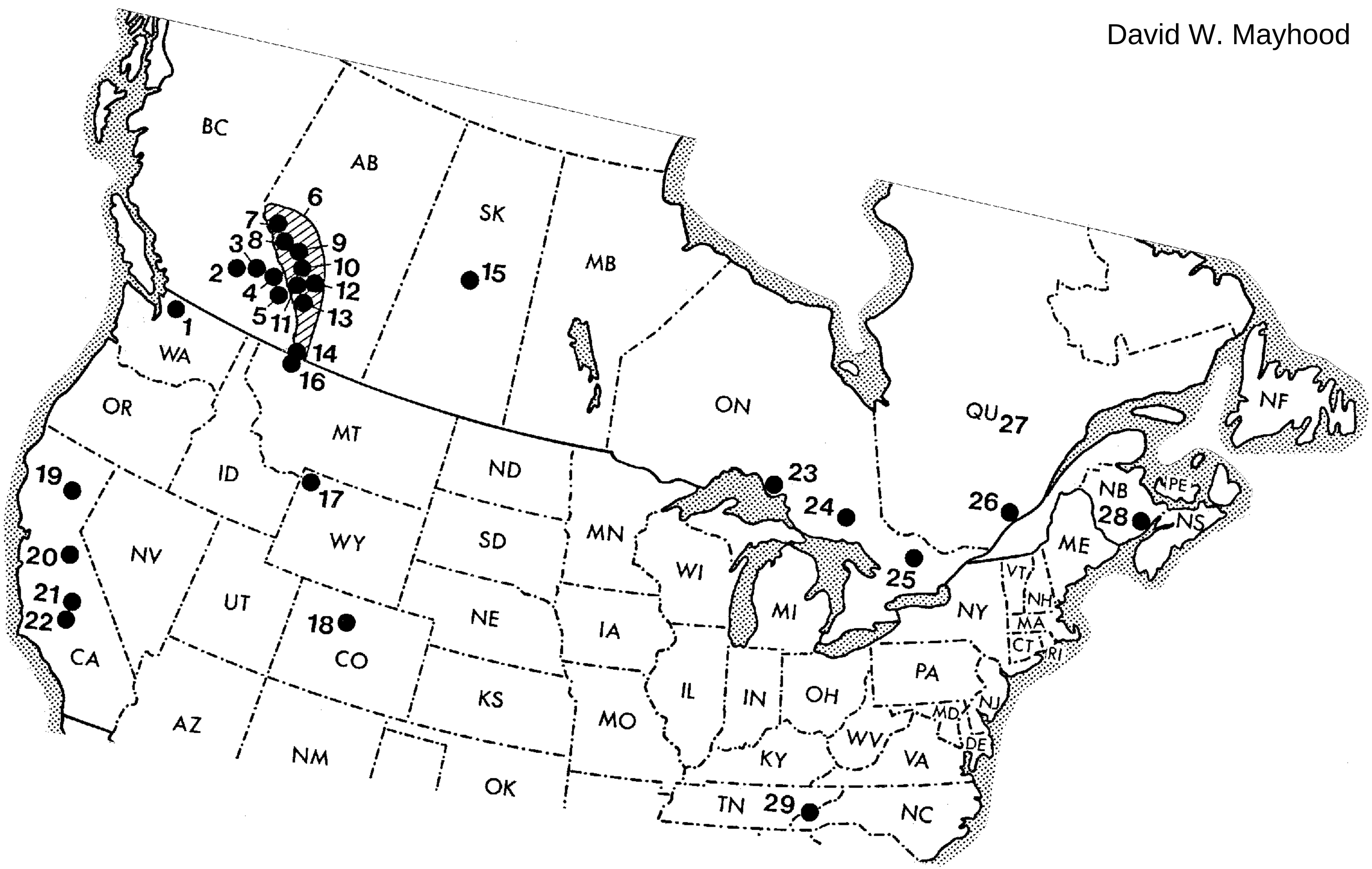
Approaches to Managing Freshwater Fishes in North American Parks and Reserves

David W. Mayhood



Part 2 of a Fish Management Plan for Jasper National Park

Freshwater Research Limited

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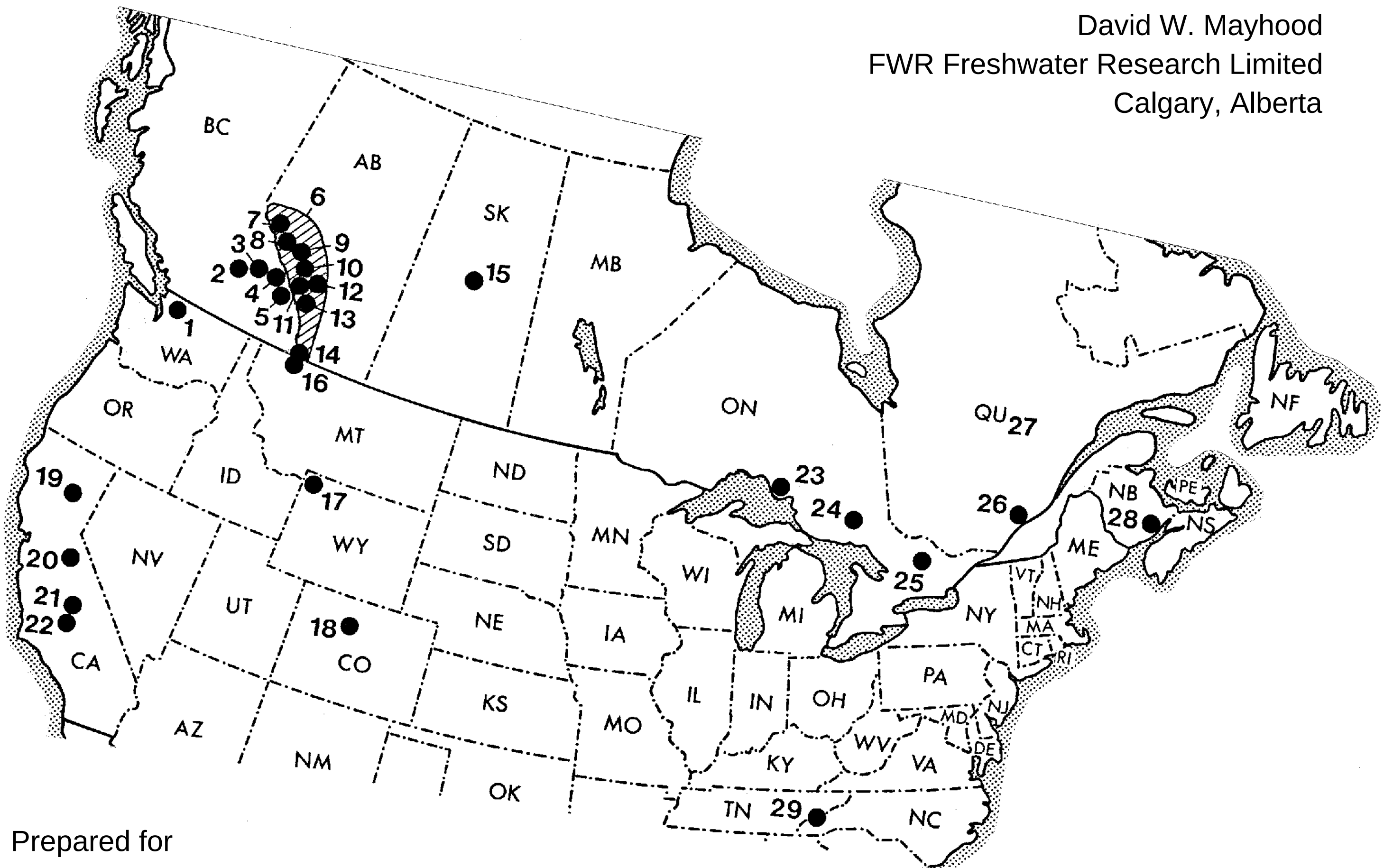

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Part 2 of a Fish Management Plan for Jasper National Park

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Cover & Title Page. The parks, reserves and management areas included in this survey. The names of the locations are listed in Figure 1.

ABSTRACT

I surveyed fish management programs and individual projects in 16 national parks, provincial parks and other similar jurisdictions throughout North America to help establish a context for fish management in Jasper National Park, to examine the pitfalls that have been encountered elsewhere, and to investigate approaches and specific techniques that may be applied to fish management problems in Jasper. Only a small minority of fish management documents are ever published, so the survey relied upon internal manuscripts and direct telephone interviews with fisheries managers for much of its source material. The principal conclusions follow.

By virtue of their governing legislation and their physical circumstances, the mountain national parks in Alberta must play a role much different from that of the provincial government in managing the fishes and fish habitats of the region. Alberta Fish and Wildlife has a mandate to maximize sport fishing opportunities in East Slopes waters, and has under its jurisdiction most of the coldwater fish habitat in the East Slopes for carrying out its mandate. The mountain national parks have significant indigenous fish populations and aquatic ecosystems of special value which they must, as their first priority, preserve in a condition as close as possible to the pristine state. The primary fish management role of the Alberta mountain national parks is to protect native fishes of the East Slopes, and the natural ecosystems of which they are a part, so that people might learn about and enjoy them *in that context* now and in the future. This protective and educational role complements fish management practices on the East Slopes outside the parks, where consumptive sport fishing is the principal use of the fish resources. By carrying out their different roles, the federal and provincial jurisdictions together will provide a complete, coherent fish management program for the Rocky Mountain East Slopes. Similar divisions of conservation- and recreation-focussed fish management are found in a variety of forms in every North American jurisdiction surveyed in this study.

Despite their common legislation and guiding policy, the Canadian national parks examined in this study vary widely in the goals and practices of their fish management programs. Nevertheless, all show a concern for restoring aquatic ecosystems or selected fish populations to something like their natural state, and a decreasing tendency to view fish management in isolation. Fish management is increasingly done in larger contexts: treating fishes as integral parts of aquatic ecosystems, or as important elements in educational programs dealing with park natural history. Most of the Canadian national parks surveyed incorporate consumptive sport fishing on native fish populations as a major use of the resource, if not *the* major use, but are de-emphasizing the practice. Consumptive fishing on native stocks clearly contravenes the 1988 National Parks Act provision requiring

maintenance of ecological integrity to be the first priority in planning for visitor use. Permitting consumptive sportfishing on native park fishes is a dubious practice at best in Canada's national parks, and is avoided in this fish management plan.

Sportfishing has many legitimate purposes in national parks, and does not need to be given special dispensation under park policy. In particular, it is a valuable management tool. It is not a first priority use of aquatic resources in national parks, however, and angling cannot legitimately be permitted in parks merely on the grounds that it is a traditional use. Catch-and-release fishing can enable large numbers of visitors to experience and learn about the rare fishes that parks protect, but it is not harmless to them and undoubtedly is seen as unethical by some part of the public. Catch-and-release alone thus is not a suitable substitute for consumptive fishing.

Managing for sustained yield, an undefined concept currently used to guide fisheries management in Canadian national parks, is dangerous to the resource it is supposed to protect because, among other problems, it relies on evidence of actual overfishing to protect against overfishing. It is an approach arranged primarily to satisfy angling harvest demand. Even to meet its limited goal of sustaining fish yield, it is probably only safely usable where angler access can be strictly controlled, quotas can be enforced, and angler catches can be closely monitored. It is being successfully used in La Mauricie National Park under those conditions. Sustained yield management on native fishes in national parks cannot in principle adequately protect the ecological integrity of parks, because it takes a "harvestable surplus" that under natural conditions would be used within the ecosystem. Managing with the goal of maintaining self-regulating aquatic ecosystems, as is currently being done in several US national parks, is much more favourable to good conservation practice while encouraging a substantial degree of appropriate visitor use.

According to current policy, stocking in Jasper must be reviewed with a view to phasing it out of the fish management program. Experience in several US parks has shown that a no-stocking policy will face stiff opposition in parks where the great majority of the lakes were originally barren of native fish. Success in implementing the policy under these conditions has been highest where good reasons for the policy were communicated to the opponents, and especially where it could be demonstrated that some fishing could be maintained without stocking.

All fish management projects need to be implemented as controlled experiments to ensure that they work in the way they are intended, and to enable us to learn from them. Some particularly risky or complex fisheries projects should be left if there is no serious immediate threat to natural ecosystems. Future fisheries specialists will have more refined tools with which to attack the more difficult problems.

The arguments supporting these conclusions are detailed in the Discussion.

ACKNOWLEDGEMENTS

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INTRODUCTION

Jasper National Park (JNP) is one of several hundred parks and similar reserves in North America principally intended to protect natural landscapes and their component ecosystems (Part 1; see also Allin 1990a and several chapters therein, especially Eidsvik and Henwood 1990, Frome et al. 1990, Stankey 1990). Each park is in a different part of the continent, contains different natural resources and has a different history, but like Jasper, a great many contain significant freshwater systems. In this sense, Jasper National Park is part of a network of similar reserves, each responsible in part for preserving some element of the greater primeval North American ecosystem.

The aquatic resources are different in each park, but many of the problems in managing them are similar. In particular, the problem of how to protect fish populations, and the ecosystems of which they are a part, in the face of exploitation by sport fishermen is almost universal.

This report, the second in a series comprising a fish management plan for Jasper National Park, summarizes the approaches and techniques used by selected natural parks and similar reserves in North America to manage their freshwater fishes. It is intended as a survey to discover how some of Jasper's partners in the continental preservation network are addressing problems in this field. Its objectives are

1. to reveal the regional, national and continental context for fish management in Jasper National Park;

2. to expose the potential pitfalls of approaches and techniques that have been used elsewhere; and

3. to discover approaches and specific techniques that might be applicable to solving problems of fish management in Jasper National Park.

No single criterion was used to select the management programs for review. I included brief overviews of fish management in the seven Canadian mountain national parks, the Alberta wilderness areas, and the East Slopes to show the regional context for fish management in Jasper. I reviewed the fish management programs of Glacier (Montana), Rocky Mountain and Yellowstone national parks in the USA in some detail because as Rocky Mountain national parks they are the American reserves to which Jasper is most closely and naturally related. All three have long experience with particularly difficult fish management and preservation problems resembling some in Jasper, and Yellowstone has served as a laboratory for innovative approaches to sport fishery management. The national parks of the Sierra Nevada and North Cascades National Park are western mountain parks with important natural similarities to ours.

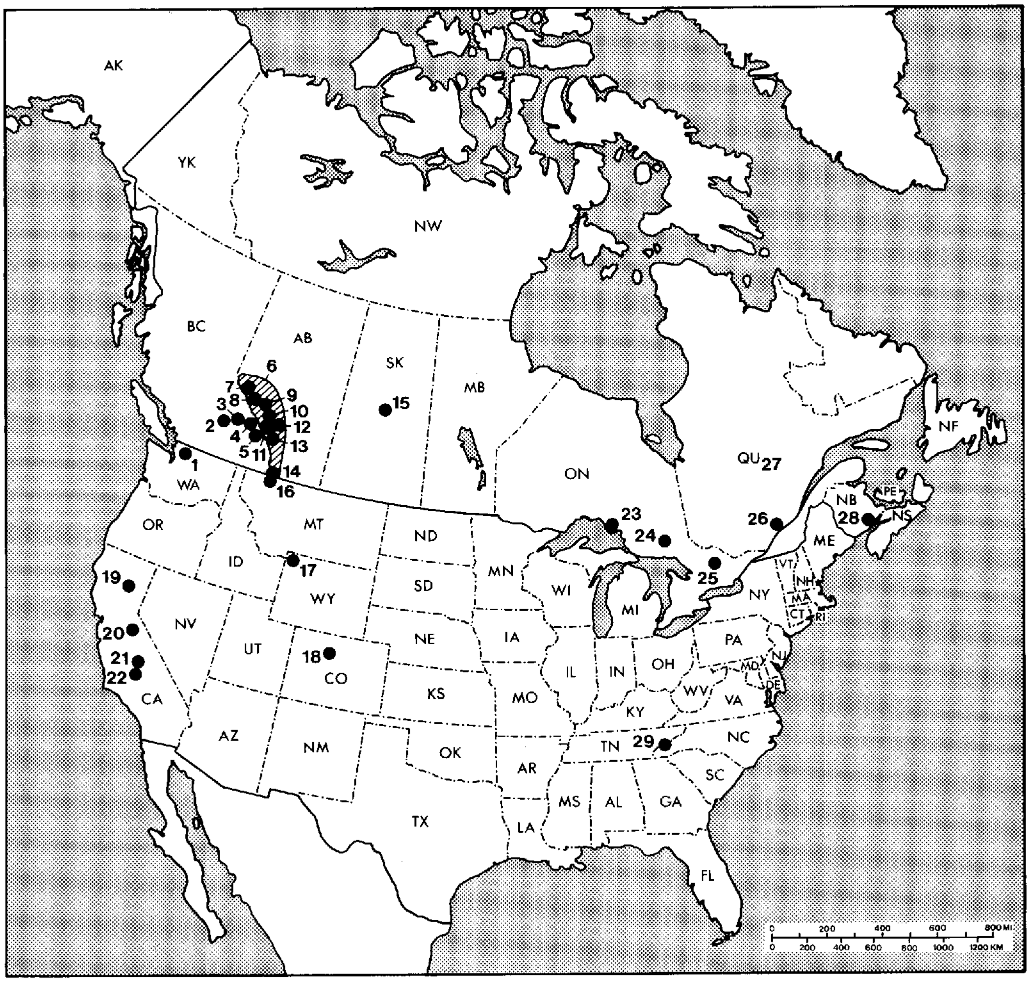
All have had to deal with a protracted and sometimes ugly dispute over fish stocking policy, a matter at issue in Jasper. Great Smoky Mountains National Park is likewise a mountain park with trout management concerns similar to ours, despite being in the southeast.

In contrast, several other parks have very different aquatic resources from those in Jasper. I included the fish and/or aquatic resource management plans for Algonquin, Fundy, Prince Albert and Pukaskwa parks in the survey because they are the most recently completed in Canada, and new ideas pertinent to this country would be expected to appear there. As might be expected, national and provincial parks in Quebec take an independent course in managing their sport fisheries, one distinctly different from those with which I am familiar. Their approach is instructive and highly intriguing.

Finally, I included an isolated recovery project, an attempt to reestablish a unique stock of charr endemic to Canada: Ontario’s aurora trout recovery plan. This, the Point Wolfe River Atlantic salmon restoration project in Fundy National Park and Rocky Mountain National Park’s cutthroat trout restoration projects, are useful examples of similar activities that may be necessary in Jasper.

The locations of the parks, reserves and project sites discussed in this survey are illustrated in Figure 1. Table 1 lists the scientific names of fish species mentioned in the text.

Figure 1. Location of parks, reserves, planning areas and special fish management projects discussed in the text. Base map adapted from Pyle (1981).



1. North Cascades NP
2. Mount Revelstoke NP
3. Glacier NP (BC Canada)
4. Yoho NP
5. Kootenay NP
6. Alberta East Slopes management region
7. Willmore Wilderness Park
8. Jasper NP
9. White Goat Wilderness
10. Siffleur Wilderness
11. Banff NP
12. Ghost Wilderness
13. Kananaskis Country
14. Waterton Lakes NP
15. Prince Albert NP
16. Glacier NP (MT USA)
17. Yellowstone NP
18. Rocky Mountain NP
19. Lassen Volcanic NP
20. Yosemite NP
21. Kings Canyon NP
22. Sequoia NP
23. Pukaskwa NP
24. Aurora Trout Recovery Project
25. Algonquin Provincial Park
26. La Mauricie NP
27. Quebec provincial parks
28. Fundy NP
29. Great Smoky Mountains NP

Table 1. Common and scientific names of the fishes mentioned in this volume. Taxonomy, nomenclature and listing order from Robins et al. (1991), except where noted otherwise. Family names in bold print.

COMMON NAME	SCIENTIFIC NAME
Lampreys	**Petromyzontidae**
northern brook lamprey	*Ichthyomyzon fossor* Reighard & Cummins
American brook lamprey	*Lampetra appendix* (DeKay)
sea lamprey	*Petromyzon marinus* Linnaeus
Sturgeons	**Acipenseridae**
lake sturgeon	*Acipenser fulvescens* Rafinesque
Herrings	**Clupeidae**
alewife	*Alosa pseudoharengus* (Wilson)
Minnows	**Cyprinidae**
lake chub	*Couesius plumbeus* (Agassiz)
longnose dace	*Rhinichthys cataractae* (Valenciennes)
Banff longnose dace	*Rhinichthys cataractae smithi* Nichols[1]
redside shiner	*Richardsonius balteatus* (Richardson)
Suckers	**Catostomidae**
longnose sucker	*Catostomus catostomus* (Forster)
Jasper longnose sucker	*Catostomus catostomus lacustris* Bajkov[2]
white sucker	*Catostomus commersoni* (Lacepède)
Pikes	**Esocidae**
northern pike	*Esox lucius* Linnaeus
Smelts	**Osmeridae**
rainbow smelt	*Osmerus mordax* (Mitchill)
Trout & allies	**Salmonidae**
lake whitefish	*Coregonus clupeaformis* (Mitchill)
golden trout	*Oncorhynchus aguabonita* (Jordan)
cutthroat trout	*Oncorhynchus clarki* (Richardson)
Yellowstone cutthroat trout	*Oncorhynchus clarki bouvieri* (Bendire)[3]
westslope cutthroat trout	*Oncorhynchus clarki lewisi* (Girard)[3]
Colorado cutthroat trout	*Oncorhynchus clarki pleuriticus* Cope[3]
greenback cutthroat trout	*Oncorhynchus clarki stomias* Cope[3]
pink salmon	*Oncorhynchus gorbuscha* (Walbaum)
coho salmon	*Oncorhynchus kisutch* (Walbaum)
rainbow trout	*Oncorhynchus mykiss* (Walbaum)

Continued…

1 Renaud and McAllister (1988)

2 McAllister and Camus (1984), and this study (Part 3)

3 Johnson (1987)

Table 1 (concluded)

COMMON NAME	SCIENTIFIC NAME
Trout & allies (continued)	**Salmonidae**
pygmy whitefish	*Prosopium coulteri* (Eigenmann & Eigenmann)
mountain whitefish	*Prosopium williamsoni* (Girard)
Atlantic salmon	*Salmo salar* Linnaeus
brown trout	*Salmo trutta* Linnaeus
Arctic charr[4]	*Salvelinus alpinus* (Linnaeus)
bull trout	*Salvelinus confluentus* (Suckley)
brook trout	*Salvelinus fontinalis* (Mitchill)
Aurora trout	*Salvelinus fontinalis timagamiensis* Henn & Rinkenbach[3]
splake	*Salvelinus fontinalis* × *Salvelinus namaycush*
lake trout	*Salvelinus namaycush* (Walbaum)
Arctic grayling	*Thymallus arcticus* (Pallas)
Montana grayling	*Thymallus arcticus montanus* (Milner)[3]
Sculpins	**Cottidae**
mottled sculpin	*Cottus bairdi* Girard
deepwater sculpin	*Myoxocephalus thompsoni* (Girard)
Sunfishes	**Centrarchidae**
rock bass	*Ambloplites rupestris* (Rafinesque)
smallmouth bass	*Micropterus dolomieu* (Lacepède)
largemouth bass	*Micropterus salmoides* (Lacepède)
Perches	**Percidae**
yellow perch	*Perca flavescens* (Mitchill)
walleye	*Stizostedion vitreum* (Mitchill)

4 Morton (1980)

FISH MANAGEMENT

IN SELECTED

CANADIAN NATIONAL PARKS

The Mountain National Parks, Alberta and British Columbia

The mountain national parks of Jasper, Banff, Waterton Lakes, Yoho, Kootenay, Glacier (BC) and Mount Revelstoke are located in the Selkirk and Rocky Mountains of Alberta and British Columbia (Figure 2). Within their total 22,376 km^2 area they contain 1464 lakes larger than 1 hectare (Donald 1987:545) and thousands of miles of streams that provide habitat for a wide variety of native and exotic fishes. The four contiguous mountain parks (Jasper, Banff, Kootenay, Yoho) are a World Heritage Site designated by UNESCO at Canada's request, and the country has a special international obligation to care for the aquatic resources in those parks.

It is beyond the scope of this study to review in detail the voluminous literature on fisheries and aquatic resources in the mountain national parks. This overview is intended to set fish management in Jasper National Park in historical and regional context, and to enlarge upon a similar short review by Wiebe (1990). The seven parks have similar fish management problems and a similar history of fish management practices, so it is convenient to treat them together. More detail on fish management in JNP is provided in Part 3.

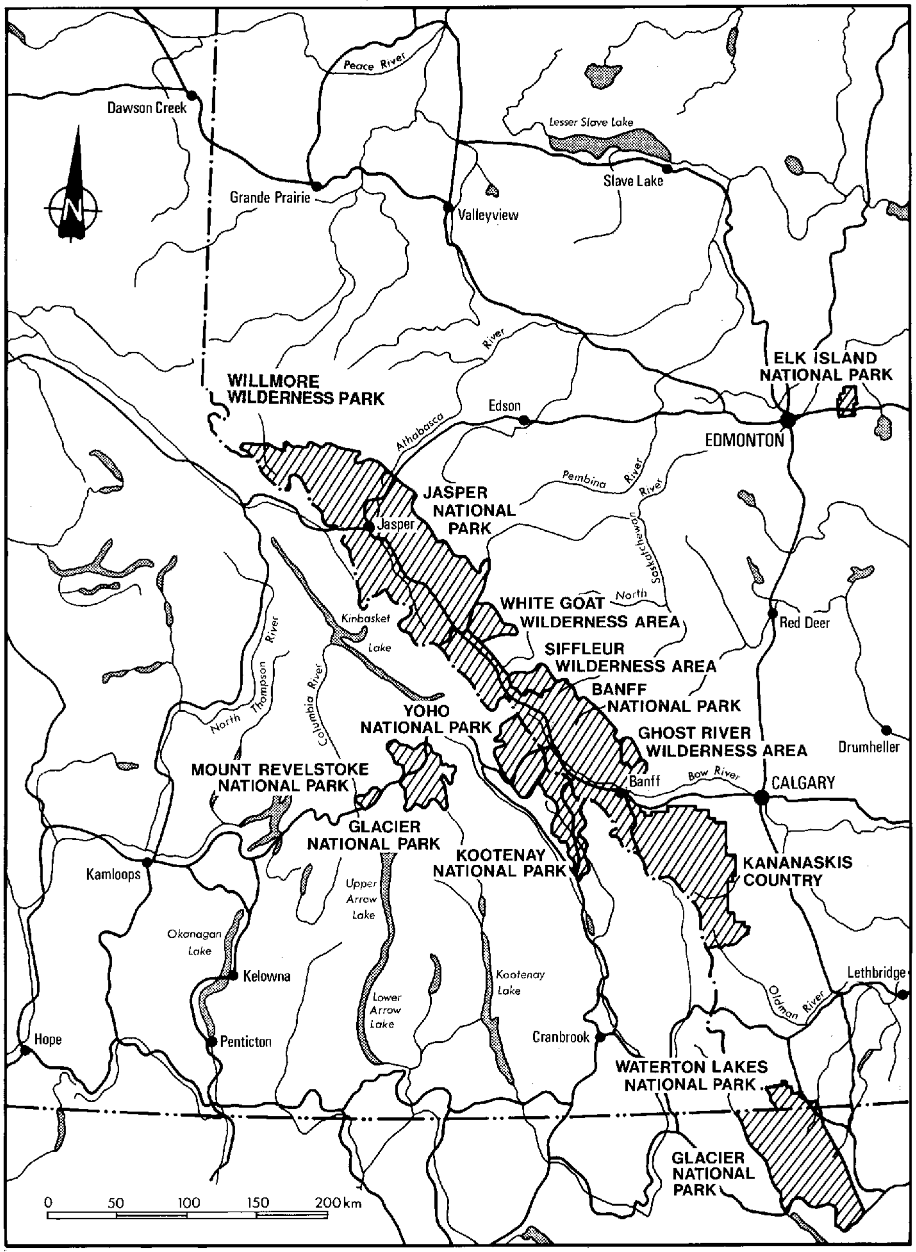


Figure 2. Location of some of the western Canadian mountain parks, wilderness areas and reserves discussed in the text. Base map modified from key map in Surveys and Mapping Branch (1985).

Fishes

The fishes and their distributions in the mountain national parks have been described by Ward (1974). Additional information is available from Paetz and Nelson (1970) and Scott and Crossman (1973).

All of the mountain parks have native species or stocks of special value[1]. Waterton Lakes National Park originally held populations of westslope cutthroat trout and bull trout. Waterton Lake itself holds or once held relict populations of pygmy whitefish, lake whitefish, lake trout and deepwater sculpin, as well as relict populations of three invertebrate species, *Mysis relicta, Pontoporeia hoyi* and *Senecella calanoides* (Anderson et al. 1976). Banff National Park waters are or were home to indigenous westslope cutthroat trout, bull trout[2], a few lake trout populations, and an endemic subspecies of longnose dace. Jasper National Park is one of only three known locations on the continent where rainbow trout were native east of the continental divide (MacCrimmon 1971:664). Other significant native fishes in Jasper include bull trout[2], lake trout and a population of longnose sucker proposed as a distinct subspecies endemic to the park (McAllister and Camus 1984). Yoho National Park protects native bull trout, possibly native westslope cutthroat trout, and is the type locality for pygmy whitefish. Kootenay National Park is home to westslope cutthroat trout and bull trout. Glacier and Mount Revelstoke national parks hold native populations of bull trout, and both parks lie in drainages in which the rainbow is the native black-spotted trout, but near areas believed to hold relict populations of westslope cutthroat trout (Carl et al. 1967, MacCrimmon 1971:664, Behnke and Wallace 1986, Behnke 1988:4).

Westslope cutthroat trout populations are being decimated throughout their range by introgression with introduced rainbows, and the few remaining genetically pure stocks require special protection (Leary et al. 1985, Behnke and Wallace 1986). Bull trout populations are listed as a species of special concern in BC and Alberta (Williams et al. 1989). The mountain national parks hold significant populations of both species.

Early Fish Management

Lothian (1981) outlined the history of fish management in the national parks of Canada up to 1972. The following discussion is based on his work unless noted otherwise.

Although Canada’s federal park system originated in 1885 when the Government of Canada protected a small area around the Banff hot springs under the Hot Springs Reservation Act, federal provision for protecting water resources in the Rocky Mountains had been made somewhat earlier. The Dominion Lands Act of 1883 was amended in 1884 to provide for the creation of “forest parks”, the purpose of which

1 The special significance of many of the fishes noted here is described at length in Part 3.

2 including some uncommon lake populations

was the preservation of forest trees on the crests and slopes of the Rocky Mountains, and 'for the proper maintenance throughout the year of the volume of water in the rivers and streams which have their sources in the mountains and traverse the Northwest Territories' (quoted by Lothian 1981:16). The "forest parks" provision later was used to establish several of the mountain national parks.

The first national parks fisheries investigation was launched in 1886 in anticipation of the Banff hotsprings reserve being expanded into a larger national park. A former Commissioner of Fisheries examined the proposed park area, describing the fish and wildlife species and their habitats in anecdotal terms (Whitcher 1887). Several of the species records in this report are questionable, and many of them may not have been Whitcher's own observations. For example, he made many comments about changes in the fish and wildlife populations, although he certainly could not have observed them himself. But Whitcher's comments give insight into the prevailing attitudes of the day toward fish conservation and management. He blamed overharvesting for decimating fish populations.

"Large game and fish, once various and plenty in this mountainous region, are now scattered and comparatively scarce. Skin-hunters, dynamiters and netters, with Indians, wolves and foxes, have committed sad havoc" (Whitcher 1887:86).

"Nothing else but the ravages of giant (sic) *powder, nets, and the improvidence of Indian fishing, can adequately account for the decimation of the fluvial trout in these waters"* (Whitcher 1887:88).

To conserve and manage the remaining fish populations in the proposed national park, Whitcher (1887) advocated

1. that predators of fish should be destroyed;

   "Wolves, coyotes, foxes, lynxes, skunks, weasels, wild cats, porcupines and badgers should be destroyed.… The same may be said of eagles, falcons, owls, hawks and other inferior rapaces (sic), *if too numerous; including also piscivorous specimens, such as loons, mergansers, kingfishers and cormorants"* (Whitcher 1887:87);

2. that fishing be restricted to rod and line;

3. that fishing be permitted by license only;

4. that fishing be restricted to June, July, August and September; and

5. that "trout culture in all of these waters be practised on a large scale" (Whitcher 1887:91), particularly with rainbow trout, for which methods of artificial cultivation in large numbers already had been developed, and sources of supply were readily available along the Canadian Pacific Railway.

Several habitat modification projects were proposed as well. These involved placing dams on certain small streams and planting beds of wild rice in suitable locations, both intended in part to improve habitat for trout.

Whitcher (1887) thus produced the first fish management plan for any Canadian national park. Many of his recommendations regarding fish and fishing found their way into the Rocky Mountains Park Act of 1887 and its 1889 regulations, and many of the methods he advocated, especially his suggestions regarding stocking, were followed for nearly a century in the mountain national parks. In 1889 the General Regulations for the national park restricted fishing to angling with rod and line, and a year later fishing with nets was specifically outlawed. Game fish in all national parks were protected in 1909 with size and catch limits, and seasonal closures. Selling of fish taken in park waters also was forbidden that year (Lothian 1977:36).

In 1910 and 1911, a federal fisheries commission examined the fisheries of western Canada, including those in Banff and Jasper parks, with a view to making recommendations for their proper management (Prince et al. 1912). The commission made only two recommendations regarding the national parks specifically. It urged that a fish hatchery be built at Banff, to rear chiefly trout and grayling for stocking streams in the Bow and perhaps the Red Deer watersheds (Prince et al. 1912:47). It also stated that the lakes in Jasper and Banff parks should be reserved for angling rather that net fishing (Prince et al. 1912:11). Many other more general recommendations applied to the parks as well, such as the proposed prohibition against stocking non-indigenous fish.

"We are of opinion (sic) *that there should be stringent prohibition against the introduction and planting of new species of fish not native to the waters of the two provinces. Great harm has resulted in many cases from the planting of foreign species of fish, which have become a nuisance"* (Prince et al. 1912:32).

The commission made specific recommendations for implementing angling licenses and fees, minimum size limits, daily limits, fishing gear, and closed angling seasons that evidently were intended to apply to the national parks. The recommended minimum size limit of cutthroat and rainbow trouts, mountain whitefish and grayling was 9 inches (23 cm); that of lake trout, 12 inches (30 cm). No more than 15 of the former group, nor 6 lake trout, were to be taken per day. Hooks were to be single and not more than three in a line in rainbow and cutthroat trout streams so that undersize fish could be returned safely to the water. Proposed closed seasons ranged from November 1 to June 30 in southern East Slope drainages, to November 1 to May 31 in the Athabasca system. Lake trout lakes were to be closed from September 1 to April 30 (Prince et al. 1912:46).

It is not clear to what extent the commission's recommendations were followed in the national parks. An amendment to the national park general regulations in 1919 provided for netting and sale of “coarse” (non-game) fish under permit. In 1925, the species considered game fish were listed for the first time, the use of fish roe as bait was forbidden, the practice of chumming was outlawed, an 8-inch (20-cm) minimum size limit was set, and daily fishing hours were specified (Lothian 1977:36).

Fish Culture and Stocking

The first recorded introductions of fish into a national park were in Banff in the early 1900s. Prince et al. (1912:48) mentioned that “500 parent Black Bass[3] and some 3000 fingerlings were placed in Lake Minnewanka near Banff some ten years ago”. Ward (1974:2) refers to a file memo placing the date of this introduction in 1901-02. In 1904, 800 adult brook trout of Nipigon stock were deposited in the Bow River by the Canadian Pacific Railway, and there are hints at earlier stocking (Lothian 1981:19). Whitcher (1887) noted that brook trout, which he explicitly identified as *Salvelinus fontinalis*, were to be found at least by 1886 in what is now Banff National Park[4]. If true, the species had to have been introduced from its native eastern North America.

From those early beginnings, fish stocking was the foundation of fish management in the mountain national parks for the next 70 years. Fish hatcheries were established in Banff in 1913, Waterton Lakes in 1928, and Jasper in 1941. By 1952 the park hatcheries had distributed 43 million trout. The great majority of these fish went to waters in the mountain national parks, creating new trout populations in approximately 120 formerly “virgin” fish-free waters (Solman et al. 1952). Donald (1987:545) estimated that a total of approximately 305 lakes in the mountain parks — most of them naturally free of fish — were stocked with cutthroat, brook and/or rainbow trout in various combinations. Although some of the introduced populations were unable to maintain themselves through natural reproduction, many were sustained by periodic stocking.

The stocking and fish culture program produced many high-quality sport fisheries for self-sustaining or hatchery-maintained trout stocks (e.g., Rawson 1940). With the spectacular and well-publicized success of trout introductions into the Maligne system and elsewhere, the park authorities were under pressure before and after World War II to produce more fish (Lothian 1981:22). The two Canadian railway companies and the federal and provincial governments featured sport fishing prominently in their tourism advertising (Lothian 1981:21). The Canadian Wildlife Service added new fisheries expertise in 1949 and 1951 (Lothian 1981:21,66-7), and between 1951 and 1965, an additional 115 lakes in the mountain parks were stocked for the first time (Donald

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3 This common name may apply to either largemouth or smallmouth bass (Scott and Crossman 1973:734, 740). Ward (1974:2) seems to suggest it was the latter in this case.

4 It is not clear how much credence should be given this record. At least some of Whitcher’s species records apparently were based on anecdotal accounts of others, so he may not have seen specimens. Introductions certainly were possible (and likely, one suspects) by the mid-1880s after the railway arrived.

1987:546).

Most of the fish culture work had to be borne by the Maligne Hatchery in Jasper: the Banff hatchery had been crippled in 1956 by an unsuitable water supply, and capacity at the Waterton hatchery was low. Also, serious disease problems had arisen at the Waterton facility at least by 1955. Reviews were undertaken in 1954 and 1955 of the productive capacity of the three hatcheries and the economics of consolidating the operation at Jasper. The consolidation was approved in 1960. The Banff operation became a seasonal rearing facility, Waterton was closed as a fish culture station, and supplemental fish supplies were obtained from other hatcheries in the US and Canada (Cuerrier et al. 1967:316, Lothian 1981:22).

Costly problems continued in the national park fish culture operations after 1960. Gill diseases, "cold water disease", "kidney disease", infectious pancreatic necrosis (IPN), copper and zinc contamination from hatchery pipes caused or were implicated in mortalities at the Maligne Hatchery, and soon were joined by DDT contamination in feed as a suspected mortality source (Cuerrier et al. 1967). A consultant reported the water supply to be inadequate and the hatchery itself obsolete, recommending that it be replaced by a new facility. In 1972, bacterial kidney disease and IPN were confirmed in the hatchery, concern for contamination of wild stocks grew, and the hatchery was quarantined while it was thoroughly disinfected. Shortly after reopening in 1973, IPN was again found in hatchery fish, and the hatchery was closed for good. The news release announcing the closure cited disease and hatchery obsolescence as the deciding factors in the shutdown (Lothian 1981:22-23).

The closure of the last hatchery in the national parks followed some major rethinking of policies on fish stocking. Fish stocking policy up to the mid-1960s, though not formally stated, had been to maintain or increase the supply and variety of fish and fishing lakes for anglers (e.g., Rawson 1940, Solman et al. 1952). In contrast, provisional master plans for the four contiguous mountain parks published in 1970 stated:

"In keeping with the concept of preservation of wild areas and the free play of natural forces, some lakes are neither stocked nor fished. These include certain remote lakes which do not naturally support fish. The objective of management is to ensure that stocking, fishing, or any other activity will not interfere with the existing natural system. Studies are required to determine the extent to which this objective is obtainable" (e.g., National and Historic Parks Branch 1970:7).

A policy statement issued at the same time that forbade "alteration of a feature so that, in effect, the alteration itself becomes the thing of interest" (National Parks Policy Statement 1969, quoted by Mayhood and Anderson 1976a:41) also would seem to have limited the scope of appropriate uses for stocking. Later policy statements, management directives and recommendations reviewed in Part 1 of this study define the limitations on stocking even more tightly, one of them directing that all stocking programs be reviewed with a view to phasing them out. As of 1991, Jasper and Banff were to be the only national parks in Canada in which stocking formed part of the fish management program (P. Wiebe, personal communication 9 May 1990).

Fisheries Management and Limnological Research

Scores of studies have been completed in the mountain national parks of the fish, their habitats, aquatic communities and the sport fisheries that depend on them. Most have been identified and summarized in several annotated bibliographies prepared for limnological and fisheries surveys completed since 1975 (Mudry and Anderson 1975; Anderson and Donald 1976, 1977; Mayhood and Anderson 1976b; Donald and Alger 1984a, 1984b), to which the reader is referred for documentation of the following remarks. Only those not listed in the annotated bibliographies are cited below. This review pertains only to selected studies and projects carried out expressly for national parks purposes. Most of the many independent studies are listed in the annotated bibliographies mentioned above. Studies referring specifically to Jasper National Park are mentioned in Part 3 (The Study Area, Sources of Information on Fish and Their Habitats).

The first fish management projects in the mountain parks, apparently consisting of stocking lakes and streams with whatever fish were available, went almost entirely unrecorded and unstudied. It was not until the mid-1920s that the first formal limnological studies were conducted by the Biological Board of Canada, resulting in descriptive publications on the aquatic biota collected from several waters in Jasper National Park.

The objective of the national parks at that period, however, was to improve sport fishing, not to describe and catalogue the resource. D. S. Rawson was engaged during the 1930s and 1940s to extend the lake inventory work in the mountain parks, and to advise on fisheries management. He not only recommended fish management actions, but attempted to monitor and document the results. He published his findings widely, including data from the lakes of the mountain parks in many of the landmark analytical studies that he produced before his death in 1961. Among the most important of his studies for fish management were those documenting the changes in certain introduced trout populations, his efforts to improve angling by selectively removing competitor fishes in one Jasper lake, and his original limnological surveys themselves.

The first national park creel census was introduced in 1933 in Jasper National Park (Solman 1951:226), and became an important tool used to monitor fish populations and evaluate the effects of various fish management decisions (Solman 1950, Solman et al. 1952). Such angler surveys have been carried out in some mountain parks — with many interruptions — to this day. Usually a self-reporting, voluntary format was used, but interview-type studies have been conducted more recently (e.g., Antoniuk and Yaciansky 1983, and several other Jasper Park surveys).

Much of the fisheries management work undertaken between approximately 1940 and 1970 went undocumented in formal reports. The only documentation for many projects existed in files, which Wiebe (1990:5) reports were purged at about 10-year intervals. The reports and publications still extant from this period reveal a research and management program of considerable diversity, including descriptions of the limnology and fisheries of Waterton Lake and Lake Minnewanka, incidental hatchery projects, a series of creel census papers and reports, papers describing the production of splake (lake trout × brook trout hybrids) in a national park hatchery (Stenton 1950, 1952) and subsequent studies on its genetics. Numerous important management projects involving habitat manipulation or attempts to remove unwanted "coarse" fish were not documented in formal reports.

In the late 1960s R. S. Anderson was hired by the Canadian Wildlife Service (CWS) to carry out a program of fundamental limnological research in the mountain parks. Using zooplankton as the most efficiently sampled and easily studied biological community to represent biotic conditions in mountain lakes, Anderson produced a copious body of research to elucidate the fundamentals of limnology in the Canadian Rockies. In addition to numerous published and unpublished studies of zooplankton taxonomy, predation, community structure and population dynamics, he published and reported extensively on the physical and chemical limnology of mountain lakes; their bacterial, primary, secondary and tertiary productivity and their benthos; not to mention dozens of limnological survey reports and several water quality and contaminant survey reports. All of this was completed in the space of little more than fifteen years, often in collaboration with several associates near the end of his tenure, but much of it on his own.

Anderson's research on mountain lake productivity demonstrated that the productivity levels implied by the fish stocking rates used in the mountain lakes were far too high in many cases. He devised a crude but workable method of estimating potential fish yield from mountain lakes from estimates of the productivity of the fish food supply (Anderson 1975) that in an improved form served to guide fish management and stocking in several mountain parks. He demonstrated the devastating impact that introduced salmonids could have on the indigenous biota of naturally fishless lakes (Part 1). He published what is even today one of only a few investigations documenting the effects of fish toxicants on aquatic invertebrate communities. His research still is dismissed by some as irrelevant to fish management in the mountain parks, but in fact it was instrumental in convincing fish managers to drastically reduce rates of stocking, to leave representative naturally fishless lakes unstocked, to cease stocking dozens of lakes that simply were too small and unproductive to support a sport fishery, and to handle more lightly the sensitive Rocky Mountain aquatic ecosystems generally.

Anderson's principal associate not only contributed substantially to his research program, but carried out his own research concomitantly, taking over from Anderson in the early 1980s. D. B. Donald completed extensive lake and stream surveys in Waterton, Jasper, Kootenay, Glacier and Mount Revelstoke national parks before the Canadian Wildlife Service park research group was disbanded in 1985. The results of these studies were used to formulate recommendations for managing those waters and their fish populations. Donald published a series of fisheries research and management papers based largely on his reports. These dealt with methods for predicting salmonid growth from easily-measured limnological parameters (Donald et al. 1980, Donald and Anderson 1982), a study of a lake trout population showing extreme stunting (Donald and Alger 1986a), a study of population characteristics in unexploited rainbow trout populations (Donald and Alger 1986b), an assessment of fish stocking in the mountain parks (Donald 1987), an evaluation of exploitation as a fish management technique to improve trout growth (Donald and Alger 1989) and studies of stoneflies in the mountain parks (Donald 1980, Donald and Anderson 1977, 1980).

Although the CWS biologists were responsible for much of the fisheries-related research done in the mountain parks from the 1940s to 1985, others were occasionally engaged for their special expertise. For example, T. Yamamoto of the University of Alberta undertook several research projects on the IPN virus for Parks Canada, beginning in 1972. He produced several reports and publications, culminating in a study demonstrating that IPN might be eliminated from wild trout populations by stocking IPN-free fish (Yamamoto and Kilistoff 1979). D. J. McAllister et al. (1981) produced another important study, identifying genetically-pure and introgressed populations of westslope and Yellowstone cutthroat trout in some waters of the mountain parks.

Since the disbanding of the CWS park research group in 1985, fish management and research activities in the mountain parks until recently have been limited almost exclusively to enforcement, small surveys, creel census, incidental test fishing, and similar small scale studies carried out in some cases by seasonal or temporary staff. Some development-related studies in Banff National Park have been contracted to private consultants (T. Hurd, personal communication).

Recently research scientists from the University of Alberta have become active in the mountain national parks. D. W. Schindler and his associates S. Lamontagne, P. Leavitt, B. Parker and A. Paul have initiated studies in paleolimnology and lake restoration in Banff and Jasper. C. Strobeck and his students have begun conservation genetics work on cutthroat trout populations in Banff, and on the Banff longnose dace. J. S. Nelson is extending his studies of the fishes of the Cave and Basin marsh in Banff.

Problems and Prospects

The mountain national parks are required by law and policy to preserve their aquatic resources and protect them from impairment; that is, they must maintain them essentially in their natural state, or restore them to a natural state if damaged (Part 1).

Unfortunately, historical development and fish management activities in the mountain parks have created serious impediments to meeting this goal, many of them listed by Wiebe (1990:3-5). Among the most difficult to overcome are the changes that have been made in the resources themselves, creating what are in effect artificial aquatic ecosystems, communities, habitats and populations. For example, nearly a century of fish stocking has created artificial fish populations in hundreds of lakes and streams in the mountain national parks. The introduced populations have changed the structure of the biotic communities in the lakes, and very likely those in the streams as well.

It is uncertain to what extent the artificial communities could be restored to their natural condition. Removing artificial fish populations would be feasible perhaps in some situations, but not likely in all with the methods presently available. If artificial fish populations were to be successfully removed, communities eventually might return to something approaching their natural state without further intervention, but there is reason to believe some would not. For most of the altered communities the original condition is not known, but detailed comparative studies and experimental work might provide a reasonable answer.

Damage to critical, scarce or unique habitats is of particular concern. It seems likely that many of the scarce or unique aquatic habitats in the mountain parks are to be found at low elevations in the main valleys. The main valleys themselves are after all rare features by definition, as are the large rivers or lakes that occupy them, and take up only a small proportion of each park. They are the areas of lowest elevation in the mountain parks, and therefore have longer growing seasons. It was along the main valleys that fishes and some other aquatic organisms invaded the parks after the last Ice Age, and to which they were restricted by natural barriers to dispersal. It follows that the aquatic habitats that are associated with large valleys in the mountains will be different from, and rarer than, those in the much more numerous steep tributary valleys and high elevation areas that occupy most of the mountain parks. Likewise, critical habitat for most indigenous fish must be in the main valleys.

Development in the major valleys of most of the mountain parks has been extensive by almost any standard. The main valleys have been the favoured locations for roads, railways, towns, power lines, pipelines, communication facilities and most recreation developments. The aquatic resources of the main valleys are those most heavily used by people. Thus the greatest damage, or potential for damage, has been concentrated where the scarce, critical or unique aquatic habitats are located. Damage has been caused when streams have been channelized, lake and marsh water levels have been manipulated, dams have been constructed, improperly installed culverts have blocked fish movements, streams have been silted, noxious substances have been spilled and sewage has been discharged (Wiebe 1990:4, in part), to name but a few impacts.

The usual response to either plan for, or respond to, such damage has been to use rehabilitation and mitigation. Some of the damage indeed can be repaired, more can be mitigated, and some habitats can be rehabilitated, but most threats to aquatic resources in developed areas probably cannot be significantly reduced in the long term unless development itself is reversed. All of the developments mentioned above pose a continuing threat to aquatic resources in the mountain parks to a greater or lesser degree. While it may be true that removing these developments is unrealistic, one must face the consequences of such a decision. Those consequences are that aquatic habitats in the main mountain valleys will continue to be degraded, and that the degraded habitats will tend to be critical, scarce or even unique.

Another major problem for fish management in the mountain parks has been the destruction of indigenous fish stocks. The extreme variability of the western black-spotted trouts in structure, coloration and spotting patterns was evident even to the earliest pioneers, and created persistent confusion for fish taxonomists. Whitcher (1887:88) commented upon it at some length in his description of trout in the Banff area.

"There is a remarkable confusion of trouts hereabouts that may be related to the former profusion. Of identified river trout the rainbow variety (salmo irideus) *ranks originally in form, size, colour, flavor, and gaminess; the brook trout* (salvelinus fontinalis)*, though much smaller, ranks next; the Rocky Mountain brook trout* (salmo stellatus) *runs small, but is very lively and tasty; the largest river trout* (salmo purpuratus) *is heavy and dull, but is fairly catable* (sic)*; a brownish trout, called 'bull trout', seems to be a variation of fontinalis — an awkward country cousin and a hard fighter when hooked, but of insipid flesh. There has been so much interbreeding among these trouts that many others are found, and their aspect and flavor are affected by consequent irregularity of spawning condition. If like circumstances exist elsewhere, in the myriad waters flowing by circuitous routes through diversified strata and variable temperatures towards the South and North Saskatchewans, within the trout range, it is no wonder that so many persons express uncertain opinions and relate diverse experiences respecting the regular spawning seasons.*

"In the larger lakes the salmo namaycush *predominates, and is logy and coarse fleshed, like* salmo ferox. *In the smaller lakes there is a trout answering in size, shape and markings to* salmo amethystus*, but not structurally differing from other lake trouts. Brook trout also occur in these small lakes ….*

"The above particulars are stated in support of a recommendation to generalise close seasons rather than as data relating to species and variations, which in these north-western wilds develop strange perplexities."

Whitcher (1887:88) also stated "there is reason to think" Arctic charr inhabit "some mountain tarns in the Rockies".

The species name *irideus* is now considered to be a synonym for rainbow trout, while *stellatus* and *purpuratus* have been used for both cutthroat (as *Fario stellatus*) and rainbow trout (Scott and Crossman 1973:182,191). Perhaps like his contemporary Macoun (1902:398), Whitcher (1887) made no distinction between cutthroat and rainbow trout, and did not mention cutthroats at all in his report. A credible later report (Prince et al. 1912:5,8,17) describes cutthroats as the only black-spotted trout species in the drainage system, noting particularly that the cutthroat "… is very often called, erroneously the Rainbow trout …" (Prince et al. 1912:18). The species names *ferox* and *amethystus* are synonymous terms with *namaycush* for lake trout (Scott and Crossman 1973: 227). Whitcher's possible "Arctic charr" is most likely bull trout, which commonly are more highly coloured (like Arctic charr) in mountain lake populations (Part 3:bull trout).

The myriad of "strange perplexities" that so confused Whitcher I believe reflected stock differences, at least in part. Recent studies (McAllister et al. 1981, Leary et al. 1985, Carl and Stelfox 1989) confirm there are genetic differences among westslope cutthroat stocks in southern Alberta, and separate stock development appears to be more pronounced in this subspecies in our area than elsewhere within its range (Leary et al. 1985). Distinctive differences in meristics and colouration also were noted by Bajkov (1927) among populations of rainbow trout, at least some of which must have been indigenous, in Jasper National Park.

Stock differences are not restricted to salmonids in the mountain parks. A distinctive stock of longnose dace once inhabited the Cave and Basin hotspring at Banff (Renaud and McAllister 1988), and a stock of longnose sucker distinct from that in the Athabasca River occupied a few lakes near Jasper (Bajkov 1927, McAllister and Camus 1984).

Thus the waters of the mountain parks originally were home to innumerable distinct stocks of trout, charr, and other fishes. But several stocks certainly have been lost, and many others probably have been lost, have been reduced in numbers or are otherwise threatened. The Banff longnose dace was extirpated by the cumulative impact of damaged habitat, competition from exotics and introgressive hybridization (Renaud and McAllister 1988). The Jasper longnose sucker is now known only from a single lake, where it is no longer the dominant species (McAllister and Camus 1984). Bull trout have disappeared from or have been reduced in numbers in several lakes where lake trout have been introduced (Donald 1988, D. B. Donald, personal communication 8 May 1990). Several indigenous populations of fish, including "coarse" fish and an indigenous stock of lake trout, have been destroyed deliberately with fish toxicants (national parks fish stocking records). Scores of indigenous salmonid populations have been exposed to introduced exotics with which they may introgressively hybridize (national parks stocking records).

Wiebe (1990:7) has made a suggestion that deals in part with the problem of destroyed or threatened indigenous stocks of fish. He proposed that park authorities "provide special protection to representative, sensitive (endangered, threatened, rare) and unique species and their habitats, by determining their presence and status in the parks, and managing for their continued existence by special regulations, management plans, etc." For reasons described at length elsewhere (Part 1), it is individual stocks of fish that should be managed in the mountain parks. Stocks would be better protected in the above proposal if the word "stocks" were substituted for "species". In addition, the management plan for certain stocks might include procedures to restore them to their former numbers and habitats.

Finally, "special regulations" mentioned by Wiebe, above, have come to mean some form of catch-and-release approach to sport fishing. Catch-and-release recently has been studied as a fundamental concept for sport fishery management in the national parks (Schiefer 1989). Particularly if implemented in its "no-kill" form, catch-and-release would provide better protection for individual fish stocks in the mountain parks than do current regulations.

Pukaskwa National Park, Ontario

Schiefer and Lush (1986) produced a sport fish management plan for Pukaskwa National Park from which the following information was taken.

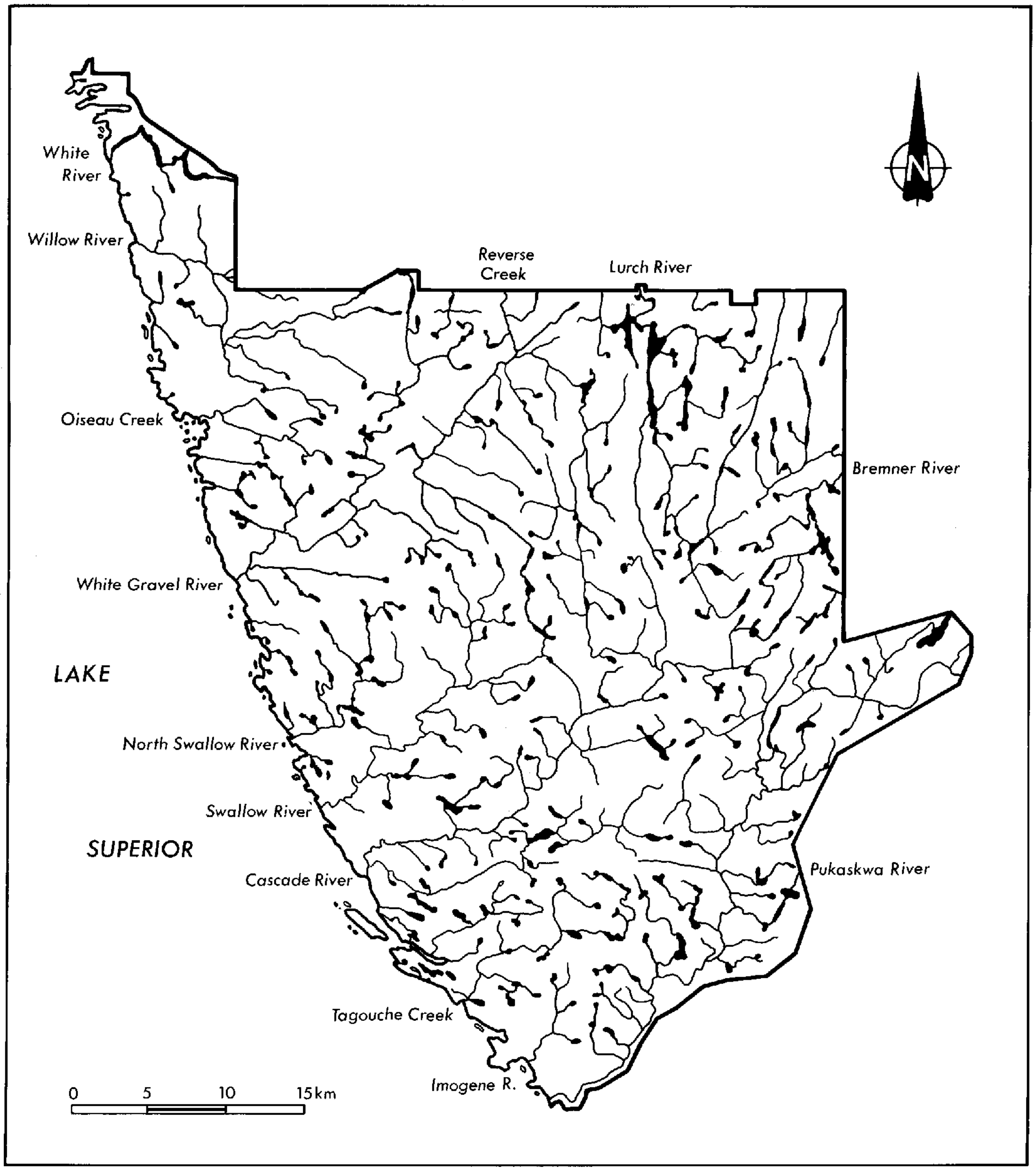
Pukaskwa National Park is a 1878 km^2 wilderness area located on the north shore of Lake Superior, Ontario (Figures 1 and 3). The park, established in 1971 and formally opened in 1983, is intended to protect a representative area of the Canadian Shield and Great Lakes shoreline. A highway provides access to the park at the extreme north end, and three unmaintained resource roads reach the boundary at other locations. Travel within the park is restricted to a long coastal trail, some shorter ancillary trails, canoe routes down two rivers, and boat access along the Lake Superior coast.

Aquatic Resources and Fisheries

Pukaskwa Park contains over 900 lakes, including 16 km^2 of Lake Superior, and many hundreds of kilometres of streams in 14 small watersheds, all ultimately draining to Lake Superior. The interior lakes are characteristic of Shield country, being generally dilute with steep bedrock shores, and are biologically unproductive. Lake Superior within the park has an extremely rugged shoreline with 225 small islands, exposed rocky headlands and some small sheltered coves with sand beaches. The streams are turbulent with numerous rapids and waterfalls, many of sufficient height to block upstream movements of fish.

Fifty-seven species of fish have been listed for the park. Most of these occur only in Lake Superior; not all have been recorded from within Pukaskwa Park. Native fish species in Lake Superior include lake whitefish, brook trout and lake trout; important introduced species are alewife, pink salmon, rainbow trout and rainbow smelt.

Figure 3. Pukaskwa National Park, Ontario, illustrating the abundant small lakes and streams characteristic of the Canadian Shield region. Numerous waterfalls block fish movements into much of the park interior. Adapted from Schiefer and Lush (1986).



Rivers and streams entering Lake Superior contain resident and so-called "anadromous" fish populations. The latter migrate upstream to spawn in park rivers, but spend much of their lives in Lake Superior. River-resident native fishes include brook lamprey and brook trout; migratory native fishes in park rivers and streams include brook trout ("coasters"), longnose and white suckers, and walleye. In addition several important introduced species enter park rivers from Lake Superior, including pink salmon, coho salmon, rainbow trout, brown trout, sea lamprey and rainbow smelt. Pink salmon and rainbow trout are important sport fishing species; sea lamprey are a serious pest in the Great Lakes and some park streams are regularly treated with lampricide to kill larvae and keep the species in check.

Access by migratory fish to interior waters of the park is usually blocked a short distance upstream of Lake Superior by rapids and waterfalls. The lakes of the park interior have a depauperate fish fauna due to the migration barriers and lack of suitable spawning or overwintering habitat. Brook trout and northern pike are the main sport fish species in the interior waters, at least some of the brook trout populations being introduced stocks.

Sport fishing in Pukaskwa National Park is a popular activity with visitors. Effort is concentrated around the periphery at points easily accessible by boat from Lake Superior, from the main coastal trail, by air or resource road from outside the park, and by canoe along two major rivers. The park interior apparently is seldom visited by anglers. The most important sport species are brook trout taken from Lake Superior, the river mouths, and interior park waters; rainbow trout, brown trout, coho salmon and pink salmon taken from river mouths along the Lake Superior coast; lake trout taken from Lake Superior and one small coastal lake; northern pike caught in several isolated coastal lakes, one Lake Superior cove, and one river; and walleye caught in a short section of one river.

Schiefer and Lush (1986:1.3) did not articulate clear overall goals for fish management in Pukaskwa, other than to indicate that management means had to be consistent with Parks Canada policy. Instead, they identified a dozen issues that had to be addressed by their sport fish management plan for the park, examined alternatives, and recommended the actions described below.

Basic Aquatic Resource Inventory

Only 55 of the more than 900 lakes in the park had been limnologically surveyed as of 1986, and there was little information available on any of the running waters. Inventory information was required to describe and interpret aquatic resources, to properly manage the sport fishery, and to provide baseline data for longterm monitoring.

Schiefer and Lush (1986:8.1) proposed a "selective, phased" approach to meeting the park's inventory needs because of the very large number of waters and the consequent high cost of conducting a complete inventory. They gave first priority to surveying waters where sport fishing is most active, second priority to surveying waters "which are important to Parks Canada's mandate of preserving representative or unique ecosystems", and third priority to studying representative lakes in remote interior watersheds where an adequate inventory will not be completed for a long time.

Among first priority waters Schiefer and Lush (1986:8.2) urged that spawning and rearing habitat for several fish species be inventoried in accessible parts of rivers entering Lake Superior, and that standing stocks and production be determined for their major sport species. They suggested that a Lake Superior cove holding an isolated and highly representative northern pike population be given high priority for surveying because of recent increased fishing pressure. They outlined standard methods for collecting and systematically cataloguing inventory data. They suggested inventorying two to four water bodies per year for a ten-year period in priority areas, after which the program should be reviewed and new priorities assigned.

Protecting Unique, Rare or Representative Fish Populations

Schiefer and Lush (1986) stated that there were no fish species documented in Pukaskwa National Park that are rare, endangered or warranting special status on a national or provincial scale, but identified one lake trout and one brook trout population that were rare or unique within the park. These they proposed should receive a moderate level of protection, including unspecified special catch limits, closer monitoring through angler surveys or creel census, more attention to enforcement and periodic monitoring for effects of exploitation and lake acidification.

Sport Fishing Regulation

Although sport fishing within Pukaskwa National Park is fully under the jurisdiction of the park, regulation is somewhat complicated by interests of the Province of Ontario in the Lake Superior fishery and by the treaty rights of local natives in the Robinson-Superior Treaty Group. In practice, however, it appears that the complications are more apparent than real, being adequately addressed by formal agreements and consultations among the interested parties.

The principal concern at the time the fishery management plan was prepared was the park’s continued use of Ontario’s sport fishery regulations to regulate fishing within the national park. Schiefer and Lush (1986) argued that Ontario’s regulations, with catch limits founded upon average conditions for tens of thousands of lakes with widely varying ecological characteristics, did not grant adequate protection to the park’s fisheries.

Schiefer and Lush (1986) proposed generally more restrictive regulations for individual or small groups of water bodies based on their species composition, population characteristics, fishing pressure and their estimate of potential long term yield (based primarily on the morphoedaphic index of Ryder 1965 and Ryder et al. 1974). Catch limits in particular were reduced in most cases, reflecting the low estimated potential yields of most park lakes as well as an underlying philosophy that sport fishing in national parks be treated as part of an overall wilderness experience rather than as a resource harvesting activity.

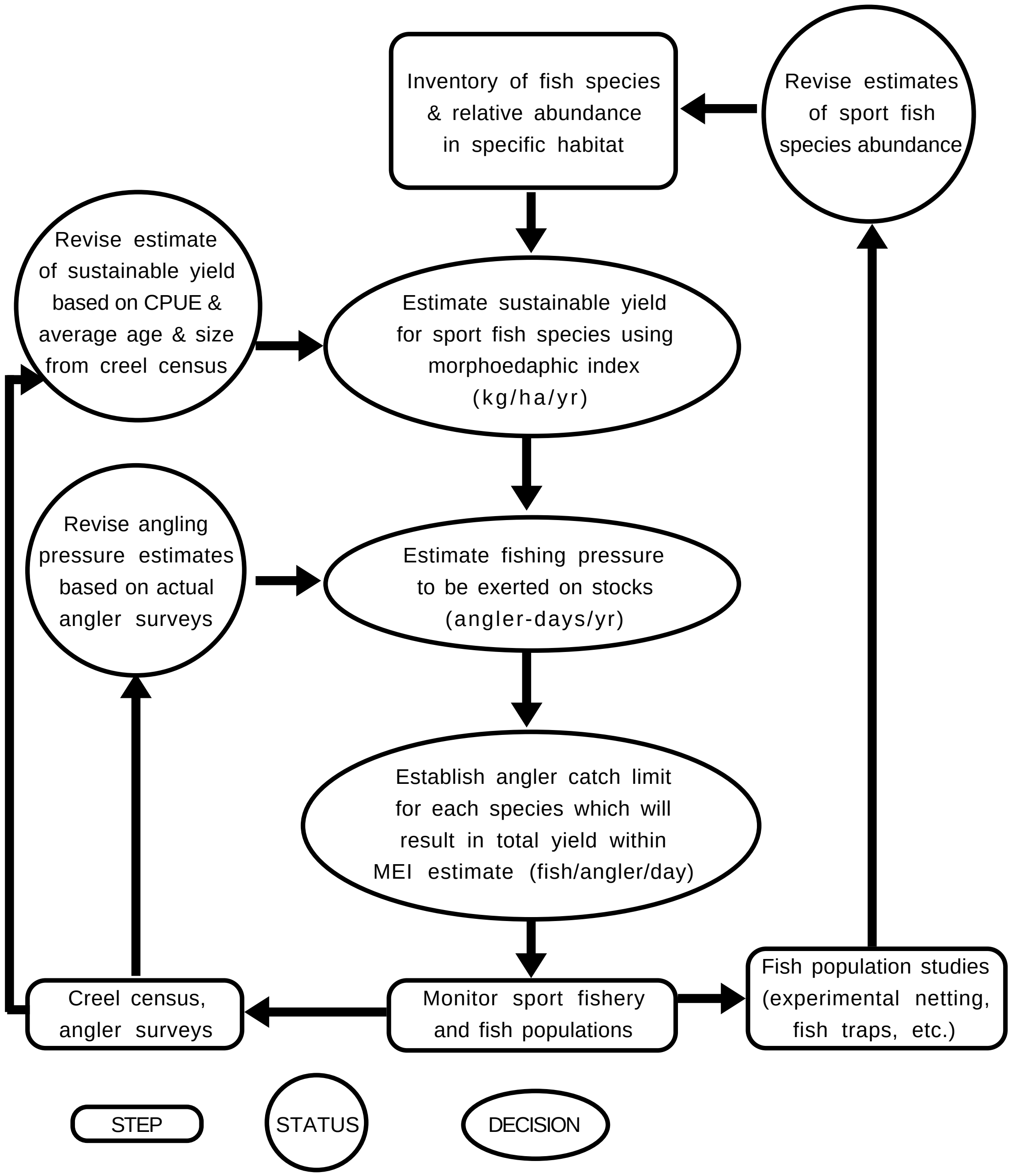
The daily catch and possession limit for trout, salmon, pike, walleye and bass was reduced to 1 to 3 fish from 3 to 7 fish in the Ontario regulations, depending on species and water body. The limit for lake sturgeon remained at one. Possession and daily catch limits for whitefish remained at a very high 25 fish. The reason for this was not explained. It may be that the Robinson-Superior Treaty Group, which has the right to fish in the park but is subject to the same regulations as govern the sport fishery, relies on whitefish as a domestic food supply. Schiefer and Lush (1986) may have been reluctant to deprive them of this resource.

The fishing season opening and closing dates also were adjusted to protect fish during vulnerable periods, especially the spawning period, and to simplify regulations, making them easier to understand and enforce. The plan proposed a ban on live bait. The plan advocated intensive enforcement of regulations in key areas or at selected times, such as lakes having unusual fish populations that are vulnerable to overfishing and areas that are intensively fished at certain seasons.

Schiefer and Lush (1986) considered other fishery regulations, but rejected them for various reasons. A quota system, in which a fishery would be closed after a predetermined allowable catch had been reached, was felt to be a more sophisticated approach that would better prevent overharvesting. It is a labour intensive method, however, and was felt to be unnecessary at the present level of fishing pressure in Pukaskwa Park. In contrast, periodic lake closures were seen to be simpler to implement, but run a high risk of overfishing that would be unacceptable in a national park. Schiefer and Lush (1986) suggested that anglers “be encouraged to consider” catch-and-release fishing with barbless hooks, but did not actually propose any enforced catch-and-release fisheries for the park.

The management plan outlined an ongoing process for managing the sport fisheries of the park (Figure 4). Schiefer and Lush (1986) proposed that, *as angling pressure increases to the point where sport fish populations begin to decline*, harvest could be reduced to acceptable levels by (1) reducing catch limits, (2) reducing the open season, (3) introducing terminal gear restrictions (artificial lures, barbless hooks, etc.), (4) setting “angler quotas” (limits on angler numbers?), and closing lakes.

Figure 4. Schematic diagram of the fish management process proposed for Pukaskwa National Park, Ontario. CPUE: catch per unit effort. Adapted from Schiefer and Lush (1986: Figure 15).



Acidification

Park surface waters are moderately to highly susceptible to acidification from acid precipitation because of the insoluble nature of their granitic drainage basins. Fish populations in acid lakes eventually die out due to reproductive failure. Acid conditions also can mobilize heavy metals from bottom sediments and from rock in the drainage basin, and these may be directly toxic to aquatic life and to humans through concentration in the food chain.

The fisheries management plan recommended that lake acidification studies conducted by other agencies in the area be followed closely. Within the park, acidification could be monitored by making pH and alkalinity measurements as part of the proposed limnological inventory of park lakes. In addition, "sensitive" lakes would be monitored regularly as part of the monitoring program for fish populations and aquatic ecosystems (see below).

Trace Elements in Fish

Mercury concentrations in sport fish in many waters of the park are above the level considered safe for unrestricted human consumption. Schiefer and Lush (1986) recommended that mercury concentrations in fish flesh be monitored as part of the monitoring program for fish populations and aquatic ecosystems (see the following section), and as part of a periodic creel census of angler catches (see Monitoring Fishing, below). The authors recommended that a particular watershed in which mining development was taking place upstream of the park should be monitored routinely for "materials … that may pose a risk to health or to the natural environment" (Schiefer and Lush 1986:6.8).

Monitoring Fish Populations and Aquatic Ecosystems

Schiefer and Lush (1986) felt that fish populations need to be monitored to provide information for adjusting regulations and management plans as conditions change. Other parameters (acidification, mercury concentrations) needed to be monitored for reasons discussed above. They assigned "high" or "moderate" priority to several park waters, and recommended that fish populations and water bodies be periodically monitored ever three to five years, or every eight to ten years, in a systematic and standardized manner. They recommended that the techniques and parameters used in the initial baseline surveys be used for monitoring.

Monitoring Fishing

Schiefer and Lush (1986) recommended that fishing be monitored to provide information necessary to determine if angling regulations, especially catch limits, were preventing overexploitation, and to change them if they were not. For monitoring fishing park-wide, they proposed that a self-administered questionnaire be attached to the fishing permit that would request dates, locations, hours fished, number of anglers, numbers and approximate weights of each fish species taken, comments and "any other relevant survey information" (Schiefer and Lush 1986:8.14). This survey would be conducted over an initial three-year period. They proposed an interview-type creel census be carried out at five- to eight-year intervals on more intensively fished waters, and on waters with unusual or vulnerable fish populations.

Restoring Fish Communities

Many non-native fish species have been introduced inadvertently or otherwise to Pukaskwa National Park waters, and acidification may have eliminated native fish from some lakes. Schiefer and Lush (1986) noted that most of these introduced species were seen as beneficial by the public, and recommended that they should be accepted in park waters where they occur. Sea lamprey they noted would continue to be periodically controlled with lampricide in at least one park river, but prospects for eliminating the species under the current control program were poor. An important consideration in their recommendations against attempting to restoring any fish communities was the fact that large numbers of natural, native fish communities continued to exist throughout the park.

Habitat Enhancement

Schiefer and Lush (1986) observed that manipulating habitat to enhance sport fishing is contrary to park policy, but noted that there were unspecified opportunities to do this in Pukaskwa Park. They recommended that no such work by undertaken at that time, but suggested that the limnological monitoring program might identify opportunities that should be considered. They also recommended that the park should consider liming acidified lakes if further acidification jeopardizes park lakes and fish communities.

Intensive Sport Fishery Management

By this, Schiefer and Lush (1986) meant stocking. They observed that there were many opportunities for creating or enhancing sport fisheries in the park by stocking, because hundreds of lakes apparently lack fish only because they lack adequate spawning habitat, or because migration barriers prevent fish from reaching them. They also noted that all fish stocking is generally prohibited under current parks policy, and a no stocking policy was their selected course of action.

Program Coordination

Treaty fishing rights, the transfer agreement with the Province of Ontario, and the migratory nature of Lake Superior fish stocks complicate fisheries management in Pukaskwa National Park. As well, geographically broad research, management and monitoring programs for acid precipitation and other pollutants, and for pest fish control, that include the park area are operated by other federal agencies and by the province. Schiefer and Lush (1986) recommended park participation, cooperation and consultation with the Robinson-Superior Treaty Group and the other agencies to facilitate fisheries management within the park.

Visitor Information and Interpretation

Schiefer and Lush (1986) called for a moderate to intensive program under this heading. They proposed the park develop a detailed information brochure for fishermen that would describe the background behind and rationale for the fish management plan. A second brochure would target hikers, interpreting the aquatic habitats and fisheries along the Coastal Hiking Trail.

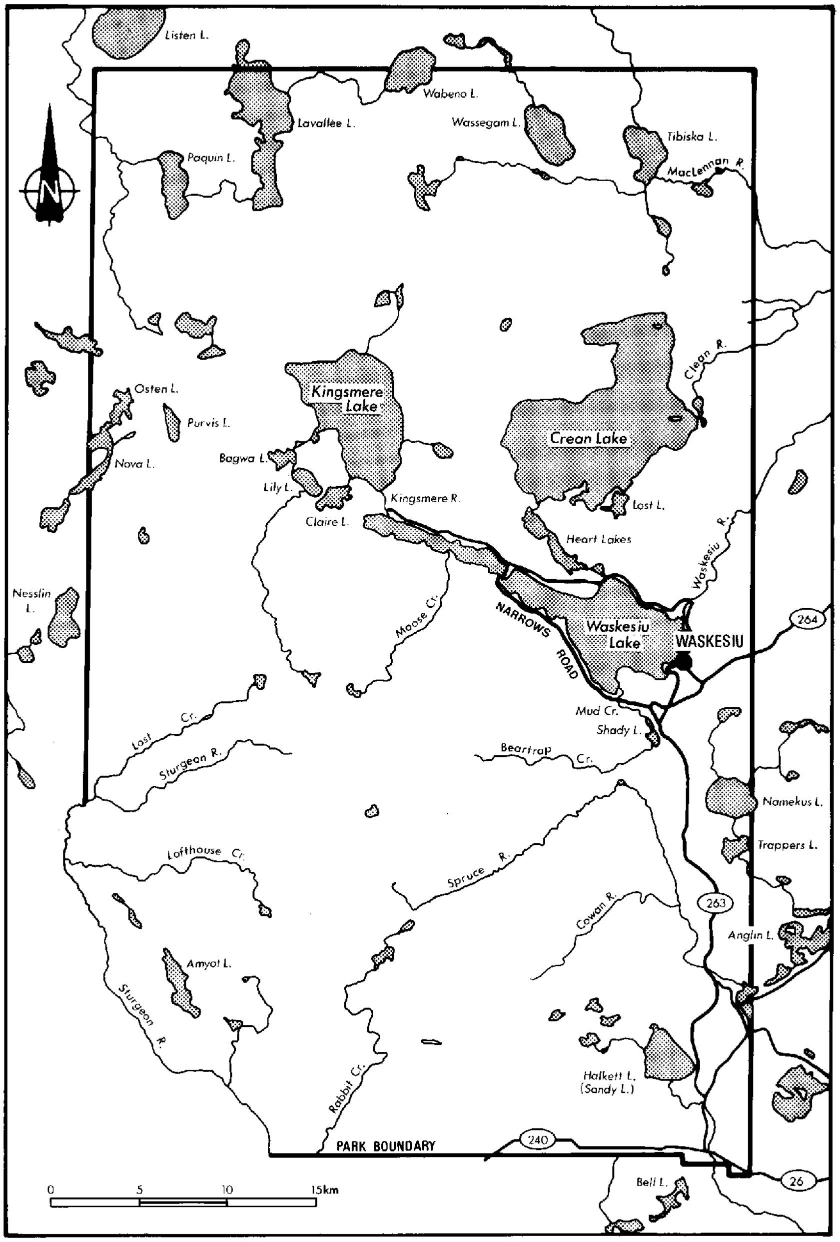
Schiefer and Lush (1986) tabulated a schedule for implementing their proposed program, together with priorities, manpower requirements and estimated costs. They recommended that the plan be reviewed at five-year intervals, but that revisions should be made as required, regardless of the scheduled review.

Prince Albert National Park, Saskatchewan

Aquatic Resources and Fisheries

Prince Albert National Park, established in 1927, encompasses 3875 km^2 of boreal forest and lake country near the geographic centre of Saskatchewan (Figures 1 and 5). The aquatic resources of the park (summarized from Mayhood 1974) consist of more than 1500 surface waters ranging from hundreds of ponds and small lakes to lakes over 100 km^2 in area and up to 55 metres deep, as well as hundreds of kilometres of small rivers and streams. At a conservative estimate, surface water covers perhaps 20 percent of the park area. The lakes lie in deep till dominated by features of stagnant ice disintegration, and range in character from small dilute bog waters in the highlands of the Waskesiu Hills through open-basin lakes typical of the Forest Zone of Freshwater Lakes (Northcote and Larkin 1963) to moderately saline types in the grasslands of the extreme southwest corner of the park.

Figure 5. Prince Albert National Park, Saskatchewan. The small lakes and streams comprising most of the park's aquatic habitats have been left off this map for clarity. They are particularly abundant in the Waskesiu Hills, the headwater area southwest of Waskesiu Lake. Adapted from Mayhood et al. (1973:9).



Twenty-one native species of fish have been reported from Prince Albert Park; attempts to introduce two non-native species were apparently unsuccessful. The principal sport fish species are northern pike, walleye, yellow perch (most major lakes and streams) and lake trout (indigenous to three deep lakes, introduced into a fourth). Sport fishing is concentrated in a half-dozen accessible medium- to large-size lakes and their associated water bodies, the three largest being Crean, Waskesiu and Kingsmere lakes.

Aquatic Resource Management Objectives

An aquatic resource management plan for the park was adopted in 1989 that included planning for sport fishery management in the most heavily used lakes (Canadian Parks Service 1989). The goals of the plan were to

1. *"ensure the ecological integrity of the aquatic ecosystems of the park by maintaining or restoring natural water level regimes, pristine water quality, natural aquatic habitats and viable, naturally reproducing, endemic fish populations;*

2. "*provide quality visitor experience by increasing angling success rates, supplying more information about aquatic ecosystems to park users, and improving opportunities to appreciate natural aquatic systems in a non-consumptive way;* [and]

3. "*designate lakes representative of the natural region for total protection of aquatic resources to serve as aquatic benchmark reserves"*.

Several major areas of concern for fish management can be recognized in the plan, most of them related to habitat damage and declining sport fish populations. These concerns and the ways of addressing them proposed by the plan are outlined below.

Artificially High Water Levels

The water levels of the two largest lakes were raised with dams built across the outlet rivers as early as the 1930s to facilitate boat docking and access. The higher water levels are believed to have produced serious shoreline erosion in the lakes, causing damage to lake trout spawning habitat in Crean Lake and walleye spawning habitat in Waskesiu Lake. Artificially high water levels in Crean Lake also allow heavier fishing pressure on populations in Lost Lake, which at lower lake levels is suggested to have been a refuge from anglers for pike and walleye.

The management plan proposes that a separate Crean Lake Management Plan be developed with a view to reducing both the artificially high water levels and the environmental impacts arising from them. Engineering, environmental impact and socio-economic assessments are proposed to aid in developing a more natural regime of water levels in Waskesiu Lake.

Lake Trout Rehabilitation, Crean Lake

It is believed that the high water levels and ensuing erosion problems combined with overexploitation has reduced the lake trout population to dangerously low numbers. The management plan proposes to close Crean Lake to fishing for lake trout, to monitor natural reproduction and recruitment, and to implement an active rehabilitation program. The nature of the rehabilitation program was not specified, and presumably would be the result of further study.

Kingsmere River Rehabilitation

The Kingsmere River was dammed first in the 1930s and again in 1963 to facilitate boat access to Kingsmere Lake. The river also was channelized, removing one kilometre of potential spawning habitat from the Waskesiu Lake walleye population. This together with the negative effects of heavy boat traffic during the spawning period and flow control resulting from the dam is blamed for greatly reduced walleye spawning in this river. The spawning run is not only necessary for the survival of the Waskesiu Lake walleye sport fishery, but is potentially of great interpretive and educational value.

The Aquatic Resource Management Plan proposes to study the modifications to determine what the natural stream conditions were like with a view to reconstructing them, then prepare a Resource Management Plan and an Area Development Plan based on the findings.

Sport Fishery Rehabilitation

Many of the sport fish populations in the park show evidence of overharvesting, and angler success has declined over many years. The Aquatic Resource Management Plan sets specific objectives for angler success rate, reduces catch limits for lake trout, northern pike and walleye, and adjusts the open season to protect the spawning periods of these species to reduce the kill rate and preserve stocks.

Baseline Survey and Monitoring Programs

The lakes and streams of entire regions of the park still have not been described even in a preliminary way, so baseline conditions of aquatic resources remain unknown over large areas. Ongoing monitoring is required to detect incipient management problems and especially to evaluate the effectiveness of management actions so that adjustments can be made when necessary.

The management plan proposes an ongoing baseline survey and monitoring program for aquatic resources to include

1. baseline limnological surveys of major lakes and streams, especially in the northern part of the park;

2. surveys of fish communities in selected streams to develop biotic indices for long term monitoring;

3. population monitoring of fish in the major sport fish lakes;

4. creel census on the major lakes, including sampling the catch for obtaining life history information;

5. monitoring spring spawning runs annually on three creeks;

6. baseline survey and monitoring of fish diseases and parasites;

7. a comprehensive water quality monitoring program for the major lakes;

8. monitoring water levels on Waskesiu, Crean and Kingsmere lakes and discharge on the Kingsmere River;

Ecological Research

The writers of the Aquatic Resource Management Plan recognized that human activity in the park would affect whole aquatic ecosystems, and that it would be necessary for resource managers to understand more precisely how those ecosystems normally function so that they could recognize changes in function when they occur. The plan proposes to conduct an ongoing program of basic research on community energetics, community structure, nutrient cycling, and ecosystem stability in park waters, working jointly with a research institute and universities.

Aquatic Benchmark Reserves

Whole aquatic ecosystems preserved entirely in their unmodified state could serve as benchmarks against which changes in aquatic ecosystems elsewhere could be measured, and as sources of healthy stocks of aquatic organisms for rehabilitating damaged areas. The Aquatic Resource Management Plan for Prince Albert Park proposes that benchmark ecosystem reserves be established in the park, and outlines criteria to be used in evaluating candidate ecosystems. Criteria include ecological integrity, representativeness, rarity, diversity, fragility, impact on the public, and opportunities for research.

Interpretive Programs

Consumptive sport fishing continues to be the primary use of aquatic biological resources in Prince Albert Park. Interpretive programs and facilities offer a way of promoting greater public understanding and appreciation of other ways of using the resources. The Aquatic Resource Management Plan favours establishing sanctuaries for fish viewing on particularly suitable streams and lakes, and incorporating these into interpretive programs for the park.

Public Consultation and Implementation

Public comment on aquatic resource management in the park was solicited in two information brochures, at a seven-hour open house, and in other less formal ways. Sixty-three written responses were received. The views expressed in these submissions in general supported the approaches that ultimately appeared in the Aquatic Resource Management Plan. Some contentious issues did arise, especially concerning access to Kingsmere and Crean lakes under proposed lower lake levels, and to a lesser extent concerns were raised relating to absolute protection for lakes in benchmark ecosystems.

A ten-year schedule for implementing the plan is provided, showing dollar and person-year requirements.

La Mauricie National Park, Quebec

Bouin (1988) summarized the approach used to manage sport fishing in La Mauricie National Park, Quebec (Figure 1). The approach is described more fully in the park's fish management plan (Bouin 1980). The park also has published a superb booklet for visitors (Parks Canada 1983), detailing the park's limnology, fisheries and fish management practices in a professional way using plain, easy-to-read language. The following discussion is based on these documents.

Aquatic Resources and Fisheries

La Mauricie National Park, 65 km north of the city of Trois Rivières, was created in 1970 to protect a representative portion of the St. Lawrence and Great Lakes Precambrian Region. Surface waters comprise approximately seven percent of the park's 544 km^2 area, and include 95 mapped lakes. Two rivers, the Mattawin and the St. Maurice, bound the park on the north and east, respectively.

The various waters hold 25 species of fish, including two relict species, rainbow smelt (2 populations) and Arctic charr (1 population). The most widespread sport fish is brook trout, found in 58 water bodies and accounting for 80 percent by weight of the annual catch. Other sport fish species include lake trout (seven lakes), yellow perch (8 water bodies), smallmouth bass (7 water bodies), pike and walleye (1 lake each). Several exotic species were introduced before the area became a park, among them lake trout, smallmouth bass and rock bass. Sport fishing is allowed on thirty lakes and many streams. It is a popular park activity, and is believed to contribute significantly to the local economy.

Sport Fisheries Management

Park fisheries are managed in accordance with national parks policy, that is, with the objective of protecting the resource while providing fishing as an outdoor recreation activity that depends upon the park's natural resources, requires few man-made facilities, and is actively managed where necessary using techniques that duplicate natural processes as closely as possible. In La Mauricie, this has been interpreted as managing for sustainable yield.

It appears that the sustainable yield of each fishing lake has been estimated subjectively by successive approximation. Initially, a very rough estimate was made of average potential annual yield for all park lakes. Using this as a first estimate of sustainable yield for each lake, fishery managers adjusted the figure up or down based on their knowledge of local conditions. Creel census results provided feedback on how well their estimates of sustainable yield reflected reality, and the estimate of sustainable yield was adjusted accordingly.

The sustainable yield estimates are used as catch quotas. A compulsory registration system and creel census is used to monitor fishing on each lake. Each angler must fill in a card at the end of each trip detailing the number, weight, length and species of each fish caught. Data on catches are compiled weekly, and the lake is closed to further fishing once the quota has been met. The catch data are later analyzed to evaluate the adequacy of the current quota in maintaining a healthy fish population and a high quality fishery. Quotas are adjusted up or down depending on the outcome of this assessment.

The La Mauricie approach has been an unequivocal success in maintaining both high quality sport fisheries and self-sustaining fish stocks over a period of fifteen years. Structural changes in the populations (e.g., age, sex, maturity, recruitment, growth) are not monitored, however, leading Bouin (1988:207) to warn that “we cannot draw the conclusion that the fish populations have not been affected by harvest activity.” He points out also that there are many other important questions left unresolved, such as the effect of selective fishing on fish community structure, but observes that an exploited brook trout population “can regain its initial state in only a few years if harvesting is discontinued”, and asks “is it our objective to ensure the viability of a fish population while accepting that it may undergo major, but reversible, changes?” (Bouin 1988:207).

Recent fishery management effort in the park has been directed toward promoting fishing as part of a wilderness experience and as a prime means of discovering and understanding aquatic resources; i.e., as a means to an end, rather than an end in itself. Motorboats have been banned from the park since 1974, but wardens used them to some extent for patrol work. Recently wardens have had to patrol only by canoe. Some lakes have been set aside for the sole use of canoeing anglers who stay overnight; daily limits on the number of visitors have been instituted on other lakes. Still other lakes are reserved for the sole use of senior citizens. Catch limits have been reduced and sonar has been banned in some locations.

The park’s aquatic resource management plan (Bouin 1980) is presently being revised and updated (T. Bouin, personal communication 2 May 1990). Among the improvements being considered are (Bouin 1988:209):

1. adequate protection for all fish species (including non-sport species), water quality, and rare or unusual species;

2. proactive management through new research and monitoring;

3. habitat reclamation projects;

4. removal of exotic species;

5. creation of fish sanctuaries; and

6. improved interpretation programs for aquatic resources.

Fundy National Park, New Brunswick

Fundy National Park (Figure 1) recently prepared a special management plan for its Atlantic salmon stocks (Grainger and Priest 1988). The Atlantic salmon is under severe pressure nearly everywhere, so protecting,and restoring stocks takes high priority wherever the species occurs (or once occurred) in the national parks of Atlantic Canada. The plan includes stock restoration, protection and interpretation components; however the actual interpretive plan was not included in the document, so I do not consider it here.

Point Wolfe River Stock Restoration

Stock restoration projects for freshwater species do not appear to have been attempted frequently in Canadian national parks. There have been many attempts to restore extirpated stocks of anadromous salmonids in Canada, however. One such effort has been made in the Point Wolfe River of Fundy National Park (Alexander and Galbraith 1982).

Point Wolfe River once held a substantial population of Atlantic salmon. The river was dammed near its mouth first in 1824, partially impeding migrations to upstream spawning areas. The initial dam was later replaced by successively larger and better-constructed dams until access to most of the river was completely blocked to salmon near the turn of the century. Fundy National Park attempted to remove the dam by blasting in 1950, shortly after the park had opened, but this was unsuccessful. Later attempts were able to provide fish passage intermittently, but the dam was repaired in 1967 and 1972, again forming a complete barrier to migrating fish.

Because the run was blocked for many successive years, the original Point Wolfe River stock is thought to have been extirpated in its pure form. The original genetic strain may have had some impact on current stocks in the short accessible portion of the lower river, but it is believed the salmon that returned prior to the 1982 restoration program were a mixture of strays from other rivers and descendants of strays or previous hatchery releases (Alexander and Galbraith 1982).

At the time the salmon restoration plan was developed, the dam was considered as a heritage resource to be preserved by the park, but it was also an intrusion on the natural scene that was continuing to damage the natural ecology of the Point Wolfe River and many of its tributaries. Parks Canada decided to provide fish passage through the dam in 1981 so that a self-sustaining population of Atlantic salmon could be restored to the river system.

The restoration plan documented the available critical habitat and production potential for salmon in the river system, and evaluated a variety of strategies that were available to establish a new, self-sustaining stock. Among the alternatives considered were the following.

1. *Allow the river to be colonized by natural strays.* This was the least expensive approach, but would have taken several years and would have run the risk of producing a stock that would be seriously deficient genetically.

2. *Transfer adult Atlantic salmon to spawn in the river.* This alternative would have had the greatest likelihood of producing a genetically well-adapted stock, but would have been exceedingly expensive, would have put large numbers of scarce adult fish at risk, and would have been politically unpopular.

3. *Stock smolts (two-year-olds).* With this option, it would have been possible to maintain favourable genetic characteristics, distribute the fish at low cost, and monitor the fish easily. Hatchery costs would have been high, however, with high losses at sea and poor imprinting contributing to relatively low returns to the river.

4. *Stock fingerlings.* This option would have had lower hatchery and other costs than those associated with option (3), would have provided for adequate gene pool size and reasonable opportunity for selecting good stock, but stocking itself would have been somewhat more difficult and some instream monitoring would have been needed.

5. *Stocking fry.* This approach would have had the lowest costs of any of the stocking methods, good instream natural selection and good gene pool size and stock selection opportunities. Large quantities of eggs would have been required, however, and both stocking and monitoring would have required extensive effort. Mortalities could have been unexpectedly high.

Alternative (4) was selected as being the most acceptable option. A Bay of Fundy stock, assumed to be similar to that formerly using the Point Wolfe River, was selected from an adjacent river system for a source of eggs after taking into consideration the status of the various stocks available.

As the plan was being implemented, a fortuitous event (for the salmon) occurred. The fishway through the dam had to remain uncompleted through one winter, and unusually high runoff destroyed the structure the following spring, making the river again accessible to the fish. Because the dam was a heritage resource under the protection of the park, there was significant criticism for the park's failure to protect it adequately (L. Harbidge, personal communication 25 June 1990).

The 40,000 fingerlings stocked annually produced escapements of 25 to 40 percent, somewhat higher than that expected, but adult returns have not been as high as had been hoped. Expectations were only crude estimates and may have been too high for a number of reasons (Grainger and Priest 1988). Alternatively, this may be merely a local manifestation of a much more widespread and serious problem. Most Fundy stocks of Atlantic salmon are badly depleted at present, and some Department of Fisheries and Oceans scientists suspect some factor in the Bay of Fundy as a whole is responsible (L. Harbidge, personal communication 25 June 1990).

The Point Wolfe River was closed to angling as the stock was being established to protect the rearing young salmon. The original intention in the 1982 restoration plan had been to open the river to sport fishing as the stock grew. Because all other Fundy rivers are exploited to some extent, the river is now a candidate for "benchmark" status to be protected by the park (Grainger and Priest 1988). A final decision on benchmark status for the Point Wolfe River will be made in 1992 (L. Harbidge, personal communication 25 June 1990).

Upper Salmon River Stock Protection

Initially the Upper Salmon River suffered the same fate as the Point Wolfe River, with a dam built as part of logging operations extirpating the local salmon stock in the 1800s. In contrast to the Point Wolfe River, a salmon run became re-established on its own from stray fish when the dam fell into disrepair. This new stock has been fished by anglers for several years, and provides the principal sport fishery for Atlantic salmon in the park at this time. The fishery is managed to "allow for more tha[n] adequate spawning escapement" to "best approximate natural population conditions" (Grainger and Priest 1988:36). In essence, fish surplus to the spawning requirement are made available to anglers.

To do this, the small population is counted directly at intervals through the open season. If the number of mature salmon is less than the number (about 120) determined to be a safe estimate of the required escapement (leaving a reasonable margin for error), the fishery is closed even if the published angling season is still open. Angling also may be closed if water levels drop so low as to expose the salmon to poaching. If angling pressure becomes excessive, a daily in-park lottery allocates angling access to the river. A maximum size limit and bag limit of 1 per day is imposed, and terminal gear restrictions (fly fishing only) are in force, presumably to ease the release of oversize fish. Retained fish must be tagged and registered with park authorities, who take basic statistics and issue a replacement tag, (up to a maximum of five tags).

The essence of the management approach thus is accurately to forecast returns from the spawning stock and adequately to limit harvest to the estimated "surplus" number of fish (surplus to spawning requirements). A realistic approach to forecasting returns is available from the extensive research that has been conducted of Canadian Atlantic salmon stocks; however it had not been verified for the FNP rivers at the time the plan was implemented. Developing and testing the approach for park rivers forms a major part of the plan.

SELECTED PROVINCIAL FISH MANAGEMENT PROGRAMS

Alberta's Wilderness Areas

The Province of Alberta has set aside as designated Wilderness Areas three small portions of the Rocky Mountain East Slopes within its jurisdiction. One of these, the White Goat Wilderness Area, is a 445 km^2 reserve bordering Jasper National Park on the south. The remaining two, the Siffleur (412 km^2), and Ghost River (153 km^2) wilderness areas, lie on the northeast and eastern boundaries of Banff National Park, respectively (Figure 2). Their combined area, 1010 km^2, is approximately one-tenth that of Jasper National Park.

All three of the wilderness areas include major streams, and two (Whitegoat and Siffleur) hold several small lakes. Falls and canyons in the Whitegoat and Siffleur wilderness areas apparently prevented native fishes from colonizing their waters. The only known native fish stock in these areas is part of a bull trout population occupying the extreme lower end of McDonald Creek in the Whitegoat (Tebby 1974). Introduced rainbow and cutthroat trout occupy parts of the Siffleur drainage in the Siffleur Wilderness Area (Tebby 1974). There is no information on the fish populations (if any exist) in the Ghost River Wilderness Area (Alberta Forests, Lands and Wildlife 1987:34). Although a portion of the Ghost River and some short tributaries in the Ghost River Wilderness Area conceivably might hold native mountain whitefish, native westslope cutthroat trout and native bull trout, the watershed is open to invasion by any of a number of exotic stocks introduced into Lake Minnewanka and the Ghost lakes, into which the Ghost River was diverted many decades ago.

Extractive resource use, including fishing, is not permitted in Alberta's designated wilderness areas. The point of the no-fishing regulation is unclear. Unless it can be shown that the upper Ghost River holds genetically pure indigenous fish stocks, the no fishing regulation in Alberta's designated wilderness areas would appear to have little or no value for conserving native fish. There likewise seems to be little point in protecting from exploitation the introduced rainbow trout populations in the Siffleur drainage unless they are shown to be non-introgressed pure stocks having as yet unidentified conservation value. (Most introduced stocks of this species are very widespread domesticated strains with dubious value for conservation at best; see Part 3.) The introduced cutthroat trout of the Siffleur Wilderness Area would have great value for conservation if they have not introgressed with the rainbows, and especially if they are the westslope cutthroat subspecies native to the province. Neither of these conditions has been ascertained.

The ban on fishing and hunting in the wilderness areas originally was criticized by one conservation group, the Alberta Wilderness Association, because it tends to erode the base of public support for more wilderness areas in the province (V. Pharis, personal communication). During the initial planning stages and in response to pressure from oil and gas interests, hunters and anglers rashly urged that the wilderness areas be closed to hunting and fishing. Later they worked to drastically reduce the size of at least one wilderness so as not to include favoured hunting and fishing areas (Carl Hunt, personal communication).

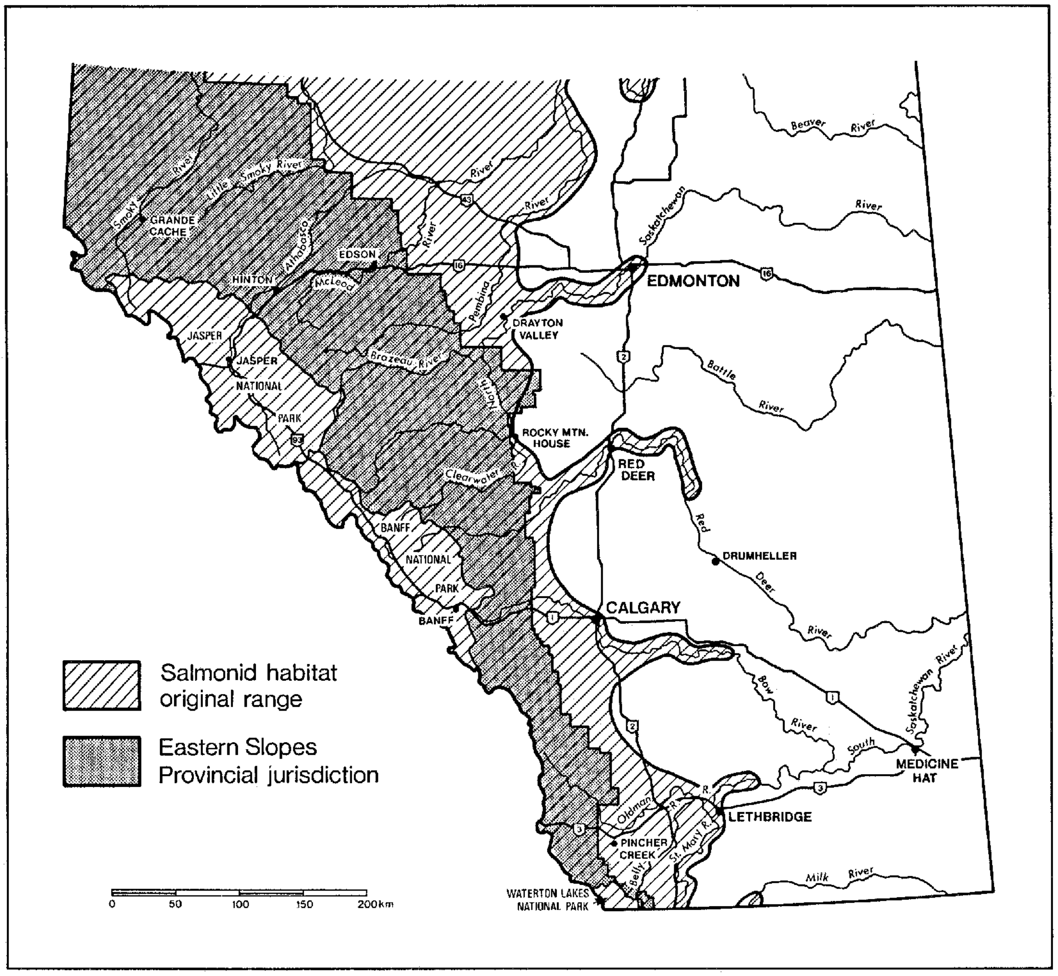
The Rocky Mountain East Slopes

In southern Alberta the East Slopes region comprises a 108,000-km^2 area of forests, mountains and foothills east of the Continental Divide. The region includes approximately two-thirds of the native range of coldwater fishes (salmonids — trout, charr, whitefish, grayling) in the southern half of the province. Approximately 83 percent (90,000 km^2) of the East Slopes is under the jurisdiction of the Alberta government; the remainder is contained within Jasper, Banff and Waterton national parks (Figure 6).

Various parks and recreational development areas, several of considerable size, have been designated along the East Slopes by the Province of Alberta. The two largest are Willmore Wilderness Park, immediately north of Jasper National Park, and Kananaskis Country, immediately south of Banff National Park (Figure 2). Willmore Park is managed as a primitive recreational wilderness in which hunting and fishing are allowed, but other extractive resource uses (mining, logging, etc.) are prohibited. Kananaskis Country is managed as an intensive-use outdoor recreation zone in which virtually every form of outdoor recreation is accommodated along with facilities-oriented tourism, domestic livestock grazing, hydroelectric generation, hydrocarbon exploration/development, and other industrial uses. Sport fisheries are managed without benefit of formal fish management plans for these areas (J. D. Stelfox and Carl Hunt, personal communications).

The only official guidance for managing fish resources of the East Slopes is provided by broadly-stated province-wide policies and objectives (Alberta F&W 1984, Stenton 1985) within the context of overall resource management policies for the East Slopes (Alberta ENR 1984). Statements in these documents do not reveal what the specific fish management objectives are for the various types of parks and recreation areas, or specifically how they are to be met.

Figure 6. The Rocky Mountain East Slopes in Alberta, showing the national parks, East Slopes planning area (provincial jurisdiction) and the approximate native distribution of coldwater sportfish species (salmonids).



Fisheries objectives for the East Slopes as a whole as listed by Alberta ENR (1984:7) are:

1. *" to protect aquatic habitat and ensure high water quality;*

2. *" to establish optimal instream flow for fish through modification of land/water use practices;*

3. *"to recognize sport fishing as the principal use of the fishery resources in the Eastern Slopes;*

4. *"to maintain naturally reproducing salmonid (trout, char, grayling and whitefish) populations in the region and to expand these fish resources into presently vacant and appropriate aquatic habitat;* [and]

5. *"to supplement or enhance game fish stocks by stocking when natural reproduction does not occur or is limited."*

There are explicit province-wide goals for selected fish species to which fish managers in the East Slopes parks and recreation areas must address themselves (Alberta F&W 1984). For example, native species are to be used as much as possible for stocking. All naturally-reproducing populations of rainbow, cutthroat, lake and golden trout are to be maintained at, or increased to, maximum production levels. Arctic grayling and mountain whitefish populations are to be maintained at present production levels. Naturally-reproducing populations of the introduced exotic species brook and brown trout are to be maintained at maximum production levels only where they are better suited to the habitat than native trout; they may be stocked only where they are more suitable to the habitat than are native fish.

Bull trout stocks have been depleted throughout the Eastern Slopes wherever they have been exposed to significant fishing pressure (Carl 1985:77, Roberts 1987), and now are given special management consideration everywhere in the province. A special management plan was drafted for the species (Carl 1985), but apparently it was not fully implemented. Alberta Fish and Wildlife (Alberta F&W) does intend to increase all naturally reproducing populations of bull trout, to reintroduce them into previously occupied habitat, to maintain critical spawning and rearing areas, and to educate the public about its sportfishing value. There are plans to reintroduce cutthroat trout into previously occupied habitat as well (presumably their native habitats in the Bow and Oldman drainages), but there is no explicit commitment to protect the native Athabasca rainbow trout. To facilitate management by species, Alberta F&W proposes to promote species identification by the public (Alberta F&W 1984).

There is at least one sport fishery on the East Slopes with a no-kill rule. The North Ram River holds a sanctuary population of what is believed to be a genetically pure stock of westslope cutthroat trout. A British Columbia stock was introduced above barrier falls in 1955 by some farsighted Alberta fisheries biologists. They wanted to protect from genetic pollution at least one river population of this characteristic Alberta fish (Scammell 1988).

A no-kill catch-and-release sport fishery was opened on the river in 1982, but failed dismally perhaps because the population had been nearly wiped out by disastrous spring floods the previous year. The catch by the end of August that year was said to have totalled just 14 fish. By 1987 the population, although described as “not large”, had recovered enough to provide high-quality fishing (Scammell 1988).

A survey of angler opinions of the North Ram no-kill fishery (Dolsen and Butler 1987) showed that 93 percent of trout fishermen believed it to be a worthwhile trout management concept, and 70 percent felt an expansion of the program was warranted. Forty-one percent of the anglers interviewed felt that there were enough benefits that they would like to try it themselves. Twenty percent were not willing to try it themselves, and 10 percent directly opposed using no-kill fishing to manage Alberta trout fisheries.

A new policy document entitled “Fisheries Conservation Strategy for Alberta” may be applicable to fish management in East Slopes parks and recreation zones. It is now in draft form, but could not be made available for this review (T. Mill, personal communication 25 June 1990).

Algonquin Provincial Park, Ontario

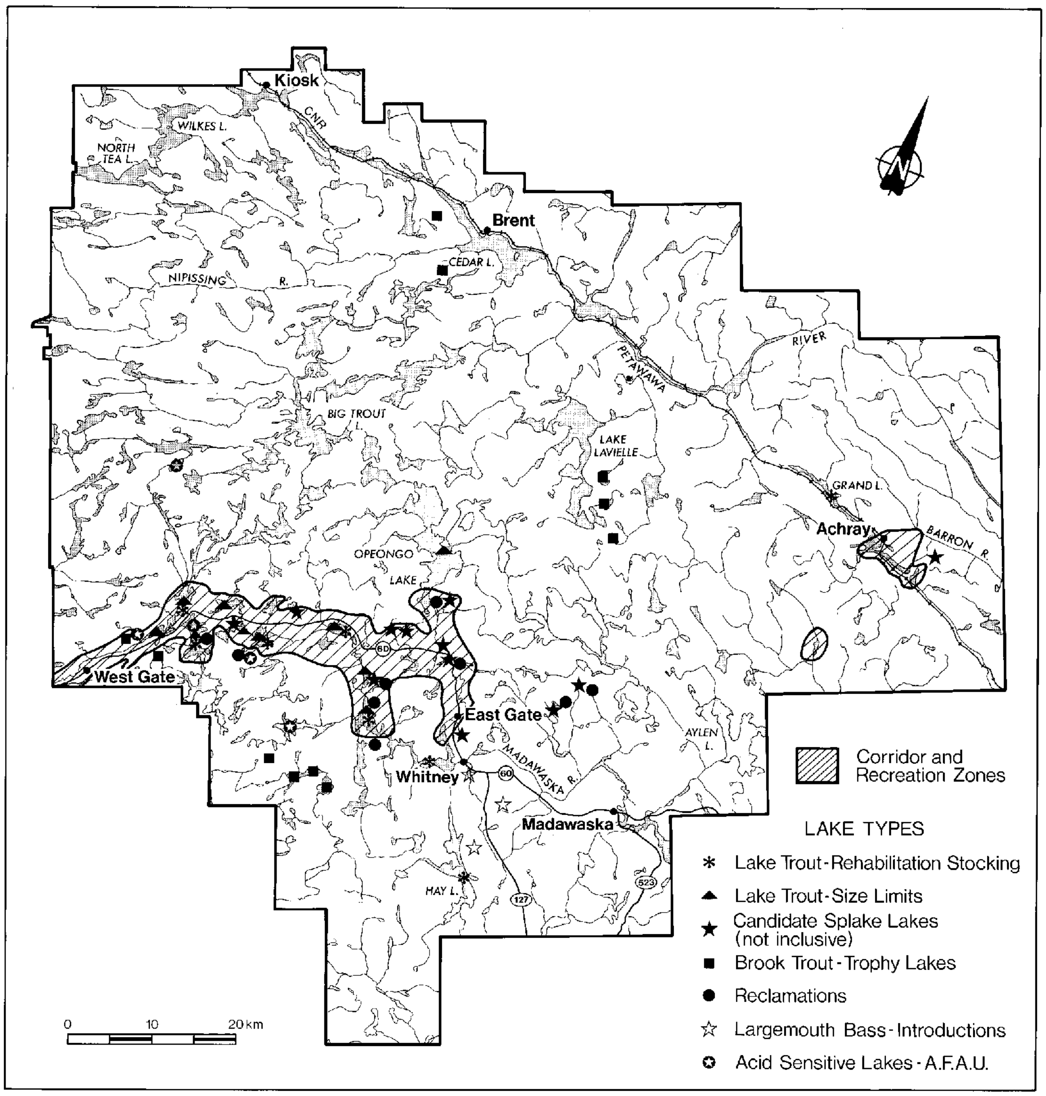
Algonquin Provincial Park is a 7600 km^2 reserve of one of the largest remaining areas of wild country in southern Canada (Figures 1 and 7). Classified as a Natural Environment Park under the planning system used in Ontario, Algonquin contains the only major complex of fisheries for native trout still extant in the southern part of the province, with many of the lakes and their trout stocks said to be still in near-pristine condition. A fisheries management plan, from which the material in this section was obtained unless noted otherwise, was developed over a four-year period to protect and manage these resources through the year 2000 (Ontario Ministry of Natural Resources 1988).

Fisheries Resources

Sport fishing is a primary activity in the park, especially in spring, when recreational use until mid-June is largely by anglers fishing the park’s 230 brook trout, 149 lake trout and 85 smallmouth bass lakes. An estimated 512,000 angler-hours per year are expended to harvest 35,500 kg of brook trout and 30,500 kg of lake trout, among other species, from park waters. Angling pressure is projected to increase by 15 percent by the year 2000.

The park is divided into two zones for fish management purposes: the wild and inaccessible Park Interior, and the highly-accessible Parkway Corridor along the main highway (Figure 7). The fish management objective for the Park Interior is "to maintain a very high quality, low intensity fishing experience"; that for the Parkway Corridor is "to provide an optimum of opportunities for fishing based recreation consistent with the limits of sustained yield management and the recreation objectives of the Park Master Plan" (Ontario Ministry of Natural Resources 1988:6). The plan sets specific overall targets for harvest (in terms of weight) and numbers of "angling opportunities" that it hopes to achieve.

Figure 7. Algonquin Provincial Park, Ontario, showing the basic fish management plan, and the Interior (white) and Corridor/Recreation (hatched) zones. The five townships lying directly south and east of Whitney are part of the Algonquin District planning area but are not part of the park. Adapted from Ontario Ministry of Natural Resources (1988: Figure 3).



The Algonquin management plan recognizes six major fishery problems faced by the park, and addresses these problems as outlined below.

Local Overfishing

The harvest figures quoted above represent 156 percent of the estimated allowable brook trout harvest and 106 percent of the estimated allowable lake trout harvest for the park as a whole. The overfishing problem in certain waters is in fact much worse than these overall figures suggest, because trout fishing is concentrated in a small number of accessible lakes mostly in the Parkway Corridor.

To deal with local overharvesting, the plan proposes to reduce the number of lake trout killed in Parkway Corridor waters by limiting retained catch per angler to two, setting minimum or slot size limits on lakes fished by motorboats, banning the use of ciscoes as bait, and increasing enforcement during peak periods. It also proposes to set an aggregate trout limit of five, no more than two of which may be lake trout, and establish "special regulation" (catch/release) lakes with zero to two fish possession limits for brook trout on waters in both fish management zones of the park.

Inadequate Supply in High Demand Areas

Good fishing is available in the park interior, but there are not enough fish to go around in accessible waters near the main highway. Intensive stocking has not been successful in meeting the shortfall.

To overcome this problem, the fish management plan proposes to establish new fisheries, primarily in the Parkway Corridor. The new fisheries include 25 new splake lakes, and may also include new self-sustaining brook trout populations in presently fishless lakes. Managers propose to evaluate, and if necessary improve brook trout spawning habitat, and to establish new spawning stocks of lake trout. Lake trout and brook trout introductions will all be made from native Algonquin Park Interior stocks. Underutilized smallmouth bass fisheries in the Park Corridor will be actively publicized and promoted.

The park's extensive stocking program will be made more effective by decreasing lake trout stocking, which has been exceedingly ineffective in supplementing wild populations to date (Strickland 1988:14), in favour of splake stocking, which has proven to be effective in providing high quality "put-grow-take" fisheries (Strickland 1988:15). Stocking of brook trout is to be maintained at present levels, but stocking of inaccessible lakes will be eliminated. Perch infested waters are to be reclaimed, apparently for later restocking with splake. The plan proposes to develop a "lake rotation schedule" (regular stocking schedule for each lake?) for brook trout and splake, and also establishes clear formal guidelines for managing a fishery based on the nature of present populations and the history of fishery management in the lake (Table 2).

Table 2. Criteria determining the fish management strategy to be used for coldwater lakes within the Corridor/Recreation zones, Algonquin Provincial Park, Ontario. Even within this zone, which is managed intensively for sport fishing, the plan emphasizes the use of native Algonquin stocks whenever stocking is applied as a management tool. Unique communities of scientific interest within the zone are not managed for sport fishing. Adapted from Ontario Ministry of Natural Resources (1988:Appendix 1).

Criterion	**Management**
Lake has a healthy self-sustaining trout population	Do not stock
Lake has natural trout reduced by overexploitation	Rehabilitate via population and/or habitat management. Stocking hatchery-reared lake trout will be phased out
Lake has natural lake trout that are chronically suppressed at a very low density by some uncontrollable natural limiting factor	Stock with F_1 splake
Lake is devoid of sport and coarse fish, is demonstrably successful put and take brook trout fishery	Stock with hatchery-reared brook trout
Lake is devoid of sport fish and has a history of failed brook trout stocking (many are infested with perch)	Stock with F_1 splake

Deterioration of Native Fish Stocks

Introduced hatchery fish, and invasions of undesirable warmwater fish species, threaten to eliminate many indigenous trout stocks.

The Algonquin Park fisheries management plan proposes “to optimize production of appropriate species or strains of sport fish” (Ontario Ministry of Natural Resources 1988:8) and manage lake community structure in the Parkway Corridor lakes, but aims to maintain native sport fish communities in the Park Interior. To achieve this, stocking of hatchery strains of fish will be restricted to lakes within the Parkway Corridor or to those within one portage of the Corridor — and then only with brook trout, lake trout and splake. Stocking will cease in lakes having self-sustaining trout stocks, and will be done in the Park Interior only for rehabilitation or introductions with native Algonquin Park stocks. Possession of live bait fish within the park will be banned, and managers will attempt to prevent the further spread of non-trout (i.e., warmwater) species within the park. Rare and endangered stocks will be protected, and compliance with the baitfish ban will be enforced.

Acid Precipitation

A water quality survey showed that 2.5 percent of the lakes tested had been completely acidified, and that another 22.7 percent were extremely sensitive to acidification. At least some of these are thought to be naturally acidic (Strickland 1988:5). Acidified lakes will not support fish populations. While acid precipitation was not seen as an immediate threat to the fisheries, the plan suggested that “the course of events is difficult to predict” (Ontario Ministry of Natural Resources 1988:5).

The management plan calls for monitoring the effects of acid precipitation on park fisheries, mitigating them where possible. Five lakes judged to be especially sensitive will continue to be monitored. Limestone rock will be used in artificial spawning beds, and other techniques may be used as they are developed.

Resource Development and Extraction

Logging activities, road building and stream crossings within the park are concerns, presumably as threats to fish habitat. Fluctuating water levels, apparently connected with dams, are considered to be local problems.

Park managers will monitor, and mitigate if necessary, the effects of commercial development on fisheries habitat by reviewing development plans, forest management plans, water control plans, shoreline development plans, stream crossings, hydro lines and other projects. Construction and mitigation standards and approval procedures for stream crossings in the park will be reviewed, as will water level management and its implications for lake trout spawning.

User Perception

“Poor communication with the angling public has resulted in a number of misunderstandings concerning fisheries management issues (for example, fish stocking strategies)”, according to the plan (Ontario Ministry of Natural Resources 1988:6). Improved communications are seen as necessary for effectively implementing the new plan.

The Algonquin Park fisheries management plan proposes that managers increase public awareness of fishery management principles, and the objectives of fishery management in the park, by enhancing the interpretive programs that relate to fisheries. In particular it urges that the value of the park's native trout stocks be emphasized. Once fishing is improved within the Parkway Corridor, a brochure entitled "Fishing the Algonquin Corridor" will be developed. Fact sheets, news releases, speaking engagements and other promotional activities will be used to improve communications with interest groups throughout southern Ontario.

Implementation

To implement the fisheries management plan, Algonquin Park managers prepare annual work plans under a system of five-year implementation schedules. In general, the first five-year schedule gives priority to projects that will immediately increase fishing opportunities, especially in the Parkway Corridor. Experimental management methods have been given lesser priority.

Two additional features of the Algonquin Park fisheries management plan worth noting are its use of regional integration and its emphasis on public input to guide managers in developing the plan and assessing the public acceptability of various proposals.

Regional Integration

In the fisheries management plan, managers are attempting to relieve some fishing pressure on the park by developing and improving intensive fisheries immediately outside the park. For example, three outside lakes are proposed for largemouth bass introductions, three for splake introductions, two for reclamation, and one for lake trout rehabilitative stocking. In addition, the plan proposes to take advantage of some regional or province-wide fisheries programs. Algonquin Park's status as a provincial park, the fisheries of which are managed by the same agency that manages waters outside the park, makes this sort of regional integration a simple matter.

Public Input

Before and while preparing the fisheries management plan, fish managers solicited public views on various options. Questionnaires were distributed during creel census in 1984. A background document including various options was prepared in 1986 and distributed to key user groups and news media, forming the basis of discussion at three community open houses and a display/open house throughout one season in the park museum. Articles were printed in park and local communications media. Finally, eight evening programs about fisheries were presented to visitors at regular interpretive programs in the park theatre.

Public comments and submissions resulting from the above activity were reviewed and a draft plan was prepared in 1987 that took into consideration this information. The draft plan was submitted to 90 individuals and groups for comment, and the Toronto papers wrote articles on the plan. The articles and publicity stimulated more requests for information, and a small amount of new input from respondents.

Extensive public consultation helped managers to recognize which proposals would be supported by users and which would not. One proposal, to ban downriggers and electronic fish locators, was dropped as a result of opposition identified during public consultation. Other comments helped managers to identify areas of serious public misunderstanding that they would have to address through interpretive and public education programs. For example, public responses showed widespread misunderstanding of fish stocking strategies. Finally, public input demonstrated where managers had high degrees of support for their proposed actions, and could therefore proceed with the expectation that there efforts would not be sabotaged by disgruntled anglers. Public responses showed strong support for maintaining the integrity of the park's native fish stocks, for example.

Ontario's Aurora Trout Recovery Program

The aurora trout is a distinctive shoal-spawning form of brook trout endemic to just four lakes in northern Ontario. The lakes — White Pine, Whirligig, Aurora and Wilderness — lie in the Temiskaming district approximately 100 km north of the smelter city of Sudbury. The form was extirpated at least 20 years ago from all four of its native habitats by acid precipitation, and exists only in a handful of brood lakes maintained completely by hatchery recruitment (Ontario Ministry of Natural Resources 1984, McAllister et al. 1985). This tenuous status led to aurora trout being listed as endangered both by Canadian agencies (McAllister et al. 1985:44,184; Ontario Ministry of Natural Resources 1987:2, Campbell 1988:82) and by the American Fisheries Society Endangered Species Committee (Williams et al. 1989:4).

Aurora trout differ from the typical form in lacking the characteristic brook trout vermiculations on the back, and in having none or very few of the typical blue-haloed red spots on the sides. There are some small but significant osteological differences between the two forms. The reference to aurora in the name evidently comes from a "gleaming silver or purplish sheen" that gives the fish the "shimmering and cascading splendour of the northern lights" (Ontario Ministry of Natural Resources 1984:2-3).

Although they apparently coexisted naturally in sympatry with little hybridization, the two types hybridize when non-native or hatchery brook trout are introduced into aurora trout waters (Behnke 1980:473-474, McAllister et al. 1985:46-7). Significant genetic distinctions have not been found between aurora and typical brook trout in studies using karyotypic, electrophoretic or mitochondrial DNA methods, leading some biologists to conclude that the aurora trout does not merit subspecific rank (Ontario Ministry of Natural Resources 1984:3; McAllister et al. 1985:46-7; Parker and Brousseau 1988; Grewe et al. 1990:985-986, 989; G. A. Duckworth, personal communication 13 June 1990). The fish does clearly constitute a distinctive stock (Behnke 1980:473-474, Parker and Brousseau 1988:90). It has high potential value for supporting an unusual trophy fishery, and is managed as a unique stock by the Ontario Ministry of Natural Resources (1984, 1987:2).

In the 1970s, several attempts were made using hatchery stocks to restore aurora trout populations to their native lakes, but these efforts failed because of continuing highly acidic conditions. The stock was preserved under hatchery conditions, with several attempts being made to establish self-sustaining populations in secure lakes. Some of these attempts succeeded in establishing populations, but all had to be maintained with hatchery stock: natural reproduction was unsuccessful. Six of the lakes served as sanctuaries for the stock, providing brood stock for hatchery use. Eggs were collected in the field to be incubated at the hatchery and stocked as fry in these and other candidate lakes identified as having the potential to support a self-sustaining population (Ontario Ministry of Natural Resources 1984).

An aurora trout management committee was struck in 1980 to develop an Aurora Trout Management Plan and carry it out. In its most recently-stated form, the goal of the plan is “to maintain aurora trout and to rehabilitate the stock to provide naturally reproducing populations and limited angling opportunities and associated benefits to society” (Ontario Ministry of Natural Resources 1987:2). The committee identified four objectives as being essential parts of the overall goal.

First, it intended to maintain the stock. Eggs continue to be collected annually, incubated in hatcheries, and stocked back into the two brood lakes.

Second, it wanted to rehabilitate the strain as a wild stock by establishing three naturally reproducing populations by 1993. To achieve this, candidate lakes that might meet the spawning requirements of the stock are identified, protected as sanctuaries, stocked with fry for two years, assessed for spawning success after four years, and maintained as sanctuaries thereafter if natural reproduction is found.

Third, it proposed to provide angling for aurora trout in four lakes by 1990 in an attempt to build interest in the stock and support for the recovery program. To achieve this, the general closed season on aurora trout was removed from the regulations, two existing sanctuary lakes were opened for fishing, put-grow-take fisheries were provided on two additional lakes, and a creel census was implemented to assess use of the stocks by anglers.

Fourth, the committee wished to create public awareness of the trout and obtain life history data by 1993. Public education programs and life history studies were implemented to meet the objectives.

As of 1990, six lakes were open for fishing for aurora trout, and the stock continued to be maintained in brood lakes with hatchery support. One of the lakes to which the stock is indigenous has been reclaimed by liming, and aurora trout have been reintroduced with the hope they will be able to maintain a population by natural reproduction (G. A. Duckworth, personal communication 13 June 1990). The reintroduction into Whirligig Lake in spring of 1990 was covered by the national news on CBC television, greatly assisting the publicity campaign for the project. Whether the principal goal of the program, to restore self-sustaining populations of this unusually attractive stock to its native waters, has been achieved will not be fully apparent for a few more years. There is a recent report of successful natural reproduction in at least one lake, however (McNeilly 1992:14).

Quebec's Provincial Parks

Georges (1988) provided an overview of sport fisheries management approaches used in the provincial parks of Quebec. The following description is based on his account.

The provincial park system in Quebec is nearly 100 years old, beginning with the establishment of Laurentides and Mont Tremblant parks. As of 1985, the provincial parks supported approximately nine percent of the total sport fishing activity in the entire province. This total (Quebec) activity amounted to 15 million angler-days worth over one billion dollars in direct and indirect benefits to the provincial economy.

The Quebec park system now includes two distinct types of parks: recreation parks, managed to maximize the recreational use of their natural environments; and conservation parks, managed to preserve the natural environment. The sport fishing in recreation parks receives no special consideration; it is managed simply as another part of the provincial fish management district within which it falls. Sport fishing in conservation parks, however, is seen as a secondary use which is tolerated but not encouraged unless it is associated with some other form of outdoor activity (canoeing, camping, etc.).

As a result of their common history and despite their different purposes, a similar approach is taken in both types of park to regulate sport fishing — an approach similar to that described previously for La Mauricie National Park (Bouin 1988). The parks regulate sport fish harvest by a quota system. Quotas initially are based on estimated potential long term yield estimated from a modification of Ryder's morphoedaphic index (Ryder 1965). This estimate may be modified by the regional fishery biologist, who uses his knowledge of local conditions to adjust the estimate up or down. The estimate so determined is used to set the annual quota for that lake. The quota may be expressed in the original units (weight), but more frequently is translated into a quota in terms of allowable numbers of fish by using an estimate of average individual weight. The quota even may be expressed as the allowable number of boat-days or fishing-days per season, but these are said to be the least accurate. Local staff keep daily records of fishing activity, and close the lakes to further angling once the quota for those lakes has been reached.

Georges (1988) does not describe precisely how fishing harvest on the many thousands of individual lakes is monitored, whether by a formal creel census, aerial or ground surveys, self-reporting system or some other method. A self-reporting system like that described for La Mauricie National Park (Bouin 1988) seems most likely, although various techniques are possible depending on the resources available and the value or intensity of the fishery. Careful and accurate monitoring is obviously a critical component of the approach.

At the end of the fishing season, the data collected on the fishery of each lake is analyzed and compared to that collected on that lake during the previous five years. Any lakes showing a marked deviation from average conditions are singled out for more careful attention in following years, and may even be examined by a field team. The quota then may be adjusted to correct any problem found.

The entire fish management program is computerized on a large central system, apparently similar, if not identical, to a geographic information system (GIS). Lake survey data, the sport fishery catch data, stocking data and watershed information all can be accessed, analyzed and combined in various ways for a variety of uses. The uses include the setting of quotas and the automatic analysis of annual harvest data on each of the park lakes.

Where fishery management in recreational and conservation parks differs significantly is in the use of fish stocking and habitat manipulation to improve fisheries. Stocking is prohibited in conservation parks. Artificially increasing fish abundance to replenish populations depleted by overfishing, or to increase fish abundance to satisfy demand, is considered inappropriate in waters set aside to preserve the natural environment. Stocking has been used in a conservation park to restore a long-extirpated stock of Atlantic salmon, but this was with the intent of reestablishing a self-sustaining population that would have been there under natural conditions. Habitat manipulation in conservation parks also is limited to restoring natural conditions.

In contrast, stocking is used aggressively in recreational parks to maintain angling throughout the season. Either indigenous stocks or domesticated hatchery fish may be used. Habitats in recreation parks are manipulated to enhance sport fishing, especially for brook trout. Competitor fish may be eradicated, artificial spawning sites may be built, dams may be constructed to increase lake areas, and acidified lakes may be reclaimed by liming.

FISH MANAGEMENT IN SELECTED U.S. NATIONAL PARKS

Overview

The US national park system had its official beginning when Yellowstone National Park was established in 1872, although the core of what was to become Yosemite National Park had been protected as early as 1864 (Allin 1990b:6). As of 1987, the park system comprised 343 areas totalling more than 307,792 km^2, approximately 3.3 percent of the total area of the country. Of these, 49 lands comprising 60.3 percent (by area) of the entire system are national parks proper. The remaining 18 park types are a diverse mixture of areas of national historic, natural or recreational significance, ranging widely in the degree to which they are managed to maintain natural conditions (Frome et al. 1990:421, Watson 1980:118).

As of 1979, 90 lands in the system were said to have aquatic resources regarded to be of substantial importance (Watson 1980:119). Today, recreational fishing occurs in 143 units of the system (US National Park Service 1991:2). Sport fishing has been permitted by law in some parks, by rules and regulations in others, and by tradition throughout the park system (Wallis 1960:234). Estimates based on 1975 figures for 59 lands in the park system indicated that about 7.5 percent of visitor use was fishing-oriented (Watson 1980:120).

Fish resource management in the US park system is complicated by a highly complex arrangement of park classifications and planning zones, by the nature of the federal jurisdiction (i.e., the history of how the federal government obtained the land), and by variances granted to accommodate existing rights, legal requirements and political pressures. The 19 different types of parks fall into three broad classifications: *natural areas*, *historical and archaeological areas*, and *recreation areas*. No matter what category they are in, however, each park is zoned into one or more of *natural*, *historic*, *park development*, or *special use* zones for planning purposes. Depending on precisely how and when the park was established, it may be under *exclusive jurisdiction* of the National Park Service (NPS), in which case the NPS has full authority for fish management; *concurrent jurisdiction*, under which there may be a variety of regulatory arrangements subject to control by two to several levels of government, with a complex order of precedence in case of conflicts; or *proprietary jurisdiction* granting the NPS only the same rights and privileges given to any landowner (Watson 1980:118, Schullery 1979). In general the older parks are likely to have exclusive jurisdiction; the younger parks are more likely to have proprietary jurisdiction only (R. Wasem, personal communication 13 June 1990).

Evolution of Fish Management in the National Parks

The Early Years

The history and nature of fish management in US national parks until thirty to forty years ago was similar to that in all other parts of the country, its treatment of fish differing markedly from the way all other natural resources were treated in national parks. The founding act for Yellowstone National Park in 1872 asserted that the timber, mineral deposits, and "natural curiosities or wonders" were to be preserved in their natural condition, but failed to definitely protect fish and wildlife (Yellowstone Staff 1979:31). In 1894, the same law that forbade the killing of birds and mammals in Yellowstone also specifically allowed park visitors to kill fish by angling, and provided for regulations governing the taking of fish from park lakes and streams (Wallis 1960:234). The new regulations, however, were a marked improvement over the completely unfettered despoliation that characterized early nonaboriginal use of fish resources (e.g, Jennings 1980:149).

For decades national park fish populations were managed almost exclusively to provide angling opportunities for the small minority of park visitors who fished. Management was largely confined to stocking, often with exotic fishes (Watson 1980:119). What regulations there were were very liberal. Preserving native fishes and natural conditions was seldom considered (Wallis 1960:235), although there were rare but important exceptions (Yellowstone Staff 1979:33, Varley and Gresswell 1988:15; see the discussion of impacts on the fish resources of Yellowstone Park, below).

The law that established the US National Park Service in 1916 gave the NPS responsibility to conserve the scenery, natural and historic objects, and wildlife of the parks, and to leave it unimpaired for the enjoyment of future generations (Wallis 1977:58). Park managers generally were slow to recognize the impairment caused to the fish and their habitats by sport fishing and fish management practices. Wallis (1977:58) identified the following factors that contributed to their lack of awareness.

1. *"Fishing was provided for by law.*

2. *"The prevailing concepts were that fishery resources could be readily renewed or replenished by use of hatchery stocks and that greater numbers of fish planted resulted in improved fishing.*

3. *"Lack of full understanding and appreciation of the uniqueness and significance of fishes and other aquatic life and aquatic ecosystems in national parks.*

4. *"The early desire to promote visitor use in the high country by using the availability of waters stocked with trout to serve as a magnet to attract fishermen.*

5. *"The recognition of trout fishing as a*[n] *acceptable recreational use activity within national parks."*

The effect of fish management activity during this period was to alter profoundly the natural aquatic ecosystems of the national parks. Nonnative strains of fish, invertebrates and even plants were widely introduced, producing largely unknown ecological changes. Native fish stocks in large numbers were reduced or eliminated completely through introgressive hybridization, competition and predation from introduced fish (Wallis 1960, 1977; Schullery 1979), fish culture operations (Gresswell and Varley 1988), or just plain overexploitation by fishermen caused by the failure of the sustained yield concept of fish management (e.g., Gresswell 1980). In some parks, migrations of native fishes were impeded or completely blocked by dams (Wallis 1960:235). Significantly for current policy, national parks were spared the rampant destruction of aquatic habitat that eradicated native fishes from so many waters outside their boundaries (Varley 1979, Varley and Gresswell 1988:15).

The Mid-Century Period

By the 1950s, managers recognized that many native fish populations either had been extirpated from their native habitats, or were fated to become so. They set out to control exotics and to restore and protect native stocks. The first attempts were made in Great Smoky Mountains National Park of North Carolina and Tennessee (Wallis 1960:235, Schullery 1979) where they continue to this day (Moore et al. 1983, Larson et al. 1986). Programs for controlling exotic fishes and restoring native stocks since have been a part of the fish management programs in many US national parks, including Yellowstone (R. D. Jones, personal communication 21 February 1990) Glacier (W. Michels, personal communication 1 March 1990), Rocky Mountain (Rocky Mountain National Park, no date), and Sequoia (H. Warner, personal communication 12 June 1990).

By 1960, the NPS had adopted a new, more preservation-oriented fish management policy to allow it to meet the requirements of its 1916 founding Act while still providing for sport fishing. It launched a Service-wide program (Wallis 1960:234-5)

1. to determine original and present aquatic conditions;

2. to perpetuate and restore native fishes, natural aquatic conditions, and associated plants and animals;

3. to protect wild fish populations, both native and exotic;

4. to provide angling for wild, colourful, vigourous trout amid natural surroundings, interfering as little as possible with wildlife, scenery, scientific or historical values, or with the enjoyment of these features by other park visitors; and

5. to create a greater appreciation of the aquatic resources by interpreting them to park visitors.

With this program the NPS clearly introduced a number of important changes (Wallis 1960:235-6). It proposed ultimately to "restore native fishes to their natural waters wherever and whenever feasible", recognizing that exotic species would have to be eliminated in most cases. Further, it proposed to give equal consideration to sport and non-sport fishes in any restoration plan. Where restoring natural conditions was not possible, it intended to manage the existing populations (introduced or indigenous) as wild entities, relying on natural reproduction rather than stocking to maintain them. Stocking was retained as a fish management option, but only to supplement existing fish populations with little or no natural reproduction in lakes and streams that were originally fishless. Any lakes still naturally fishless it proposed to keep that way. Park animals consuming fish would not be limited in doing so. The program introduced some of the earliest formal catch-and-release ("fish-for-fun") fisheries to limit the effects of heavy fishing pressure without lowering the quality of the fishing experience.

In the new view of 1960,

> *"… angling within national parks and monuments cannot be managed independently of other park uses and values. This sport is recognized as an incidental park recreational activity. The primary purpose of a visit to a park is the enjoyment of all natural features for which that individual park was created"* (Wallis 1960:236).

Furthermore,

> *"The interest of the National Park Service in its fishery resources extends beyond the utilization of sport fishes by anglers. The fish fauna is a vital part of the natural history of an individual area, and its proper interpretation to*

the park visitor is an important function of the Service. Species which are of little interest to the angler may be of greater significance ecologically and biologically than sport fishes" (Wallis 1960:237).

Since 1975

Fish management policy in the national parks was revised next in 1975. The policy continued to distinguish between fish and all other animals in national parks, specifically exempting them from protection accorded all other fauna.

> *"Animal life in the National Park System shall be given protection against harvest, removal, destruction, harassment, or harm through human action, except where … fishing is permitted by law for either sport or commercial use or is not specifically prohibited; …"* (NPS 1975, quoted by Wallis 1977:58).

The NPS intended to rely upon natural processes to regulate native populations of animals to the greatest possible extent. The agency changed its stocking policy accordingly, terminating all stocking of fish species exotic to a park, allowing stocking only to reestablish native species. The interdiction on stocking in naturally fishless waters was reaffirmed (Wallis 1977:59).

Continuing a trend to manage fish populations as integral parts of the overall park ecosystems, the NPS introduced several new policies providing for restrictions on angling. Sport fishing could now be closed to protect rare, threatened, or endangered plant or animal species in the waters or in adjacent habitat; to permit other uses of the fish resource where it has greater value for visitor appreciation, scientific study, interpretation or environmental education; or to maintain native wildlife species that use fish for food. In the natural zones of the parks, fish management was to be dedicated to preserving and/or restoring native species, angling was to be regulated so that fishing mortality was compensated by natural reproduction, and angling mortality was not to be permitted to alter the historical unexploited population density or age structure (Wallis 1977:59).

The US Fish and Wildlife Service (USFWS) provides technical support to the NPS on fish management, especially in the parks under the exclusive jurisdiction of the Park Service. In 1978 it launched a major review of fish management policy in the national parks (Watson 1980). It found that the present policies were generally inadequate to meet the needs of most park managers in the field. In particular, the "traditional" policy (allowing for sport fishing in natural areas of the parks) had become "… a *de facto* priority to be accommodated even at the expense of other objectives or purposes and against competing or conflicting uses" (Watson 1980:120). In the view of the USFWS reviewers, this situation caused park managers (especially those whose parks were under joint jurisdiction) to accept sport fishing programs based on only minimal assurances that fish resources would not become depleted. Furthermore, they did not allocate sufficient resources to fish management, since angling, they believed, had to be accommodated in any case.

Put bluntly, the fish preservation policies of the national parks were being systematically subverted by the prevalent view that angling was an acceptable "traditional" use of park fish resources.

The USFWS urged that the first priority for use of fish resources in natural zones should be *to preserve and maintain natural processes* (Watson 1980:121). The agency asserted that this could be achieved without prohibiting sport fishing by the expedient of allowing only catch-and-release (presumably no-kill) angling. The USFWS reviewers observed that a firm national policy on this goal was required, that such a policy would reduce flexibility desired by local park managers, but that the overall integrity of each park and that of the park system itself would be strengthened thereby.

The USFWS recommendations resulting from its review contained some important new viewpoints. In particular, it recommended (Watson 1980:122)

- that policy provide for preserving unique populations and endangered species in fishless or formerly fishless waters in exceptional circumstances;

- that objectives for sport fishing in natural zones "should be to provide a high quality angling experience in a naturally regulated ecosystem";

- that fishing programs outside natural zones encourage users to appreciate fish resources and the fishing experience;

- that, after careful analysis and considering all relevant factors, nonnative species "appropriate to the well-being of the ecosystem" may be declared by the NPS Director as naturalized and managed as native species;

- that policy guidelines should be developed for habitat restoration and improvement; and

- that the NPS actively support efforts to protect and/or restore historical native fish populations even outside the parks.

The USFWS advanced a new aquatic resource policy for American national parks based on the review (Watson 1980:123-5). Its overall goal was to manage aquatic resources as an integral part of the total park ecosystem according to the following priorities.

Priority 1. Aquatic organisms shall be managed to allow them to fulfill natural functions as predators and prey within ecosystems.

Priority 2. Aquatic resources will be managed to satisfy nonconsumptive human needs and uses.

Priority 3. With appropriate justification, aquatic resources may be made available for consumptive human uses.

Priority 4. Existing exotic species may be used, reduced or eliminated to preserve or restore aquatic ecosystems.

In natural zones, the primary goal was to preserve and restore native aquatic ecosystems. Proposed visitor uses appropriate to natural zones included viewing and interpretive programs. Sport fishing properly regulated to provide a high quality angling experience (defined as fishing in a naturally regulated ecosystem) was seen as an appropriate way of enabling visitors to experience and appreciate fishes in natural zones. Fish stocking was intended only to be used to restore indigenous species, and waters that were originally free of fish were to be allowed to revert to their natural state.

The US National Park Service and National Sportfishing Policy

In 1988 the US National Park Service, together with more than 60 federal, state and private organizations, adopted a national policy on recreational fisheries. For the first time US national parks had a national framework within which they could define their role in the overall US recreational fishery. The result was the publication of the National Park Service Recreational Fisheries Program (US National Park Service 1991)[1]. This document presents formally and without significant change the policies followed in practice by the NPS (Michael A. Coffey, personal communication 20 August 1991).

The Recreational Fisheries Program sets out NPS policy on sport fishing *for the park system as a whole* in the United States. The roles of the individual units or classes of units are not clearly identified. As pointed out above, the US park system manages a very wide diversity of lands for widely different purposes. Many lands, such as National Recreation Areas, National Seashores, National Lakeshores and National Rivers, are strongly oriented toward providing outdoor recreational opportunities as a major part of their mandate. One large type, National Preserves, permits hunting and trapping (and perhaps consumptive fishing) to accommodate traditional uses; many types are intended primarily to protect resources of national historic value. Others, including the national parks proper, are intended to preserve ecosystems as much as possible in their natural state as their first priority.

1 Page numbers mentioned in this section refer to this document.

Thus, the policies described below apply throughout the US park system, but do not apply equally to each unit. In particular, some intensive fish management practices included in the policy do not apply at all in most national parks. The fundamental policy is to restore and maintain naturally-functioning ecosystems in all units administered by the NPS.

"The National Park Service manages all park resources *with an emphasis on fundamental ecological processes as well as for individual species, communities and natural areas. Natural processes are allowed to progress without intervention whenever possible. In keeping with this philosophy, the National Park Service Recreational Fisheries Program seeks to preserve and/or restore natural aquatic habitats; the natural abundance, age, and size distribution of native aquatic species; and associated terrestrial species and habitats. The fisheries management policies of the Park Service also strive to preserve or restore the natural behaviour, genetic variability and diversity, and ecological integrity of fish populations.*

"It is recognized that wild fish populations are an integral part of a much larger aquatic and riparian ecosystem. Their role in the natural food chain includes utilization by other aquatic predators, bears, eagles, and other raptors/scavengers. Within the context of national parks, *it is a management objective to protect the opportunity of natural systems to operate without significant human interruption."* (p. 2, emphasis added)

In keeping with this guiding philosophy, Goal 1 of the Recreational Fisheries Program is to "protect, restore and conserve fishery resources" (p. 5). Under this heading are included objectives to

1. promote, conserve, restore, and (where authorized by legislation and policy) enhance fish populations and their habitats (p. 5-6);

2. promote, support and research fisheries management and ecosystem processes (p. 7);

3. develop and enhance biological, social and economic data bases on recreational fisheries (p. 8); and

4. increase public awareness by improving fisheries education, outreach and angler ethics programs (p. 10).

Specific "action items" are defined to achieve each objective.

Under Objective 1, the writers have attempted to clarify where fish population and habitat enhancement may be appropriate in the system. As an example they cite Lake Mead National Recreation Area, where a large artificial reservoir may be developed for recreational fishery purposes (with "caution … exercised in identifying and selecting the most appropriate management alternatives") using enhancement techniques "while preserving natural ecosystem processes along with remnant species and their habitat" (p. 6).

Goal 2 of the NPS Recreational Fisheries Program is to increase the quality, quantity and diversity of recreational fishing opportunities in the US park system where appropriate (p. 12). Specific objectives under this goal are to increase and diversify fish-related recreational experiences, and to increase access to recreational fisheries. Action items include proposals to implement recreational fisheries in at least 15 urban units of the park system, promote and further develop fishwatching and related activities, and increase recreational fishery opportunities for children, the elderly and disabled. Substantial changes to increase access in national parks evidently is not envisioned by this policy.

Goal 3 of the program is to improve partnerships between governments and the private sector for conserving and managing recreational fisheries (p. 15). Specific objectives in reaching this goal are to develop forums for information exchange among interest groups, and to further develop mechanisms for public participation in fisheries projects. The fourth goal is to identify and incorporate economic values and opportunities in developing recreational fisheries programs in the parks system (p. 18). Particular action items to reach this goal propose small-scale improvements to existing programs. In the case of both goals 3 and 4, no significant changes in current policy are envisioned.

The US National Park Service (1991) sets its recreational fisheries program in a national context. The overall intent of the National Recreational Fisheries Policy signed in 1988 was to provide long-term common goals from which the signatories could identify roles and specific actions for their organizations. The NPS continues to define its fisheries role as primarily conservationist. It continues to see its job as restoring and protecting natural ecosystems, not manipulating them to maximize recreational fishing opportunities.

Rocky Mountain National Park, Colorado

Rocky Mountain National Park is a high elevation mountain preserve of 1073 km^2 (Frome et al. 1990:423) lying about 100 km northwest of the city of Denver, Colorado. Straddling the Continental Divide, its west slopes form the extreme headwaters of the Colorado River; its east slopes are in the headwaters of the South Platte River of the Missouri drainage system. A new fisheries management plan recently has been produced for this park (Rocky Mountain National Park, no date) from which the following information has been taken unless otherwise noted.

Aquatic Resources and Fisheries

The aquatic resources of the park consist of 761 kilometres of streams and 147 small lakes covering 446 hectares. At least 51 of the lakes presently contain fish populations, most of them introduced: natural barriers prevented natural colonization of many of the higher lakes and streams. The fish species native to the east slopes of the park are believed to have been the greenback cutthroat trout and the western longnose sucker. Only the Colorado River cutthroat trout is thought to have been native to west slope streams within the park boundaries. Greenback cutthroat trout presently are listed as threatened and Colorado River cutthroat trout are considered a species of special concern by the American Fisheries Society's Endangered Species Committee (Williams et al. 1989).

Non-native species and subspecies of trout were introduced widely into park waters in the early part of this century, including rainbow, brook, brown, and various subspecies of cutthroat trout. In addition, white suckers have been introduced into west slope waters. Native non-game fish still inhabit the waters in which they originally existed, but were occasionally released unintentionally into some areas. For the most part, the fish populations and their habitats have been modified so extensively that the native distribution and composition of fish communities is now difficult to determine.

A substantial number of anglers fish in the park, but represent a low proportion of the total visitors. An estimated 1.7 percent of the visitors to the park fish, amounting to 40,000 anglers in 1986. Total harvest in 1986 was estimated at 70,000 fish, nearly 80 percent of them brook trout.

Fish Management Policy

Preserving and restoring native fish stocks became a priority with the US National Parks Service in the 1950s (Wallis 1960), and Rocky Mountain National Park ended stream stocking in 1959. A long range management plan was then prepared outlining a ten-year recovery program through 1975. Its key features were:

1. restore native cutthroat to representative streams;

2. eliminate or control brook trout populations where they would compete with native cutthroat trout;

3. maintain wild trout angling in designated waters with minimum reliance on hatchery stock.

All park waters were classified for management action, and 16 lakes were stocked periodically with native cutthroat fingerlings. All stocking was suspended partway through the program as a study was launched to find ways of rehabilitating native fish populations. The suspension on fish stocking was made permanent in 1976 as the greenback cutthroat recovery program was expanded and a new Colorado River cutthroat trout reintroduction program began.

Cutthroat Trout Recovery Plans

The recovery plans for the two indigenous trout species have been the focus of the park's fisheries management plans since that time. The US Fish and Wildlife Service provides technical assistance to the National Parks Service for fisheries management, and the two agencies participate with the Colorado Division of Wildlife, the US Forest Service and the Bureau of Land Management in the recovery programs. The programs involve locating possible genetically-pure stocks, confirming their purity, securing the habitat, establishing a hatchery program to provide stock for reintroductions, identifying and researching suitable secure waters for reintroduction, reclaiming the selected waters with toxicants, reintroducing the fish, and monitoring the population to evaluate the success of the project (Stevens and Rosenlund 1986, Rosenlund 1989).

The programs have been successful in establishing three secure populations of native Colorado River cutthroat trout and at least five secure populations of greenback cutthroat trout within Rocky Mountain National Park (Rocky Mountain National Park, no date; Stevens and Rosenlund 1986). The status of the greenback cutthroat trout, once thought to be extinct as long ago as the 1930s, has been upgraded from endangered to threatened, largely because of the success of the recovery program in this park.

Angling Management

The remainder of the fish management program in Rocky Mountain Park is devoted to surveying fish populations of lakes and streams, setting and enforcing fishing regulations, and monitoring fishing pressure. In addition to protecting the restored native fish populations, the fishing regulations are designed to maintain a high quality fishing experience for anglers within limits required to sustain fish populations and protect riparian vegetation. They are used "to protect the resource and minimize the effect of angling on the population structure but still allow the appreciation of fish by park visitors" (Rocky Mountain National Park, no date:9).

Consumptive angling is used aggressively as a management tool in an attempt to keep populations of exotic brook trout in check. Up to 8 brook trout over 25 cm and 10 brook trout under 20 cm may be retained. There has been some difficulty in convincing anglers to keep every brook trout they catch within these limits, however. Consumptive angling is prohibited for native stocks, but some native populations are open to catch-and-release (no-kill) fishing with artificial lures and barbless hooks only. Data from 1986 indicate that these policies have produced a reasonably good fishery (in terms of numbers of fish) primarily for brook trout, with 41 percent of anglers successful, averaging 1.67 fish per outing and 0.64 fish per hour of effort.

Angling is monitored by the park rangers, apparently during public information and enforcement activities. Standard forms are used for recording information, but it is unclear whether a formal creel census is operated in the park. Restored populations are monitored annually until the populations are declared stable.

Research and Public Information

Fisheries research in Rocky Mountain Park centres on developing restoration techniques for native trout, describing and classifying aquatic ecosystems, and evaluating population and habitat status, particularly with regard to the effects of angling. One study has been conducted to monitor the effects of antimycin, the fish toxicant used for reclamation, on other elements of the aquatic ecosystem. The treatment is said to have had “considerable impact” on macroinvertebrates, but the effect was “temporary” (Stevens and Rosenlund 1986).

A public information campaign is said to be an essential part of the management program. Fisheries management is emphasized in park interpretive programs, and rangers undertake to inform the public during their regular patrols. Special full colour brochures have been used on some waters to assist fishermen in distinguishing brook trout from native greenback cutthroats, so to assist them in removing the unwanted brook trout from park waters.

Glacier National Park, Montana

Aquatic Resources

Glacier National Park, Montana, adjoins Waterton Lakes National Park, Alberta, to form the Waterton-Glacier International Peace Park (Figure 2). Straddling the Continental Divide, Glacier Park encompasses 4100 km^2 of the Rocky Mountains in the headwaters of three major river drainages, the Columbia (Pacific), South Saskatchewan (Hudson’s Bay) and Missouri (Gulf of Mexico). The park’s aquatic resources consist of approximately 650 lakes larger than 2 ha in area and 2600 km of streams ranging in elevation from 1000 m to 2500 m above mean sea level (Marnell et al. 1987).

Fish occur in at least 64 lakes and numerous streams in the park, including twenty-three indigenous species (Marnell et al. 1987, Marnell 1988) and seven exotic species and subspecies (Glacier National Park, no date). Some stream populations of westslope cutthroat trout and bull trout are significant contributors to economically-important migratory stream (fluvial) and lake (adfluvial) native populations outside the park boundaries (Martin et al. 1987:76, Marnell 1988).

Fish Conservation Problems

Like those of the Canadian mountain national parks, Glacier National Park waters have been subjected to an onslaught of stocked exotic fish strains. Tens of millions of nonnative trout were stocked in park waters over a period of 70 years, establishing numerous viable populations of five nonnative salmonid species or subspecies, including self-maintaining populations in more than a dozen originally fishless lakes, and exposing all but two of the park's indigenous trout stocks to potential introgression (Marnell et al. 1987, Marnell 1988). Remarkably, the park continues to harbour 15 genetically uncontaminated populations of native westslope cutthroats in their original habitats, as well as several other uncontaminated populations introduced into waters to which they are not native (Marnell et al. 1987, Marnell 1988).

Glacier National Park is one of the last remaining enclaves protecting westslope cutthroat trout, a subspecies decimated throughout its former native range in Montana, Idaho, British Columbia and Alberta through a combination of exploitation, genetic introgression, competition from introduced species and habitat degradation (Behnke and Wallace 1986, Bjornn and Liknes 1986, Marnell 1988). Westslope cutthroat trout are imperiled by nonnative species through 84 percent of their native range within the park (Marnell 1988).

Several unusual populations of bull trout exist within the park as well, and may require special management (Glacier National Park, no date; Marnell 1985). This species is recognized as a species of special concern by the Endangered Species Committee of the American Fisheries Society (Williams et al. 1989).

Fish Management Plan

The park's current resource management plan (Glacier National Park, no date), covering the period 1983-87, is presently being updated but will remain "basically intact" (W. R. Michels, personal communication 1 March 1990). An additional management strategy document is current (Lusk et al. 1987), providing up-to-date information on resource management strategy for the park. The following review is based on these documents unless noted otherwise.

The management plan primarily deals with the adverse effects on aquatic resources resulting from the widespread and longterm introduction of exotic fish species outlined above. It recognizes two broad categories of environmental impact from exotic fish introductions into pristine aquatic communities in the park.

1. Indigenous gene pools have become contaminated through introgressive hybridization between native and exotic species.

2. Introduced species compete with and/or prey upon native species, disrupting natural ecological relationships.

There is said to be evidence that both types of impact have caused native populations of fish to decline within the park. In addition, it is postulated that introduced fish species may have drastically altered the composition and relative abundance of indigenous aquatic invertebrates, and that some plankton species have been extirpated by fish introduced into lakes that were originally free of fish.

To address the first of these problems, Marnell et al. (1987) undertook a genetic survey of the most seriously affected native fish, the westslope cutthroat trout, forming the basis of a detailed status report on the subspecies in Glacier National Park (Marnell 1988). With the remaining pure populations of native westslope cutthroat trout identified, it is now possible to manage the populations to protect them from damage. Studies of another indigenous species of special concern, the bull trout, were initiated in an attempt to identify and characterize unusual populations (Glacier National Park, no date; Marnell 1985).

The aquatic ecosystems management plan proposes to assess in detail the ecological impacts of introduced fish on native populations in one of the park's major lakes. The proposed study would examine species interactions, habitat use, pollution, spawning habitat and other critical aspects of the overall problem. Other studies would examine the genetic and ecological status of a zoogeographically informative species, the pygmy whitefish. Routine lake inventories and a volunteer creel census, both already in place, will be continued to provide data necessary for setting angling regulations.

The available information was judged to be adequate to support a pilot project to rehabilitate selected native trout populations and return some lakes containing introduced trout back to their naturally fishless condition. Plans still are being considered to return some lakes back to a fish-free state, and exotic species are being replaced by native fish in one chain of lakes (W. R. Michels, personal communication 1 March 1990). To provide fish for reintroductions within the park and elsewhere, the management plan proposed to establish a brood stock of native westslope cutthroat trout at a local hatchery.

Present angling regulations generally allow limit of 2 native trout and 5 exotics. As in Rocky Mountain National Park, Glacier National Park uses sport fishing for management purposes. Unlimited numbers of lake trout may be taken in one large lake where, as an exotic species, they are a major problem for native fish. The lake trout move into the park following migrating native populations and prey upon them heavily (W. R. Michels, personal communication 21 February 1990).

Future Focus

The present goal of natural resource management in Glacier National Park is "to further restore and protect Glacier's naturally functioning ecosystem, recognizing man as a part of this system, and to allow natural processes to maintain the integrity of the ecosystem" (Lusk et al. 1987:3). This goal, and the specific tactics to be used in achieving it, apply to the management of fish in the park. The tactics emphasize natural processes, meticulous protection, and aggressive management when necessary, especially to protect threatened resources. The following approaches, which illustrate these points particularly well, are to be used by managers to achieve the goal as it relates to fish (Lusk et al. 1987:3-4; emphasis and numbering as in the original).

1. "Allow *natural processes* including natural extirpation and colonization to progress unless threatened or endangered species must receive special management for survival.

2. "Minimize *consumptive use* of any native component of the natural system. If there is evidence that any consumptive use is significantly altering natural processes, the use will be modified or eliminated.

5. "Preserve *genetic integrity* of native species unless genetic augmentation is necessary for the survival of a remnant species that has been isolated by human activity.

6. "As feasible, reintroduce or augment *populations* of species ex[t]irpated or diminished because of man's actions.

7. "Use Park plants and animals to *augment* or restock diminished *populations* and use Park genetic stock to enhance genetic diversity outside the Park, providing it does not significantly impact the naturally functioning ecosystem.

8. "Contain, control, or eliminate *non-native plants and animals* as feasible utilizing Integrated Pest Management concepts….

9. "Maintain or restore *natural fish species and populations* by: 1) changing fishing regulations; and 2) researching the elimination of non-natives through poisoning

or mechanical means and implementing such means if appropriate.

10. “Protect *exotic species* on which threatened or endangered species are dependent only as long as the exotics are key to the survival of the threatened or endangered species. If populations of such exotics should fail, the Park should not artificially provide sustenance to the threatened or endangered species.”

Natural resource management in Glacier Park, including fish management, is supported by a science program that includes resident staff scientists and cooperative research with universities, other government agencies, and scientific foundations. The goal of the park’s science program is “to conduct and encourage scientific research which contributes to the understanding and management of ecological and cultural systems” (Lusk et al. 1987:5). Tactics to be used in achieving this goal and applicable to fish management include the following (Lusk et al. 1987:5-6, numbering and emphasis as in the original document).

1. “Address those study needs that extend over *ecologically significant periods* of time using a *resident team* of research scientists. Project emphasis will shift from reactive to proactive justification, species to systems orientation, park to regional study areas, and individual to study team approaches.

2. “ … The concept of visitor capacity based on acceptable impacts to defined Park values will be a priority research topic.

4. “Expand *conservation biology* to an important program element …. Research that develops inventory and monitoring techniques for species diversity will be emphasized and used to identify sensitive indicator species.

6. “Continue current *research on threatened and endangered species* with an emphasis on publishing results and developing strategies for long-time population analysis.

8. “Move toward an ecological *understanding of lowland lakes* and their relationships with surrounding terrestrial communities by continuing aquatic studies of Lake McDonald, with an emphasis on publishing results and developing management recommendations.

13. “Establish a system of *research natural areas* to provide a focus for management monitoring and scientific research over time.”

Natural resource management, including fish management, at Glacier National Park is integrated with visitor use and service functions. The goal of visitor use/services is to “provide the facilities and services needed for visitors to experience the beauty and understand the natural processes involved in the formation of Glacier National Park” (Lusk et al. 1987:6). In particular, the park undertakes to “encourage *contemplative* *and non-consumptive use* while providing the visitor … with a unique experience that is characterized by a high degree [of] personal involvement and freedom in selecting activities", and to "recognize that Glacier is a *distinctive landscape* with geologic, aquatic, vegetative, and wildlife resources that can be found nowhere else in the world and, therefore, provides an unusual opportunity for respite, contrast, reflection, and contemplation" to visitors (Lusk et al. 1987:6, emphasis as in the original).

Other important visitor use/services tactics relevant to fish management are as follows (Lusk et al. 1987:6, emphasis and numbering as in the original).

2. "Recognize that visitors to Glacier National Park differ in age, education, physical ability, language, and other characteristics that affect the way they use the Park. Provide a *variety* of facilities and programs to meet these needs and create an atmosphere where the visitor is treated as a special guest….

3. "Provide visitor *access* to the Park resources to a degree that enables the visitor to understand and appreciate the processes they reflect. Provide the opportunity to fully sample the various … ecologic regions of the Park….

6. "Advances in conservation biology, visitor management and other technology will be used to develop a process for establishing Park *visitor capacities* that reflect visitor service and resource conservation requirements.

7. "Managing a balanced *natural ecosystem*, with man as an integral part of that system, will be the focus of interpretation and education. Develop interpretive programs to *instill understanding and appreciation* of the Park's natural and cultural resources and develop public support for preservation….

13. "Develop *information and training programs* that ensure the Park and concession employees understand the visitor service and resource management issues involved in the operation of the Park as well as the technical aspects of their jobs."

Yellowstone National Park, Wyoming

Yellowstone National Park occupies 8983 km^2 of northwestern Wyoming and small parts of adjacent Montana and Idaho (Frome et al. 1990:423) (Figure 1). It is the oldest and one of the most heavily-visited of the US national parks. Yellowstone was the world's first national park, set aside by the US Congress in 1872 to protect its many "natural curiosities and wonders" and retain them in their natural condition. It is currently managed to perpetuate the natural processes within the park ecosystem, including the interactions among native fauna, flora, geology and scenic landscapes (Jones et al. 1989:1).

Fish and Aquatic Resources

The aquatic resources of the park consist of 168 lakes and 604 streams, including the largest lake in North America over 2200 m in elevation (Yellowstone Lake, 360 km^2 — Yellowstone National Park 1983:51). It is believed that only 17 lakes originally contained indigenous fish populations, but now approximately 40 lakes have self-sustaining populations of either native or introduced fish (Yellowstone National Park 1983:70). In addition, populations of indigenous or exotic species have been established in numerous streams above barrier falls where originally there were no fish (Yellowstone Staff 1979:32). The eleven species of fish native to park waters include Montana grayling, three subspecies of cutthroat trout, mountain whitefish, three species of suckers, four species of minnows, and mottled sculpin; exotics include rainbow trout, brown trout, brook trout, lake trout, lake chub, and redside shiner (Yellowstone National Park 1983:70, Jones 1980:136, Gresswell and Varley 1988:47).

Impacts on the Resource

Present fish management is strongly influenced by past stocking practices. Although fish stocking was initiated in 1881 (Yellowstone National Park 1983:70, Gresswell 1985), exotics were not introduced until 1889 (Varley and Gresswell 1988:15). From 1881 to 1909, stocking policy emphasized the introduction of trout into naturally fishless lakes (Yellowstone National Park 1983:70). “Put, grow and take” stocking of native and exotic species predominated from 1920 until 1955, when concern for protecting and restoring indigenous stocks became the principal focus of fish management (Wallis 1960, Yellowstone National Park 1983:70).

The stocking of 310,000,000 fish in Yellowstone waters between 1881 and 1980 (Yellowstone National Park 1983:70) profoundly changed the fish resources of Yellowstone Park. Introductions helped to extirpate westslope cutthroat trout and Montana grayling from most of the Madison drainage (Schullery 1979, Gresswell 1985), expanded the range of Yellowstone cutthroat trout (Gresswell 1985) and longnose suckers (Gresswell and Varley 1988:47) within the park, produced several hybrid swarms of cutthroat × rainbow trout (Jones et al. 1989), established numerous populations of exotic salmonid species (Jones et al. 1989), and artificially founded over twenty fish populations in waters that were naturally fishless (Yellowstone National Park 1983:70).

Stocking probably was the most significant but not the only negative influence on

Yellowstone fish populations. From modest beginnings in 1899 with the first egg collections of Yellowstone Lake cutthroat trout grew an immense fish culture operation involving up to three fish culture stations in the park and 14 traps on Yellowstone Lake tributaries (Yellowstone Staff 1979:32, Gresswell and Varley 1988:48). The park supplied eggs and fry to other jurisdictions worldwide in such quantities that it once may have been the planet's leading supplier of an inland trout species (Schullery 1979, Gresswell and Varley 1988:48). Spawn-taking activities on Yellowstone Lake were ceased in 1953, but by then reduced escapement coupled with intense angler harvest had decimated some spawning migrations of the lake's cutthroat population, and the genetic integrity of distinctive stocks within the lake may have been compromised (Varley and Gresswell 1988:48).

Although much of the damage to park fish resources was brought about by the deliberate actions of fish managers, some of these same managers made several remarkably forward-thinking decisions early in Yellowstone's history that saved many native stocks from oblivion, and protected natural aquatic communities. Varley and Gresswell (1988:15) point out that a decision apparently in the late 1800s not to mix salmonid species and to reserve each major drainage for a particular salmonid served to preserve Yellowstone cutthroat genotypes and retarded introductions of such damaging species as brook trout, a species which almost invariably eliminates Yellowstone cutthroats in that park. A 1936 fish management policy (Yellowstone Staff 1979:33) further dictated that

1. "*non-native fish shall not be stocked into waters containing native fish;*
2. "*propagation and stocking of native species shall be encouraged;*
3. "*distribution of non-native fish species shall not be expanded;*
4. "*no artificial lake and stream improvements shall be made;*
5. "*introduction of non-native aquatic fish food organisms shall not be made;* [and]
6. "*selected waters shall be left barren of fish.*"

The effect of these amazingly prescient policies, perhaps unique in their time, was to maintain in a more natural condition many as yet untouched native fish stocks and the park's aquatic ecosystems. Thus, despite the damage referred to above, Yellowstone continues to protect fish resources of exceedingly high value.

Values and Competing Interests

The original users of the fishes of Yellowstone were the park's native wildlife. Pelicans, mergansers, grebes, loons, cormorants, diving ducks, bald eagles, ospreys, herons, kingfishers, grizzly and black bears, otters and mink rely to a greater or lesser extent on the park's fishes as food (Anderson 1977:7, Jennings 1980:150, Yellowstone National Park 1983:70). While extensive stocking may have provided additional sources of food for some wildlife species, exploitation of these new stocks by anglers could have reduced this effect in two ways. First, consumptive angling potentially competes with wildlife for the resource. Second, heavy angler use of an area, as often happens in Yellowstone, can make habitat unavailable to wildlife. For example, anglers in Hayden Valley along the Yellowstone River became so abundant prior to 1965 that they displaced wildlife from the area (Yellowstone Staff 1979:35, Jennings 1980:148). It is conceivable also that some wildlife species suffered from changes in aquatic ecosystems caused by fish introductions into formerly fishless waters.

Some of Yellowstone's fish stocks are of great scientific and fish management importance. The Montana grayling is listed as a species of special concern by the American Fisheries Society's Endangered Species Committee (Williams et al. 1989:4). The Yellowstone cutthroat trout, formerly widespread in three western states and the subspecies native to most park watersheds, is now restricted as a native fish to the park and its immediate environs (Varley and Gresswell 1988:14). The highly specialized lacustrine-adapted stocks of this subspecies from Yellowstone Lake (of which there may be up to 68 distinct reproductive entities) have been widely introduced throughout North America, and indeed worldwide (Varley and Gresswell 1988, Gresswell and Varley 1988). Yellowstone harbours several valuable stocks of exotic fishes in the form of brown trout, lake trout and brook trout populations resulting from single plantings in 1889 (Jones 1980:136). One rare stock of brown trout was introduced directly from Europe to Yellowstone, and presently receives special protection (R. D. Jones, personal communication 21 February 1990). A population of lake trout introduced from the Great Lakes decades ago and extirpated in its original home, is being reintroduced to Lake Michigan from the archived Yellowstone stock (R. D. Jones, personal communication 21 February 1990, Jones et al. 1989:150).

Angling constitutes another significant value in this park. The Yellowstone fish populations support a multimillion dollar sport fishery prosecuted by more than 100,000 anglers annually. Although about 100 waters are commonly fished, 96 percent of the angling is done on only nine of these (Yellowstone National Park 1983:70-1). In 1988, the most recent year of record, an estimated 134,600 anglers made 293,800 trips and spent 753,400 hours to land 788,100 fish, of which 92 percent were released under the park's no-kill regulations (Jones et al. 1989:5). It has been stated that Yellowstone by itself hosts over 1 percent of the coldwater anglers in the USA (Yellowstone Staff 1979:33), and issues more angling permits than do a dozen US states (Schullery 1979). The total expenditure for fishing Yellowstone in 1988 may be estimated as $28,498,600 US from figures cited by Jones et al. (1989:2), who estimated the total "resource value" (i.e., including that additional amount surveyed anglers said they would be willing to pay above what they actually paid) of the park fishing program at $61,698,000 US for that year. More than a decade ago local expenditures alone for fishing in Yellowstone were thought to be in the order of $4,000,000 US annually (Yellowstone Staff 1979:33, Schullery 1979).

While these figures are remarkably high, especially considering that the entire fishery is supported by wild fish, it is worth noting that anglers represented only about 6 percent of the total 2.2 million recreational visitors Yellowstone Park received in 1988 (Jones et al. 1989:5). Nonangler use of the fish resource is large and growing larger. At just two popular fish viewing locations in the park where angling is no longer permitted, Fishing Bridge and LeHardy Rapids, 389,415 visitors spent 71,578 hours watching fish (Jones et al. 1989:175). The figures for Fishing Bridge alone show that 800 percent more visitors spent 30 percent more total time watching fish when compared to the angling use of the area when fishing was permitted, yet total visitation to the park during the same period increased only 18 percent (Jones et al. 1989:174-5). In certain time periods, more people use the Fishing Bridge area for fish viewing than angle in the entire park (Jennings 1980:150). “Comparing nonangler use to Park fisheries, more people utilize Fishing Bridge than any single fishery in the Park …. LeHardy Rapids ranks seventh and Fishing Bridge fourth when compared, in terms of total hours, to angler effort among Park fisheries” (Jones et al. 1989:176). Figures on total nonangling use of Yellowstone’s fish resources, and the economic value of these uses, were not provided by Jones et al. (1989).

Comparisons between angling and nonangling uses of the resource have been made in Yellowstone because sport fishing often is incompatible with other uses which may be both more valuable to more people, and more in keeping with the preservation purpose of the park. The example of Hayden Valley previously mentioned is an excellent example (Yellowstone Staff 1979:35, Jennings 1980:148). Before 1965 fishermen were the principal species seen from the road, becoming an “offensive intrusion” to nonanglers who made up over 90 percent of the visitors to the valley. Fishing was banned in this extremely productive segment of stream in 1965, and by 1979 Hayden Valley had become the prime place in the park for viewing wildlife. Elk, moose, bison, rare trumpeter swans and pelicans now are nearly always present, and otters, grizzly bears and bald eagles are occasionally seen as well. More to the point for the fish resource, the large and abundant native cutthroat in the area apparently became less wary, offering to bankside viewers a highly visible and very rare picture of what pristine trout populations of this region were like more than a century ago. In short, this region became a benchmark aquatic community even though it had not been protected expressly for that purpose (R. D. Jones, personal communication 21 February 1990). In addition it is thought to have served as a fish refuge or sanctuary, a source of trout permitting consumptive fisheries above and below the reach to stand up to the crushing pressure of 4000 anglers per mile per year (Yellowstone Staff 1979:35).

Fisheries Management Plan

The present fisheries management plan (Yellowstone National Park 1983) governs current activity, but is badly out of date and is being rewritten (S. E. Coleman, personal communication 6 March 1990). The information in this section is taken from that document unless noted otherwise. Its goals as most recently stated by Jones et al. (1989:1) are to

1. *"manage the aquatic systems as an integral part of the park ecosystem;*

2. *"preserve and restore native species and aquatic habitats;* [and]

3. *"provide recreational fishing opportunities for enjoyment of Park visitors consistent with the first two objectives."*

To meet these goals, managers chose from several alternatives an approach designed to protect and restore native fishes and the aquatic environment where practical, to continue or expand present management on exotic fish species, and to progress toward management by species. Fishing regulations were to be used as the primary tool to achieve the desired results, with regulation by species on a park-wide basis. The regulatory program was to be supported by a program to educate anglers to identify the various fish species, coupled with strict enforcement of the regulations.

The fisheries management plan has substantial management, monitoring, education and research components. The National Parks Service manages the fisheries cooperatively with the US Fish and Wildlife Service (USFWS). The USFWS has assigned several fisheries biologists and support staff to continuing fisheries work in the park. The agency prepares detailed annual reports analyzing data from projects undertaken that year, formulating management recommendations based on these analyses and submitting them for review to park staff, which includes at least one more active fisheries biologist. Currently only catch-and-release (no-kill) fishing is permitted for indigenous species on all park waters open to angling, except for Yellowstone Lake, where two native trout may be creeled (R. D. Jones, personal communication 21 February 1990). Park rangers carry out all enforcement.

Several monitoring programs are carried out on the sport fishery. A voluntary creel census is used as the most efficient way to monitor angler use, provide fishery statistics and evaluate regulations. Anglers receive a catch report form on a card with their free fishing license to fill out and return to park staff (Varley 1975, D. Levis, personal communication). An interview-type creel census is used periodically to calibrate the system and maintain accuracy. Fish population structure is monitored by periodic sampling of various park waters. An intensive monitoring program is conducted annually on Yellowstone Lake, involving trapping of spawning runs on important creeks and regular gillnetting in the lake itself.

Education and information are provided to the public by the rangers and interpretive staff at entrance stations and visitor centres, and through formal interpretive programs. Park staff have published semitechnical or popular-style articles on Yellowstone's aquatic ecology directed toward an informed lay readership.

An active program of applied research is carried out by the fisheries staff. As of 1983, research included studies on productivity and stock identification in Yellowstone Lake, the effects of natural fires on aquatic habitats, the status of exotic fishes in Yellowstone Lake, the predator-prey relationships of exotic fishes, and the biology and status of westslope cutthroat trout in the park. More recently, park fisheries research staff have been involved in evaluating the effects of the large 1988 fires on park aquatic resources, including an investigation of a fish kill caused by fire retardant; developing a sophisticated stream classification system; removing a population of brook trout threatening to become established in a Yellowstone Lake tributary; and studying nonangling uses of fish resources. An active program of regular stream surveys has been continued, and the group has supported and assisted a wide variety of research projects on park aquatic resources by outside researchers from universities and other government agencies (Jones et al. 1989). Several of the fisheries biologists have published formal research papers in the primary literature, and contribute to proceedings of symposia, conferences and similar compilations of a technical nature.

Fisheries Management in Practice

The goals of the fish management plan described above are part of the overall intention of the NPS that the park be managed to perpetuate natural processes within the Yellowstone ecosystem, including interactions among native fauna, flora, geology, and scenic landscapes. Wild fish populations must be maintained to achieve these goals. In particular, natural replenishment rates, size and age structure, total population size and genetic integrity must be preserved. The populations of wild fish must be maintained not only for their own sake, but to fulfill the role they play in the ecosystem, particularly as food for wildlife. Angling is permitted only to the extent that all of these conditions are met (Jones 1987:95).

Preserving Stocks and Habitats

Fish managers have used a variety of approaches to achieve their goals of preserving functioning ecosystems and protecting native fish. The fact that the fish populations are in habitats protected within a national park has been an important factor in helping the aquatic habitats and their fish populations to maintain themselves (Varley 1979, Jones 1987:95, Varley and Gresswell 1988:15). In many cases, the approach simply has been to discontinue an activity that was working counter to the goals.

Stocking is not a natural process in Yellowstone, so fish are no longer stocked in park waters — whether they be native or exotic strains (Jones 1987:95). This policy has the additional benefit of protecting native stocks from further threats to their population structure, reproductive success and genetic integrity through predation, competition, or introgression. Fish *may* be introduced into park waters for the purpose of restoring a native stock (Jones 1987:95). Apparently the single attempt to do this in Yellowstone, an endeavour to restore Montana grayling, was not successful (R. D. Jones, personal communication 21 February 1990).

A very few waters have been closed to angling to protect threatened species and nesting birds, or to provide scenic vistas with undisturbed wildlife (Jones 1987:95). These areas might serve as aquatic benchmark communities, although that was not their intended purpose (R. D. Jones, personal communication 21 February 1990). Spawn-taking and fish culture operations were terminated on Yellowstone Lake years ago to stop further deterioration of the numerous indigenous stocks of Yellowstone cutthroat trout there, with considerable success (Gresswell and Varley 1988:48).

Occasionally it has been necessary to take extreme measures to remove exotic species that were threatening valuable fish stocks. For example, an entire drainage of a tributary to Yellowstone Lake was poisoned with antimycin to remove a newly-discovered brook trout population, considered a threat to the many unique Yellowstone cutthroat stocks indigenous to the lake.

Providing a High Quality Sport Fishery

The management objective for angling in Yellowstone National Park is "to provide the angler with the opportunity to fish for wild trout (both native and nonnative) in a natural setting" (Jones 1987:95). Varley (1975), using a detailed voluntary angler report, examined the question of what constitutes high-quality fishing to fishermen in Yellowstone National Park. Catch rate, surroundings and fish size were found to be important characteristics to most anglers. Native cutthroat trout provided the best all-round sport fishing in the park in terms of catch rate, mean length and overall angler satisfaction. Later, Varley (1980:141) reported that anglers in the park, derived from all states and Canadian provinces, liked to catch many fish of large size. Satisfaction increased with the first few fish caught, distinctly levelling off after the third fish. The minimum acceptable size was about 18 cm in length, and satisfaction increased continuously with increasing fish size.

Managers of sport fisheries commonly use stocking, habitat improvement and regulations to provide high-quality angling (Gresswell 1983). Stocking and habitat improvement would be unnatural intrusions into the natural functioning of the Yellowstone ecosystem, so only regulatory techniques are available to manage sport fishing in the park. Regulations have included seasonal closures, terminal tackle restrictions, creel limits, size limits, and no-kill catch- and-release. In addition, selected parts of waters could be closed to improve angling elsewhere. In at least one case an area closed to fishing for other reasons worked very effectively as a refuge for fish, helping to support heavy fishing pressure outside its boundaries (Yellowstone Staff 1979:35).

Yellowstone National Park has been a leader in "no-kill" angling regulation, setting up the first fulltime no-kill catch-and-release sport fisheries in 1969 for grayling, and expanding the no-kill rule to several other waters in 1973 (Anderson 1977:9, Varley 1980:138, Barnhart 1989:74-5). Wallis (1960:236) described no-kill fishing as "a means of limiting the kill rather than the catch and of coping with high fishing pressure without resorting to measures that would lower the quality of the fishing experience." Jones (1987:95) claimed that no-kill regulations "have been one of the most successful regulations at meeting the park's fishery objectives."

In a native cutthroat fishery in Slough Creek, data published by Jones (1987:96-7) appear to show a general decline in catch rate and a nearly 5-cm increase in fish length, while angling pressure approximately doubled during 14 years of a no-kill rule. (Jones' description of his data on page 96 differs in several respects from his graphs on page 97). In the Yellowstone River, probably one of the most intensively fished wild trout waters in the USA, Jones' (1987:98) data suggest a no-kill regulation produced an immediate dramatic decline in angler use that persisted for eight years before recovering to pre-no-kill levels. Catch per hour showed an equally dramatic initial increase followed by a consistent decline over eight years, levelling out and remaining constantly above pre-no-kill rates thereafter. Mean length of trout caught increased by about 2.5 cm over the 14-year period of the study.

In general, no-kill regulations improved the sport fishery on these waters. These results, and those from several other no-kill fisheries in the park (Varley 1980, Jones 1984), prompted managers to implement a parkwide no-kill regulation for cutthroat, rainbow and Montana grayling in 1987 (Jones 1987:99). The principal exception was Yellowstone Lake, where fishermen may keep up to two cutthroat trout (R. D. Jones, personal communication 21 February 1990).

The Yellowstone researchers found that the effectiveness of a no-kill regulation *in providing high-quality angling* depends on several factors related to the biological characteristics of the fish stock and the habitat (Varley 1980, Gresswell 1983). For example, cutthroat trout are especially well suited to catch-and-release because their behaviour makes them easy to catch, they tolerate hooking and handling well, and they can live a relatively long time so may be caught over several seasons. Schill et al. (1986:230-1) estimated that cutthroat trout in the Yellowstone River were caught an average of nearly 10 times — or an average of once very 5 days — during the summer fishing season. According to Gresswell (1985), cutthroats remain susceptible to the fishery for three years, and tagging studies have shown that many individual trout are caught two or three times in a single day. The mortality rate on the Yellowstone River cutthroats caused by hooking and handling has been estimated at only 0.3 percent per single capture; 3.2 percent of the population was estimated to have died from angling-related mortality in one year (Schill et al. 1986:229-30).

The characteristics that make cutthroat trout so “reusable” ultimately gives the species a very high economic value for fisheries management. Varley (1984, cited in Varley and Gresswell 1988:19) estimated that the value of the species to the Yellowstone River fishery was $45 US *per fish* in costs avoided by releasing the fish rather than replacing them with hatchery stock. In 1989, anglers caught well over 80,000 cutthroats from just one part of the river (Jones et al. 1989:43), so the avoided cost arising from the no-kill rule in this reach alone was over $3.6 million US.

Experience in Yellowstone suggests that as a general rule cutthroat trout, grayling and possibly rainbow trout are better suited to catch-and-release than are brown trout and perhaps brook trout (Anderson 1977, Varley 1980, Jones 1984, Gresswell 1985). Anderson (1977:9) stated that several grayling fisheries responded to a no-kill regulation with increased catch rates and sizes, features perhaps influenced by reduced angling pressure in some cases (e.g., Varley 1980:138). Early observations on a no-kill brown trout river fishery showed an unexplained decline in length under the regulation (Varley 1980:140). Gresswell (1985) stated that this species showed improved size and age structure under a no-kill rule, though catch rates remained low, observing that larger fish of this species had low catchability where secure habitat was abundant. Anderson (1977:9) stated that the size, but not the catch rate improved for rainbow trout under a no-kill regulation.

The extent to which no-kill angling, size limits and very restrictive creel limits meet the *preservation goals* of Yellowstone’s resource management policy to a large degree depends on the mortality rate from hooking and handling. Fish managers have attempted to minimize mortality from this source with terminal tackle restrictions. Anglers may use only artificial lures on park waters, because research has consistently shown that bait-caught fish are more likely to die after release than are fish caught on artificial lures (e.g., Wydoski 1977; Behnke 1989 provides an updated popular-style account).

Yellowstone National Park also has used various size limits, often in combination with catch-and-release, to manage angling. Gresswell (1983) summarized their use in the park, concluding that *minimum* size restrictions were probably useful only for managing trophy fisheries. He further concluded that minimum size restrictions commonly reduce survival for fish over the minimum size, and therefore may result in overharvest if the minimum size takes in a significant proportion of spawning-age fish. In contrast, *maximum* size limits will support harvest at much higher levels of angling effort, provided that the maximum size is set low enough to protect an adequate number of spawning-age fish. The maximum size regulation is intended to take advantage of compensatory mortality; i.e., the young fish that are removed by anglers leave resources that allow more of the remaining small fish to survive.

As an example of the differing effects of minimum and maximum size limits, Gresswell (1987) showed that in Yellowstone Lake, a minimum-size regulation initially curbed overharvest, but serious decreases in older trout occurred within four years. Instituting a maximum size limit restored a more natural population size and structure. As yet there is not enough information to judge the effect of no-kill rules, maximum or minimum size limits on easily-caught species like cutthroat trout and brook trout in unproductive habitats (Gresswell 1983).

Aquatic Resource Inventory

A regular program of lake and stream surveys is used to monitor fishery and limnological conditions, providing data essential for detecting changes in the aquatic resources over time.

Stream surveys were initiated in the 1960s, and have now been completed on 580 streams in the park. The surveys may be *cursory-level*, providing data only on a small number of basic physical conditions, macroinvertebrate community composition and fish presence/absence; or *reconnaissance-level*, providing more detailed data on flow, channel and riparian features, macroinvertebrate and fish presence/absence by reach (Jones et al. 1989:51). Lake surveys collect data on a wide variety of drainage basin characteristics, physical limnology, water chemistry, plankton, shoreline, benthos and fish communities (Gresswell 1984).

Interpretive and Educational Programs

Interpretive and educational programs are an important part of fish management in Yellowstone, and have been described briefly by Jennings (1980).

Fishing Bridge on the outlet of Yellowstone Lake, an important spawning area for cutthroat trout, was a very heavily-used and seriously overfished angling spot. It was closed to fishing in 1973, and has been used as a fish viewing area ever since. Visitors can watch at close range the spawning behaviour of colourful native cutthroats (two distinct stocks) in very large numbers, as well as longnose suckers. The large concentrations of fish attract fish-eating birds — kingfishers, pelicans, mergansers, ospreys and eagles — that visitors can watch in action. Dense populations of caddisflies, mayflies and stoneflies produce huge hatches of emergent adults at times, providing for impressive displays of feeding activity by resident cutthroats. Live closed circuit television with an underwater camera is used to show the spawning and feeding trout to visitors in the interpretive centre.

There are at least two other important fish viewing areas in Yellowstone (Jennings 1980:150-1). At LeHardy Rapids on the Yellowstone River, visitors by the thousands watch native cutthroat trout leap the cataracts during their spawning migration. This area, too, is closed to fishing. Visitors likewise watch brown trout ascending rapids on the Gardner River during their fall spawning migration.

The large numbers of visitors that use these viewing sites already has been described under the heading "Values and Competing Interests", above. At certain times more people use the Fishing Bridge area for fish viewing than fish in the entire park (Jennings 1980:150), and visitor use of the both Fishing Bridge and LeHardy Rapids sites is comparable to that of some of the park's most heavily used fisheries.

National Parks of the Sierra Nevada, California

The Pacific Coast state of California holds four major natural-area mountain national parks that have significant aquatic and fish resources: Yosemite, Sequoia, Kings Canyon and Lassen Volcanic. Although the parks are under the exclusive jurisdiction of the NPS, their fishing regulations are those of the state, and a state fishing license is required to fish in them (Wallis 1977, Schullery 1979).

It has been estimated that these parks together contain more than 1500 lakes, the vast majority of which originally had no fish populations (Fullerton 1976:16, Schullery 1979). A wide variety of trout were introduced into hundreds, perhaps nearly all, of the lakes over a period of more than a century, beginning as early as 1850 (Christenson 1977:13, Cordone 1977). Data published by Wallis (1977:56-7) suggest that well over 300 lakes in these parks now contain self-sustaining trout populations, and that approximately an equal number have trout populations that would have to be sustained (at least to some extent) by stocking.

In the mid-1970s, the NPS reaffirmed its policy not to stock naturally fishless lakes, and introduced a new policy to stock only to restore populations of native fish (Wallis 1977:59). The NPS policy changes came at a time when the US Forest Service had just instituted a similar restrictive policy on aerial fish stocking in wilderness area waters under its jurisdiction.

Both federal agencies came under strong attack from some quarters, instigating at least two special symposia to deal with the matter (Gottschalk 1976, Hall and May 1977). Opposition was strong from some western state agencies charged with sport fish management (e.g., Cordone 1977; Fullerton 1976; McKean 1976; S. Thompson, personal communication 12 June 1990; H. Warner, personal communication 12 June 1990; R. Wasem, personal communication 13 June 1990), and was supported by various anglers organizations (May 1977, Wallis 1977:59). Federal personnel of the US Forest Service (Griswold 1976, Hall 1977), National Park Service (Wallis 1977) and US Fish and Wildlife Service (Hester 1976) firmly defended the new policies, and were supported to various degrees by others (Erman 1977, Grandy 1976). Opinions of many other fisheries biologists tended to be much more noncommittal or at least muted (e.g., Dean 1977, Johnston 1977, Pister 1977, Gregory 1976, Marcuson 1976).

The virulent tone of the debate on the part of one state agency director attests to the depth of hostile feeling engendered by restrictions on stocking. Speaking to an audience of state and federal fisheries administrators and biologists, McKean (1976:9) accused the agencies administering the lands in question, and especially the US Congress, of lacking judgment or discipline, of imposing discriminatory rules, and of passing emotionally motivated legislation. He continued (McKean 1976:10):

"An important point to remember is that wilderness is not the only special land use classification to have serious impacts on management and use of fish and wildlife. National wild and scenic rivers, monuments, recreation areas, parks, natural areas, all have objectives that negatively affect fish and wildlife and/or their use. Militant protectionists or escapists are often more concerned about such irreversible impacts as footprints in the sand or bent blades of grass than about potentials of the Nation's renewable resources."

Although McKean was from Oregon and was speaking about the reduced stocking policy for federal wilderness areas, his comments raise the most substantive objection to the restrictive stocking policy in national parks as it concerns California. State officials there estimated that fully 75 percent of their mountain lakes were contained in national parks or official federal wilderness areas, and they promulgated the fear that all of these would be lost to sport fishermen. The Director of California Fish and Game stated (Fullerton 1976:16):

"To the best of our knowledge, all of California's high mountain lakes were barren of fish when first visited by European man. Now, incredibly, a handful of people would evidently prefer to see them all return to a fishless state. That feeling is evidently shared by some federal personnel."

Another representative of the same agency warned (Cordone 1977:64):

"Since all of the lakes and nearly all of the streams in the four 'natural category' Parks were originally barren of fish life, strict application of Park Service policy would mean the total elimination of all trout…. Clearly, complete removal would be a monumental task which the Park Service is not contemplating at this time. But the policy calls for it, and if carried out at some future date, it would constitute an unthinkable loss of an important, legitimate, and harmless form of recreation."

These worries are difficult to credit, at least as they concern national parks. Neither Cordone (1977) nor Fullerton (1976) cited any part of any NPS or Forest Service policy document that could support their argument. Sport fishing in national parks is permitted clearly and explicitly in the same document that outlined the stocking policies Cordone was condemning (Wallis 1977:58-9). The NPS representative in fact had admitted in a previous publication (Wallis 1960:235) that although removal of exotics "… shows promise on a selected basis, … wholesale elimination of exotics and restoration of indigenous species probably is not feasible."

The California opponents to the NPS policy delivered what proved to be a profound setback to NPS fish management in the High Sierra parks. Although the state was not successful in getting a formal permanent variance from the policy for those parks, it did succeed in delaying its implementation — for more than 15 years in Sequoia and Kings Canyon, indefinitely so far for Yosemite. The NPS agreed "to enter into a cooperative two-year study with the California Department of Fish and Game to determine the biological, economic, recreational, and social impacts of this policy" in the state. The "objective of the study was not to justify the fish stocking policy but to develop a recreational fisheries management program consistent with natural area m[a]nagement and policies". During the study period, trout stocking within the four parks was to continue at a level not exceeding that of 1974 (Wallis 1977:60).

The cooperative two-year study was never concluded. A draconian tax limitation initiative, Proposition 13, was passed in California, and the state agency assigned its funds elsewhere. Data were collected, but no investigator was assigned to analyze it and report the results. Stocking continued in seven lakes in Sequoia and Kings Canyon. When the NPS again reaffirmed its restrictive stocking policy two years ago, no official or *de facto* variance was granted to the High Sierra parks, and local park authorities were able to cease stocking altogether in Sequoia and Kings Canyon as of 1990. Although state opposition to the policy is still strong, NPS staff have been able to make a strong case justifying the policy. Angling groups are much less concerned about stocking now, being more interested in catch-and-release for native fish outside the parks (H. Warner, personal communication 12 June 1990). A fishery management plan for Yosemite National Park has not been drawn up to this day, and stocking continues in 13 lakes, although this is dramatically lower than in former years as California Fish and Game is becoming convinced of the National Park Service stated intention to retain sport fishing in this park (S. Thompson, personal communication 12 June 1990).

North Cascades National Park, Washington

This section is based primarily upon brief telephone interviews I conducted with national park biologists Bob Wasem (North Cascades), Steve Thompson (Yosemite) and Harold Warner (Sequoia and Kings Canyon), as well as National Forest Service fisheries biologist Brady Green (North Cascades). Interpretations of their remarks are my own. I thank them for their time, patience, and understanding.

North Cascades National Park, Washington, is a young park formed in 1968 from national forest lands extending south from the forty-ninth parallel. Unlike all other American parks reviewed here, North Cascades is managed under joint NPS and state jurisdiction. In other words, the NPS is merely a proprietor subject to much the same laws governing other landholders. As such, it has some serious fish management problems to a degree not encountered in the other parks.

Before the park existed, the lakes and streams were managed for sport fishing. A large number of the high mountain lakes were originally barren of fish, and were regularly stocked with a variety of trout species. Many of the waters could not support trout populations without periodic stocking. Under the terms establishing the park, the State of Washington maintained the right to manage park waters for sport fishing. In doing this, they frequently employed the voluntary help of local fish and game associations, who enlisted their members to stock the lakes. Formal records of the introductions often were not kept, and it is believed that trout often reached lakes other than those for which they were destined.

When in the mid-1970s the NPS reaffirmed its policy not to stock naturally fishless lakes, and introduced a new policy to stock only for the purpose of restoring populations of native fish (Wallis 1977:59), fish management in North Cascades National Park became highly contentious (see the discussion under “National Parks of the Sierra Nevada, California”, above, for details). The Washington state agency that shared responsibility with the NPS for fish management in the park opposed the restrictive stocking policies, and it was supported by several angler groups in the state.

To break the impasse, the park administrators obtained an official variance from the NPS policy, with the proviso that stocking be maintained only in those lakes traditionally stocked prior to the park’s establishment just a few years earlier. The state continued to enlist fishermen to assist in stocking. Because records were poor or nonexistent, disagreement soon erupted over which lakes had a “tradition” of stocking. Relations between the agencies reportedly deteriorated to such an extent over the issue that the NPS promised to arrest state officials if they carried out their threat to continue stocking in direct contravention of park policy.

By the time the restrictive stocking policies of the NPS recently were reaffirmed yet again, more than 20 lakes were being stocked. This time the NPS has refused to grant an official variance from its policy, but detailed studies have been funded in excess of $300,000 US to determine the effects of trout introductions on the park’s aquatic ecosystems to support decision-making in the future.

Great Smoky Mountains National Park, Appalachia

Great Smoky Mountains National Park, established in 1926, is located in the Appalachians of North Carolina and Tennessee (Schullery 1979). It is of interest in this review as being perhaps the earliest park to attempt to restore native fish stocks, and to limit damage to them by means of catch-and-release sport fishing regulations.

Rainbow and brown trout were heavily stocked in streams near the present park in the early 1900s and later invaded park waters, replacing native brook trout populations. Between 1950 and 1970, the length of stream occupied exclusively by native brook trout declined by 45 percent, being restricted almost entirely to the extreme headwaters; and by 1983 the species occurred in only 29 percent of its former stream habitat (Schullery 1979, Moore et al. 1983:72).

There was apparently no single cause for the change. A complex series of cumulative environmental impacts have been implicated, involving a prolonged history of environmental destruction that included habitat damaged by logging and fires, native trout overexploited by means of angling, explosives and nets, sport fishing selectivity and competition from the nonnative trout species (Schullery 1979, Moore et al. 1983:72-3, Larson and Moore 1985). There are fears that brook trout eventually may be reduced to a few small inbred populations in headwater refugia, and ultimately could be extirpated from many park streams unless effective action is taken (Larson and Moore 1985).

Attempts were made prior to 1960 to restore a stock of brook trout native to the area. A toxicant was used to eradicate rainbows from one creek in the park, and the "Appalachian strain" of brook trout was reintroduced (Wallis 1960:235). Apparently there were other attempts to eradicate rainbow and brown trout as well (Moore et al. 1983:73). There were plans in place in the 1970s to preserve native stocks in the headwaters, protecting them from invasions of exotics with barriers preventing migration, and favouring native brook trout elsewhere with selective fishing regulations (Schullery 1979). Intensive electrofishing was used from 1973 to 1981 to selectively remove exotic trout from several streams, effectively reducing the nonnative populations and improving the native stocks (Moore et al. 1983, Larson et al. 1986). Larson et al. (1986) also used anglers to reduce populations of exotics, and found the method to be cost-effective relative to electrofishing.

As Schullery (1979) pointed out, fish management experience in Great Smoky Mountains National Park well illustrates why many national park fish stocks cannot be managed in isolation, without regard for conditions outside the parks. The parks are not ecological islands; park rivers flow out onto nonpark lands. In this park, it is not enough to restore brook trout if nothing is done to prevent a repeat of their demise. Rainbow and brown trout populations really must be prevented from continuing to colonize streams in Great Smoky Mountains National Park, and this ultimately will require management work beyond park boundaries.

Sport fishermen probably have released some of their catch voluntarily since angling became a sport rather than a food-gathering technique. Voluntary catch- and-release was advocated at least as early as 1873, but its use as a method of regulating sport fishing was pioneered by Great Smoky Mountains National Park in 1954, when it designated two creeks as “fishing for fun” areas (Barnhart 1989:74). Catch rates improved dramatically under the new rules, and the streams were opened year-round for catch- and-release just four years later (Thompson 1958, Lennon and Parker 1960, both cited by Barnhart 1989:74). Park managers quickly expanded the program to a total of four streams in which anglers could fish year-round and catch unlimited numbers of trout on single-hook artificial lures, provided they released all fish less than 40 cm long. They used the catch- and-release regulations to limit drastically the effects of heavy fishing pressure “without resorting to measures that would lower the quality of the fishing experience” (Wallis 1960:236).

DISCUSSION

As noted in the introduction, the objectives of this report are to place fish management in Jasper in regional, national and continental context; to discover pitfalls in the approaches used elsewhere; and to discover approaches and methods that might be applicable to solving problems of fish management in JNP. In this section I discuss the applicability of the findings of the present survey to these objectives. Several of the topics are considered in much greater detail in Part 4, where they are applied to specific fish management problems in Jasper National Park.

Jasper National Park in Context

The Regional Context

The survey of fish management in the mountain national parks, the Alberta wilderness areas and the East Slopes places fish management in Jasper National Park in regional context. The following discussion links those observations.

The provincial government controls over 86 percent of the native range of salmonids in southern Alberta. Two-thirds of this range lies within the East Slopes region, of which the province controls approximately 83 percent (Figure 6). In comparison to those in the national parks, most of the provincially-controlled East Slopes streams and rivers are more productive habitat for salmonids because of their generally lower elevation, lesser gradients and larger size. The East Slopes region outside of the national parks has substantially fewer lakes suitable for salmonids, but they are by no means rare. Some of the Alberta-managed lakes support (Job, Watridge, Pinto), or once supported (Spray Lakes, Kananaskis Lakes), sport fisheries of extraordinary quality.

Alberta Fish and Wildlife (Alberta F&W) has a mandate to maximize sport fishing opportunities in East Slopes waters (Alberta ENR 1984:7) and throughout the province (Alberta F&W 1984). Alberta F&W has under its jurisdiction most of the best stream habitat, and a lesser but still significant amount of lake habitat, in the East Slopes for carrying out its mandate. Large areas of the provincially-controlled East Slopes are zoned for Prime Protection or Critical Wildlife management, which provide maximum scope in policy terms for sport fisheries development.

Nevertheless, the Province of Alberta chooses to manage most of its portion of the East Slopes, including much of the productive coldwater fish habitat, under a policy of multiple use, believing that its version of multiple use management is compatible with sport fishery development (Alberta ENR 1984:11-12). Whether or not this is true, there is an indisputable ongoing threat of serious damage to aquatic resources in the Multiple Use zone from expanding industrial development.

The province has given legislated protection from angling to fishes in three small wilderness areas in the East Slopes, comprising a total area of 1010 km^2, less than one percent of the region. None of the three areas has native fish stocks of significant size. One introduced archive stock of presumably genetically pure westslope cutthroat trout (upper Ram drainage) is fished under catch-and-release only rules, and a few other isolated native or quasi-native stocks may be similarly protected by regulations in limited areas. There remains a need to manage *strictly for preservation* a significant portion of our native East Slopes fishes in their native habitats, for reasons discussed in Part 1.

In contrast to the provincially-managed East Slopes, the mountain national parks of Jasper, Banff and Waterton Lakes occupy more than one-half of the Rocky Mountain area in Alberta, but less than 17 percent of the East Slopes region, and contain an even smaller proportion of the total regional native range of coldwater fishes (Figure 6). Large areas of the parks have no indigenous populations of fish because of waterfall barriers to dispersal. These areas frequently have unproductive aquatic habitats because of their high elevation, steep stream gradients, and frequently small size. Nevertheless, all three of the mountain national parks have significant indigenous fish populations and aquatic ecosystems of special value (this survey; see also Part 3).

By law and policy, preserving ecological integrity is the first priority of fish management in the national parks. The mountain parks must, as their first priority, preserve naturally functioning ecosystems in a condition as close as possible to the pristine state. The national parks have a mandate to protect aquatic resources from human alteration, and to restore damaged ones to their natural condition. They also have a mandate to manage aquatic resources for sport fishing, but it is secondary and supplementary to the mandate to preserve the ecological integrity of the resource (Part 1)[1]. Thus by virtue of their governing legislation and their physical circumstances, the mountain national parks must play a role much different from that of the provincial government in managing the fishes and fish habitats of the region.

Historically, the approach to fish management in the mountain national parks has been essentially the same as that taken outside the parks. The goals have been to maximize consumptive fishing opportunities, fishing variety, and returns to anglers.

1 As noted throughout this management plan, there already have been substantial changes to the natural ecosystems in the mountain parks (e.g., introduced fish species). This fact does not change the role of these parks, only the way in which it is carried out. How this general problem may be addressed is described at length in Part 4.

Now the more recently implemented legal and policy requirements for protecting ecological integrity in national park waters must be adequately recognized in managing fishes. Today the primary role of the Alberta mountain national parks is to protect native fishes of the East Slopes, and the natural ecosystems of which they are a part, so that people might learn about and enjoy them *in that context* now and in the future (Part 1).

This protective and educational role complements fish management practices on the East Slopes outside the parks, where consumptive sport fishing is the principal use of the fishery resources. By carrying out their different roles, the federal and provincial jurisdictions together will provide a complete, coherent fish management program for the Rocky Mountain East Slopes.

The National Context

The role of Jasper National Park in managing Canada's fish resources was described in detail in Part 1. Briefly, Jasper is part of a national system of landscape and ecosystem conservation. With regard to aquatic ecosystems, JNP is intended to protect the park's native fishes and their habitats as part of a representative cross-section of the eastern Rocky Mountains natural area. It is also expected to ensure that park users can learn about and enjoy the park's fishes and their habitats as integral parts of this natural area. Here I discuss how fish management in JNP relates to fish management approaches followed by the other Canadian parks and reserves discussed in this report.

Despite their common legislation and guiding policy, the Canadian national parks examined in this study vary widely in the goals and practices of their fish management programs. The range of these programs provides an indication of the type of fish management options available in Canadian national parks.

As interpreted in La Mauricie in 1980, fish management means providing consumptive sport fishing on most fish-bearing park lakes by maintaining a constant annual supply of fish, using carefully monitored and enforced quotas to sustain yield. It appears to be achieving that goal well — not always the case under sustained yield management (see Sustained Yield, Stock Preservation and Aquatic Ecosystems, below, and Part 4). Despite this apparent success, fish managers there have expressed concern that angling may have induced structural changes in fish populations. Providing a satisfactory recreational experience is an important goal of the program; thus, limits are set on the numbers of fishermen on particular lakes at any one time, and some lakes are set aside as canoeing only (no fishing), or for the use of special groups such as the elderly or disabled. New provisions in the updated fish management plan (circa 1989) were intended to emphasize restoration, establishment of benchmark ecosystems or sanctuaries, and an improved interpretive program for fish resources.

Consumptive sportfishing also is the focus of fish management in Pukaskwa (1986), but it includes an element of restoration (liming lakes to counteract the effects of acid precipitation, treating streams with lampricides to control introduced sea lampreys). A La Mauricie-like model of sustained yield management was rejected there because it was considered too labour-intensive. The fish management plan for Pukaskwa reveals at least a rudimentary awareness of the need to protect selected native stocks, although it fails to account adequately for the conservation value of native fish stocks as a whole. In fact, the plan in places seems to see parks legislation and conservation policy as regrettable impediments to providing good sportfishing, as in its comments on habitat enhancement and stocking.

In Prince Albert National Park, fish management is an integral part of an overall aquatic resources management plan (1989). This plan places maintaining ecological integrity first among its goals, followed by providing a high-quality visitor experience, then by identifying and protecting benchmark ecosystems. Much attention is paid to restoring damaged habitats and fish populations. Consumptive sportfishing retains a prominent place in fish management; however reduced catch limits are introduced to allow sportfish populations to recover. Significantly, sportfishing is seen as an important, but not the only, means of providing a high quality visitor experience of the resource. The plan provides for fishing to cease in some systems of lakes to be protected as benchmark aquatic ecosystems. The plan emphasizes improved public education about aquatic resources, through ongoing public consultation and improvements in interpretive programs.

The management program for Atlantic salmon in Fundy National Park illustrates another approach to meeting both the need to preserve fish populations in as natural a state as possible and the mandate to provide consumptive sport fishing in national parks. The Point Wolfe River salmon restoration project in that park appears destined to provide a benchmark stock that is protected from angling mortality. The angling mandate is satisfied by allowing strictly controlled consumptive sport fishing on the Upper Salmon River. On this river it appears to be possible to monitor both anglers and fish closely enough that harvest can be strictly limited to only the number of fish estimated to be surplus to spawning needs.

The Fundy National Park salmon management plan is an excellent example of stock-oriented fish management for conservation purposes in a Canadian national park. As in all sustained yield approaches to fish management, including those in Prince Albert, Pukaskwa and La Mauricie national parks, it relies on the concept of a harvestable surplus. Whether this concept can be reconciled with the need to maintain ecological integrity under the National Parks Act is considered later in this Discussion (see Sustained Yield, Stock Preservation and Aquatic Ecosystems, below).

The three provincial fish management areas and projects outside of Alberta examined in this survey help define the national context further.

Described officially as a Natural Environment Park by the Ontario Government, Algonquin is a multi-use area in one important respect. Logging is a permitted use of long standing, and is a significant fish management problem. Despite this, the park still protects the only remaining major complex of native trout waters in southern Ontario. It thus serves one of the most important functions that ordinarily would be assigned to a national park. Consumptive sport fishing is one of the main park-related use of aquatic resources. A zoning system is used to designate waters for intensive fish management (stocking and habitat manipulation) from remote waters managed so that the stocks are self-maintaining. Algonquin takes a strongly stock-oriented approach to fish management, seeing native fish stocks as one of the most valuable attributes of the sport fishery, as well as worth preserving for technical fish management reasons. This attitude toward fish management also is well shown by Ontario's elaborate efforts to restore self-maintaining aurora trout north of Sudbury.

Quebec's two types of parks have different fish management functions. Although consumptive sportfishing is conducted in both recreation and conservation types of parks, it is merely tolerated in conservation parks. Conservation parks are intended primarily to preserve the natural environment. In this they serve the same role as national parks. Intensive fish management to promote and enhance sportfishing is restricted to the recreation parks, where angling has a major recreational role. Artificial manipulation is used in conservation parks only to restore native fish populations or their damaged habitats.

Despite the obvious differences, fish management programs in the Canadian national parks covered in this survey share some important common elements. All show a concern for restoring aquatic ecosystems or selected fish populations to something like their natural state. Taken together, they also reveal a decreasing tendency to view fish management in isolation. Increasingly there is tendency to manage fishes in larger contexts: as integral parts of aquatic ecosystems, or as important elements in educational programs dealing with park natural history. These are trends appropriate to the legal and policy mandates of the parks (Part 1), and are adopted in this fish management plan for Jasper (Part 4).

Most of the Canadian national parks surveyed also incorporate consumptive sport fishing on native fish populations as a major use of the resource, if not *the* major use. Most of them also are showing clear signs of de-emphasizing the practice. Consumptive fishing on native stocks clearly contravenes the 1988 National Parks Act provision requiring maintenance of ecological integrity to be the first priority in planning for visitor use (Part 1). Why this has occurred (apart from the obvious fact that several of the fish management programs pre-date the Act) and what should be done about it is taken up in detail below (see The Role of Sport Fishing). For now it is enough to mention that permitting consumptive sportfishing on native park fishes is a dubious practice at best in Canada's national parks, and is avoided in this fish management plan for Jasper (Part 4).

The natural landscapes and ecosystems of Ontario and Quebec are poorly represented in national parks. Provincial parks in those provinces have taken different approaches to meeting the need to preserve representative natural aquatic ecosystems while addressing sportfishing demand. In Algonquin Park, Ontario uses zoning to set aside large areas for preserving natural aquatic habitats and native fishes. A smaller zone inside the park, and an extensive area surrounding the park, are managed more intensively to maximize sportfishing opportunities. Quebec uses two different types parks, recreation parks and conservation parks, to achieve a similar result. Consumptive sportfishing is allowed in the conservation areas in both provinces, but at low intensity. There is an obvious parallel with fish management on the Alberta East Slopes, where the national park mandate is to undertake the conservation role as its prime responsibility, while the provincial government has adopted the responsibility of managing most of the fishery resources under its jurisdiction primarily for sportfishing.

The North American Context

The role of Jasper National Park in managing North America's fishes and aquatic ecosystems was touched upon in the introduction to this volume. Jasper is part of a global system of landscape and ecosystem conservation administered by each of the world's nations. Canada shares parts of many landscapes and ecosystems with its neighbour on this continent, the USA. With regard to aquatic ecosystems, Jasper is intended to protect the park's native fishes and their habitats as part of a representative cross-section of Canada's eastern Rocky Mountains natural area, a part of the North American Cordillera. In this section I briefly discuss how fish management in Canadian parks relates to fish management approaches followed by the US parks and reserves discussed in this report.

There is a marked difference between US and Canadian national parks in the approach they take toward fish management. As a matter of explicit, fundamental policy in the US national parks, native fishes are managed as essential parts of the natural ecosystems that the parks exist to protect. For this reason few native fish in the US parks are subjected to consumptive fishing. Consumptive sportfishing is a major part of the fish management program in the US park system as a whole, but is restricted almost exclusively to non-native stocks in national parks, and to stocks in non-national park units of the system (e.g., National Recreation Areas). Sportfishing on native fishes in US national parks proper is almost exclusively catch-and-release in the parks considered in this survey. This division of responsibilities for various kinds of fish management within the US park system is similar to that between the Quebec recreation and conservation parks.

In Canadian national parks, native fishes as a rule have *not* been managed as essential parts of the parks' natural ecosystems. The reason is easy to divine.

Consumptive sportfishing has been allowed on the ground that it is a traditional activity, as an *explicit exception* to the policy against consumptive use of park natural resources (Part 1). This has led resource managers to ignore the ecological truth: that native fishes are integral parts of the natural ecosystems of the parks. These are the same natural ecosystems the integrity of which the national parks have a firm policy to protect.

Now that the National Parks Act requires the national parks to maintain the integrity of their ecosystems as a matter of law, this approach must change. Canadian national parks must manage their fishes in such a way that they preserve ecosystem integrity, but still provide high quality opportunities for learning about and enjoying fishes and their habitats. Useful lessons have been provided by most of the North American parks examined in this survey. Several of these are discussed in detail below.

The Role of Sport Fishing

In national parks in Canada and the USA, sport fishing is nominally a second-priority use of fish resources. In both countries, sport fishing is permitted in national parks on the grounds that it is a "traditional" use of fish populations. The first priority in both jurisdictions is to preserve the ecological integrity of the aquatic ecosystems, so sport fishing is seen as an anomaly in Canadian and US national parks. Consumptive sportfishing in particular is an extractive use of a resource in areas specifically set aside for nonextractive use.

The US parks considered in this report generally do not permit consumptive sportfishing of their native fish stocks. But in its national park policy, Canada has made sportfishing an *explicit exception* to the general policy against consumptive use of resources in national parks. In effect, we grant special dispensation to sport fishermen to use a park resource in a fashion directly contradictory to the main purpose of national parks.

Special dispensation is a very weak justification for anything. It is likely to be resented because it is undemocratic and arbitrary, and there are bound to be continuing pressures to revoke the special privileges conferred under it. If sport fishing is to continue in national parks under the present law and policies, it must justify itself completely on its own merits.

The strongest argument against special dispensation for sportfishing is that it is not needed. This review has suggested several valuable uses of sport fishing in national parks under particular circumstances. In Glacier (Montana), Rocky Mountain, Yellowstone and Great Smoky Mountains national parks in the USA, consumptive sport fishing is used as a fish management tool. Higher catch limits and in some cases less restrictive size limits are set on exotic species than on indigenous species. Under such regulations anglers selectively remove unwanted exotics from park waters, favouring the recovery of the ecosystem to a more natural condition. A similar effect could be obtained if biologists did this sort of culling, but experience in Great Smoky Mountains suggests that sport fishing is cost effective. Selective sport fishing programs offer considerable opportunity for educating fishermen about some fundamental problems in ecology and resource management.

Sport fishing also might prove to be an effective method of partially restoring formerly fishless lakes to a condition more closely resembling their natural state. More importantly, sport fishing might prevent artificial fish populations from becoming so abundant that they permanently damage the invertebrate populations upon which they feed.

If properly managed, sport fishing can promote an understanding of aquatic ecosystems not available through any other use of the resource. Yellowstone park managers see sport fishing as a way of allowing park visitors to experience fish, which unlike other park animals are otherwise invisible to them in many habitats. Sport fishing encourages an appreciation and depth of ecological understanding in certain people that just is not evident in other users of the resource. Fly fishermen frequently display a knowledge of aquatic entomology that many professional biologists would envy. Fishery managers in national parks should examine this phenomenon so that they can better learn how to foster it among all users of the resource.

Sport fishing has had an important role to play in building support for projects to restore native stocks of fish. Stock restoration projects have used fishing for that purpose in Rocky Mountain National Park (Colorado) and the Ontario Aurora Trout Recovery Program. Fundy National Park had intended to use it to build support for its Point Wolfe River salmon recovery project, but may drop it because the project has produced a rare opportunity to establish a benchmark Atlantic salmon river.

Whatever the value of sport fishing in national parks, it is appropriate only as a means to an end, not an end in itself. In this connection, it is worth repeating the warnings of the US Fish and Wildlife Service (USFWS) on the point. In a comprehensive review of aquatic resource management in the US national parks (Watson 1980), a USFWS investigating committee found that where sport fishing was permitted as a “traditional” use, it tended to become the *priority* use of the resource. Park managers found it expedient to accept sport fishing programs based on only minimal assurances that fish resources would not be depleted. Sport fishing in Canadian national parks is not and cannot be the priority use of fish populations in the parks. It can no longer be justified on the grounds of tradition. Its role, though it may be an important one in some cases, is entirely supportive to the first priority, that of protecting self-maintaining natural aquatic ecosystems.

Catch-and-Release Regulations

Catch-and-release regulations are used in several US national parks (e.g., Yellowstone, Rocky Mountain, Glacier, Great Smoky Mountains) as a way of allowing park visitors to sport fish without causing significant damage to the indigenous fish populations. It is used both in its strictest "no-kill" form and as part of what might be termed a "minimal kill" approach, where up to two fish may be retained, provided they are above or below a certain size. Catch-and-release recently has been promoted for use in Canadian national parks (Schiefer 1989).

The approach has obvious attractions. Ideally, large numbers of visitors could see and handle the fish and release them completely unharmed. In this respect, certain Yellowstone no-kill fisheries have approached the ideal. There, many tens of thousands of fishermen catch and release hundreds of thousands of beautiful genetically pure Yellowstone cutthroat trout every season, and have done so now for nearly a decade and a half. Catch rates are high and mortality is amazingly low. The average size and the numbers of large fish have both increased in some populations under a no-kill rule.

But there are problems with catch-and-release that are becoming more apparent. Experience in Yellowstone shows that fishing quality does not always improve, and in some cases fish populations do not improve, under a no-kill regulation. Although in some areas such as Yellowstone catch-and-release regulations initially decreased angler use, in some places a no-kill rule may have greatly increased use by fishermen (Wells 1987). The numbers of fishermen using no-kill streams can be very high. Some parts of the Yellowstone River, for example, would appear to be fished by an average 60+ anglers per kilometre daily. In one Montana catch-and-release fishery, some fishermen were disturbed by the number of mutilated fish in the population (Wells 1987:69). Although inadvertent mortality from single captures can be very low, repeated captures increase the probability of death. The stress of capture has important sublethal effects that can be cumulative (Wydoski 1977). If these sublethal effects reduce reproductive capacity, there will be selective effects on the population and possibly a decline in numbers in the long term. As a result of these problems, some jurisdictions are considering limiting entry to the fishery, or have already done so (Wells 1987).

Philosophical concerns have been raised about catch-and-release fishing as well. It may come as a shock to conservationist anglers who favour catch-and-release fishing that they are considered barbaric in some quarters. The following quotations are taken from the proceedings of a major Canadian symposium on sport fishing (Tuomi 1985:312), and were part of an open discussion of ethical concerns about sport fishing at the conference. They convey something of the flavour of the ethical arguments that have been raised against catch-and-release. The speakers, incidentally, are sport fishing supporters.

“The Inuit in the eastern Arctic disdain the word sportfishing. They don’t like sport fishermen, they feel they are people who come and, in their words, play with the fish, humiliate them, and then let them go again…. I see a lot of problems with catch and release. There are many people who are going to say that, in the end, catching and releasing fish just for the sake of catching them is a barbaric act. I believe in the 90’s bodies like this are going to have to wrestle with that issue.” (John Clarke)

“As far as the catch-and-release is concerned, the gentleman opposite says he has no hang-ups on it, and I don’t really have any hang up on it, but I will say this. If I wanted to attack the sport fishing industry, or fishing community, the first people I would look for would be the catch-and-release guys who don’t legitimately want to take their fish home and eat, but want to torture a fish on the end of a line and then let it go. And whether you have no hang-up or not, or whether I have no hang-up, there are a hell of a lot of people out there who will have a hang-up on it.” (Ed Mankelow)

Ethical concerns about sportfishing in the national parks are considered in detail in Part 4. Other related material on environmental ethics in general was presented in Part 1.

Catch-and-release fishing has an important role to play in fish management in the national parks, but the problems that are surfacing in connection with it show that it is not a panacea. Catch-and-release cannot be used simply to replace consumptive sport fishing in the national parks.

Sustained Yield, Stock Preservation and Aquatic Ecosystems

National parks in Canada have been directed to control sport fishing so as to manage native and “established exotic” fish populations on a sustained yield basis (Parks Canada 1981). The term “sustained yield” is an unfortunate one. Unless accompanied by some modifying term or a clear definition, managing for sustained yield means nothing more than that fish populations not be totally obliterated. It could, however, be interpreted to mean maximum sustained yield, the maximum quantity of fish that can be removed from the population annually, year after year, without any decline in the population. It has become apparent that there is no such thing for real fish populations; at best there is some figure for single-species fisheries that might be useful as a rough initial estimate (Larkin 1977). Or, sustained yield might be interpreted as some sort of optimum sustained yield, a term with absolutely no useful meaning at all: it can mean anything one wants it to mean, permitting everything from no fishing to near-extirpation (Roedel 1975).

Of the jurisdictions covered in this survey, La Mauricie National Park appears to have been the most successful in implementing fish management under the sustained yield concept. As its definition of sustained yield, it has adopted the concept of longterm potential fish yield as estimated apparently by a version of the morphoedaphic index (Ryder 1965, Ryder et al. 1974). This admittedly very rough estimate for each lake is used to set the annual allowable quota. The quota then is adjusted as necessary to maintain constant average fish weight and constant catch rate at some constant angling effort. The average fish weight and catch rate are set by a combination of what the productivity of the lake will support and what is thought on balance to be desirable to anglers.

Under this system, La Mauricie has been able to maintain more or less constant yields in some of its lakes over a 15-year period. The secrets to its success are its strictly-controlled quotas coupled with constant monitoring of the catch. The high degree of control exercised over the fishery has permitted fish managers in La Mauricie to respond quickly and effectively when overharvesting becomes evident, overcoming one of the principal objections to management under the sustained yield concept (Larkin 1977:4).

There remain important questions about the La Mauricie approach, which in effect is designed to supply a constant supply of fish flesh to anglers, for managing national parks fish resources.

1. The period of apparent success in La Mauricie, 15 years, is only about five generations for the brook trout that are the subject of most of the fisheries, and even fewer generations of longer-lived or slower-maturing fish. It is therefore not at all clear that a sustained yield has been achieved in the long term.

2. The system relies on detecting a measurable amount of what it is trying to prevent — overharvesting — to tell it to reduce the catch. This is reminiscent of the old joke about death being Nature's way of telling you to slow down.

3. The system implicitly recognizes that different stocks of fish have different abilities to sustain fishing pressure, but only so long as fish populations in a lake constitute a single stock. This may be true for some small lakes, but in a lake with more than one stock, (for example, Yellowstone Lake with its 68 stocks of cutthroat trout, few if any of them identifiable by visual means), sustained yield management will almost certainly overexploit some stocks and the overexploitation will not be detected. This almost certainly will affect yield and population viability in the long term.

4. The level of sustained yield chosen maximizes in some way the benefits to anglers, but is not necessarily that most beneficial for other park values. The parks are

intended to protect naturally functioning ecosystems. The fish are key parts of aquatic ecosystems, and removing some of them inevitably will affect those ecosystems (Conserving Aquatic Ecosystems, Part 1).

The latter point exposes the principal flaw in the sustained yield approach to managing fishes in Canadian national parks. The concept of managing for a sustained yield envisions that there is a number of fish required to just reproduce the population. Fish in excess of this number are surplus to the needs of the population, and are considered as safely harvestable by anglers. But this so-called "harvestable surplus" is not surplus to the needs of the ecosystem. In the absence of angling, these fish would be used within the ecosystem — by predators or by microorganisms — and thereby would enter the food webs of the ecosystem as a nutrient source. Removing these "surplus" fish from the ecosystem by definition destroys the integrity of the ecosystem, an action which directly contravenes Section 5(1.2) of the National Parks Act (Part 1).

Whatever the justification of sustained yield management on native fish stocks may have been under previous legislation, it is no longer justifiable under the present Act. In contrast, several of the parks surveyed in this report manage fish resources as integral parts of whole ecosystems, allowing the ecosystems to maintain themselves as much as possible through the functioning of natural forces. This approach was examined in greatest detail for Yellowstone Park, but is used in Glacier (Montana), Rocky Mountain and evidently other US national parks as well. These jurisdictions provide almost complete protection to indigenous fish stocks while permitting substantial use of the resource — through catch-and-release, viewing areas and other methods. They also provide for consumptive angling — but almost entirely on introduced, non-native stocks, not on indigenous stocks. This general approach appears to be more appropriate to the policy purposes and legislative mandate of Canadian national parks, and is the one followed in the fish management plan for Jasper National Park proposed in Part 4.

Stocking

Stocking to supplement exploited fish populations is an accepted fisheries management technique in at least some part of all of the provincial jurisdictions surveyed. In Algonquin Park, it is restricted to only the most heavily used part of the park; in the Quebec provincial parks it is widely used in the recreation parks but excluded from the conservation parks. In Alberta's East Slopes, though it is used relatively sparingly, it is not permitted in principle only in the three wilderness areas.

In the Canadian national parks, the Canadian Parks Service permits stocking apparently with some considerable discomfort, and there are strong moves to remove it altogether as a management option. The present policy favours sport fishing only in waters with self-sustaining fish populations. Stocking is not used at all in Pukaskwa, La Mauricie or Prince Albert, all parks with an abundance of self-sustaining fish populations. In the mountain parks it is now used only to maintain populations in a few lakes in Waterton, Banff and Jasper that lack self-sustaining stocks and had a tradition of being stocked prior to 1980.

In the US national parks, stocking has been banned for many years. The goal of all resource management, including aquatic resource management, has been to allow the park ecosystems to maintain themselves by completely natural means. Stocking is clearly an intrusion, so is not permitted. Despite this policy, stocking has been maintained in certain lakes in certain parks in response to strong political pressures.

The US National Park Service (NPS) ban on stocking engendered its strongest opposition in situations where people felt that they would lose most of their opportunities to fish in mountain lakes if stocking was not continued. In all cases where parks were forced to abandon their policy and continue stocking, virtually all of the lakes within the park were originally fishless. At the time the no-stocking policy was announced, hundreds of the lakes contained fish populations only because they were stocked with them beginning many decades previously.

This was the situation in the four Sierra Nevada parks of California. Opponents of the stocking ban argued that they would lose about 75 percent of the fishing lakes in the Sierra Nevada because of the no-stocking policy announced almost simultaneously by the NPS for the parks, and the US Forest Service for the designated wilderness areas in the Sierras. This happened to be a wildly false claim. Opponents believed, or claimed to believe, that the NPS and the US Forest Service intended to return all of the mountain lakes under their jurisdiction to their original fish-free state. Their concerns had at least minimal credibility only because the NPS overall policy was well known to favour naturalness in the parks above all else. The near-identical dispute in North Cascades National Park appears to have been made even worse when it degenerated into public threats between the principals.

The NPS gradually is managing to implement its no stocking policy in the Sierra Nevada parks. It is doing so by demonstrating that there is adequate natural reproduction in enough mountain lakes to support a substantial high-quality sport fishery. Also, it has been able to show that in many lakes, stocking just does not make good ecological sense. They have been assisted by a strong shift in opinion among California anglers in favour of catch-and-release fishing for wild trout. In North Cascades National Park, a resolution to the problem seems less certain. The present major study of the effects of stocking in the park now being conducted may at least form a basis for rational discussion between the antagonists.

There is a lesson here for fish management planning in Jasper National Park. Under present policy the park is directed to carefully review its stocking program with a view to phasing it out. If stocking is to be phased out in Jasper, the new policy will be opposed by those who fear that fishing opportunities or angling quality will be significantly reduced. Experience with the same problem in the US parks suggests that the policy will be more likely to succeed if its purpose and implementation make good sense and are honestly and completely communicated, and if fishing of adequate quality still can be provided.

Sobering Second Thoughts

There are two features common to many of the parks and fish management projects reviewed here that are especially striking. First, there has been prodigious damage done to North American freshwater fish stocks; and second, a very sizable proportion of it has been done by people who believed they knew what they were doing. These men were not stupid or irresponsible; some were among the best in the field of fisheries management. We should not ignore the implicit lesson. Fisheries biologists generally don't entirely know what they're doing when they attempt to manipulate fish populations. Too often they are conducting uncontrolled experiments.

In managing fish resources in the national parks in future, we should exercise a great deal of humility and admit that everything we do with fish populations or aquatic ecosystems — *everything* we do — is an experiment. If we allow a population to be fished, that is an experiment. If we *stop* a population from being fished, that, too, is an experiment. If we restore a population, that is an experiment. How do we know what the original population was really like? Again we experiment when we remove an exotic population. Each decision we make needs to be carefully studied, reasoned out, and prepared for beforehand, and its outcome equally carefully monitored afterward.

No matter what course we take to manage fishes in the national parks, there are certain to be better ways of doing things in the future. Archaeologists have recognized this in their field. Now it is considered essential practice on important digs to save large parts of the site for later archaeologists to study with newer and better methods. In managing fish populations and aquatic ecosystems in the parks, we need to save many for others to handle using better methods as yet undeveloped. We might, for example, try to restore native stocks to replace exotics in one or two streams as an experiment. But we should reserve other such projects for others to do — if in future it is still thought to be a good idea.

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PERSONAL COMMUNICATIONS

As noted in the Introduction to this volume, few fish management documents are ever published in the primary literature. This survey relied to a considerable extent on information supplied by managers and biologists with firsthand knowledge of what was happening (or had happened) in their parks.

The following have been cited in the text for supplying particular information by way of personal communications. Most interviews were conducted by telephone, but some information was supplied in letters or in person. Notes were kept on all telephone conversations. Nevertheless, personal communications are inherently subject to misinterpretation, therefore all references to them require confirmation. Any such errors are my responsibility, and I apologize here for any that may have crept in. Everyone I spoke to was exceedingly accommodating, patient and helpful. I thank all for their assistance and suggestions.

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