown
MR-15-01	Unnamed (U Dee Dee)	Wild	OC			
MR-16-01	Unnamed	Wild	OM	ONE ST	60	Last stocked 1983
SM-02-01	Triplet (L)	Wild	OCL	ONE ST	50	
SM-02-02	Triplet (U)	Wild	OCL	ONE ST	50	

FIGURE 16. Geographic distribution of lakes currently managed by Washington Department of Fish and Wildlife in the Ross Lake and Lake Chelan National Recreation Areas.

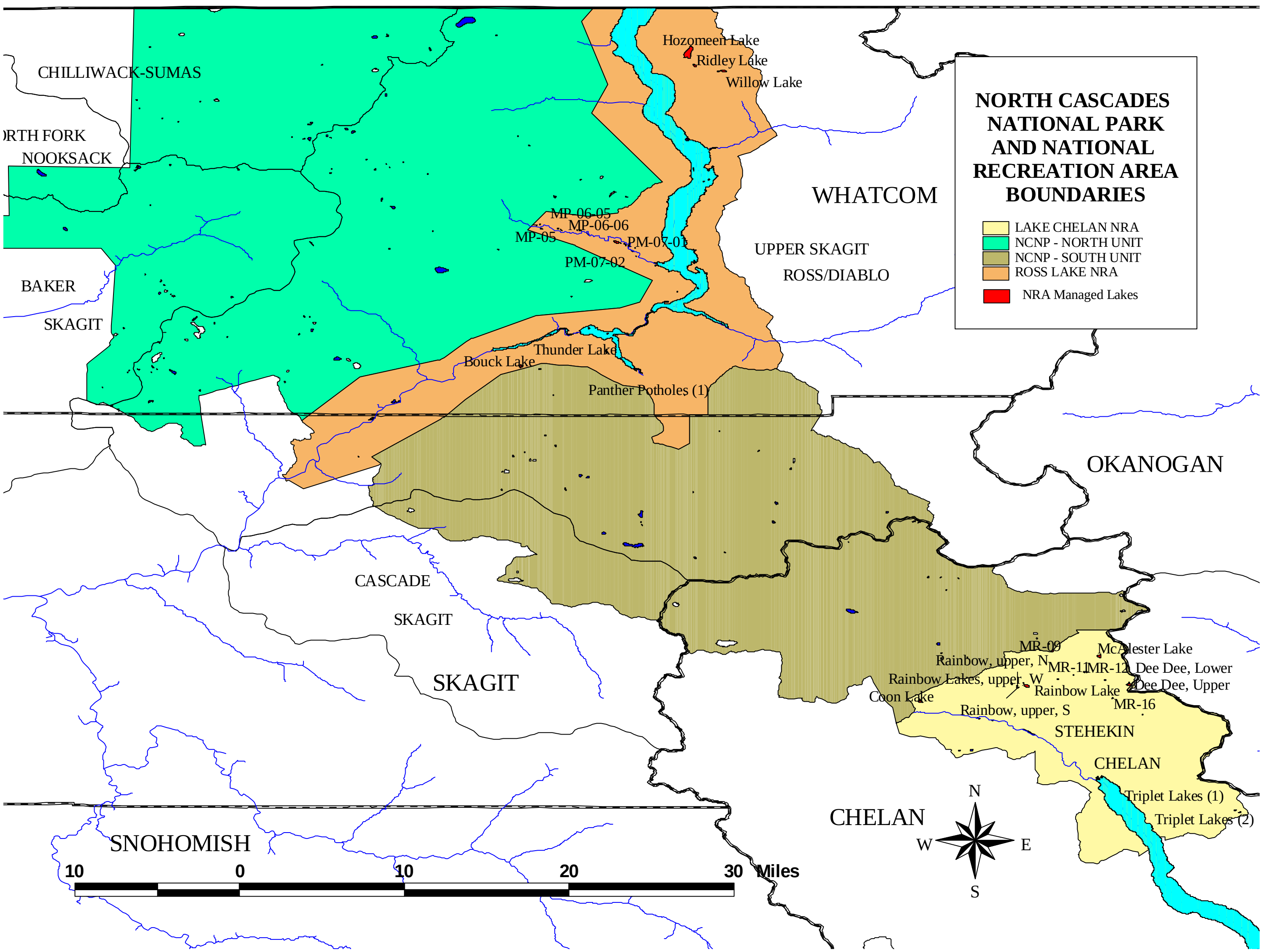


TABLE 8. Sums and averages from high lakes reports between 1967 and 2001 for fishing in North Cascades National Park lakes.

NPScode	Water	#	Last Survey	# party	Species	Number	Min_{avg}	Max_{avg}	FL_{avg}	Hrs fished	fish/hr	fish/angler	non-anglers	other anglers	Camp use
CP-01-01	Doubtful	2	10/22/1999	4	CT	12	9.5	12.1	10.1	4	3.0	3.0	0	0	light
DD-04-01	Bouck	1	08/26/1988	3	CT	10	5.0	10.0	8.0	2.5	4.0	3.3	0	3	light
EP-09-02	Stout	2	08/17/1996	3	CT	5	5.0	12.5	9.0	2	2.5	5.0	2	0	moderate
EP-14-01	Hidden Lk Tarn	1	09/23/1987	1	CT	3	11.0	12.0	11.0	4	0.8	3.0	0	0	light
EP-14-01	Hidden Lk Tarn	5	08/22/2002	8	RB	15	8.0	11.3	10.7	9.5	1.6	1.9	0	0	light
HM-02-01	Hozomeen	7	08/19/2001	9	EB	43	8.9	11.2	10.1	18.75	2.3	4.8	14	7	heavy
HM-03-01	Willow	5	07/11/2001	8	CT	3	19.0	19.0	19.0	7.75	0.4	0.4	0	1	moderate
HM-04-01	Ridley	14	08/19/2001	25	RB	29	12.1	14.4	13.1	41.25	0.7	1.2	3	0	light
M-07-01	Berdeen, L	1	08/25/1998	2	CT	15	4.0	8.0	6.0	2	7.5	7.5	0	0	light
M-08-01	Berdeen	1	08/23/1998	2	CT	10	4.0	13.0	8.0	8	1.3	5.0	0	0	light
M-09-01	Berdeen, U	1	08/23/1998	2	CT	15	4.0	13.0	8.0	1	15.0	7.5	0	0	none
M-11-01	M-11	1	09/20/1997	2		0	ND	ND	ND	2	0.0	0.0	0	0	light
M-17-01	Triumph	4	10/07/1997	1	RB	15	13.0	14.3	13.5	4.5	3.3	15.0	1	0	light
M-18-01	Thornton, U	2	09/21/1991	1		0	ND	ND	ND	0.25	0.0	0.0	0	0	light
M-19-01	Thornton, M	4	09/15/1995	6		0	ND	ND	ND	3	0.0	0.0	3	2	moderate
M-20-01	Thornton, L	2	09/15/1995	2	CT	5	6.0	9.0	7.5	5	1.0	0.0	0	0	light
M-23-01	Monogram	2	09/05/1990	5	CT	18	7.5	10.5	9.0	7	2.6	3.6	0	0	heavy
M-24-02	Quill, L	2	08/05/1985	2	RB	2	13.0	14.0	13.5	2	1.0	1.0	0	0	
MP-02-01	Firn	1	09/11/2000	2	CT	5	6.0	11.0	10.0	0.5	10.0	2.5	0	0	none
MR-04-01	Dagger	2	10/07/1995	3	CT	18	7.5	11.0	10.0	3.5	5.1	6.0	1	0	heavy
MR-05-01	Stiletto	4	08/22/1997	10	CT	6	12.0	14.0	12.0	6.5	0.9	0.6	4	0	moderate
MR-15-02	Tamarack	5	09/04/1999	6	CT	33	6.4	8.8	7.5	9.75	3.4	5.5	0	0	light
MR-16-01	MR-16	1	07/28/1999	1		0	ND	ND	ND	1.5	0.0	0.0	0	0	light
PM-01-01	No Name	1	08/30/1996	2	RB	2	8.0	12.0	10.0	4	0.5	1.0	0	0	light
PM-12-01	Sourdough	2	09/16/2001	3	EB	24	6.3	9.8	7.8	2.75	8.7	8.0	2	0	light
RD-02-01	Thunder	1	07/23/1994	1		0	ND	ND	ND	0.75	0.0	0.0	1	0	light
RD-03-01	Pyramid	2	10/21/2000	2		0	ND	ND	ND	0.25	0.0	0.0	0	0	light
RD-05	Panther Pot, L	4	09/23/2000	6	CT	8	9.0	11.0	10.0	7	1.1	1.3	0	0	light
SB-01-01	Hidden	3	09/23/1987	4	GT	10	7.0	14.0	10.5	6.5	1.5	2.5	0	0	light
SB-01-01	Hidden	3	09/05/1997	4	RB	18	8.0	13.5	13.0	5	3.6	4.5	1	0	light
SM-02-01	Triplet, L	1	07/12/1998	2	CT	10	7.0	8.0	7.5	0.5	20.0	5.0	0	0	light
SM-02-02	Triplet, U	1	07/12/1998	2	CT	10	7.0	10.0	9.0	1	10.0	5.0	0	0	light
Grand		90		138		343	8.2	11.7	10.1		3.4	2.5	32	13	

FUTURE FISH MANAGEMENT

Ecological impacts of fish in high-elevation lakes

Future fish management in North Cascades National Park will be influenced by research conducted by Oregon State University (OSU) and the US Geological Survey (USGS), and presented in the Phase I, II, and III NPS technical reports (see Liss et al. 1995, 1999, 2002). This research was conducted from 1989 through 2001 to describe the aquatic ecology of alpine lakes in the North Cascades, and demonstrate the impacts of non-native trout on native biota of mountain lakes in the park. The research investigated a diverse array of biotic and abiotic factors in high lakes of the park, and cannot be fully summarized here. The most prominent findings with respect to fish impacts on native biota involved fish interactions with long-toed salamanders (*Ambystoma macrodactylum*) and large-bodied copepods (*Diaptomus spp*). The density and reproductive status of fish populations also emerged as major factors.

Researchers found that observed larval densities of long-toed salamanders were positively correlated with total Kjeldahl nitrogen (TKN) and water temperature. Long-toed salamanders are widely distributed throughout the park (Figure 17) and are known to occur in several waters currently managed for fisheries (Table 9). In lakes with TKN values <0.045 mg/L, larval salamander densities were low and no significant differences could be detected among fishless lakes (n = 17), lakes with non-reproducing trout (n = 10), or lakes with reproducing fish populations (n = 9). In waters with TKN > 0.045 mg/L, lakes with reproducing fish (n = 8) had significantly lower salamander densities than fishless lakes (n = 11) or lakes with non-reproducing fish (n = 7). However, larval salamander densities were significantly higher in fishless waters (n = 8) where TKN was > 0.055 mg/L than in waters with non-reproducing fish (n = 4).

Researchers also found significantly lower densities of large copepods in lakes with reproducing fish populations than in fishless lakes, or lakes with non-reproducing fish when water temperatures exceeded 12^{o}C. They concluded that larval salamanders and large crustacean zooplankton are at greatest risk in lakes with reproducing fish populations where TKN concentrations exceed 0.045 mg/L or water temperatures are greater than 12^{o}C. Moreover, they concluded that larval salamanders were at risk in lakes with non-reproducing fish when TKN concentrations exceed 0.055 mg/L, and that native biota are at minimum risk where TKN concentrations are less than 0.045 mg/L regardless of fish presence or reproductive status.

The OSU and USGS researchers recommended not stocking any lake with TKN > 0.045 mg/L or where water temperatures rise above 12^{o}C. Should these guidelines be strictly followed, 23 of 26 lakes with fisheries maintained exclusively through stocking would no longer be stocked, including Ridley, No Name, Willow, Coon, and Panther Potholes (Table 10). Seven of 12 lakes with reproducing populations that are supplemented with stocking would no longer be stocked (Table 11), and 14 of 21 remaining lakes with naturally reproducing fish populations would be considered at risk (Table 12) based on available median TKN and maximum water temperature data.

Before such an approach should be considered, some limitations to the research should be addressed. The first is the small sample size of productive waters with non-reproducing fish (n = 4). The second is the statistical difference in surface area between waters with and without fish that are known to harbor long-toed salamanders, and the lack of waters over ten acres considered in the analysis (Figure 18). Lack of representation of larger lakes makes extending statistical conclusions to the majority of fish-bearing lakes inappropriate. With regard to specific impacts on long-toed salamanders, statistical differences in lake parameters among treatments and limiting factors other than fish, such as limitations in terrestrial over-wintering habitat for adult salamanders, were not adequately controlled for. Finally, many of the lakes with reproducing populations of fish have harbored these fish for many decades, giving rise to such questions as when does a reduction in abundance constitute a significant risk to that species in a given lake or a significant alteration of natural ecological processes?

With regards to the use of water quality parameters as thresholds for interaction in park lakes, no standardized methodology has yet been developed for time of year, frequency, or seasonal and spatial variability in measurements. Variable and collection-intensive water quality data should probably not be used to infer biological conditions when so much research has indicated the need to infer the overall influences of abiotic factors from biological indicators. Biological signals, not just of individual species but of community-level response to disturbance should be measured instead (Karr 1987; Karr 1991; Harig and Bain 1998; Barbour et al. 2000).

Another fundamental problem with this approach would be the uncertainty of risk to organisms outside the scope of research. Researchers cannot assume that guidelines that protect relatively vulnerable long-toed salamanders will protect all native species in general. Organisms such as the blind amphipod (*Stygobromus* spp.), recently discovered in Redoubt and Upper East Lakes, may be unprotected if their ecological requirements are substantially different and if they are susceptible to fish predation or competition for resources. Ignoring the potential for unknown impacts in a whole class of communities in larger, deeper, nutrient-limited lakes would be unwise and indefensible. A responsible fish management plan for the park should include protecting a diversity of fishless aquatic ecosystems, rather than just those suited for one or two particularly well studied species.

With respect to amphibians, the OSU/USGS research should be applied to identifying critical larval long-toed salamander habitats in order to better understand and conserve metapopulation dynamics of salamanders and ensure a distribution of salamander source populations throughout the park within their known or assumed range. Factors conducive to salamander abundance such as lake depth, temperature, and productivity have been identified, but the spatial distribution and overall productivity of salamanders in park lakes would benefit from further examination. On a broader level, incorporating TKN as an index of lake productivity in a multivariate array of lake classification factors such as physiogeographic zone, surface area, and elevation could reduce uncertainty and risk by ensuring protection of a wider range of aquatic ecosystems. Maintaining the greatest diversity of fishless ecosystems would protect the greatest diversity of aquatic communities, and would require ensuring that lakes with a variety of depths, surface areas, elevations, and productivities from both east and west geographic regions be maintained in a fishless condition.

Some of the limitations in extending conclusions from the research could be addressed in future monitoring of low-density, non-reproducing stocked lakes. One emergent conclusion, however, appeared robust, and apparently led to the ad hoc analysis presented in Phase III of lakes based on fish reproductive status: the significance of fish density and impacts of excessively reproducing populations in high lake ecosystems in general. High densities and multiple age classes of fish exert constant pressure on lower trophic levels, and more vulnerable or preferred prey species may be disproportionately affected, with the potential for causing significant changes in community composition. Low densities of a single age class progress through trophic levels periodically in diminishing numbers, and their effects may be much more difficult to detect.

A more prudent approach to future fish management in the park would be to incorporate the research on long-toed salamanders, large-bodied copepods, and other aquatic organisms in general into a conceptual model of biological integrity that treats fish presence as an environmental disturbance whose magnitude is affected by density, duration, and reproductive status. The concept of biological integrity, as developed by Karr and others in the last 15 years, represents untrammeled, pristine functioning ecosystems where natural processes and assemblages of species evolve in the absence of large-scale human disturbance. Conservation of biological integrity could occur where pristine or nearly pristine systems are not sufficiently disturbed by human activity, including fish stocking, that their species compositions and ecological processes deviate significantly from those expected in the absence of human disturbance.

Application of research to a model of biological integrity for minimizing impacts of wilderness fishery management

Current and future WDFW fisheries management in the North Cascades National Park would continue to follow trends in wilderness fisheries management in the state of Washington in general (see Pfeifer et al. 2001). With respect to the Wilderness Act, WDFW strives to provide fishing opportunity in historically managed waters with historically managed species by the least intrusive means possible. More recently, WDFW has emphasized stocking species native to watersheds, and/or non-reproducing fish in order to minimize fish stocking disturbance in wilderness areas, to minimize downstream impacts to native fish populations, and to control density and maximize the growth of fish in high lakes. Biologically based stocking programs implemented by WDFW are intended to provide recreational opportunity and fulfill angler desires for a wilderness fishing experience while minimizing the potential for the unsanctioned spread of fish species. These efforts are, therefore, consistent with other agency goals such as conserving biological integrity of nearly pristine ecosystems and protecting wilderness values.

Some important conclusions have emerged from the NPS research, including the importance of fish reproductive status and density in determining potential for impacts on native biota, and factors correlated with salamander abundance and the susceptibility of long-toed salamanders to fish predation. Moreover, the research underscores the need for continued monitoring, education, and research in high lake ecosystems. The Washington Department of Fish and Wildlife proposes incorporating these study conclusions and implications into a broader framework of fish management in the park that is based on a general model of biological integrity with respect to fish density and reproductive status (Figure 19).

Prior to the immigration of early settlers into western regions of North America more than 95% of nearly 16,000 high-elevation lakes were historically fishless (Bahls 1992) and nearly all high-elevation lakes in what is now the North Cascades National Park Complex were fishless due to topographical barriers to fish migration. Today, fishless waters in North Cascades National Park fall into two major categories. The first category is characterized by nearly pristine wilderness aquatic ecosystems that have never held fish and, consistent with commonly used definitions of biological integrity, support a biota produced by evolutionary and biogeographic processes with little or no anthropogenic influence (Harig and Bain 1998; Karr 2000). Such ecosystems represent important resources as undisturbed and often undescribed biological communities. Protection of these resources is paramount to the mission of the National Park Service, is central to the goals of wilderness advocacy groups, and is also important to WDFW.

The second category includes lakes that have had a history of fish presence where fish no longer persist either due to die-out of a population or due to cessation of stocking over a prolonged period of time (>15 years). Depending on the level of fish presence and species affected, such lakes may be permanently altered (Landis et al. 1996) or minimally impacted (Liss et al. 2001), or they may be converging toward their previously unaltered state (Wissmar et al. 1982; Harig and Bain 1998; Knapp et al. 2001). Although uncertainty and paucity of data may preclude distinguishing particularly sensitive or isolated lakes beyond a general category of recovery, these waters can still fulfill an important NPS objective by being managed, generally, for natural processes.

For these reasons, park waters without a fish history and ones that have reverted to a fishless state for long periods (>15 years) should be considered for protection in the future as wilderness resources. Such fishless waters in the park represent the pristine or nearly pristine end of the disturbance continuum with respect to non-native fish management. They should also include a variety of lake types with respect to productivity, elevation, depth, and surface area (Figure 12). Moreover, should fish bearing waters within the park be demonstrated to be truly unique with respect to elevation, surface area, and productivity, they should be considered for restoration.

The balance of park waters hold fish either by introduction or stocking. The introduction of fish into fishless ecosystems impacts native biota at multiple temporal, spatial, and ecological scales. Therefore, a useful distinction should be made between the term "introduction" and the term "stocking" for distinguishing the most fundamental level of impact. Introduction, for the purposes of this discussion, will be defined as a release of fish into an ecosystem that subsequently founds a persistent, self-perpetuating population. Such naturalized populations undergo the evolutionary process of selection and are maintained and constrained within naturally functioning, though altered, ecosystems. Stocking will be defined as a release of fish into an ecosystem that persist only through the lifespan of the individual fish and the duration of the fish management program. This distinction is important for two reasons. First and foremost, a reproducing fish population takes on an evolutionary trajectory and has the potential to persist across evolutionary time scales. Second, reproducing fish form multiple age classes. In many lakes, fish species that are well adapted to high lake environments reproduce in excess of the limited growth resources available. Since fish undergo ontogenetic niche shifts as they grow (Werner and Gilliam 1984), they may occupy multiple feeding niches and impact multiple trophic niches simultaneously and into the foreseeable future.

Human introduction of fish into wilderness areas often affects ecological processes in obvious ways, as well as in subtle and probably unknowable ways. Introductions of persistent, reproducing populations of fish can have significant impacts on indigenous macroinvertebrate, zooplankton, and amphibian populations (Liss and Larson 1991; Liss et al. 1999; and Hoffman and Pilliod 1999), and potentially influence the evolutionary trajectories of aquatic ecosystems even if the fish subsequently become extirpated (Landis et al. 1996). Such introductions may fundamentally undermine the ecological values inherent in some interpretations of the Wilderness Act by degrading broad protection of uncharismatic fauna over undetermined periods of time (Landres et al. 1999). Therefore, such introductions represent the highest level of disturbance along the continuum with respect to fish management due to the spatial and temporal scale at which populations may persist, due to the competition of multiple age classes at different trophic levels, and due to the lack of management tools at fisheries managers' disposal to control fish once they are established in large aquatic ecosystems.

Central to considerations of wilderness ecosystem disturbance, fisheries managers must assess the potential for, and level of natural reproduction as a primary consideration for how fish stocking in high-elevation lakes will affect lake ecology in addition to the quality of the fishery (Pfeifer et al. 2001). Most populations of fish became established in the park long before their potential for ecological impact or propensity to become stunted and undesirable to anglers were fully understood. Preventing the founding of new fish populations in high lakes has become central to high lake fish management, while controlling trout numbers by adjusting stocking rates to produce quality fisheries. Ironically, efforts of minimizing ecosystem disturbance and maximizing the growth rates of fish for a quality fishery are somewhat synonymous, first having been expressed in terms of lake carrying capacity and effects of overstocking and reproduction on the fish forage base and subsequent growth (Williams 1972 and Johnston 1973), and more recently, in terms of impacts to uncharismatic species presence, composition, abundance, and behavior (Larson and Liss 2001).

Both perspectives point to the need to control trout density in high lakes where fisheries are to be managed. This goal can be achieved by assessing current levels of fish reproduction; evaluating available habitat and fish species propensity for reproduction; stocking either functionally or obligate non-reproducing fish; evaluating effects of fish stocking at given densities on aquatic communities on a lake-by-lake basis; and finally, by instituting a program to remove or reduce populations that compromise the biological integrity of their environment in national park waters.

Intermediate levels of disturbance along the continuum must be defined and ranked based on fish density, age class distribution, temporal duration, and the ability of managers to control these parameters. Periodic stocking of non-reproducing fish into a high lake ecosystem affects biological processes over a much shorter time scale, the lifespan of the fish, and the duration of the program, than naturally reproducing fish. Moreover, it remains within the control of natural resource managers who can regulate the density, frequency, and duration of stocking efforts in response to monitoring. Under a periodic stocking regime, one age class of fish progresses through trophic niches periodically as well, potentially allowing whole trophic levels a recovery period. Low stocking densities are set to maximize fish growth, which tends to lead to conservation of the limiting trophic level of the forage base, whatever that may be. Since fish are only available two or three years out of a five to six year stocking cycle, impacts of angler usage are also cyclical. These characteristics of non-reproducing fish assemblages have apparently led to difficulties in demonstrating significant effects on larval salamander and large-bodied copepod densities or other impacts in North Cascade high-elevation lakes (Liss et al. 2002), and allow for a general line of sustainability to be drawn in the proposed conceptual biological integrity model.

Terminating fish stocking in lakes that are poor producers of fish, identified as critically important to other native aquatic life, or unvisited by wilderness anglers represents an important concession as a responsible fish management program is developed for high lakes in the North Cascades National Park. Where lakes are removed from current management for fisheries due to sensitive species issues or amphibian metapopulation dynamics, other lakes with a fish history should be considered for substitution if a determination can be made that periodic stocking of non-reproducing fish will have minimal impacts and provide a quality fishing opportunity. Such lakes might also be considered for stocking where reductions in stocking frequencies of currently managed lakes could further reduce impacts and allow for longer recovery periods.

Defining the extreme ends of the continuum as fishless on the pristine end and excessive reproduction of non-native fish on the altered end with periodic fish stocking falling somewhere in between is straightforward, but it is important distinguish among differing levels of stocking and reproduction that may ultimately influence fish density and duration, and to point out possible exceptions or areas of overlap in these levels of fish impact. There may be lakes with limited reproductive habitat or with species of limited reproductive potential where reproducing fish exist at low density in a large, complex lake ecosystem. The biological condition of these environments may be more similar to those of periodic stocking regimes or fishless waters than to those inhabited by excessively reproducing fish populations. However, their impacts would still extend beyond those of non-reproducing fish waters, and remain outside managers' ability to easily control. Conversely, high density, frequent (annual) stocking could quickly fill trophic niches with multiple age classes and exert pressure on multiple trophic levels simultaneously. The biological condition of these environments may be more similar to those inhabited by excessively reproducing fish populations, but only through the duration of the program rather than across evolutionary time.

Despite such exceptions and areas of overlap, varying levels of fish occupation of wilderness lake ecosystems can be ranked along a continuum based on the preceding discussion (Figure 19) because magnitudes of fish presence in terms of duration, density, and frequency result in different levels of disturbance. Waters that have never experienced fish stocking or introduction represent nearly pristine environments with regard to fish presence in wilderness lakes. Waters where fish have died out, or are no longer stocked, represent minimally influenced environments with respect to fish presence. Waters stocked periodically with low densities of fish, or supporting low densities of reproducing fish, cannot be considered pristine, but rarely demonstrate significantly detectable changes in aquatic communities. Finally, waters frequently stocked with high densities of fish, or with excessively reproducing populations, occupy the high end of human-induced disturbance with regard to fish introduction in wilderness lakes.

A region of this continuum does appear to exist for some lakes where low levels of fish stocking will conserve biological integrity by minimally impacting natural biological processes and sustaining native biological resources. Incorporating the degree of isolation, presence of sensitive species, habitat complexity and prey refugia, depth, and surface area would aid in making such determinations on a lake-by-lake basis. Assessment and monitoring for each lake based on identified risk factors within the context of fish reproductive status should be the basis for drawing these conclusions.

This model can form a basis for management of lakes with a number of potential objectives and management goals (Figure 20). Park waters without fish history should be managed for natural processes. Numerous taxa, including amphibians, insects, and zooplankton will continue to evolve in the absence of non-native fish presence. Park waters without current fish presence (>15 years) should be managed primarily for recovery of natural processes. However, redistribution of recreational opportunity to these lakes due to fish removal or cessation of stocking programs in more sensitive lakes would be a reasonable exception. Such an exception would be contingent upon environmental characteristics that would minimize impacts of non-reproducing fish on native biota within the proposed lake while the sensitive lake would then be managed for recovery of natural processes. Waters with excessive reproduction should not be stocked until fish removal and assessment can be accomplished. Waters with low levels of reproduction or with current stocking programs should continue to be stocked unless specific risk factors are identified that preclude even low numbers of periodically stocked fish.

Ranking theoretical impacts for levels of fish introduction based on duration, density, and ecological niche occupation of fish in a lake ecosystem (Figure 19) should be applied to park lakes. Whether those lakes fall into the sustainable zone should be determined based on fish reproductive status and its interaction with lake-specific risk factors. Issues, central to the continued development of a park fisheries management program that conserves biological integrity should include recognition of the evolutionary importance of historically fishless waters and identification of specific waters that should be allowed to revert to a fishless state due to their function as rare species refugia, or their critical role in metapopulation dynamics of native species. Where potential for ecological risk is low, the need for controlling fish densities should be central to fish management in waters where native biota are impacted by fish presence. Balanced angler usage, a positive relationship between user groups and managing agencies, and biological monitoring should also be part of successful fish management in wilderness lakes (Figure 20).

Issues of angler usage should also be addressed in future fisheries management plans for park high lakes. Some high-elevation lakes are rimmed with fragile plant communities with short growing seasons while others are rimmed with rock. The potential for degrading the former is a major concern with NPS botanists. While many anglers fish from rafts, thus minimizing such impacts, others may work the shoreline systematically. At lakes stocked with low densities of non-reproducing fish, angler usage is cyclical, and cumulative usage impacts at such lakes may be greatly diminished. However, not nearly enough information exists on which lakes have degraded plant communities, and what the relative contribution by anglers is. Clear cases exist in Washington of usage impacts around high wilderness lakes where fish have never existed (Pfeifer et al. 2001). The aesthetics of untrammeled, wilderness environments is a major aspect of high lakes fishing and should be included in the previously mentioned definition of a quality wilderness fishery. Therefore, WDFW is committed to cooperating with NPS in evaluation and monitoring, and is also committed to engaging wilderness anglers in outreach and education in order to minimize these impacts.

Monitoring of high lakes fisheries has evolved to play an essential role in management of these fisheries since the first half of the 20th century. Methods for monitoring originated with the beginning of a coordinated relationship between the Washington Department of Game (now WDFW) and the earliest high lakes sportsman's club, Trail Blazers, Inc., beginning in 1933. During the past 70 years, most stocking programs were developed iteratively through trial and error and a number of fish species and strains, later found to reproduce in wilderness lakes, were spread throughout high lakes (Pfeifer et al. 2001) including some within the park. However, monitoring of these management actions and their subsequent effects on lake ecosystems and fish growth led to greater understanding of the interaction between stocked and introduced fish and high-elevation lake environments.

Such monitoring through angler report cards and professional lake surveys undertaken by agency biologists continues into the present and has led to management principles that emphasize the stocking of appropriate species, non-reproducing fish, and controlling the density of fish that occupy limited trophic levels in order to promote growth of quality fish. Monitoring and future research should be expanded to include more detailed surveys of macroinvertebrate, zooplankton, and amphibian populations, as well as impacts of angler usage on nearshore environments. Growth rates of fish should also continue to be a fundamental indicator of overall balance, sustainability, and ecological integrity of managed lakes. Moreover, correlations between fish growth and other biological signals such as expected native species presence, abundance, and diversity should be rigorously examined.

Proposed management approach for North Cascades National Park

With interagency coordination, cooperation, and standardized monitoring plans as a foundation, WDFW would propose an approach to fishery management that recognizes the importance of protecting biological integrity in the park while providing low-impact, quality recreational fishing opportunity based on best-science.

All lakes that have been historically fishless in the park should remain fishless. The park's obligation to preserve this level of biological integrity supercedes providing recreational opportunity. Lakes without a history of human disturbance should be assumed to represent the highest level of biological integrity for aquatic ecosystems within the park and should be protected from human impacts, including fish stocking. Other lakes should be evaluated on a lake-by-lake basis. Most lakes that have become fishless for multiple generations generally represent waters where fishery development was unsuccessful and in many cases were only stocked once. Some of these waters, such as Redoubt, Pyramid, and Upper East Lakes, may harbor rare or sensitive species, while others, such as Silver and Azure Lakes, may represent unique ecosystems due to lake size and elevation,. Such waters should be allowed to undergo processes of recolonization by native biota and recovery. However, lakes with a history of fish stocking that do not currently hold fish should not be categorically ruled out for future stocking if environmental characteristics limit the risk of fish interaction with native biota, and if the lake has the capacity to support a quality fishery. Examples of such lakes include Green Bench Lake, Vulcan, and unnamed FP-01-01.

Park lakes currently holding fish should be classified into three major categories based on the reproductive status of the fish inhabiting the lake: 1) lakes with trout populations reproducing at high levels; 2) lakes with trout populations reproducing at low levels; and 3) stocked assemblages of non-reproducing trout. Within these categories any of several management approaches should be pursued based on how fish reproduction influences trout density and how that density interacts with currently identified risk factors, such as lake depth and size, habitat complexity, elevation, and presence of sensitive species. Finally, the potential for supporting quality fishing opportunity should also be considered before stocking fish even into low-risk waters.

Fish bearing lakes with high-density reproducing populations of trout represent waters with the highest risk of ecological alteration due to fish presence (Table 13). Based on screening these lakes for risk factors, lakes with excessively reproducing populations that are also vulnerable to irreversible, long-term impacts to native biota from even low numbers of fish should have the management goal of conversion to a fishless state. Lakes such as Diobsud #1, Upper Wilcox, and Upper Berdeen appear to fall into this category based on NPS macroinvertebrate monitoring. Monitoring such lakes for the recovery of native organisms after successful removal of fish would provide useful information on the long-term effects of introduced fish and native biota and subsequent recovery that would not only supplement the published literature on the subject, but form the basis for future management decisions.

Some lakes may be at low risk from the effects of periodic stocking once reproducing fish are removed, but it may still be desirable to return these to a fishless state for other reasons. For example, Hozomeen Lake is large and deep, with great habitat complexity and is unlikely to suffer major impacts from non-reproducing fish stocked at low densities, yet its uniqueness as the only middle-elevation, large lake in the park might make it worthy of restoration to a fishless state, particularly if the other two lakes in the area continue to be stocked.

Other lakes with high-density populations may be less vulnerable to unacceptable impacts from low-density, single age-class assemblages of fish. Such waters include Battalion, Bear, Blum #4, Diobsud #2, Doubtful, Doug’s Tarn, Ipsoot, Lower Bouck, Lower Stout, Monogram, Rainbow, Skymo, Stout, Sourdough, Lower Wilcox, Lower Triplet, and possibly Berdeen and Green. These waters, after successful fish removal, should be considered for continued fishing opportunity, supported through the periodic stocking of low densities of non-reproducing fish after a 2- to 3-year resting period. Where the risk associated with low densities of fish is unknown, such as with Battalion Lake where apparent long-toed salamander extirpation correlated with fish presence, monitoring should be employed as a pre-condition for subsequent stocking. Where interaction risks are low and the prospect for providing a low-impact quality fishery is reasonable, as with the majority of remaining lakes listed above, stocking programs should be implemented and monitored. However, before any fish removal project is implemented, there should be a sound biological basis for the removal. Where wild, naturalized fish populations do not pose a significant threat to native biota, particularly in larger more complex lakes, they should be allowed to continue to provide wilderness fishing opportunity.

In situations where complete removal of reproducing fish may not be feasible, density reductions may be a practical alternative that could potentially reduce impacts of fish in some lakes while increasing growth potential and providing increased quality fishing opportunity. Such lakes potentially include all larger, deeper waters with higher densities of reproducing fish, but this strategy could work particularly well for Upper Dee Dee, Dagger, and McAllister, since these populations are comprised of a fish species native to downstream waters. Hanging Lake may also benefit from density reduction. However, an agreement must be pursued with the Canadian government before any management action is taken. Wherever lakes with highly reproductive fish populations that are not native to the watershed drain to waters with sensitive native fish species, additional evaluations should be made to assess potential downstream impacts. In the lower Skagit, WDFW has detailed survey information for several important bull trout spawning tributaries including Bacon, Goodell, and Marble Creek and the south fork of the Cascade River, that suggests most downstream impacts are negligible. Lakes identified as having potential downstream impacts such as Hozomeen, Sourdough and Blum #4, with high densities of eastern brook trout, and Monogram with moderate densities of intermountain cutthroat trout, should be prioritized for fish removal and subsequent management under one of the above scenarios.

The next major group of waters based on fish reproductive status would be those where fish populations reproduce at low density (Table 14). While generally not as detrimental to native lake biota as high-density populations, this condition perpetuates impacts over long periods and at multiple trophic levels simultaneously, increasing the potential for cumulative effects. Moreover, this condition is outside of fishery managers' ability to control by simply terminating or adjusting a stocking program. Fish species non-native to a given watershed, or ecologically incompatible with sensitive native fish species downstream, could further raise levels of risk. Most of the waters falling into this category are larger lakes with limited spawning habitat in relation to lake size as evidenced by overall growth rates of fish in the lake, as well as other indicators. The easiest approach to fishery management in these lakes may be to identify and maintain conditions that promote low fish density. Lakes such as Jeanita, Trapper, Blum #3, and Unnamed MR-16-01 fall into this category. For larger lakes with extremely low densities of fish due to irregular or chronically low reproductive activity that are also at low risk for adverse interactions between fish and native biota, such as Hidden and Lower Thornton, supplemental stocking of non-reproducing fish should be employed.

The final major class of waters based on fish reproductive status would be those where fish are currently stocked but do not reproduce (Table 15). In a few cases where lakes are small, shallow or isolated, such as Upper Bouck, Monogram Tarn, and Bowan, even low densities of fish are likely to have unacceptable negative impacts on native biota. Stocking should be discontinued in such lakes where data are available to support this management decision. Some currently stocked lakes such as Nert and Upper Rainbow N, may not be providing quality fishing opportunity and such waters should not be stocked either. A few others may have sufficient uncertainty associated with them as to warrant discontinuing stocking until necessary data can be collected and evaluated. One example of such lakes is Copper Lake, due to its isolated location. However, the majority of lakes stocked with low densities of non-reproducing fish are larger, deeper, cooler waters. Many have extensive shoreline complexity or satellite ponds. Stocking such waters as Diobsud #3, Firn, Hi-Yu, Kwahnesum, No Name, Coon, Sweet Pea, Lower Quill, Ridley, Willow, Middle Thornton, Triumph, Unnamed MR-09-01, Unnamed MR-11-01, and Stilletto, periodically with low densities of non-reproducing trout represents a low risk to native biota and a high potential for maintaining quality fishing opportunity.

General stocking guidelines for species, densities, and frequencies

Mt. Whitney rainbow trout, with limited reproductive potential, should continue to be the standard species for park waters, particularly those larger waters with potential spawning habitat. This rainbow trout strain has demonstrated consistent performance in a variety of high-elevation lakes with respect to survival, growth and condition without evidence of successfully reproducing in Washington State high lakes. Golden trout, coastal cutthroat trout (for west side waters), and intermountain cutthroat trout (for east side waters) should be used to diversify fishing opportunity in lakes with low reproductive potential. Lakes to be stocked with golden trout should be carefully selected to handle the usage generated by this highly sought-after species. Lakes such as Middle Thornton and Hidden are best accessed by raft, significantly rimmed with talus and boulders, and have a history of golden trout, making them good candidates for such a program.

Ultimately, development of sterile fish will provide a valuable tool for developing low-impact quality fisheries in North Cascades National Park. Sterile hybrid crosses such as tiger trout (*S. fontinalis* x *Salmo trutta*), for example, would have no chance of reproducing in high lakes. However, usage of such exotic hybrids would require review via the State Environmental Policy Act (SEPA) and NEPA. Chemical methods have been partially successful in sterilizing fish as well, and this methodology should not be ruled out should it become more fully developed. Currently, triploidy is the most common way of achieving sterility in fish, and resources should be secured to develop a triploid fish program in Washington State.

The process of triploiding fish involves exposing eggs to temperature or pressure changes that result in three rather than two sets of chromosomes in the developing embryo. Although this has no outward effect on the fish, the change renders them incapable of producing viable gametes and thus sterile. Success rates for the triploid process vary from 60 to 100% depending on the method used. Successful temperature treatment requires specialized disease–free water supplies and can be expensive with variable success rates. Pressure treatment has been a more effective method with success rates of up to 95% once the process is developed and fine-tuned for the hatchery where it is implemented. Ideally, all stocked fish should be triploided to further minimize risk of undesired reproduction.

The Washington Department of Fish and Wildlife is currently developing a native upper Skagit rainbow brood stock for use in the Skagit basin. Wild, native Skagit rainbow trout have been collected from tributaries to Ross Reservoir in the Ross National Recreation Area and spawned for the rearing of a captive brood stock at the Marblemount Hatchery in Marblemount, Washington. An annual infusion of gametes from wild fish will be made to maintain the genetic integrity of the brood stock. Triploiding upper Skagit rainbow trout may eventually bring the stocking program for lakes within the Ross drainage even closer to park goals with respect to exotic species in the park.

The Upper Skagit brood stock program is funded from the Settlement Agreement with Seattle City Light for the purpose of enhancing fishing opportunity in waters above the Seattle City Light projects. The principal destination for these fish are the Diablo and Gorge reservoirs where limited spawning habitat and poor connectivity with other native resident rainbow populations limit recruitment of rainbow trout. However, Upper Skagit rainbow have already been stocked into Ridley Lake because it lies within the Ross drainage, has no reproductive habitat, and was previously stocked with an exotic strain of rainbow trout. A recent assessment of the Upper Skagit rainbow trout in Ridley revealed rapid growth with one-year-olds growing from 80 mm at the time of stocking to 300 mm the following spring.

General stocking densities and frequencies should follow current trends and be supported by monitoring the growth of fish and other biological indicators. Lakes with fisheries currently supported through low-risk stocking programs should continue to be stocked with current species at current densities and frequencies unless new management goals dictate otherwise. For example, a species change should be made for Middle Thornton from rainbow exclusively, to rainbow and golden trout. Stocking rates for these fish should be adjusted so that the total density is no greater than current rainbow-only densities. Wherever stocking programs follow problem fish population removal, decisions concerning species, density and frequency will need to be made on a lake-by-lake basis, based on habitat, forage base, and angler usage and desires. However, stocking densities should generally fall between 25 and 100 fish/acre at frequencies of four to seven years depending on the lake. One exception would be Willow Lake, which should continue to receive a very low density of 25 fish/acre annually due to extremely variable survival.

The need for interagency cooperation

Interagency coordination has been a reality in wilderness fish management since the 1970's. The Washington Department of Fish and Wildlife has continued managing fish on federal lands with notification of and input from both the US Forest Service and National Park Service staff. Although relationships between federal and state agencies have not always been cooperative in this area, particularly where the NPS and WDW were concerned during the mid-1980's, recent years have seen a renewed effort on the part of both agencies to work together. The most recent evidence for this has been WDFW's acceptance of the NPS invitation to participate in an environmental review of high lakes stocking and fish management in the North Cascades National Park under the National Environmental Policy Act (NEPA).

Interagency cooperation can lead toward meeting the missions and achieving goals of both federal and state agencies in the future and should therefore be encouraged. Recognizing the mission of the NPS to protect native biological integrity and preserve native ecosystems, and mindful of the mission of WDFW in preserving, protecting and providing opportunity to recreate on fish resources raises the question of how these agencies as well as public utilities, user groups, and academic institutions might work together to meet an array of objectives. The most important objective from an ecological perspective would clearly be the successful removal of problem populations of fish from impacted lakes and long-term protection of historically fishless waters rather than categorically terminating stocking programs for the sake of expedience.

The prospect of combining resources and expertise to remove reproducing eastern brook trout wherever they occur in the park, excessively reproducing intermountain cutthroat trout from lakes draining into the Skagit drainage, and possibly reproducing rainbow trout from lakes in the Stehekin River drainage should be pursued. Moreover, engaging user groups in such activities and in education would reduce the risk of such restorations being inadvertently undone through unsanctioned reintroduction or future spread of these fish species and strains in high-elevation lakes. Removal of such populations of non-native fish and reduction of risks associated with their reintroduction would serve to move the high-elevation lakes in the park toward biological integrity at a landscape level. Continuing to provide angling opportunity through biologically-based stocking of non-reproducing fish at ecologically acceptable densities would reduce within-lake impacts, offer the option to terminate stocking should problems arise, and foster a positive relationship between NPS, WDFW, and the angling community. Ultimately, all stakeholders would benefit from practical, positive relationships, and the success of any fish management plan will depend upon interagency cooperation.

TABLE 9. Physical characteristics of waters with long-toed salamander (*A. macrodactylum*) observations in North Cascades National Park that are currently managed for fisheries.

NPScode	Water	Drainage	Side	SA	Elevation	Depth	Mgmt
MM-11-01	Unnamed (Upper Rainbow, West)	Stehekin	E	3.5	6473		Stock
MR-15-01	Unnamed (Upper Dee Dee)	Stehekin	E	12.2	6303	89.2	Wild
MM-10-01	Coon	Stehekin	E	11.3	2172	17.2	Stock
MR-09-01	Unnamed (Pond Se Of Kettling Lks)	Stehekin	E	4.7	5945		Stock
MR-12-01	Unnamed	Stehekin	E	1.5	6495		Stock
MR-13-01	Unnamed (Upper Rainbow, North)	Stehekin	E	0.6	5900		Stock
MR-13-02	Unnamed (Upper Rainbow, South)	Stehekin	E	3.6	5865		Stock
MR-05-01	Kettling	Stehekin	E	9.9	5375	2.2	Wild
MR-10-01	McAlester	Stehekin	E	13.2	5507	23	Wild
MR-14-01	Rainbow	Stehekin	E	15.5	5630		Wild
MR-16-01	Unnamed	Stehekin	E	1.9	6230		Wild
EP-05-01	Unnamed (Lower Wilcox/Sandie)	Skagit	W	5.4	5120	18.9	Mixed
LS-02-01	Unnamed (Diobsud No. 2)	Skagit	W	3.1	4220		Mixed
M-23-01	Monogram	Skagit	W	27.9	4873	37	Mixed
DD-05-01	Unnamed (Upper Bouck)	Skagit	W	5.5	5030		Stock
M-19-01	Thornton (Middle)	Skagit	W	11.9	4700		Stock
ML-02-01	Unnamed (Sweet Pea)	Ross Lake	W	10.3	5540		Stock
ML-03-01	Unnamed (Torment)	Ross Lake	W	3.6	6460	45	Stock
DD-01-01	Jeanita	Skagit	W	1.4	4904	8.2	Stock
LS-03-01	Unnamed (Diobsud No. 3)	Skagit	W	3.9	4420		Stock
M-01-01	Unnamed (Hi-Yu)	Skagit	W	3.6	3830		Stock
M-05-01	Unnamed (Nert)	Baker	W	3.6	4556	27.7	Stock
MC-06-01	Copper	Chilliwack	W	12.7	5263	67.2	Stock
MC-07-01	Unnamed (Kwahnesum)	Chilliwack	W	16.7	5102	104.3	Stock
M-07-01	Unnamed (Lower Berdeen)	Skagit	W	7.5	4460		Wild

TABLE 10. Physical, chemical, and biological data for stocked lakes in North Cascades National Park, associated with risk factors identified in Oregon State University Phase I through III studies**.**

			Epilimnetic T (C)				Total Kjeldahl Nitrogen					Risk Factors		
NPS Code	**Water**	**D(m)**	**Min**	**Max**	**Median**	**n**	**Min**	**Max**	**Median**	**n**	**Repro**	**#elevated**	**#unknown**	**Mgmt**
M-19-01	Thornton (Middle)	23	7.4	10.3	8.2	3	0.009	0.05	0.035	4		0	0	Stock
MC-06-01	Copper	20.5	9.0	11.8	10.3	3	0.03	0.033	0.032	2		0	0	Stock
ML-03-01	Unnamed (Torment)	13.7	7.1	8.9	8.0	2	0.01	0.07	0.04	2		0	0	Stock
MR-09-01	Unnamed (Se Of Kettling Lks)					0	0	0.05	0.014	3		0	2	Stock
EP-14-01	Unnamed (Hidden Lk Tarn)		10.1	15.5	12.8	2				0		1	2	Stock
M-17-01	Unnamed (Triumph)		17.1	17.1	17.1	1				0		1	2	Stock
M-24-01	Unnamed (Upper Quill)		20.0	20.0	20.0	1				0		2	2	Stock
ML-02-01	Unnamed (Sweet Pea)	7	5.6	9.0	6.5	5	0.009	0.02	0.01	3		1	0	Stock
MR-01-01	Unnamed (Stiletto)	25.6	3.3	12.0	6.1	3	0.07	0.07	0.07	1		1	0	Stock
MR-12-01	Unnamed					0	0.03	0.17	0.085	4		1	2	Stock
MR-13-02	Unnamed (Upper Rainbow, S)	2	5.6	17.2	10.6	7	0.012	0.07	0.029	10		1	0	Stock
MR-15-02	Unnamed (Lower Dee Dee)	3	5.3	9.0	7.1	2	0	0.01	0.005	2		1	0	Stock
DD-05-01	Unnamed (Upper Bouck)	8.9	7.1	13.9	10.5	2	0.06	0.06	0.06	1		2	0	Stock
HM-03-01	Ridley	10.7	15.9	22.5	18.2	7	0.194	0.194	0.194	1		2	0	Stock
M-20-01	Thornton (Lower)	33	7.7	17.8	12.2	4	0.016	0.09	0.053	2		2	0	Stock
MC-07-01	Unnamed (Kwahnesum)	31.8	11.2	13.3	12.3	2	0.05	0.05	0.05	1		2	0	Stock
MM-11-01	Unnamed (Upper Rainbow, W)	7.6	10.8	16.0	13.4	2	0.01	0.03	0.017	4		2	0	Stock
PM-01-01	No Name	9.5	6.4	10.2	7.6	3	0.021	0.436	0.229	2		2	0	Stock
DD-01-01	Jeanita	2.5	8.0	19.0	12.7	6	0.045	0.12	0.06	3		3	0	Stock
HM-04-01	Willow	7.5	9.8	23.6	19.5	8	0.07	0.127	0.12	3		3	0	Stock
LS-03-01	Unnamed (Diobsud No. 3)	5.12	9.3	21.3	14.8	5	0.05	0.059	0.055	2		3	0	Stock
M-01-01	Unnamed (Hi-Yu)	5.5	11.1	19.7	16.4	3	0.05	0.07	0.06	2		3	0	Stock
M-05-01	Unnamed (Nert)	8.6	11.6	20.3	15.8	5	0.055	0.17	0.084	3		3	0	Stock
MM-10-01	Coon	5.25	0.2	21.9	16.6	10	0.14	0.15	0.147	3		3	0	Stock
MR-11-01	Unnamed	8.4	7.9	17.5	14.6	6	0.021	0.47	0.06	9		3	0	Stock
MR-13-01	Unnamed (Upper Rainbow, N)	2.2	8.0	20.8	15.7	5	0.012	0.09	0.053	8		3	0	Stock
RD-05-02	Panther Potholes (Lower)	2.8	15.5	23.3	17.4	4	0.04	0.09	0.06	15		3	0	Stock

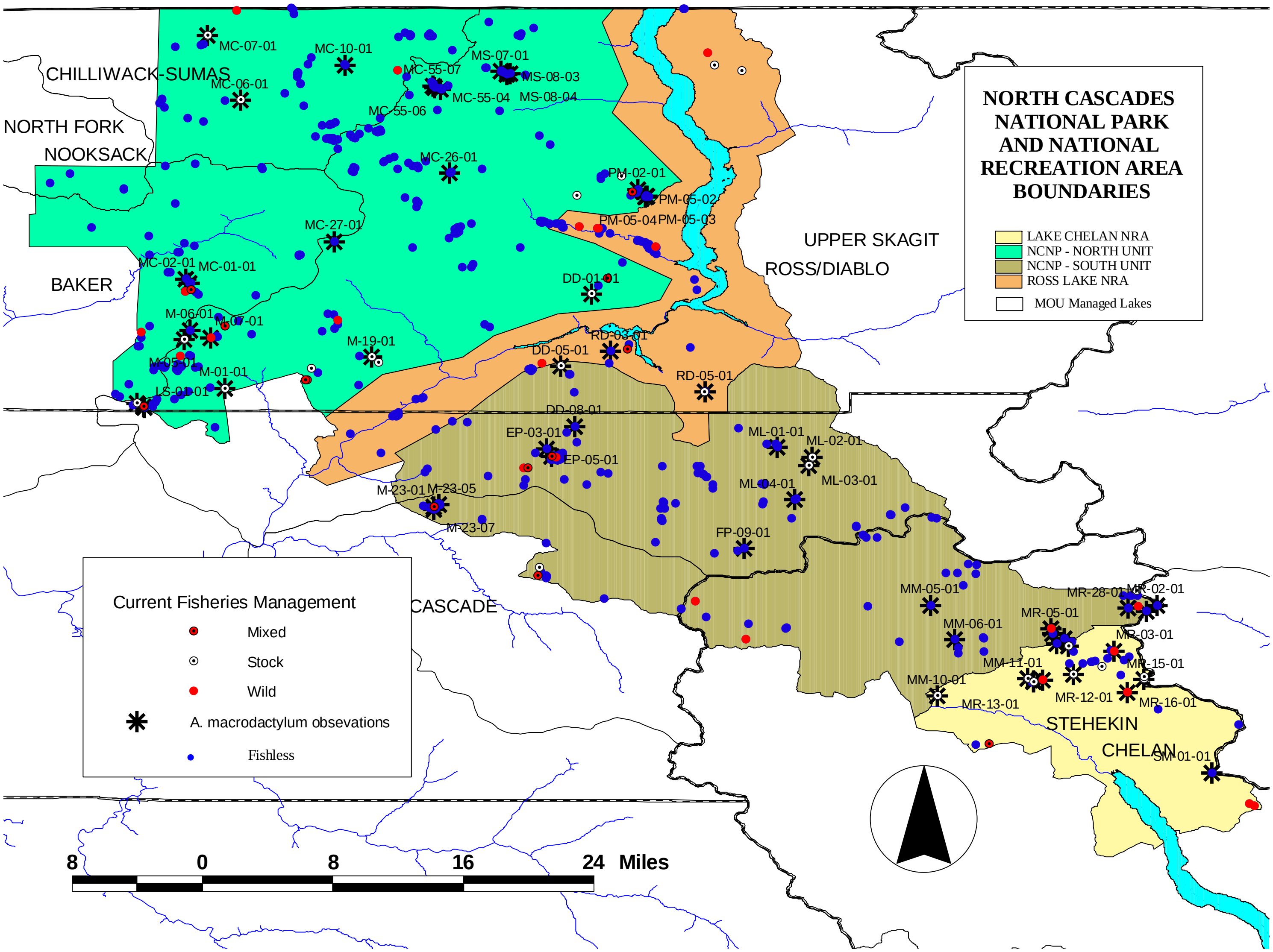
TABLE 11. Physical, chemical, and biological data for stocked lakes with limited natural reproduction in North Cascades National Park, associated with risk factors identified in Oregon State University Phase I through III studies.

			Epilimnetic T (C)				Total Kjeldahl Nitrogen					Risk Factors		
NPS Code	**Water**	**D(m)**	**Min**	**Max**	**Median**	**n**	**Min**	**Max**	**Median**	**n**	**Repro**	**#elevated**	**#unknown**	**Mgmt**
EP-09-02	Unnamed(Lower Stout)		4.0	6.8	5.4	2				0	Y	1	2	Mixed
M-08-01	Berdeen	65.5	3.5	15.0	9.3	2				0	Y	1	1	Mixed
M-11-01	Blum (Largest/Middle, #3)		11.0	11.0	11.0	1				0	Y	1	2	Mixed
M-24-02	Unnamed (Lower Quill)					0				0	Y	1	3	Mixed
SB-01-01	Hidden	78.7	3.4	9.7	7.2	3				0	Y	1	1	Mixed
M-23-01	Monogram	37.2	10.5	17.0	12.3	6	0.016	0.03	0.023	2	Y	2	0	Mixed
PM-03-01	Skymo	6.1	5.3	13.9	11.1	6	0.02	0.078	0.04	4	Y	2	0	Mixed
PM-12-01	Sourdough	32.6	14.7	14.7	14.7	1				0	Y	2	1	Mixed
EP-05-01	Unnamed (Lower Wilcox)	5.75	13.1	13.9	13.5	2	0.03	0.03	0.03	1	Y	3	0	Mixed
MLY-02-01	Battalion	2.4	7.8	16.4	12.2	8	0.02	0.054	0.035	4	Y	3	0	Mixed
LS-02-01	Unnamed (Diobsud # 2)	5.75	7.0	20.4	13.7	10	0	0.081	0.06	11	Y	4	0	Mixed
RD-02-01	Thunder	8.25	0.4	25.5	15.3	79	0.071	0.166	0.12	5	Y	4	0	Mixed

TABLE 12. Physical, chemical, and biological data for lakes in North Cascades National Park managed exclusively from wild reproducing fish populations, associated with risk factors identified in Oregon State University Phase I through III studies.

			Epilimnetic T (C)				Total Kjeldahl Nitrogen					Risk Factors		
NPS Code	**Water**	**D(m)**	**Min**	**Max**	**Median**	**n**	**Min**	**Max**	**Median**	**n**	**Repro**	**# elevated**	**#unknown**	**Mgmt**
CP-01-01	Doubtful	17.7	3.8	13.3	10.9	5	0.016	0.03	0.019	4	Y	1	0	NR
DD-04-01	Bouck	19.25	6.3	16.0	11.2	2	0.04	0.04	0.04	1	Y	1	0	NR
M-04-01	Green	46.7	4.9	12.5	8.7	2				0	Y	1	1	NR
M-07-01	Unnamed (Lower Berdeen)	11	6.9	12.5	9.7	2	0.02	0.02	0.02	1	Y	1	0	NR
MC-12-01	Bear	46.3	11.3	11.5	11.4	2	0.012	0.012	0.012	1	Y	1	0	NR
EP-06-01	Unnamed (Upper Wilcox)	20.1	7.3	16.7	14.5	3	0.021	0.027	0.024	2	Y	2	0	NR
EP-09-01	Stout	55.3	13.2	13.2	13.2	1	0.04	0.04	0.04	1	Y	2	0	NR
GM-01-01	Trapper	49	13.3	15.0	14.1	4	0.009	0.023	0.019	3	Y	2	0	NR
LS-06-01	Ipsoot	15.5	17.5	21.9	19.7	2				0	Y	2	1	NR
M-21-01	Unnamed (Doug's Tarn)	3.1	8.4	14.0	11.2	2	0.01	0.01	0.01	1	Y	2	0	NR
MP-02-01	Unnamed (Firn)	11.5	12.6	12.6	12.6	1				0	Y	1	1	NR
MR-14-01	Rainbow	10.4	3.8	19.0	13.1	8	0.02	0.1	0.045	8	Y	2	0	NR
MR-15-01	Unnamed (Upper Dee Dee)	27.2	6.2	8.5	7.4	2	0	0.04	0.015	4	Y	1	0	NR
MR-16-01	Unnamed					0	0.04	0.07	0.055	2	Y	2	2	NR
HM-02-01	Hozomeen	19	11.4	22.2	17.4	16	0.09	0.112	0.101	2	Y	3	0	NR
LS-07-01	Blum (Lower/West, N0. 4)	7.9	12.5	13.3	12.9	2	0.02	0.02	0.02	1	Y	3	0	NR
MR-05-01	Kettling	6.7	11.4	11.4	11.4	1	0.04	0.07	0.055	2	Y	3	0	NR
MR-10-01	McAlester	7	6.9	18.3	13.0	8	0.031	0.12	0.045	6	Y	3	0	NR
SM-02-02	Triplet (Upper)	3.8	19.7	19.7	19.7	1	0.03	0.07	0.03	3	Y	3	0	NR
MR-04-01	Dagger	4	10.0	23.0	12.3	6	0.1	0.17	0.15	4	Y	4	0	NR
SM-02-01	Triplet (Lower)	2.2	17.5	17.5	17.5	1	0.05	0.09	0.06	3	Y	4	0	NR

FIGURE 17. Geographic distribution of long-toed salamander (*A. macrodactylum*) observations in relation to waters currently managed for fisheries in North Cascades National Park



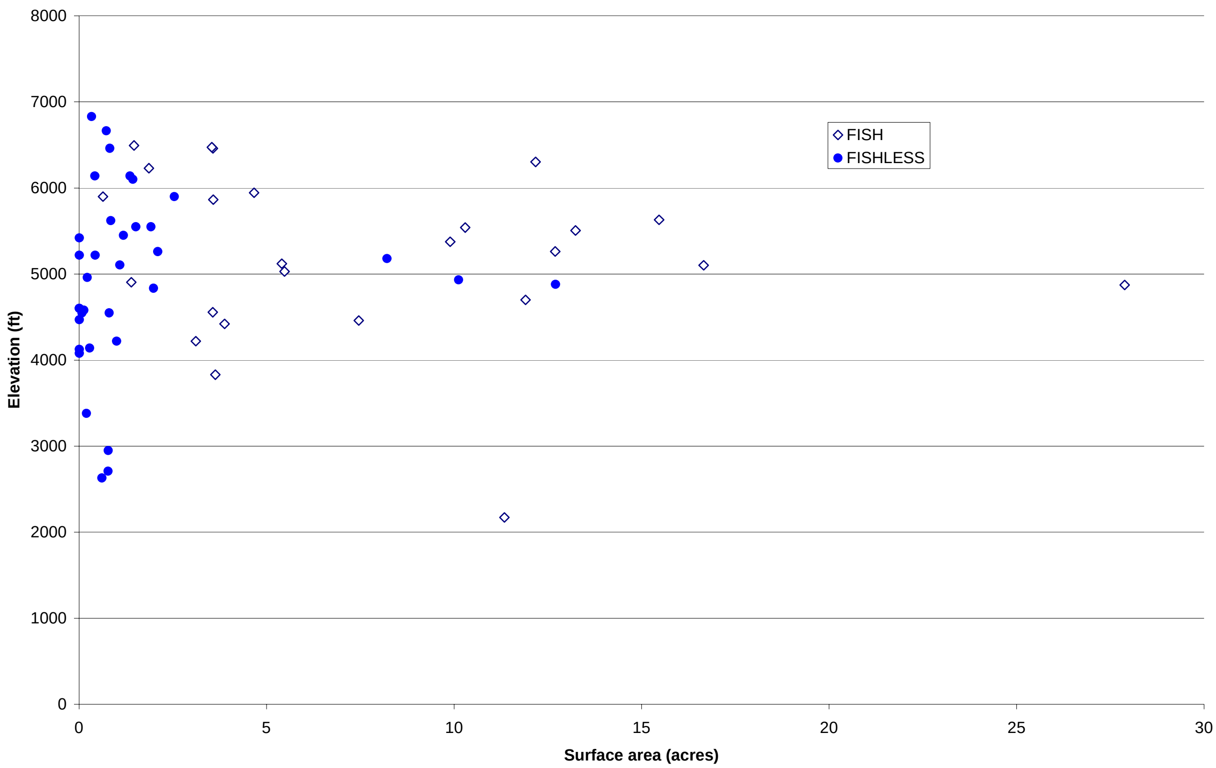


FIGURE 18. Distribution of fishless and fish inhabited waters with respect to surface area and elevation where long-toed salamander (*A. macrodactylum*) have been observed.

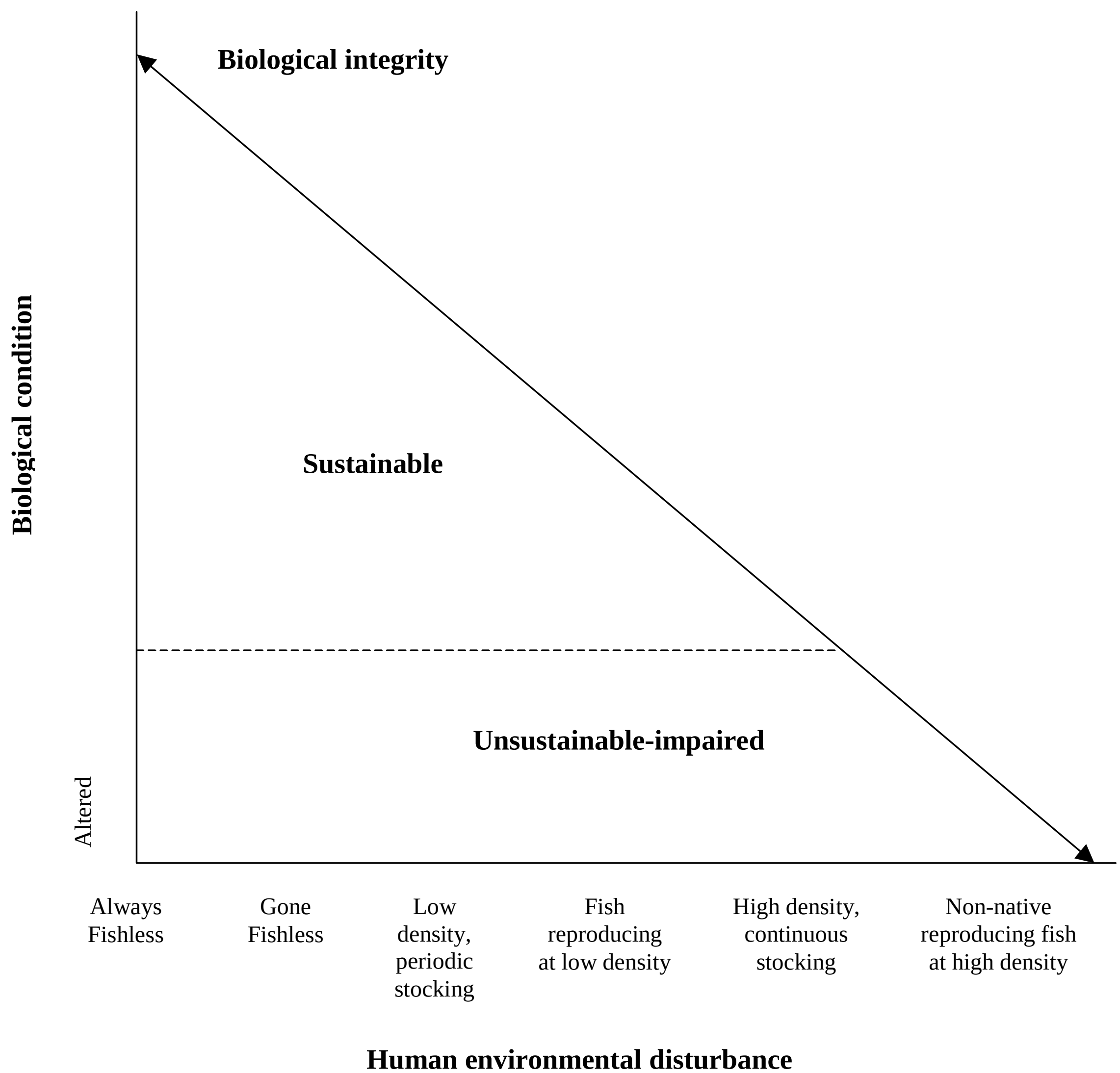


FIGURE 19. Application of conceptual biological integrity model to disturbance associated with various states of fish presence in historically fishless waters. (see Karr 2000)

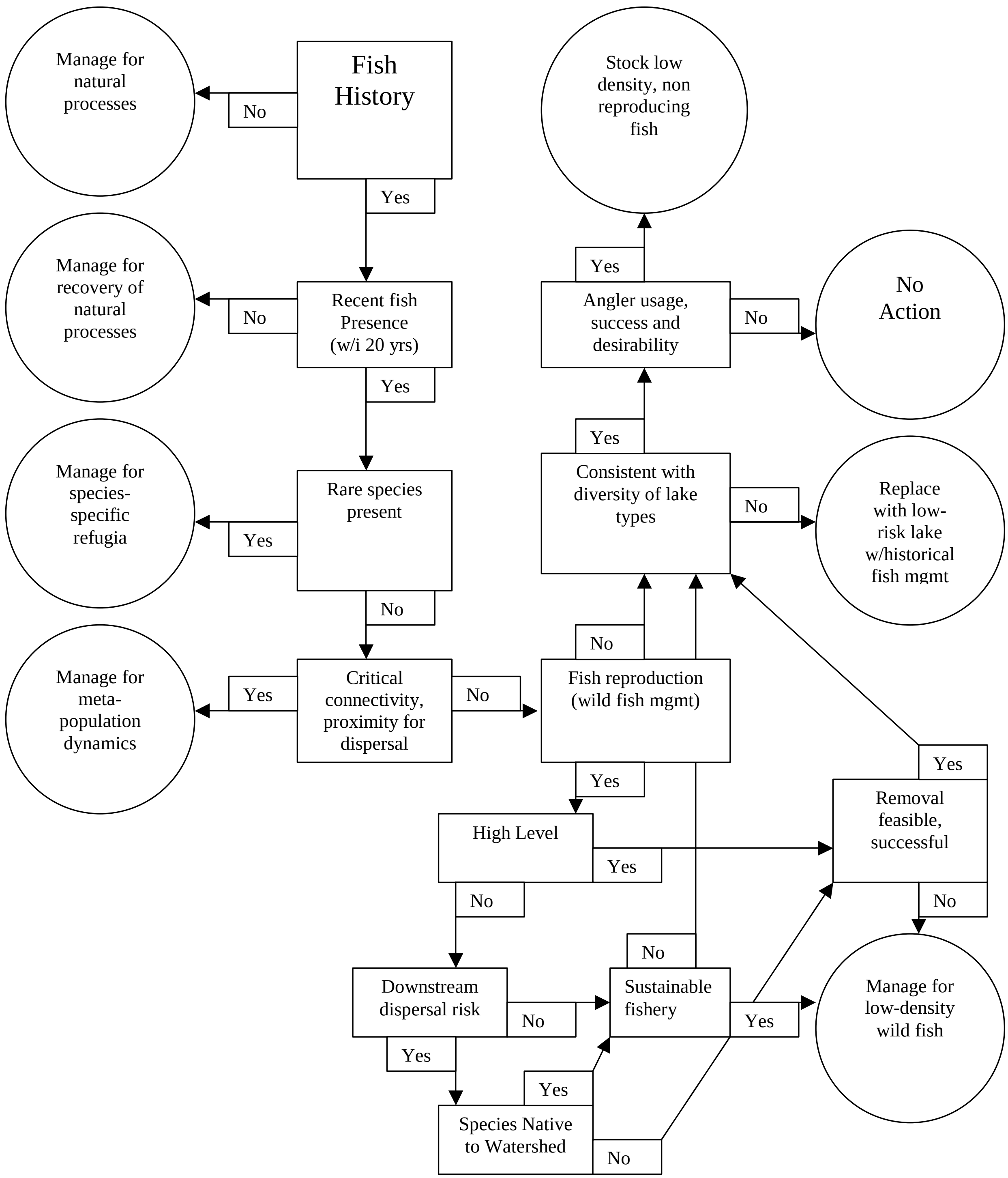


FIGURE 20. Proposed management decision tree for lakes in North Cascades National Park.

TABLE 13. Potential future management of North Cascades National Park lakes with non-native fish, with high levels of reproduction (H) or with potential for downstream risks (PDSR) based on application of biological integrity model.

NPScode	Water	Unit	SA (ac)	Current Mgmt	Reproductive Status	Mgmt under BI	TB Rating
M-24-01	Unnamed (U Quill)	South	0.9	Mixed	H	Fishless	GP
MR-15-02	Unnamed (L Dee Dee)	Chelan	0.8	Wild	H	Fishless	FP
SM-02-02	Triplet (U)	Chelan	2.3	Wild	H	Fishless	GP
CP-01-01	Doubtful	South	30.2	Wild	H	Reduction	FP
M-24-02	Unnamed (L Quill)	South	0.5	Mixed	H	Reduction	GP
MC-08-01	Hanging	North	88.8	Wild	H	Reduction	GP
MR-04-01	Dagger	South	8.2	Wild	H	Reduction	GP
MR-10-01	McAlester	Chelan	13.2	Wild	H	Reduction	GP
MR-15-01	Unnamed (U Dee Dee)	Chelan	12.2	Wild	H	Reduction	GP
SM-02-01	Triplet (L)	Chelan	2.2	Wild	H	Reduction	FP
PM-03-01	Skymo	North	10.8	Mixed	H	R Stock NRF	GP
EP-06-01	Unnamed (U Wilcox)	South	10.5	Wild	H (PDSR)	Fishless	GP
HM-02-01	Hozomeen	Ross	97.4	Wild	H (PDSR)	Fishless	GP
M-07-01	Unnamed (L Berdeen)	North	7.5	Wild	H (PDSR)	Fishless	GP
MR-05-01	Kettling	South	9.9	Wild	H (PDSR)	Fishless	FP
DD-04-01	Bouck	Ross	10.8	Wild	H (PDSR)	R Stock NRF	NA
EP-05-01	Unnamed (L Wilcox)	South	5.4	Mixed	H (PDSR)	R Stock NRF	GP
EP-09-01	Unnamed (L Stout Lk)	South	1	Wild	H (PDSR)	R Stock NRF	GP
EP-09-02	Stout	South	25.2	Mixed	H (PDSR)	R Stock NRF	GP
LS-02-01	Unnamed (Diobsud # 2)	North	3.1	Mixed	H (PDSR)	R Stock NRF	GP
LS-06-01	Ipsoot	North	8.9	Wild	H (PDSR)	R Stock NRF	GP
LS-07-01	Blum (L/West, # 4)	North	6.4	Wild	H (PDSR)	R Stock NRF	GP
M-04-01	Green	North	80	Wild	M (PDSR)	Evaluate WF	GP
M-08-01	Berdeen	North	126.7	Mixed	M (PDSR)	Evaluate WF	GP
M-21-01	Unnamed (Doug’s Tarn)	North	5	Wild	H (PDSR)	R Stock NRF	GP
M-23-01	Monogram	South	27.9	Mixed	H (PDSR)	R Stock NRF	GP
MC-12-01	Bear	North	25.7	Wild	H (PDSR)	R Stock NRF	GP
MLY-02-01	Battalion	Chelan	6.3	Mixed	H (PDSR)	R Stock NRF	FP
PM-12-01	Sourdough	North	27.6	Mixed	H (PDSR)	R Stock NRF	GP
MR-16-01	Unnamed	Chelan	1.9	Wild	H (PDSR)	R Stock NRF	GP

M = Moderate levels of reproduction
H = High levels of reproduction
PDSR = Potential downstream risk
R Stock NRF = Remove and stock non-reproducing fish
TB = Trail Blazers, NP, PP, FP, and GP = no, poor, fair, or good fishing potential
WF = Wild fish

TABLE 14. Potential future management of North Cascades National Park lakes with non-native fish, with low levels of reproduction (L) based on application of biological integrity model.

NPScode	Water	Unit	SA (ac)	Current Mgmt	Reproductive Status	Mgmt under BI	TB Rating
M-20-01	Thornton (Lower)	North	55.1	Mixed	L	Augment	GP
SB-01-01	Hidden	South	61.7	Mixed	L	Augment	GP
RD-02-01	Thunder	Ross	6.8	Mixed	L	Fishless	FP
DD-01-01	Jeanita	North	1.4	Wild	L	Wild	FP
GM-01-01	Trapper	South	147.2	Wild	L	Wild	GP
M-11-01	Blum (Largest/Middle, # 3)	North	12.9	Mixed	L	Wild	GP
MR-14-01	Rainbow	Chelan	15.5	Wild	L	Wild	GP

L = Low levels of reproduction
TB = Trail Blazers, NP, PP, FP, and GP = no, poor, fair, or good fishing potential

TABLE 15. Potential future management of North Cascades National Park lakes with stocked, non-reproducing non-native fish (N) based on application of biological integrity model.

NPScode	Water	Unit	SA (ac)	Current Mgmt	Reproductive Status	Mgmt under BI	TB Rating
DD-05-01	Unnamed (U Bouck)	South	5.5	Stock	N	Fishless	FP
EP-14-01	Unnamed (Hidden Lk Tarn)	South	4.9	Stock	N	Fishless	GP
M-05-01	Unnamed (Nert)	North	3.6	Stock	N	Fishless	NP
MC-06-01	Copper	North	12.7	Stock	N	Fishless	FP
ML-03-01	Unnamed (Torment)	South	3.6	Stock	N	Fishless	PP
MM-11-01	Unnamed (U Rainbow, W)	Chelan	3.5	Stock	N	Fishless	PP
MR-11-01	Unnamed	Chelan	2.9	Stock	N	Fishless	FP
MR-12-01	Unnamed	Chelan	1.5	Stock	N	Fishless	FP
MR-13-01	Unnamed (U Rainbow, N)	Chelan	0.6	Stock	N	Fishless	PP
MR-13-02	Unnamed (U Rainbow, S)	Chelan	3.6	Stock	N	Fishless	PP
HM-03-01	Ridley	Ross	10.9	Stock	N	Stock NRF	GP
HM-04-01	Willow	Ross	16.9	Stock	N	Stock NRF	GP
LS-03-01	Unnamed (Diobsud # 3)	North	3.9	Stock	N	Stock NRF	GP
LS-04-01	Green Bench	North	4.1	Fishless	N	Stock NRF	FP
M-01-01	Unnamed (Hi-Yu)	North	3.6	Stock	N	Stock NRF	GP
M-17-01	Unnamed (Triumph)	North	4.3	Stock	N	Stock NRF	GP
M-19-01	Thornton (Middle)	North	11.9	Stock	N	Stock NRF	FP
MC-07-01	Unnamed (Kwahnesum)	North	16.7	Stock	N	Stock NRF	FP
ML-02-01	Unnamed (Sweet Pea)	South	10.3	Stock	N	Stock NRF	PP
ML-04-01	Vulcan	North	8.2	Fishless	N	Stock NRF	FP
MM-10-01	Coon	Chelan	11.3	Stock	N	Stock NRF	GP
MP-02-01	Unnamed (Firn)	North	5.7	Stock	N	Stock NRF	GP
MR-01-01	Unnamed (Stiletto)	South	9.9	Stock	N	Stock NRF	FP
MR-09-01	Unnamed (SE of Kettling Lks)	Chelan	4.7	Stock	N	Stock NRF	GP
PM-01-01	No Name	North	7.5	Stock	N	Stock NRF	GP
RD-05-02	Panther Pots (L)	Ross	0.5	Stock	N	Stock NRF	FP

N = No reproduction
Stock NRF = Stock non-reproducing fish
TB = Trail Blazers, NP, PP, FP, and GP = no, poor, fair, or good fishing potential

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APPENDIX A: LIST OF LAKES WITH STOCKING RECORDS

NPS Code	Water Name	Freq	First Stocked	Last Stocked	Species
CP-01-01	Doubtful	1	09/07/1950	09/07/1950	O. clarki
		2	09/16/1962	09/23/1962	O. mykiss
DD-01-01	Jeanita	1	10/05/1986	10/05/1986	O. aguabonita (Tokul)
		3	07/01/1961	08/19/1978	O. aguabonita aguabonita
DD-04-01	Bouck	2	07/01/1939	07/01/1947	O. clarki
DD-05-01	Unnamed (Upper Bouck)	3	08/28/1986	09/17/1994	O. aguabonita (Tokul)
		3	09/28/1968	10/02/1999	O. aguabonita aguabonita
EP-05-01	Unnamed (Lower Wilcox/Sandie)	1	07/01/1967	07/01/1967	O. clarki
		3	09/06/1981	08/25/1993	O. mykiss (Mt Whitney)
EP-06-01	Unnamed (Upper Wilcox/Lillie)	1	07/01/1967	07/01/1967	O. clarki
EP-09-02	Unnamed(Lower Stout Lake)	1	07/01/1953	07/01/1953	O. clarki
		1	09/10/1967	09/10/1967	O. clarki clarki
EP-10-01	Pegasus	1	01/01/1967	01/01/1967	O. mykiss & clarki
		1	09/06/1981	09/06/1981	O. mykiss (Mt Whitney)
EP-13-01	Sky	1	09/04/1968	09/04/1968	O. mykiss
EP-14-01	Unnamed (Hidden Lk Tarn)	1	08/20/1966	08/20/1966	O. mykiss
		1	10/10/1991	10/10/1991	O. mykiss (Hagerman)
		3	08/16/1986	08/22/2002	O. mykiss (Mt Whitney)
FP-01-01	Austera	1	01/01/1967	01/01/1967	O. mykiss & clarki
GM-01-01	Trapper	9	08/14/1948	08/01/1968	O. clarki
	Ridley	1	05/07/1998	05/07/1998	O. mykiss
		8	06/28/1975	05/23/2000	O. mykiss (Mt Whitney)
HM-04-01	Willow	2	09/27/1960	07/01/1967	O. clarki
		9	05/12/1993	05/21/2002	O. clarki clarki
		2	08/21/1985	08/26/1988	O. clarki lewisi (Twin Lk)
		1	08/20/1978	08/20/1978	O. mykiss (Mt Whitney)
LS-01-01	Unnamed (Diobsud No. 1)	1	08/06/1960	08/06/1960	O. clarki lewisi (Twin Lk)
LS-02-01	Unnamed (Diobsud No. 2)	2	08/06/1960	09/10/1990	O. clarki lewisi (Twin Lk)
		1	09/01/1997	09/01/1997	O. mykiss (Mt Whitney)
LS-03-01	Unnamed (Diobsud No. 3)	5	08/06/1960	09/10/1990	O. clarki lewisi (Twin Lk)
		2	08/31/1993	09/01/1997	O. mykiss (Mt Whitney)
LS-06-01	Ipsoot	2	07/01/1936	07/01/1961	O. clarki lewisi (Twin Lk)
		1	08/16/1951	08/16/1951	O. mykiss
LS-07-01	Blum (Lower/West, N0. 4)	1	07/19/1937	07/19/1937	Salvelinus fontinalis
LS-14-01	Unnamed (Upper Noisy Ck)	1	08/06/1960	08/06/1960	O. clarki
M-01-01	Unnamed (Hi-Yu)	1	07/01/1961	07/01/1961	O. mykiss
		5	08/20/1978	08/25/2001	O. mykiss (Mt Whitney)
M-04-01	Green	1	08/18/1947	08/18/1947	O. clarki lewisi (Twin Lk)
		1	08/21/1946	08/21/1946	O. mykiss
M-05-01	Unnamed (Nert)	1	10/12/1986	10/12/1986	O. aguabonita (Tokul)
		2	09/21/1968	09/16/1980	O. aguabonita aguabonita
		1	09/25/1993	09/25/1993	O. mykiss (Mt Whitney)
M-06-01	Unnamed (Talus Tarn)	2	09/21/1968	09/16/1980	O. aguabonita aguabonita
M-07-01	Unnamed (Lower Berdeen)	1	07/01/1946	07/01/1946	O. mykiss
M-08-01	Berdeen	1	08/16/1946	08/16/1946	O. clarki bouvieri
		4	09/01/1967	09/20/1989	O. clarki lewisi (Twin Lk)
		1	08/22/1946	08/22/1946	O. mykiss

		1	09/11/1995	09/11/1995	O. mykiss (Mt Whitney)
M-11-01	Blum (Largest/Middle, No. 3)	1	09/17/1960	09/17/1960	O. aguabonita aguabonita
		1	08/01/1938	08/01/1938	O. mykiss
		2	08/31/1993	09/19/1994	O. mykiss (Mt Whitney)
M-13-01	Despair #1	1	09/05/1965	09/05/1965	O. clarki
M-14-01	Despair #2	1	09/05/1965	09/05/1965	O. clarki
M-17-01	Unnamed (Triumph)	1	07/29/1961	07/29/1961	O. mykiss
		6	08/09/1980	08/24/2002	O. mykiss (Mt Whitney)
M-19-01	Thornton (Middle)	3	08/19/1986	09/19/1997	O. aguabonita (Tokul)
		4	10/04/1959	09/12/1981	O. aguabonita aguabonita
		2	09/30/1941	06/03/1945	O. mykiss
		1	09/30/1944	09/30/1944	O. mykiss (Steelhead)
M-20-01	Thornton (Lower)	1	08/01/1966	08/01/1966	O. aguabonita aguabonita
		2	07/01/1953	09/05/1968	O. clarki
		1	09/29/1970	09/29/1970	O. clarki clarki
		1	10/07/1976	10/07/1976	O. clarki lewisi (Twin Lk)
		3	07/01/1941	07/01/1952	O. mykiss
		2	07/21/1988	10/01/1998	O. mykiss (Mt Whitney)
		1	09/30/1944	09/30/1944	O. mykiss (Steelhead)
M-21-01	Unnamed (Doug's Tarn)	1	09/05/1965	09/05/1965	O. clarki
M-23-01	Monogram	4	07/01/1947	09/01/1964	O. clarki
		1	07/01/1932	07/01/1932	O. clarki bouvieri
		2	09/29/1970	10/07/1976	O. clarki lewisi (Twin Lk)
		1	08/20/1949	08/20/1949	O. mykiss
		2	08/20/1986	08/22/1995	O. mykiss (Mt Whitney)
M-24-01	Unnamed (Upper Quill)	2	07/29/1961	08/10/1989	O. mykiss
		3	08/09/1980	08/24/2002	O. mykiss (Mt Whitney)
M-24-02	Unnamed (Lower Quill)	1	08/10/1989	08/10/1989	O. mykiss
		2	08/09/1980	08/24/2002	O. mykiss (Mt Whitney)
MC-01-01	Blum (Small/North, No. 2)	1	07/01/1938	07/01/1938	O. mykiss
MC-02-01	Blum (Vista/Northwest, No. 1)	1	10/01/1968	10/01/1968	O. aguabonita aguabonita
MC-06-01	Copper	1	07/01/1960	07/01/1960	O. clarki
		1	07/01/1939	07/01/1939	O. clarki bouvieri
		1	10/01/1980	10/01/1980	O. clarki clarki
		2	08/21/1985	08/07/1989	O. clarki lewisi (Twin Lk)
		2	08/31/1993	10/06/1998	O. mykiss (Mt Whitney)
		2	07/01/1937	07/01/1957	Salvelinus fontinalis
MC-07-01	Unnamed (Kwahnesum)	1	09/02/1966	09/02/1966	O. clarki
		4	07/29/1983	10/06/1998	O. mykiss (Mt Whitney)
MC-11-01	Redoubt	1	07/01/1967	07/01/1967	O. clarki lewisi (Twin Lk)
MC-12-01	Bear	1	08/14/1967	08/14/1967	O. clarki
MC-14-01	East Lakes (Upper)	1	08/15/1967	08/15/1967	O. mykiss
MC-14-02	East Lakes (Lower)	1	08/15/1967	08/15/1967	O. mykiss
MC-16-01	Middle (Upper)	1	07/01/1967	07/01/1967	O. mykiss
MC-16-02	Middle (Lower)	1	07/01/1967	07/01/1967	O. mykiss
MC-17-01	Tapto (Upper)	1	09/21/1960	09/21/1960	O. clarki lewisi (Twin Lk)
MC-17-02	Tapto (Middle)	1	07/01/1960	07/01/1960	O. mykiss
MC-17-03	Tapto (Lower)	1	09/21/1960	09/21/1960	O. clarki lewisi (Twin Lk)
MC-17-04	Tapto (West)	1	07/01/1960	07/01/1960	O. clarki lewisi (Twin Lk)
MC-21-01	Reveille (Upper)	1	07/01/1968	07/01/1968	O. mykiss

MC-21-02	Reveille (Lower)	1	10/20/1968	10/20/1968	O. mykiss
MC-27-01	Wild	1	09/30/1968	09/30/1968	O. clarki lewisi (Twin Lk)
		1	07/01/1967	07/01/1967	O. mykiss
ML-01-01	Unnamed (Sourpuss)	1	01/01/1968	01/01/1968	O. mykiss
ML-02-01	Unnamed (Sweet Pea)	1	01/01/1968	01/01/1968	O. mykiss
		4	08/10/1985	09/20/1999	O. mykiss (Mt Whitney)
ML-03-01	Unnamed (Torment)	3	08/11/1985	08/18/1995	O. mykiss (Mt Whitney)
ML-04-01	Unnamed (Vulcan)	1	08/01/1968	08/01/1968	O. mykiss (Hagerman)
MLY-02-01	Battalion	4	08/05/1978	09/27/1996	O. mykiss (Mt Whitney)
MM-10-01	Coon	3	01/01/1915	09/18/2000	O. clarki
		9	09/20/1976	08/24/1992	O. clarki lewisi (Twin Lk)
		1	07/29/1939	07/29/1939	O. mykiss
		3	01/01/1930	05/18/1963	Salvelinus fontinalis
MM-11-01	Unnamed (Upper Rainbow, West)	2	08/03/1988	08/14/1998	O. mykiss (Mt Whitney)
MP-02-01	Unnamed (Firn)	1	10/01/1983	10/01/1983	O. clarki lewisi (Twin Lk)
		1	09/01/1968	09/01/1968	O. mykiss
		2	07/21/1988	09/11/2000	O. mykiss (Mt Whitney)
MP-09-01	Azure	1	09/01/1961	09/01/1961	O. aguabonita aguabonita
		1	01/01/1938	01/01/1938	O. mykiss
MR-01-01	Unnamed (Stiletto)	1	09/18/1966	09/18/1966	O. aguabonita aguabonita
		1	09/01/1967	09/01/1967	O. clarki
		3	09/28/1979	08/25/1989	O. clarki lewisi (Twin Lk)
		1	09/12/1995	09/12/1995	O. mykiss (Mt Whitney)
MR-04-01	Dagger	1	07/14/1934	07/14/1934	O. clarki
MR-09-01	Unnamed (Pond Se Of Kettling Lks)	3	07/28/1988	08/15/1998	O. mykiss (Mt Whitney)
MR-10-01	McAlester	3	09/09/1941	09/01/1967	O. clarki
		1	09/20/1976	09/20/1976	O. clarki lewisi (Twin Lk)
		1	08/31/1942	08/31/1942	O. mykiss
MR-11-01	Unnamed	3	09/10/1990	09/05/2002	O. mykiss (Mt Whitney)
MR-12-01	Bowan	4	10/01/1983	09/28/2002	O. mykiss (Mt Whitney)
MR-13-01	Unnamed (Upper Rainbow, North)	3	08/28/1984	08/01/1988	O. mykiss
MR-13-02	Unnamed (Upper Rainbow, South)	2	08/28/1984	10/29/1984	O. mykiss
		3	08/03/1988	09/09/1996	O. mykiss (Mt Whitney)
MR-15-01	Unnamed (Upper Dee Dee)	2	08/27/1983	09/04/1999	O. mykiss (Mt Whitney)
MR-16-01	Unnamed	1	08/27/1983	08/27/1983	O. mykiss (Mt Whitney)
MS-01-01	Silver	1	07/01/1961	07/01/1961	O. aguabonita aguabonita
PM-01-01	No Name	2	07/01/1947	08/27/1978	O. mykiss
		3	09/21/1985	09/03/1993	O. mykiss (Mt Whitney)
PM-03-01	Skymo	1	09/01/1968	09/01/1968	O. clarki
		3	08/31/1993	10/06/1998	O. mykiss (Mt Whitney)
PM-12-01	Sourdough	3	08/31/1993	10/06/1998	O. mykiss (Mt Whitney)
RD-02-01	Thunder	8	09/04/1952	05/01/1979	O. clarki
		8	08/25/1974	09/09/1986	O. clarki clarki
		2	10/05/1972	08/16/1985	O. clarki lewisi (Twin Lk)
		6	06/28/1947	05/23/1984	O. mykiss
		4	06/03/1981	08/31/1992	O. mykiss (Mt Whitney)
RD-03-01	Pyramid	1	09/20/1968	09/20/1968	O. aguabonita aguabonita
		1	07/01/1948	07/01/1948	O. clarki
		1	01/01/1936	01/01/1936	Salmonidae
RD-05-01	Panther Potholes (Upper)	1	06/23/1979	06/23/1979	O. clarki bouvieri (Henry Lk)

		2	09/15/1984	09/18/1988	O. clarki lewisi (Twin Lk)
RD-05-02	Panther Potholes (Lower)	3	09/11/1948	07/01/1967	O. clarki
		1	06/23/1979	06/23/1979	O. clarki bouvieri (Henry Lk)
		3	09/15/1984	09/10/1990	O. clarki lewisi (Twin Lk)
		2	01/01/1935	01/01/1994	Salmonidae
SB-01-01	Hidden	1	09/10/1993	09/10/1993	O. aguabonita (Tokul)
		1	10/01/1965	10/01/1965	O. aguabonita aguabonita
		3	07/01/1946	10/01/1966	O. mykiss
		1	08/10/1963	08/10/1963	O. mykiss (Kamloops)
		5	08/21/1985	08/27/2001	O. mykiss (Mt Whitney)
SM-02-01	Triplet (Lower)	1	09/01/1972	09/01/1972	O. clarki
SM-02-02	Triplet (Upper)	1	09/01/1972	09/01/1972	O. clarki

APPENDIX B: UNDOCUMENTED INTRODUCTIONS OF FISH

NPScode	Water	Species Observed	Survey Source	Year
EP-09-01	Unnamed(Lower Stout Lake)	O. clarki	NCNP survey	1974
HM-02-01	Hozomeen	Salvelinus fontinalis	NCNP survey	1979
LS-04-01	Unnamed	O. clarki	High Lake Report	1971
M-23-11	Unnamed (Monogram Tarn)	O. clarki	NCNP survey	1998
MC-15-01	Tiny	O. clarki	NCNP archive files	1969
ML-09-01	Unnamed(Fisher Ck Pond, Main)	O. clarki	NCNP survey	1998
ML-09-02	Unnamed(Fisher Ck Pond West)	O. clarki	NCNP survey	1998
MR-05-01	Kettling	O. clarki, O. mykiss, hybrids	NCNP survey	1976
MR-15-02	Unnamed (Lower Dee Dee/Tamarack)	O. clarki, O. mykiss	NCNP survey	1985, 98
MR-28-01	Below Dagger Lake Wetland	O. clarki	NCNP survey	1997
ML-09-03	Unnamed(Fisher Ck Pond West)	O. clarki	NCNP survey	1998
MR-14-01	Rainbow	O. mykiss	OSU survey	1992