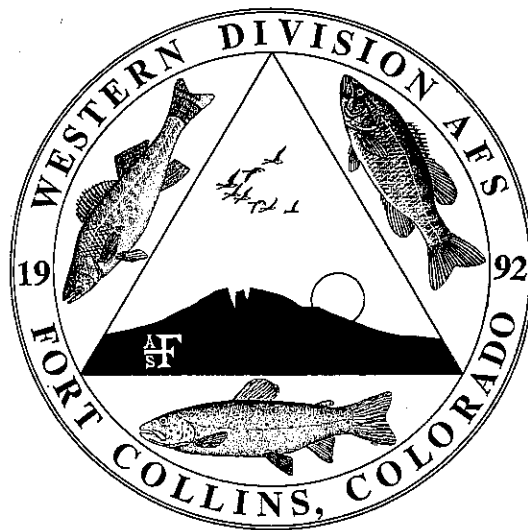


**WESTERN DIVISION  
AMERICAN FISHERIES  
SOCIETY**

**JULY 13-16, 1992**

**PROGRAM ABSTRACTS**



**AMERICAN  
FISHERIES  
SOCIETY**



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**Environmental Uses of Water: Is the Existing Legal Framework Adequate?**

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The ecological values of water have begun to command the recognition of the legal system in recent years. Almost totally neglected in the past, the uses of water for such things as support of fisheries now are routinely considered in water rights decisions. Subject to a number of important limitations it may even be possible to establish some kind of "right" or other legal protection for water necessary to maintain a fishery in a stream or lake.

These developments, important as they are, promise much more than they deliver. The range of environmental uses of water considered is far too limited. Protection of coldwater fisheries dominates other considerations in most cases. Inadequate attention has been given to riparian values dependent on streamflows, to the water necessary to maintain wetlands, and to the biota in a water-centered ecosystem. Not only are too few uses considered, but also too few interested in these uses can participate in decisions about what gets protected and how it gets protected. For the most part these are the carefully circumscribed decisions of politically sensitive state agencies.

In a word, existing law is inadequate. This presentation will raise, in a general way, the limits of existing law and suggest the kinds of additional developments that are necessary to place environmental uses of water on a par with other uses.

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### **Instream Flow Protection in the Western States: Current Status and Future Challenges**

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The protection of instream resources in the West is generally accomplished through statutes, regulations, and policies that allow certain entities to reserve unappropriated water for instream flows. While nearly every western state has adopted one or more of these approaches, their implementation varies considerably from state to state. Additionally, existing instream flow protection is relatively junior to other water rights in the western continental states and may actually provide little if any instream flow protection. The exception is Alaska (with approximately 40% of the Nation's fresh water), where the majority of water still remains unappropriated. There, some question whether existing laws and traditional approaches to water appropriation will be sufficient to safeguard against the overappropriation of water experienced by other states.

Existing instream flow water allocation measures do not address what may be the most important flow issues in the western states:

1. how to increase inadequate instream flows in overappropriated streams, and
2. how to ensure that instream flows are acquired and protected in water bodies where overappropriation has not yet occurred.

Several western states are addressing these issues by experimenting with mechanisms that allow certain entities to acquire, through purchases or leases, existing out-of-stream senior water rights for instream uses. Others are attempting to find solutions through litigation. The innovative leasing and market-based policies provide the opportunity to increase flows in dewatered streams through cooperative transactions. The litigation approach appears to challenge existing policies. Recent experiences suggest several challenges to implementing these new policies and approaches for the future of instream flow protection in the West.

### **Protecting Instream Flows in Riparian Doctrine States: A Preliminary Assessment**

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The purpose of this research is to identify state-level institutional factors that affect the implementation of state instream flow laws and programs. These factors include perceived severity of the problem, presence of instream flow protection advocates in state fish and game agencies, the degree of fiscal dependence on state legislatures on the part of the fish and game agencies, degree of coordination and cooperation among the various agencies responsible for instream flow programs, public support, and agreement on appropriate methodology for quantifying flow requirements. While other factors undoubtedly influence policy implementation, states with independent and vocal fish and game agencies that maintain cooperative relationships with other responsible state agencies, and those with strong public support for instream flow protection, seem to be more successful in protecting instream flow values than are their less active counterparts.

### **Protecting Instream Flows on National Forest Land in the Intermountain Region**

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Forest Service policy is to determine the amount of water needed for instream and standing water purposes for adjudications, land management planning, and water development projects. Policy also calls for the Forest Service to claim instream flows for channel maintenance purposes under authority of the Organic Administration Act of 1897. Instream flow claims under other authorities such as the Multiple-Use Sustained-Yield Act of 1960, the Wild and Scenic Rivers Act, or the Wilderness Act require consultation with the Chief and the Office of the General Counsel. While the Forest Service needs instream flows to accomplish its multiple-use mission as directed by Congress, the Forest Service mission and state law collide when it comes to instream flow.

Three states in the Intermountain Region have instream flow laws: Idaho, Utah, and Wyoming. Nevada has a Supreme Court decision that arguably creates an instream flow right. The three statutory laws apparently restrict an appropriation of instream flow to the state itself, generally a wildlife or recreation agency. The Forest Service has been encouraged to use state law, yet on its face the state law would doom any such effort to failure. Forest Service efforts to get instream flows through state adjudications have so far been unsuccessful.

The Forest Service has other options at its disposal through its occupancy permitting authority and its authority to impose conditions on Federal Energy Regulatory Commission licenses. But that does not protect stream reaches that have substantial areas of non-National Forest land upstream, nor does it meet the demand to use state law. How this basic conflict will be resolved is unclear.

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### Limitations of Federal Reserved Water Rights

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Federal reserved water rights are created when federal lands are withdrawn or reserved from the public domain for a specified federal purpose if water is necessary to fulfill the primary purpose for which the land was reserved. However, legal, political, and technical factors tend to limit the effectiveness of federal reserved water rights as a means of fully protecting natural systems. Western states regard federal reserved rights as an encroachment on the states' prerogatives to allocate water and on private rights. Consequently, the courts tend to construe the reserved rights doctrine very strictly and will probably continue to do so. Federal reserved rights are not an effective means of resolving conflicts between federal water projects and other federal interests. There are also problems in quantifying water rights for natural systems. For example, one of the purposes of a national park is to keep it in an unimpaired state. How do you determine the timing and amounts of water required to keep a national park "unimpaired"?

### Summary of Damages to the Fisheries of Alaska as a Result of the *Exxon Valdez* Oil Spill

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The March 1989 *Exxon Valdez* oil spill discharged approximately 11 million gallons of crude oil that contaminated marine habitat. In Prince William Sound, all Pacific herring and 75% of wild pink salmon spawn in the intertidal zone, the most heavily oiled habitat. In affected areas of Prince William Sound in 1989, herring suffered greater than usual egg mortality and a large increase in abnormalities (primarily eye tumors) in embryos and larvae. These abnormalities were also observed in 1990, but at a lower rate. Preliminary analysis of data indicates a 70% greater mortality of pink salmon eggs in oiled areas in 1989 and a 50% greater mortality in 1990. Pink salmon larvae from heavily oiled areas also showed gross morphological abnormalities, including curved spines and club fins. Eggs and larvae of wild populations of pink salmon continue to be exposed to oil in intertidal gravel. Because of the spill, the commercial harvest of sockeye salmon was curtailed in 1989, which allowed an overescapement of sockeye to reach the Kenai, Skilak, Red, and Akalura lake systems. Sockeye salmon suffered poor survival to the smolt stage, which is predicted to result in smaller returns in 1993 and 1994 and possible reductions or closure to the commercial and sport sockeye fisheries.

***Exxon Valdez* Oil Spill: Overview of Impact Studies from Auke Bay Fisheries Laboratory**

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In March 1989, the *Exxon Valdez* oil spill became the dominant habitat issue in Alaska. Within 1 week of the spill, Auke Bay Lab had field crews working in Prince William Sound sampling water and sediments. Eight damage assessment studies were initiated focusing on determining oil contamination in water, sediments, and tissues and biological damage to juvenile pink salmon, bottomfish, and Dungeness crabs.

In 1989, areas sampled prior to spill impact were pristine. Pink salmon growth was less in oiled areas than in un-oiled areas, and oil-contaminated pink salmon fry were found.

In 1990, there were strong indications of recovery occurring in the sound. Cleaning by the Exxon Valdez crews and natural cleansing were effective in eliminating the visible oil from the beaches. However, hydrocarbons were detected at the deeper depths 1 and 2 years after the spill.

Although the sound looked clean, there continued to be troubled areas. The highest concentrations of oil in sediments and tissues were found in oiled mussel beds 2.5 years after the spill. There appears to be linkage with damage in other species.

In 1992, the settlement with the Exxon Corporation precluded the need for studies to support litigation. Restoration of the sound is the current goal, with significant efforts in management of the harvested species and land acquisition of critical areas.

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### Walleye Semen Collection, Preservation, and Storage

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The goal of this research project was to develop approaches and methods for the collection and short-term preservation of walleye *Stizostedion vitreum* semen on a large scale. Male walleye were most effectively collected by trap-netting in shallow water (1-2 m). Most fish (78%) were collected at water temperatures over 6°C, and the ratio of males to females in the catch was inversely related to water temperature. The most efficient dosage of MS-222 for anesthesia prior to stripping was 99 mg/L, which averaged 211 s in immobilization time. Average amount of milt produced per fish from first, second, and third strippings of 154 fish was 3.1, 1.3, and 0.5 mL, respectively. Plastic sandwich containers were judged to be the most desirable storage vessel at a volume of 24 mL of extended semen per container. A semen extender ratio of 1:2 produced an average hatching rate at the Wray Fish Hatchery of 46.0% versus 74.6% for fresh semen. Differences in hatching rates for extended versus fresh semen may be a function of storage procedures and quality control. Semen extender ratios of 1:6 and 1:10 yielded 72-h fertilization rates of 46.1% to 62.8% in experimental petri dish lots. Evaluation of shelf-life (d) and motility time (s) of nine treatments rendered the following guidelines for use of extended walleye semen: (1) extended semen containers should be stored in an ice bath at approximately 1-2°C and re-oxygenated on a daily basis; (2) a semen extender ratio of 1:2 at 4.0 mL/L of eggs is recommended; (3) water or fecal contamination during preparation of extended walleye semen must be avoided to prevent significant decreases in storage potential and motility time; (4) present maximum storage potential using the methods in this project is approximately 10 d; and (5) motility of stored walleye semen can be monitored easily with a lighted microscope of 400X magnification.

### Intensive Culture Techniques for Colorado Squawfish

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A review of the literature revealed that no work had been done on intensively culturing first-feeding squawfish prior to the studies done at the Colorado Division of Wildlife's Fish Research Hatchery in 1989-1990. The first year's study objectives were to determine minimum temperature requirements that would promote acceptable growth and to evaluate the acceptance of four different commercial diets. The second year's study was to build on the information gained the previous year and to continue to develop and enhance culture techniques. The goal of my research is to develop a hatchery manual so that future fish culturists working with Colorado squawfish can propagate them effectively. There are many objectives to address in this project to establish culture techniques that will promote optimum growth. The objectives are as follows: (1) determine loading and density parameters; (2) determine whether an extended photoperiod will increase growth rates during the winter months; (3) determine if the depth of the water column will affect growth and feed conversions; (4) evaluate the use of belt feeders versus hand feeding; (5) determine growth potential of these fish at 20-21°C; (6) evaluate the use of moist and semi-moist feeds; and (7) evaluate the use of Tricaine Methanesulfonate (MS 222) to determine safe dosages for anesthesia. The results of this research will be completed in the summer of 1992 and will be presented at that time.

### Effect of Short-term Acclimation on the Stress Response of Rainbow Trout to an Increase in pH

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Rainbow trout *Oncorhynchus mykiss* were loaded, transported for 110 min, and stocked into raceway compartments of pH 8.27 (control) or pH 9.37, either directly or after 15 or 45 min of acclimation. Plasma chloride was significantly lower in fish that had been stocked into the high-pH raceway after 15 min acclimation than in undisturbed fish sampled prior to loading. No other combination of pH and acclimation time caused a significant change in chloride concentrations from baseline values. There were no significant differences in chloride concentration between fish from ambient and high-pH water or among acclimation time treatments. Plasma cortisol was significantly higher in all treatments than in undisturbed fish, reflecting the stress response to handling and transport, but did not differ among acclimation time treatments or due to high pH. Survival 24 h after stocking into high-pH water was 98%, 95%, and 95% after 0, 15, or 45 min of acclimation, respectively. Results indicated that short-term acclimation to high pH did not improve survival or reduce the physiological stress response.

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### **Heron Predation Study at Bellvue/Watson State Fish Hatchery Complex**

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Predation by black-crowned night herons *Nycticorax nycticorax* and great blue herons *Ardea herodias* at the Bellvue/Watson complex has had a major impact on fish production since 1985. Losses, primarily of rainbow trout, averaged 70,000-80,000 fish annually at the Watson Rearing Unit, while losses at the Bellvue hatchery complex increased tenfold from 1990 to 1991. These losses were temporarily slowed by use of electric fencing, netting around feeders and on walkways, and strobe lights. A 4-month intensive program in May-August 1990 surveyed bird numbers and capture attempts and successes, and evaluated a hazing operation. Bird numbers reached 120-130 birds per night at Watson and 12-15 birds at the Bellvue Hatchery. Predation success for both species averaged 85%. Total fish consumption per bird averaged 3-4 times higher than normal rates for "wild feeding" birds. An intensive hazing campaign using cracker and screamer bombs fired from hand-held pistols reduced bird numbers to 1-2 birds in 14 d. The hazing continued every fifth night for 2 months thereafter, and bird numbers increased to only 18-20 birds before the fifth night's hazing resumed. While no hazing was done in April, most of May, and August 1990, fish losses at the Watson Unit were reduced to about 9,500 fish.

### **An Outbreak of Type E Botulism in Inland Trout in Colorado**

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The cause of mysterious, often heavy, losses in a lot of 240,000 rainbow trout *Oncorhynchus mykiss*, occurring from late summer through fall 1986 at Rifle Falls State Fish Hatchery, was ultimately diagnosed as Type E Botulism syndrome. Affected fish displayed a characteristic swimming behavior due to the descending paralysis from botulinum toxin and little else in the way of clinical signs. Seven 0.5-0.7-acre earthen ponds, originally constructed as settling ponds and later adapted to fish culture, were involved. Botulism syndrome in fish can occur under the right series of circumstances, including pond design, fish culture practices, and prolonged temperatures close to 17.7°C (60°F). Concerns for human and wildlife safety at Rifle Falls resulted in the immediate destruction of remaining stocks and implementation of a thorough cleanup process. Direct losses to botulism in this outbreak approximated 95%.

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### Use of Fish Health Condition Index for Determining Winter Feeding Methods

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Rainbow trout *Oncorhynchus mykiss* were fed on seven different regimes during the coldest water period--January 1-February 16, 1990--to establish which regime would provide the most efficient use of feed by maintaining best overall condition of the fish. The autopsy-based Fish Health Condition Profile was used to monitor the overall condition of the test groups. Growth and mortality were also measured. The use of double vitamin had little benefit to overall fish condition. Feeding 2 weeks and then starving for 2 weeks resulted in a lower overall condition. Demand-fed fish had the poorest overall condition for each feeding regime. Hand feeding and then starving for 1 month produced fish with a Health Profile close to the controls. Growth was very low for all groups except for demand-fed fish, and mortality was not adversely affected by any of the feeding regimes. I concluded that the best regime for maintaining an acceptable Health Condition Profile was hand feeding and then starving the fish for 1 month.

### Fish Housing--Prescription Ideas for Reservoir Habitat Projects

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In planning for the Bartlett Lake Fish Habitat Project, an I.D. team attempted to answer the whats, wheres, hows, and particularly, the whys of installing fish habitat in a major southwest reservoir. Considerations for the project have included availability, cost, and durability of materials, logistics of structure placement, lake morphology, and target fish species behavior.

Successful results of past projects in Arizona at Lake Havasu and Canyon and Saguaro lakes have served as a springboard for application of tried and true methods of planning and placement of fish habitat types.

Innovative structures such as "Fish 'N Forests," "Crappie Condos," and "Flathead Flophouses" will be used in conjunction with traditional woody structures such as evergreen trees and local hardwood vegetation.

By examining topographic relief features such as prominent points, islands, and troughs, structures will be placed to take advantage of fish congregating and spawning behaviors in these areas. Also, by using these landforms, we will be able to maximize structure use by largemouth bass, black crappie, bluegill, and catfish at fluctuating water levels.

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### **The Fish Meet the Habitat: A New Day in California for Warmwater Fisheries Management**

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Historically, the Forest Service (FS) and the California Department of Fish and Game (CDFG), by formal agreement, have managed the fishery resource under an unwieldy constraint. The habitat is managed by the Forest Service and the fish are managed by the department, and "never the twain shall meet." This boundary has been considerably violated in recent years by the monitoring needs of the FS in streams, requiring intensive assessment of fish populations. The FS has had very little involvement in reservoir management, even though many popular reservoirs in California are within the National Forests. The FS and the CDFG have initiated a cooperative reservoir program that seeks to correct the management coordination problems. The program focus will be on adaptive management, with both agencies as full partners in fisheries assessments and management decisions. It is proposed that the program begin with one reservoir in each of the five CDFG regions in the state. Two reservoirs have been designated, and action plans are currently being implemented. The guiding principle of adaptive management recognizes the need for accurate biological and fisheries data, but also that the best available information can be used to make management changes early in the project. Evaluation of this new management direction can then be included in the program.

### **Responsive Management? The Striped Bass Issue in New Mexico**

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An inadvertent stocking of 200 striped bass fry into Elephant Butte Reservoir in 1972 launched the New Mexico Department of Game and Fish into the inland striped bass management business. A stocking program was instituted in 1976, and a management plan for a trophy fishery was implemented in 1987. The harvest of trophy striped bass became commonplace during the late 1980's.

The trophy striped bass program was at once successful and controversial. For every proponent of the striped bass there seems to be an equally adamant opponent. Due to below average rainfall and subsequent low nutrient loading during the latter 1980's, reduced harvest of all gamefish was experienced at Elephant Butte Reservoir. Vocal opponents expressed their concerns and placed the blame for the reduction on one of the larger predators of the lake, the striped bass. In an effort to be responsive to the state's anglers, meetings were held to receive input on the future of the striped bass program in New Mexico. As a result, stocking of striped bass was curtailed. A hue and cry arose from the proponents of the species, who felt they had not been adequately represented. This prompted the department to conduct a telephone poll of a broader segment of the angling population.

I will discuss the scope and intent of these public forums, the management implications, and the concerns of responsive management.

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**Direct Observation of Warmwater Fish Associated with Natural and Artificial Habitats  
in Ruth Reservoir, California**

Gregory J. Bryant, Fishery Biologist, U.S. Forest Service, Six Rivers National Forest, Eureka, California 95501, (707) 442-1721 and Thomas J. Hassler, Assistant Project Leader, U.S. Fish and Wildlife Service, California Cooperative Fishery Research Unit, Humboldt State University, Arcata, California 95521, (707) 826-3268

The purpose of this study was to evaluate the effectiveness of three brush structure designs as spawning cover for adult basses and as rearing habitat for young-of-year, juvenile, and adult basses, and to observe the interaction of all species around the structures compared with natural habitat locations. An additional purpose of the study was to develop a direct observation sampling methodology utilizing SCUBA for monitoring habitat enhancement projects in reservoirs and lakes. Eight manzanita brush structures of three designs (dense, discrete open center, and continuous open center) were placed in selected areas of Ruth Reservoir, California, during low level in fall 1988; nine control sites were also established in various habitats throughout the reservoir. Comparisons of habitat utilization by young-of-year, juvenile, and adult largemouth bass and smallmouth bass were made between control sites and structures and between sampling dates within each cove and between coves. The use of the brush structures and control sites was evaluated by two divers every other week from July through September in 1989 and 1990. Data were analyzed by year between transects and between sampling dates using Friedman's test. Adult bass were occasionally observed in habitats located towards the back of coves; however, after spawning adult largemouth bass and smallmouth bass utilized rocky point habitats and brush structures located near the entrance of coves, adjacent to deepwater channels, through the summer and fall in 1989 and 1990. Juvenile largemouth bass and smallmouth bass utilized backwater areas and structures located towards the back of coves from spring to early fall as water temperature increased and water levels remained fairly constant. Juvenile largemouth bass and smallmouth bass migrated from shoreline habitats to the brush structures and control sites located towards the entrance of coves in deeper water as water temperatures and water levels decreased rapidly. Young-of-year largemouth bass and smallmouth bass utilized backwater areas and brush structures located towards the back of coves. As the number of juvenile bass increased in backwater areas, young-of-year largemouth bass and smallmouth bass migrated towards the brush structures located near the entrance of coves. Numbers of young-of-year bass were highest in habitats where the numbers of juvenile bass were lowest. The discrete open center structure was the most utilized brush structure by young-of-year, juvenile, and adult largemouth bass and smallmouth basses in 1989 and 1990. Water temperature, water level, brush structure location, and brush structure design were found to be the most important physical factors influencing habitat utilization by largemouth bass and smallmouth bass in Ruth Reservoir.

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### **Managing Arizona's Warmwater Fishing Resources Through Regulation Changes --How Are We Doing?**

Tom McMahon, Fish Program Biologist, Arizona Game and Fish Dept., Region VI, 7200 E. University, Mesa, Arizona 85207, (602) 981-9400

Arizona's fisheries managers are currently challenged with being able to balance angler demands and increasing pressure on the state's warmwater systems with basic fish biology and natural water fertility.

In the past, we only needed to be concerned with finding or creating new waters and distributing fish. This attitude took a strong about-face in the 1950's, and most state agencies began to see a need for size limits. But by the 1970's, fisheries studies indicated that what everyone thought could never happen was happening--overharvest.

To form the noted balance, we as fisheries managers are expected to enhance various size, bag, and season restrictions that have been implemented in Arizona in the past and are presently in use. What does the future hold for warmwater fishing regulations and fish management in Arizona? As the state's population grows, more and more pressure will be placed on our fisheries resources. Various regulations and habitat enhancement projects, along with angler participation and cooperation, will become a bigger part of Arizona's fish management programs in order to direct future statewide fishing effort, adjust harvests, and rebuild warmwater fish populations.

### **Impacts of Electrofishing on Fish**

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Electrofishing, a valuable sampling technique in North America for 4 decades, is in a state of flux. The field is expanding with new equipment, applications, and understanding but is contracting with increased concern for comparability of data and safety of operators and fish. In some situations it is even being switched off to prevent adverse impacts on fish. Recent investigations have documented substantial injury to the spine (>40% and sometimes much more for certain species) using relatively modern equipment and pulsed direct current waveforms. The problem is real, seems to be widespread, and is not simply a matter of too much power. Why this sudden recognition of a problem? Probably because we have come to expect some injury, and perhaps mortality, as a by-product of most fish collection techniques, and because the electrofishing injuries of immediate concern are often not externally obvious and are seldom fatal. The questions generated by this concern are many, but primarily: What species and size groups are affected? To what degree? Using what equipment and techniques? And what can be done to eliminate or minimize, the problem? Perhaps the time has come for a concerted, well-funded, national (or international) effort to resolve these questions.

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### **Effect of Electroshock Voltage, Wave Form, and Frequency on Trout Egg Mortality**

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Electrofishing has been shown to sometimes cause injury to fish. Tests with trout eggs have also shown that this technique may be having more detrimental effects than previously thought when shocking over redds. In the laboratory we showed that eggs can be killed during the sensitive period by electroshock. In the field eggs placed into artificial redds were also susceptible when exposed to the same voltage gradient using the same equipment. We have continued to study the effects of electroshock on egg mortality to better define threshold levels. In this paper we report the results of a test defining the effects of continuous DC, pulsed DC at two different frequencies, and CPS, all at two different voltages.

### **Injury of Wild Brook Trout by Backpack Electrofishing**

Bruce Hollender, Pennsylvania Fish and Boat Commission, 450 Robinson Lane, Bellefonte, Pennsylvania 16823-9616, (814) 359-5118, and Robert Carline, Pennsylvania Cooperative Fish and Wildlife Research Unit, Pennsylvania State University, Merkle Building, University Park, Pennsylvania 16802, (814) 865-4511

Most studies of injuries caused by electrofishing have been conducted on large brown trout *Salmo trutta* and rainbow trout *Oncorhynchus mykiss* in medium- or high-conductivity waters. The objective of this study was to assess internal injuries of wild brook trout *Salvelinus fontinalis* that were captured with alternating current (AC) and pulsed direct current (PDC) backpack electrofishing units in four, small, infertile streams. We used x-ray and autopsy to assess injury rate of 579 brook trout captured by electrofishing and 89 captured by angling. Fish total length averaged 136 mm and ranged from 87 to 237 mm. Injuries consisted of internal hemorrhages, spinal misalignment and fracture, or both. We found 74 hemorrhages and 91 spinal injuries. Injury rate was not significantly different ( $P < 0.05$ ) between current types: 26% for AC and 22% for DC. Less than 7% of angled trout had injuries. Injury rate increased with fish length, ranging from 13.9% for fish  $< 125$  mm to 42.1% for those  $> 175$  mm. Among spinal injuries, an average of six vertebrae were damaged, usually in the posterior region of the spinal column between the dorsal and anal fins. We conclude that even for relatively small trout in infertile waters, the incidence of electrofishing-induced injury can be significant. The relation of these injuries to mortality remains to be explored.

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**Evaluation of Electrofishing-induced Spinal Injuries Resulting From Field Electrofishing Surveys in Montana**

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Examination of 693 trout sampled from Montana rivers by electrofishing was conducted to document the incidence and severity of electrofishing-induced spinal injury; 769 hemorrhages and 2,647 injured vertebrae were documented, categorized, and described. Substantial evidence demonstrated that 60 Hz pulsed DC current results in excessive injury rates to both rainbow trout (60-98%) and brown trout (44-62%) regardless of waveform (rectified sine-wave or square-wave), water conductivity (33-900 umhos/cm), or equipment design variables. Longer trout did not show a noticeable trend toward higher injury rates, but fish with "brand" marks did exhibit higher spinal injury rates. Limited sampling of Arctic grayling, sauger, and shovelnose sturgeon did not reveal spinal injury problems with these species. A discussion of electrofishing efficiency and proposed guidelines to minimize spinal injury are included.

**Spinal Injury of Walleye Caused by Pulsed DC Electrofishing**

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Walleye *Stizostedion vitreum* ranging from 183 mm to 475 mm total length were captured in 1991 by pulsed DC electrofishing and analyzed by x-ray photography and autopsy for spinal injuries. Of the 30 fish examined, 9 (28%) had spinal injuries involving fractured vertebrae and rupture of dorsal arteries. Two pulse rates were tested (30 and 120 pulses per second), and no difference was found in the injury rate. Experiments using larger sample sizes and controls, and experiments on the effect of electrofishing on walleye egg viability, are being conducted in 1992 and will be included in this report.

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### **Injury and Survival of Northern Pike and Rainbow Trout Captured by Electrofishing**

James B. Reynolds, Stafford M. Roach, and Thomas T. Taube, Alaska Cooperative Fish and Wildlife Research Unit, 158 Arctic Health Research Building, University of Alaska Fairbanks, Fairbanks, Alaska 99775-0110, (907) 474-7661

During 1990 and 1991, we conducted studies in controlled environments and the field to determine the effects of various electrical waveforms on large northern pike *Esox lucius* and rainbow trout *Oncorhynchus mykiss*. The results were quite different for the two species. Pulsed DC (30-60 Hz, 100-400 V) produced spinal injury rates among northern pike of only 5-12%, but the rate increased to 29% when a 120-Hz waveform was applied at 300-600 V. In field trials, we caught three northern pike with 60-Hz pulsed DC for every one caught with DC or 30-Hz pulsed DC. Survival and growth of injured and control groups of northern pike held for nearly 1 year in a lake were not significantly different. However, all types of conventional pulsed DC (20-60 Hz), as expected, produced spinal injury rates of 40-60% in hatchery rainbow trout. Only DC and CPS™ produced injury rates under 18% in the hatchery. During field trials, injury rates among rainbow trout were lower with CPS™ than DC, but DC produced higher capture rates in the low-conductivity (30 uS/cm) water. Survival of shocked rainbow trout held in a hatchery was 65% after 203 d; most of the deaths occurred in the first 30 d. We concluded that 60-Hz pulsed DC could be used to capture northern pike with minimal injury problems and that DC and CPS™ should be further evaluated for electrofishing rainbow trout. Electrofishing-induced injuries and associated problems clearly vary among species. Results from rainbow trout studies do not imply that electrofishing-induced injuries are a widespread problem. More species must be studied.

### **The Use of the Mysid *Neomysis mercedis* in Acute Toxicity Tests**

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The mysid *Neomysis mercedis* was examined as a test organism for use in acute toxicity tests in estuarine waters. Several sensitive invertebrate species are available for marine (mysids) and freshwater (cladocerans) environments, but few are available for estuarine waters. This mysid is an important food organism in West Coast estuaries and can be reared successfully in the laboratory. Acute toxicity tests (96-h) have been performed with several pesticides, and *N. mercedis* is comparable to marine mysids (*Mysidopsis* spp.) and freshwater cladocerans (*Daphnia magna* and *Ceriodaphnia dubia*) in acute sensitivity to toxicants. Mysids have been used to detect and monitor acute toxicity from pesticide residues in agricultural wastewater effluent entering two California river systems.

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### **Biomonitoring Nonpoint Toxic Threats to National Park Waters: Case Studies**

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Toxicants carried in waters from nonpoint sources can adversely affect aquatic and terrestrial ecosystems. Unfortunately, this occurs in our National Parks. Approximately 70% of nonpoint issues originate outside park boundaries. Results of biomonitoring using daphnids, amphipods, fathead minnows, and germination of grass seeds indicate that some nonpoint issues would have gone unnoticed had it not been for the sensitivity of these test species. Parks studied were Biscayne and Everglades National Parks, Florida; the Fort Darling Unit, Richmond National Battlefield Park, Virginia; Wilson's Creek National Battlefield Park, Missouri; Upper Delaware Scenic and Recreational River, Pennsylvania; and the Namekagon River, a tributary of the St. Croix National Scenic Riverway, Wisconsin. The Wilson's Creek study indicated that biomonitoring (i.e., biosurveys followed by bioassays in conjunction with toxicity identification, then by chemical analyses) was effective in signalling short- and long-term ecological degradation from nonpoint source pollution.

### **Chemical Kinetics—An Ignored Factor in Aquatic Toxicology**

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Toxicologists have generally assumed instantaneous kinetics (i.e., fast chemical reaction rates) and equilibria in conducting toxicity tests. Experiments were performed to evaluate (1) effects of kinetics on results obtained from toxicity tests and (2) use of differential pulse anodic stripping voltametry (DPASV) as a method to measure the toxic or bioavailable fraction of cadmium (Cd) in waters of low (25 mg/L) and high (225 mg/L) alkalinity. Chemical experiments conducted in the laboratory revealed that it took 48 h for Cd to reach a state of equilibrium in hard, alkaline water. In unaged soft- and hard-water experiments, Cd concentrations were added directly to aquaria containing rainbow trout. In aged hard-water tests, concentrations of Cd were first added to 270-L aquaria to allow free and complexed forms to come to equilibrium prior to flowing to aquaria containing fish. Toxic responses were assessed based on added, total, total dissolved, and labile (free) Cd. Despite large differences in the complexing capacities of these two waters, labile Cd, determined by DPASV, predicted the toxic (bioavailable) form of Cd where other methods failed. In unaged hard water, bioassay results significantly underestimated toxicity due to chemical kinetic effects.

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### **Physiological Mechanisms Involved in Metal Toxicity in Fish**

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A number of metals exert their toxic effects on fish through direct action on the gills of the animal, rather than through (or in addition to) bioaccumulation and subsequent effects on other target tissues. These "surface-active metals" can affect respiration or ionoregulation, depending on the metal concentration and speciation. In at least some cases, particularly for those metals with toxicities dramatically affected by water hardness, we can infer that the proximate cause of toxicity involves competition of the metal for calcium binding sites on the gill. Relevant toxicological and physiological data for aluminum and copper effects on fish will be reviewed as related to these concepts.

### **Contaminants May Be Adversely Impacting Endangered Fish in the Upper Colorado River**

Steve J. Hamilton and K. J. Buhl, U.S. Fish and Wildlife Service, National Fisheries Contaminant  
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The primary concern for the endangered fish in the upper Colorado River has been the influence of physical (flow, habitat) and biotic (introduced species) changes. Recent results from Department of the Interior Irrigation Drainwater Program investigations indicated elevated concentrations of selenium and other inorganics in water, sediment, and biota from the middle Green River. Unpublished results of a similar investigation on the San Juan River also indicated inorganic concentrations are elevated in water and biota. We conducted acute toxicity tests with hatchery-supplied Colorado squawfish, razorback suckers, and bonytail in a water quality simulating the middle Green River. Comparison of acute toxicity data with information from these investigations indicates that boron, vanadium, and zinc in the San Juan River are moderate water-borne hazards to endangered fish. Selenium may be an important dietary hazard in both river systems. Thus, chemical changes in the upper Colorado River may also be a contributor to the decline of endangered fish

### **Denver's Quality Urban Fishery**

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Approximately one-half of the 720,000 licensed anglers in Colorado reside in the greater Denver metropolitan area. To provide convenient quality fishing, over 200 lakes and reservoirs have been intensively managed since the early 1980's to produce a diversity of fishing opportunities. Major program objectives include (1) opening new waters, (2) improving aquatic habitat, (3) improving facilities, (4) optimizing fish population structure and function, and (5) providing aquatic-related information and education programs. Metro area fisheries have been managed through the use of chemical reclamations, supplemental and introductory fish stocking, and application of special regulations. Primary fishery categories include put-and-take rainbow trout in a variety of settings; put, grow, and take through subcatchable salmonid plants; and warmwater panfish and gamefish communities. Many larger waters are managed as two-story fisheries to maximize fishing opportunities. Development and maintenance of quality fisheries in the Denver metro area are most influenced by maintaining adequate water quality and quantity, and by securing special regulation compliance. Specific problems and solutions are described for issues such as angler crowding, overharvest, regulation compliance, and identification of appropriate management strategies.

### **Planning, Development, and Implementation of Urban Anadromous Salmon Sport Fishing Opportunities in Alaska**

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Anchorage, Alaska's largest community, is home to over 40% of the state's population. Within this area of industrial and rural settings, anglers have the opportunity to participate in varied sport fisheries. Urbanization, habitat degradation, and limited availability of wild stocks have required that fish abundance be increased through stocking to expand sport fishing diversity and participation. Until recently, urban-area fisheries were supported primarily through the stocking of rainbow trout in the area's landlocked lakes. New sport fishing opportunities have been developed for anglers to fish for and harvest anadromous chinook salmon, and programs are being developed for coho salmon. Providing these fisheries allows for the cost-effective increase in angler participation and may help to reduce the pressure on wild stocks. The development of new salmon fisheries in areas surrounded by industry and private property requires that significant planning be provided in the design of stocking strategies and that the public and area landowners be involved throughout the process. Present management strategies for these fisheries are directed at providing for orderly growth in participation through time and area restrictions while maintaining historical levels of natural production.

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**The "Fish Wyoming" Program: More Bang for the Urban Fishery Buck**

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The "Fish Wyoming" program provides 50% matching grants, up to \$20,000 maximum, for projects that increase Wyoming's sport fishing opportunities. Local governments, other agencies, civic and conservation groups, and individuals are eligible to participate. Total departmental funding for the program is \$200,000 annually. "Fish Wyoming" was implemented on a 2-year trial basis beginning in fiscal year 1991. Over the 2-year life of the trial program, the department's \$400,000 in grants has resulted in completion of projects valued at over \$1.6 million, when sponsor's funds and in-kind contributions are considered. Advantages of the "Fish Wyoming" program include (1) ease of administration; (2) ability to handle federal and nonfederal matching funds; (3) flexibility to work with most sponsors; (4) elimination of departmental "bottlenecks" due to present overloads in engineering, construction, land acquisition, and environmental permitting; and (5) local "ownership" of projects, which provides for better monitoring and maintenance. The 2-year trial program received overwhelming public support. The Wyoming Game and Fish Commission just extended "Fish Wyoming" for 5 years.

**Blue Ribbon Bass in an Urban Pond: A Look at the Effect of Controlled Access and Harvest**

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Two similar-sized Arizona urban ponds fed by the same canal system, one open to public fishing with no size limits and one closed to public fishing with a voluntary 14-inch minimum on largemouth bass *Micropterus salmoides*, were electrofished and subsequently drained to determine fish biomass and population structure. The pond open to public fishing had a largemouth bass density of 22 lb/acre compared with 288 lb/acre in the closed pond. Results show a severely overharvested public fishery, and regulations to reduce bass harvest are indicated.

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### Albuquerque Urban Angler Survey

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Nearly 1,100 angler interviews were conducted at Tingley Beach (Conservancy Park Lake) from January through March 1991. The purpose of the interviews was to determine catch rates, exclusivity of angler use at Tingley Beach, and angler preferences and desires concerning special regulations and stocked species. The mean angler count was 50 anglers per day, an average of about 5 anglers per surface acre. The mean catch rate for all species was 0.61 fish per hour (fph), and 0.58 fph for rainbow trout. Catch rates varied according to the number of days past stocking, but overall were higher on the first and third days after stocking. Most of the anglers surveyed fished elsewhere in New Mexico, planned to fish Tingley Beach again, approved of reducing the bag limit from eight trout per day to six trout per day, and would fish Tingley Beach if it were stocked with catfish during spring and summer. Anglers gave their overall fishing trip a weighted response of 2.7 on a scale of 1-5, had fished Tingley Beach within the last 7 d, and needed to catch 1-2 fish to have a successful fishing trip.

### Resistance and Resilience in Glen Canyon, Colorado River, Arizona

Ted R. Angradi, Arizona Game and Fish Department, P.O. Box 2423, Page, Arizona 86040, (602) 645-0499 and Dennis M. Kubly, Arizona Game and Fish Department, 2223 W. Greenway Road, Phoenix, Arizona 85023, (602) 942-3000

Load-following power generation at Glen Canyon Dam on the Colorado River results in large daily fluctuations in stage (several meters). Measurements of biomass and chlorophyll accretion rates on artificial and natural substrates indicate that algal colonization (primarily *Cladophora glomerata*) is slow (=low resilience) in the zone of daily dewatering. Periphyton colonization rates ( $k = \log_{10} \text{biomass/day}$ ) in the zone of fluctuation ( $< 0.01$ ) are 3-5 times slower than in the permanently inundated channel ( $\geq 0.03$ ). The periphyton community is apparently very vulnerable to disturbance (=low resistance). Field experiments indicate that relatively brief ( $< 12$  h) daytime exposures in summer devastate periphyton. Freezing may also damage exposed periphyton at night in winter. The periphyton community in Glen Canyon supports the food base for rainbow trout and may also be important to aquatic biota downstream in Grand Canyon as a source of particulate organic matter. The apparent low resistance and resilience of periphyton in Glen Canyon implies that disturbances severe enough to alter periphyton structure and function will have protracted effects at several trophic levels.

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### Activity of Adult Humpback Chub Under Fluctuating Flows in the Colorado River, Grand Canyon

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Adult and juvenile humpback chub in the Colorado River in Grand Canyon exhibited high fidelity for specific river locales with variable activity patterns under fluctuating flows from Glen Canyon Dam. Mean net displacement (horizontal distance from release to last contact) of 48 radio-tagged adults observed for an average of 86 d was 1.34 km (range 0-5.55 km), and mean gross displacement (sum of all movements) was 4.23 km (range 0-16.33 km). Mean net displacement of 61 PIT-tagged juveniles and adults recaptured after an average of 99 d was 0.83 km (range 0-5.79 km). Near-surface occurrence of radio-tagged adults (radio contacts within 4.5 m of surface) was three times higher at night than in the day and, in the daytime, under high turbidity than low. Local horizontal movement of some of these radio-tagged fish was greatest during flow stage changes, indicating movement in response to changing habitat parameters (i.e., depth, velocity). Some fish failed to move during stage changes, while others moved during crepuscular periods and at night corresponding to stage changes. Movement of spawning adults into the Little Colorado River in April and May was greatest in the evening and early nighttime and during low flow stage.

### Movement of Endangered Humpback Chub *Gila cypha* Within the Little Colorado River in the Grand Canyon, Arizona

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The humpback chub *Gila cypha* is a large cyprinid endemic to the Colorado River basin of western North America. The largest known population inhabits the Little Colorado River and is the object of a 5-year demographic study by Arizona State University and the Navajo Natural Heritage Program. During the first 6 months of research (through December 1991), 8,423 chubs were captured, and Passive Integrated Transponder (PIT) tags were implanted into 2,131 of 3,647 fish that were > 15 cm total length (TL). Recaptures of 1,002 PIT-tagged chub, plus 462 fish carrying PIT, Carlin, or Floy tags applied by other investigators, indicated that most chubs > 15 cm TL remained in the Little Colorado River during late spring into autumn 1991. Catch rates fell dramatically during colder months, probably a result of general inactivity of fish. A few larger (> 35 cm TL), presumably older, fish moved in late winter-spring 1992 from the mainstem Colorado into lower reaches of the Little Colorado, where they may spawn. We hypothesize that a large population of juvenile and young adult chub may be resident in the Little Colorado River year-round, while a component of larger, older fish is more migratory, moving seasonally between the mainstem Colorado and Little Colorado rivers.

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### **A Genetic Analysis of Rainbow Trout in the Colorado River Below Glen Canyon Dam**

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The goal of this study was to use protein electrophoretic techniques to assess the distribution of genetic variation among the rainbow trout in the portion of the Colorado River extending from Glen Canyon Dam to Diamond Creek. Specifically, adult and young-of-the-year rainbow trout were collected from main channel areas and tributaries in April-May 1986 and again in March-April 1991. Analysis of the allele frequencies obtained from 10 polymorphic loci revealed that the spatial distribution of variation was not stable over time. Various hypotheses to explain the temporal and spatial distribution of variability will be presented and discussed.

### **For Better Production, Should We Change the Flow or Change the Fish (or Both)?**

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A literature search was conducted for information on performance of rainbow trout strains that may be used to replace the Bel-Aire strain in a tailwater fishery below Glen Canyon Dam on the Colorado River. Information was compiled on 164 strains and brood stocks for nine performance characteristics. The ultimate goal was to see if changing strains of rainbow trout would yield larger fish because the strain would be better adapted to the conditions of the Glen Canyon Dam tailwater. Another alternative is changing flows to accommodate habitat requirements of the existing strains. Evaluations of strains were limited because of a lack of consistent information; however, pair-wise comparisons found in the literature were used to evaluate 21 strains for best spawning period, food conversion, growth in first year, survival, and catchability. Although additional evaluation is needed, the Eagle Lake strain showed the most promise for this application.

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**Fishery Studies on the Hualapai Indian Reservation  
in Lower Grand Canyon and Lake Mead Inflow**

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The Hualapai Indian Tribe of northern Arizona has initiated a 2-year investigation of the lower Grand Canyon and Lake Mead Inflow, from Diamond Creek (river mile 226) to Pearce Ferry (river mile 286). The study will be conducted cooperatively by BIO/WEST, Inc. and the Hualapai Wildlife Management Department, with support from the Bureau of Reclamation and Glen Canyon Environmental Studies. The purpose of the investigation will be to characterize the ichthyofauna, habitat, and energy support systems in this region of the Colorado River and to evaluate the impacts of interim flows from Glen Canyon Dam operations. Biologists will sample fish in the 60-mi study reach with gill and trammel nets, electrofishing, hoop nets, seines, larval drift nets, and light traps. Benthic macroinvertebrate communities will also be characterized, as well as allochthonous energy biomass. This region of the Colorado River has received relatively little attention and may support significant aquatic resources, including endangered Colorado River fishes.

**A Community Celebration of the Return of the Salmon**

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Over 8,000 children and adults enjoyed watching, painting, and learning about Pacific Northwest salmon and their cultural significance at the first annual Wenatchee River Salmon Festival. The celebration was hosted by the Wenatchee National Forest, U.S. Fish and Wildlife Service, and Leavenworth Chamber of Commerce. With a focus on children, the festival proved to be a major success, conveying natural resource information while contributing to the economic diversity and health of the community. Hands-on activities, guided walks, storytelling, and good food provided by local businesses and social organizations held the interest of all who attended. This festival reflects the transition taking place in the Pacific Northwest, as many communities are emphasizing recreation and tourism to strengthen their economic bases.

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### **A Tale of Two Streams, or: The Good, the Bad, and the Possible**

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Structurally diverse streams in unmodified watersheds typically have great buffering capacity, which helps sustain fish populations. Channel pattern, bed configuration, and woody debris loading tend to moderate the effects of floods and low flows, while streamside canopy cover moderates thermal loading. Two rivers drain into Lake Coeur d'Alene in northern Idaho, the Coeur d'Alene and the St. Joe. Both rivers drain basins of approximately the same size, are largely managed by the Forest Service, and have similar geology and forest type, but they support greatly different numbers of native cutthroat trout and bull trout. In the Coeur d'Alene drainage, land management activities since before the turn of the century, and large fires in 1910 and 1930, have resulted in changes in the stability and structural diversity of the stream channel. These changes in fluvial geomorphology are reflected in the numbers of cutthroat observed, 67/km in the Coeur d'Alene and 300-600/km in the St. Joe. Implementation of Idaho Panhandle National Forest habitat action plans for cutthroat trout and bull trout and watershed restoration measures provide opportunities to restore channel stability and to improve fish habitat and aquatic community complexity, while helping to diversify the local economy and to develop a sense of public ownership for sound watershed management.

### **Preferred Summer Holding Habitat Characteristics for Adult Summer Steelhead**

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Preferred oversummering habitat characteristics for adult summer steelhead were assessed during the summer of 1991, in New River, California. Stepwise linear regression revealed that adults preferred lateral scour pools associated with boulders, and channel confluence pools. Within the two habitat types, adults preferred pools of moderate size (200-600 m<sup>2</sup>), less than 2% habitat gradient, less than 30% embeddedness, riparian canopy cover of 20-45%, mean substrate diameter larger than gravel (> 64 mm), mean habitat flows of 4-12 cm/sec, and maximum depths of 2-3 m. Microhabitat observations indicated that adult steelhead utilized available bedrock or boulder cover associated with flow velocities averaging 9.3 cm/sec (range 1-34 cm/sec); the greatest adult densities were observed at higher velocities. Analysis of variance demonstrated that mean water temperature for pools used by adults (mean equal to 17.96°C, range 11.46-24.65°C) was significantly cooler than pools not used by adults (mean equal to 18.3°C, range 8.70-26.61°C). Results of the study demonstrate that increased summer habitat utilization was associated with moderately deep habitats that contained cover associated with flow, reduced water temperature, and moderate mean habitat-flow velocity over substrate larger than gravel. Habitat improvement projects for adult summer steelhead should focus on optimizing these variables.

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### **The Evolution of a Conservation Strategy for Spring Chinook Salmon in the Upper Grande Ronde River, Oregon**

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The U.S. Forest Service, Oregon Department of Fish and Wildlife, Oregon State University, and tribal governments have developed a comprehensive conservation strategy for spring chinook salmon in the upper Grande Ronde River basin. The strategy has been developed in response to continued declines in Snake River anadromous fish stocks. Protection and restoration measures are described in the strategy, as is a monitoring program to evaluate effectiveness in meeting basin management objectives. Key elements of the conservation strategy include: an overview of existing conditions and historical events and activities contributing to those conditions, agency and tribal involvement and responsibilities, consistency with existing Columbia River Basin programs, development of measurable objectives for habitat conditions, integration of research findings, and prioritization of restoration program activities.

### **Researching Problems of Habitat and Population Fragmentation**

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The fisheries Research Work Unit at the USDA Forest Service-Intermountain Research Station in Boise, Idaho has two primary responsibilities--research and technology transfer. Research goals are to improve understanding of the effects of stream channel changes and land use on critical habitat of native and sensitive species, and to better understand the importance of habitat fragmentation on the conservation of these species. This paper describes specific research projects designed to meet these goals. Studies are described on the influence of substrate condition on salmonid spawning and incubation; identification of critical spawning, summer rearing, and overwintering habitat; comparison of habitat changes in wilderness and non-wilderness watersheds; critical habitats for bull trout; approaches to evaluate characteristics of fragmented and non-fragmented populations; and modeling risks of decline in fragmented populations. The Technology Transfer goal is to develop and implement decision-support tools to help managers protect critical habitats and viable fish populations.

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### **Flushing Flow Requirements of a Large, Regulated Wyoming River to Maintain Trout Spawning Habitat Quality**

Christopher R. Wenzel and Thomas A. Wesche, Department of Range Management and Wyoming Water Resources Center, University of Wyoming

Regulation of flow releases below large dams can cause a reduction in peak runoff. Past reservoir storage and dam releases have often been geared toward municipal, power, and irrigation needs, with little regard for fisheries, other than the recent requirements for maintenance of a minimum instream flow.

Peak (flushing) flows can serve to remove fine sediment deposits from trout spawning areas and to increase trout production. The goal of our study was to determine whether a flushing flow regime to maintain suitable spawning bed material is a viable fisheries management objective for the North Platte River below Gray Reef Dam, given present channel conditions, habitat trends, and water management. We will discuss the overall changes in channel morphology and hydraulic geometry observed on this section of the North Platte and present the methods used to address our study goal.

### **Potential Effect of Climatic Warming on Salmonid Distributions in Wyoming**

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We used the relation between elevation and mean July air temperature to examine present geographic distributions of salmonids in Wyoming. A regression equation to predict mean July air temperature from elevation and latitude was used to develop a thermal isobar map for the state. Available data were examined to determine thermal limits for brook trout *Salvelinus fontinalis*, brown trout *Salmo trutta*, and Colorado River cutthroat trout *Oncorhynchus clarki pleuriticus*. Potential regional distributions, predicted by using thermal limits in conjunction with the thermal isobar map, were adjusted to simulate an increase in summer temperature of 3°C (as predicted by global climate models). Under this scenario, the geographic distribution of brook trout was reduced by 57%, brown trout by 29%, and cutthroat trout by 65%. To predict distributional shifts on a local scale we used data from two Wyoming streams (Horse Creek--brook and brown trout, North Fork Little Snake River--cutthroat trout). We assumed that current elevation limits result from thermal constraints. With a 3°C increase in mean July air temperature, brook trout distribution would be reduced from 97 km to 22 km of stream, brown trout from 102 km to 44 km, and cutthroat trout from 15 km to 3 km. Our research will also be valuable for examining how other factors, such as species interactions and stream gradient, influence distributional limits of fish.

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**Habitat Use of Young-of-Year Brown Trout during Fall in Douglas Creek,  
Medicine Bow National Forest**

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Little is known about the habitat used by young-of-year (YOY) brown trout *Salmo trutta* during fall. Observations of YOY brown trout were made along stream margins of Douglas Creek, Medicine Bow National Forest, from late summer until ice formation in November 1991. The habitat types assessed included stream margins with clean cobble and silted-over cobble, backwaters, and deeper areas associated with higher current velocities. In the daytime, YOY brown trout in stream margin areas used concealment cover, usually in the form of cobble substrate. At night, the fish emerged from concealment cover. As the season progressed, fewer fish were found along stream margins with clean cobble. They appeared to move into areas of higher velocities as they increased in size. The use of stream margins with silted-over cobble during this period remained constant. Backwaters served primarily as nighttime habitat, but the use of such areas was variable. No noticeable change in habitat use or behavior immediately prior to ice formation was apparent. This information may be useful in understanding the habitat requirements of YOY brown trout and in identifying systems where such habitat is limited.

**Angler Catch Rate, Effort, and Satisfaction for a Community  
Put-and-Take Rainbow Trout Fishery**

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Success of put-and-take trout programs has contributed to a belief among anglers that trout can be produced in virtually unlimited numbers at low costs. However, production limitations of hatcheries, limited funds for hatchery expansion and fishery programs, and increased demands for recreational fishing will ultimately result in stocking fewer fish, of all species, per angler. Therefore, there is a need to develop stocking strategies to maximize benefits from a limited number of fish.

Stratified angler creel surveys were conducted over a 3-year period to determine a cost-effective stocking strategy for a community put-and-take rainbow trout *Oncorhynchus mykiss* fishery in Lubbock, Texas. Catchable-size rainbow trout were stocked in the winters of 1988 through 1991 at three densities: low (700 trout/hectare), medium (1,400 trout/hectare), and high (2,100 trout/hectare). Angler effort and satisfaction levels increased with increased stocking density. However, catch rates were greatest for the medium density treatment lakes, followed by the high and low density treatment lakes, respectively. Overall, angler satisfaction was rated less than "good." To provide anglers with what they consider a "good" put-and-take trout fishery, a catch rate of greater than 1.7 trout per hour is needed. This is significantly higher than the 0.5 trout per hour catch rate targeted by many states implementing put-and-take trout programs.

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### **A Test of the Precision of the Habitat Quality Index Model II**

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We conducted an experiment to test the precision of the Habitat Quality Index Model II. We hypothesized that variation in individual attribute evaluations and subsequent ratings would lead to substantial variation in model predictions. Three 50-m reaches were evaluated by three different teams. Resulting HQI scores and data were used to evaluate model precision. Among individual attributes, cover and eroding bank ratings and measurements had the greatest variability. The late summer stream-flow attribute ratings also reflected high variability. Based on overall model performance, our analysis indicated the number of independent observations required to estimate the mean HQI score for the upper, middle, and lower reaches is 7, 14, and 3 respectively. Therefore, our hypothesis cannot be rejected for the upper and middle reaches but can be rejected for the lower reach. The range of measured values for the cover and eroding stream bank attributes demonstrates the need for quantitative definition to reduce subjectivity and associated variability.

### **Endangered Species in the Year 2092: Where Will We Be?**

Phil Pister, Desert Fishes Council, P.O. Box 337, Bishop, California 93515, (619) 872-8751

There is an old saying that unless you change direction, you will get where you are going. This statement is thoroughly applicable to threatened and endangered fishes, as we analyze those taxa that have become extinct, recognize the underlying reasons, then project these same factors into the next century. Doing so bodes ill for North America's native fish fauna, especially in the arid Southwest, as we view probable impacts of escalating water demand by burgeoning human populations and related habitat loss and change, and other negative factors such as seemingly incessant requests to introduce non-native fishes into the evolutionary habitats of native species. Retaining biodiversity of native fishes while maintaining an acceptable level of angling success for game species will require a thorough analysis of societal and professional values, as well as a redefining of fisheries management and success in the context of probable societal direction toward the end of the 21st century. Although we will not be around as witnesses, now is the time to direct our thoughts toward such matters. Only in this way can we begin to fulfill our obligation to future generations.

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### **A Review of Recovery Efforts for Colorado River Fishes**

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Four native fish that inhabit the Colorado River have been listed by the Federal Government as endangered: the Colorado squawfish, the humpback chub, the bonytail chub, and the razorback sucker. The Recovery Implementation Program for Endangered Fish Species in the Upper Colorado Basin (Recovery Program) is a consortium of federal and state agencies, environmental organizations, and private water development interests whose mission is to recover the endangered fishes of the Colorado River while allowing for new water development to continue. The Recovery Program has five major elements: (1) habitat management through reregulation of federal reservoirs and legal protection of instream flows, (2) habitat development and maintenance through nonflow alternatives, (3) artificial propagation and genetics management, (4) management of nonnative species and impacts of sport fishing, and (5) research, monitoring, and data management. The Recovery Program is a unique example of how a broad-based coalition of competing interests can work together to implement the Endangered Species Act (ESA) through collaboration and cooperation. It also demonstrates that the ESA has adequate flexibility to accommodate legitimate needs for water development and recovery of endangered fishes.

### **Harvest Management of Columbia River Salmon With Respect to the Endangered Species Act**

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The decline of Columbia River Basin salmon stocks over the past century has been caused by the cumulative effects of various factors associated with human development, including overfishing, dam construction, habitat degradation, and biotic community alternations. Reform in harvest management has been a controversial issue surrounding Salmon Summit negotiations, the Northwest Power Planning Council's Fish and Wildlife Program Amendment, and the development of recovery plans for Columbia basin stocks listed as threatened or endangered under the Endangered Species Act (ESA). Proposed changes in harvest management include implementation of weak-stock management principles for mixed-stock fisheries, establishment of stock-specific escapement objectives, restrictions on ocean and river harvest of depleted salmon stocks, improved stock identification and fishery monitoring, review of sport fishing regulations, accounting for incidental catches in ocean fisheries, increased law enforcement and public awareness of the detrimental impacts of illegal fishing, development of alternate harvesting strategies and technologies, a commercial fishing permit buy-back and lease-back program, inclusion of upstream states and tribes in formulating harvest regulations, and unified reporting of harvest data. To conserve and rebuild the Snake River salmon stocks listed under the ESA, as well as over 100 other depleted fish populations in the Columbia River basin, a comprehensive enhancement program will be needed that includes scientific harvest management, improved hydropower operations and dam passage for adults and juveniles, basin-wide habitat improvements, ecosystem research, and evaluation of the efficacy of specific enhancement measures.

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### **Endangered Species Act Section 7 Consultation Procedures for Listed Columbia River Salmon Stocks**

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The listing of populations of Pacific salmon has placed the Fish and Wildlife Service (Service) in the unfamiliar role of being on the other side of section 7 consultation requirements of the Endangered Species Act (ESA). The Service must now evaluate its activities, such as brood stock collection, hatchery operation, stocking, and research, to determine if they will adversely affect the listed salmon populations. Section 7 consultations must be initiated with National Marine Fisheries Service (NMFS) for those activities that are likely to adversely affect listed species. State and private agencies and organizations whose activities will result in incidental take of listed salmon need to apply for a section 10(a)(1)(B) permit from NMFS. Highlights of the section 7 and 10 process will be presented to ensure compliance with ESA.

### **Use of Antimycin to Remove Rainbow Trout From White Creek, New Mexico**

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A major goal of recovery for the endangered Gila trout *Oncorhynchus gilae* is reestablishment of populations within its native range. Six streams have been treated with the piscicide antimycin A to remove nonnative rainbow trout *O. mykiss* and brown trout *Salmo trutta*. Toxicant application and monitoring techniques have been refined with each treatment. White Creek, a tributary of West Fork Gila River, met criteria established by the Gila Trout Recovery Team for reestablishment of Gila trout, but it supported a population of rainbow trout. Data on the population of rainbow trout and aquatic habitat were gathered in 1990 and used to develop the renovation plan for the stream. More than 10 km of stream above a 10-m-high natural waterfall barrier were treated with antimycin A in June 1991. Posttreatment surveys are planned for summer 1992 to determine if the population of rainbow trout was eliminated. A second application of antimycin may be applied then. Methodologies used for survey and renovation are described.

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**Habitat Selection by Shoreline-spawning Kokanee in Flaming Gorge Reservoir, Wyoming-Utah**

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Kokanee *Oncorhynchus nerka* were introduced into Flaming Gorge Reservoir shortly after impoundment in 1963 and have become an important component of the sport fishery and forage base. Shoreline-spawning kokanee were first observed in 1981 and currently are thought to provide most of the recruitment to the kokanee stock. We assessed the spawning habitat of kokanee in fall 1990 and 1991. Kokanee generally selected shale substrate less than 10 cm in diameter on shores with slopes of 21°-40° for spawning. Three sites with these physical conditions were studied intensely. Kokanee were observed to spawn to depths of 30 m with no apparent selection for depth. Because kokanee are fall spawners and the embryos incubate in the substrate through winter, drawdown of the reservoir during winter may affect survival of embryos.

**Spawning Habitat Mitigation for Kokanee in the Green River Downstream  
From Fontenelle Dam**

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In 1986 an emergency drawdown of Fontenelle Reservoir resulted in the erosion of large amounts of cobble and gravel into the Green River downstream from the dam. Traditional kokanee *Oncorhynchus nerka* spawning areas in the Fontenelle Dam tailwater were covered with large deposits of cobble and gravel. In 1990, as mitigation for the habitat loss, the U.S. Bureau of Reclamation constructed three spawning channels through a large island of gravel and cobble that was deposited 0.8 km downstream from Fontenelle Dam. We evaluated the mitigative value of the spawning channels for kokanee in fall 1990 and 1991. Habitat in the Green River within a 3.5-km reach immediately downstream from Fontenelle Dam was measured and compared with habitat in the spawning channels. Use of the river and the spawning channels by spawning kokanee was also assessed. Suitable spawning habitat was found in both the river and spawning channels. About half of the spawning occurred in the spawning channels, but they formed only <0.1% of the available habitat. The spawning channels seemed to have been an effective mitigation effort, but they were found to be unstable and were damaged by high discharges during spring.

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### **Evaluation of A Spawning Channel Used to Sustain a Wild Trout Population in a Fluctuating Coldwater Reservoir in Colorado**

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In 1979, Joe Wright Reservoir was enlarged and refilled. The fishery objective for the drainage, including the reservoir, was to manage for a self-sustaining trout fishery. Annually during 1980-83, fry reared in a hatchery using eggs from a wild cutthroat trout-rainbow trout hybrid population were stocked in this fluctuating coldwater reservoir. Special fishing regulations were implemented in the drainage to prevent overharvest by anglers and to ensure adequate adult spawning populations. In 1983, a spawning channel was constructed immediately above the reservoir and evaluated during 1984-87. Fish migrations originating from the reservoir were monitored, and adult rainbow trout were placed in the spawning channel. During the evaluation period the spawning channel produced 4,350-10,100 trout fry. Annual measurements of water depths and water velocities were used for calculating the area of suitable spawning habitat in the spawning channel. Suitable spawning habitat ranged between 682 and 953 ft<sup>2</sup>. Production rates of 6.4-14.8 fry/ft<sup>2</sup> of suitable spawning habitat were estimated for the spawning channel. The reproductive habitat created in the spawning channel currently sustains the rainbow trout population in the drainage. The spawning channel is also used for egg-taking operations.

### **Effects of Fall Drawdown on Northern Pike and Largemouth Bass Movement in a Colorado Impoundment**

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Adult northern pike and largemouth bass were monitored with ultrasonic tags in two 50-hectare lakes at the Rocky Mountain Arsenal, Colorado, to evaluate the effects of lake-level drawdown on movement and home range size. Water levels in Lower Derby Lake were reduced for 3 months, while an adjacent lake was held at full-pool during the study. Largemouth bass in Lower Derby Lake moved greater distances and showed larger or nonexistent home ranges (minimum convex polygon area) during low water levels than during either pre- or post-drawdown conditions. The same trend was evident for tagged northern pike, but increases in movement and home range size associated with low water levels were not significantly different from full-pool values. Bass and pike movements in the stable lake remained unchanged throughout the study. These results indicate that water-level fluctuations may disrupt normal predator behavior. Managers should consider this possibility prior to implementing management practices that employ water-level manipulations to enhance a fishery.

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### **Pyramid Lake Fisheries: Past, Present, and Future**

M. K. Alam and Paul Wagner, Pyramid Lake Fisheries, Star Route, Sutcliffe, Nevada 89510

This video presentation on Pyramid Lake, Nevada, is in a narrated, still-slide format. The video presents the issues affecting the fishery resources of the lake. The show begins with a historical perspective, describing the land, its people, and the fishery resources of the lake. The decisions made at the turn of the century, which decimated the lake's fishery, are described. The show concludes with a description of hatchery activities being pursued to restore the fishery, and possible solutions for resolving the lake's long-term problems are presented.

### **Estimating the Social Impacts of the Trinity River Fish Run Restoration with Survey Data**

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The Trinity River provides California citizens with nonmarket instream-flow social benefits, as well as important market goods and services. The dollar value of the nonmarket benefits provided by the instream flows of the Trinity River can be estimated and used as a yardstick for measuring the social value of the instream uses versus the diversionary uses of Trinity River water. Resource managers and fishery biologists should be aware of the fact that other tools can be used to estimate the value of the instream uses of the Trinity River. In general, and in the particular case of the Trinity River, quantitative, empirical, site-specific information plays a critical role in estimating the net economic benefits of instream flow. I describe state-of-the-art techniques for quantifying the nonmarket benefits of the instream flow uses. A brief review of the role of nonmarket benefit estimation techniques in the water allocation arena is given. The limitations of nonmarket valuation procedures as a decision-making tool are noted and explored.

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### **Physical Habitat-based Fish Population Model for the Trinity River**

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We describe a computer model built to mimic the dynamics of juvenile chinook salmon *Oncorhynchus tshawytscha* in the Trinity River, California. The model's premise is that egg and pre-smolt mortality are directly related to spatially and temporally discrete micro- and macro-habitat limitations, which themselves are related to the timing and amount of stream discharge. Habitat limitations result either in direct mortality or mortality associated with habitat-colonizing movement. Habitat use and mortality relations are functions of the size of the fish, which is in turn governed by water temperature. The quality or capacity of the habitat is characterized using a mesohabitat-typing approach that defines the spatial computational units used in the model.

The model tracks the population as "cohorts" originating as eggs and advancing from one class to another through growth. Individual cohorts either remain in the computational unit in which they emerged or move, in whole or in part, to nearby units. Components of the computer model, called processes, may be assembled by model users to describe a particular population in a specific study area. Model processes include spawning (with redd superposition), growth (including egg maturation), mortality, movement (both freshet and habitat-induced), and stocking.

### **Managing Reservoir Storage for Instream Flow**

Terry Waddle, U.S. Fish and Wildlife Service, 4512 McMurray Avenue,  
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Two possible approaches to using a portion of storage to supply instream flows are (1) to determine a fixed amount to be released each year for instream flows, and (2) to set aside a fraction of storage and inflow for instream management. I define the storage account in the second approach as a "water budget." I present a spreadsheet example showing operations of these two alternatives to provide instream habitat below a reservoir. I use a limiting event model, the effective habitat time series, to determine when water budget releases will produce habitat benefits. The effective habitat time series acts as a surrogate for the fish population and reflects the mid- to long-term influence of water management decisions on the life cycle of a fish species. I demonstrate an operation rule for the water budget that considers water rights and habitat events. I conclude by contrasting the habitat benefits of water budget operation with the fixed volume approach.

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### Evaluating Substrate Conditions in Natural and Artificial Redds of Idaho Salmonids

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Relationships between fine sediment in spawning gravels and incubation success of salmonids are not well understood. To evaluate quantitative tools for assessing fine sediment effects in different geologies, we sampled redds of steelhead *Oncorhynchus mykiss* and chinook salmon *O. tshawytscha* in streams draining granitic rocks, and redds of Yellowstone cutthroat trout *O. clarki bouvieri* in a stream draining marine sedimentary rock. To describe temporal and spatial changes in the redd environment, we measured substrate particle size distributions, intragravel dissolved oxygen, and water temperature in egg pockets, redd pits, tailspills, undisturbed substrate outside redds, and artificial redds. Spawning activities displaced fine sediments from locations in redds. Steelhead and cutthroat trout egg pockets contained fewer fines than other sites and exhibited declining dissolved oxygen concentrations as incubation progressed. Vertical stratification of substrate samples illustrated increasing fines with depth. Trends in measured parameters were similar among the three species tested. We discuss the use of surrogate sites, including artificial redds; for monitoring conditions in spawning gravels and egg pockets. Research is needed to define factors influencing the intrusion of fines into redds and to relate gravel quality to incubation success.

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### **Sediment Intrusion Within Fry Emergence Traps: A Confounding Factor in Survival Studies**

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Currently there are two procedures for estimating Survival To Emergence (STE) of salmonids within spawning gravels, direct and indirect. Indirect techniques include those in which the quality of substrates within which eggs have been deposited are assessed. This generally includes the quantification of fine sediments, and the extrapolation of such estimates to laboratory-derived survival functions. Direct measurements can be made through the use of fry emergence traps, which are installed directly over known redds, and emerging fry are captured within a collection bottle at the posterior end of the trap. Provided that the number of eggs deposited within each redd are known, the application of fry emergence traps theoretically would provide the best index of STE of all techniques available. However, unless consideration is given to factors which may influence the performance of the traps, their use can result in erroneous conclusions. We present the results of a study conducted on the Clark Fork River, Montana, which utilized fry emergence traps to determine STE estimates from brown trout redds. A total of 12 brown trout redds were identified during fall 1988 and marked for relocation and capping in 1989. Because of potential groundwater recharge to the river, the emergence traps were placed over each redd in March and monitored through June. During this period, storm events resulted in high flow conditions, resulting in the transport and deposition of fine sediments within many of the emergence traps. Just prior to trap removal, substrate core samples were collected, both inside and outside of each emergence trap. Results of sieve analysis indicated that significantly higher concentrations of fine sediments ( $\leq 0.84\text{mm}$ ) were present in samples collected inside the traps than outside ( $P = 0.005$ ). The mean percentage of fines outside the traps was 9.2% (range 3.8%-13.9%); the mean percentage inside the traps was 25.5% (range 6.9%-51.3%). The results indicated that the fry emergence traps influenced the sediment transport pattern of the river, with increased deposition of fines occurring inside the traps, presumably because they serve to locally reduce stream velocities, causing the settling out of fines. An understanding of the ambient sediment concentrations and transport capabilities of river systems is important when considering the use of fry emergence traps. In systems where sediment deposition is likely to occur, attention should be given to projected emergence times of fry based on Temperature Unit (TU) estimates, to ensure that trap installation corresponds with estimated emergence times. The premature placement of fry emergence traps in these systems may result in the selective deposition of sediments within the trap confines and may confound STE estimates.

**Development, Testing, and Refinement of a Program For Monitoring Spawning and Incubation Habitat Quality in Montana's Flathead Drainage**

Thomas M. Weaver, Montana Department of Fish, Wildlife, and Parks

Montana's Flathead Drainage supports the largest population of adfluvial bull trout in the United States. Adfluvial westslope cutthroat trout are also native to the Flathead System. During the late 1970's and early 1980's, a 5-year study identified critical bull trout spawning areas. Researchers discovered that bull trout use less than 25% of the available stream length for spawning. This study resulted in development of a program for monitoring fine sediment levels (<6.35 mm) in critical spawning areas by hollow-core sampling. Between 1983 and 1985, preliminary efforts to determine the effects of fine sediment on bull trout embryo survival to emergence occurred. Results of laboratory and field testing showed significant inverse relationships between material <6.35 mm and emergence success. During the mid 1980's, researchers began to identify westslope cutthroat trout spawning areas in Flathead tributaries. The Department of Fish, Wildlife and Parks (MDFWP) included these areas in the ongoing hollow-core sampling program and began embryo survival-to-emergence testing using westslope cutthroat trout. From 1989 through 1991, MDFWP conducted refined embryo survival-to-emergence testing for both species. This work incorporated points identified by Chapman (1988) as critical for valid survival-to-emergence testing, including freeze-coring natural redds to determine egg pocket structure and depth, particle size distribution, and monitoring of interstitial permeability, dissolved oxygen concentration, and temperature. Results showed significant inverse relationships between material <6.35 mm and emergence success by both species and refined our predictive capability. This work also resulted in recommendations to land managers for threshold levels of fine material in critical spawning areas.

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## **Integrating Streambed Sediment Analyses Into Land Management Decisions**

Bruce E. May, U.S. Forest Service

Fisheries biologists provide streambed sediment information in two distinctly different environments. These environments include the purely scientific environment and the land-use decision environment. The scientific environment functions without the influence of value-oriented factors. This environment fosters the analytical role. The land-use decision environment tends to be heavily charged with value-oriented factors. The trade-off assessment replaces cause and effect analysis. Political and social factors are considered along with scientific information. Advocacy is rampant.

The scientific environment dictates employment of the best available procedures to define stream substrate attributes and to display relationships between biological and land-use conditions. The tendency is for a high level of precision and accuracy. Information is judged by strict and rigid levels of significance. The decision environment, by contrast, doesn't rely on levels of significance but rather levels of risk. Many of the factors evaluated in the decision process are political or social, and trade-offs can be arbitrary.

Many biologists find the scientific environment more objective and less stressful than the decision environment; many withdraw because of uncertainty in information and analytical tools. The reality is that land-use decisions move on, with or without information provided by the scientific environment. It is incumbent upon fishery professionals to keep these environments in perspective. Rigid levels of scientific significance, accuracy, and precision must give way to strengthening the power of our information in the decisional environment. In reality, the fishery resource is best served by fishery professionals who strive to improve scientific skills and tools but at the same time realize the reality and rules of the decision process.

### **Fine Sediment: Time, Space, Biology, and Monitoring**

Michael K. Young, Rocky Mountain Research Station, U.S. Forest Service, 222 S. 22ND Street,  
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Though fine sediment is widely recognized as a problem for salmonids in streams, the strategies for monitoring the extent and severity of its effects are not well recognized. To design a monitoring program, the biologist must understand the stream and its biota and must tailor the monitoring to them. For example, the salmonid life stage and species of concern and a particular stream's hydrograph will determine the time, location, method, and intensity of sediment sampling. Nonetheless, the most important question to ask is whether fine sediment is truly a problem. In some streams in the central Rocky Mountains, fine sediment may benefit salmonids.

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### **Application of a Population Simulation Model to the Selection of Angling Regulations for Stream Fisheries**

Dirk D. Miller, Wyoming Game and Fish Department, 528 S. Adams Street,  
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A population simulation model was used to evaluate the potential impact of changes in angling regulations for stream fisheries in Colorado. The model is deterministic, considering growth, mortality, and recruitment, and it simulates various angling regulations through several parameters associated with angling mortality. Several regulations were considered: 18-, 25-, 30-, and 40-cm minimum size limits and a 30- to 40-cm slot limit. The South Platte River is near a major metropolitan area and receives extremely high fishing pressure (6,000 angler hours/hectare/year). Simulation results indicate that only the most conservative regulations will maintain the fishery. The Black Canyon of the Gunnison River is difficult to access and receives relatively low fishing pressure (320 angler hours/hectare/year). Simulation results indicate that only the most liberal regulations would degrade the fishery to an unacceptable level. Both of these rivers have the biological potential to produce adequate numbers of quality-size fish when protected from anglers.

### **Application of a Surplus Production Model to Echinoderm Fisheries in Southeast Alaska**

Doug Woodby, Alaska Department of Fish and Game, Douglas, Alaska 99824, (907) 465-4250

Management of sea cucumbers *Parastichopus californicus* and sea urchins *Strongylocentrotus franciscanus* in southeast Alaska is based on a unique application of a surplus production model. Without adequate precautions, this model type is potentially too simplistic to provide for a sustained yield. To prevent overharvesting a correction factor is applied to harvest quotas to account for errors in model assumptions, only a portion of the population is subject to harvest, and the population size estimate used to set a harvest quota is the lower bound of a 90% confidence interval. Our application of the model differs between the two species due to differences in life histories. Preliminary results from both the sea cucumber and sea urchin fisheries indicate that harvests are conservative. In particular, the method of estimating population size in the sea urchin fishery was found to be highly conservative in the first year of fishing, due to a bias in sampling. We conclude that conservative management is satisfying the need for orderly fishery development and, in the case of sea cucumbers, has satisfied legal requirements for meeting the needs of subsistence users. Research this year includes experimental harvest rates and population assessment with a manned submersible.

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**Applications of a Generalized Computer System for Simulating Fish Populations: Management Programs for Bass, Sturgeon, and Salmon Based on Harvest Modeling**

Raymond C. Beamesderfer, Oregon Department of Fish and Wildlife, 17330 SE Evelyn St.,  
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Effects of alternative harvest regulations can be systemically weighed with computer models of fish populations, but this task is complicated by the mechanics of computer programming. Many fish population models are portions of a general life-cycle model that can be programmed along with a series of menus to simplify selection of population processes, entry of parameters, and display of results. We used a flexible system to evaluate a variety of harvest management problems in the Columbia River. Comparisons of potential tradeoffs in number and size of smallmouth bass harvested with an increase in the minimum size limit to 12 inches led to experimental implementation of that regulation. Model predictions of optimum harvest rates of white sturgeon much lower than those observed in recent years led to more conservative management of sturgeon fisheries. Projected reductions in predation by northern squawfish on migrating salmon smolts stimulated a large-scale predator harvest program to mitigate hydropower losses. Finally, effects of different harvest rates were factored out in estimates of potential production foregone in several impounded sturgeon populations.

**Implementation and Performance of the Management Plan for the Kenai River  
Chinook Salmon Fishery, Alaska**

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The Kenai River, Alaska, supports large recreational and commercial fisheries for chinook salmon *Oncorhynchus tshawytscha*. Growth in these fisheries has fueled severe allocative disputes and heightened concern that stocks are vulnerable to overexploitation. Upon the recommendation of resource managers, management plans were implemented through regulations for these fisheries in 1989. These management plans provide for sustained yield through a spawning escapement goal policy and means by which to regulate competing fisheries in the event of conservation shortfall. The management plans are implemented through predictions of fishery parameters and population abundance. Migratory time density models are used to forecast harvest, in-river return, and escapement. To achieve escapement goals, the management plans provide for the use of catch-and-release and no-bait regulations. Implementation of these regulatory mechanisms has been crucial in achieving escapement objectives. The no-bait regulation reduced angler efficiency by approximately 50% without reducing participation in the fishery. The catch-and-release regulation reduced fishing mortality by approximately 90%; however, angler effort decreased dramatically. During 1992, the catch-and-release provision will include retention of trophy fish in an attempt to maintain more participation in the fishery.

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### **Using the FISHREGS Model to Assess the Potential Effects of Angler Exploitation on a Wild Stream Rainbow Trout Population**

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A user-friendly, interactive computer model, FISHREGS, was used to evaluate the potential impacts of angler exploitation of wild rainbow trout and brown trout populations of the Rio Grande River, in Colorado. The availability of 11 years of trout population data (subject to several different angling regulations) facilitated an effective evaluation of the responsiveness of the model.

The FISHREGS model proved to be a useful tool for evaluating the appropriateness of various restrictive angling regulation options. The results indicate that modeling scenarios (when tempered with sound professional biological judgement) can be an effective management tool in assessing the need for and the probable response of a trout population to different regulation scenarios. Modeling the trout population response can result in great savings in time, money, and manpower, offering a real alternative to setting a regulation and conducting long-term (years) field evaluations.

### **Stormwater Management Guidelines For Protection of Fish and Shellfish Habitat**

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Concentrated primarily in the Puget Sound basin, Washington State has been undergoing an extended period of rapid growth. Many urban streams that once provided high quality habitat to maintain fish now support only remnant populations. Intertidal and shallow subtidal areas into which these streams drain historically produced abundant, high quality shellfish. Many areas have now deteriorated such that production is minimal. In others, shellfish populations have been declared unfit for human consumption. Direct and indirect impacts of stormwater run-off are largely responsible. Historically, stormwater regulations were designed to prevent flooding; more recently, protection of water quality has been the objective. None of the regulations, however, have been adequate to protect fish habitat. The Washington Department of Fisheries has developed and implemented stormwater regulations specifically designed to protect fish habitat in streams. These more protective requirements will also benefit downstream marine and estuarine areas.

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### **Habitat Requirements of Spawning and Rearing White Sturgeon in the Lower Columbia River**

Allen Miller, U.S. Fish and Wildlife Service, National Fishery Research Center-Seattle, Columbia River Field Station, Cook, Washington 98605, (509) 538-2299

From 1987 through 1991, the U.S. Fish and Wildlife Service has been investigating white sturgeon *Acipenser transmontanus* early life history and habitat requirements in the lower Columbia River as part of a four-agency study to examine the effects of hydropower development on white sturgeon populations. Three impoundments were studied, each with a dam at the upstream end; an unimpounded reach downstream from the lowermost dam served as a control area. Spawning occurred in 10° to 18°C water from May through July in tailrace areas with high water velocities. Catch-per-unit of effort values for eggs, larvae, and young-of-the-year (YOY) were greater in relatively high-flow years than in low-flow years. Larvae and YOY distributed downstream rapidly, primarily using deep main channel areas. Young-of-the-year and older juveniles used areas over 4 m deep with a wide range of water velocities and substrates. Abundance of eggs, larvae, YOY, and juveniles was greater in the unimpounded reach than in three impoundments. White sturgeon use of water depths, velocities, and substrates varied by life stage; rearing requirements were more general than spawning requirements.

### **Idaho's Endangered Salmon**

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There is no question that habitat loss, destruction, and modification have decimated Idaho salmon. Idaho once produced nearly half the spring and summer chinook in the Columbia basin. Sockeye are now listed as endangered, and three races of chinook are listed as threatened under the Endangered Species Act. Hydroelectric development permanently sealed off 39% of Idaho's salmon habitat. Federal dams built for hydropower, flood control, and navigation inundated about 375 miles of the migration corridor from Asotin, Washington, to Portland, Oregon, changing 87% of the habitat from lotic to lentic. Inappropriate management of public lands has degraded major areas within the remaining production area. Panther Creek, Yankee Fork, South Fork Salmon River, and Bear Valley drainages are sterling examples of habitat degradation. Redd counts and parr density monitoring clearly indicate that juvenile production of Idaho salmon is far below the potential for all habitat types. Juvenile production in designated wilderness is no better than in degraded habitat in many cases. Hatchery production has tripled in the past 10 years, but hatchery rack returns are currently underescaped. Clearly, increases in production through hatchery expansion, supplementation, or habitat enhancement will not ensure recovery unless the migration corridor habitat is rehabilitated.

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### **Effect of Habitat Enhancement and Canopy Removal on the Fish Community of a Headwater Stream**

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The riparian trees along a 2-km section of stream in western Oregon were logged in 1985, in violation of forest practice regulations. As part of the judgment against the landowner, wood was placed in the channel to improve habitat in 1988. Fish populations and habitat have been monitored since 1986 at three sites: the enhanced area, a non-enhanced reach without a canopy, and a non-enhanced reach with a canopy. Pool area increased 20% as a result of the wood addition at the enhanced site. Pool area during summer also increased at the site with the canopy due to beaver activity. Speckled dace *Rhynchichthys osculus* have exhibited the greatest response, increasing in numbers at all three sites, with the greatest gains in the enhanced reach. Salmonid density at all three sites also has increased since 1988. Age 0 steelhead *Oncorhynchus mykiss* exhibit an inverse relationship between density and growth. However, no such relationship is evident between age 0 steelhead growth and dace density, which indicates that the two species are not competing for resources. Increased food availability, due to elevated autotrophic production, in the enhanced and non-enhanced uncanopied reaches and improved habitat in the enhanced and canopied reaches are the probable causes of the elevated fish populations.

### **Habitat and Species Restoration Within the Golden Trout Wilderness: Ethical Choices in Applied Ecology**

Phil Pister, Desert Fishes Council, P.O. Box 337, Bishop, California 93515, (619) 872-8751

For more than a century, overgrazing by livestock has seriously degraded the watershed, stream habitat, and riparian areas of the majority of the South Fork Kern River drainage within the Golden Trout Wilderness. This has gradually created habitat conditions favoring invading, exotic brown trout *Salmo trutta* to the exclusion of the endemic California golden trout *Oncorhynchus aquabonita* within the area where it was isolated and has been evolving since the Pleistocene. This magnificent fish was in serious danger of being extirpated from the entirety of its range.

In an extensive program, which has now been in progress for more than 25 years, the California Department of Fish and Game and Inyo National Forest have worked cooperatively to restore the basic integrity of the biota through extensive fencing, construction of major fish barriers and erosion control devices, and chemical treatment of more than 160 km of stream. Although the project has been costly and of long duration, any admirer of native fish faunas will be heartened by the eradication of brown trout prior to the re-establishment of the native golden trout and Sacramento sucker *Catostomus occidentalis* in an effort to recreate as closely as possible the evolutionary circumstances of the latter two species.

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### **Mitigating the Effects of Hydropower Development on White Sturgeon Populations in the Lower Columbia River**

Allen Miller, U.S. Fish and Wildlife Service, National Fishery Research Center-Seattle, Columbia River Field Station, Cook, Washington 98605, (509) 538-2299

The U.S. Fish and Wildlife Service investigated the early life history and habitat requirements of white sturgeon *Acipenser transmontanus* in the lower Columbia River from 1987 through 1991 as part of a four-agency study to examine the effects of hydropower development on white sturgeon populations there. One objective was to identify methods for protecting, mitigating, and enhancing white sturgeon populations in the lower Columbia River. Three impoundments and a free-flowing reach were studied. Abundance and reproductive success were greatest in the free-flowing reach and declined progressively upstream in the lower-most three impoundments. Spawning success was affected primarily by water velocity, which varied with channel morphology. Reproductive success was highest in high-flow years. Possible mitigative measures include manipulation of flows during spawning periods to maximize spawning habitat below dams; management of each impoundment and reach separately; supplementing white sturgeon populations in impoundments where abundance is low, with cultured fish or by moving fish from areas where they are abundant; and increased enforcement of harvest regulations.

### **Crisis or Opportunity: The Endangered Redfish Lake Sockeye in the Columbia River**

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Under the Endangered Species Act (ESA), classification of Redfish Lake sockeye salmon as endangered has initiated an aggressive plan to restore and enhance a unique Snake River sockeye salmon population on the Columbia River. Classification as endangered requires precise ability to identify the stock and to pursue methods to recover the population, even without having addressed the cause of decline. Research is directed at identifying DNA markers to separate stocks, developing short-term captive brood stocks from smolts and remnant spawners, and increasing lake productivity by fertilization. There is no doubt that Redfish Lake sockeye have diminished to the point where definite measures are necessary to preserve them. The issue, however, is whether the ESA is the appropriate measure to impose in this circumstance. The Columbia River was developed as a working river. Sockeye salmon are healthy as a species, and they have established records of maximum abundance in the North Pacific in the last few years. The cost of recovery and the potential impact of recovery measures on agriculture, hydropower, shipping, and other resource-related activities are factors that will ultimately determine whether the ESA was the best method to apply to the Redfish Lake sockeye salmon problem.

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**The Role of Supplementation in the Columbia Basin--Concepts from the Regional Assessment of Supplementation Project**

Cleve Stewart, Mobrand Biometrics, Inc., 9920 Bank Road SW, Vashon, Washington 98070, (206) 463-5003, and the Regional Assessment of Supplementation Project

Supplementation is expected to make a major contribution to rebuilding salmon and steelhead runs in the Columbia River basin. More than half of the projected increases are attributed to supplementation projects. These expectations are based on a set of assumptions about which there is significant uncertainty.

The Regional Assessment of Supplementation Project (RASP) is developing a framework for determining a role of supplementation where risks due to uncertainty can be managed. This framework is based on existing science coupled with a new set of management values and priorities. This framework defines supplementation and identifies survival, reproductive success, long-term performance, and ecological impact as the qualities by which success must be measured. We outline a theory for supplementation that allows us on the one hand to make consistent decisions about the use of supplementation, and on the other hand provides a platform for progressive debate and research. A clinical approach is taken in applying the theory; the stock/stream is viewed as the patient, supplementation as a range of possible treatments. Historical reconstruction and current objectives are combined to describe the template for health. The view of supplementation as a highly variable treatment is emphasized. We dismiss the notion that supplementation is either categorically undesirable or a universal solution to rebuilding. The prescription of supplementation is as variable as the patient.

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### **The Columbia River Northern Squawfish Control Program**

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The Columbia River Squawfish Control Program is a multi-million dollar, Bonneville Power Administration-funded program to implement and evaluate fisheries for northern squawfish in an effort to reduce the impact of squawfish predation on juvenile salmon and steelhead migrating through the mainstem Columbia and Snake rivers.

Development of the Columbia River basin hydropower system has resulted in creation of reservoirs throughout the basin and seasonal alteration of flows, which have enhanced populations of resident fishes that prey on juvenile salmon and steelhead migrating to the ocean. Recent studies confirmed that predation by northern squawfish was significant throughout the mainstem Columbia River. Annual consumption of juvenile salmonids by squawfish in the John Day pool alone was estimated at approximately 2 million smolts, or 11% of the run. Based on these findings, the Squawfish Control Program was developed to implement and evaluate fisheries on squawfish and to determine their efficacy in reducing losses of juvenile salmonids to squawfish predation on a sustained basis.

In 1991 a sport, reward fishery, an angling fishery at eight Columbia River and Snake River dams, and a tribal, commercial longline fishery were employed. In all, these fisheries harvested approximately 200,000 squawfish. Alternative harvest methods that may be usable on a large scale for harvesting squawfish and the market potential for harvested squawfish are also being investigated.

### **Changing the Way the Columbia River Runs**

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The Columbia River is a highly engineered system providing the Pacific Northwest with electric power, irrigation, municipal and industrial water supplies, recreation, water-borne transportation, and flood control. It is also the home and migration route for the region's prized salmon and steelhead. With the recent listing of the Snake River sockeye salmon and spring/summer and fall chinook salmon under the Endangered Species Act, many believe that the engineering/biological experiment of the past 50 years has failed one of its most important tests.

No one knows for sure what changes will help ensure the survival of the salmon, but many of the proposals call for major changes in the way the Pacific Northwest uses the Columbia River. The Bonneville Power Administration, with the Corps of Engineers and Bureau of Reclamation, is examining how the system might be re-engineered physically and operationally. Drawdown of the Snake River reservoirs, drafting the upstream storage reservoirs to augment flows during the migration periods, and increasing velocities of the river to more closely approximate the natural river are the components of the second grand experiment.

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### Identification of Cutthroat Trout--Problems and Prospects

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Accurate identification of the polytypic group of cutthroat trout *Oncorhynchus clarki* is not an easy proposition and is confounded by the occurrence of hybrid swarms of cutthroat trout and rainbow trout *Oncorhynchus mykiss*, as well as hybrids of various subspecies of cutthroat trout. What is known of the phylogeny and historic distribution of native cutthroat trout is based, to some degree, on collections made around the turn of the century, interpreted by "classical taxonomic techniques." The burgeoning field of molecular systematics, which relies on the use of biological macromolecules to infer phylogenetic relationship, is becoming an increasingly important component of taxonomic identification. More-traditional approaches, such as protein electrophoresis and chromosome karyotyping, are now supplemented with analysis of various DNA, RNA, and mtDNA using restriction digests or direct sequencing. Though much valuable insight can be gained by these new techniques, the ability to successfully isolate DNA, and to run restriction digests, does not ensure resolution of taxonomic questions. Furthermore, identification of intraspecific diversity regarded as non-taxa, which should be considered "significant evolutionary units," may not be possible using molecular techniques alone. Validation of taxonomic conclusions using "classical techniques" is strongly recommended.

### Status of the Greenback Cutthroat Trout Recovery Plan

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The greenback cutthroat trout *Oncorhynchus clarki stomias* is native to the South Platte River and Arkansas River drainages and once occupied a wide range of aquatic habitat within these drainages. Overharvest, loss of habitat, and the introduction of non-native fish virtually displaced the greenback cutthroat trout, and it was considered to be extinct by 1930. Early interagency recovery efforts identified two small remnant populations that represented less than 2,000 individuals, and the species was listed as an endangered species in 1973. Recovery of the species has involved captive breeding programs, chemical removal of non-native species, and catch-and-release fishing programs. The proposed recovery goal for the species is 20 stable, reproducing populations, representing a minimum of 50 hectares of lake habitat and 50 km of stream habitat. Up to 19 stable populations have been established, with 17 of the 19 located in the South Platte River drainage. Expanded experimental fishing programs and at least five stable Arkansas River populations are proposed prior to complete delisting of the greenback cutthroat trout.

### **Cutthroat Trout Management in Wyoming**

Michael D. Stone, Fish Division, Wyoming Game and Fish Department, 5400 Bishop Blvd.,  
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Wyoming is home to more varieties of cutthroat trout than any other state, including the Yellowstone, Snake River, Bonneville, Colorado River, and west slope cutthroat trout. A sixth variety, the greenback cutthroat trout, historically inhabited Wyoming. Recognition and active management for these native trout has taken place for several decades. Historical and current management and problems are reviewed. Future needs and management challenges are identified.

### **A Draft Conservation Plan for Colorado River Cutthroat Trout in the Little Snake River Enclave, Wyoming**

Calvin C. Speas, Medicine Bow National Forest, USDA Forest Service, 2468 Jackson Street,  
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An interagency working group composed of representatives of Wyoming Game and Fish Department, Bureau of Land Management, and USDA Forest Service-Medicine Bow National Forest set out in 1991 to develop a Conservation Plan for Colorado River cutthroat trout *Oncorhynchus clarki pleuriticus* for the Little Snake River drainage, Wyoming. This "second-generation" plan is being built on a previous plan that was developed and implemented cooperatively between Wyoming Game and Fish and the Medicine Bow National Forest in 1986. The purpose of the new plan is to reestablish and protect genetically pure populations of Colorado River cutthroat trout (CRCT) in the drainage. The plan emphasizes protecting current populations and habitat of high purity CRCT; reestablishing CRCT within its native range; increasing public awareness concerning the status of CRCT and their management needs; supporting research efforts on CRCT life history, habitat needs, and limiting factors; monitoring to determine progress towards the stated objectives in the plan; and developing funding sources to implement the conservation strategy. The duration of the plan is from 1992 through 1997.

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### Colorado River Cutthroat Trout Management in Currant Creek in Southwestern Wyoming

- o Kevin M. Johnson, Wyoming Game and Fish Department, 351 Astle Avenue, Green River, Wyoming 82935, (307) 875-3223

Drought, livestock grazing, decline of beaver and beaver habitat, and suppression of wildfire caused deterioration of the Currant Creek watershed. The stream contains one of the few remaining populations of Colorado River cutthroat trout *Salmo clarki pleuriticus* in southwestern Wyoming. Drastic fish stock decline initiated extensive changes in stream and watershed management. With an ecosystem perspective, a long-term (15-year) project was begun in 1990 to change vegetative climax communities to more-diverse vegetation, towards a healthier watershed. Inventory of aspen, conifer, mixed-shrub, and riparian communities has been completed and treatment techniques proposed. Timber overpour devices were placed in the stream in 1991 and will continue through 1993 to provide immediate benefits to fish and to prevent further downcutting of the stream channel. Grazing management changes were implemented for recovery of riparian areas and to protect stream channel improvements. The Wyoming Game and Fish Department, Bureau of Land Management, Trout Unlimited, landowners, and lessees are cooperating on the project.

### Bear River Cutthroat in Wyoming--Worth Saving?

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The Bonneville cutthroat trout *Oncorhynchus clarki utah* (locally known as the Bear River cutthroat) is a remarkably adaptive species. Its native range in Wyoming includes all of the Bear River drainage, about 2,500 square miles. There are nine streams and one natural lake known that contain pure or only slightly hybridized Bear River cutthroat trout. Within this native range, about 262 stream miles and 2,800 acres of standing water contain wild or stocked Bear River cutthroat trout. Ninety percent of the wild population in its native range is taxonomically rated A or B, despite the fact that many of these waters were stocked with Snake River cutthroat trout during the 1950's and 1960's. Approximately 320,000 fingerlings were stocked in 1991, with 60% of these fish stocked outside of their native range. Wyoming Game and Fish Department's management efforts include constructing habitat improvement structures and implementing special regulations on waters within the native range, brood stock maintenance and routine rearing, stocking pure populations "on top" of wild populations to improve purity, and increased emphasis on watershed management. Continued coordinated management efforts with federal land management agencies and the Wyoming Game and Fish Department will emphasize activities to ensure this species is never listed as a threatened or endangered.

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### **Sampling Time Influences on Habitat Suitability Curves for Young-of-Year Brown Trout**

Wayne A. Hubert and Douglas D. Harris, U.S. Fish and Wildlife Service, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming, Laramie, Wyoming 82071-3166

The Instream Flow Incremental Methodology (IFIM) was developed to evaluate the effects of altered stream flows on fish habitat. One criticism of IFIM has been the use of suitability curves to represent habitat preferences of fish. Instream flow studies often employ habitat suitability curves that were developed from data collected during daylight in a single summer. Generalized suitability curves may not be sufficient to describe microhabitat use by fish, especially when diel or seasonal shifts in behavior occur, such as with rapidly growing young-of-year (YOY) fish. We observed diel (day vs. night) and seasonal (June vs. July) shifts in habitat use by YOY brown trout *Salmo trutta* in a mountain stream. The influence of these shifts on habitat suitability curves for water depth, water velocity, and substrate, as well as resultant weighted usable area predictions, was substantial. Significantly more weighted usable area was predicted using curves developed from fish locations in June and at night in July. No significant difference was observed in weighted usable area between day and night in June, but in July the nighttime weighted usable area was significantly less than the daytime weighted usable area. The computations of weighted usable area indicated greater habitat availability in June than in July during the day and night. Our estimates of weighted usable area depended on which curves were used. These observations indicate that interpretations and recommendations for instream flow could vary greatly, depending on when data are obtained for development of habitat suitability curves. Our findings support the contention that generalized suitability curves, developed without consideration of the size of YOY fish or time of day, may not be sufficient.

### **Application and Testing of a Procedure to Evaluate Transferability of Habitat Suitability Criteria**

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A procedure designed to test the transferability of habitat suitability criteria was evaluated in the Cache la Poudre River, Colorado, using criteria for active adult and juvenile rainbow trout developed from the South Platte River, Colorado. A third set of criteria, obtained from a published source, was also tested. A one-sided variant of the chi-square test, using 2 X 2 contingency tables, was used to test for nonrandom selection by adult rainbow trout for optimal habitat over marginal habitat and for suitable over unsuitable habitat, as defined by each set of criteria. Test results indicated that the active adult criteria from the South Platte River were transferable to the Cache la Poudre River, but the juvenile criteria (applied to adults) and the literature-based criteria were not. The inclusion of very complex test sites increased simulation errors, which led to increased probability of Type II errors, but not Type I errors. Both types of error resulted from insufficient sample sizes, with the probability increasing exponentially as the sample size was decreased from 50 observations. If study sites are selected judiciously, data collected carefully, and a sufficient sample size used, the procedure is simple and reliable for testing transferability of habitat suitability criteria.

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**An Evaluation of Boulder Structures Placed in the Rio Grande River,  
Colorado, Using the IFIM/PHABSIM Model**

Scot Shuler, R. Barry Nehring, and Kurt Fausch, Colorado Division of Wildlife and Colorado State University, Fort Collins, Colorado 80526

Habitat suitability criteria developed for adult and juvenile brown trout in the Rio Grande and South Platte rivers, Colorado, were used in the Physical Habitat Simulation Model (PHABSIM) of the Instream Flow Incremental Methodology (IFIM) to evaluate habitat gains of single boulders, midchannel boulder groupings, and boulder wingdams placed in the Rio Grande River. Model validity and accuracy were verified by testing the relation between weighted usable area (WUA) and age-specific estimates of brown trout made in 1989-1991 in 10 study sections. Composite suitability indices (CSI) calculated for individual cells within study sections were compared with diel fish location data made by snorkeling and angling to test fish occupancy relative to habitat quality and availability. Boulder structures, fish locations, and habitat contours depicting habitat quality were drawn on maps of each study section to compare use and effectiveness of the three structure types over a range of flows. In general, habitat (WUA) and adult trout density were positively correlated regardless of criteria set used, and significance of the relationship increased with age. Adult and juvenile trout occupied cells with high CSI's more frequently than cells with low CSI's. Results demonstrated that structures increase the availability of preferred habitat conditions, and that the IFIM/PHABSIM methodology can be a useful tool to evaluate a stream enhancement project.

**A 12-year Study of Rainbow Trout and Brown Trout Population Abundance in the South Platte River, Colorado, and Physical Habitat (WUA) Variability as Determined by the IFIM/PHABSIM Models**

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Twelve years (1978-1990) of brown trout and rainbow trout density and biomass estimates collected in two IFIM study sites on the South Platte River, Colorado, were used to assess species-specific life stage responses to physical habitat (weighted usable area--WUA) variability. June fry habitat (first month post-emergence) was the most critical factor determining recruitment success and subsequent year-class strength for brown trout and rainbow trout. Fry sampling during spring corroborated brown trout fry emergence from late May through June, while rainbow trout fry emerged during June. Year-class strength (number/hectare) at age 1 was positively correlated ( $p \leq 0.05$ ) with June mean monthly fry WUA and negatively correlated ( $p \leq 0.05$ ) with June mean monthly discharge. Juvenile (age 1) rainbow trout and brown trout densities (number/hectare) were not correlated with mean summer (April-October) juvenile WUA for either species at either study site. Biomass (kilograms/hectare) was significantly ( $p \leq 0.05$ ) correlated with mean summer adult habitat for each species at one study site. The lack of a significant relation between trout biomass and adult trout WUA at the second site was probably masked by inconsistent levels of recruitment in many years.

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### **The Relationship Between Brown Trout Abundance and Physical Habitat as Measured by IFIM/PHABSIM in Rush Creek, California**

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To develop a biologically based PHABSIM model for Rush Creek, Mono County, California, time series results of 32 PHABSIM models were first converted to trout abundance with a population response model, and then the models were compared with adult brown trout abundance in nine 100-150-m sites from 1985 to 1991, when streamflows ranged between 19 and 400 cfs. Only the PHABSIM model that used site-specific utilization criteria for depths and velocities at the location of the trout, depth and velocity criteria for adjacent cells that supply food, and geometric means for compositing HSI criteria was significantly correlated ( $R^2 = 0.51$  and  $p = 0.04$ ) with the abundance of adult brown trout. This model accounted for the variance due to changing flows within sites, but not for the variance between sites. The other 31 PHABSIM models, which used various combinations of preference curves, depth and velocity data collected regionally, criteria for overhead cover provided by boulders and submerged woody debris, and the multiplicative method for compositing the various HSI criteria, were not significantly correlated or were negatively correlated with adult trout abundance. We believe that cover criteria did not improve the models because although nine randomly selected transects were used to characterize each site, they were insufficient to measure the small clusters of submerged woody debris that were preferred by adult trout.

### **Fishery Management Dilemmas in the National Parks: Coping with Gray**

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Historically, fisheries management in the national parks has been characterized by a wide gap between policy and practice. Pristine aquatic ecosystems in many Natural Area parks, including Glacier National Park, have been radically altered as a consequence of the "Johnny Appleseed" approach to fisheries management that prevailed for more than half a century. Beyond the predictable problems resulting from decades of nonnative fish introductions, a perplexing array of issues and questions has emerged that will require micro policy interpretations and perhaps a bit of soul-searching. Limitations of knowledge and technology often impede a simple resolution. For example, if an introduced fishery is eliminated from a remote mountain lake, can it be claimed that the lake has been restored to its "natural" state, even though the microbiota of the lake has been permanently altered by 50 years of planktivorous fish grazing? What is the appropriate designation for a rare or unusual native fish population that has been introduced into a historically "barren" lake? Should a distinction be made between the terms "native" and "indigenous" in these situations? These and other issues are discussed in the context of new knowledge as applied to fisheries management in Glacier National Park.

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### Effects of Fish Introductions in Historically Fishless Lakes of North Cascades National Park

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The lakes of North Cascades National Park Service Complex (NOCA) in northern Washington were formed by glacial activity thousands of years ago and, until recently, were devoid of fish. Prior to fish introduction, salamanders *Ambystoma* were the dominant aquatic vertebrate predators in many lakes. One generalization that has emerged from other research on the ecological role of fish in aquatic communities is that they have the potential to eliminate or reduce the abundance of indigenous vertebrate and invertebrate species when stocked in historically fishless systems. Park management is concerned about whether trout stocked in previously fishless high mountain lakes in NOCA have altered the structure of native communities. A research program was initiated at NOCA to investigate this question. A major focus of the program has been on ecological interactions of components of lake communities, particularly fish, salamanders, zooplankton, and macrobenthos. Preliminary results suggest that fish, through predation and perhaps competition, are capable of reducing abundance of and perhaps eliminating salamanders from some lakes. Different species of salamanders may differ in their interactive responses to fish. High densities of reproducing fish may be capable of depressing and possibly eliminating large diaptomid copepods from higher elevation, lower productivity lakes.

### The Role of Genetics in the Management of Native Fishes in National Parks

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National parks and wilderness areas have played important roles in the preservation of the genetic diversity of *Oncorhynchus clarki*. Four genetically distinct groups of cutthroat trout are recognized: coastal (*O. c. clarki*), westslope (*O. c. lewisi*), the Lahontan complex (5 ssp.), and the interior Rocky Mountain complex (7 ssp.). Glacier National Park, Yellowstone National Park, Rocky Mountain National Park, and the Frank Church Wilderness in Idaho each harbor native cutthroat trout populations representing the interior Rocky Mountain and westslope groups. The genetic and ecological status of native coastal cutthroat trout populations is under evaluation. No Lahontan cutthroat trout populations are located in wilderness areas or national parks, and currently these are the most endangered of losing diversity due to extinction events. The continued identification of native *Oncorhynchus clarki* populations by analysis of contemporary and preserved type specimens will be critical for the continued management, restoration, and protection of cutthroat trout genetic stocks in their historical stream habitats. We are using polymerase chain reaction, DNA sequencing, and restriction analysis of mtDNA in conjunction with morphological, geographic, and isozyme analysis to identify subspecies and hybrids. Polymerase chain reaction has allowed the study of formalin-preserved specimens and the nonlethal application of DNA techniques to endangered or fragile populations.

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### **Preservation of the Yellowstone Cutthroat Trout: A Discussion of Values**

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Ethical and ecological values associated with protection of native species are becoming more widely accepted; however, preservation is often perceived to conflict with other uses of natural resources. The recreational fishery for Yellowstone cutthroat trout in Yellowstone National Park demonstrates that these goals need not be mutually exclusive. In accordance with park policies, special regulations have been used to limit angler harvest. Although angler harvest of Yellowstone cutthroat trout has been drastically reduced or curtailed in many park waters, this native fish species was rated above all other sport species by recreational anglers. Nonconsumptive uses of the Yellowstone cutthroat trout, including "fish watching" and intangible values such as "existence demand," emphasize other advantages of protecting wild Yellowstone cutthroat trout populations. To maintain fishery resources of this quality with hatchery propagation is not economically feasible. A management strategy of resource persistence provides a means to sustain a quality recreational fishery that greatly exceeds the expense of protection.

### **Management of Native, Nongame Fishes In National Parks**

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Because of its unique mandate and related management philosophies and policies, the U.S. National Park Service occupies an enviable position in the conservation biology program for native fishes, especially nongame forms. Whereas governmental agencies in other jurisdictions may find fisheries management policies strongly influenced by political considerations, the paramount allegiance of the National Park Service is to the protection and preservation of its indigenous fauna and flora. Such a position is consistent with two related roles of the Park Service: (1) as a signator (along with 60 federal, state, and private organizations) to the *National Recreational Fisheries Policy*, and (2) as implementer of the new program, *A Heritage of Fishing*, which lists its primary goal (Goal 1) to "Protect, Restore, and Conserve Fishery Resources," and its primary objective (Objective 1) to "Promote and effect the conservation, restoration and, where authorized, enhancement of fish populations and their habitats."

National Park Service fisheries management activities in desert ecosystems are emphasized, and reference is made to the occasional dilemma posed by multi-agency jurisdictions. The potential role of the National Park Service in the North American efforts to protect native fish faunas is emphasized and clarified.

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**Regional Inventories of Fisheries Resources:  
A Basis for National Assessments of Resource Condition**

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The influence of human land use and management has become so extensive that the effects of such disturbance must be evaluated on a macroscale to capture the cumulative impacts from local activities. Prominent ecological issues, including global change, increased rarity of species, and regional land use policy, require spatial and temporal scales that extend beyond traditional fishery research and impact analyses. While there is widespread recognition that addressing these issues will require a macroecologic perspective, the lack of geographically extensive data has limited basic empirical study. Although state fishery biologists have been compiling information for decades, site specificity and the absence of a consistent set of attributes to characterize fishery resource condition have prevented regional and national evaluations to support management and policy decisions. In late 1989, the U.S. Forest Service, U.S. Soil Conservation Service, U.S. Fish and Wildlife Service, and Sport Fishing Institute initiated a project to test the feasibility of developing a data system that will allow regional and national assessments of fishery resources. Trial data compilation of extant data in eight north-central states has resulted in a prototype computerized information system of fish stocks in this region. Continuing efforts will be aimed at refining and expanding this system to facilitate its implementation in other regions of the country.

**Vision of a Stock Status Information Retrieval System (SSIRS)**

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Difficult access to meaningful information concerning wild and naturally reproducing fish stocks often frustrates the use of current, scientifically sound data in management decisions. The U.S. Fish and Wildlife Service (Service) proposed to bring on line an information system for (1) inventorying the status of wild and natural stocks, (2) identifying information gaps, and (3) expanding monitoring activities to address those gaps. Use of the system will be shared among Service and non-Service fishery professionals and interested persons. Service personnel will work closely with cooperators to obtain suggestions on system development, to gain accurate data for the database, and to develop cooperative monitoring programs. The Service envisions such a system as essential in assessing stock status, identifying and monitoring stock restoration projects, and providing the information needed to gain funding support for wild stock programs.

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### **Northwest Environmental Database**

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Development of the Northwest Environmental Database (NED) began in 1984 as a cooperative effort of the Bonneville Power Administration (BPA), the Northwest Power Planning Council, the four Northwest states, Indian tribes, and Federal land management agencies to assess the significance of the region's rivers for use in the council's protected area designations, system planning, and BPA's regional hydropower supply estimates. The effort has resulted in seven detailed resource databases--anadromous fish, resident fish, wildlife, natural features, cultural features, recreation, and institutional constraints--and a network of over 1,000 experts in the seven resource categories. The databases cover all four states (comprehensive) and contain the same data elements for each state (consistent structure and content).

### **Salmon Escapement Information System**

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Annual escapement counts of Pacific salmon and steelhead for more than 1,100 locations throughout the Pacific Northwest and Alaska were organized in a computer database. A common data format and coding system was developed for more than 26,000 escapement records obtained from a variety of published and unpublished sources. Programs were written that provide a means of displaying trends in spawning populations by individual stream and watershed, and by state and regional determinations.

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### Wyoming Game and Fish Department's Computerized Fisheries Information, Storage, Retrieval, and Analysis System

Ron Remmick, Wyoming Game and Fish Department, P.O. Box 850, Pinedale, Wyoming 82941, and  
Dirk Miller, Wyoming Game and Fish Department, 528 S. Adams Street, Laramie, Wyoming 82070

A data storage and management system has been used by the Fish Division, Wyoming Game and Fish Department, since 1986. To ensure consistency, a computer committee was formed of individuals from the Management, Research, Culture, and Administrative sections. This committee agreed on the type and format of data to be recorded. The integrated program, ENABLE, was chosen as the primary software. Databases were created for lake and river physical, chemical, and fish species data, as well as stocking, fish health, culture, and creel survey information. A menu-operated system was created that allows for consistent entry and retrieval of information. Field personnel can design individualized systems to meet additional needs but are still required to store basic information using the statewide system. Data exchange with other systems is possible because ENABLE uses a standard dBASE format and can export or import ASCII files. Department personnel have met with other state and federal agencies to demonstrate the system and to discuss standard data exchange possibilities. We feel that our system is flexible enough to fit into a national or regional system. A workable system is possible if there is coordination and cooperation between those who design the system and those who use it.

### Use of a Fish Population Response Model to Relate WUA Time-series and Brown Trout Abundance

Peter F. Baker, Ed Cheslak, and Carl Mesick, EA Engineering, Science and Technology, 41A  
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Even when a population is controlled by habitat limitations, the actual population size at any given time need not be determined by the habitat availability at that time--past events affect present populations. This makes it difficult to verify the biological relevance of proposed measures of habitat availability, or to discriminate between alternative measures. We propose that the natural way to represent habitat models is through simple habitat-driven population models. Such a population model was constructed for brown trout *Salmo trutta* in Rush Creek, California, and used to translate various formulations of WUA, reflecting different hypotheses about habitat usage by brown trout, into adult population time-series. The relative merits of the habitat hypotheses were assessed comparing these time-series with population estimates from the field.

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### **Development of Suitability Index Curves for Rainbow Trout in the Clavey River, California**

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We describe the development of depth and mean column velocity suitability index (SI) curves for use in the Physical Habitat Simulation Model (PHABSIM) of the Instream Flow Incremental Methodology (IFIM) for rainbow trout in the Clavey River (Tuolumne County, California). All data were collected by snorkeling and observing individual fish holding in position. The initial curves were based on data we collected in the neighboring North Fork Kings River and its tributaries (360 adults, 165 juveniles). These curves were then compared to another pre-existing data set (130 adults, 332 juveniles) from the Tuolumne River (to which the Clavey River is tributary) and to a new data set we collected at another site in the Clavey River and at two sites in its tributary, Reed Creek (50 adults, 56 juveniles). All data showed an unexpectedly high utilization of locations in which the mean column velocities were low, including zero velocity water. Because rainbow trout are not usually thought of as feeding in zero velocity water in streams, there was concern that their use of it was an artifact of the observations being made during summer low-flow conditions, when the velocities throughout the rivers were at their lowest annual levels. To test this hypothesis, a new data set (219 adults, 344 juveniles) was collected in 1988 in the Clavey River at moderate early summer flows ranging from 56 cfs to 129 cfs. Most of the observations were made at a readily accessible moderate-gradient stretch dominated by riffle/cascade and run/pool habitat with large boulders, but additional observations were made at four other sites that included all habitat types over the length of the river. These data were used to prepare a new set of SI curves, which were used in the Federal Energy Regulatory Commission (FERC) license application for the Clavey River Project (Project No. 10081). They reflected, as before, a high utilization of locations with mean column velocities  $<0.5$  fps, with peak utilization occurring between 0.0 and 0.2 fps. As an additional verification, another data set (255 adults, 340 juveniles) was collected in 1991 at flows between 59 and 121 cfs with emphasis on even distribution of observations between three structurally different sites. These data again showed peak utilization at locations with 0.0-0.2 fps mean column velocities. We conclude that many of the adult and juvenile rainbow trout in the Clavey River and in similar streams and rivers nearby make use of the still water in the lee of the abundant large boulders to minimize energy expenditure, while still having access to food drifting past in adjacent fast water. The use of SI curves that reflect this use of slow water is an accurate depiction of the habitat selection of trout in the Clavey River, but it raises the issue that habitat selection, and the attendant SI curves, are not solely species specific—they are also related to the type of structural habitat that is available. SI curves developed in streams without abundant large boulders could not reflect this same type of habitat utilization, and would not be appropriate for the Clavey River.

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### **Deriving Temperature-conditioned Physical Habitat (WUA) and Projected Effects on the Trout Population of the Dolores River, Colorado**

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Physical habitat-discharge relations for brown trout and rainbow trout for the Dolores River, Colorado, are modified to reflect the effects of high water temperature. Observed maximum water temperatures under a variety of flow conditions and temperature suitability relations are used to develop temperature profiles and composite suitability indices for the 12 mi of river downstream of McPhee Dam. The composite temperature suitability indices are applied as weighing factors that scale the physical habitat values at various discharges. The effective habitat time series model is then used to illustrate possible out-year effects of various discharge-temperature events on the two trout species.

### **Comparison of Weighted Usable Area and Observed Densities of Juvenile Chinook Salmon in the Trinity River, California**

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The relation between weighted usable area and fish density was evaluated for juvenile chinook salmon in four study sites in the Trinity River. Weighted usable area in habitat cells was calculated using site-specific habitat use criteria multiplied by actual transect measurements of field data, instead of using Instream Flow Incremental Methodology hydraulic simulation programs. The number of juvenile chinook salmon present in each habitat cell was determined by snorkel divers using line transect methods. Results of this investigation indicate that there is a positive relation between weighted usable area and standing crop of juvenile chinook salmon in the Trinity River, and microhabitat measurements of depth and velocity are reasonable predictors of habitat quality. However, the assumption that the highest quality microhabitats fill to capacity before lesser-quality microhabitats are used is not entirely true. We found that when the system was underseeded, juvenile chinook salmon use in all habitat cells, regardless of habitat quality, remained significantly lower than under fully seeded conditions. Juvenile chinook salmon proved to be an ideal species for this type of habitat validation study because they can be found in relatively high numbers and were rarely frightened by the presence of divers.

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**Stratified Random Selection Process for the Placement of  
Physical Habitat Simulation Model (PHABSIM) Transects**

Thomas R. Payne, Thomas R. Payne and Associates, P.O. Box 4678, 850 G Street,  
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The process for selection of Instream Flow Incremental Methodology (IFIM), PHABSIM transects may be improved through the use of stratified random selection techniques in many circumstances. Habitat mapping is used to describe the occurrence and frequency of habitat types (strata) within an affected stream segment. All river segments where transects may be placed are located by eliminating inaccessible or atypical segments. The least-available ecologically significant habitat type is identified, and all habitat units of this type are sequentially numbered. Potential habitat units are drawn from this pool through a simple random number generator. After field verification for acceptability, one or more transects are placed within the selected units to represent that habitat type. Transects representing the remaining habitat types are then placed in the closest possible proximity to the randomly selected units. Additional transects are placed in the same way until the desired number of transects is obtained. The process has distinct advantages over standard transect selection methods and has been used successfully in many recent IFIM applications.

**An Equal Area-Cluster Sampling Approach for the Development of  
Instream Flow Incremental Methodology (IFIM), Physical Habitat Simulation Model  
(PHABSIM) Species Habitat Suitability Criteria**

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Equal area sampling within habitat type strata is a proposed alternative to traditional methods of developing species habitat suitability criteria for Instream Flow Incremental Methodology (IFIM), Physical Habitat Simulation Model (PHABSIM) studies. These methods have typically involved reweighing habitat use data by independent estimates of habitat availability to predict fish "preference." Effective habitat stratification ensures the opportunity to define habitat use of resident species within the full range of available habitat. Equal allocation of sampling effort within each habitat type stratum produces a pooled habitat use data base weighted by the observed density of fish in each habitat type (and their associated depths and velocities). This indirect assessment of habitat preference requires the assumption that local fish densities within each habitat type stratum are determined by habitat quality. The equal area sampling scheme is conducted within randomly selected habitat "clusters" to control for habitat-independent effects (e.g., angling, temperature, species composition) on fish densities between habitat type strata.

### Food Web Influence on Fish Population Responses to Instream Flow

Donald J. Orth, Department of Fisheries and Wildlife Sciences, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061-0321

Fish population responses to changes in streamflow have seldom been correctly forecasted from physical habitat predictions, yet the assumption that physical habitat drives the dynamics of fish populations is often invoked. In this talk, I compare the influence of streamflow on physical habitat for various fishes with the observed variation in insect production. Physical Habitat Simulation Model (PHABSIM) analyses for common warmwater sport fishes indicated that weighted usable area was either insensitive or maximized at low flows. However, average to high flows are undoubtedly important for a variety of reasons, such as recruitment of floodplain tree species, streambed scouring, organic matter inputs, and benthic invertebrate production. Production of aquatic insects in the New River, West Virginia, and other rivers shows considerable annual and spatial variation. Similarly, growth and foraging success of young smallmouth bass *Micropterus dolomieu* varies among sites and years due to temperature and prey abundance. A food web model was developed to investigate the influence of the food base (aquatic insects, small prey fishes, and crayfish) on production of sport fishes (smallmouth bass, rock bass *Ambloplites rupestris*, and flathead catfish *Pylodictis olivaris*). Analysis of the model suggested that production and yield of the sport fishes were strongly dependent on the bottom-up influence of aquatic insects and crayfish. These analyses and review of studies on insect production and foraging success of fish suggest that decreases in flow during the growing season may decrease insect production and thereby indirectly depress sport fish production.

### The National Park Service Recreational Fisheries Program

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The National Park Service has many excellent fishery resources, including marine, estuarine, coldwater, warmwater, riverine, and reservoir systems. Recreational fishing occurs in 143 units of the 359-unit National Park System. The National Park Service recently developed and released a plan about its recreational fisheries program, "A Heritage of Fishing." The program is based on the National Park Service's mandate to preserve and protect resources within its jurisdiction, and "A Heritage of Fishing" has four major goals and more than 60 action items. This program outlines future actions by the Service to provide recreational fishing opportunities while preserving and restoring aquatic systems within parks. The goals are to protect, restore, and conserve fishery resources; promote, support, and conduct research and development in support of fisheries management and ecosystem processes; develop and enhance biological, social, and economic data bases on recreational fisheries; and improve fisheries education, outreach, and angler ethics programs to increase public awareness. Implementation is underway. The National Park Service has recruited for a fisheries biologist at the Washington Office to direct the program, and has completed an assessment of fisheries needs within its jurisdiction.

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### **Use of Antimycin for Removal of Exotic Fishes in National Parks and Wilderness Areas**

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Because of its effectiveness in removing salmonids from cold, neutral pH, subalpine, aquatic habitats in very low concentrations, antimycin (Fintrol 5) was used to remove exotic salmonids from 33 lakes and streams from 1973 to 1990. Other advantages of antimycin include the nonavoidance of treated water by salmonids and the apparent natural degradation of antimycin in stream habitat after an elevation loss of 80-150 m. Treatment with as little as 2  $\mu\text{g/L}$  of antimycin has resulted in the elimination of brook trout from lakes for over 15 years. Factors favorable to the use of antimycin, planning procedures, application and detoxification rates and procedures, safety considerations, and factors that affected the long-term success of these projects are reviewed.

### **Anadromous Fisheries Restoration in Redwood National Park**

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In 1978, Redwood National Park was expanded to include lands that had been damaged by past logging activities. As part of an interdisciplinary program to restore these areas, anadromous fisheries restoration has utilized a watershed approach to identifying problems and developing solutions. Aquatic systems rehabilitation has focused on habitat restoration rather than enhancement of sport or commercially important species. Inventory, assessment, and research provided the information necessary to prioritize areas of critical need and to begin restoration efforts. Research projects have ranged from estuary, stream, invertebrate, and water quality studies to identification of fish stocks through laboratory electrophoresis of cell proteins. Restoration projects based on inventory and research efforts have included control of erosion through logging road removal and restoration of natural stream-flow patterns, revegetation of logged-over areas, wetland restoration, management of estuarine water levels, dam removal, and woody debris restoration to streams. Interdisciplinary project planning and implementation is continuing.

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### **Restoration of the Elwha River Ecosystem**

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The Elwha River basin is the largest drainage within the boundaries of Olympic National Park. The river historically contained all of the anadromous salmonids native to the Pacific Northwest. In 1911, a dam that blocked migration of all anadromous fish was constructed at river mile five. Another dam was constructed 8 miles upstream in 1924. These dams resulted in the extirpation of the sockeye salmon population and a precipitous decline in the other stocks of fish within the Elwha River drainage. In addition to the loss of valuable commercial and recreational fishing opportunities, these dams are believed to have had a significant impact on other natural processes, including the accumulation of salmon carcasses used as a food source by numerous birds and mammals. Restoration efforts, initiated in 1983 by the National Park Service and a number of other agencies, focused on passage of juveniles and adults over the dams. Current results suggest that ecosystem restoration goals cannot be met through a costly fish passage program, and removal of both dams is necessary. A bill that authorizes federal acquisition of the dams and detailed studies for their removal has been introduced in the U.S. Congress.

### **Fishery Management in Voyageurs National Park**

Larry W. Kallemeyn, Aquatic Research Biologist, Voyageurs National Park, NCR 9, Box 600,  
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Approximately 34,400 ha or 39% of Voyageurs National Parks total area is covered by water with Kabetogama Lake and those portions of Namakan, Sand Point, and Rainy lakes that lie within the park comprising 96% of the total water area. Recreational fishing and water level management have been identified as two of the principal factors affecting the fish communities in these large lakes, which have been regulated by dams since the early 1900s. Approximately 800,000 hours per year are expended in the recreational fishery, which is the principal visitor activity. Walleye, northern pike, sauger, and smallmouth bass are the principal species harvested with the average annual harvest of all species being 70,133 kg. Annual angling yields of walleye have in some years exceeded sustainable levels in both Rainy and Kabetogama lakes. Regulated lake levels have been found to effect reproductive success of both walleye and northern pike, and to negatively impact several other components of the aquatic ecosystem. Because of the interjurisdictional nature of the lakes, any management program designed to address these issues must provide for coordination with state, provincial, and private interests. The National Park service is currently working with the various interests to develop a more environmentally sensitive water management program.

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**Fisheries Benefits From Seasonal Energy Transfer between the Pacific Northwest and Southwest  
Via the Intertie**

Brian Marotz, Montana Department of Fish, Wildlife and Parks, 490 North Meridian, Kalispell,  
Montana 59901 and Pat Mangan, Bureau of Reclamation, P.O. Box 25007, Denver, Colorado  
80225-0007

As part of the Columbia Basin System Operation Review, Montana Department of Fish, Wildlife and Parks, and the Bureau of Reclamation assessed the effects of power marketing strategies on the aquatic environment associated with Hungry Horse and Libby dams in Montana. Quantitative biological models were used to examine site-specific biological conditions, within the context of Columbia River operation. Results are applicable to other headwater storage projects.

The proposed marketing strategy expands existing power sales to the Pacific southwest during the "water budget," a spring/summer release of storage water to reduce the travel time of emigrating salmon smolts and improve survival while passing hydropower dams in the lower Columbia.

Conversely, power transfers to the northwest to meet energy needs during fall and winter would "save" water behind headwater dams for later release. Resident fish in storage reservoirs benefit from higher reservoir elevations during winter and early spring, shallower maximum drawdowns, and improved reservoir refill probability. Refill failure impairs biological productivity in the reservoirs. Deep drawdowns cause long-lasting biological impacts.

Spring releases benefit resident fish below storage projects by returning river flows to a nearly natural hydrography. Specific improvements include maintenance of minimum dam discharges, flow stimulus to initiate spawning, and channel maintenance flows.

Expansion of interregional power markets could balance the needs of anadromous and resident fish populations within the physical limits of basin hydrology, power production, and regional flood constraints.

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### **Badger Creek Bait-hooking Study**

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The primary objective of this study was to estimate potential benefits of cutting the line on deep-hooked wild rainbow trout. I also sought to estimate overall bait-hooking mortality for a wild, stream salmonid population without holding test fish in small, confining netpens. Confinement weirs were constructed at both ends of a 2-km segment of Badger Creek, a 15-m-wide Teton River tributary. We caught 272 wild rainbow trout with #8 worm-baited hooks. An additional 200 fish were captured with dry flies to serve as controls. Survivors were counted using electrofishing gear 5-6 weeks after capture. We deep-hooked 18% (49) of the bait-caught fish. Habitat type where hooking occurs (pools, runs, riffles, pocket) affects deep-hooking incidence. Results indicate that past hatchery bait-hooking estimates may not apply to some stream situations. Cut-line fish returned at nearly twice the rate of hook-removed fish, but low numbers precluded statistical comparisons. I estimated overall bait-hooking mortality at 14%.

### **Fisheries Management on the Chequamegon National Forest--A Cooperative Approach**

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Fisheries management on the Chequamegon National Forest, Wisconsin, is done through a cooperative effort between the U.S. Forest Service and the Wisconsin Department of Natural Resources (WDNR). It is a unique relationship in which the Forest Service contracts the WDNR to do fisheries work on waters within the Chequamegon National Forest. With the abundance of lakes and streams in northwest Wisconsin, the contract fisheries program is designed to provide supplemental fisheries management activities on many smaller, less-developed waters within the forest. Through this program, 6 to 8 fishery surveys and management evaluations are conducted annually. These result in numerous management activities and habitat improvement projects, which have included the installation of aeration systems, log fish shelters, and a walleye spawning reef; streambank stabilization; fish stocking; and various special size and bag limit regulations. The result has been improved fishing opportunities in northwest Wisconsin, as well as an excellent working relationship between the Forest Service and the WDNR.

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### Feeding Response of Northern Squawfish to a Hatchery Release of Juvenile Spring Chinook Salmon

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We collected gut contents from northern squawfish *Ptychocheilus oregonensis* from the Clearwater River, Idaho, about 65 km downstream from Dworshak National Fish Hatchery, in conjunction with the release of 1.1 million juvenile spring chinook salmon *Oncorhynchus tshawytscha*. Before the release, the diet of northern squawfish (by weight) consisted of 38% crustaceans, 26% insects, and 19% fish; no salmonids were consumed. About 20 h after the release, salmonids composed 53% of the diet, and 5-7 d after the release, they composed 76%-86% of the diet. Northern squawfish consumption of juvenile salmonids was high compared with previous studies, especially considering the low water temperatures (6-9°C) during sampling. At these temperatures, we estimated it would take a northern squawfish (650-800 g) 1.4 to 3.8 d to evacuate a salmonid meal of 13 to 34 g. Our results indicate that northern squawfish can quickly exploit juvenile salmonids following hatchery releases, even at low temperatures.

### Localized Genetic Effects of Long-term Stocking of Hatchery Rainbow Trout on Resident Rainbow Trout in the Metolius River, Oregon

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The Metolius River is a 44-km-long, spring-fed tributary of the Deschutes River in central Oregon that has been stocked annually since 1934 with hatchery rainbow trout. Annual stocking levels have been as high as 60,000 catchable-size rainbow trout in the midriver campground section; however, stocking has not occurred in the upper 5 km near the headwater springs or in the lower 25 km of the river. We examined variation in allozymes (70 protein loci) and mitochondrial DNA (mtDNA) among three samples of wild rainbow trout from the Metolius River and the Cape Cod hatchery strain of rainbow trout. Rainbow trout in the headwater springs section and the midriver campground section showed both allozyme and mtDNA evidence of introgression with hatchery rainbow trout, whereas wild rainbow trout from the lower river showed no evidence of introgression for allozymes or mtDNA. Survival of hatchery fish in the upper river was enhanced by the stable and cold water temperatures (45°C) and the lack of infection by *Ceratomyxa shasta*, a parasite that is lethal to hatchery rainbow trout in the warmer Deschutes River. Absence of introgression between hatchery and wild rainbow trout in the lower Metolius was attributed to lack of survival of hatchery rainbow trout in the harsh environment, characterized by high water volumes and steep flow gradients.

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