FISHERY RESEARCH

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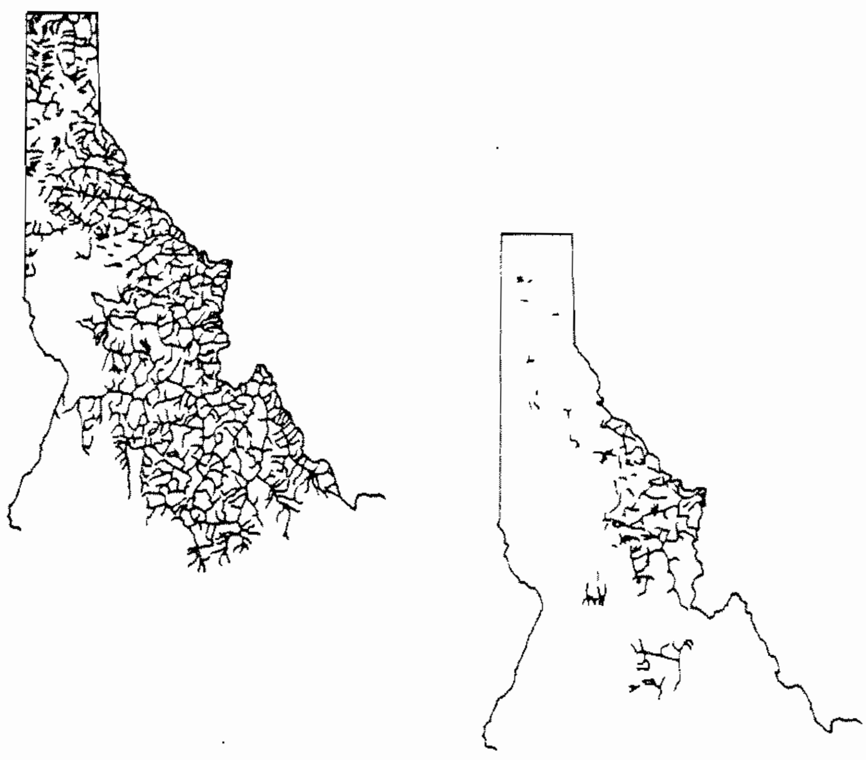
STATUS AND ANALYSIS OF SALMONID FISHERIES
Westslope Cutthroat Trout Synopsis and Analysis of Fishery Information

Project F-73-R-11, Subproject No. II, Job No. 1
Period Covered: March 1, 1988 to February 28, 1989



by

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State of: Idaho

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ABSTRACT

In behavioral, genetic, and population characteristics, westslope cutthroat trout are substantially different than other trout. They are uniquely adapted to the sterile, relatively cold environment of northern Idaho and are particularly vulnerable to anglers. Westslope cutthroat trout probably represent the best management option for much of northern central Idaho.

Historically, westslope cutthroat trout were found in virtually all waters of Idaho north of and including the Salmon River drainage. We believe that viable populations still exist in 36% of the historic range, but strong populations are in only 11%. Most strong populations are in roadless and wilderness areas.

Westslope cutthroat trout populations have responded dramatically to restrictive fishing regulations. Several very important fisheries now exist under this type of management. With continuing loss of habitat and increased access and angling pressure, special regulations and, perhaps, the extreme of catch-and-release fishing will be necessary to maintain any viable population.

Some populations have not responded to management, and hatchery programs have been successful only in mountain lakes. Lost habitat, competition and predation with introduced fishes, and hybridization may all prevent some populations from rebuilding, even under intensive management. Social conflicts with complex regulations and mixed-stock management can also result in angler noncompliance and a lack of public support for cutthroat management.

Future work should include a genetic inventory to identify populations with the best potential for management and the best sources of broodstock. Research should focus on problems with hatchery production, standards for inventory and monitoring, and clear demonstration of habitat problems. Management should prioritize protection of genetic integrity and habitat for remaining strong populations and closely weigh the costs and benefits of rehabilitating depressed and remnant stocks. Management should also explore new alternatives for minimizing social conflict and develop clear policy on when wild populations should be considered not viable.

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INTRODUCTION

Westslope cutthroat trout Oncorhynchus clarki lewisi represent a tremendously important fishery resource for Idaho. They once were the dominant trout throughout the central and northern part of the state and in some areas remain so. We have had some striking successes with management of trout under special regulations, and several streams provide very popular and even nationally recognized fishing. Small resident cutthroat persist in some small, headwater streams and also provide an important opportunity for anglers recognizing the intrinsic value of fishing for the "natives." In general, however, management and fishing for westslope cutthroat trout is associated with the word decline. Many populations are remnants of historic ones and some are extinct. Dramatic declines are particularly evident in the large lakes of the Panhandle.

A lot of research and management work has been done with westslope cutthroat trout. There is a large volume of literature available, most of it in the form of agency reports. There is also information tucked away in files, memos, and biologists' minds that is not readily accessible. Much of the work done on westslope cutthroat trout has focused on specific populations and specific or local management problems. Because westslope cutthroat populations are sensitive to change, problems are common. As a result, special management programs or requests for research on a particular population are common. Because the data, experience, and information on westslope cutthroat trout is large and not readily accessible, and because biologist and managers rarely have the time to become experts on a particular topic, our biology may not always make the best use of experience. The result may be a piecemeal and independent approach to cutthroat management among states, among our management regions, and even among cutthroat populations within a region. It seems prudent to step back and take a larger look at research on, and management of, westslope cutthroat trout. The goal of this report was to summarize existing knowledge and to identify the most important problems to be addressed by future research and management. Our objectives were:

1. To describe the current status of westslope cutthroat trout populations in Idaho.

2. To summarize current literature, knowledge, and experience with westslope cutthroat trout, and provide a synopsis useful for "updating" biologists working with the subspecies.

3. To provide recommendations for future management and research priorities.

Our approach was threefold. First, we conducted a review of available literature. We provide a synopsis of important results, observations and ideas, and a list of references used to develop that information. The literature is large and sometimes redundant. Even with this "focused" attempt, we found it difficult to read and digest it all.

Much of it we simply did not cover in any detail, and information of specific importance may have been omitted. To assist any further reviews we also include references for papers we did not cite but which contain information on, or relevant to, westslope cutthroat trout. Second, we used a simple simulation approach and sensitivity analysis to examine data commonly used to model population responses. We used the simulations to look at the relative importance of data that might be collected in typical biological surveys. Third, we held a workshop of biologists with experience in westslope cutthroat trout biology and management. The workshop was an attempt to gather the unpublished information and experience. Much of the workshop results are represented in this report as "personal communications." We also used the workshop as a forum for discussion of the ideas and conclusions that were taking shape from the literature review and modeling. Many of our conclusions were either strengthened or modified from those discussions.

The authors of this report do not have the depth of experience with westslope cutthroat trout that several biologists have gained from years of work. In some cases, our interpretations and synthesis of ideas may be controversial, or even wrong. Management of westslope cutthroat trout has been difficult, complex, and even emotional. We do not profess to solve some of the very difficult problems or make the difficult decisions. Hopefully this work can generate the discussion and focus, however, to help in that process.

The report is written in major sections related to biology and management. Each section is summarized, and the entire report is recapped in the final section of Discussion and Conclusions. The casual reader can make a quick review by focusing on those sections.

RECOMMENDATIONS

1. Manage westslope cutthroat trout as the number one priority in waters supporting the remaining strong populations. Emphasize: 1) maintenance of habitat in entire drainages; 2) restricted harvest or catch-and-release fishing; and (3) maintenance of genetic integrity by eliminating introduction of other trout.

2. Emphasize angler education rather than regulation in waters where westslope cutthroat trout are a secondary management priority. Emphasize identification, unique characteristics, extreme vulnerability to fishing and habitat loss, and encourage voluntary release.

3. In waters where westslope cutthroat trout are a secondary management priority, support new work on the feasibility of alternative regulations (i.e., one-fish bag, rotational closure, species-specific size or bag, and zoning).

4. Conduct a genetic inventory (biochemical methods) throughout the range of viable populations. Use the results to identify broodstock sources, to provide baseline data for monitoring genetic management, and to identify populations with the best potential for priority management.

5. Develop a new broodstock with broad genetic diversity and genetic purity for use in maintenance of mountain lake programs, and maintenance of cutthroat fishing opportunity where viable, wild populations cannot persist. Incorporate as many Idaho populations as possible to include any unique alleles and maximize genetic diversity.

6. Do not use hatchery supplementation with viable but depressed wild populations unless the broodstock is developed only from the local population. If at all possible, attempts to reintroduce westslope cutthroat trout in barren habitat should use broodstocks with characteristics similar to the native stock.

7. Use hatchery fish to maintain fisheries (put-and-grow or put-and-take) primarily in small lakes with few potential predators or competitors. Maximize size-at-release to minimize time from release to recruitment to the fishery. Eliminate hatchery maintenance of fisheries if return to the creel or economic benefit is not demonstrated as cost effective. Fishery managers should develop specific criteria that define acceptable returns or economic benefits.

8. Support new work to clarify the best size and time of release for reintroduction programs (i.e., unfed fry, fed fry, or fingerling).

9. Develop new populations from adfluvial stocks to "gene bank" potentially unique genetic material. Support new work on the genetic basis of different life history patterns.

10. Develop specific and objective criteria for decisions on eliminating westslope cutthroat as a management priority.

11. Consider all regulation changes as management experiments. Where possible, use extreme alternatives (closure) to eliminate the influence of confounding factors in population responses.

12. Develop standardized population sampling and reporting methods to facilitate long-term monitoring and comparison of data among drainages. Use the existing data base to record information.

13. Support new work that can demonstrate relations between land use and westslope cutthroat habitat in belt geologies and between land use and westslope cutthroat population potential in any land type.

14. Where drainagewide habitat maintenance is impossible, emphasize protection of small tributary streams.

15. Do not accept local habitat manipulation (structures) as full mitigation for land-use management that affects entire drainages.

16. Support new work to define the sociological trade-offs between nonconsumptive wild trout management and lost or displaced angling opportunity. Develop objective criteria for the allocation of wild trout opportunity. In the absence of that information, management priorities should be as outlined in Recommendations 1 and 2.

OVERVIEW

History and Characteristics

Historically, westslope cutthroat trout Oncorhynchus clarki lewisi were the dominant salmonid in streams of central and northern Idaho (Behnke 1972a; Behnke and Wallace 1986). The range extended into Montana and Canada throughout the headwaters of the Columbia and also into headwaters on the eastern side of the Continental Divide (Behnke 1979; Trotter 1987).

We believe the historic distribution in Idaho included all of the Kootenai River drainage above barrier falls and all of the Pend Oreille and the Spokane River drainages. Westslope cutthroat trout were obviously present in the upper Clearwater drainage and the Salmon River above and including the South Fork. We have no clear records of cutthroat in lower tributaries of either river, although habitat would have been suitable. Behnke (1979) found no evidence of cutthroat in tributaries to the Snake River above the Salmon. The Weiser, Payette, and Boise River basins all contain what could have been ideal and accessible habitat for westslope cutthroat trout. A personal diary kept by Ted Trueblood notes catches of "native cutthroat" in tributaries to the Middle Fork Boise River. The observations, however, could have been a confusion with the "redband" trout, a form of rainbow trout Oncorhynchus mykiss believed to be native to these drainages (Robert Behnke, Colorado State University, personal communication). These rainbow trout commonly show a red "slash" very similar to cutthroat.

We found little data documenting historic abundance of westslope cutthroat trout, but densities were probably high throughout the range. Captain Mullan described Coeur d'Alene Lake as "a noble sheet of water filled with an abundance of delicious salmon-trout" (Ellis 1932). From 1901 to 1905, the St. Maries Courier reported catches of 7 to 9 lb. trout and fishing trips where anglers caught 50 to 100 "speckled trout" averaging 3 to 5 lbs.; in 1892, trout were a major source of protein to settlers and were commonly sold in Wallace butcher shops (Idaho Fish and Game, Region 1 Files). Gilbert and Everman (1894) reported that the Pend Oreille River was "abundant with trout and salmon trout." Only bull trout Salvelinus confluentus and cutthroat trout were native to most of these drainages. From current understanding of habitat use, trophic status, and abundance in undisturbed areas, we believe cutthroat were easily the numerical dominant of the two. Residents of the South Fork Salmon River drainage reported cutthroat as common, with fish ranging up to 450 mm (Thurow 1987).

Biologists believe that cutthroat were the first of the Parasalmo to penetrate inland from the Pacific. Fish moving into the headwaters of the Columbia are thought to have been isolated by geologic diversions and ice dams about 1 million years ago, forming the first divergence from the cutthroat group. As many as 16 subspecies, with 8 major subspecies, are now recognized (Behnke 1979; Trotter 1987; Allendorf and Leary 1988).

Isolation of cutthroat in drainages of the upper Columbia led to the evolution of the form now known as the westslope cutthroat trout. Behnke (1979) and others believe that this group spread from the Columbia to the Clearwater River, Salmon River, and drainages east of the Continental Divide by headwater capture during periods of glaciation. The presence of westslope cutthroat trout above many barrier falls suggests that they preceded the advent of rainbow trout and chinook salmon Oncorhynchus tshawytcha throughout the Columbia Basin (Behnke 1979).

Westslope cutthroat trout probably evolved in coexistence with bull trout, mountain whitefish Prosopium williamsoni, northern squawfish Ptychocheilus oregonensis, and several species of cyprinids and sculpin Cottus spp. They coexist naturally with rainbow trout (steelhead) and chinook salmon only in the Clearwater and Salmon River drainages. Rainbow trout occur naturally in the Kootenai River system above Kootenay Lake, but we believe westslope cutthroat trout were found in that drainage only above barrier falls (Ned Horner, Idaho Fish and Game; and Dick Wallace, University of Idaho, personal communications).

Early isolation in the upper Columbia resulted in distinct differentiation from other cutthroat. Available data suggest that westslope cutthroat trout are genetically more similar to rainbow trout and coastal cutthroat than they are to four subspecies (Yellowstone, Snake River, Green River, Colorado) thought to have diverged from the original cutthroat in the upper Snake River (Behnke 1979; Loudenslager and Thorgaard 1979; Loudenslager and Gall 1980a, 1980b; Allendorf and Ryman 1987; Allendorf and Leary 1988). The subspecies can be clearly distinguished electrophoretically (Allendorf and Leary 1988). Genetic divergence between westslope cutthroat trout and other subspecies exceeds that typical of other conspecific fish (Allendorf and Leary 1988). Allendorf and Leary (1988) believe differences are important enough to recognize westslope cutthroat trout as a separate species.

Differentiation in cutthroat is evident phenotypically as well. The subspecies can be partly distinguished on the basis of spotting pattern and meristic characteristics (Roscoe 1974; Behnke 1979; Wallace 1980). Biologists recognized differences in appearance and behavior of westslope cutthroat trout and Yellowstone stocks as early as the 1950s (Bjornn 1957a, 1957b; Hanzel 1959; Behnke 1979). Distinct differences in survival and performance in different waters have become obvious more recently (Behnke and Zarn 1976; Behnke 1979; Marnell et al. 1987).

Westslope cutthroat trout seem to be particularly well suited to a relatively sterile and cold environment. Forage consists primarily of invertebrates. Stream and lake populations rely heavily on insects (Bjornn 1957b; Ortmann 1969; Athearn 1973) and, in some cases, zooplankton (McMullin 1979). Small fish are sometimes eaten (Ortmann 1969; Mauser 1972; Goodnight and Mauser 1981), but unlike other cutthroat, piscivory seems rare. The westslope cutthroat trout food habits probably reflect an evolution with other fish predators (bull trout, northern squawfish) in unproductive waters where forage was limited (Behnke 1979; Trotter 1987; Marnell et al. 1987). Many stocks also show extensive seasonal movements. During summer, the bulk of a population may inhabit upper main stem and tributary areas, moving downstream up to 100 km or more to overwinter (Mallet 1963; Bjornn and Mallet 1964; Lewynsky 1986; Wilson et al. 1987; Apperson et al. 1988; Peters 1988). Downstream movements seem to be an adaptation to habitat availability (Chapman and Bjornn 1969; Bjornn 1971; Lewynsky 1986; Wilson et al. 1987; Peters 1988). High quality pools which offer winter cover (and perhaps protection from common winter floods in the species range) are often more available lower in a drainage. In some populations where high quality pools are available in summer habitat, little or no movement occurs (Peters 1988). Westslope cutthroat trout may also spawn and rear in the very small tributaries of a drainage. An adaptation thought to minimize vulnerability of embryos or juveniles to dramatic variation in spring flows and scour typical of mountain streams (Johnson 1963; Lukens 1978; Gamblin 1988; Peters 1988).

Westslope cutthroat trout show three distinct life-history forms. Resident populations inhabit small headwater streams and are not believed to migrate (Averett 1962; Bjornn 1975; Thurow and Bjornn 1978). Resident populations occur throughout the range in Idaho. Fluvial populations use larger streams and main rivers and may show the extensive migrations described earlier. Fluvial westslope cutthroat trout represent the dominant form in Idaho and support most of our current fisheries. Adfluvial populations are associated with the large lakes in northern Idaho. Typically, adfluvial stocks spawn and rear in tributary streams and migrate to a lake at age 2 to 4.

Extended tributary rearing, which is less common in other cutthroat subspecies, may be an adaptation to evolution with predators (Marnell et al. 1987). All three of the life-history forms may occur in an individual drainage. Although distributions have not been clearly documented, we believe that adfluvial stocks are usually dominant in tributaries to lower reaches of a drainage and in small streams directly tributary to a lake (Thurow and Bjornn 1978; Apperson et al. 1988).

Many biologists believe the specific adaptation that has occurred in westslope cutthroat trout makes them better suited to north-central Idaho than other trout. Westslope cutthroat trout can occupy a greater range of habitats than typically seen in rainbow trout, other cutthroat, or brook trout Salvelinus fontinalis. They may be more efficient as well, reaching large sizes in relatively unproductive waters. Westslope cutthroat trout commonly exceed 400 mm. Anglers frequently catch fish in excess of 300 mm in waters where exploitation is limited. Brook trout, which have been introduced throughout the range, have not produced comparable fishing. Rainbow trout which have been established in much of the range typically inhabit only the lower reaches of a drainage. Attempts to introduce Yellowstone cutthroat trout have failed to produce viable populations (Beach 1971; Heimer 1970; Goodnight and Mauser 1974) perhaps because that subspecies is poorly adapted to the predation, parasites, and low productivity typical of the westslope cutthroat trout range (Marnell et al. 1987).

The degree of genetic divergence within the westslope cutthroat trout subspecies also appears to be high. Electrophoretic analysis shows that genetic variation is low within populations but relatively high among populations (Leary et al. 1987; Allendorf and Leary 1988). The genetic variation in westslope cutthroat trout is distinctly different than in Yellowstone cutthroat trout where most of the genetic variation in the subspecies occurs within and not among populations (Allendorf and Leary 1988). Maintenance of genetic diversity in westslope cutthroat trout stocks will, therefore, require the maintenance of many discrete populations (Leary et al. 1985; Allendorf and Leary 1988).

We do not know if the genetic divergence among populations is indicative of important local adaptation and "stock" level differences. As yet, there is no clear evidence that even the different life history patterns represent a genetic differentiation. Managers in British Columbia do believe that releases of an "adfluvial" stock in a large river provided poor returns because those fish migrated out of the system (Gerry Oliver, British Columbia Ministry of Environment, personal communication). Adfluvial stocks also have developed in new reservoirs only when an adfluvial population was trapped in the new system or introduced (Behnke 1979). Specific or local adaptation can strongly influence the performance of other fish (Kapuscinski and Philipp 1988). Management of anadromous salmonids clearly recognizes a stock concept and the problems inherent in transplantation or replacement of local stocks (see for example ODFW 1986; Reisenbichter 1988). Management of westslope cutthroat trout has barely reached the point where such concerns might be important. If artificial supplementation and reintroduction programs continue, however, local adaptation should be considered.

Westslope cutthroat trout provide a distinctly different fishing opportunity compared to other trout. Westslope cutthroat trout were substantially more vulnerable to angling than rainbow trout and brook trout in the same streams (MacPhee 1966; Lewynsky 1986). High vulnerability may be the result of aggressive feeding developed through evolution in unproductive water. In any case, westslope cutthroat trout are readily available to stream anglers, and even low densities of fish can support good catch rates. In lakes, cutthroat are often associated with the shoreline and the surface. Many anglers find cutthroat readily available to simple gear, while those fishing for other trout or kokanee Oncorhynchus nerka may need elaborate trolling equipment (Ned Horner, Idaho Department of Fish and Game, personal communication). The difference in distribution and availability can add an important diversity to a fishery. Many anglers also find some intrinsic value in fishing for "wild" or "native" fish (Behnke and Zarn 1976). Westslope cutthroat trout, bull trout, mountain whitefish, rainbow trout (residualized steelhead), and chinook salmon are the salmonids native to north-central Idaho. The westslope cutthroat trout probably represents the most available of these fishes to most Idaho stream anglers. That anglers find some intrinsic value in cutthroat is supported by recognition of cutthroat as one of the three most preferred species in the recent Idaho angler survey (Reid 1989).

Montana biologists believe that westslope cutthroat trout offer higher fishery values than any other species or programs in much of their northwestern water (Joe Huston, Scott Ramsey, Brad Shepard, Montana Department of Fish, Wildlife, and Parks, personal communications). They have begun an extensive program to reestablish westslope cutthroat trout. Where westslope cutthroat trout have been replaced by brook trout or are seriously introgressed (hybridized) with other cutthroat or rainbow trout, biologists are removing fish and restocking with pure-strain westslope cutthroat trout.

Westslope cutthroat trout have declined dramatically from historic numbers. Presently, they are absent or seriously depressed throughout much of the historic range (Behnke 1979; Bjornn and Liknes 1986; Liknes and Graham 1988). Populations in Idaho seem to have fared slightly better than those in Montana (Liknes and Graham 1988). Current status of westslope cutthroat trout in Idaho is summarized in the next section. Genetic introgression, habitat loss, and overfishing are considered the most important causes of population decline. We discuss each area in greater detail in following parts of this report.

Current Status

Biologists believe that westslope cutthroat trout have declined dramatically throughout the historic range (Behnke and Zarn 1976; Behnke 1979). Montana biologists found populations in 27% of the historic range (Liknes 1984; Liknes and Graham 1988). Montana populations are thought to be genetically pure in only 2.5% of the native range. Populations in Idaho are thought to have fared better (Bjornn and Liknes 1986). There has been no comprehensive attempt, however, to document the status of Idaho stocks. Electrophoretic data has been collected on only one wild population (Horner et al. 1987).

We used the Idaho River's Data Base (Allen et al. 1986) as a framework for summarizing current knowledge and management of westslope cutthroat trout in the state. We added seven variables specific to cutthroat and classified each variable for every EPA stream reach within the historic and introduced westslope cutthroat trout range (Appendix A). We reviewed each stream reach with the regional fishery managers and biologists that have experience in the specific drainages. We incorporated actual data wherever possible, but the classifications were subjective in many reaches where little or no data were available. Any classifications made on the basis of actual field inventory were noted to document the reliability (noted under range) and extent of existing information. A summary and discussion of each variable follows.

Range

We used our best judgment of historic range as the basis for describing status of populations in Idaho. The range of westslope cutthroat trout was classified as historic adfluvial, historic fluvial-resident, introduced, and unknown. Where adfluvial and fluvial-resident overlap, the range was classified as adfluvial. The introduced range includes reaches where westslope cutthroat trout have been stocked but establishment has not been documented.

The known historic range totaled about 10,000 miles (Table 1, Figure 1). About 1,400 stream miles within the known range were classified as unknown. The unknown areas were principally in the lower Salmon and Clearwater drainages and tributaries to the lower Snake River where westslope cutthroat trout might have existed. The range has been potentially expanded by about 2% of the known range, primarily through introductions in the Payette River system. Adfluvial fish dominated in 11% of the reaches, all of which were in Region 1.

Abundance

Abundance was classified as strong, depressed, remnant, absent, or unknown. Our criteria for the first three classifications, respectively, were: ≥50% of historic potential; <50% of historic potential but still a viable population and common in samples; and present but don't occur in many or most samples. Wherever data were available, we assumed densities of 1 to 10 fish per 100 m^2 characteristic of strong populations in streams supporting 2 year and older fish (see Methods of Evaluating Regulations). We assumed densities of 10 to 100 fish per 100 m^2 characteristic of good fry and juvenile rearing areas (see Characteristics of Habitat). Because we cannot know the historic potential of many streams and because data were limited and variable, the classification of abundance is highly subjective.

Classification was a particular problem in some reaches of the Middle Fork Salmon River. Cutthroat have been protected by catch-and-release regulations, and habitat is still good or even pristine in many areas. The population showed a definite response to special regulations, but densities are still relatively low (0.5 to 1.5 fish per 100 m^2). Some biologists believed the population is depressed, primarily because of heavy fishing. Others felt that densities were never high because of interaction with salmon and steelhead and a very unproductive environment. Whenever a choice between two classifications was not possible by consensus of those involved, we arbitrarily used the higher of the two; therefore, our overall results could be optimistic.

By our classification, 11% of the reaches within the historic range were strong and 36% were viable (strong or depressed). Westslope cutthroat trout were classified as remnant or absent in 45% of the historic range and abundance was unknown in 20%. Less than 5% of the adfluvial reaches were classified as strong. Actual data were available for classification of 23% of all reaches (Table 1). Strong populations were found primarily in the Clearwater, St. Joe, and Middle Fork Salmon River drainages (Figure 1). The distribution of strong reaches was closely associated with the distribution of roadless and wilderness areas (Figure 1). Over 50% of the strong areas were found in the Clearwater River drainage and Region 2.

Table 1. Summary of River's Data Base variables (stream miles classified) for westslope cutthroat trout in Idaho by total (statewide) ranges and by Idaho Fish and Game Management Region. Classifications are described in the text.

RANGE

	Historic		Introduced			
	Adfluvial	Fluvial	Adfluvial	Fluvial	Unknown	Reliable
Statewide	1,071	8,837	151	22	1,429	2,606
Region 1	1,058	1,578			4	779
Region 2	11	3,242	6	22	1,293	1,061
Region 3	0	1,128	145	0	120	507
Region 6	0	2,642				220

ABUNDANCE

	Strong	Depressed	Remnant	Absent	Unknown
Statewide	1,120	2,388	2,708	1,774	3,520
Region 1	300	1,342	549	97	351
Region 2	598	523	653	1,398	1,403
Region 3	133	202	400	82	576
Region 6	59	302	1,030	144	1,106

ABUNDANCE FACTORS

	Habitat	Overfishing	Competition	Genetic	All	Unknown
Statewide	5,908	3,195	806	1,039	387	908
Region 1	1,866	1,271	806	131	387	119
Region 2	1,276	290				466
Region 3	582	606				137
Region 6	2,017	941		824		168

GENETIC INTEGRITY

	Documented		Suspected		Unknown
	Pure	Introgression	Pure	Introgression	
Statewide	52	7	1,331	4,245	4,273
Region 1	52	7	724	891	179
Region 2			273	1,338	2,025
Region 3			285	525	404
Region 6			12	1,442	1,188

Table 1. Continued.

REGULATIONS

	Length	Catch-and-release	Bag	General	Closed	Length & bag
Statewide	0	850	1,059	7,497	191	1,187
Region 1		307	62	887	191	1,187
Region 2		250	278	3,381		
Region 3		193	265	935		
Region 6		101	395	2,108		

	Delayed closure	Early closure & bag	Early closure
Statewide	673	15	38
Region 1			
Region 2	666		
Region 3			
Region 6	38		

MANAGEMENT OPTIONS

	Hatchery augmentation	Habitat enhancement	Species removal
Statewide	29	955	13
Region 1	17	159	13
Region 2		274	
Region 3	12	518	
Region 6			

POTENTIAL

	Passive management	Active management	Both	Poor with any management	Unknown
Statewide	1,354	178	1,748	3,203	387
Region 1	196	27	911	1,021	202
Region 2	786	56	241	1,340	212
Region 3	154	35	583	54	191
Region 6					

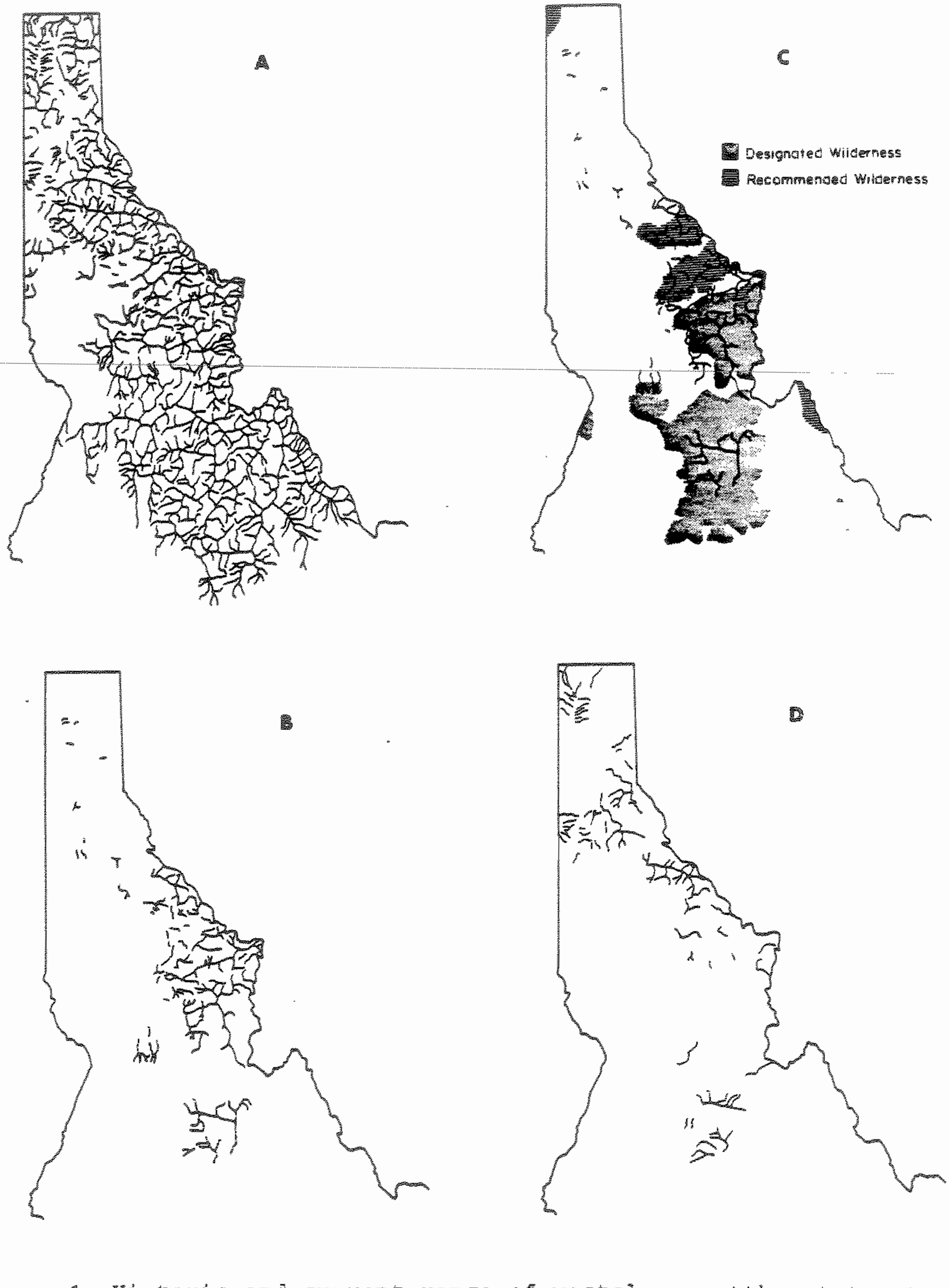

Figure 1. Historic and current range of westslope cutthroat trout in Idaho. "A" represents the historic range. "B" represents the current range of "strong" populations. "C" represents strong populations and the location of "wilderness" areas. "D" represents the range of "viable" (strong or depressed) and suspected genetically pure populations.

Abundance Factors

Causes for abundance less than strong were classified as habitat loss, overfishing, competition with or predation by introduced fish, genetic introgression, and unknown. In many cases, we could not identify a single cause and considered several or all of the factors to be equally important. Our classifications, therefore, represent the reaches where each factor was included as the, or one of the, primary causes for decline.

Habitat loss was the most important factor listed in 87% of the reaches (Table 1). Fishing was considered a primary factor in 47% of the declines. Competition and genetic introgression were considered less important in population declines (12% and 15%). Many biologists, however, felt we really knew too little about these processes to accurately classify their roles in population declines. In Montana where far more genetic inventory has been done, introgression with other introduced trout was identified as the primary threat to westslope cutthroat trout populations. Introgression clearly eliminates pure populations and can influence performance or survival of the hybridized stock (Allendorf and Leary 1988). As with any of the factors other than fishing, however, clear data showing the significance of introgression in population declines is not available.

Genetic Integrity

We classified stream reaches within the historic range as documented pure (based on electrophoretic analysis), suspected pure, documented introgressed, and suspected introgressed. We classified populations as suspected pure if they were considered viable (strong or depressed) and the immediate drainage had not had a history of extensive stocking of other trout (catchable rainbow trout in the main reach or rainbow trout and other cutthroat in headwater lakes).

Less than 1% of the range contained documented pure stocks. However, only one population (upper Priest Lake) has been sampled (Horner et al. 1987). About 13% of the historic range was classified as suspected pure. We found less than half of the strong populations classified as suspected pure. As a result, only 4% of the historic range was considered strong both genetically and numerically (Figure 1).

We may have even fewer genetically pure populations. In Montana, an electrophoretic survey showed that more than 40% of populations subjectively classified as pure were actually hybridized (Joe Huston, Montana Department of Fish, Wildlife, and Parks, personal communication).

Current Regulations

We summarized current management on the basis of 1988 fishing regulations. Seven different types of regulations in addition to general regulations were used on waters managed for westslope cutthroat trout (Table 1). About 35% of the historic range was under some type of special regulation. A minimum length restriction in combination with a reduced bag was the most common type, covering 10% of the range. About 7% of the range is under catch-and-release fishing, and 2% is closed. Over 78% of the strong range is under special regulation, 46% as catch-and-release.

Other Management

We also summarized current management on the basis of other active programs. We included any habitat enhancement, hatchery supplementation, or species removal programs that took place within the last five years or are planned within the next five years and are expected to benefit self-sustaining westslope cutthroat trout populations (i.e., we did not include mountain lakes). Supplementation was present in 0.3% of the range, with active programs on Priest, Hayden, and Payette lakes and Deadwood Reservoir. Habitat enhancement was present on 10% of the range, most of that associated with work in the South Fork Salmon River in Region 3. Species removal had been used in less than 0.1% of the range and was associated with brook trout removal and cutthroat fry stocking experiments in the Priest Lake drainage.

Potential to Restore

We tried to get some sense of the outlook for westslope cutthroat trout by classifying the potential to restore populations to historic levels. This classification was entirely subjective, based solely on the Regional Fishery Manager's perspective. We classified the potential as passive, possible only with special regulations alone; active, possible with extensive habitat recovery, barrier removal, species removal and reintroduction or hatchery supplementation; both, requiring both regulations and an "active" program; or poor, not possible with any effort. We classified 20% of the not-strong range under passive. Forty-six percent of the range was considered to have a poor potential to restore historic cutthroat abundance. The waters under the poor category generally are those where cutthroat are seen as of little importance and have essentially been excluded from management considerations.

Summary

Westslope cutthroat trout is the dominant native trout throughout north-central Idaho. Historically, they were present in most streams north of, and including, the Salmon River drainage. They preceded the advent of rainbow trout (steelhead) and chinook salmon but probably evolved with bull trout.

Early (in geologic time) isolation and evolution with predators and potential competitors resulted in a distinct divergence from other cutthroat. Genetic and behavioral differences are large enough to consider and manage westslope cutthroat trout as a separate species. Most of the genetic variation in the subspecies occurs among, rather than within, populations. Maintenance of genetic diversity will require the maintenance of many distinct populations.

Westslope cutthroat trout provide unique fisheries values that may not be available with other stocks or programs. They appear to be particularly well adapted to the relatively cold and sterile environment of the native range. Introductions of other cutthroat have failed to become established. Other trout may not utilize the available habitat or do so less efficiently. Westslope cutthroat trout are particularly vulnerable to fishing. Low densities can support good catch rates, and large fish can be readily available even to novice anglers. Many anglers also find an important intrinsic value in native fish. The State of Montana believes that westslope cutthroat trout offer much higher fisheries values than any introduced fishes in much of the native cutthroat range. Biologists there have undertaken an extensive program of stream reclamation and reintroduction of pure westslope cutthroat trout where populations have been lost or severely introgressed.

Westslope cutthroat trout have declined throughout the native range in Idaho and Montana. In Montana, westslope cutthroat trout still exist in 27% of the historic range. Genetically pure populations persist in 2.5% of that range. Genetic and population inventories are very limited in Idaho. From our best judgment, strong populations persist in 11% of the historic range. Strong and genetically pure populations probably exist in less than 4%. We believe we still have viable populations in 36% of historic westslope cutthroat trout habitat, but nearly 50% of the range is thought to offer little potential for management. Habitat loss, hybridization with introduced trout, and overfishing are considered the most important causes for decline. Those influences are reflected in the association of most strong populations within wilderness and roadless areas.

HABITAT

Characteristics of Habitat

The preferred or optimum habitats for westslope cutthroat trout have not been well described (Shepard et al. 1984; Shepard et al. 1984; Griffith 1988). The limiting factors associated with habitat cannot be readily defined (Brad Shepard, Montana Department of Fish, Wildlife, and Parks, personal communication) as they might be for other species (see, for example, Reeves et al., in preparation). Some characteristics of westslope cutthroat trout habitat use have been described, however. Most information was derived by relating densities, or the distribution of a population, to habitat characteristics and by measuring the habitat associated with positions of individual fish.

In general, distribution of westslope cutthroat trout tends toward higher elevations and lower order streams (Platts 1974, 1979; Fraley and Graham 1982). Many biologists describe the distribution as headwater to mid-drainage, although some populations obviously make seasonal use of entire drainages (i.e., the Middle Fork Salmon and Coeur d'Alene rivers). Platts (1974) reports that westslope cutthroat trout were limited to two geomorphic land types (fluvial and depositional) in the South Fork Salmon River and negatively correlated with stream order.

Westslope cutthroat trout will use all of the major habitat components (i.e., pool, run, riffle, pocket water) (Pratt 1984; Irving 1987). Distribution tends toward lower gradients and lower velocities, however. Griffith (1970), Pratt (1984), and Hanson (1977) report typical facing velocities of 0.1 to 0.3 m/sec. for rearing fish. There is some evidence that smaller fish were associated with lower velocities (Hanson 1977) though differences were not large. Spawning habitats observed by Shepard et al. (1984) had velocities of 0.3 to 0.4 m/sec. and gravels ranging from 2 to 75 mm in diameter.

Several workers found pools to be a particularly important habitat for rearing cutthroat (Radford 1977; Pratt 1984; Irving 1987; Wilson et al. 1987). Utilization of pools may increase in the presence of other fish (Hanson 1977; Shepard et al. 1984), although segregation seems to be more selective than interactive (Pratt 1984; Griffith 1988).

Cover and complex habitat also are important for westslope cutthroat trout, particularly juvenile fish (Griffith 1970). Pratt (1984) found that small cutthroat trout were typically associated with some form of instream cover, such as cobble or woody debris, while large fish (>100 mm) might range more fully in the water column. Large fish did use large instream and overhanging cover when present (Pratt 1984). Lider (1985) found that the percent cover in pools was more strongly correlated with fish density than any other habitat component. Lider (1985) associated the highest densities with woody debris, such as root wads and logs.

Shepard et al. (1984) found the overhead turbulence provided cover and that social hierarchies were defended only when visually isolating cover was present. Moore and Gregory (1988b) found that stream margins and backwaters or "lateral habitats" provide important summer rearing areas for coastal cutthroat Oncorhynchus clarki clarki. Manipulation of stream complexity by artificially increasing the amount of lateral habitat resulted in a proportional increase in cutthroat numbers (Moore and Gregory 1988a). Lere (1982) found westslope cutthroat trout densities were correlated to pool riffle periodicity.

Many westslope cutthroat trout make only ephemeral use of specific habitats. Platts (1974) suggested that cutthroat are not typically found in first order streams. Others believe that very small tributaries may serve as a spawning and initial rearing habitat (Johnson 1963; Lukens 1978; Shepard et al. 1984; Apperson et al. 1988). Many of these streams may dry or flow subsurface in summer, forcing young fish to migrate early in the first year (Lukens 1978; Apperson et al. 1988). Use of very small tributaries for spawning and rearing may be an important adaptation that provides protection from very high flows and bedload movement (Johnson 1963; Liknes and Graham 1988) that is common in larger, high-elevation streams. Because spawning streams are small, and many are ephemeral, their significance may not have been recognized in past management (T.C. Bjornn, University of Idaho, personal communication). Logging plans typically have not provided buffers or protection of very small streams.

In many systems, westslope cutthroat trout move extensively using different reaches and habitats between spawning, summer rearing, and overwinter. High quality pools and gravel substrate seem to be particularly important in winter habitat use. Lewynsky (1986), Wilson et al. (1987), Peters (1988), and others have found large aggregations of adult and subadult cutthroat in pools during winter. Densities of wintering cutthroat have been strongly and positively associated with pool quality (defined by width, depth, and cover) (Peters 1988). Peters (1988) found fish most often in low or negative velocities. Pools with escape cover or with another pool immediately adjacent seem to support more fish than isolated pools.

Gravel substrates may be especially important for overwintering of juvenile cutthroat. Small fish typically move into the substrate as temperatures drop (Bjornn et al. 1977; Wilson et al. 1987). Porous substrate (not embedded with fines) of a size allowing fish to move in and out is important. Recent observations indicate that young cutthroat use the substrate as cover during the day and move out at night (Wilson et al. 1987; Peters 1988; T.C. Bjornn, University of Idaho, personal communication).

The availability of winter habitat probably has a strong influence on seasonal movements of westslope cutthroat trout. Extensive migrations may result where high quality pools are found downstream of spawning and rearing habitat (Bjornn and Liknes 1986; Liknes and Graham 1988; Peters 1988). Peters (1988) observed that cutthroat reside the entire year in some stream reaches where both summer habitat and high quality pools are found together. Juvenile cutthroat may emigrate from systems with unsuitable substrate when temperature drops (T.C. Bjornn, University of Idaho, personal communication). The juvenile carrying capacity of a particular pool may be strongly related to the degree of gravel embeddedness (Chapman and Bjornn 1969; Klamt 1976; Bjornn et al. 1977; Irving et al. 1983). The striking movements and apparent dependence on winter habitat suggest high quality pools and appropriate substrate could be a winter "bottleneck" for many populations in Idaho streams (T.C. Bjornn, University of Idaho, personal communication; Klamt 1976).

Because westslope cutthroat trout often make extensive movements and use different habitats during the year, a "limiting" habitat is hard to identify (see Irving et al. 1983; Peters 1988). In many cases, we do not know when, or for how long, a particular habitat or stream reach is used or its relative importance to other habitats and life stages (Peters 1988). Attempts to describe distribution and use contain inherent variability and may be confounded by changes in behavior with changes in flow or other habitat characteristics.

Detailed studies on habitat capacities or manipulative experiments could provide useful information in some streams where movements are limited. A "limiting factor" analysis similar to that developed for coho salmon Oncorhynchus kisutch (Reeves et al., in preparation) has been proposed with the hopes that results could be used to predict effects of land use management on cutthroat populations (Brad Shepard, Montana Department of Fish, Wildlife, and Parks, personal communication). Such studies may not be practical, however, with populations showing extensive movements (see Peters 1988).

We do have information on the fish densities some habitats can support. Irving (1987) summarized several studies and concluded that "good" rearing habitat may support up to 200 fry/100 m^2. Densities may approach 20 fish/100 m^2 for age 1 and 2 fish. Fraley and Graham (1982) found that cover, stream order, and substrate size could be used to predict trout densities within a single river drainage. Observed densities are highly variable, however, and it is not clear whether differences are due to subtle differences in habitats, to the presence of other fish, to the seeding of those habitats by the existing populations, or to seasonal movements. Seeding experiments may help better define habitat capacities (B. Shepard, Montana Department of Fish, Wildlife, and Parks, personal communication). Gross approximations of potential drainage production are possible with existing methods (Fraley and Graham 1982; Irving 1987), but estimates probably cannot obtain precision much better than an order of magnitude. Identification of limiting conditions will be speculative unless large differences in habitat available for different life stages exist. Results could be used, however, to identify streams with the highest potentials and to direct development to less sensitive areas (Fraley and Graham 1982).

Degradation of Habitat

Land use practices and other cultural development have undoubtedly degraded habitat and negatively affected westslope cutthroat trout populations. Biologist in Montana (Liknes and Graham 1988) and Idaho (status section of this report) believe habitat degradation is one of the most important causes of decline throughout the range.

Habitat changes influence westslope cutthroat trout populations in several ways. Fine sediments (defined variously as substrate materials anywhere from less than 1 mm to less than 10 mm) have been negatively correlated with embryo survival (Bjornn et al. 1977a; Irving and Bjornn 1984; Chapman and McLeod 1987). Fine sediments may physically eliminate important pool habitat (Klamt 1976; Bjornn et al. 1977a). Fines also fill intergravel spaces (embedded substrate), eliminating cover for young fish and altering the composition and production of benthos that serves as forage. Both winter and summer carrying capacity of pools have been related to the amount of fines (Klamt 1976; Bjornn et al. 1977a; Irving et al. 1983). Thurow (1987) found that total densities of all salmonids (including cutthroat) was inversely related to gravel embeddedness in streams of the South Fork Salmon River drainage. The amount of fine sediment in stream substrate has been strongly correlated with road construction and logging activities (Edwards and Burns 1986; Bob Rainville, Deschutes National Forest, personal communication) in the westslope cutthroat trout range. The movement of fines into a stream may often be aggravated by poor road construction activities and mass wasting following disturbance in unstable land types (Gamblin 1988). Mining activities also are thought to have introduced large amounts of fine sediment to some streams (Thurow 1987).

Westslope cutthroat trout habitat has been eliminated or isolated by construction of barriers and migration blocks. Highway construction in the Coeur d'Alene River drainage produced impassable culverts (Ned Horner, Idaho Fish and Game, personal communication). Improperly placed or sized culverts are a common passage problem with many forest roads throughout the range. Migration blocks primarily influence fluvial and adfluvial stocks. Although habitat above a barrier may continue to produce resident cutthroat, all of the habitat can be eliminated for production of fish moving to and from larger streams and lakes.

Dams have also influenced cutthroat habitat. Cabinet Gorge Dam on the Clark Fork River eliminated access to over 90% of the historic spawning and rearing habitat once available to adfluvial fish in Pend Oreille Lake. Dams have also eliminated habitat by inundating important stream reaches. Jim Vashro (Montana Department of Fish, Wildlife, and Parks, personal communication) estimated that dams eliminated 50% of the cutthroat habitat once available to fish from Flathead Lake. Similar losses may have occurred with Dworshak Dam on the North Fork Clearwater River in Idaho.

Habitat complexity and cover, and ultimately the rearing or winter carrying capacity of streams, can be altered by land use practices. Woody debris is an important component of cover and pool development in westslope cutthroat trout streams (Pratt 1984a; Lider 1985; Gamblin 1988). Removal of riparian timber has eliminated recruitment of woody debris. As old debris rots, is lost, and not replaced, pools and cover are lost. Woody debris also appears to play an important role in stream stability and storage of bedload (Gamblin 1988; Bob Rainville, Deschutes National Forest, personal communication). Loss of debris results in excessive bedload movement in a drainage, a loss of stream stability, substrate diversity, and the complexity which provides habitat (Gamblin 1988). Bedload movement may be aggravated by clear cutting in small drainages where large volumes of sediment are "stored" (Bob Rainville, Deschutes National Forest, personal communication). Gamblin (1988) believed that high transport of large bedload material (gravel and small cobble) in tributaries of the North Fork Coeur d'Alene River resulted in extensive loss of rearing habitat for cutthroat. In some cases, high bedload transport has resulted in aggrading stream channels in the lower gradient reaches of some northern Idaho streams (Ned Horner, Idaho Fish and Game, personal communication). Bedload deposition has aggravated stream stability problems, resulting in channelization and streambank armoring by riparian landowners. Bedload deposition has also produced porous and elevated channels resulting in subsurface flow and dewatered habitat, either eliminating habitat entirely or blocking fish movements (Ned Horner, Idaho Fish and Game, personal communication).

Stream channelization has also been associated with road construction and mining (Thurow 1987). Channelization has been common with Forest access roads built in stream corridors. Channelization eliminates complexity and stability but also results in shorter channel length and increased velocities. Irizarry (1969) and Thurow (1988) demonstrated that channelization can result in a several-fold reduction in trout numbers.

Alteration of habitat may also influence westslope cutthroat trout populations in subtle ways. Chapman and May (1986) suggested that flow and temperature regulation in the Kootenai River following construction of Libby Dam created conditions more suitable for rainbow trout, allowing them to replace westslope cutthroat trout. Brad Shepard (Montana Department of Fish, Wildlife, and Parks, personal communication) found that clear cutting one of two paired streams was followed by a shift from cutthroat to brook trout dominance. He suggested that the changes in stream habitat related to logging favored brook trout.

Habitat degradation has undoubtedly played an important role in the decline of westslope cutthroat trout populations. The distribution of remaining strong populations almost entirely within wilderness and roadless areas of Idaho (Figure 1) and wilderness and National Parks of Montana (Liknes 1984) suggests that any development may be important in population declines. Unfortunately, most of the evidence for habitat influences on population decline is indirect and often confounded by problems of overfishing. Platts (1974) did find that cutthroat densities were much higher in unlogged stream reaches, and Thurow (1987) found densities of all trout declined with substrate embeddedness. Both of these studies were uncontrolled, however, and results might be confounded by differences or covariation in other habitat variables or fish distribution (Platts 1974; Chapman and McLeod 1987).

Models have been used to predict both existing habitat potential and the effects of land use management (Fraley and Graham 1982; Irving et al. 1983; Stowell et al. 1983). Relationships between sediment composition and embryo survival (Irving and Bjornn 1983) or sediment and juvenile carrying capacity (Bjornn et al. 1977a) have been used to predict population responses to increased fine sediment loading. Sediment composition has either been sampled directly in the field or predicted using hydrologic and sediment transport models (Irving et al. 1983; Stowell et al. 1983).

The modeling approach has been used extensively in land use planning, but has major limitations. The relationships between sediment and embryo survival were developed in artificial channels and may not accurately reflect responses in a natural stream (Chapman and McLeod 1987; Chapman 1988). Estimates of sediment composition can vary dramatically depending on method (Everest et al. 1982; Pratt 1985; Gamblin 1988), personnel (Pratt 1985), and experience. Some methods may not accurately represent substrate conditions of the incubation site (Chapman 1988). Cutthroat populations are also dynamic biological systems. The changes estimated by the models might actually occur but could be unimportant in regulation of the population (see Chapman and McLeod 1987). Changes in rearing capacities, for example, would have no influence on populations that are not fully seeding the available habitat. At the same time, changes in embryo survival might not be apparent in populations that were more than fully seeding available rearing habitat. Gamblin (1988) found no relationship between intergravel fines and cutthroat density in Coeur d'Alene River tributaries. He felt that limited rearing habitat in those streams was far more important in controlling population size than the influence of fine sediments on embryo survival.

Biologists may have overemphasized problems related to fine sediment. Emphasis of fine sediment models to streams in all land types is probably inappropriate. The emphasis reflects research conducted in streams on the Idaho Batholith, where fragile granitic soils result in high transport and loading of fines. Belt rather than granitic geology typifies many cutthroat streams north of the Clearwater drainage. In these systems, bedload sediments tend to be larger gravels and small cobbles rather than sand. Heavy bedload movement and a loss of stream stability and complexity may more strongly influence rearing and holding capacities than embryo survival (Gamblin 1988; Ned Horner, Idaho Fish and Game, personal communication). The field or laboratory data necessary to predict habitat loss associated with forest practices on these types of streams have not been collected.

Habitat Manipulation

Habitat use by westslope cutthroat trout suggests construction or improvement of pools could improve rearing and overwintering capacities. Pratt (1984a) emphasized that rearing pools should be less than 200 m^2 or 100 m^3 in size. Peters (1988) suggested that "linked" pools, or pools associated with escape cover, were the best winter habitat. Peters (1988) also provided a ranking system to define pool quality.

Attempts to physically improve pool and cover habitat for westslope cutthroat trout have been widespread. Much of the work has been conducted as part of routine mitigation or management activities by U.S. Forest Service districts, however, and has been poorly evaluated or documented. "Drop logs" and "K-dams" have been used to create pools in many streams tributary to the Coeur d'Alene River (Ed Lider, Panhandle National Forest, personal communication). Boulder clusters have been placed on larger streams throughout the forest. Large woody debris has been added by felling and anchoring trees and root wads. Some data show that fish will use structures, and local densities may be strongly correlated with new habitat (Lider 1985; Bob Rainville, Deschutes National Forest, personal communication). Creation of more complex stream margins also resulted in a proportional increase in rearing densities of coastal cutthroat (Moore and Gregory 1988a).

Biologists have not clearly shown that structural improvements provide cost effective or significant benefits for population management. Although westslope cutthroat trout will clearly use new habitat, such correlations may only be a result of displacement from previously existing areas. The addition of pools as cover should provide some benefits in streams lacking these components; however, we did not find any case where a population level response was demonstrated. It is possible to predict stream potential based on habitat inventory (Irving 1987) and also to predict net increases in potential from structural improvement. Although some forest management plans incorporate this type of approach on a gross scale (Bob Rainville, Deschutes National Forest, personal communication), we did not find any analysis showing the theoretical costs and benefits for habitat improvements for an individual westslope cutthroat trout stream or population.

Larger scale habitat management programs have also been considered. Road management plans and treatment of major sediment sources are typically part of the forest management process. Gravel mining has been considered in areas with extreme bedload movement. Any programs that significantly reduce sediment loading to an entire drainage could be expected to produce substantial habitat improvements over a number of years. Timber harvest management has also been proposed as a means of improving stream cover and complexity. Harvest of riparian areas on an extended (200 year) rotation could maximize the proportion of a stand in middle and older age classes, thereby increasing recruitment of trees to the stream (Bob Rainville, Deschutes National Forest, personal communication).

Summary

Habitat degradation has undoubtedly had an important negative influence on Idaho's westslope cutthroat trout populations. The most important losses are associated with forest management. Increases in fine sediment in streams can reduce embryo survival and wintering capacity for juveniles. Reduced embryo survival will reduce the resilience of any population, resulting in either an immediate decline or a less productive population more vulnerable to other losses. Fine sediments are probably important in all streams but are a particular problem for streams on granitic soils. Increases in larger (gravel and small cobble) sediment loading result in reduced stream stability and complexity and lost rearing or overwinter capacity. Loading of larger sediment appears to be a particular problem in belt geology streams north of the Clearwater River.

Although habitat loss is obviously important, the relative significance in population declines has not been clearly quantified. We do not understand, or have not been able to describe, the bottlenecks in habitat for most populations. Previous attempts have relied on models of fine sediment and embryo survival. The approach may be inappropriate where rearing capacity is more strongly influenced by development than is spawning habitat. Models are also based on laboratory experiments that may not accurately represent natural conditions. Many biologists believe better quantification of the development-habitat-population relationships will be necessary to effectively influence land management practices.

Large scale correlative approaches, or paired drainage approaches, might be used to demonstrate the effects of forest management. To generate meaningful results, sampling must minimize confounding by other variables (see Chapman and McLeod 1987). Sampling must be stratified by geology, geomorphic process, and seeding. Sampling must also be detailed enough to account for inherent variation in the populations (see Platts and Nelson 1988). To our knowledge, a comprehensive approach of this nature has not been attempted.

Optimum habitat for westslope cutthroat trout has not been clearly defined. Populations tend to have a higher elevation headwater distribution but may use entire drainages. Extensive movements are probably tied to the availability and relative distribution of spawning and rearing and overwinter habitats. We may find it possible to describe critical or "limiting" habitats for each life stage of a population, but it is probably more realistic to protect all components. For populations that move long distances, habitat protection will require a system or drainagewide approach. The importance of maintaining whole systems is emphasized by the fact that most of the remaining strong populations in Idaho are contained within undeveloped (roadless and wilderness) areas. Maintenance of pristine habitat in entire drainage systems is obviously impossible in much of the westslope cutthroat trout range. Realistically, protection must be focused in smaller areas. Subdrainages which provide all habitat requirements, evidenced by nonmigratory stocks, could be emphasized. Generic protection of known "critical" habitat should also be a priority. Small (first or second order) tributaries represent critical spawning and early rearing habitat for many populations. Small tributaries also "store" much of the sediment in a drainage. Protection of small streams has often been ignored because they were ephemeral or considered insignificant in size. Pools and cover are also important components of rearing and overwinter habitat for cutthroat.

Habitat improvement projects have focused on structures creating pools and cover. Artificial structures are used by fish, but it is not clear that use of structures has or can increase the carrying capacity of a stream. The relative cost and benefit of habitat improvements need to be demonstrated both theoretically (through estimates of stream potential) and through population responses. Large scale management programs that maximize recruitment of woody debris, minimize sediment loading, and maintain stream stability and complexity through major portions of a drainage should be more effective than mitigation with structures.

INTERACTION WITH OTHER FISHES

Westslope cutthroat trout populations can be influenced by many other fish through competition, predation, and hybridization. Westslope cutthroat trout coexist (within a given drainage) naturally with several salmonids: chinook salmon, rainbow trout (steelhead), mountain whitefish Prosopium williamsoni, and bull trout. Historically, westslope cutthroat may have been in streams with arctic grayling Thymallus arcticus east of the Continental Divide (Simpson and Wallace 1982). Chinook salmon and rainbow trout were native only to the Clearwater and Salmon River basins (Behnke and Zarn 1976). Other native fish in the cutthroat range included several species of sculpin, cyprinids, and catostomids (Simpson and Wallace 1978). Rainbow trout and brook trout have been introduced extensively. Kokanee salmon, lake trout Salvelinus namaycush, and brown trout Salmo trutta have also been introduced, the first two to many of the lakes throughout the range. Kokanee may have coexisted naturally with westslope cutthroat trout in lakes at the headwaters of the Salmon River (Stanley Basin), but we found no confirming records. Yellow perch Perca flavescens may have occurred with westslope cutthroat trout but only east of the Continental Divide. Yellow perch and other centrarchids have been widely introduced to lakes throughout the range in Idaho.

Some work has been done on the interactions between westslope cutthroat trout and rainbow trout, bull trout, brook trout, kokanee, Yellowstone cutthroat trout Oncorhynchus clarki bouveri, and lake trout. Very little is known about interaction with other fishes.

Competition

Evidence for competition between westslope cutthroat trout and other trout is mixed. Griffith (1988) suggested that westslope cutthroat trout were more specialized than other cutthroat, a result of westslope cutthroat trout evolution with a number of other fishes. Liknes (1984) suggested that in pristine habitat, westslope cutthroat trout should have an advantage over other trout. The implication was that habitat change could result in advantages to other fish. Other authors suggest that westslope cutthroat trout may not compete effectively with other trout. Platts (1974) found westslope cutthroat trout in streams of only two geomorphic types, while other salmonids were found in more. Platts felt cutthroat were at a competitive disadvantage and were abundant only where other species were not. Griffith (1988) observed that other trout were typically larger and more aggressive and should hold a competitive advantage. Bisson et al. (1988) found that coastal cutthroat lacked morphological adaptations for high or low water velocities found in steelhead trout and coho salmon. The authors felt that such differences explained the domination of coastal cutthroat by the other species. Morphological adaptations have not been compared between westslope cutthroat trout and coastal cutthroat trout.

Within the westslope cutthroat trout range, westslope cutthroat trout seem to have a competitive advantage over introduced Yellowstone cutthroat trout. In Glacier National Park after widespread stocking, Yellowstone cutthroat trout did not persist in most lakes, while westslope cutthroat trout did (Marnell et al. 1987). Similar results followed heavy stocking of Yellowstone cutthroat trout in Priest Lake (Beach 1971). Behnke and Zarn (1976) suggested the two subspecies might complement each other because of apparent differences in food habits and distribution. Marnell et al. (1987), however, suggest that Yellowstone cutthroat trout do not persist because they are more vulnerable to predators and parasites that co-evolved with westslope cutthroat trout. Although competition could be important, Yellowstone cutthroat trout may also have failed in much of the westslope cutthroat trout range simply because they were poorly adapted to other parts of the environment.

Westslope cutthroat trout coexist with rainbow trout throughout the westslope range. In the Salmon and Clearwater drainages where rainbow trout exist naturally, the two species exhibit strong segregation. Hanson (1977) did not find any case where the two used the same macrohabitats. In streams where both species did occur, cutthroat were restricted to headwater areas while rainbow trout used lower reaches. Hanson (1977) believed that interactive segregation isolated the two species and demonstrated that rainbow trout can exclude cutthroat in experimental streams.

Others believe selective segregation is more important (Griffith 1988). In the North Fork Clearwater River drainage, westslope cutthroat trout did not replace steelhead when the latter declined following construction of Dworshak Dam (Moffitt and Bjornn 1984). Goodnight and Mauser (1980) report an increase in the proportion of cutthroat to rainbow trout following elimination of steelhead in the Little North Fork Clearwater River, but did not note an overall increase in cutthroat numbers. The lack of increase in cutthroat with a decline in native rainbow trout supports the hypothesis of selective segregation and limited competition (Griffith 1988). It may be, however, that cutthroat did not respond because of some other constraint. Cutthroat are more vulnerable to fishing than rainbow trout and could be at a competitive disadvantage as exploitation increases (Griffith 1988).

Cutthroat trout also show segregation from introduced rainbow trout, although overlap in habitat use may be more common. Pratt (1985) found cutthroat primarily in the headwaters of tributaries to Pend Oreille Lake, while juvenile rainbow trout were more common in lower reaches. In many streams, however, she found both fish using the same macrohabitats and hybridization was common. In the Coeur d'Alene River, cutthroat are found concentrated in upper reaches and rainbow trout in the lower river but some overlap occurs (Bowler 1974). Apperson et al. (1988) found cutthroat dominated rainbow trout in many tributaries of the lower Coeur d'Alene River but observed higher rainbow:cutthroat ratios in streams with higher riffle:pool ratios and gradients in excess of 3%. Rainbow trout typically seem to select higher velocity microhabitats than cutthroat.

Hatchery-produced rainbow trout ("catchables") have been heavily stocked in many westslope cutthroat trout streams. Thurow and Bjornn (1978) report that westslope cutthroat trout numbers in one stream increased when hatchery stocking was eliminated and declined again when stocking resumed. Petrosky (1984) and Petrosky and Bjornn (1988), however, found that hatchery rainbow trout had little or no influence on westslope cutthroat trout in the St. Joe River. Even when heavily stocked, most rainbow trout segregated spatially from cutthroat and rarely fed. Petrosky (1984) concluded that catchable rainbow trout stocking had little influence on cutthroat because overlap in habitat use was incomplete and because the numbers of wild cutthroat found in the main river were not density dependent. Juvenile cutthroat that do experience significant density-dependent regulation and could be more vulnerable to displacement by hatchery trout typically rear in small tributaries where hatchery stocking is uncommon.

Hatchery trout could result in higher exploitation of westslope cutthroat trout if stocking resulted in higher fishing pressure (Petrosky 1984). Although hatchery programs may not directly displace or limit wild cutthroat, catchable stocking could aggravate problems of overexploitation.

Westslope cutthroat trout and bull trout co-evolved throughout the range. The two occupy similar macrohabitats and seem to coexist most successfully (highest densities for both) in streams with complex cover (Pratt 1984). Pratt (1984) found evidence of strong selective segregation in microhabitat use. She described bull trout typically in close association with the bottom, while cutthroat made more use of the water column. Microhabitat characteristics did not change between allopatric and sympatric observations.

Brook trout have been introduced to most of the westslope cutthroat trout range. Brook trout populations have increased as cutthroat declined in many areas and some displacement might occur. Some biologists believe the expansion of brook trout represents only a replacement of cutthroat that declined for other reasons. Griffith (1970, 1988) found strong selective segregation by facing velocity and suggests brook trout have expanded only to fill fringe habitats where the two overlapped. Cutthroat are far more vulnerable to exploitation than brook trout (MacPhee 1966; Griffith 1970) and may be more sensitive to habitat alteration (Brad Shepard, Montana Department Fish, Wildlife, and Parks, personal communication). The decline of cutthroat with increased fishing and increased sedimentation and stream alteration may simply have created more habitat available for brook trout. Some interaction must occur between the species, however. Griffith (1988) noted morphological character displacement in populations coexisting for a number of years. Wilson et al. (1987) noted that brook trout declined following a closure to cutthroat harvest in Rattlesnake Creek, Montana. Irving (1987), Cowley (1987), and Strach (University of Idaho, personal communication) report that stocked cutthroat fry survive much better in streams without brook trout or stream reaches where brook trout were removed.

Kokanee salmon were introduced to all of the lakes in northern Idaho where westslope cutthroat trout were once important. Kokanee increased dramatically in Coeur d'Alene, Pend Oreille, and the Priest lakes concurrent with declines in cutthroat. Again, competition may have been important. Both species feed heavily on small invertebrates in lakes that are not considered productive. Food habits do seem to diverge, with kokanee using zooplankton and cutthroat using insects. Differences could reflect some interactive segregation. Cutthroat used zooplankton heavily in Koocanusa Reservoir before kokanee became important (McMullin 1979). Mauser et al. (1988b) presented some evidence that growth of cutthroat in Priest Lake and Coeur d'Alene Lake was negatively associated with large changes in kokanee abundance. Whether differences in growth were real is not clear. Although cutthroat declines have been common with kokanee, we note that in some lakes following establishment of kokanee, local stocks remained strong. Numbers of westslope cutthroat trout in Wolf Lodge Creek, a tributary to Coeur d'Alene Lake, remained at high levels despite declines in most other cutthroat stocks in the lake and very high densities of kokanee.

Management for kokanee and cutthroat may be in conflict. Despite a "feeling" by many biologists that competition may be a major limitation of adfluvial stocks, management programs often seek to enhance both populations in a single system. Special regulations and hatchery programs for cutthroat enhancement have been used in the same systems as hatchery programs for kokanee. Better information on the competitive interactions could help clarify conflicting goals. Studies of competition are difficult and often ambiguous. However, studies of character displacement could provide some clues. Cutthroat populations exist with and without kokanee or with radically different densities of kokanee. A study of feeding morphology among those populations (see Magnan 1988) could be useful and relatively simple.

Predation

Several fishes are thought to prey on westslope cutthroat trout. Beach (1971) reported all sizes of cutthroat in stomachs of bull trout from Priest Lake. Mauser (1986b) also found cutthroat in lake trout stomachs from Priest Lake. He reported that 13% of all cutthroat sampled from Priest Lake in 1985 had predator wounds, presumably from lake trout (Mauser 1986b). Mauser et al. (1988a) believed that lake trout predation was the primary reason for a failure of cutthroat enhancement in Priest Lake but could not estimate the predation-related mortality. Athearn (1973) observed sculpin eating cutthroat fry. Northern squawfish are commonly believed to be an important predator of westslope cutthroat trout (Jeppson and Platts 1959; Jeppson 1960). Northern squawfish have been shown capable of important predation on other salmonids (Foerster and Ricker 1941; Rieman et al. 1988). Jeppson and Platts (1959) suggested that six years of intensive removal of northern squawfish in Hayden Lake produced an increase in cutthroat numbers. MacPhee and Reid (1971) report an increase in fingerling trout survival in the St. Joe River following squawfish removal with the selective toxin, Squoxin. Others have found little evidence of westslope cutthroat trout in northern squawfish stomachs (Bjornn 1957b; Jeppson 1960; Falter 1969; Apperson et al. 1988). Some argue that predation on salmonids by squawfish is unimportant in natural systems (Brown and Moyle 1981; Rieman et al. 1988).

Despite a lack of clear evidence for predation on westslope cutthroat trout, we believe that predation can be an important source of mortality, particularly in altered or overexploited populations. The introduction of new predators that do not naturally coexist with a prey can result in collapse of the prey population (Larkin 1979). Additional stress on a population (such as exploitation or habitat loss) can make predation, in a normally stable system, a destabilizing force. Population collapse through depensatory predation mortality, or a population restricted to low numbers in a predator trap, can result (Peterman 1977). Artificial concentration of prey at hatchery release sites or passage barriers can increase vulnerability to predation (Rieman et al. 1988). Hatchery fish that are stressed through release handling or disease or are disoriented in a new environment might also be particularly vulnerable. Lake trout, Gerrard rainbow trout, chinook salmon, yellow perch, several centrarchids and ictalurids, and northern pike Esox lucius have all been introduced in westslope cutthroat trout lakes. In some cases, the new predator populations have flourished. Bull trout and northern squawfish represent the most important native predators. Bull trout have declined in most waters, but squawfish still seem to be common in lakes and the lower reaches of many rivers. As cutthroat have declined in most waters, predators have become established or persisted. Predation could be associated with the declines, but more importantly, might make recovery extremely difficult or impossible. Predation might explain the poor performance of hatchery programs.

Genetic Introgression

Westslope cutthroat trout readily hybridize with other cutthroat subspecies and rainbow trout (Behnke and Zarn 1976; Behnke 1979; Leary et al. 1983; Leary et al. 1987; Allendorf and Leary 1988). Westslope cutthroat trout have segregated from native rainbow trout (steelhead) where the two coexist naturally in the Clearwater and Salmon River drainages (Behnke and Zarn 1976). In other drainages, however, hybridization is often extensive where introductions of hatchery-produced rainbow trout and Yellowstone cutthroat trout have been made (Allendorf and Leary 1988). Genetic introgression seems most prevalent in drainages where westslope cutthroat trout have been depressed through other causes and hatchery introduction of other trout have persisted for some time. Mountain lake stocking programs seem to be a particularly important source of exotic genetic material (Joe Huston, Montana Department of Fish, Wildlife, and Parks, personal communication). Although the hybrid trout are viable and support important fisheries, introgression results in the progressive loss of genetic variability in westslope cutthroat trout populations (Allendorf and Leary 1988). Lost variation may lead to poorer performance (growth, survival, fertility, development) of individual stocks and greater susceptibility to epizootics, environmental change, or catastrophic events (Allendorf and Leary 1988). Ultimately, genetic dilution can lead to a loss of the characteristics we think make cutthroat unique and to a loss of viability. Genetic introgression is believed to be the most important cause for decline of westslope cutthroat trout in Montana (Liknes and Graham 1988). As discussed earlier, fishery managers in Montana have undertaken an extensive program to re-establish genetically pure populations (Allendorf and Leary 1988).

We have not made a comprehensive survey of the genetic purity of Idaho cutthroat stocks. We know that extensive hybridization has occurred in many areas, but we suspect that some populations are relatively pure (see Status section). Any further loss of genetic variation in Idaho westslope cutthroat trout can be mitigated by maintenance of strong populations and by care in hatchery programs. Hatchery stocking of Yellowstone cutthroat trout and rainbow trout has been discontinued in most Idaho mountain lakes tributary to westslope cutthroat trout water but not throughout the range. We need a clearly defined policy on non-native stocking to protect the genetic integrity of important remaining populations. We suggest that rainbow trout or other cutthroat not be stocked in drainages supporting "strong" or "depressed" westslope cutthroat trout populations.

To fully understand the genetic integrity of Idaho westslope cutthroat trout and compare that with data from Montana, an extensive electrophoretic inventory will be necessary. Hybridization of westslope cutthroat trout and other trout can be obvious phenotypically. Biologists have attempted to use external appearance as a guide for a selection in management programs (i.e., broodstock selection at Hayden Lake and Fish Lake). Leary et al. (1983) showed, however, that morphological criteria are virtually useless in identifying all hybrids. Biochemical analyses are the only reliable methods of evaluating genetic purity. A genetic inventory in Idaho should be used to: (1) clearly identify population strongholds and prioritize management areas by highest biological potential, (2) provide a baseline for monitoring the genetic effects of other stocking programs (i.e., mountain lakes and catchable rainbow trout) in priority westslope cutthroat trout waters, and (3) identify the best sites for collection of broodstock.

Summary

Westslope cutthroat trout interact with other fishes through competition, predation, and hybridization. The role of each mechanism in regulation or limitation of any population has not been clearly shown. All are probably important, however, in the decline of populations or the failure of populations to rebuild.

Competition with native and introduced fishes is minimized in streams by habitat segregation. The expansion of brook trout probably represents a replacement of cutthroat that declined for other reasons. Brook trout may be particularly successful where habitat has been altered, however. Cutthroat may not be easily re-established where brook trout now exist, either because brook trout offer some resistance or because habitat is unsuitable. Rainbow trout and cutthroat trout may compete where rainbow trout did not exist naturally and have been introduced. The species typically segregate, but rainbow trout can displace cutthroat where the two overlap. Coexistence of introduced rainbow trout and native westslope cutthroat trout more likely results in extensive hybridization.

The use of "catchable" rainbow trout does not appear to displace westslope cutthroat trout. Catchable stocking can create increased fishing pressure, however, and aggravate exploitation of cutthroat in the same waters.

In lakes, westslope cutthroat trout are most likely to compete with kokanee salmon. Evidence of competition is only circumstantial. If competition is important, however, management of single lakes for enhancement of both species is counterproductive.

Predation may be a particular problem for adfluvial westslope cutthroat trout populations. The introduction and/or enhancement of predators is most common in lakes, and adfluvial stocks must typically migrate through, or concentrate, in areas where they can be vulnerable. The decline of cutthroat stocks because of overfishing or habitat loss may allow predation to become a destabilizing force. Predation could make the rehabilitation of some adfluvial populations difficult or impossible.

Hybridization of westslope cutthroat trout with rainbow trout and Yellowstone cutthroat trout has undoubtedly occurred throughout the range. Although hybridized populations still support fisheries, the loss of variability results in a loss of the species characteristics considered important and greater vulnerability to environmental change or catastrophic events. Extensive hybridization is most likely where cutthroat populations have been depressed and extensive stocking of other trout has persisted for some time. Mountain lake stocking programs may be an important source of foreign genetic material. A clear policy on non-native introductions is needed to help protect genetic integrity of important populations. Current data is inadequate to determine the genetic integrity of Idaho's westslope cutthroat trout stocks, and an electrophoretic inventory of important stocks would be useful.

POPULATION DYNAMICS

Growth

Estimated growth (length-at-age) of westslope cutthroat trout varies substantially (Figure 2). Growth estimates tend to be higher among adfluvial populations than fluvial (Figure 2), but such differences are not consistent. The highest apparent growth rate was from Pend Oreille Lake (Pratt 1985), but the largest estimated length at age 6 as from the Coeur d'Alene River (Lewynsky 1986). Growth of westslope cutthroat trout appears to be slightly allometric. Estimated coefficients for the length-weight relationship ranged from 3.05 (Hanson 1977) to 3.15 (McMullin 1979; Mauser et al.). Huston et al. (1984) observed a change in condition of westslope cutthroat trout in Koocanusa Reservoir. Neither Huston et al. (1984) nor other authors have documented factors influencing condition or causing variation in growth within a population.

Growth is probably related to the productivity of individual waters, although no one has shown such a relationship. All of the estimates we found show substantially slower growth than that observed for rainbow trout from a "productive" southern Idaho stream (Figure 2). Growth usually increases as fish move from relatively small and sterile early rearing streams to larger and more productive rivers or lakes (Lukens 1978). We found no documentation of growth for resident cutthroat. Small size at maturity (150-200 mm) (Thurow and Bjornn 1978), however, suggests very slow growth. Earlier age-at-migration from rearing areas to lakes or rivers can result in faster overall growth (Lukens 1978) and larger size at maturity.

There is no evidence that growth of cutthroat is influenced by density. Mauser et al. (1988) did note differences in estimated growth of cutthroat in North Idaho lakes over time and suggested competition with kokanee could be important.

Growth of cutthroat has typically been estimated by scale analysis and back-calculation. We found no work validating the method. The potential bias and relative precision of growth estimates for cutthroat have not been clearly addressed. Some work has shown that in many populations an annulus is not laid down following the first year (Mallet 1961; Shepard et al. 1984; Lewynsky 1986; Lentsch and Griffith 1987). The location of the scale sample on the body can also result in a missing first annulus (Huston et al. 1984).

Scale analysis and ageing in general can be strongly biased and highly variable. The lack of annuli and interpretation of early growth can be a particular problem. A better evaluation of growth patterns could help determine whether apparent differences among stocks are real. Some caution should be used in the interpretation of existing data and apparent difference among populations.

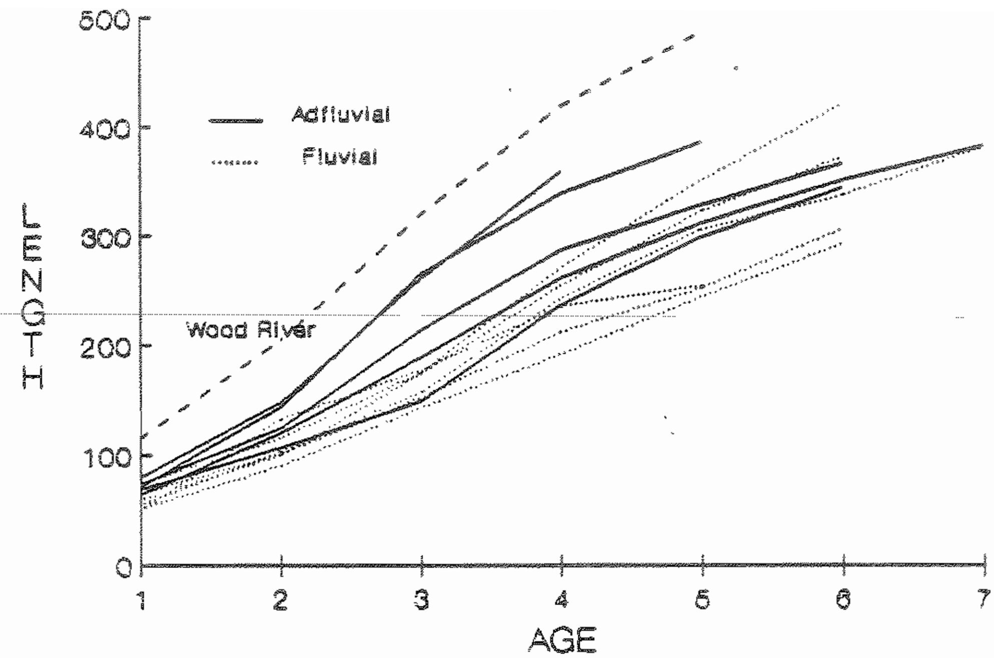

Figure 2. Growth of westslope cutthroat trout. Dark lines represent adfluvial populations, light lines represent fluvial populations. Growth of Wood River rainbow trout is shown for comparison with a productive trout stream outside the westslope cutthroat trout range. Wood River data are from Thurow (1989). Other data are summarized in table 2.

Table 2. Estimated mean length-at-age for fluvial and adfluvial westslope cutthroat trout. Data were summarized by Lukens (1978) and Pratt (1985).

MIGRATORY TYPE	Age						
Water	1	2	3	4	5	6	7
FLUVIAL (River)							
Middle Fork Salmon	60	100	174	254	322	371	
Flathead	55	103	157	242	305	336	381
Coeur d'Alene	74	115	175	270	350	420	
St. Joe	52	91	143	192	243	291	
Marble Creek	50	133	178	235	254		
Kelly Creek	66	101	153	212	251	306	
ADFLUVIAL (Lake)							
Wolf Lodge[a]	74	125	214	287	328	365	
Wolf Lodge[b]	69	107	149	236	299	343	
St. Joe	72	143	266	338	386		
Flathead	64	120	189	261	311	350	382
Pend Oreille	80	148	261	358			
Priest Lake[a]	89	147	271	326	366		

[a] Two-year migrants.
[b] Three-year migrants.

Growth can have an important influence on the productivity of a stock, potential yield, and the response to exploitation. Although growth has been estimated for a number of populations, we found no attempts to use the data to interpret or compare productivity of populations. We typically assume that slower growing populations are less productive or less resilient, but differences have not been quantified.

Mortality

Natural Mortality

We found few attempts to estimate all the components of mortality in any westslope cutthroat trout population. Available estimates of total mortality are for fish vulnerable to fishing and typically represent fish older than age 3. Estimates in exploited populations range from 0.58 to 0.78 (Table 3). Bjornn et al. (1970) estimated lower rates (0.31-0.51) in Kelly Creek and the St. Joe following the implementation of special regulations. Because the new regulations resulted in dramatic reductions in fishing effort and catch-and-release fishing on all or most of the stock, they should represent liberal estimates of natural mortality (Table 3). Apperson et al. (1988) estimated total mortality of 0.58, exploitation of 0.30, and resulting natural mortality of 0.40 (Table 2) in the Coeur d'Alene River. The Coeur d'Alene exploitation estimate could be biased low so natural mortality might have been less. The available data suggest that natural mortality for cutthroat in rivers may range from 0.30 to 0.50. The only comparable data for adfluvial populations was from Mauser et al. (1988) and was similar to the fluvial estimates (Table 3). We found no estimates of mortality in resident cutthroat.

We found very little data on mortality during early life (egg to age 3). Bjornn and Johnson 1977 assumed 95% mortality from swim-up fry to age 1. Irving and Bjornn (1984) showed that survival from egg to swim-up fry may range from 0.4% to 95% in the laboratory, depending upon the level of fine sediment in incubating gravels. We found no estimates of mortality during early life in the wild, though the laboratory data are often used to predict emergence success in wild populations (Stowell et al. 1983; Chapman 1988).

Differences or changes in natural mortality among and within populations have not been documented. The factors influencing mortality, other than fine sediment and exploitation, are not commonly addressed in the available literature. Bjornn et al. (1977a), Johnson and Bjornn (1978), and Behnke and Zarn (1976) did suggest that natural mortality in cutthroat could compensate for some exploitation. The implication was that if populations are regulated primarily by habitat capacity, changing exploitation will have little influence on total mortality (i.e., only the

Table 3. Total mortality, natural mortality, and exploitation estimated for westslope cutthroat trout in Idaho.

Water	Total mortality	Exploitation	Natural mortality	Source
Middle Fork	0.68	----	----	Mallet (1963)
Salmon River	0.78	----	----	Ortmann (1969)
St. Joe River				
Upper St. Joe	0.72	----	0.31[a]	Bjornn, Johnson,
Lower St. Joe	----	----	0.54	and Thurow (1977)
Lower St. Joe	0.78	----	----	Rankel (1971a)
Kelly Creek	0.72	----	0.47[a]	Bjornn, Johnson, and Thurow (1977)
Coeur d'Alene River				
	0.58	0.30	0.40[b]	Apperson et al. (1988)
	0.69-0.71	----	----	Lewynsky (1986)
Priest Lake	0.57	0.27	0.44	Mauser et al. (1988a)

[a] Total mortality estimated following special regulations and substantial decline in effort, assumed to approximate natural mortality.

[b] Conditional natural mortality as an annual proportion assuming no other mortality was present (after Ricker 1975).

TABLE3W

number fully seeding available habitat can survive). The likelihood of compensation in cutthroat vulnerable to exploitation depends on the carrying capacity of habitat for all life stages. Density dependence in most fishes is limited to juveniles and not fish recruited to the fishery (Cushing 1971). Important compensation in cutthroat also seems more likely during the first year when spawning and emergent fry might overseed available rearing habitat.

Catastrophic events, such as winter flooding and scour, may be an important cause of natural mortality for cutthroat. Habitat degradation could make cutthroat more vulnerable to these losses, but the frequency and severity of such mortality for any population is unknown.

Predation by other fish is a documented cause of natural mortality (Beach 1971; MacPhee 1966; Falter 1969; Mauser 1988; Horner 1978) and can limit population size (Horner 1978). Predation could be particularly important for adfluvial cutthroat and may be more important than in the past. Fish migrating to a lake are exposed to more predators than those remaining in tributaries or rivers. In most lakes, several new predators are present as a result of exotic introductions. Predator populations probably are not limited by cutthroat as prey, and most predators have remained stable, or even flourished, as cutthroat populations declined. Examples include most northern squawfish populations, and the lake trout, Gerrard rainbow trout, chinook salmon, black basses Micropterus spp., and northern pike, all present in northern Idaho lakes. Predation under those conditions may create a depensatory mortality (Ricker 1954; Peterman 1977). If this is true in westslope cutthroat trout waters, initial population declines resulting from habitat loss or overexploitation will be accelerated by predation. The result may be collapse of the population or maintenance of very low densities in a predator trap (Peterman 1977).

Fishing Mortality

Apperson et al. (1988) provide the only estimate of exploitation (0.30) for westslope cutthroat trout under general regulations. If we assume a natural mortality of 0.40 in all populations, exploitation of populations in Table 3 would have been on the order of 0.40 to 0.50.

Cutthroat are obviously vulnerable to angling. Relatively low fishing effort can produce high exploitation. Fishing effort associated with declines of cutthroat on Kelly Creek and the Lochsa and Coeur d'Alene rivers ranged from 100 to 200 h/km (Lewynsky 1986). We have documented declines of cutthroat in wilderness streams like Big Creek, the Middle Fork, and Selway where effort might have been even lower. MacPhee (1966) showed that cutthroat in a small stream were more vulnerable to fishing than brook trout and that effort of only 8 h/km resulted in exploitation of 0.50.

Obviously, substantial exploitation can be generated with moderate or even limited fishing pressure. Extreme exploitation is possible under conditions that are probably not unusual. In British Columbia, westslope cutthroat trout were virtually eliminated from some streams in a few weeks following opening of the fishing season (Al Martin, British Columbia, Ministry of Environment, personal communication). Exploitation could even become excessive at moderate or even low levels of effort. A cursory summary of Lochsa snorkeling and catch rate data (our analysis from data of Lindland 1982) suggests that catch rates are not directly related to density (Figure 3). The asymptotic relationship implies that vulnerability (proportion of the population taken by a unit of effort) increases as population size declines. Depensatory mortality could result from fishing in the same way as predation. Excessive exploitation could occur on some streams even with limited fishing pressure because a population decline had been started by previous overfishing or other causes.

On some accessible streams, overexploitation could prevent a population from recovering even under special regulations. Complete closure may be the only way to rebuild some stocks and reduce vulnerability. Lewynsky (1986) noted that special regulations are typically associated with a dramatic reduction in effort. He suggested that on accessible streams, a special regulation without the drop in effort could be ineffective. The density-dependent nature of exploitation should be studied further. Information similar to the Lochsa data we used should already be available for several populations.

Recruitment

Recruitment of juvenile cutthroat to a population will be a function of stock characteristics, the environment, and available habitat. Stock characteristics including sex ratio, maturity rates (spawning frequency by ages or size), number and size structure (influenced by mortality and growth), and fecundity will determine potential egg production and potential recruitment. Environmental, habitat, and biological factors that influence survival of embryo and early juvenile life stages will determine the realized recruitment. The latter will include both density-dependent and independent mechanisms. The stock-related data necessary to predict potential recruitment of westslope cutthroat trout are available.

Lukens (1978) summarized sex ratios ranging from approximately 2:1 to 1:5, male to females, for six adfluvial populations. Sex ratios typically were more heavily weighted toward females (average=1:2.6). Factors causing seasonal variability and generally higher proportion of females have not been documented. Differential rates of maturity and mortality, with variation in year class size could have some influences; however, Huston et al. 1984 found a higher female:male ratio in older age classes.

Rates of maturity are also variable both within and among stocks. Typically, cutthroat begin maturing during their third year, with virtually all of the population spawning for the first time by the sixth year (Behnke 1979; Bjornn and Liknes 1986). From available data, the majority of a population typically spawns for the first time at age 4 or 5 (Table 4). Causes of variation and differences in maturity schedules again are poorly understood. Both growth and genetic programming are

Table 4. Maturity rates (proportion mature at age) of westslope cutthroat trout. Data for Hungry Horse Creek, St. Joe River and Wolf Lodge Creek were summarized by Lukens (1978). Data for the Lower Coeur d'Alene River (Apperson et al. 1988) and that summarized by Lukens are predicted rates from age composition of spawners. Data for the Upper Coeur d'Alene River (Lewynsky 1986) and Middle Fork Salmon River (Mallet 1963) are actual proportions of maturing fish in population samples.

Population	Age 3	Age 4	Age 5	Age 6
Hungry Horse Creek	0.10	0.73	0.98	----
St. Joe River	0.18	0.88	0.98	----
Wolf Lodge Creek	0.00	0.03	0.65	0.90
Middle Fork Salmon R.	----	0.75	1.00	0.00
Upper Coeur d'Alene River[a]	0.13	0.14	0.60	1.00
Lower Coeur d'Alene River[b]	0.20	0.55	1.00	----

[a] Lewynsky (1986).
[b] Apperson et al. (1988).

TABLE4W

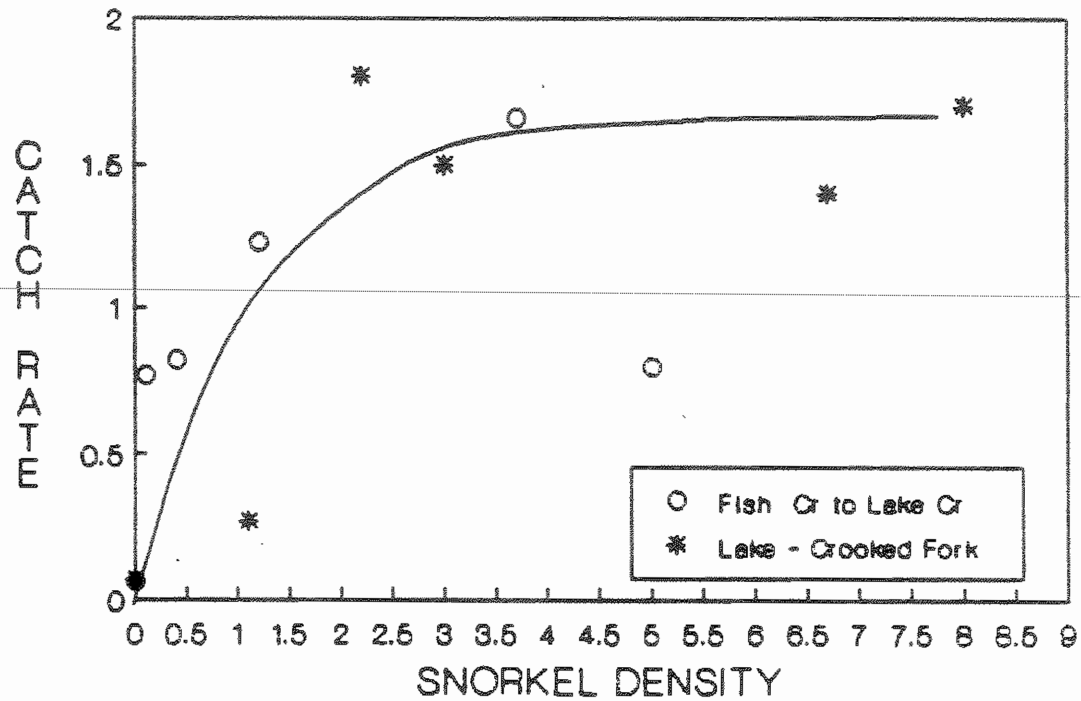

Figure 3. Relationship of catch rate (cutthroat/angler hour) and snorkel density (fish/transect) in the Lochsa River. The line was fit by inspection. Data are from Lindland (1982).

often discussed in salmonid biology. Ages at migration from natal stream to lake is correlated with age of spawning in some stocks (Lukens 1978); and in individual stocks, variation in growth may be important. Slow growing resident cutthroat, however, may mature at a similar age but much smaller size than fast growing fluvial or adfluvial stocks in the same drainage (Mauser 1972; Thurow and Bjornn 1978). Repeat spawning does occur in westslope cutthroat trout but seems rare. The documented contribution of second-time spawners is variable, ranging from 0.7% to 24% (May and Huston 1975; Huston 1972, 1973). Repeat spawning may occur predominately in alternate years (Liknes and Graham 1988; Bjornn and Liknes 1986). Data on maturity rates can be misleading since they are often collected by sampling a spawning run. Variation in year class size can strongly influence the age class components of any run. The most useful data come from directly sampling the population prior to spawning and noting the proportion of reproductively active fish in each age class.

Documented fecundities for westslope cutthroat trout range from 200 to about 2,000 eggs per female (Averett 1962; Johnson 1963 Smith et al. 1983). From a Montana broodstock (Smith et al. 1983), eggs per gram of body weight ranges from 1.6 to 3.5 ($\bar{x}$=2.3) and the gonado-somatic index (g eggs per kg body weight) ranges from 2.8 to 9.1 ($\bar{x}$=4.1). Using observations of individual cutthroat from the St. Joe River (Averett 1962) and the Flathead River (Johnson 1963), we fit a fecundity (E) length (L) relation of $E=3\cdot10^{-4}\cdot L^{2.57}$, with an r^2=0.88. Fecundity and reproductive effort in cutthroat appears similar to other salmonids. We could find no data demonstrating variability or differences in fecundity among and within stocks.

With available data on sex ratio, maturity rates, and on fecundity and observation or assumptions about growth and mortality, biologists can make reasonable predictions about reproductive potential. Simple models have been used to evaluate management alternatives to maximize recruitment in other fish populations (Prager et al. 1987). That approach has not been applied in cutthroat management. Such work could be useful where regulations are needed to rebuild depressed stocks as quickly as possible.

The factors influencing early survival and the difference between realized and potential recruitment are not well known for cutthroat. Compensation must exist, however, for any population to establish an equilibrium under changing mortality from other causes (i.e., exploitation). Density-dependent changes in early survival are well established for salmonids. In stream dwelling salmonids, early survival may be regulated by available habitat (Chapman 1966). When reproductive potential is enough to overseed the available habitat with juveniles, the surplus may be displaced and ultimately lost. The result may be a relationship between adult stock and realized recruitment resembling A in Figure 4, equivalent to a stock-recruitment curve (Ricker 1954). Early monitoring results from Kelly Creek suggest that numbers of juvenile cutthroat remained stable over several years, even though the adult population (and potential recruitment) was increasing under new catch-and-release regulations (see Chapman et al. 1973). Similarly,

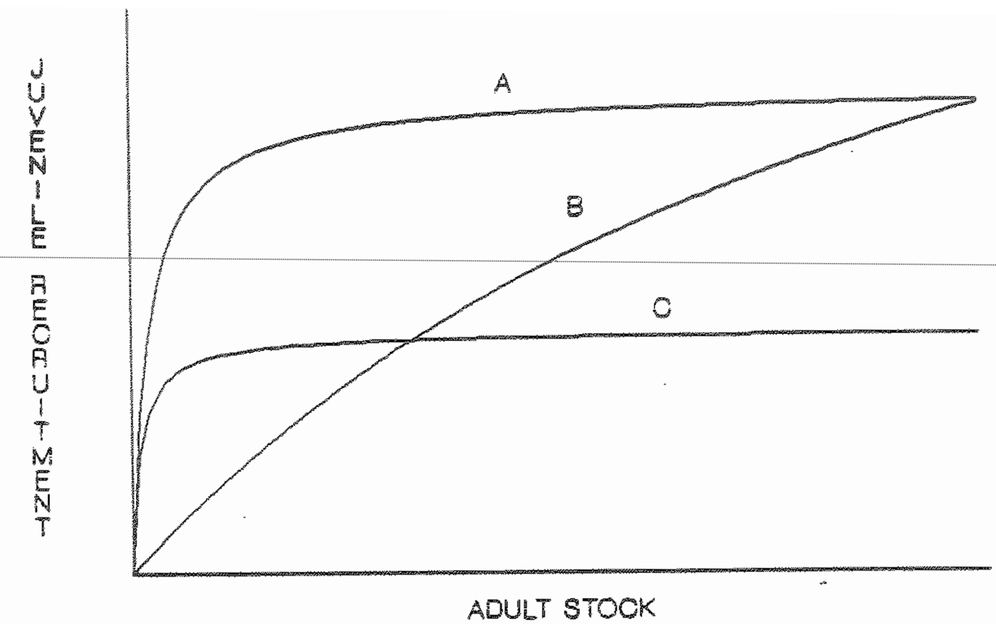

Figure 4. Hypothetical stock-recruitment relationships for westslope cutthroat trout. The different curves are discussed in the text. "A" represents a population in pristine habitat, "B" represents a population under heavy density independent mortality, and "C" represents a population where carrying capacity has been reduced.

relatively high numbers of juvenile cutthroat were common in the St. Joe, even though fish in excess of 12 inches were heavily exploited under the 13-inch minimum size limit. These circumstantial evidence suggest that a relationship similar to Figure 4A may exist for westslope cutthroat trout under some conditions. Such a relationship might be considered typical of resilient stocks, and very strong compensation in early survival (for example, see Ricker 1954; Goodyear 1980; Francis 1986). Bjornn et al. (1977b) suggest that compensation in cutthroat recruitment may not be strong because the St. Joe and Kelly populations declined under exploitation. We believe that compensation may actually have been very strong. The rapid growth of the St. Joe and Kelly Creek populations (which seemed to approach new and higher equilibrium) under special regulations could not occur without a productive recruitment response (see following section on population simulations).

Characteristics of the environment may directly influence the nature of cutthroat recruitment and the strength of the compensation that occurs. Density-independent mortality can alter the relationship between potential and realized recruitment. A general increase in early mortality should produce a less resilient response (Figure 4B) (Goodyear 1980; Ricker 1954).

Habitat changes can also influence the capacity of a stream for juvenile fish. A change of that sort should lower the asymptote in the recruitment relationship (Figure 4C). Stream channelization, increased bedload, and a loss of woody debris, associated with timber harvest and road construction, have resulted in lower habitat complexity in many northern Idaho cutthroat streams (Ned Horner, Idaho Department of Fish and Game, personal communication; Bob Rainville, U.S. Forest Service, personal communication).

Although stock or density-dependent recruitment relationships have not been demonstrated for cutthroat, we believe a relatively productive response is a reasonable assumption for westslope cutthroat trout in pristine habitat. We also believe that resilience and/or juvenile carrying capacity will decline with degradation of streams. The magnitude of the change with any given level of degradation is unknown. Given available models of fine sediment and embryo survival, new information on juvenile overwinter survival, available models of habitat quality, available population models, and the data necessary to predict potential recruitment, it may be possible to simulate changes in recruitment expected from at least some kinds of habitat alteration. To our knowledge no one has attempted to do that for westslope cutthroat trout. We used simulations to evaluate the relative importance of the stock recruitment function in recruitment and the need for further work (see next section).

Population Simulations

Management of westslope cutthroat trout has produced inconsistent results. Fishing regulations have caused dramatic responses in some populations but not in others. Regulations have typically been based on the perception of overfishing and general assumptions in population dynamics. Although heavy exploitation undoubtedly occurs, differences in population characteristics can obviously influence the relative importance of fishing in the population. Some attempts at regulation have considered growth and maturity data in the selection of size limits. Several authors have modeled westslope cutthroat trout populations (see Bjornn et al. 1977b; Horner et al. 1988; Cowley 1987; Mauser et al. 1988b), but none have examined the effects of errors in assumptions or parameter estimates. Better data on population dynamics can obviously lead to better predictions of population responses (to management). We used simulation analysis to examine available information and describe the relative importance of different population data to predictions of population response.

Our objectives for the analysis were:

1. To describe a range of westslope cutthroat trout responses to exploitation given the differences we expect in growth, maturity, recruitment, and mortality; and

2. To prioritize information on population characteristics needed to evaluate management alternatives.

Methods

We used a generalized population model, MOCPOP, designed for simulation of age-structured populations (Beamesderfer 1988). The model was an adaptation of Taylor (1981) with the exception that recruitment was stock-dependent, described by a Beverton-Holt function (Ricker 1975). Output provided annual summaries of total age or size-specific number, catch, and yield. Simulations could be run for any number of years. Required inputs were size-specific exploitation, growth (Von Bertalanffy coefficients), age-specific maturity rates, age-specific natural mortality, length-weight coefficients, length-fecundity coefficients, and recruitment-function coefficients.

We did not incorporate any density dependence in growth or mortality after the first age class in the model. Density-dependent growth has rarely been considered important in stream fishes and has not been documented in fluvial or adfluvial westslope cutthroat trout. We did incorporate density dependence in recruitment using the Beverton-Holt function in the model.

We used a simple sensitivity analysis to describe the influence of changes in key population characteristics. We held all parameters constant and independently varied coefficients for growth and rates of maturity, the recruitment function, and natural mortality.

We exploited each population, initially at equilibrium, at rates ranging from 0.0 to 0.90 for a period of 20 years. We assumed that all fish larger than 150 mm were equally vulnerable to fishing. We summarized results as the total population larger than 150 mm and the proportion larger than 300 mm. To standardize results among simulations, we present numbers at 20 years as a proportion of the unexploited number (population in equilibrium). We used our results to describe changes in number with increasing exploitation, time necessary for a population to recover from overexploitation (unexploited population growing from 10% to 90% of the unexploited equilibrium), and the influence of minimum size limits ranging from 250 to 500 mm. We used the differences in output resulting from change in the parameters as the measure of sensitivity.

Our parameter estimates were based on the data summarized from the literature (Table 5) and in the preceding section of this report. The high and low values of growth, mortality, and maturity were assumed to be representative of the upper and lower range anticipated for cutthroat populations. We used intermediate values for growth and mortality and high rates of maturity in initial simulations. To describe growth, we used the Von Bertalanffy models fit to the data shown in Figure 2. For mortality, we used the range (0.30 to 0.50) indicated in available data. We assumed maturity to be dependent on age and selected rates of maturity similar to the reported range (Table 4). We had no data to select a range of recruitment responses. We chose then to represent the recruitment functions with two Beverton-Holt models approximating Figures 4A and 4B. The difference in the two represents difference in the "resilience" of recruitment we might expect between populations in pristine habitat and those where significant degradation of habitat has occurred (see the previous section on recruitment). We used the former model in the initial simulations. Each simulation was started with a population at equilibrium under no exploitation. Natural mortality was constant among all ages after the first year, with the exception that no fish survived beyond age 8. Mortality during the first year was selected to produce a stable population in equilibrium with no exploitation and numbers at age 1 of 1,000. Each simulation was run until the population reached a new equilibrium, or 20 years. When a population failed to stabilize in the 20-year period, results were presented for that year.

Simulation Results

Harvestable number (fish ≥150 mm) declined with exploitation in all simulations, but results varied dramatically with the parameters we used. The change in number, as a proportion of the unexploited population, was most sensitive to changes in the recruitment function. The model was insensitive to changes in the rates of maturity and moderately sensitive to changes in mortality and growth (Figure 5).

Table 5. Parameter estimates used in westslope cutthroat trout population simulations.

Parameters for	Estimate or equation[a]	Source
Fecundity	$0.0003 * L^{2.57}$	Averett (1962) Johnson (1963)
Length-Weight	$W = (4.5 * 10^{-6})L^{3.14}$	Mauser (1972a) Hanson (1977) McMullin (1979)
Growth		
High	$L = 1600(1 - e^{-0.07(Age - 0.34)})$	This Report
Low	$L = 950(1 - e^{-0.06(Age - 0.34)})$	
Intermediate	$L = 1100(1 - e^{-0.06(Age - 0.20)})$	
Maturity Schedule		
Best	Age 3 = 0.15 Age 4 = 0.70 $\geq$ Age 5 = 1.00	This Report
Low	Age 3 = 0.05 Age 4 = 0.15 Age 5 = 0.70 $\geq$ Age 6 = 1.00	
Natural Mortality[b]		
High	0.50	This Report
Low	0.30	
Intermediate	0.40	
Recruitment A[c]		This Report
High	0.98	
Low	0.50	

[a] In each equation L = length in millimeters and W = weight in grams.
[b] Conditional natural mortality as a proportion assuming no other mortality is operating in the population.
[c] Coefficient for the shape of a Beverton-Holt recruitment curve (Ricker 1975).

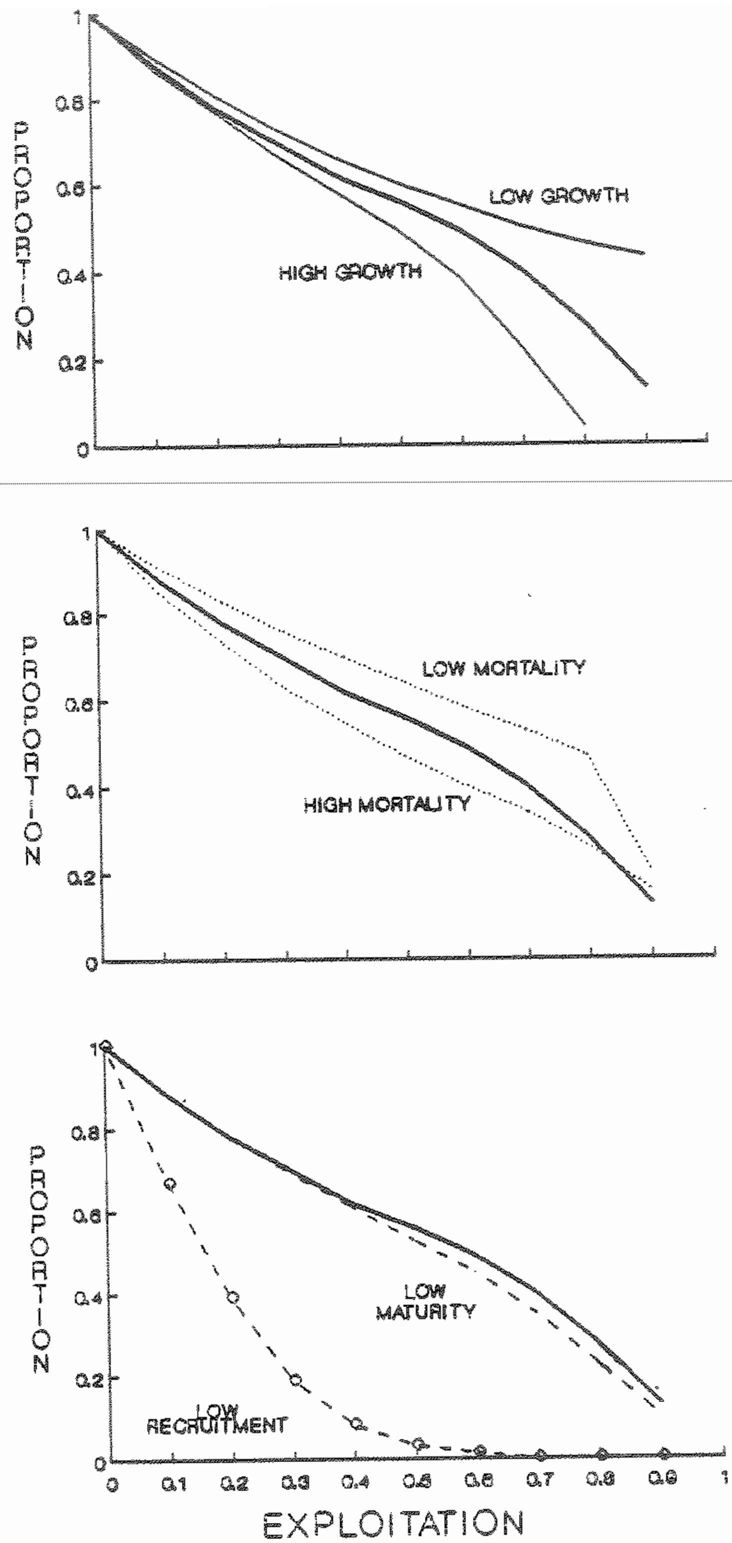

Figure 5. Simulations of westslope cutthroat trout number (proportion of unexploited population number) with varied growth, natural mortality, spawning frequency, and resilience in the stock recruitment relationship, under different levels of exploitation. The dark line shows a population with initial parameter estimates, the light lines show deflection of results with changes in single parameters described in the text.

In the base simulations, the population declined by about 65%, with exploitation of 0.80. Differences in mortality produced declines ranging from 50 to 70%. Differences in growth resulted in declines of 50% to 90%. The change in recruitment produced similar declines with much lower exploitation (0.20 to 0.40). Under low recruitment the population collapsed, with exploitation exceeding 0.60.

Higher growth and lower mortality produced populations more sensitive to exploitation. With faster growth, fish became vulnerable at lower ages. Under low natural mortality, the initial (stable) population was larger, and the additional mortality from exploitation was, relatively, more important.

Under low exploitation, simulations with high growth and low natural mortality resulted in populations up to three times larger than under opposite conditions (Figure 6). Given equivalent recruitment, fast growth and low mortality can obviously produce more fish available to fishing, but a population <u>less resilient</u> to exploitation (i.e., relative changes caused by exploitation will be more pronounced in a population with fast growth and low mortality than under the opposite conditions).

Growth and mortality had the most important influence on the structure of simulated populations (Figure 7). Results were moderately sensitive to recruitment only at high exploitation.

Recovery of depressed populations was almost entirely dependent upon the recruitment function (Figure 8). With high recruitment, no exploitation, and changes in growth, mortality, and maturity, it took 7 to 10 years for simulated populations to grow from 10% to 90% of unexploited numbers. Under low recruitment, it took more than 50 years to reach the same level.

Simulated responses to size limits were similar to those with varied exploitation. Results were again only moderately sensitive to changes in growth and mortality. Rates of maturity were more important than in other simulations. Under lower size limits (8 to 10 inches) differences in these parameters produced differences of up to 40% of the base population (Figure 9). Simulations under low recruitment again resulted in the largest differences (up to 65% of the base population). Differences among all simulations were less with higher size limits (Figure 9).

Discussion

Our simulations do not represent specific populations and cannot be used to guide management of any single stock.

They do show the range of responses to exploitation and management we can expect among our populations. Our data suggest that any two populations can respond in dramatically different ways.

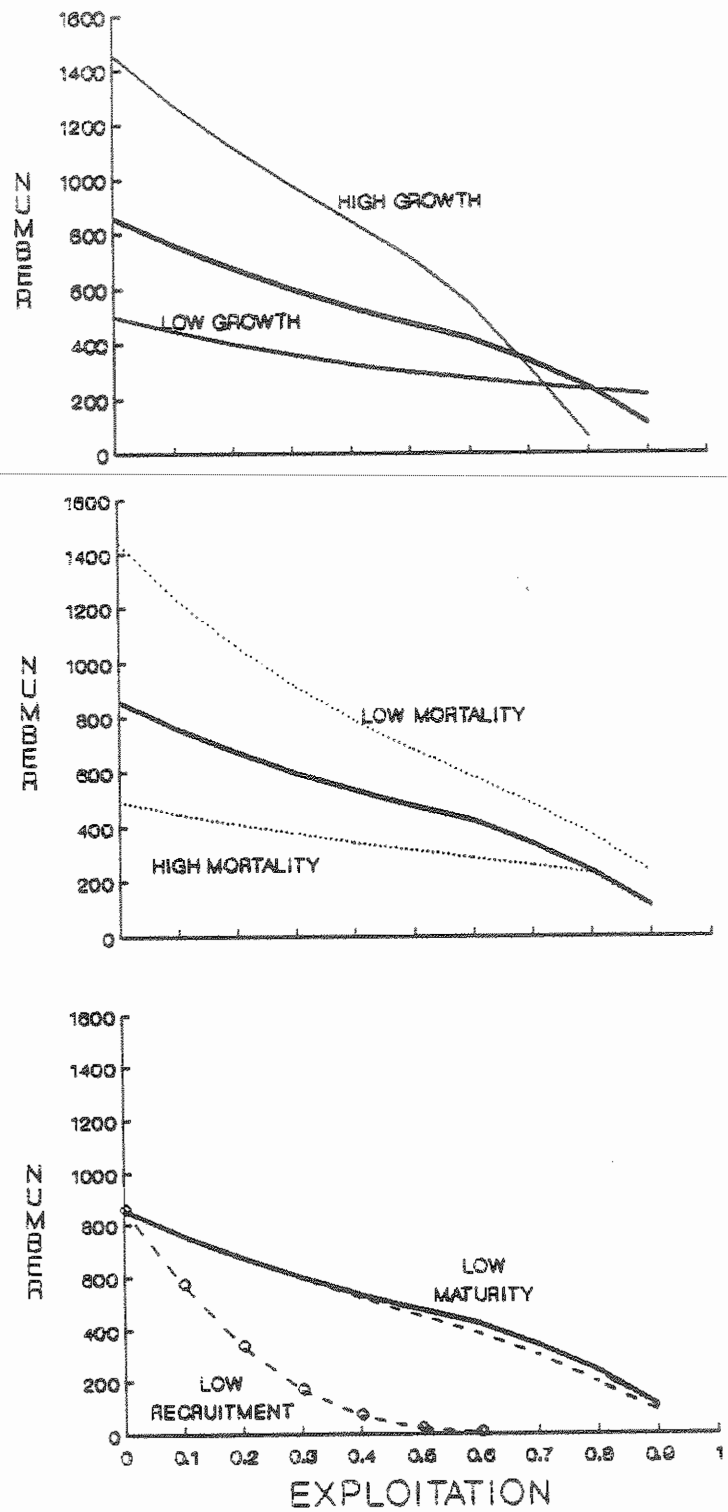

Figure 6. Simulations of westslope cutthroat trout number (absolute number) with varied growth, natural mortality, spawning frequency, and resilience in the stock recruitment relationship, under different levels of exploitation. The dark line shows a population with initial parameter estimates, the light lines show deflection of results with changes in single parameters described in the text.

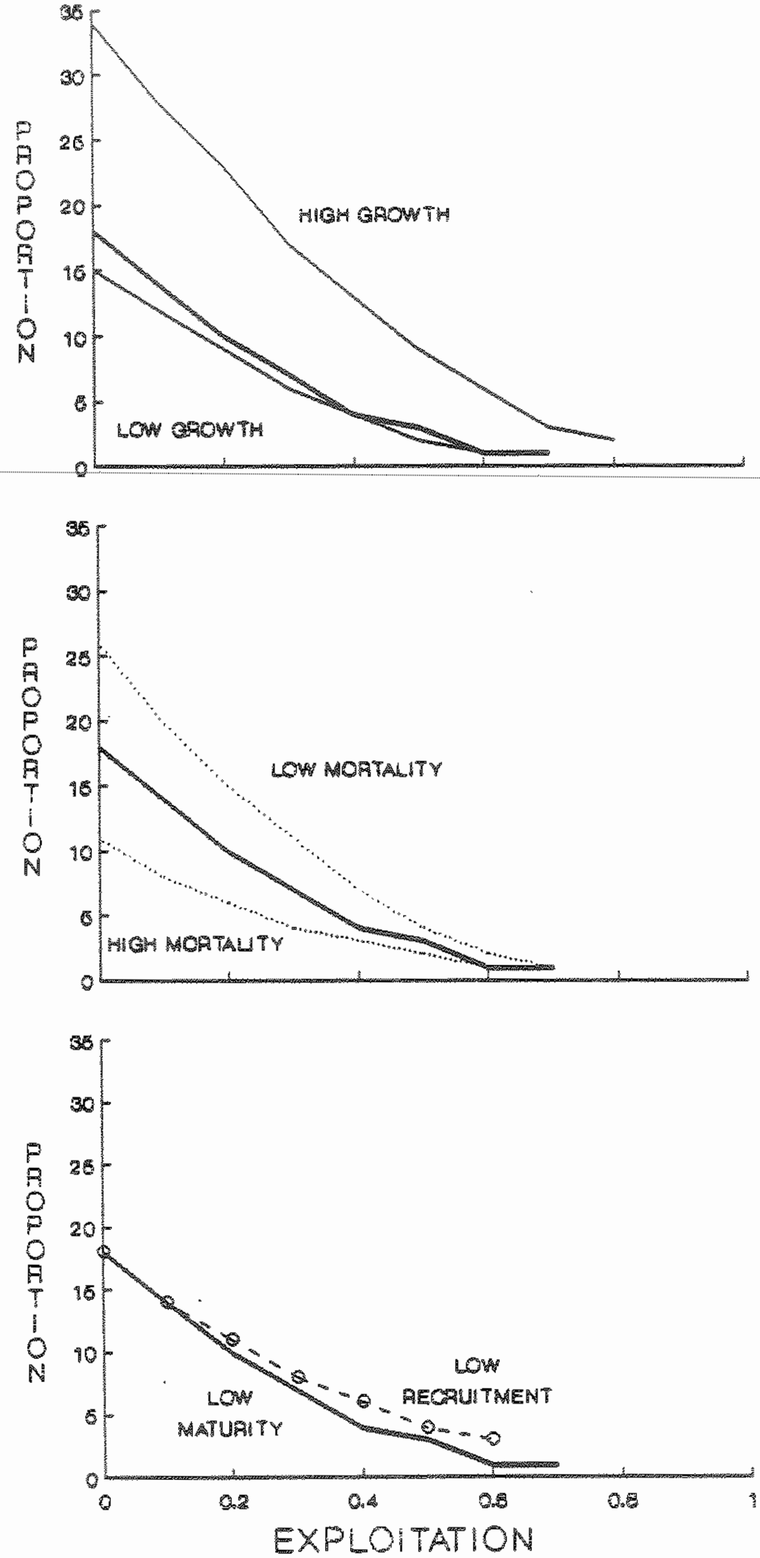

Figure 7. Simulations of westslope cutthroat trout population structure (proportion of recruited population that was larger than 300 mm) with varied growth, natural mortality, spawning frequency, and resilience in the stock recruitment relationship, under different levels of exploitation. The dark line shows a population with initial parameter estimates, the light lines show deflection of results with changes in single parameters described in the text.

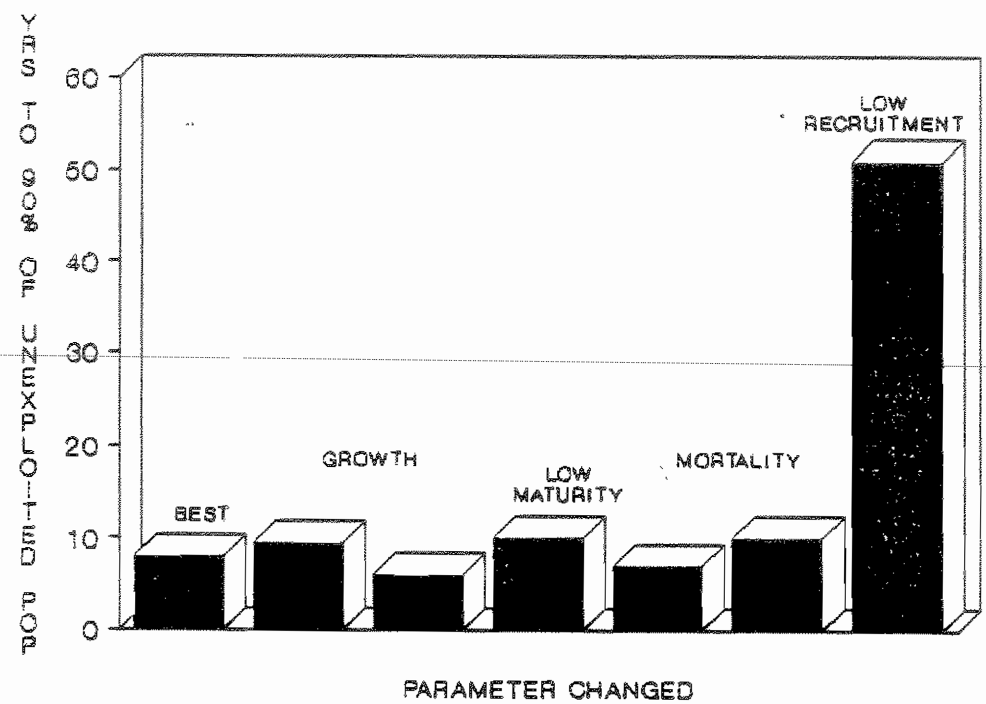

Figure 8. Simulated time (years) for westslope cutthroat trout populations to recover from overexploitation with varied growth, natural mortality, spawning frequency, and resilience in the stock recruitment relationship. Populations were exploited to 10% of the unexploited population size. Recovery was to 90% of the unexploited population size.

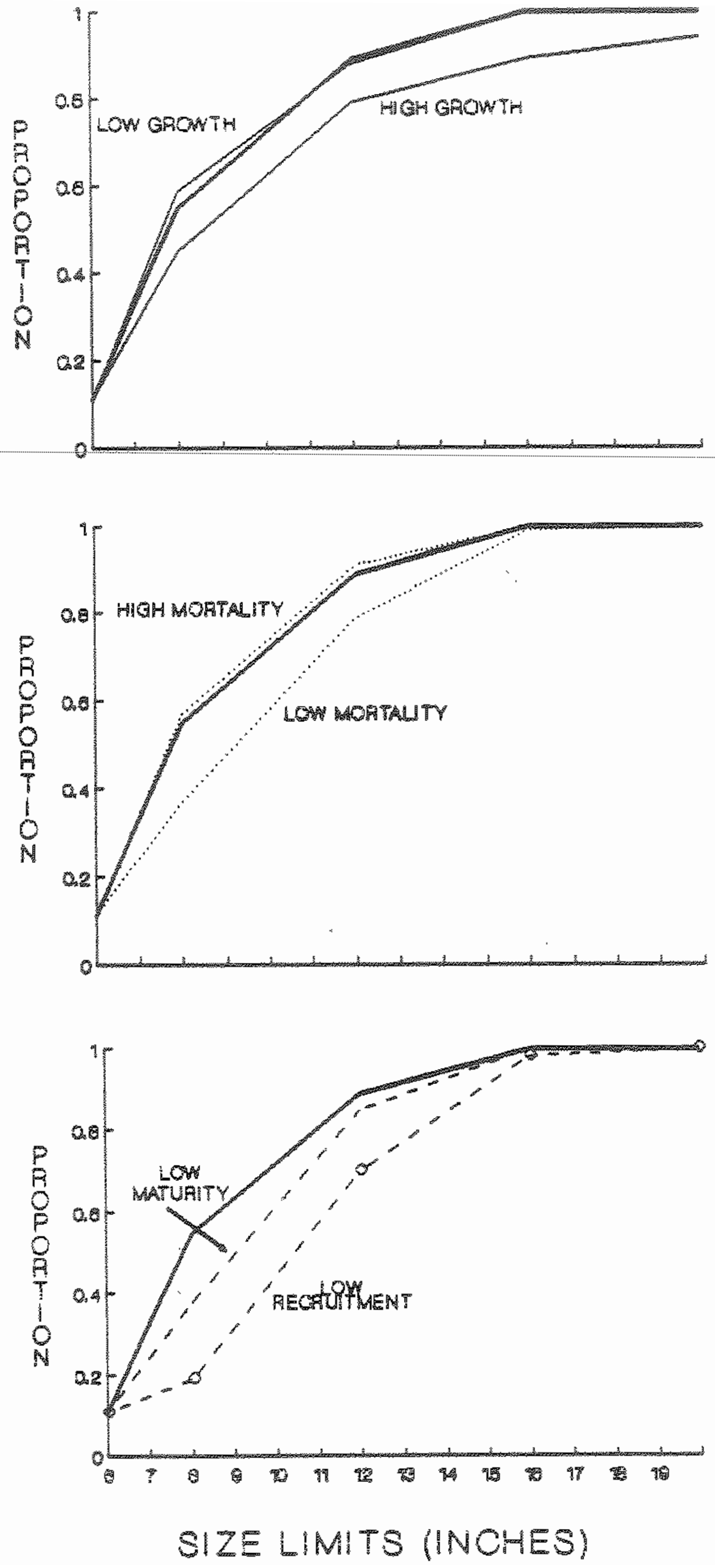

Figure 9. Simulations of westslope cutthroat trout population number (proportion of unexploited population) with varied growth, natural mortality, spawning frequency, and resilience in the stock recruitment relationship, under different minimum size limits in the fishery. The dark line shows a population with initial parameter estimates, the light lines show deflection of results with changes in single parameters described in the text. Exploitation was at a level that reduced the population to 10% of the unexploited numbers with no size limit.

Our results show that growth and mortality of westslope cutthroat trout is important to the absolute number and size of fish in the population. Productive waters should simply produce more large fish given the same recruitment. Our results suggest, however, that recruitment is by far the most important characteristic controlling any response to exploitation. Any decline in the strength of the recruitment function (resilience) will make the population more vulnerable to exploitation and greatly exaggerate recovery time under any regulation. Theoretically, changes in habitat caused by development can result in less resilient recruitment. Differences represented by the function in our simulations are not unrealistic. Extensive development might easily result in an response even less resilient than our lower function. Because cutthroat are so vulnerable to fishing, even very low effort could produce excessive exploitation. With substantial loss in resilience, it may be impossible to protect or re-establish some populations with any regulation.

A loss of resilience could explain the failure of special regulations on several populations. We have noted poor, or at least much slower than anticipated, responses of cutthroat to special regulations on Priest Lake (Mauser et al. 1988b), the Coeur d'Alene River (Lewynsky 1986; Cindy Robertson, Idaho Department of Fish and Game, personal communication), the South Fork Salmon River (Don Anderson, Idaho Department of Fish and Game, personal communication), and Hayden Lake (Gregg Mauser, Idaho Department of Fish and Game, personal communication). All of these drainages have suffered extensive habitat degradation. At the same time, we have seen dramatic recoveries in other drainages such as the upper St. Joe River, Kelly Creek, Selway River, and Big Creek (tributary to Middle Fork Salmon River). These drainages are, at least partially, in wilderness or undeveloped settings where habitat changes are probably less severe.

The recognition of recruitment as the dominant process for cutthroat management is important since it is the process we know least about. Virtually all of our work documents growth, and several projects have considered maturity and mortality rates. We know that exploitation can approach 70% or more, with relatively low fishing effort. We do not have any data documenting the recruitment process. We can speculate about the process as we have done here and safely conclude that it will be influenced by habitat degradation. We do not understand (or have not estimated) the loss of resilience expected with any degree of development, however. One reason we know so little about recruitment is the difficulty in actually measuring a response. Typically, a long time series with a highly varying adult stock is needed. A synthesis of existing habitat, sediment, and population models may provide an alternative approach. Better documentation of juvenile abundance and population response times in newly regulated drainages could also be helpful. The observations in Kelly Creek and the St. Joe suggest strong recruitment in drainages under nearly pristine conditions. Documentation of habitat conditions in those drainages and in others where populations have not responded could at least give us bounds for consideration in future management.

Summary

Growth of cutthroat varies substantially among populations. Variation and error in growth estimates have not been described within populations. Although growth can have an influence on productivity of individual stocks, the importance of observed and potential variation has not been evaluated.

We found few attempts to estimate mortality and its components. Experimental management has shown that fishing mortality can be high and can clearly limit populations. Causes of natural mortality are less well known, but fine sediment, catastrophic events, and predation could all be important. Changes in systems caused by habitat degradation and the introduction of new predators could result in higher natural mortality. Depensation in mortality caused by fishing and predation may result in collapse of some populations. Depensatory mortality could prevent recovery even with special regulations and artificial enhancement. Better information on the density-dependent nature of some mortalities may be critical to rehabilitation of some stocks.

We know very little about the nature of recruitment in westslope cutthroat trout. The biological data necessary to predict potential egg deposition (potential recruitment) are available. Information on both the density-dependent and independent mortalities between spawning and actual recruitment, however, are limited. Habitat can obviously influence both kinds of mortality. The decline in recruitment and loss of resilience in the stock-recruitment relationship associated with habitat degradation has not been demonstrated in wild populations.

Most of our information on population dynamics has been inferred from experimental manipulation of populations via regulations. Estimates of actual population parameters are few. Estimates (with the exception of growth) are usually difficult to obtain and can be of questionable accuracy. Manipulative research may be the best approach in understanding population responses.

Because the resilience in recruitment can so strongly influence the response to exploitation and management, it seems important to have better information. A decision of whether or not to implement new regulations or attempt an artificial enhancement (or reintroduction) should be strongly influenced by predictions of population response. Those predictions are virtually impossible without at least some judgment about the resilience in recruitment. If we can develop a reasonable assumption about recruitment, then additional data on growth, mortality, and rates of maturity will be useful in fine tuning our management predictions. If assumptions must be general, then any new management will be experimental in nature. We should be prepared for a wide range of population responses.

HATCHERY SUPPLEMENTATION

History

A variety of hatchery programs have been used for more than 50 years in attempts to enhance westslope cutthroat trout populations and fisheries. Westslope cutthroat trout were not identified as a subspecies in Idaho's hatchery planting records until 1981. Prior to 1977, however, production was minimal, with the possible exception of large egg takes in Priest Lake in the 1930s and 1940s. Between 1977 and 1982, production expanded dramatically with an enhancement program on Hayden Lake (Table 6).

Both fingerling and fry production have been used to augment wild populations in several large lakes (Bjornn 1957; Goodnight and Mauser 1978, 1979, 1980; Ellis 1983; Horner and Rieman 1985; Mauser et al. 1988), rivers (Walch and Mauser 1976; Gerry Oliver, British Columbia Fish and Wildlife Branch, personal communication), and reservoirs (Huston et al. 1984b). Fingerlings have also been used in attempts to establish new populations in Payette Lake and Deadwood Reservoir (Don Anderson, Idaho Fish and Game, personal communication). Region 1 of Idaho Department of Fish and Game has used fingerling releases to entirely support the cutthroat fisheries of several small lakes. "Catchable" size westslope cutthroat trout have not been used in Idaho.

Initial hatchery production was primarily of fingerling size fish, but production of westslope cutthroat trout fry expanded in the early 1980s (Table 5). Fry have been used to stock high mountain lakes throughout the state (Idaho hatchery records). Most fry, however, have been used in attempts to re-establish production in underseeded tributaries to Priest Lake (see Irving 1987 and Cowley 1987) (Table 6).

Montana is currently using hatchery production to re-establish pure-strain westslope cutthroat trout populations in drainages where introductions of non-native trout have resulted in severe genetic introgression (Allendorf and Leary 1988).

Hatchery production in Idaho, Montana, British Columbia, and Washington has been supported by wild spawning runs, hatchery-produced or naturalized spawning fish in "brood lakes," or captive hatchery populations. Broodstocks have developed from single populations (i.e., Kings Lake, Washington originally from Priest Lake) (Goodnight and Mauser 1979) and from a collection of stocks thought to have similar adfluvial characteristics (Goodnight and Mauser 1979) or to be genetically pure (Allendorf and Leary 1988).

Evaluations

Not all of the westslope cutthroat trout hatchery programs have been evaluated. Available results, however, show mixed success. In Priest Lake, spawning cutthroat were trapped, and some resulting production returned to the lake as early as 1940 (Bjornn 1957b). Releases of 400,000

Table 6. Numbers and total pounds of hatchery-reared westslope cutthroat trout planted in Idaho waters from 1977 to 1987. Hatchery data base is complete only after 1981, but virtually all previous production went to Hayden Lake.

Year	Fry	Fingerling	Adult[k]	Total pounds
1977	-----	30,000[a]	-----	-----
1978	-----	53,000[a]	-----	-----
1979	-----	54,000[a]	-----	-----
1980	-----	12,000[a]	-----	-----
1981	-----	135,000[a]	-----	-----
1982	25,400	441,000[b]	200	17,400
1983	9,300	480,000[c]	500	12,700
1984	444,000[d]	276,000[e]	175	9,500
1985	1,032,000[f]	271,000[e]	840	-----
1986	388,000[g]	342,930[h]	2,900	8,900
1987	840,000[i]	99,000[j]	2,000	6,600

[a] Hatchery data base incomplete; summary is for Hayden Lake only (Ellis 1983).
[b] 67% to Hayden Lake; 33% to Priest Lake.
[c] 57% in an unexplained release to the Pend Oreille River; 45% to Priest Lake.
[d] 67% to Priest Lake; remainder to mountain lakes.
[e] 100% to Priest Lake.
[f] 64% to Priest Lake; remainder to mountain lakes.
[g] 43% to Priest Lake; remainder to mountain lakes.
[h] 72% to Priest Lake.
[i] 72% to Priest Lake; remainder to mountain lakes.
[j] 49% to Priest Lake.
[k] Releases of spawned out broodstock in Region 1 lowland lakes.

to 800,000 fry of mixed origin (including Henrys Lake and Bear Lake) were made into the 1950s with no apparent benefit (Bjornn 1957b). Decline of the Priest Lake population might actually have been accelerated by hatchery intervention (Bjornn 1957b). Recognition of westslope cutthroat trout as a unique and locally adapted subspecies resulted in other programs to develop pure broodstocks. Cutthroat originating from several lakes in Idaho and Hungry Horse Reservoir in Montana were used to establish several broodstocks (Goodnight and Mauser 1979; McCall Hatchery, unpublished report 1987).

Idaho Department of Fish and Game released up to 300,000 fingerlings (~ 200/ha) annually into Hayden Lake from 1977 to 1982 (Ellis 1983). All releases more than doubled (hatchery fish = 59%) the catch of cutthroat from Hayden Lake. Although fishing was better than without hatchery support, a single release of 134,000 fish produced catch and harvest rates of only 0.12 and 0.04 fish/h, respectively (Ellis 1983). Harvest rates were substantially lower than catch rates because fishing regulations included a 14-inch minimum size limit. Most fish recruited to the catch were below the minimum size in the year of census. Total return to the creel was 0.6% (Horner and Rieman 1985). Survival from release to returning adult was estimated at 4% (Goodnight and Mauser 1980) to 0.8% (Horner and Rieman 1985). A minimum survival of 1% to 2% was considered necessary just to maintain a viable program (Horner and Rieman 1985).

In 1983, managers concluded that supplementation of a cutthroat fishery in Hayden Lake was not meeting program goals (Horner and Rieman 1985). Most production was shifted to Priest Lake in an effort to accelerate recovery of a seriously depressed stock. Releases of 39,000 to 420,000 (44/ha) fingerlings were made to Priest Lake from 1981 to 1987 (Mauser et al. 1988b). As in Hayden Lake, the releases substantially increased the total population (hatchery fish ≤64% of all first year cutthroat) in younger age classes, but hatchery fish virtually disappeared in older age classes. Estimated returns as spawning adults were very low (0 to 0.1%) (Mauser et al. 1988b). No hatchery fish were observed in the catch during systematic census. Priest Lake fishing regulations also included a minimum size limit. Gregg Mauser (Idaho Fish and Game, personal communication) believes that significant numbers of fish may actually have been available to the fishery during the first or second year of lake residence. Use of hatchery fish without regulations designed to produce quality fish or re-establish a spawning escapement (i.e., no minimum size limit) might produce a more reasonable fishery.

The Montana Department of Fish, Wildlife, and Parks stocked over 5 million westslope cutthroat trout fry and fingerlings in Koocanusa Reservoir and its tributaries between 1970 and 1982 (Huston et al. 1984). Hatchery fish made up to 60% of the total population and also supported catch rates ranging from 0.04 to 0.14 hatchery fish/h. Survival of fish stocked in tributaries was good (30 to 40% from YOY to yearling) and resulted in the establishment of new spawning runs. Estimated survival of smolt to returning adult in one tributary was also high (38% to 40%), but releases made directly into the reservoir supported virtually the entire fishery. Huston et al. (1984) concluded the hatchery augmentation was important to maintain the cutthroat fishery on Koocanusa Reservoir. Survival of hatchery releases and condition of fish apparently declined through the study, however (Huston et al. 1984b). Benefits of the hatchery program apparently were not sustained in the changing reservoir system. Competition or predation with growing populations of other fishes may have been important in the decline (Huston et al. 1984).

Cutthroat fry have been used intensively in some tributaries of Priest Lake. Releases were used to fully seed underutilized habitat and accelerate population recovery. Stocking densities of 500 to 1,000 fry/100 m^2 has established rearing populations (Irving 1987; Cowley 1987; Strach 1989). Introductions produced the best results in small streams (<5 m wide). Heavy stocking on top of established brook trout did not result in displacement of brook trout or any improvement in cutthroat survival. Stocking was most successful where brook trout were removed or naturally absent (Strach 1989). As yet, there is no evidence to show whether fry releases will result in adult returns and the re-establishment of strong natural production in the Priest Lake system.

Use of hatchery westslope cutthroat trout in large rivers has been limited. Walch and Mauser (1976) found only 0.2% of fish released in the St. Joe River were returned to the creel. Hatchery cutthroat released in the St. Mary River, British Columbia, apparently moved completely out of the system and did not contribute to any fishery (Gerry Oliver, British Columbia Fish and Wildlife Branch, personal communication).

Westslope cutthroat trout have been used extensively for mountain lake plants in Idaho since the early 1980s. Programs have shifted from other cutthroat strains previously used throughout the westslope cutthroat trout range. The change was made to protect the genetic integrity of populations lower in the stocked drainages. Over 200 different lakes have been stocked since 1984. The performance of westslope cutthroat trout has not been evaluated in comparison to other salmonids used in mountain lakes. Several fishery managers believe, however, that performance is good and better than for other stocks (Bert Bowler, Idaho Department of Fish and Game, personal communication). Fish are obviously surviving and growing well in some lakes (Bahls 1989).

Montana is currently engaged in an extensive program of cutthroat introductions intended to re-establish genetically pure populations (Allendorf and Leary 1988). The Montana Department of Fish, Wildlife, and Parks is stocking some areas in attempts to dilute non-native genes. Other streams will be eradicated and then restocked. No results are available on this program.

In general, hatchery programs have not been clearly successful, and the utility of supplementation is questionable. Fingerling production can produce significant increases in severely depressed fisheries. Overall survival in large lakes has been poor, however. Management goals will require very large hatchery programs that may not be cost effective, or substantial improvement in survival to adult or to the fishery. Questions regarding size and time of release have not been fully addressed. Mauser et al. (1988a) suggested that fingerlings larger than 150 mm survived at nearly 40 times the rate of smaller fish. Survival, even of large fingerlings (0.2%), however, was inadequate to produce a self-sustaining (i.e., no need for an outside egg source) program.

It is also unclear whether fry stocking can produce an increase in rearing numbers faster than natural recovery. In the Priest Lake drainage, Strach (1989) found a significant increase in rearing cutthroat density in a stocked stream compared to an unstocked control stream where brook trout were absent but not where brook trout were present. He also noted, however, a similar increase in cutthroat density in other unstocked streams where angling had been eliminated and brook trout were absent. He speculated that habitat in the latter streams was better suited to cutthroat than in the test streams (Russ Strach, University of Idaho, personal communication). We speculate that in appropriate habitat, angling restrictions and brook trout removal may result in cutthroat recovery as quickly as the addition of hatchery fish. Obviously such recovery would be dependent upon the presence of a viable population. We do no know what minimum viable numbers are necessary for a population to recover naturally. If the population drops too low (<100 pairs), genetic deterioration through inbreeding could hasten a decline. If cutthroat are absent or at extremely low densities, some stocking could be useful to furnish a seed population or increase genetic diversity. If moderate numbers are present, but lack the resilience to rebuild naturally when fishing is curtailed, we question whether support is useful.

Alternatives for the Future

The poor performance of hatchery programs could be related to the enhancement sites. Hatchery fish have been used primarily to re-establish or supplement populations in large (>2,000 ha) lakes or reservoirs, with limited or poor success. The native and introduced fish communities in those waters could seriously restrict survival. Predation by lake trout and northern squawfish is probably important (Mauser et al. 1988a; Huston et al. 1984), but competition, particularly with kokanee (Mauser et al. 1988b; Huston et al. 1984), might also play a role. Cutthroat introductions in smaller lakes with a less diverse (or barren) fish community seem to have fared better. Fishery managers in Washington use westslope cutthroat trout only in relatively small (<300 ha), barren, or reclaimed lakes. They believe that hatchery programs can sustain a fishery only where competition or predation is unimportant (Steve Jackson, Washington Department of Wildlife, personal communication). The broodstocks established in Kings Lake (23 ha) and Twin Lakes (120 ha), Washington, and Fish Lake, Idaho, are obviously successful. The mountain lake programs in Idaho also seem to be effective, and Idaho's Region 1 has had some success in small (<300 ha) lowland lakes (Ned Horner, Idaho Department of Fish and Game, personal communication). Re-establishment or maintenance of a primary fishery on large lakes may simply be infeasible given the existing fish communities. Hatchery programs to produce high quality cutthroat fishing opportunity might be better suited to smaller or less diverse lakes.

It may be possible to produce a reasonable cutthroat fishery on a limited "put-and-grow" or even "put-and-take" basis. If program goals are changed from reestablishing or augmenting wild production to simply providing cutthroat fishing opportunity, special regulations could be eliminated. Release of large fish to minimize natural mortality and time to recruitment could produce an acceptable fishery. That type of program has not yet been successfully demonstrated.

Hatchery fingerling production might also be better used to establish geographically restricted fisheries rather than to support entire systems. Available data in Priest Lake suggests that cutthroat move throughout the basin (Gregg Mauser, Idaho Department of Fish and Game, personal communication). On Coeur d'Alene Lake, however, concentrations of cutthroat, probably from a single spawning stream (Wolf Lodge Creek), support a spatially and seasonally localized and popular fishery. Development of similar performance with a hatchery-supported stock could maximize returns, provide the opportunity and diversity of cutthroat fishing, and not require the full seeding of a large system to achieve reasonable fishing success. Similar results might be achieved by educating anglers on the times and areas where hatchery cutthroat are most vulnerable and on the gears that are most effective.

Fry seeding might be a more efficient alternative to fingerling production in efforts to supplement fisheries of appropriate lakes (Cowley 1987). The feasibility of supplementation with fry needs to be demonstrated, however. The costs and benefits relative to the range of available release sizes (fry and fingerling) and times (see, for example, Hurne and Parkinson 1988) should also be established.

At present, fry production would seem best suited to reintroduction in streams where no wild recruitment is possible, but habitat is adequate to support a self-sustaining population.

The use of hatchery production to supplement westslope cutthroat trout populations and fisheries has been controversial, in part because of expense and relatively "poor" returns. Unfortunately, criteria defining a "cost effective" program have not been established. We suggest that fishery managers responsible for westslope cutthroat trout should develop objective and specific criteria for an acceptable hatchery program. A cost benefit approach could be one alternative. The average total economic value (travel cost and willingness to pay) for a fishing day in Idaho was estimated at $43.67 (Sorg et al. 1985). Production cost of fingerling cutthroat trout at the Clark Fork Hatchery is about $0.30 per fish (Mike Larkin, Idaho Department of Fish and Game, personal communication). If a program cost-to-value-produced ratio of 1:1 is necessary for an acceptable program, a fingerling release of 100,000 fish must support about 700 days (or 3,000 hours) of angling. By an alternative measure, if 1% of fish released are returned to the creel (similar or better than past programs), our cost of a fish in the creel is $30. If return is 5%, cost is $6 per fish. An acceptable cost per fish should be derived by comparison with other hatchery programs or some measure of the value of an individual fish in the creel.

Broodstock and Genetic Considerations

Genetic considerations are important in any hatchery program and could be the basis of poor results in Idaho. Reduced genetic variability resulting from a small founding population can seriously reduce growth, survival, and vulnerability to disease and other stress (Allendorf and Leary 1988). The original Montana broodstock was founded from 15 adult pairs. Within a few generations, the population was extremely inbred, exhibited developmental and survival problems, and a high frequency of bilateral asymmetry (Allendorf and Phelps 1980; Joe Huston, Montana Department of Fish, Wildlife and Parks, personal communication). Founding with 500 adult pairs has been recommended (Robb Leary, University of Montana, personal communication) and broodstock management should include periodic infusion of wild genetic material. Extreme care should also be taken to prevent selection by virtue of captive performance (Allendorf and Phelps 1980; Allendorf and Ryman 1987; Allendorf and Leary 1988).

Selection of an appropriate broodstock could also be important in attempts to re-establish self-sustaining production. Montana's new program of reintroduction emphasizes genetic purity and diversity. The new broodstock incorporates 12 geographically distinct populations and was founded with a total of 6,400 fish (Joe Huston, personal communication). The Montana broodstock was not selected on the basis of life history type and incorporates stocks of resident, fluvial, and adfluvial backgrounds. The Montana approach to life history diversity in the new broodstock is appropriate for a reintroduction in a number of different drainages where viable populations no longer exist. Performance of existing locally adapted stocks, however, might be compromised by such broodstock diversity.

Performance of stocks may be influenced by introgression and genetic diversity but also by local adaptation (Allendorf and Leary 1988; Reisenbichler 1988). Stocks of fluvial or resident cutthroat may perform well in streams but not in lakes. In British Columbia, use of an adfluvial stock in a large river failed, perhaps because fish emigrated from the system (Gerry Oliver, British Columbia Fish and Wildlife Branch, personal communication). An adfluvial population has failed to develop in Dworshak Reservoir, where much of the drainage supports strong resident and fluvial stocks (Bert Bowler, Idaho Department of Fish and Game, personal communication). The genetic basis of migratory behavior in westslope cutthroat trout is unknown. Specific and local adaptation, however, is well established in other fish. Maintenance of local adaptation is a primary goal in coastal steelhead management (ODFW 1986) and has been strongly endorsed by other fish geneticists (Kapuscinski and Philipp 1988). Much of the total genetic variability in westslope cutthroat trout occurs among, rather than within, populations (Leary et al. 1987), suggesting that relatively strong differentiation exists among populations. The use of a genetically distinct broodstock might hasten the decline of some depressed but locally adapted wild stocks. The intensive introduction of other stocks can dilute the wild gene pool and result in a loss of genetic variation and ultimately survival (Kapuscinski and Philipp 1988). Stock characteristics should be considered in broodstock selection. Research specifically designed to evaluate the genetic basis of life history patterns will be helpful. Whenever possible, hatchery programs designed to augment or rebuild a self-sustaining local population should be supported only by broodstocks developed from the local stock (Kapuscinski and Philipp 1988).

Idaho presently maintains two westslope cutthroat trout broodstocks. Both broodstocks have problems that make their use for supplementation of wild stocks questionable. Neither broodstock is genetically pure. Recent analysis indicates that the Clark Fork broodstock has about 0.3% introgression and the Fish Lake broodstock about 2% (Horner et al. 1987). Hatchery managers also report phenotypic evidence of hybridization in the Fish Lake stock (Rick Lowell, McCall Hatchery, Idaho Fish and Game, personal communication). Although fish from several wild populations have been added at random intervals, infusion of wild material has not been common or well documented. The majority of the founding stock came from a hatchery-maintained run in Kings Lake, Washington, which in turn was founded from fish out of Priest Lake in the 1940s. The present diversity of Idaho's broodstock has not been documented, but inbreeding and selection for captive performance is possible. The Clark Fork broodstock also suffers from chronic exposure to IHN and BKD.

Current westslope cutthroat trout broodstocks pose some problems for future management. The introduction of fish diseases to new drainages poses a clear risk and violation of Department policy. Use of heavily introgressed and inbred fish is also of questionable value where our intent is to re-establish wild cutthroat trout production. We have further argued that stock characteristics should be maintained (i.e., use of the local stock only) for supplementation of any important wild population. The genetic diversity and purity and disease problems can be solved within our current system. The hatchery program has already proposed to rebuild our broodstock with pure fish of broad genetic origin in a disease-free station or brood lakes. Obviously it is not possible to develop a separate broodstock for every depressed population we might wish to supplement. Economic and logistic constraints will limit Idaho to one or two broodstock programs. Considering the genetic risks and relatively poor performance of past hatchery programs, we suggest that the existing Idaho broodstocks or any new broodstock of broad genetic origin (many contributing stocks) not be used for intensive supplementation of depressed but still viable stocks. Production could be used for limited experimental evaluations in viable populations but not with the intent of restoring full seeding.

Current or future hatchery production should be used primarily for the maintenance of fisheries requiring complete hatchery support, or reintroduction of populations where natural wild recruitment offers no potential to support or rebuild a viable population. Broodstocks with limited introgression are acceptable where hatchery programs will not influence wild populations, but genetic purity should be emphasized in programs designed for supplementation or reintroduction of wild stocks.

Summary

Hatchery production of westslope cutthroat trout has been used to supplement fisheries on wild stocks in attempts to accelerate recovery of depressed populations and to establish or re-establish populations in barren or reclaimed habitat. Benefits from supplementation in large lakes have been marginal. Hatchery fish have produced substantial temporary increases in the total population. Relatively poor or declining survival, however, has resulted in modest catches and poor adult returns. Past programs did not appear to be biologically viable.

Substantial improvement in survival or more efficient use of hatchery fish will be necessary to justify supplementation programs on large lakes. New broodstocks should be considered, or at least compared, with existing broodstocks. Without much better survival, the best use of cutthroat supplementation may be through developing or publicizing spatially and temporally isolated fisheries and by stocking smaller lakes, barren lakes, or lakes with few potential predators and competitors. Maintenance of an acceptable cutthroat fishing opportunity with "put-and-grow" and "put-and-take" stocking may be possible but has not been demonstrated. Such programs will be most successful with a large size at release and no size limit in the fishery to minimize the time from release to recruitment in the fishery.

Use of hatchery cutthroat to re-establish viable populations is possible but has not been demonstrated through a complete life cycle in Idaho. Current efforts to accelerate recovery of cutthroat in Priest Lake tributaries and re-establish genetically pure populations in Montana should be fully evaluated before any new large scale programs are started. Further research should document the relative cost and benefits of different size and life stages used in reintroduction programs (i.e., are the best results obtained with egg, unfed fry, fed fry, or fingerling releases?) and clearly compare the benefits of hatchery production to natural recovery.

Care should be taken to maximize the genetic variability and purity of broodstocks and to minimize selection for hatchery performance. Wild fish should be brought into the broodstocks at regular intervals. Specific adaptation and life history characteristics should be considered in broodstock selection, but it is impossible to build a broodstock for every system we might supplement. Broodstocks of broad genetic origin or with measurable introgression should not be used to supplement important wild populations. Hatchery production should be used only for enhancement research and for maintenance or reintroduction in systems where natural recruitment cannot support a viable population.

Biological Results

Fishing can strongly influence westslope cutthroat trout populations. Cutthroat are more vulnerable to angling than other species (Lewynsky 1986; MacPhee 1966), and as a result, even limited effort can depress populations (see mortality under Population Dynamics section). Regulations designed to minimize fishing mortality have had dramatic effects on populations and fisheries.

Initial work on Kelly Creek and the St. Joe River showed that catch-and-release regulations on all or part of the population (minimum size limit) resulted in increasing cutthroat numbers (Ball 1971a, 1971b; Chapman et al. 1972, 1973; Bjornn 1975; Johnson and Bjornn 1978a). Following the initial change on Kelly Creek, restrictive regulations were imposed on a number of westslope cutthroat trout waters in Idaho, Montana, and British Columbia (Table 7).

The most common regulations have been catch-and-release and minimum size limits (Table 7). Gear restrictions (i.e., no bait) were usually part of the regulation. Other regulations include reduced bag, tributary closure, alternate year or temporary closure, and shortened seasons.

Catch-and-release regulations were followed by a modest increase in cutthroat number in the Middle Fork Salmon River (Jeppson and Ball 1979). Catch-and-release regulations on Kelly Creek (Johnson and Bjornn 1978), Rock Creek, Montana (Peters 1988), Big Creek (Anderson and Scully 1988), Lochsa (Lindland 1982), and the Selway (Lindland 1985) resulted in more dramatic population changes. Numbers of cutthroat increased 4 to 13 times within 10 years (Table 7). Relative size structures shifted toward larger (>300 mm) fish. Angler catch rates increased with numbers. In Kelly Creek, estimates of total mortality declined (Johnson and Bjornn 1978). Similar results followed a 13-inch minimum size limit on the St. Joe River (Johnson and Bjornn 1978), though large fish were not as prevalent as in catch-and-release waters.

Bag restrictions have not had obvious effects on populations (Radford 1977; Johnson and Bjornn 1978), but very restrictive limits (i.e., one fish) have not been studied. Closures have also produced population increases (Radford 1977; Thurow and Bjornn 1978; Martin and Bell 1984; Lewynsky 1986). Benefits to populations under closure, however, have been short-lived when fishing was reopened (Martin and Bell 1984), or when habitat was degraded (Apperson et al. 1988).

Table 7. Summary of westslope cutthroat population and fishery responses to special regulations that have been evaluated.

Water	Special regulation	Years since regulation	Response: Cutthroat number	Response: Catch rate	Response: Effort	Comment	Reference
Kelly Creek, Idaho	C & R no bait	5	+1200%	+550%	-80%		Johnson (1977) Johnson and Bjornn (1978b)
N. Fk. Clearwater, Idaho	3 fish bag	3	----	no change	no change		Johnson and Bjornn (1978b)
St. Joe River, Idaho	13 in. min. no bait	5	+400%	+780%	-10%	Few fish >300 mm in the catch	Johnson (1977)
	3 fish bag	10	+500%	----			Petrosky (1984)
		11			+500%		Horner and Rieman (1984)
	trib. closure	3	+20%	----	----		Thurow (1976)
							Apperson et al. (1988)
M. Fk. Salmon River, Idaho	C & R no bait	8	+160%	----	----	Number >300 mm increased about twofold	Jeppson and Ball (1979)
Lochsa R., Idaho	C & R; no bait	5	+470%	+100%	-60%		Lindland (1982)
Selway R., Idaho	C & R; no bait	7	+300%	----	----		Lindland and Cannon (1981)

TABLE7WCT

Table 7. Continued.

Water	Special regulation	Years since regulation	Response: Cutthroat number	Response: Catch rate	Response: Effort	Comment	Reference
Coeur d'Alene River, Idaho	13 in. min. no bait 3 fish bag	7	no change	no change	no change	Effort did not change but surrounding area increased	Lewynsky (1986)
	C & R no bait	3	+150%	----	----	No changes in numbers >300 mm	Horner et al. (1988)
Big Creek, Idaho	C & R no bait	4	----	+400%	----		Anderson and Scully (1988)
Rock Creek, Montana	closure	2	+118%	----	----		Peters (1988)
Daly Creek, Montana	closure	2	no change	----	----		Peters (1988)
Teepee Creek, Idaho	C & R no bait	3	-70%	----	----		Horner et al. (1988)
Priest Lake, Idaho	15 in. min. 2 fish bag	2	no change	----	----		Mauser et al. (1988)
	trib. closure	4	no change	----	----		Cowley (1987)
St. Maries R., B.C., Canada	closure	2.5	----	no change	----	Mean size increased but population was quickly depleted following reopening	Martin & Bell (1984)

TABLE7WCT

Restrictive regulations may be necessary to sustain most cutthroat populations. Fishing effort associated with overexploitation on Kelly Creek, and the St. Joe, Lochsa, and Coeur d'Alene River populations was 100 to 200 h/km (Lewynsky 1986). Johnson and Bjornn (1978) believed that without special regulations, these populations would eventually have been fished to extinction. Effort on less accessible populations in Big Creek, Middle Fork Salmon, and Selway might have been even lower, but still resulted in depressed populations. Recent effort on roaded sections of the St. Joe and Coeur d'Alene rivers ranged from 500 to 1,500 h/km (Horner and Rieman 1985). Areas stocked with hatchery catchables can receive even higher pressure. Cutthroat are still present throughout many large rivers under general regulations. Some cutthroat may find refuge even in isolated segments of individual streams that generally receive heavy pressure (Thurow and Bjornn 1978; Tim Cochnauer, Idaho Department of Fish and Game, personal communication). However, some isolated populations accessible only by air or trail show signs of significant decline under general regulations (Bert Bowler and Don Anderson, Idaho Department of Fish and Game, personal communications). In the future, we may find it difficult to maintain even these isolated stocks without some form of restrictive harvest regulation.

Restrictions on cutthroat harvest have not always been effective. Populations have not responded or have responded weakly to regulation changes on Teepee Creek (Lewynsky 1986; Region 1, Idaho Department of Fish and Game, unpublished data), the Coeur d'Alene River (Lewynsky 1986), North Fork Coeur d'Alene River (Lewynsky 1986), Priest Lake (Mauser et al. 1988), and Hayden Lake. Reasons for regulation failures are not clear, but explanations include angler noncompliance (Lewynsky 1986), habitat loss (Horner and Rieman 1985; Mauser et al. 1988), inappropriate size limit for existing growth and maturity (Horner and Rieman 1985), and excessive exploitation of fish that migrate out of river reaches under special regulation (Horner et al. 1988; Apperson et al. 1988; Jim Lukens and Jim Davis, Idaho Department of Fish and Game, personal communications). Lewynsky (1986) suggested that cutthroat may be so vulnerable to fishing that some populations could be overexploited even under special regulations. Because a few anglers can remove a significant part of the population, noncompliance or handling mortality might represent excessive fishing mortality. Because fishing pressure typically declines under special regulations, it is impossible to tell whether the positive population responses (i.e., Kelly Creek, St. Joe, Lochsa, etc.) were the direct result of releasing fish or of reduced effort.

All of the above mechanisms can have some role in failure of regulations, but the excessive vulnerability of cutthroat is important. Cutthroat may become more vulnerable at lower densities (see Population Dynamics section on exploitation). If so, declining populations could be fished to extinction (Johnson and Bjornn 1978). Some depressed populations might never recover under any regulation. Fishing may, in effect, become a predator trap (Peterman 1977). Some cutthroat populations may require complete closure to rebuild, while some may never support any fishing at all. Other populations that have increased dramatically under special regulations could begin declining again as fishing pressure increases in response to better fishing (Lewynsky 1986). Limited entry might even be necessary to maintain extremely popular cutthroat fisheries.

Sociological Results

Restrictive regulations, even when they work, can create some problems. In all documented cases, fishing effort declined or did not increase as in adjacent waters (Lewynsky 1986). The composition of anglers has also changed (Johnson and Bjornn 1978; Lewynsky 1986). Obviously, some anglers are displaced by new regulations. Reasons include a reluctance to change gear (Gordon 1970; Lewynsky 1978) and the obvious desire to harvest fish. Despite an increase in numbers and size of fish, the result can be a net loss in social and even economic value if some segment of the angling public is displaced (Lewynsky 1986).

Lewynsky (1986) argued that management goals behind special regulations have been poorly defined and often confused. The primary goal may be either rehabilitation of a population or an increase of fishing opportunity. Some form of both are used, often together. If fishing opportunity is the primary goal, our management may be failing even when populations and catch rates increase. Results of regulations that are not adoptable by the existing angling public can be noncompliance (and perhaps failure biologically as well), lost fishing opportunity, lost license sales, increased exploitation of other waters, and lost agency credibility. In some cases, new regulations have incorporated extensive public involvement (Bjornn 1975). Typically, some form of angler preference is sought (Bowler 1974; Horner and Rieman 1985; Mauser et al. 1988). These efforts are easily biased, however, and are often poorly designed (Lewynsky 1986). The trade-offs in social and economic values and their implications for management of westslope cutthroat trout have not been seriously studied.

The characteristics of westslope cutthroat trout create a management paradox. As a native wild stock, westslope cutthroat trout receive management priority. They are best suited to the relatively sterile waters of their range, and no other species offers a more productive alternative, short of hatchery catchables. Cutthroat are easily caught and are preferred by many anglers. Populations cannot support heavy pressure, however, and very restrictive regulations are, or will be, necessary to maintain most strong populations.

Regulations designed to protect cutthroat can displace anglers and eliminate other fishing opportunity. Unless we find new alternatives, managers are faced with the choice of either allowing many cutthroat stocks to disappear or of restricting angling opportunity. Efforts to manage cutthroat can conflict with management of other stocks. Rainbow trout and other species are less vulnerable and can support higher effort. Use of hatchery fish often results in very high effort. Effort supported by hatchery catchables could overexploit westslope cutthroat trout (Petrosky 1984). Mixed-stock management favoring cutthroat can result in gear restrictions, underutilization of other fisheries, and thus, lost opportunity.

Management Alternatives

Cutthroat-specific regulations have been implemented in Idaho's Region 1. It is not clear, however, whether this type of regulation is workable. Walch and Mauser (1976) thought anglers could easily differentiate rainbow trout and cutthroat trout while Bjornn (1975) felt they could not. Anglers unsure of species identification might again be displaced. Complex regulations could again alienate some anglers and affect agency credibility, especially if regulations fail. Extensive angler education may be necessary to insure proper identification, understanding of regulations, and compliance. Even with public acceptance, hooking and handling mortality could be excessive without gear restrictions.

Other alternatives for management of wild cutthroat have not been clearly evaluated. Alternatives that provide some consumptive opportunity might include the following:

1. Stream or lake zoning. Special regulations in Idaho typically involve a major (>40 km) part of a river or drainage basin. Much smaller areas have often been used in other states (Lewynsky 1986). Smaller regulation areas could be focused on the most productive, least accessible, or most critical habitats. A diversity of management areas could provide a diversity of angling opportunity and reduce displacement and noncompliance. Such regulations could work only where fish movement is restricted and predictable and angler education is possible. Special regulation areas could add some angling diversity where local cutthroat populations persist in an otherwise depressed drainage. Russ Kiefer (Idaho Fish and Game, personal communication) believes some tributaries of the South Fork Clearwater offer such potential.

   Persistence of cutthroat in isolated reaches or areas of otherwise heavily fished systems (i.e., Upper Priest Lake, upper St. Joe, upper Marble Creek, Wolf Lodge Bay of Coeur d'Alene Lake) suggests that such an alternative can work.

2. One-fish bag limit. Bag limits usually have little influence on harvest, but very low bag limits have not been evaluated. A one-fish limit probably would not sustain a strong population but might at least allow some populations to persist. Evaluation of new bag limits in Region 1 are, unfortunately, confounded by new size and season restrictions.

3. Rotational closure. Managers in British Columbia considered a systematic closure (for one to two years) of half the streams in a drainage (Al Martin, British Columbia Fisheries Branch, personal communication). After evaluating a single stream, they concluded that the stockpiling from a short closure was quickly eliminated in the first year of fishing (Martin and Bell 1984). The approach will not allow maintenance of "quality" fishing. It might provide enough protection, however, to at least maintain populations that would otherwise be eliminated.

4. Public and angler education. An intensive program of public education could improve the recognition of westslope cutthroat trout from other trout and the understanding of population and habitat constraints. Education might also build the intrinsic value some find in ecologically distinct and unique species. Public recognition of westslope cutthroat trout as a species of special concern might be more effective in encouraging nonconsumptive fishing than regulations alone, particularly where mixed-stock management is necessary. That recognition might also build public support for better habitat management.

Methods of Evaluating Regulations

Status and changes in cutthroat populations have been described with a variety of methods. Typical approaches include monitoring project catch rates (i.e., Bowler 1974; Johnson 1977; Johnson and Bjornn 1978a; Lindland 1982; Anderson and Scully 1988), snorkel index transects (i.e., Chapman et al. 1973; Bowler 1974; Lewynsky 1986), snorkel estimates of absolute abundance (i.e., Thurow 1985), and size structure of the catch or population (as estimated from snorkeling and hook-and-line sampling).

Although the methods seem straightforward, they have not been clearly standardized or evaluated. Data are not reported in a consistent fashion among projects, or even within long-term monitoring programs. We found it difficult to compare estimates in single systems over time or among systems. Snorkel counts, for example, may be expressed by transect, by transect length, by snorkeler, or by surface area. Methods are seldom described or referenced in monitoring or inventory projects. They can include one or two snorkelers, counting upstream or downstream, in counting lanes, or in random searching patterns. Transects are either fixed and replicated annually, or randomly selected by habitat type or stream reach.

The accuracy of different methods is a concern. Statistical considerations were rarely reported. Snorkel counts can vary dramatically within a season (Lewynsky 1986 Idaho Fish and Game, unpublished data for the St. Joe and Coeur d'Alene and Middle Fork Salmon rivers), among seasons (Idaho Department of Fish and Game, Region 1, unpublished data; Don Peters, Montana Department of Fish, Wildlife, and Parks, personal communication), and with environmental conditions. Catch rate data are often strongly biased (Lewynsky 1986) and highly variable (Parkinson et al. 1988). Without appropriate replication and analysis, our results can be useless to detect anything but long-term trends or dramatic population responses. This can pose a problem for management where evaluation of regulations requires decisions on shorter time frames. For example, the Coeur d'Alene River management proposal committed the Department to re-evaluation of regulations at five years. Without some understanding of sampling and population variability, we may not conclude whether the population is not responding, or responding as might be expected, given environmental limitation (see Population Dynamics). We might not make an important distinction about failure in the program because of problems with the regulation and/or noncompliance, or severe habitat degradation.

Standardized methods and preservation of data could help future cutthroat evaluations. Lewynsky (1986) provides a good example of experimental design and discussion of sampling limitations. Parkinson et al. (1988) presents a standard approach to sample allocation and consideration of detectable changes. Chapman et al. (1973) and Lewynsky (1986) describe snorkel techniques for index counts, and (Scully unpublished) describes methods for absolute estimates.

We suggest that in the future all estimates should be made on an areal (fish/100 m^2) basis. A consistent reporting format would allow comparison of densities among populations and perhaps the development of realistic seeding goals. In some cases, bias may exist in the total estimates because of difficulty in sampling the entire stream. Methods can be adjusted to compensate for known bias, however, and typically errors are relatively small if sampling conditions are good (Rohrer 1989). Even if bias is significant, the errors should be systematic and consistent within a particular stream and should provide the same results for monitoring long-term trends as index counts. Monitoring data should also be recorded on a standardized and available data base. In many cases all of the data for a single population were not available in a single document, making the analysis of population responses or trends difficult or impossible for anyone but the "keepers of the data." As personnel change, we face a real risk of lost or inconsistent data. The River's Data Base provides an easily accessible and appropriate format for westslope cutthroat trout data. The anadromous parr monitoring work (C. Petrosky and R. Scully, Idaho Department of Fish and Game, personal communications) is an excellent example of the maintenance and application of such information. All research and management projects that sample westslope cutthroat trout should make a regular summary of results on the data base a priority. Minimum data should include:

1. Stream reach - identified by EPA reach number
2. Transect identification
3. Stream width

4. Transect surface area -
5. Total cutthroat number -
6. Number by appropriate size groups - (we suggest <100 mm, 100-300 mm, and >300 mm
7. Habitat types
8. Gradient zone.

Information on other species and habitat characteristics could also be valuable. The "core data" set outlined by Petrosky and Holubetz (1986) could be incorporated in all sampling with little additional effort. Comparison of cutthroat densities among streams can provide useful perspective about the status and potential of a given stream. Several biologists in Idaho strongly urged a summary of existing westslope cutthroat density estimates as part of this report. As we've just discussed, inconsistent methods and reporting procedures limit the use of much of the existing information. Several streams have been censused in consistent fashion, however, and some index counts have been extrapolated to density estimates (Table 8). Available estimates are for mainstem rivers or major tributaries and could be considered representative of holding areas for subadult and adult (≥age 2) fish. The highest densities were in streams under catch and release regulations with relatively pristine habitat and may approach the potential of these systems.

Management Experiments

All new regulations are really management experiments. Catch-and-release regulations on the Coeur d'Alene River were conceived as an experiment to test whether habitat or fishing limitations were more important (Horner and Rieman 1985). Unfortunately, poor responses in some areas may still be confounded by angler noncompliance, and/or by exploitation of migrating fish outside the regulation area (Horner et al. 1988). We may never be able to estimate noncompliance mortalities or habitat relationships precisely enough to conclude what is really regulating or limiting a population. Projects designed to provide the estimates may be expensive and long-term. A simple closure experiment similar to that evaluated by Lewynsky (1986) could provide answers far more efficiently. New management should consider similar experiments wherever several factors may confound a population response. Such an approach might be used to determine whether downriver fishing on winter aggregations is a significant limitation on adfluvial cutthroat in the Middle Fork Salmon and Coeur d'Alene rivers. It could be used to determine whether habitat really limits cutthroat in the Coeur d'Alene River, or whether any population has the compensatory reserve to respond to fishing regulations.

Table 8. Densities of westslope cutthroat trout in Idaho streams and rivers, estimated from snorkeling or approximated from snorkel trend counts. Approximations assumed that trend counts actually represented complete counts, and used approximate stream widths and measured transect lengths to estimate transect area. Counts represent primarily age 2 or older cutthroat and should be representative of holding area for subadult and adult fish. All streams with the exception of the Little N. Fork Clearwater are under special regulations.

Water	Approximated Density (fish/100 m^2)	Source
Lochsa River[1]	0.5-0.8	Bert Bowler, Region 2
Selway River[1]	1.8-2.2	Bert Bowler, Region 2
Cayuse Creek[1]	1.5-7.0	Bert Bowler, Region 2
Little North Fork Clearwater R.[1]	0.3-0.6	Bert Bowler, Region 2
St. Joe River[1]	4.0	Charlie Petrosky
Middle Fork Salmon R.[2]	0.2-0.5	Jim Lukens, Salmon
Middle Fork Salmon Tribs.[2]	0.5-7.0	Jim Lukens, Salmon
Big Creek (Middle Fork Salmon)[2]	0.5	Scully and Anderson 1989

[1]Approximations expanded from trend data.
[2]Densities estimated by routine snorkel methods.

Summary

Because cutthroat are very vulnerable to fishing, regulation of harvest is an important management tool. With increasing fishing effort and declining habitat, few, if any, populations will persist without special regulations. In some cases, limited entry might be necessary to maintain very popular fisheries.

The failure of some regulations shows that our understanding of cutthroat population dynamics and angler dynamics is incomplete. Failures can be costly, resulting in lost populations, lost fishing opportunity, and lost credibility with the public. Better information on cutthroat population regulation could lead to better prediction of population response (see section on Population Dynamics). Predictions will always be uncertain, however. Recognition of new regulations and evaluations as management experiments could reduce the time necessary to understand population limitations.

Better understanding of sociological trade-offs is necessary to allocate resources and minimize conflicts. Sociological research has been beyond the scope of most fish and game management. New work will be necessary to determine whether new regulations can really increase fishing opportunity or other management goals. Management goals must be more clearly defined. Some measure of net benefit among all anglers is necessary.

Managers are faced with difficult decisions of eliminating some fishing opportunity, eliminating some wild populations, or developing new management alternatives. New alternatives include zoning, very restricted (1 fish) bag, rotational closure, and intensive education.

Methods of evaluating regulations are not standardized, and limitations of data are poorly documented. Consistent collection and presentation of data and consideration of the precision and bias in results will help future evaluations. All data should be summarized on consistent and readily accessible data base.

DISCUSSION AND CONCLUSIONS

Westslope cutthroat trout provide a unique and valuable fishery resource for northern-central Idaho. Adaptation to a relatively sterile and harsh environment make them better suited than many other species. Vulnerability to anglers makes them readily available. We believe that westslope cutthroat trout represent an important management alternative in many Idaho waters, and the only alternative in some. As the dominant native wild trout in northern Idaho, westslope cutthroat trout represent important intrinsic and ecological values, and are given management priority through Department policy. Recognition as a species of special concern and indicator species make them an important and politically sensitive environmental barometer.

Westslope cutthroat trout have not fared well throughout the native range. Most stocks have declined dramatically, though some have recovered under recent management. The biological and related fishery problems are complex, and in some cases, poorly understood. We find clear evidence, however, that populations can be strongly influenced by overexploitation, habitat degradation, and genetic introgression. Predation and competition might also be important. To effectively manage westslope cutthroat trout, managers must minimize the effects of each factor. That can be done, but clearly the potential to manage cutthroat is limited throughout much (most?) of the historic range.

Restrictive regulations have worked effectively on some waters where suitable habitat is available, and population declines are tied only to fishing. Regulations have created social conflict and displaced some anglers. In some waters, restriction of harvest and angling method is presently unacceptable to much of the public. Restrictive regulations have and will be ineffective in reducing harvest in some cases because of noncompliance. Restrictive regulations may restore populations in other areas but at the cost of lost angler participation. Restrictive regulations will be most successful where anglers support wild trout management and where populations are not strongly influenced by other factors.

With increasing effort and improving access to all waters, special regulations will be necessary to maintain any population. Catch-and-release fishing has been the most effective regulation. Catch-and-release may be the best option for most waters, but other alternatives should be evaluated where some harvest opportunity seems important. Alternatives should include very restrictive bag limits (1 fish) and stream zoning. In "mixed-stock" waters, new alternatives are necessary to minimize social conflict and lost opportunity. Species-specific regulations are unproven and should be carefully evaluated. Because no regulations are likely to be effective without public support, angler and public education should be a major emphasis in future management. Better compliance and protection of populations can probably be achieved by building public awareness and support for westslope cutthroat trout than through regulation alone.

Habitat degradation has been extensive and will undoubtedly continue. Restoration of habitat through natural recovery is possible. Habitat might be enhanced through use of artificial structures, but we find no evidence to support such a conclusion. The extensive migration of some populations and our poor understanding of habitat relationships mean that maintenance of diverse habitats or whole systems is the best hedge for maintenance of populations.

We do not understand the relationship between land use and lost stream capacity or stock resilience. We believe it is clear, however, that any change in stream complexity and sediment load represents an important risk. In priority westslope cutthroat trout waters, we should strongly oppose any development resulting in those changes. Wilderness management obviously provides the best alternative for minimizing habitat loss. A wilderness designation should be strongly supported wherever westslope cutthroat trout are the fisheries management priority. Development is unavoidable in many drainages. In those cases, special emphasis should be placed on the protection of small tributaries that may serve as trout spawning and early rearing areas, and as storage areas for sediment.

Because we cannot clearly demonstrate the loss in fisheries potential with land use, fishery managers have had a difficult time influencing land use decisions. Useful relationships between land use and fish habitat characteristics have been developed for streams on the Idaho Batholith. Similar models should be developed for streams in belt geology. Relationships between habitat characteristics and resulting fish populations or potential populations have not been clearly shown in the wild in any geologic type. Research demonstrating links between habitat and fishery potential, or directly between land use and fishery potential, should be a priority.

Interaction with other fish is common and will continue throughout the range. Genetic introgression, competition and predation are often aggravated by our attempts to diversify fishing opportunities or increase yields. Introgression is common throughout the range and is probably most important where non-native rainbow trout have been heavily stocked, primarily through "catchable" programs. We should expect hybridization in headwater areas where rainbow trout or Henrys Lake cutthroat trout have been used in mountain lakes. Introgression could represent a serious loss of genetic variation and the performance of wild stocks. A policy of no introduction of other trout should be emphasized in all waters where westslope cutthroat trout are the priority. Where hatchery catchable introductions are likely to overlap with important westslope cutthroat trout populations, we should consider the use of sterile or fall spawning rainbow trout, or domesticated westslope cutthroat trout. A genetic inventory should be completed for all important westslope cutthroat trout populations. Initial genetic information would identify populations with the best potential for management and provide a baseline to monitor introgression in important stocks.

Interaction with other species has probably been most important with adfluvial, and perhaps some fluvial, westslope cutthroat trout stocks. The establishment of potential predators and competitors has been most common in lakes. Introduced rainbow trout typically become established in the lower reaches of a drainage, and "catchable" stockings are often heaviest along the most accessible and heavily used main stem areas. Kokanee have been introduced, have flourished and are intensively managed in most lakes. Habitat losses and development that can make cutthroat more vulnerable to negative interactions are also common in lower elevation and more populated areas. Rehabilitation of adfluvial westslope cutthroat trout will be extremely difficult. Maintenance or restoration of adfluvial cutthroat populations should be emphasized on small barren lakes or those with few potential predators or competitors.

If we can deal with the problems of exploitation, habitat, and interaction with other fishes, restoration of depressed or remnant westslope cutthroat trout populations and fisheries may be possible in some parts of the range. Reintroduction with hatchery-produced fingerlings has not been effective. Stocking of hatchery fry has established some rearing fish. We have not shown that fry stockings produce fish that survive to adult or that stocking can rebuild a population faster than natural production. Maintenance of a fishery through indefinite stocking may be possible but again has not been demonstrated in large lakes. Failures in hatchery programs could be the result of an overly domesticated broodstock, inappropriate size and time of release, or predation and competition. Future work with hatchery fish should focus on the development of a new broodstock. Fingerling release programs should test the performance of larger fish, and fry stocking programs should evaluate performance of fed versus unfed fry. Fry stocking should be limited to reintroduction programs and maintenance of mountain lakes. Fry stocking should be made only in barren or reclaimed streams. Fingerling programs should be experimental only, until acceptable returns can be shown. Fingerling production should be restricted to small lakes (less than 2,000 ha) where limited numbers will have the greatest benefit and will be easiest to detect. Stocking should be limited to barren or reclaimed lakes, or those with few potential predators and competitors, until acceptable returns can be shown in larger lakes.

Hatchery programs based on broodstocks of broad geographic origin, limited genetic diversity, or with significant introgression might actually reduce the diversity or fitness of locally adapted but depressed wild stocks. Hatchery supplementation should not be used in any wild stock that has the potential to recover naturally.

In some cases, westslope cutthroat trout populations have failed to respond to management, or have responded at a level lower than anticipated. In most cases, we cannot determine whether the poor performance is due to inappropriate management (wrong regulation, inappropriate broodstock), or some other environmental (inadequate habitat, competition, predation) or social (noncompliance, increasing effort) constraint. Our knowledge of population dynamics, habitat relationships and anglers is too limited to sort out all of the confounding interactions and effects. In some cases, our understanding of westslope cutthroat trout systems might progress faster with large scale experimental management. For example, we have evaluated special regulations on the Coeur d'Alene River for 15 years. We are still unsure whether poor response in the population is due to angler noncompliance, overharvest of migrants outside regulated sections, or inadequate habitat. The potential for the population to respond or the effect of downstream harvest could be conclusively tested by closing key areas to fishing for several years. Although closure may be politically sensitive, information gain and ultimately better or more realistic management of a system could occur much faster. The resulting benefits to the angling public might be substantially higher than through long-term mechanistic research.

Any management must rely on an ability to monitor populations. Present methods provide trend data that are useful in individual systems. Data can be highly variable, however, and may be strongly influenced by environmental conditions and time of year. Monitoring targeted for other species also may not accurately represent westslope cutthroat trout populations. Data typically are not comparable among systems, and densities representative of strong or depressed populations are not clearly defined. We should develop standardized methods for monitoring populations throughout Idaho. Densities should be expressed on an areal basis, and stratification by habitat type and time of year should be clearly defined. All available data should be summarized on the River's Data Base to facilitate long-term monitoring and comparison among populations.

Clearly, strong westslope cutthroat trout populations or fisheries cannot be maintained throughout the historic range. We believe further loss of strong populations, however, represents an important loss of fishing opportunity, of genetic variation, and of the intrinsic, ecological and political value of native wild populations. We suggest the first priority for management of westslope cutthroat trout should be maintenance of existing strong populations. Every effort should be made to control exploitation, habitat loss and genetic introgression in those waters. In the remaining "strongholds", management of other species should be secondary to that of westslope cutthroat trout.

In other areas, management of westslope cutthroat trout will require some difficult decisions. Managers must weigh the loss of native wild populations against the social conflict, lost fishing opportunity, and economic cost of mixed-stock or intensive management. Current policy dictates that, "Native wild stocks of resident trout will receive priority consideration in all management decisions involving resident fish." Several managers feel further policy direction is necessary to guide decisions where wild westslope cutthroat trout management is in conflict with other programs. At what point do we give up on the native stock?

Current discussions within the Department suggest that the point of decision should be when we can no longer expect a fishery for westslope cutthroat to persist or become available in the future as a result of our management (i.e., complete closure is not an option if it will not lead eventually to a fishery). The problem is that in many cases we are not able to predict the viability of populations or fisheries with any certainty. Managers still carry the burden of "pulling the plug on the native stock" when it might still persist. We encourage fishery managers and biologists with experience in, and responsibility for, westslope cutthroat trout management to work together to develop specific and objective criteria for this decision.

We suggest two alternatives for management of cutthroat outside existing strongholds. The first would continue management or restoration attempts of cutthroat on a priority basis. This alternative should be restricted to waters where mixed stock management is not important, where special regulations are socially acceptable and where habitat is thought to be good enough to maintain fishable populations. This type of management need not be restricted to large river systems. It could incorporate single streams, or sections of streams and lakes, where localized populations persist. Maintenance of isolated "cutthroat waters" could provide an important diversity in angling opportunity.

The second alternative would make cutthroat management secondary to other programs. In many cases, the extinction of populations will occur. With further development, hatchery programs could support limited fisheries and provide some angling diversity, but should not be expected to rebuild populations. Species-specific regulations might also be used to sustain remnant populations. We believe, however, that regulations alone will not protect depressed or remnant populations either because of angler noncompliance or misidentification. An angler education program might provide better success. We suggest that public education emphasizing the unique characteristics of cutthroat identification and proper handling and release of fish should be part of any species-specific regulation, or should be used in place of restrictive regulations in secondary-priority waters. Because of the confusion with complex regulations, and potential frustration among anglers, a cutthroat education program might actually provide better protection for depressed or remnant stocks and better credibility with the public than species-specific regulations.

Adfluvial westslope cutthroat trout populations in the large northern Idaho lakes will be the most difficult to restore. Loss of existing populations may mean the loss of unique characteristics and genetic variation. Other populations could be established in other lakes that are more suitable. Some of the Stanley Basin lakes, or other lakes and reservoirs in the Idaho Batholith, could be candidates for a "gene banking" program.

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