Chapter 7

Fisheries Science and Management in the Greater Yellowstone Ecosystem: Ensuring Good Fishing by Preserving Healthy Ecosystems

Chapter 7

Al Zale gets to go fishing, a lot. Al is the leader of the Montana Cooperative Fishery Research Unit. He is the coordinator for most of the applied regional fisheries research for the State of Montana and the U.S. Department of the Interior.

Montana and the GYE has as diverse a fishery as you can find in the U.S. In the west, the large pristine rivers that drain the Rocky Mountains offer unparalleled cold water trout fishing. Fly fishermen from around the world seek out the native Cutthroat, Rainbows, and Browns of the Madison, Beaverhead, Big Horn and countless other rivers managed by Montana Fish Wildlife and Parks. Fly fishing in Montana is a high value activity and part of Al's job is to see that our native fishery is sustainable. Al is particularly active in the management of Arctic Grayling in Yellowstone National Park.

In less populated (and dryer) parts of the region warm water fisheries prevail. Species like Walleye, Pike, Muskie, and Large and Small Mouth Bass, share water with Channel Catfish and Pallid Sturgeon. The prehistoric Paddle Fish is still fished in Yellowstone and Missouri Rivers. Al has responsibility for these fisheries too.

He and his collaborators have perfected techniques for capturing and tagging every type of fish in the region. He uses a range of technologies but the bottom line is to do it without harm to the individual fish or the resource. They need to assess abundance, productivity, and demographics for a research subject they can't see and is perfectly adapted to their river environment.

Fishing is the favorite pastime of visitors to Yellowstone. If a quality experience is going to be available for future generations, fish populations need to be sustainable and healthy. Al's work is aimed at ensuring policy makers have the data to make decisions that will maintain and enhance fish populations in the Yellowstone region.

J. Johnson



Size Matters (Drew Rush)

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Alexander V. Zale

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Some of the world's best and most famous sportfisheries are located in the Greater Yellowstone region. Many of the region's clear, cold streams, rivers, lakes, and reservoirs harbor abundant populations of popular sportfish such as native Yellowstone (Oncorhynchus clarkii bouvieri) and Westslope cutthroat trout (O. c. lewisi) and Arctic grayling (Thymallus arcticus) as well as introduced Rainbow (O. mykiss), Brown (Salmo trutta), and Brook trout (Salvelinus fontinalis).

Well before the film, *A River Runs Through It,* heightened the popularity of fly fishing here, the quality and resulting economic and recreational values of the region's fishery resources were already well known and appreciated. For many, a life of fishing is not complete unless they have fished the waters of the Yellowstone region.

A primary societal value of angling is that it affords simple relaxation in the outdoors to lessen the stresses of modern life. It is also an opportunity for social activity and family fun. More pragmatically, angling is big business worth millions of dollars annually in the GYE. Fly shops, fishing guides, restaurants, motels, drift boat dealers, souvenir shops, and other businesses all profit directly from angler expenditures. Moreover, state fish and wildlife agencies and Yellowstone National Park are funded through license sales.

Fisheries are not only important for the recreational and economic values of fishing. Abundant and productive populations of both sport and non-game fish contribute to the ecological health of the GYE and the environmental services it provides. For example, 42 animal species ranging from water shrews to bald eagles to grizzly bears depend on Yellowstone cutthroat trout for food. The clean waters of Yellowstone are sources of drinking water for residents; the many rivers and lakes add to the quality of life in the region. Fisheries have wide ranging ripple effects on society and the environment in the GYE.

Fisheries management in the region has two primary goals. Maintenance of excellent fishing is a top priority; anglers want "big fish and lots of 'em". High quality angling requires active fisheries management to offset the intense fishing pressure and habitat alteration affecting many of our local waters. Restrictive regulations (e.g., catch and release, length and bag limits, closed seasons), habitat protection and restoration, and judicious stocking of hatchery fish (especially in reservoirs and mountain lakes) are some of the more important tools used by modern fishery agencies.

The other priority is preservation of native species to maintain ecosystem integrity and function. Considerable effort and funding is expended on Arctic grayling and cutthroat trout restoration and enhancement, including habitat restoration, extermination of non-native competitors, species reintroductions, and predator controls. Recently, lake trout, (*Salvelinus namaycush*), in Yellowstone Lake and brook trout in local streams have moved to the forefront of management dilemmas. Of course, sometimes these two priorities are at odds, such as when cutthroat trout conservation conflicts with rainbow trout fishing, but for the most part, what's good for ecosystem health is also good for fishing.

The inherent quality of the GYE's fisheries is a product of the area's climate, topography, and geology. Maintenance of that excellence is the result of careful and comprehensive management and monitoring. Dozens of state and federal biologists survey and monitor fisheries throughout the region. They enthusiastically implement protective regulations and management actions to preserve and enhance the resource. The sampling and analysis techniques described in this chapter are used in

our regional survey and monitoring programs. The goal of any survey program is to monitor which species exist in a water body, how many there are, how large they are, how fast they are growing, and what their age structure is. This information can be used to assess the condition of a population and thereby provide insights into effects of human actions such as land use and climate change or, the success of fishery management strategies. This chapter explains how the information acquired by fish sampling is used and describes the sampling techniques used to gather it.

Goals of Fish Sampling

PRESENCE AND ABUNDANCE

The obvious difficulty of fishery research is that the subject is hidden in deep pools and rushing currents. Fish cannot be counted using aerial surveys; we can't set up a spotting scope and count them from afar. Documenting species presence is critical if we are to preserve native species that have become reduced in number and range in recent years such as fluvial (river dwelling) Arctic grayling, Yellowstone cutthroat trout, and Westslope cutthroat trout (which, despite their name are native to both sides of the Continental Divide). This is why we survey headwater streams throughout the GYE for presence of genetically pure populations. On the other hand, detection of non-native species can also be a priority, especially where such species would compete or hybridize with rare or imperiled natives. Examples include invasion of cutthroat streams by rainbow, brown, or brook trout and the introduction of lake trout into Yellowstone Lake. In both cases the nonnative often outcompetes or is a predator of the native.

Estimation of fish abundance is an important fishery management activity in the region. After all, all those anglers visiting the world-renowned GYE fishery want to catch as many as possible, so maintaining abundant populations is critical. Abundance information can be used to help set harvest limits, indicate the success of management actions, and identify possible problems. For example, the precipitous decline of the rainbow trout population in the Madison River in the early 1990s led to the discovery of whirling disease. Repeated estimation of abundances in specific river sections over many years using standardized techniques allowed Dick Vincent, a now retired Montana Fish, Wildlife and Parks biologist, to recognize a connection between hatchery raised fish and declining number of natives. Abundance estimation is also critical for managing imperiled species, which occur at low numbers by definition. Knowing just how low those abundances are can help decision makers set priorities for rescue efforts.



▲ PHOTO 7.1 Catch and release is the primary fishing philosophy on most waters in the Greater Yellowstone Ecosystem. It has proven to be important to maintaining a high quality fishing experience as fiy-fishing has become increasingly popular. This fisherman is trying his luck on Slough Creek in Yellowstone National Park – the place where catch and release was first implemented in 1973. (Jerry Johnson)

Catch and Release

Catch-and-release fishing is so common and accepted in the GYE today that it is easy to forget that it is a relatively new solution to an old problem. Overfishing was bemoaned in the angling literature for hundreds of years, but the rapid post-World War II increase in angling and other outdoor leisure activities caused the quality of many wild fisheries to deteriorate. There is also a long tradition of eating the fish we catch. Despite its inefficiency and cost, stocking hatchery fish was the typical solution used to augment some simple size, bag, and season regulations. Yellowstone National Park had a long history of recreational fish harvest despite a legal mandate to retain its natural resources in their natural condition. Even so, evidence of depletion was evident in wild trout fisheries in and around the Park.

A desire to eliminate expensive stocking led a Michigan fishery scientist, Albert S. Hazzard, to institute the "Fishing-For-Fun" program in some high-quality wild trout streams in 1952. All trout caught were released and angling was restricted to flies and lures to decrease post-release mortality. The goal was fun, not filets. The basic concept was that fish could be caught multiple times, thereby providing recreation for many anglers over and over again. The time was ripe for its introduction because of the developing sportsmanship, environmental awareness, and conservation ethic of some anglers. The program was soon copied by other states and known as the "Hazzard Plan" and later "Catch-and-Release". It proved to be a useful management tool for many different types of fisheries subjected to high fishing pressure and became popular throughout the U.S. In fact, voluntary catch-and-release is now common practice by many anglers, even where not required.

Catch-and-release was first implemented in the GYE in 1973 in the Yellowstone River, Slough Creek, and the Lamar River in Yellowstone National Park. Full implementation was preceded by gradual institution of progressively more restrictive regulations including gear restrictions, area closures (e.g., Fishing Bridge), and size and bag limits. The program soon expanded to other waters both in the Park and nearby, and has been a resounding success. The ethic maintains ecosystem integrity and function and provides excellent fishing to great numbers of anglers. Today, cutthroat trout in a reach of the Yellowstone River below Yellowstone Lake are caught and released an average of 9.7 times during the fishing season. A key to the success of catch-and-release however, is the availability of nearby fisheries where harvest is allowed. Montana continues to stock lakes and reservoirs to support harvest fisheries where catch-and-release is unnecessary or unpopular.

The primary approaches to estimating fish abundances are mark-recapture and depletion sampling. Mark-recapture involves two sampling occasions. Fish caught during the first sample are all marked or tagged and released unharmed; a second sample is collected to recapture some of them. As long as the same methods are employed both times, mark-recapture techniques are highly reliable.

Depletion sampling involves removing fish from a sample area and temporarily not returning them. If enough fish are removed that the catch in the next sample is reduced (and if catch is proportional to abundance, which it should be except in unusual circumstances), then the reduction in catch in the second sample can be used to estimate the original abundance. For example, if 50 fish are caught in a blocked-off stream section during a first sample and only 30 are caught in the next (using the same amount of effort), then the removal of the first 50 fish reduced the catch rate—and presumably the original number of fish—by 40% (50 – 30 = 20; 20 ÷ 50 = 0.4). Therefore, 50 = 0.4×N or N = 50 ÷ 0.4 = 125



▲ PHOTO 7.2 The original Fishing Bridge was built in 1902 and refurbished in 1937. The portion of Yellowstone River beneath the bridge was a major spawning area for Yellowstone cutthroat trout and so was the most popular place for many park visitors to catch their first fish. Because of the decline of the cutthroat population and overfishing, the bridge was closed to fishing in 1973. It is still a popular place for observe fish in the clear waters of the Yellowstone. (NPS, Yellowstone National Park)

fish. Depletion estimates of fish in small streams are commonly made by electrofishing. Usually, at least three successive samples are taken to get multiple estimates of the reduction rate of the catch. These techniques are used when we want to track populations in a discrete fishery.

In many situations, an actual abundance estimate may not be needed. Rather, a relative measure of fish abundance may suffice, especially when comparing different places or times. Such measures are expressed in terms of "catch per unit effort" such as the number of fish caught in a gill net set for an 8-hour period or the number caught by electrofishing a 100-meter stream segment. Relative abundance can be measured more quickly and simply than actual abundance because only a single sample is taken. This technique might be used when we want to know if two streams that appear to be similar actually produce similar amounts of fish. If not, we might ask what we could do to increase fish population in the less productive habitat.

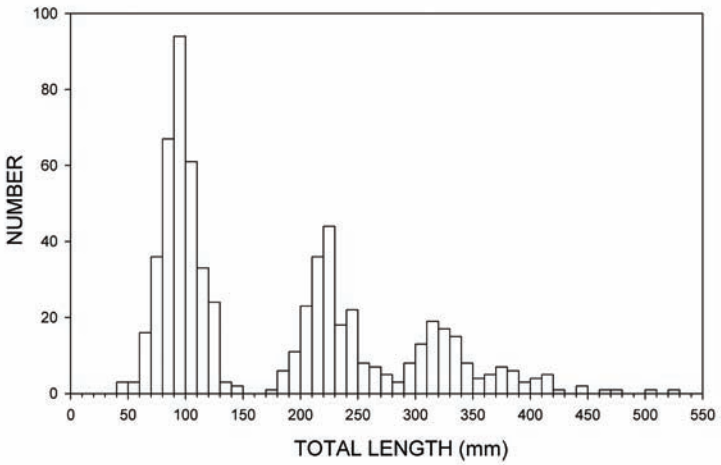
Restoring the Native Trout Fishery in Montana

In 1974, Montana Fish Wildlife and Parks did something radical at the time – it stopped artificial stocking of hatchery fish in streams and rivers that supported wild trout populations; the first state to do so. The standard policy was to supplement populations of wild trout with those from state run hatchery operations; sportsmen, businesses and fishery agencies relied on high fish numbers to attract out of state fishermen each season.

Beginning in 1968, FWP fisheries biologist, Dick Vincent, began studying the trout population of the Madison River and how it changed according to river flow on two sections of river. He noticed that on one section population didn't vary much, on the other it did. The difference turned out to be that one section was stocked with hatchery fish, the section where population changes tracked river flows (as expected) was a native fishery.

Vincent experimented with stocking previously unstocked areas and ending it in river reaches that had been stocked for years. He showed that stocking hatchery fish suppressed wild trout numbers. What seemed to be happening was that behaviors learned by hatchery-raised fish allows them to outcompete natives for food and habitat. Hatchery fish were more tolerant of the crowded, semi-sterile conditions in the hatcheries and so displaced less tolerant natives from good feeding lanes. The result was that the number of native fish declined as well as the average size because fewer grew to maturity. It took time but he finally convinced fishery managers to change decades of tradition and practice.

Vincent's electroshocking methods and willingness to challenge the accepted scientific wisdom of the day has meant that once stocking was discontinued, wild trout numbers doubled and even tripled on some rivers in the state. Today, Montana's native trout are seen as a unique fishing experience where the quality of the fish caught has replaced the quantity of fish. In Montana, thanks to good science and risk-taking fishery managers, an angler has a good chance of catching a big, wild trout and creating a memory of a lifetime.



▲ FIGURE 7.1 A length frequency distribution of rainbow trout collected during spring indicates a strong cohort of age-1 fish and consistent prior recruitment. Measuring the size of the population by cohort can inform fish managers about mortality or the health of the river system. (Al Zale, MSU)

DEMOGRAPHICS AND CHARACTERISTICS

Size matters, at least to anglers. Captured fish are typically measured, normally from the tip of their snouts to the ends of their tails (i.e. "total length"). They are usually under light anesthesia induced by chemicals dissolved in the water they are being held in. Weight is recorded less frequently because weighing fish is time consuming and time out of water is stressful. Moreover, weight can usually be estimated with reasonable accuracy using existing species-specific weight-length equations. An exception is when a measure of body condition is desired. Measures such as relative weight relate the weight of a fish to its length (i.e., "plumpness") and are sensitive to environmental conditions. Plump fish tend to occur where food is abundant, water quality is good, and habitat is of high quality. Thin, "snaky" fish are indicative of poor environmental conditions, a lack of adequate food, or disease.

Length-frequency distributions depict the number of fish of each size in a sample. Natural and fishing mortality cause fewer larger fish to be present. Peaks in the distribution represent cohorts of lengths of age classes, each of which is clumped because fish hatch during a short time period. In other words, there may be many fish of the same size and age in any given sample. Gaps in a distribution may indicate years when few young fish were added to the population for a variety of reasons. Presence of few large fish may be caused by excessive harvest or food limitations. Rough approximations of annual growth rates can be made by comparing lengths between the peaks, but these tend to run together at advanced ages because of variability in individual growth. More accurate estimates require aging of fish using rings in hard body parts such as scales or otoliths - the ear bones. Integration of lengths and ages allows determination of annual growth rates. This is a useful measure of the quality of a fish's environment and also correlates well with body condition. Faster growth produces more large fish in a shorter period of time. Aging of fish also allows calculation of age-specific mortality rates. We can identify life stages when survival is poor; poor survival may be caused by poor environmental conditions, predation, or harvest and may hurt some ages more than others.

Accurately measuring the sizes of fish in a population would appear to be a relatively simple thing, but unfortunately all sampling methods and hardware tend to be size-selective in one way or another; they tend to be better at capturing small fish, or large fish, or individuals of a narrow size range. Moreover, species selectivity occurs as well. Such tendencies are described below



▲ PHOTO 7.3 Biologists can backpack an electrofishing unit into remote locations. In this case, we sampled an irrigation diversion canal to determine how many are distracted from the main river. A net was used to prevent fish from escaping from the sample reach. (Leslie Bahn)

Mark-Recapture Sampling

Ecologists and wildlife biologists frequently try to estimate populations based on sampling part of the total population. The method was developed to sample populations of animals that are highly mobile or those for which it would be difficult to know how effectively you had sampled with only a single sampling time. Mark-recapture logic is based on the premise that the ratio of previously marked fish or other animal recaptured (R) during the second sample to the total number marked (M) is equal to the ratio of the total number of fish caught during the second sample (C) to the total abundance (N):

$$\frac{R}{M} = \frac{C}{N}$$

Rearranging that equation gives:

$$N = \frac{M \times C}{R}$$

Thus, if a biologist recaptured 6 of 42 previously marked fish in a second sample of 51 fish, then N, the total abundance is

$$N = \frac{41 \times 52}{6} = 357$$

Think of it like this. Try grabbing a handful of dried beans from a jar and marking those "captured" during that first sample with a marker or replacing them with a different color bean. Return them to the jar and mix the beans thoroughly to ensure that every bean has an equal probability of being captured in the second sample. You also don't want to wait too long between samples so as to avoid any "mortality" among the beans, if say someone were to make soup. Biologists usually wait a few days between marking and recapturing to allow the marked fish to mix back into the population, but not so long that some fish could die or emigrate out of the sampled area. This procedure was first used by C.J.G. Petersen in studies of marine fishes and F.C. Lincoln in studies of waterfowl populations, and so is often referred to as the Lincoln Index or the Petersen Index.



▲ PHOTO 7.4 We can also electrofish from an inflatable raft and cover a much larger reach with less effort. This sampling is taking place on the Gibbon River in Yellowstone National Park (Amber Steed)

for each capture technique. Use of multiple gear types with different selectivity characteristics can moderate this bias. Of course, selectivity can be advantageous in situations where capture of only a limited size range of certain species is desired, as when sampling only juvenile trout to determine year-class strength.

Fish Capture Methods

Electrofishing is perhaps the most common, useful, and effective fish collection technique used in the GYE. Limited primarily by depth, it is a shallow-water collection technique useful in streams, shallow reaches of rivers, and surface waters of lakes and reservoirs. Basically, it involves creating an electrical current in the water that stuns and incapacitates the resident

fish, thereby allowing biologists to scoop them up with a dip net. Electrofishing configurations range from small backpack units to shore-based units to floating electrofishers to large, powerful units mounted on inflatable rafts, drift boats, or jet boats. Power is supplied by rechargeable batteries or gasoline generators. The current is applied to the water by electrodes. The positive electrode, or anode, is usually mounted on a probe or boom and the negative cathode mounted to a metal boat hull or trailing cable. Fish caught in the electrical field orient towards the anode and swim towards it in a process called electrotaxis or forced swimming. When they get close they experience electronarcosis. As they lose equilibrium and roll over, biologists watch for the flash of their white bellies and net them. Some biologists use a cabled throwable anode with which they can draw fish to the boat from some distance away.

Electrofishing is highly size-selective; large fish are more vulnerable than small ones because they occupy a greater voltage gradient in the electrical field. In addition, they are more visible to dip-netters. Species with small or no scales (trout, catfish) tend to be more vulnerable than large-scaled species. Habitat selection can also influence susceptibility; fish that occupy surface waters are more likely to be captured than those in deep, open water.

Local water characteristics can influence the effectiveness of electrofishing. Pure water does not conduct electricity; rather, it is the ions dissolved in water that pass the current between the electrodes. Typically, impurities are present in sufficient concentrations for electrofishing, but some sterile headwater streams can be so clear electrofishing techniques do not work. Occasionally, biologists may temporarily add salt to some streams to raise water conductivity enough to allow electrofishing. At the other extreme, seawater is too conductive for effective electrofishing; the current disperses weakly in all directions rather than being concentrated between the electrodes. Water transparency is also critical because dip-netters must be able to see stunned fish. Fortunately, most waters in the GYE have excellent clarity except during spring runoff.

Electrofishing is exciting. A biologist can capture more large trout in a day of electrofishing than most of us can hope to catch in a lifetime of angling. It can be somewhat frustrating for a biologist who fishes to see just how many fish are out there compared to how few are caught on a fly rod. But, the effectiveness of electrofishing is tempered by the potential danger it poses both to fish and fishery workers. Workers must be insulated from the electrical current by waterproof rubber gloves and waders and must receive training in the proper and safe use of electrofishing as well as CPR. Fish can easily be injured or killed during electrofishing if



▲ PHOTO 7.5 Using a simple seining apparatus (top) allows fishery biologists to quickly and safely sample a small reach. This is a low-gradient, open stream in central Montana. (Robert Bramblett) This rainbow trout caught in gill net in Hauser Reservoir (bottom) can be released without harm if they are retrieved frequently and their struggling is minimized. (Justin Spinelli)

improper techniques or gear are used. Fish and wildlife agencies now require specific electrofishing equipment, power settings (direct current only), and procedures to minimize or prevent injuries to biologist and fish. Fish should be exposed to current as briefly as possible and should not be touched by an electrode. They must be allowed to recover fully before release to prevent predation.

The seine is perhaps the oldest and simplest fishing device. It consists of a rectangular fine-meshed net tied to poles at each end. Two netters pull the seine by the poles through the water, essentially sieving out any fish in it. Lengths of seines can range from a few meters up to about 30 meters; heights are generally a meter or two. Floats and weights are often affixed to the tops and bottoms, respectively, of longer seines to keep them open vertically. A pouch or "bag" is often located at the center of long seines to help contain captured fish. Seines tend to get caught on obstructions (logs, boulders) and are therefore most useful in open habitats such as beaches. They tend to be best for small, slow fish because large fish can swim fast enough to evade them. A common use of seines is to assess year-class strength of juvenile fish in lakes and reservoirs. They are also used to determine species occurrence in prairie streams just east of the GYE. Most streams and rivers in the GYE have too many obstructions for effective use of seines – especially after the fires of 1988 added large amounts of woody matter to waterways.

Gill nets superficially resemble seines with very large mesh openings. They are temporarily set in place and catch fish that swim into them of their own volition. They are therefore known as "passive" gears, unlike seines, which are "active" gears that are actively fished by netters. A gill net is basically a panel of coarse-meshed netting made of monofilament nylon fishing line. Those used in freshwater are typically 30 meters long and 1 meter deep. Lead weights (or a lead-core line) are attached along the bottom and floats (or a foam-core line) are attached along the top. Anchors and buoys are attached to the ends. When set in place, typically from a boat, the gill net resembles a long fence. Combinations of weights and floats can be adjusted to position nets along the bottom, surface, or at mid-water positions. Biologists sometimes set vertical gill nets (essentially horizontal gill nets turned 90°) that extend from the surface to the bottom to determine depth distributions of fish.

A fish that encounters a gill net may attempt to pass through it, but if the mesh size is appropriate for that size fish, it becomes ensnared behind its gills or fins. Mesh size is therefore critical to the success of gill-netting; small fish can simply swim through the meshes of a gill net and large fish cannot penetrate it sufficiently to become ensnared. Biologists can use this selectivity to target specific sizes, or they can use so-called



▲ PHOTO 7.6 This picket weir is set near the mouth of Red Rock Creek, Red Rock Lakes National Wildlife Refuge, Montana, looking upstream. Downstream migrating fish would be funneled into the trap in the center foreground whereas upstream migrants would be diverted to the trap on the right. The weir is made of closely spaced aluminum conduit and is held in place with metal fence posts. (Ryan Harnish)

"experimental" gill nets made of multiple panels of various size meshes to avoid size selectivity. Active, large fish that frequently move are more likely to be caught in gill nets simply because they are more likely to encounter the gear than less active fish or smaller fish that do not move as much. Nets are often set overnight to reduce avoidance by taking advantage of reduced visibility.

In the GYE, gill nets are commonly used in lakes and reservoirs to monitor fish abundances. Rivers and streams here tend to be too swift for effective use of gill nets, but they are commonly used in the lower Yellowstone River and other Great Plains rivers. Perhaps their most notable use here in the GYE is in the non-native lake trout suppression program in Yellowstone Lake, where up to 25 kilometers of gill nets are fished daily during summer. Gill nets are effective tools for catching fish, but need to be retrieved frequently to prevent injuries or death of fish as well as their needless struggling and suffering.

A variety of passive traps (hoop nets, fyke nets, minnow traps) can be used to collect fish. These may use bait to attract fish - a perforated can of cat food or salmon works well or, they may be designed to use "wings" of mesh to guide fish into them. All of them include hoops that support funnel-shaped mesh throats that guide fish into the traps and inhibit their exit. These gears tend to work best in reservoirs and lakes. The winged gears are placed in locations that fish tend to move through such as a narrow channel or entrance to a small bay.
Weirs are similar to winged trap nets, but are placed in streams and small rivers to intercept migrating fish. A typical installation involves a rigid fence of wickets or mesh positioned across the stream at an angle. Fish moving either up or downstream are channeled to live boxes with funnel-shaped openings. Weirs are very effective for assessing abundances of pre-spawn upstream-migrating adult trout and their downstream-migrating offspring. However, they tend to get clogged with drifting debris and therefore require frequent



▲ PHOTO 7.7 The rotary screw trap is a very effective long term sampling method. Fish are caught in a cone as the force of the water rotates it. This rotary trap is located on Skalkaho Creek, a tributary to the Bitterroot River in western Montana. (Al Zale, MSU)



▲ PHOTO 7.8 Snorkeling is fast, easy, and a fun way to count fish and inspect their habitat. These biologists are counting trout in Bridger Creek, Montana. (Christopher Guy)

cleaning and maintenance. They also can pose a navigation risk to canoeists. Yellowstone National Park operates a weir on Clear Creek on the eastern shore of Yellowstone Lake to monitor annual cutthroat trout spawner abundances. Sadly, whirling disease and lake trout have combined to reduce those counts to about 500 fish in recent years compared to over 70,000 in 1978.

A modern alternative to a weir for capturing downstream migrants is the rotary screw trap. It consists of a cone fitted with internal spiral planes mounted on a pontoon barge anchored in a stream. The open end of the cone faces upstream. The force of the water on the spiral planes causes the cone to rotate on its axis, much like an Archimedes screw. Downstream migrating fish that enter the open end of the cone are augured by the planes into a live box at the rear of the trap. A self-cleaning rotating-drum screen at the rear of the live box removes debris. Rotary screw traps are efficient and effective, but initial costs are much greater than weirs. Montana Fish, Wildlife and Parks operate a screw trap on Duck Creek just north of West Yellowstone (visible from Highway 191) to monitor migration of juvenile rainbow trout into Hebgen Reservoir.

Although relatively inefficient, sportfishing tackle is occasionally used in fisheries research, especially when only a few fish are needed and the trouble and expense of using a more conventional sampling gear are not worth it. Good examples are genetic or tissue sampling or collection of fish for a small radio-tracking study. Also, a fishing license is easier to get than a collecting permit, which involves considerable bureaucratic red tape. In some instances, the possible negative public perception associated with using conventional sampling gears (especially electrofishing) when people are angling can be avoided by using sportfishing gear. However, the public can also take offense when they see public employees angling while apparently at work.

Non-Capture Sampling Techniques

Fisheries biologists tend to enjoy capturing and handling fish and therefore gravitate to techniques that result in fish capture. Often, it is more efficient and just as effective to "sample" fish using less intrusive techniques that avoid capture and handling such as direct visual observation or hydroacoustics.

Snorkeling is an effective technique commonly used for counting fish in small and medium-sized, clear streams of the GYE. For example, it was used by NPS biologists to assess abundances of cutthroat trout in the Yellowstone River above Yellowstone Lake. A careful snorkeler can easily approach trout that would be alarmed by someone walking along the stream. Of course, some fish will be concealed, but conversion factors can be calculated to compensate for unseen fish. Fish can be identified to species and a trained observer can estimate lengths quite accurately despite the visual magnification property of water. Perhaps the biggest drawback to snorkeling in the GYE is water temperature; wetsuits and often drysuits are necessary to stay in the water long enough to complete counts. An alternative is to use underwater cameras and increasingly common technique in fisheries studies. Cameras mounted on remotely operated vehicles (ROV) towed behind boats can be used to count fish along transects in lakes and reservoirs. Cameras can also be lowered from boats to find fish congregations and identify spawning areas in lakes.

Trout spawning nests are known as redds. Females dig out depressions in gravel, usually at the upper ends of pools where clean, oxygenated water wells up through the substrate. After spawning, the females bury the eggs with more gravel from just upstream of the redd to hide them from predators. The disturbed gravel is often readily visible as a lighter area among surrounding darker substrates still covered with attached algae and fine sediment. Redds can be counted from the streambank and give a relative estimate of adult spawner abundances as well as information on spawning locations. Redds of larger females are more obvious, as are those of autumn spawners such as brook, brown, and bull trout (*Salvelinus confluentus*). Surrounding substrates are undisturbed by snowmelt runoff and have more algal growth in the autumn than in spring; water clarity is usually better in autumn as well.

Hydroacoustic technology such as sonar - SOund NAvigation and Ranging - uses transmitted sound to locate, count, and measure fish. Sound echoes off fish and is picked up by an underwater microphone. The intensity of the reflected sound correlates with fish size and the time lag between sound transmission and echo detection can be used to estimate distance (i.e., location). Hydroacoustics is useful when visibility is limited, such as in turbid or deep water. Applications can be "fixed" in one spot to record fish moving past it, or mobile, as when operated from a boat. Data are automatically recorded digitally and are later decoded manually or using automated computer programs. Hydroacoustics can collect vast amounts of data, especially in fixed applications, which can continuously record data almost indefinitely. A major disadvantage of hydroacoustics is its inability to identify fish to species, although inferences can usually be made based on size and location. Often, a limited amount of capture sampling to identify species is used to supplement hydroacoustics. Mobile hydroacoustics was used in Yellowstone Lake to document densities, sizes, and depth distributions of cutthroat and lake trout to better target their lake trout eradication gill-netting efforts and limit unwanted catch of cutthroat trout. Fixed beam hydroacoustics was used at Hauser Dam on the upper Missouri River by MSU researchers to estimate numbers of fish passed through the turbines and over the spillway.

Fish are tagged or marked to examine movements, growth rates, and abundances. A great variety of tags have been used in the past, but many of these were bulky and were found to affect fish survival, growth, health, and behavior. We now know that small, inconspicuous tags are best for the fish, but these can be easily overlooked. Some tags work best if noticed by the public. For example, in a study of harvest rate, an anchor tag must be external and conspicuous so the angler can report the catch. Anchor tags can be large, colorful, and imprinted with identification codes and return instructions. A T-shaped end is inserted with a grooved needle so that the T lodges behind a fish's bones to prevent tag loss. They are invasive to the fish and chronic inflammation often develops around the insertion point. An infection can affect a fish's growth and health. A less conspicuous and healthier tag is the visible implant tag - a tiny plastic chip imprinted with a unique alphanumeric code. It is inserted into the clear membrane behind a fish's eye with a hypodermic needle. Such a tag is readily visible, but only if you know to look for it. A similar method is to inject liquid colored rubber into the skin, which congeals into a permanent tattoo. Combinations of dots of different colors in different locations can be used to create an individual code for each fish.

Partial fin clips can be used when individual identification of each fish is not needed, such as for a simple mark-recapture abundance estimate. The tip of a fin is cut off with scissors and is recognizable until it grows back. Partial fin clips do not affect swimming ability. Complete fin clips do affect swimming and are therefore not used except sometimes for removal of the adipose fin, the small fleshy fin on the back just to the front of the tail. Full clips are used to trace salmon and trout to indicate hatchery origin.

Passive integrated transponder (PIT) tags are widely used in fisheries research. A PIT tag consists of a tiny computer chip and antenna encased in glass tube. No battery is involved. When activated by a PIT-tag reader antenna, the tag emits a unique alphanumerical radio signal. The tag is injected into the body cavity of a fish



▲ PHOTO 7.9 A striped bass tagged with an anchor tag. The T-shaped internal end of the tag is lodged behind the interdigitated bones of the fish that extend down from the dorsal fin and up from the backbone (top). A visible implant tag is visible behind the eye (code "V15") in an Arctic grayling. Unlike some larger tags, these tags are harmless to the fish and does not change their behavior (middle). Miniaturization has made telemetry easier to track fish via satellite. A radio tag with trailing antenna is used for tracking small trout (bottom). The battery is at left and the tag's microcircuitry is visible to the right. (Al Zale, MSU)

with a hypodermic needle and can be read each time a fish is caught. Range of detection of the small (12 mm) PIT tags is limited to a few inches and therefore requires fish capture, but larger tags (23 mm) can be detected up to several feet away allowing for detection with mobile hand-held wand antennae or fixed antennae placed across streams. Cost is about three dollars per tag, which can allow tagging of large sample sizes, budgets permitting. MSU researchers are currently using PIT tags to determine movements of fluvial Arctic grayling in the Big Hole River.

As with land mammals, radio telemetry is used to determine the locations and movements of fish. We can know the habitats they occupy, when they move among them, and the routes they use. How habitat use and movements are affected by changes in the environment is especially informative. Migratory species, such as trout, can move great distances between spawning, summer, and winter habitats. Telemetry is an indispensable tool for documenting all of the habitats and mapping their location. Telemetry was used recently in the Yellowstone River above Yellowstone Lake to determine that most cutthroat trout there used the river for spawning and resided most of the year in the lake. Other uses of telemetry include assessing hybridization risk and entrainment of cutthroat trout into irrigation diversions in the Paradise Valley, determination of spawning locations of walleye (*Sander vitreus*) in Canyon Ferry Reservoir, and movements of rainbow trout relative to whirling disease infection risk in the Madison River.

Two types of telemetry transmitters (tags) are in common usage: radio and sonic. Radio tags are similar to those used in wildlife studies, but often use different radio frequencies that penetrate water better. They emit radio signals that are received by radio receivers tuned to the specific frequencies of the tags. The tags emit coded signals that allow biologists to differentiate specific fish. Directional antennas allow determination of a fish's location by triangulation. Range can be only a few hundred yards for small, weak transmitters or up to several miles with large, powerful tags. Tags can last from a few weeks to years and can be programmed to turn off and on as needed. Most of a tag's size is a function of its battery, which determines the tag's strength and longevity. However, large tags can affect fish behavior, survival, and growth, so biologists decide if the trade offs between signal strength and longevity and the data they collect are worth the potential harm to fish.





▲ PHOTOS 7.10 (left) Restoration of native fish populations is increasingly important for ecosystem management and to conform to the Endangered Species Act. Fishery biologists can isolate reaches by constructing artificial barriers to curtail upstream migration of nonnative species. 7.10 (right) A toxic chemical is introduced to reaches of streams to poison nonnative species so biologists can restore the native population. Although the chemical is destructive to the steam ecology, systems typically repair themselves in a short time. (Peter Brown)

A disadvantage of radio tags is that radio signals are rapidly attenuated by deep or salty water. They cannot be used for marine applications or in very deep lakes and reservoirs. Because radio antennas can be mounted on boats, vehicles, or aircraft, radio telemetry is useful for highly mobile species that require searching large areas.

Sonic transmitters emit coded high-frequency sound pulses that are detected by submerged hydrophones. Sonic telemetry works well in the large lakes and reservoirs of the GYE, but not in streams and rivers. Sonic tags require no obstructions like plants, islands, or river bends and are affected by turbulence like boat motors. The primary disadvantage of sonic telemetry is the requirement that the hydrophone be submerged, which precludes use from a vehicle or aircraft. Also, tags that are removed from the water, for example by a predatory animal or angler, cannot be detected. Radio tags implanted in fish are commonly found in or below osprey nests.

Both radio and sonic tags are typically implanted internally into the body cavities of anesthetized fish. An incision is made along the belly, the transmitter is inserted, and the incision is sutured closed. Tagged fish typically take a week or two to recover fully and return to normal behaviors. Biologists must spend a great deal of time locating tagged fish, especially if they move large distances rapidly and if signal strength is low; it is very easy to lose track of fish if their whereabouts are only infrequently monitored. Inexperienced biologists often underestimate just how much time and effort are required in a telemetry study. Tags can also be fairly expensive, around a $100 or more, which can limit sample sizes. Small samples limit the inferences that can be made about a population. However, the precision of the movement and location information that can be acquired by telemetry is much greater than with conventional tagging.

Anglers themselves can be sampled to determine fishing effort (i.e., angler hours or days spent fishing), fish catch and harvest estimates, and angler characteristics. On-site “creel surveys” are used if harvested fish must be examined by biologists. These surveys can be at access

points where anglers are interviewed as they leave the fishery or "roving" surveys in which the creel agent moves through the fishery on foot or by boat and interviews anglers while they fish. Logistics usually dictate which is used. On-site surveys are expensive and time-consuming, which has led to development of off-site techniques such as mail, telephone, and internet surveys to collect economic, social, and effort data. Anglers are randomly selected from lists of license holders. Catch and harvest information from off-site surveys tends to be of low quality because of angler recall bias; they tend to better remember the bigger fish and better days. Moreover, species misidentification is common. However, off-site surveys can collect more information from more anglers (who are not hurrying to get home or still trying to fish) over a broader geographical area. Anglers sometimes tell a creel agent what they think the agent wants to hear when face-to-face in an on-site survey but anonymous surveys elicit more honest answers and is one of the major advantages of such surveys.

Fisheries biologists rarely kill large numbers of fish for research purposes. However, restoration of native fishes often requires eradication of introduced non-native populations that have outcompeted and displaced the natives. As the public and fishery managers learn to value natural fisheries and ecosystems, there will inevitably be more native restoration projects. In addition, fishery management under the Endangered Species Act may require eradication efforts.

Although repeated electrofishing can sometimes be used to successfully remove all non-natives in small streams, the use of fish toxicants is usually necessary. Rotenone, a plant derivative, and Antimycin, an antibiotic, are commonly used. They are applied using drip stations placed at intervals along a stream or from a boat in lakes. A natural (e.g., waterfall) or artificial barrier at the lower end of the treatment reach prevents reinvasion by non-natives from downstream. Single treatments are rarely fully successful because some young fish or eggs avoid coming in contact with the toxicant by occupying springs and seeps where clean groundwater enters. A second treatment in the following year kills these individuals before they get old enough to reproduce.

Both Rotenone and Antimycin hinder cellular use of oxygen and are taken up through a fish's gills. They are functionally harmless to terrestrial animals, including humans, unless inhaled, but Rotenone can kill aquatic invertebrates and amphibians. Fortunately, invertebrates usually recolonize streams quickly on their own.

Eradication programs can be controversial. On Cherry Creek, a tributary of the lower Madison River, Montana FWP teamed up with Turner Enterprise and the US Forest Service to establish a refuge for westslope cutthroat trout. Eradication of non-natives was held up for 4 years by administrative appeals and three lawsuits. Some segments of the public disagree with or see little use in native species recovery, especially if they use the existing fishery. Stressing ways in which restoration can improve angling, such as replacement of stunted brook trout fisheries by larger natives, can engender public support. Antimycin was used to eradicate brook trout in 1985 from Arnica Creek, a tributary to Yellowstone Lake. Other eradication efforts are currently ongoing or planned for several streams in Yellowstone National Park to restore fluvial populations of Arctic grayling and westslope and Yellowstone cutthroat trout.

Conclusion

The fishery resources of the GYE are extraordinary for their diversity, their health, and their public value. Unlike some other parts of the ecosystem, it is not readily appreciated because most of what goes on underwater is hidden from the public's view. Fisheries biologists use a wide variety of sampling and analysis techniques to collect information and gain inference on fish species distributions, abundances, sizes, growth rates, and ages in the GYE. These techniques all have inherent strengths and weaknesses that must be understood to collect unbiased data useful for managing the area's fisheries and maintaining their recreational, economic, and ecological values. The Yellowstone fishery is home to an outstanding recreation activity. It is also home to several important native species indigenous only to this region. Careful management based on good science will ensure this resource remains intact for many generations to come.