Freshwater Resource Management

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6 Freshwater Resource Management

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In 1976, nearly 28 million Americans over the age of 16 purchased fishing licenses costing a total of more than $150 million. An additional amount spent on fishing (boats, motors, tackle, camping gear, motels, food, entrance fees, and field clothing) was much greater than license sales. Many communities are dependent on tourism as their major industry, and many tourist areas are popular because of fishing opportunities.

Fisheries science is the profession concerned with this large and important industry and with the effective management of our freshwater renewable natural resources.

FISHERIES SCIENCE DEFINED

A fishery is an aquatic, renewable, natural resource composed of three interacting components: aquatic *habitat*, aquatic *biota*, and the *human use* of the aquatic biota.

Aquatic habitat is the physical component of a fishery, as lake, pond, or stream water quality, soil characteristics, and bottom shape and contour.

Fisheries biologists collecting trout with electric shocking instruments in order to weigh and measure them and to take scale samples. (Photo by U.S. Fish and Wildlife Service.)

Aquatic biota, the second component, is represented by the animals and plants in a fishery. The biotic component ranges from microscopic plankton to higher plants, and, of course, all kinds of fish.

The third component of a fishery deals with man's use of the biota, usually fish (although fishing for food or sport includes harvest of trout, crabs, catfish, frogs, shrimp, clams, oysters, bass, kelp, sponges, whales, and other forms of aquatic biota). Man's effects on aquatic biota may also be caused by industrial, agricultural, and domestic water used for waste chemical disposal, irrigation, or drinking.

When we treat the two fisheries components, aquatic habitat and aquatic biota together, we are simply looking at an *aquatic ecosystem.* Aquatic ecology—the study of the relationships between animals, plants, and their environment—is a complex field in its own right. When one adds a third component, human use, the discipline becomes even more complex—the hallmark of all areas of renewable natural resources management.

Many problems confront a fisheries scientist attempting effectively to manage a fishery. For example, suppose that a manager, employed by a state fish and wildlife agency, is responsible for managing a large reservoir, a mountain lake, or a coastal river. He routinely faces a number of problems and constraints in carrying out his assignment.

Largely Uncontrollable Nature of Aquatic Environments

Fisheries managers are often faced with the frustrating reality that they can only partially control or influence aquatic environments. The number and kinds of habitat changes possible in a reservoir, lake, or river environment are few. Certainly the gross degradation of aquatic ecosystems by pollution often can be eliminated, but excessive runoff resulting from widespread land-use practices (i.e., urban, agricultural, road construction) is much more difficult to control. While alteration of aquatic habitat for increased fish production is possible in most fisheries, it is most applicable in streams and ponds.

Natural Variation in Animal and Plant Populations

All populations undergo a certain amount of natural fluctuation. Crappie, for example, may be common in a lake during one year and rare the next. Many population variations are poorly understood and take place at unpredictable intervals.

Dynamic Aspects of Biotic Populations

All animal and plant populations under natural conditions are in a state of change even though the population may appear to be stable. The total weight of fish, or other animals or plants, may be roughly the same year after year. However, the rate of death, birth, predation, growth, or harvest may be drastically different.

Conflicting Desires Within the General Public

Lakes, reservoirs, rivers, streams, and ponds may be used by anglers, boaters, bird watchers, water skiers, farmers (irrigation), industrial interests (electrical generation, manufacturing), cities and towns (drinking water), and many other segments of society. Many of these uses cause severe conflicts. As an example, reservoir water for agricultural irrigation often precludes quality fishing opportunities because of excessive lake drawdown. No one likes to drag a boat over extensive mud flats, but fewer people yet want to pay more for food.

Conflicting Desires Within the Fishing Public

Anglers themselves rarely agree on what a fishery should produce. Should a particular resource be managed for trophy trout or "fryers," for hatchery or native trout, for "catch and release" fishing or for consumption? These are some of the real and routine conflicts that face any fisheries manager.

Inadequate Information for Management Decisions

As is true in all areas of conservation, there is rarely enough information available to make management recommendations and decisions. Often a fisheries scientist must recommend positions and policies with relatively little available ecological or sociological data. What will be the impact of channeling a stream on the aquatic ecosystem? How will this channeling affect public recreational opportunities? How does society feel about the trade-offs in such decisions?

Now that a fishery has been defined and some of the problems facing fisheries scientists have been identified, the profession of fisheries science can now be described. Fisheries science is clearly a blend of numerous disciplines, including management, biology, economics, chemistry, law, political science, sociology, psychology, mathematics, statistics, and others. All are oriented toward manipulating a fishery for its best societal use. Each of these disciplines is an important facet of fisheries science, and often all or many must be brought to bear on solving a single fisheries problem.

Management

This is the study of how to evaluate and implement decisions to meet specified goals and objectives. Most management principles are universal, but their application is highly variable. A manager in a commercial enterprise may measure his success by profit or income. The manager of a state or federal fisheries agency has a more nebulous objective or "bottom line." Certainly the fisheries manager is attempting to maximize the outdoor recreational experience through the aquatic resource, but how is this measured? Is it the number of fish in the creel, or the quality of the fishing experience, the total number of days spent fishing by the public, or the quality of the aquatic environment? Clearly the bottom line in fisheries management is often unclear.

Biology

Biology is a major contributing discipline to fisheries science. Information on the life history and physiological requirements of many animal and plant species is needed to manage fisheries. Simple questions, such as "when do fish spawn?" must be answered and answered accurately for effective fisheries management decisions. The behavior of animals must also be understood by fisheries scientists. Why are hatchery-reared trout more susceptible to predation than wild trout? What is the behavioral mechanism operating? Another example of the role of biology in fisheries management is determining the physiological mechanisms of pollution-caused deaths. If it is known what physiological changes take place in fish subjected to pollution, it may be possible to eliminate the specific toxic substances.

Economics

This discipline is increasingly becoming an important facet of fisheries science. The question of how society places a value on tangibles and intangibles affects all management-oriented professions, including those in conservation. Because trade-offs (jobs vs. environment, stocking fish vs. natural reproduction, commercial vs. recreational fishing interests) are at the base of all fisheries management decisions, the principles of economics are useful to fisheries scientists. Benefit/cost analyses are typically used to determine if "public works" projects are worthwhile by comparing the total benefits to the public against the total costs to the public. Such projects and benefit/cost analyses have far reaching impacts on America's fisheries resources.

Chemistry

The study of chemistry allows fisheries scientists to understand the chemical interaction of water and biota. Water contains many naturally occurring and human caused chemical constituents. These chemicals have a tremendous effect on aquatic biota. They permit life to exist in water and they may, under certain circumstances, limit the biotic potential of a stream, pond, or lake. Pollution through undesirable chemical addition to water is an example of an important problem for which a knowledge of chemistry has been useful to fisheries scientists.

Law

Law, especially related to environmental issues, is important to the practicing fisheries scientist. Few fisheries scientists are lawyers, but with so many conservation issues and problems being solved in courts, the fisheries scientist must be familiar with legal institutions and the relevant conservation and environmental legislation. The floor of the courtroom is often the arena where management recommendations are accepted or rejected. Increasingly, scientists and managers are being called as expert witnesses in complex conservation issues.

Political Science

Politics is a more important facet of fisheries science than many people wish to admit. Like it or not, fisheries scientists must recognize that decisions affecting fisheries resources are often societal decisions arrived at through governmental processes rather than purely scientific analysis. The political arena provides the means to resolve conflicts between uses and factions of society. How does society decide whether or not a dam will be built that causes extinction of a species? Can a dam project be abandoned causing the loss of many jobs and recreational opportunities associated with the lake?

Sociology and Psychology

These seldom used to be considered integral to fisheries science, but this view has changed dramatically. How people perceive fishing and fisheries problems and how they react to different management decisions are now important areas of fisheries science. We can often manipulate aquatic biotic or habitat components to adjust to public preferences, but molding public preferences to biotic and habitat needs is more difficult. Public education programs in conservation are often based on sociological or psychological approaches.

Mathematics

This is essential to modern fisheries science. The study of animal and plant populations is a highly quantitative endeavor. Mathematical analysis enables the scientist or manager to simplify information into general relationships. It is how we translate descriptive information into quantitative information. Mathematics may be used to describe processes (i.e., mortality rates, growth rate) and to predict the future based on current mathematical relationships (i.e., future fish yield under certain fishing regulations).

Statistical Inference

In its simplest form statistical inference permits the fisheries scientists to attach probability to their answers, conclusions, or recommendations. If a fisheries scientist wished to determine which of several new hatchery diets is best for growing rainbow trout, he would design a statistically valid trial test. Through statistical inference, he could attach a probability to the correctness of his answer.

Engineering

These studies are necessary or at least desirable in many areas of fisheries science. Interaction with engineers is necessary in modifying proposed dams, designing hatcheries or stream-improvement structures, developing sampling and field equipment, and designing experimental facilities. Fisheries scientists, knowing and appreciating what is feasible in road construction, can protect fisheries resources by insisting that designers and builders do their work a certain way. They can demand that logging roads be located in only certain areas and can literally save mountain streams from destruction.

Computer Technology

Computers, a recent addition to fisheries science, can perform easily computational tasks, but, as rapidly processed data become available to managers, more demands are placed on the individual to make rational use of this increased information. Far from replacing man, computers have made certain individuals desirable, if not indispensable, to modern society.

Many other disciplines are important in fisheries science. A key point to remember is that fisheries science is a whole collection of disciplines, not just one or two. Confronted with a particular fisheries problem, the fisheries scientist may have to draw on the collective knowledge of many diverse disciplines to solve the problem.

EDUCATIONAL QUALIFICATIONS

Fisheries scientists possess a wide variety of educational backgrounds. Formal educational backgrounds range from high school diplomas to doctorates. Laborers on hatchery, field, or construction crews need little formal education beyond high school. Professorships and high level research positions nearly always require a doctorate.

No single curriculum is universally appropriate for all areas of fisheries science, but any curriculum in fisheries science should at least include a foundation in the basic biological sciences, advanced mathematics, statistical methods, political science, sociology, psychology, computer techniques, public speaking, English composition, natural resource economics, and management concepts as applied in renewable natural resources (fisheries, forestry, and wildlife management). Students interested in population dynamics, for example, would be well advised to take additional management and mathematics courses. Students with a leaning toward fisheries policy should take additional courses in political science, law, international affairs, economics, and management. Students interested in the biological aspects of fisheries would be well advised to take additional advanced biology and chemistry courses.

The American Fisheries Society has set minimum educational requirements for certification of fisheries scientists:

	Semester Hours	Quarter Hours
Biological sciences	30	45
Physical sciences	15	22
Mathematics-statistics	6	9
Communications	6	9

At least four of the courses in biological sciences must be related to aquatic ecosystems. Mathematics should be at least at the level of college algebra, and statistics must include at least one course in statistical methods. It is important to note that these educational requirements are the minimum to meet the requirements for certification by the American Fisheries Society. Additional coursework and training beyond these minimums are highly desirable, if not necessary, to secure most fisheries positions.

Although no one knows precisely how many fisheries scientists are graduated each year in the United States and Canada, the number is approximately 1000 at the bachelor's level, 300 at the master's level, and 85 at the doctoral level. Many additional students are graduated in related disciplines such as wildlife, aquatic biology, natural resource economics, forestry, and outdoor recreation.

Several dozen universities offer degrees in fisheries science (see Appendix A). Others offer degrees in closely related disciplines. Some universities only offer graduate degrees in fisheries science while some community colleges only offer associate (two-year) degrees. The American Fisheries Society does not currently accredit university programs in fisheries science. The prospective student should carefully investigate various alternative programs and universities. A review of the current status of recent graduates will provide an idea of the kinds of positions likely to be available to graduates of that program.

Graduate work, including a thesis based on original research conducted by the student, is necessary for most higher level fisheries positions. Stipends in the form of teaching or research assistantships are often available to highly qualified bachelor's or master's degree graduates. Master's degrees typically require approximately two years for completion. Doctoral degrees usually require approximately three years beyond the master's.

Specialization is common in fisheries science as in most professions. While the "generalist" and fisheries manager must feel at home with biology, economics, chemistry, physics, political science, psychology, and many other disciplines, the specialist becomes an expert in one or a few facets of fisheries science. Fish parasitology is an example of a specialty. The necessary education and training in fish parasitology are extensive and concentrated in the biological area. Other common specialties are limnology, fisheries economics, population dynamics, computer applications, environmental analysis, and aquaculture. Appendix B includes references giving further details on specialties in fisheries science.

PERSONAL QUALIFICATIONS

There is no single set of personal qualifications required to be successful as a fisheries scientist. Some kinds of field work may require great physical strength and stamina. On the other hand, fisheries scientists dealing with legal issues have less need for physical attributes but must have a much greater tolerance for frustration. Desire, ambition, and intellectual ability are difficult personal characteristics to separate, but they are all important attributes of the successful fisheries scientist. The ability to persevere when confronted with complex and frustrating problems can often spell the difference between success and failure. The ability to work with people, whether they are anglers, farmers, elected officials, or other professionals, cannot be overemphasized.

The student considering a career in fisheries science should be aware that love of the outdoors, a concern for the environment, and a desire to work away from human development are poor reasons to select a career in conservation. The level of training required for professional fisheries jobs is extensive and rigorous.

There is no "typical" work in fisheries science. *Field* work may include routine hatchery operations such as fish feeding and artificial spawning, lake and stream surveys for fish population assessments, survey of fishkills and their causes, water quality determinations, chemical treatment of lakes to eliminate or reduce undesirable fish populations, life history studies, fish population analysis, aquatic herbicide treatment, creel surveys, angler surveys, and many other types of varied and important activities.

Laboratory Work

Chemical analyses, physiological determinations, diet and nutrition studies, and behavioral studies are a few examples. Evaluation of data by statistical analysis and report writing are a large part of both laboratory and field work.

Analytical Evaluation

Often fisheries problems can and should be solved without collecting additional data. Perhaps we may already know enough about a fish population to develop harvest regulations if we carefully analyze existing data mathematically. Many of the underlying principles upon which we base management were developed or crystallized by analysis of existing data.

Interaction

Work with other professionals in other agencies, special interest groups, and the general public is a more common type of fisheries work than most people realize. Many fisheries scientists spend their entire careers representing their agency's interests in interagency dealings and negotiations. Often such interaction is the most effective way to protect the environment from unnecessarily damaging "development." Interaction with special interest groups such as sportsmen clubs, environmental groups, and hiking clubs may be crucial in gaining support for a particular management program. Effective interaction with the general public is also important in fisheries science.

Teaching

In fisheries science this is mostly limited to the university level. There has been a slow but steady expansion in the numbers of professorships in fisheries science, but the total number is not large. Professors are usually involved in ongoing research projects in addition to their teaching duties.

The American Fisheries Society has promulgated a "Code of Practices" for members. The code specifies professional standards in relations with the general public, the quality and type of professional services provided, relations with clients and employers, and relationships with other professionals. Copies of the code can be obtained from the American Fisheries Society, 5410 Grosvenor Lane, Bethesda, Md., 20014.

EMPLOYMENT OPPORTUNITIES

Fisheries science is a relatively small profession. There are only about 10,000 fisheries scientists in North America (bachelor's degree or higher). The number is slowly and steadily increasing. Employment opportunities vary greatly among the disciplines of fisheries science, at different educational and experience levels, and in different geographic regions.

Summer positions are helpful in gaining experience and in increasing chances of locating a permanent job after completion of a university education. Many summer and permanent positions deal with fisheries problems but may be called something else: aquatic scientist, wildlife biologist, research scientist, environmental scientist, biologist, and others.

Federal Government

The Fish and Wildlife Service, National Marine Fisheries Service, Forest Service, Bureau of Land Management, and Environmental Protection Agency are the largest federal employers of fisheries scientists. Other federal agencies such as the Nuclear Regulatory Commission, Tennessee Valley Authority, Bureau of Reclamation, Army Corps of Engineers, and Soil Conservation Service also employ fisheries scientists.

State Government

State fish and wildlife agencies have historically been the principal employer of fisheries scientists. Recently, state environmental protection agencies have been hiring a substantial number of fisheries scientists. Most of the traditional fisheries management activities are carried out by state agencies.

Local Government

Employment opportunities in fisheries science with county, city, or town governments are limited. Many local governments do employ professionals to manage parks and wildland resources, but employment of fisheries scientists is generally left to the state government.

International Government

The United Nations Food and Agriculture Organization and the U.S. Agency for International Development are the main employers of fisheries scientists for fisheries problems abroad. Most international jobs for freshwater fisheries scientists relate to aquaculture and pond management in developing countries. Production of fish for food is the main thrust of international activities in fisheries science.

Universities and Colleges

Opportunities for fisheries scientists in academia are limited. Professorships and most permanent university research positions require a doctorate. Students aspiring to become professors should obtain a broad background (preferably both geographic and academic) while pursuing their bachelor's, master's, and doctoral degrees. Academic openings for technicians and research assistants are limited.

Utilities

There has been a dramatic increase in job opportunities for fisheries scientists with utility companies. Public awareness and legislation have resulted in hiring professionals by utility companies to provide inhouse knowledge to minimize environmental damage caused by electrical power generation, dam and transmission line construction and maintenance, and other activities.

Industry

Environmental awareness in the 1960s and 1970s has resulted in a much greater employment demand for all kinds of environmental scientists. Fisheries scientists are often the ideal individuals for these jobs, although few are explicitly identified as fisheries positions. Determining the toxicity of chemicals is a major activity of many of these positions.

Engineering Firms

Project design for dams, electrical generating plants, irrigation systems, and water diversion used to be solely concerned with engineering requirements. Environmental factors now must be considered throughout the project's design process. Fisheries scientists can often perform a valuable role when employed by engineering firms.

Consulting

An increasing number of fisheries scientists are able to work full time through private consulting to help solve fisheries problems confronting public and private organizations. Most professors are also part-time consultants. Consulting problems often relate to environmental issues and how to minimize damage to the aquatic environment.

The organizations listed in Appendix C provide further information on employment opportunities in fisheries science.

COMPENSATION AND REWARDS

Salaries in fisheries science in general are not commensurate with the training required. Average salaries are lower than medicine, law, dentistry, or engineering with comparable education and training. Salaries within the profession typically follow civil service scales. While there is little opportunity to become rich through employment as a fisheries scientist, an adequate income can be realized.

Beyond the monetary rewards, there is the opportunity to protect and use wisely for society aquatic renewable natural resources. This opportunity may well be the greatest reward for any of the conservation professions.