5 Fisheries Management: Matching Expectations to Reality

Introduction

Anglers love to tell stories, and a lake's reputation is often based on a few experiences by a limited number of anglers. Unfortunately, anecdotal evidence and casual observations by a few anglers do not give an accurate picture of a fishery's status. If a boat load of friends went fishing and were skunked, does that mean that the lake is empty of fish? A bad day of fishing could be due to bad luck, poor site selection, or poor technique, and have nothing to do with fish abundance. Scientific surveys to determine the status of a fishery are necessary to develop an accurate picture of the current state of a lake's **fishery** and to develop and evaluate fishery management plans. Without scientific surveys, fisheries management deteriorates to intuition and guesswork.

This chapter introduces fisheries ecology, data-gathering tools and management strategies for managing the fish, their habitat, and anglers.

Gathering fisheries information

The New York State Department of Environmental Conservation (DEC) is responsible for managing fisheries in New York State. As DEC conducts its own scientific surveys on most lakes, their staff may also gather information in partnership with other groups such as universities, conservation organizations, lake associations, and rod and gun clubs. With guidance from a professional fisheries biologist, citizens can gather very accurate fisheries data on their lake.

Fig. 5–1. Great expectations!
Some anglers have unrealistic expectations about the size and availability of fish for harvest in small lakes. Acre-for-acre comparisons, however, show that small lakes produce more fish than large lakes. (CREDIT: JOHN FOSTER)

Ideally, lakes should be surveyed every three to five years. Lakes with high socio-economic importance are more frequently surveyed. Small lakes are surveyed infrequently, however, because of limited state resources.

The environmental surveys discussed in Chapter four, "Problem diagnosis," provide an initial step toward identifying the physical, chemical and biological factors affecting fisheries. This information is important for understanding how best to manage a fishery since lake ecology has a tremendous influence on fish populations and the health of fisheries.

When environmental survey information is combined with fish, angler and habitat survey information, a fisheries management plan can be developed, or an existing plan evaluated. Fish, angler and habitat surveys, discussed later in this chapter, give a good

indication of how much harvest a lake can support and the level of angling pressure it receives. It will indicate where habitat improvement or stocking can enhance fish populations and angling opportunities. Before delving into these important data-gathering tools, it helps to understand some basic principles of fish habitat.

Habitat limiting factors and critical parameters

Each fish species, and life stages within the same species, require different habitats to carry out critical life functions, such as feeding, resting, hiding from predators, and spawning. The physical, chemical and biological components of the habitat affect the population dynamics of each species. Each of the species will have an optimal range and a tolerance range for every habitat component. Optimal temperature for brook trout, for example, is around 60ºF (Fahrenheit) although their range of tolerance is from 32ºF to 74ºF. As temperature deviates from optimum, however, it begins to limit brook trout survival, growth, and production and population size. Many fisheries are limited by a few obvious habitat parameters, but fisheries are more often limited by a combination or interaction of factors.

Habitat analyses focus on determining the primary limiting factor for a particular game fish. Fisheries biology and public interest can result in a lake being designated for brown-trout production. The management plan would then focus on improving the factors of brown-trout habitat that limit production. Physical limiting factors include habitat, temperature, light, elevation, substrate, depth, structure, shoreline curves, turbidity, and water clarity or transparency. The two most common factors limiting fish production are temperature and nutrient availability.

The temperature regime is the primary factor determining what species of fish a lake can support. Lakes are classified by their dominant fish habitat into three broad categories, optimal temperature of 59ºF (15ºCelsius) for coldwater fish, 68ºF (20ºC) for coolwater fish, and 77ºF (25ºC) for warmwater fish. Most trout stop feeding, for example, at 36ºF (2.5ºC), have optimum growth and survival at 59ºF (15ºC), and are stressed at temperatures above 68ºF (20ºC).

Overlap of fish communities can occur in the same lake. Temperature optimums differ among life stages within the same species. Many deep lakes can support coldwater, coolwater and warmwater species in the same lake. In deep lakes, however, available habitat will best support one particular fish community. Understanding the ecological relationships between the temperature regime of a lake and the temperature requirements of fish provides insight into the possible development of a particular fishery.

Lake fertility is the primary factor determining the number and biomass of fish. The more fertile the lake, the more fish-per-acre it will produce. Higher nutrient levels increase phytoplankton and zooplankton production. Predation transfers this energy and biomass through the food chain, resulting in increased fish production and their potential harvest.
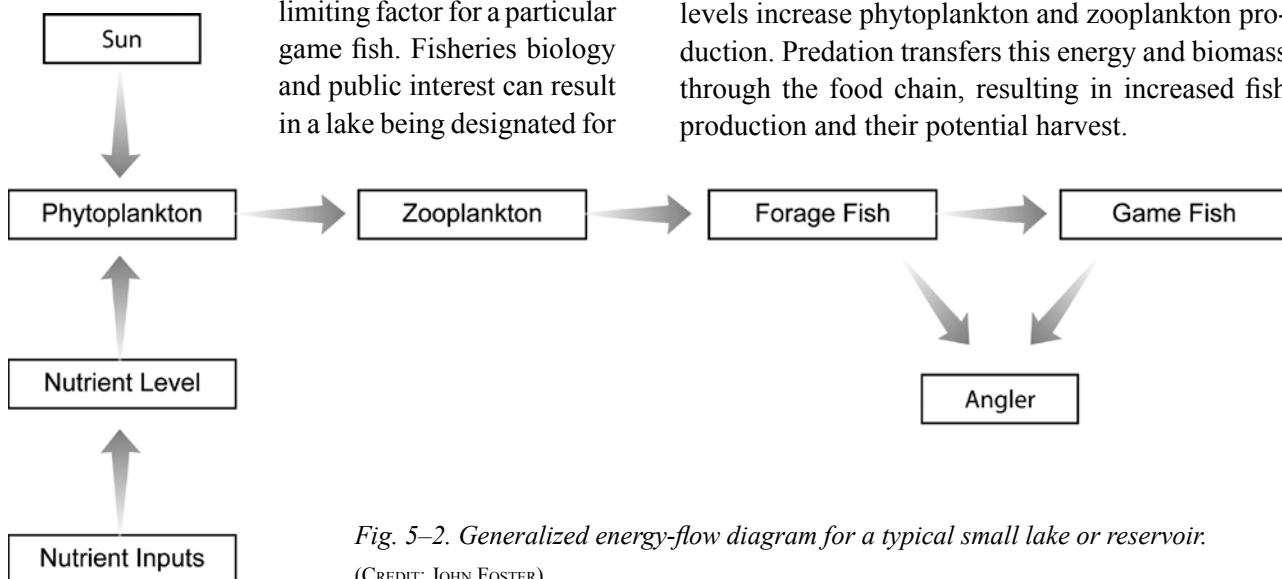

Fig. 5–2. Generalized energy-flow diagram for a typical small lake or reservoir.
(CREDIT: JOHN FOSTER)

Many anglers believe that the clear, cold, Adirondack lakes provide the best fisheries in New York State. Actually, the green, warm, downstate lakes contain and produce the most fish-per-acre. The higher altitude Adirondack lakes have shorter summer with a shorter growing season, but the main difference between these crystal-clear mountain lakes and their murkier southern counterparts is fertility.

Lake fertility is frequently used by aquatic ecologists to classify lakes. High elevation and northern lakes in New York State tend to be either relatively infertile oligotrophic lakes or **dystrophic** lakes with rocky shores and few nutrients. Oligotrophic lakes have scanty nourishment. Dystrophic lakes tend to be shallow, tea-colored, and high in humic matter, with acidic waters and few plants. Oligotrophic lakes are usually so deep and dystrophic lakes so stained with tannic acid that sunlight penetrates only the surface waters. Lowland lakes of central and southern New York State tend to be extremely fertile, nutrient-rich, eutrophic lakes, surrounded by rich farmland. They are usually shallow, and plant growth is supported because sunlight penetrates throughout the water column. Between these two extremes are moderately nourished mesotrophic lakes.

Fertility or nutrient level can be used to accurately predict the yield or standing crop biomass of fish in a lake. Lake fertility determines fish abundance and the type of fish species in a lake. Fisheries biologists measure fertility by conductivity, a measure of how well electricity is conducted through water, or by **Total Dissolved Solids** (TDS) a measure of the level of dissolved particles in the water. Optimal conductivity ranges from 100 to 300 **µmhos. (**Electrical conductivity, µmho, is the opposite of electrical resistance, ohm. Conductivity is resistance spelled backwards and preceded by the Greek letter µ.)

The morphoedaphic index is used by fisheries biologists use to predict fish yield per-acre-per-year. It is used to estimate the pounds of fish available for harvest and is calculated by multiplying the yield-per-acre by the surface area of the lake. This widely used index is derived by dividing a lake's TDS mg/l (milligrams per liter), by its mean or average depth in meters. The mean depth of a lake can be derived by dividing the lake's volume by its surface area.

Mean depth is an indicator of the extent of a lake's euphotic-littoral productive zone.

TDS provides a crude measure of a lake's limiting nutrients such as phosphorus or nitrogen. Shallow lakes are more productive than deep lakes. Phosphorus is the most limiting nutrient in standing waters, so it is also used to measure fertility. The optimal range is from .01 to 3.0 parts per million (ppm.)

Physical limiting factors

Temperature and nutrients are critically important, but there are many other factors that also limit a lake's fishery. Fish require adequate space, or habitat, to live. Steep-sided lakes provide very limited littoral-zone habitat, and thus very limited space for fish such as pickerel, bass, or bullheads that require a shallow, inshore, weedy habitat. Other physical limiting factors include light, elevation, substrate, depth, structures, shoreline curves, turbidity and water clarity.

Light is required for primary production and ultimately affects fish productivity of all fish in the lake. Fish generally are more comfortable in dim light, but too little light reduces productivity. Fish production is significantly reduced in areas of prolonged cloud cover, such as the eastern side of the Great Lakes,

Elevation can be correlated with a number of limiting factors. In central New York State, trout usually do not occur in shallow lakes less than 1,500 feet above sea level because of the correlation between altitude and temperature. High-elevation lakes have a shorter growing season and are fed by rain water which is low in nutrients. High-elevation lakes, therefore, have low productivity due to colder water, a shorter growing season, low pH and low nutrients.

Substrate has multiple effects on the distribution and production of fish. The availability and amount of spawning gravel often limits trout production. Fine sediments such as sand and silt provide habitat for bullheads. Coarse sediments such as cobbles and boulders are favored by sculpins, rock bass and smallmouth bass.

Depth can be a limiting factor, since many aquatic organisms are only found at specific

depths. Sunfish and pickerel are only found in shallow water. In general, as depth increases, biomass and productivity decreases. In the northeast, however, shallow lakes less than 10 feet deep are often subjected to winter-kill, reducing both plant biomass and fish productivity.

Structures such as shoals and artificial reefs provide substrate for algae and invertebrates whose presence increases food available to fish populations. Rocky shoals also provide shelter for structure-loving fish such as rock bass and smallmouth bass.

Shoreline curves increase the ecotone or transition zone effect and, therefore, increase productivity. Round lakes are less productive than lakes with multiple embayments and shoreline curves.

Turbidity is a measure of particulates suspended in the water column. High turbidity reduces water clarity or transparency, reducing photosynthesis, and making it difficult for fish and other aquatic animals to find food and oxygen. Optimal turbidity for standing waters is 0 to 2 Nephelometric Turbidity Units (NTU), the standard unit for measuring turbidity. (NTU replaces JTU, Jackson, and FTU, Formazin, as turbidity measurement units.)

Water clarity is the opposite of turbidity. It is measured by lowering and retrieving a round, black-and-white plate called a Secchi disk into the lake (see Fig. 4-1, Chapter four "Problem diagnosis"). Water clarity or transparency is measured by calculating the average depth at which the Secchi disk disappears and then reappears in the water column. This depth provides a crude measure of the zone where plant photosynthesis equals respiration. In lakes with low levels of inorganic suspended solids, it provides a relative measure of the density of phytoplankton.

Chemical limiting factors

Chemical limiting factors include fertility, oxygen, carbon dioxide, pH, ammonia, hydrogen sulfide, heavy metals, alkalinity and hardness. See also the discussion in Chapter four, "Problem diagnosis."

Oxygen is required for respiration and metabolism. While some species can survive at very low levels of oxygen, production for most fish begins to drop when oxygen levels fall below five ppm.

Carbon dioxide is optimal at levels from 5 to 10 ppm, but becomes limiting at levels above 10 ppm. High carbon-dioxide levels can occur in the deeper waters of highly productive lakes.

pH is a measure of hydrogen ion concentration. Optimal pH for most aquatic organisms is from 6.5 to 8.5. Brief exposure to higher and lower pH may not be limiting.

Alkalinity is a measure of carbonate and bi-carbonate ions, which buffer the changes in pH. Optimal alkalinity is from 50 to 400 ppm. Levels below 50 ppm often result in rapid fluctuations in pH levels that are detrimental to most aquatic organisms.

Hardness is a measure of magnesium and calcium ions in the water. Optimal levels of hardness are from 50 to 400 ppm; levels below 50 ppm are limiting. A low calcium level is often a limiting factor in dystrophic lakes.

Ammonia is toxic to fish and other aquatic organisms. In water, it occurs in two forms, the toxic deionized form (NH_3) and the non-toxic ionized form (NH_4^+). The amount of ammonia in the toxic form is greater at higher temperatures and pH. Total ammonia starts to become limiting around one ppm. High levels of ammonia can occur in the deeper waters of highly productive lakes in late winter or summer.

Hydrogen sulfide is very toxic to aquatic organisms, and continuous exposure to levels as low as .002 ppm is lethal to most fish. Hydrogen sulfide is more toxic at low temperatures and pH. High levels of hydrogen sulfide can occur in the deeper waters of highly productive lakes, also in late winter or summer.

Heavy metals such as cadmium, copper, lead, mercury and zinc become toxic at levels as low as .002 ppm. Acidic lakes leach heavy metals from their substrates.

Biological limiting factors

Biological limiting factors include benthic invertebrate production, zooplankton, the fish community, woody debris, submergent rooted vegetation, and shoreline vegetation.

Benthic, or bottom-dwelling, invertebrate production is consumed by benthic (or demersal) fish such as lake trout, whitefish, sculpins, suckers, bullheads and carp, which are allfree-swimming species living close to the bottom. The size and diversity of the benthic community has a strong influence on the fish community. A large biomass of benthic invertebrates does not necessarily result in a large biomass of fish. Zebra mussels *(Dreissena polymorpha)* can have a tremendous biomass, but relatively little of it is converted into fish biomass. Zebra mussels strain plankton out of the water column, reducing the food available for planktivorous fish, thus reducing the overall fish production of lakes they invade. A survey of benthic invertebrates should focus on standing crop biomass and species diversity. The presence of an **indicator species,** such as blood worms and tubificid, or tube worms, is indicative of past episodes of oxygen depletion that could be limiting the biomass of benthic fish.

Zooplankton are the main source of food for the fry stage of virtually all fish. The fry stage extends from yolk absorption by the larva to the fish reaching approximately one gram in weight. Zooplankton also feed many juvenile and adult fish. The size and species diversity of the zooplankton community influence survival, growth and abundance of the early life stages of most lake fish. Dystrophic lakes produce relatively few large zooplankton species, thus limiting the food base for planktivorous fish.

The fish community limits the production of some species through predation, competition or interference. Alewives *(Alosa sapidissima)* can limit walleye production by predation on larval walleye *(Sander vitreus)*. They can also limit production of ciscoes by out-competing them for food. Large populations of carp and bullheads uproot aquatic vegetation and cloud the water,

reducing the size of the littoral zone and interfering with littoral-zone fish.

Woody debris or deadfalls provide shelter and feeding stations for many fish species. The presence and density of many pan fish (sunfish, rock bass, bullheads and yellow perch) and game fish (pike and smallmouth bass) are highly dependent upon the amount of deadfalls in a lake. Deadfalls also provide substrate for algae and invertebrates, which increases overall lake productivity. In spite of these positive attributes, deadfalls are the most frequent thing people remove on "lake clean-up days."

Fig. 5–3. Deadfalls and woody debris attract fish by providing structure and substrate for their food, but they are often removed during shoreline development.
(Credit: Wayne Wurtsbaugh)

Submergent rooted vegetation delineates the littoral zone of a lake, the most productive of the three lake zones. Submergent rooted vegetation provides habitat for littoral zone fish and food for aquatic invertebrates and fish. When the size of the littoral zone is limited, species, population sizes and the production of the lake will also be limited.

Shoreline vegetation, such as bulrushes, provide habitat for aquatic invertebrates that fish eat, nesting areas for crappies, sunfish and bass, and spawning habitat for northern pike. Emergent, or above the surface vegetation also protects windswept shorelines from erosion by waves and boat wakes. Shoreline wetlands can provide a significant source of decaying organic material to fuel the food chain of a lake.

A tremendous amount of environmental data can be collected during one or two sample dates, but some limiting factors might be missed. Additional data and carefully selected sampling dates and times may be necessary to gain a more complete picture.

Seasonally, late summer and late winter are more likely to have limiting conditions such as dissolved oxygen, ammonia, hydrogen sulfide and temperature. During the day, early morning is likely to have low pH and dissolved oxygen problems, while late afternoon may have temperature problems.

Critical environmental conditions happen sporadically. Hot dry summers and severe winters may occur infrequently. When a fishkill is the result of a transient event, conditions can be back to normal before a sampling team can isolate the problem. It is important to remember, however, that although fish abundance, survival and productivity can be limited by transient events, physical, chemical and biological conditions support fish 99.9 percent of the time.

Fig. 5–4. Late-winter water-quality sampling may indicate limiting factors, such as low oxygen levels, that will reduce fish survival and production. The device shown can collect samples at various depths beneath the ice. (CREDIT: JOHN FOSTER)

Scientific techniques for conducting fisheries surveys

Successfully managing a fishery requires knowing the habitat needs of the fish. Scientific surveys are needed to determine existing fish populations, fishing activity and fish habitat. Information from these surveys is then used in the three major management approaches: managing the fish, the habitat, and the angler.

Fish surveys

During fish surveys, fisheries biologists capture, identify, weigh, measure, and remove scales to check for age and growth determinations. These measurements provide valuable information about fish population dynamics including population size, community structure, age/size structure, reproductive success, and growth. Information on habitat utilization and movement patterns can also be gathered.

Fish-survey techniques are adapted to different species and sizes. Fish in lakes are most often surveyed with gill nets, trap nets, seine nets and electro-fishing, although towed nets and angling are sometimes used.

Gill nets used in fish surveys are usually 300 feet long, and consist of six, 50-foot panels of different-sized mesh. Most fish are vulnerable to gill nets, and they are highly effective in both deep and shallow water. Gill nets should be used sparingly since the mortality of captured fish is high. Live fish can be released after workers take measurements and scale samples that are analyzed later to determine fish age and growth. Fish that die in the net can still be used for analysis of their reproductive condition, stomach contents and parasites.

Trap nets are most effective for fish that live in shallow water at particular times of the year. Fish that migrate along the shore are vulnerable to trap nets. These nets are very gentle on the captured fish and most can be released unharmed.

Fig. 5–5. Gill nets are used sparingly by professional fisheries biologists to sample fish populations throughout a lake. (CREDIT: JOHN FOSTER)

Seine nets are typically small-meshed nets that are used to capture young fish, and are only effective when used close to shore.

Electro-fishing is done from a boat using equipment that sends a non-lethal electrical charge into the water, temporarily stunning fish so they can be easily netted at the surface. Electro-fishers work best in water less than six feet deep and, therefore, are most effective on shallow-water species such as bass and sunfish. Boat electro-fishers are often used at night since many fish move to the surface after dark.

Towed nets can be used to sample fish eggs and larvae. Trawls can be used to survey small or young-of-the-year fish on the bottom or in the water column of the lake. Towed nets in small lakes typically use fine-mesh sizes.

Angling or fishing with a hook and line is an effective method of surveying a wide range of species. It can be used at any depth and can target specific species. It is most effective in sampling adult or sub-adult fish. For many species, angling is the most effective way of capturing fish for stomach analysis.

Fish surveys should be extended to lake tributary streams if the species of interest uses streams as part of their life cycle. Walleye and many trout species, for example, use streams for spawning and nursery areas.

Angler surveys

The goal of an angler survey is to collect information about the fishery from the angler's perspective. To be effective, angler surveys must be conducted throughout the fishing season. Five to ten percent of the available fishing days in the season should be covered, including both weekdays and weekends. A good survey of anglers will include an angler census, creel surveys, and angler interviews.

Angler censuses are usually conducted without direct contact. Small lakes can be surveyed from a lookout point, by boating around the lake, or at a boat launch if lake access is restricted. The purpose of the census is to develop counts of how many anglers are fishing the lake each day and whether they are shore fishing, trolling, or still-fishing. The census should also note boat size, angler age, and whether the angler is with other adults, families with children or is alone.

Creel surveys focus on the fish harvested by surveying the angler's creel or basket used to hold the day's catch as a measure of angler success. The species, number, and length of fish harvested, and the number kept or released are recorded. During a creel survey, fish are examined for fin clips and disease, and scales are often removed to determine age. Anglers are often asked the length of time they have been fishing, and the equipment and techniques they employed. Fishing success is defined as catch-per-unit-effort, or the number of fish caught per hour of fishing. Data collected during creel surveys can be used to monitor fish populations, fishing techniques, and the effectiveness of management regulations.

Angler interviews assess the socio-economic aspects of a fishery. The focus of the interview is to assess the angler's preferences. Data collected include the origin of the angler, the money spent in pursuit of fish in the fishery, and the species being sought. Anglers are also asked to rate the fishery and management techniques or regulations.

The combination of the above components of a good angler survey will provide significant information on the state of the fishery. Important data on fishing pressure, the size and total number of fish harvested, and the recreational value of the fishery can only be determined by combining the three different data sets. Survey information can be used to determine the

Fig. 5–6. The DEC Angler Diary is a useful tool for monitoring fisheries. (CREDIT: DEC)

effectiveness of **fish stocking** using data from fin clips, whether regulations are effective or necessary, and how anglers are impacting fish populations. Follow-up surveys measure whether the management plan is working or if it should be modified.

A bias may be inadvertently introduced into the survey data if special interest groups conduct the angler surveys. To evaluate the surveys, professional fishery biologists independently check the fishery by making a site visit to observe the fishery and perhaps do some experimental fishing as a first-hand assessment of fishing success.

Another approach to conducting angler surveys and monitoring a fishery is the Angler Diary Program conducted annually by DEC. Anglers are asked to record the date, where they were fishing, and number and type of fish caught in a diary. This approach is loosely based on the observation that 20 percent of anglers catch 80 percent of the fish. By asking the expert angler and the major users of a fisheries resource to maintain a diary of their activities, DEC fisheries biologists can efficiently monitor the fishery. The diary is mailed to DEC at the end of the fishing season, and is a useful method of monitoring the fisheries of small lakes that are infrequently surveyed.

Habitat surveys

The goal of habitat surveys is to characterize the physical, chemical and biological environment of the lake as they relate to fish production. Most game fish have critical habitat requirements that are essential for their existence and well-being. Periodic habitat surveys, coupled with fish surveys, indicate whether changing water chemistry or habitat conditions are causing changes in fish populations.

Many aspects of habitat surveys can be conducted at any time of year, but some surveys are better conducted at specific times. Physical and biological surveys are usually done during the summer. Water-chemistry surveys are generally conducted at the end of summer and in the late winter, when environmental conditions such as dissolved oxygen, ammonia, hydrogen sulfide and temperature are limiting factors. Water chemistry is discussed in more detail in Chapter four, "Problem diagnosis."

Physical habitat surveys are focused on measures of size, depth, temperature and turbidity or suspended solids. Other measures of the physical environment include flushing rate, water clarity, and substrate type. Initial habitat surveys involve the development of a **hydrographic map.** This will assist in determining the extent of the littoral, limnetic and profundal zones in a lake, and help classify whether a lake is best suited for a warmwater, coolwater or coldwater fishery.

Water-chemistry surveys are conducted to determine whether water-quality parameters are limiting fish populations. Common limiting factors are dissolved oxygen, pH, alkalinity, hardness, and fertility or available food supply. While professional fisheries biologists rely on electronic meters to make these measurements, relatively inexpensive and accurate chemical test kits can also be used to conduct water-chemistry surveys.

Biological habitat surveys focus in three areas: aquatic plants, benthic or bottom-dwelling invertebrates, and plankton. Fisheries biologists survey the biological environment to determine if adequate resources are available to support the fishery. Biological surveys of lower trophic levels can also be used to assess the relative abundance of fish. The size and species of plankton, for example, are a good indication of the relative abundance of planktivorous species such as alewife, compared to predatory species such as lake trout.

Analysis of fish populations

Surveys provide a tremendous amount of data defining the state of the fish population. Fish community structure and population dynamics are important components of these data, which are then analyzed by professional fisheries biologists.

Analysis of community structure provides an overall assessment of the lake's fish population, but most fisheries biologists and anglers focus on collecting data about game-fish populations. Common measures of game fish include population size, and physical size or age structure, as well as measures of population well being, including diet, condition and growth.

Fish community structure

The first step in characterizing the fish community of a lake is to conduct a survey on the relative abundance of the different species living in the lake. The next step is to characterize and group the fish species by their habitat, niche and value to the fishery. Habitat describes where in the lake the fish is found (residence), and niche describes what it does there (occupation) or its role in lake ecology, such as planktivore. The value to the fishery is assessed in terms of whether a fish is a game fish**,** pan fish, or forage fish. Forage fish, such as minnows, darters and sculpins are preyed upon by game fish, pan fish, or other competitors.

Fisheries biologists seek specific data to analyze the fish fauna in a lake. Do warmwater, coolwater or coldwater fish predominate? Is there a good balance between species of the littoral zone with weedy inshore species, and species that can feed on plankton in open water such as yellow perch, crappie and golden shiner? Are benthic feeders such as bullheads, suckers, or whitefish in low density? What percentage of the fish community consists of species of interest to anglers?

What constitutes a good fish community structure is often open to interpretation. Fisheries biologists and anglers are usually focused on filling most niches with fishable species. In a coldwater lake, for example, is it better to have alewives or ciscoes as the forage species for lake trout? Alewives appear to support larger populations of lake trout, but are themselves not a fishable species. Ciscoes, on the other hand, are quite tasty, and can support their own fishery. With ciscoes and lake trout, therefore, there is a fishery for both species, but with alewives and lake trout there is only one fishable species.

Data required to analyze community structure are often difficult to collect in complex lakes. Surveys usually require the use of seines, experimental gill nets, trap nets and electro-fishing.

Relative fish abundance is the most widely used measure of community structure, comparing the proportional representation of each species in the fish community and providing an overall view of community structure. Relative abundance data

indicate the "type" of fish community. If bass, sunfish and bullheads dominate the fish community, the lake is probably eutrophic and best as a warmwater fishery. Relative abundance data also permit calculations on the proportion of fishable species to game species. Relative abundance data also indicate the relative balance of the fish community, and whether all niches are filled.

The *ratio of predators to available prey* is another way to measure the balance within a fish community. Predators are carnivores that feed on other fish. Prey fish, also called forage fish, can be divided into carnivores that feed on invertebrates and zooplankton and herbivores that feed on plants and detritus. **Predator-to-prey ratio** is calculated by dividing the combined weight of all prey by the combined weight of all predators in a lake. The ratio can be determined by comparison of predators and prey in a sample collected during an electro-fishing survey. Fish production is most efficient when there exists a proper balance between predator and prey. The most desirable predator-to-prey ratio is 1:4-6 by weight. For each pound of predator, there should be four to six pounds of prey.

Relative balance of the fish community in a lake is another measure of community structure. The amount of game fish in most well-managed small lakes typically represents 15 to 25 percent of the fish community. This measure is very similar to the predator-to-prey ratio since game species, such as bass, walleye and musky, are predators. There are some predatory fish such as gar and bowfin, however, that are not considered game species, and thus are not considered desirable predators by fisheries managers.

Diversity and richness are other measures of the fish community that are used when an aquatic ecologist surveys a lake. Aquatic ecologists do not have the bias towards fishable species that fisherman and fisheries biologists do. Ecologists value all fish equally, while fisheries biologists consider game fish and pan fish to be more valuable than other fish.

Diversity measures the number of fish species in a lake and their proportional representation in the fish community. Diversity increases either by having more species or by having species numbers in balance. Having large numbers of species, without a dominant species, indicates a more diverse fish community. Fish diversity is often strongly correlated with habitat diversity. Many aquatic ecologists use the Shannon-Wiener Diversity Index as one of several measures of fish biodiversity. The fish community of most small lakes would have an expected diversity in the range of one to four species.

Richness is a similar, but much simpler measure of diversity. It is a measure of the number of species in a lake or community. Current theory is that lakes with a larger number of species have a more stable fish community than lakes with fewer species.

Population structure

Fish population structure describes the different sizes or ages of fish that make up a specific species. An accurate assessment of the population structure would require length or age measurements of a random sample of at least 100 fish. Care should be taken that the sampling gear is not overly selective for either smaller or larger fish. Electro-fishing gear, for example, is selective for larger fish, but a trap net is not size-selective.

Length-to-frequency distributions plot the number of fish in a particular species into different length groups. These distributions reflect an interaction of rates of reproduction, growth, and mortality of the age groups present. The length-to-frequency distribution is used to assess fisheries-ecology interactions, and can be used to identify problems such as year-class strength failure, high fishing pressure, habitat or life-stage bottlenecks, low recruitment, and stunting or slow growth.

Year-class strength is a measure of the proportion of a fish population born in a particular year, the interaction between birth rate and survival. Year-class failure, therefore, could be due to either a high mortality rate or a reproductive failure rate.

Fishing pressure is a measure of the percentage of fish population removed. High-fishing pressure is illustrated in a length-to-frequency distribution as a precipitous drop in abundance for fish reaching a fishable size.

Habitat or life-stage bottlenecks are illustrated by a drop in abundance when fish reach a certain life stage or move into a particular habitat.

Recruitment is a measure of the addition of new members into the population being fished. Low recruitment in a length-to-frequency distribution is illustrated by the abundance of fish in the size-classes immediately below the fishable size.

Stunting or slow-growth in a length-to-frequency distribution is illustrated by an abundance of fish in a particular size-class, with relatively fewer fish in smaller and larger size-classes.

Fish population size

Proportional stock density (PSD) is an index of the size structure of a fish population used to assess the quality of a fishery. It divides the number of fish caught of a particular species into designated sizes and then determines the percentage of fish in each size-class.

Bass anglers, for example, are likely to catch fish down to 8 inches (stock size); are allowed to keep bass with a minimum size of 12 inches (quality size); and would prefer bass larger than 15 inches (preferred size).

A balanced fishery for warmwater game fish, such as bass and pickerel, will have a PSD around 50 percent, with a range from 40 to 60 percent. For every two fish captured, one is a keeper! In a balanced population, about 10 to 25 percent of the bass captured should be greater than 15 inches. Similarly, if a pan fishery is balanced, 20 to 60 percent of fish larger than stock size should be in the quality, or keeper size range.

An accurate assessment of game-fish populations using PSD as a tool requires that a minimum of 20 stock-size fish be captured. As stated above, the method of sampling can affect results. Electro-fishing is selective for large fish, while anglers tend to catch more small fish. Using an angling survey

	Stock	Quality	Preferred	Memorable
Warmwater Fish				
Largemouth Bass	8	12	15	20
Smallmouth Bass	7	11	14	17
Pumpkinseed	3	6	8	10
Bluegill	3	6	8	10
Crappie	5	8	10	12
Bullhead	6	10	12	15
Channel Catfish	11	16	24	28
Chain Pickerel	10	15	20	25
Coolwater Fish				
Walleye	10	15	20	25
Muskellunge	20	30	38	42
Northern Pike	14	21	28	34
White Perch	5	8	10	12
Rockbass	4	7	9	11
Yellow Perch	5	8	10	12
Coldwater Fish				
Lake Trout	12	20	26	31
Rainbow Trout	10	16	20	26
Brook Trout	8	13		
Burbot	8	15	21	26

Table 5–1. Length-size designations, in inches, for various species of fish. (CREDIT: JOHN FOSTER)

alone, therefore, would most likely indicate that small fish dominate the fishery.

Estimates of fish population size are usually conducted on game fish, except in cases of pest species. It often requires considerable effort to estimate the number of a specific species of fish in a lake. The two common measures of fish population size are catch-per-unit-effort and mark-and-recapture.

Catch-per-unit-effort data are strongly correlated with fish-population size whether collected by angling, electro-fishing or netting. Fisheries biologists can make an approximate measure of population size simply by comparing catch-per-unit-effort survey data from different lakes. Catch-per-unit-effort data, collected by anglers, also provide a measure of relative population size for year-to-year comparisons. If the average catch

of bass-per-hour during the first week of bass fishing season was 25 percent lower than last season, for example, then the population of fishable bass in the lake this year was approximately 25 percent lower than last year.

Data collected by anglers are an accurate way to estimate population size of game fish. Records are kept on the number of fish captured per hour (catch-per-unit-effort), and the total number of fish removed from the fishery (creeled fish). Catch-per-unit-effort is then plotted against the cumulative catch of game fish to provide an estimate of game-fish population size.

Mark-and-recapture is the most common method of determining population size of fish in small lakes. A substantial number of fish are captured and marked by clipping the fin. Clipped fish are returned to the lake and given time to disperse. A second sample is then collected, and the ratio of marked-to-unmarked fish is multiplied by the original number of fish marked to estimate the total population of fish in the lake.

Population well being

Fish diet analysis provides a short-term measure of population well being by indicating the proportion of empty stomachs and the proportion of predators eating their preferred prey. An analysis of fish stomach contents can be used to determine predator-to-prey relationships. Stomach analysis can also indicate the availability of food, by determining if all niches are filled, or if niches are available for the introduction of new species. Fish diet analysis will also indicate which species are competing for the same prey.

To conduct an accurate diet analysis, fish must be captured using a quick, non-stressful technique. Angled fish provide good subjects for stomach analysis. Simple techniques are also available to collect stomach contents from live fish so they can be returned to the lake unharmed. To determine if fish are feeding selectively or opportunistically requires a measure of the percentage of prey available in the habitat versus the percentage of prey items in the stomach.

Fish condition is a measurement of fish well-being that indicates how well a fish has been feeding over the last few weeks. Fat fish are considered to be in good condition and skinny fish are considered to be in poor condition. If fish condition is poor, fish are not getting enough food, indicating a problem in the food supply or in feeding relationships. If fish condition is good, food supply is not limiting and fish are not having much effect in controlling prey populations.

To measure condition, fish are captured, measured and weighed. Condition is then calculated by multiplying each fish's weight in grams by 100, then dividing that product by the cube of its length in centimeters.

Condition = (Weight in grams x 100) / (length in cm^3)

Fish-condition data on most types of fish, in tables of mean-length versus mean-weight, are found in reference works such as the Shannon-Weiner Diversity Index. To evaluate fish condition in a lake, data from the lake are compared to the reference data. Average condition for largemouth bass, for example, is 1.35 and average condition for brook trout is 1.10. If the average condition of largemouth bass in a lake is 1.25, and the average condition of brook trout is 1.20, then largemouth bass in that lake are in worse condition and brook trout are in better condition than average.

Growth provides a long-term measure of population well-being. Slow growth indicates poor food, a limited growing season, or a population under stress due to poor water quality. A very high rate of growth and a falling population usually indicates over-fishing. Growth data are vital for determining how long it takes for fish to attain legal size or sexual maturity. Fisheries managers strive to maximize growth. Many of the issues faced in fish management of small lakes is devoted to correcting problems caused by minimal growth or stunting.

Length-at-age is the most common fisheries technique for analyzing the growth rate of individual fish species. Length-at-age analysis uses the **annuli** (growth rings) on a fish's scale to determine its length for each year of growth. Scale growth is proportional to body growth. Fish do not grow more scales as they get bigger, their individual scales must grow to keep the body covered, and this growth creates marks similar to annual tree-ring marks. After determining
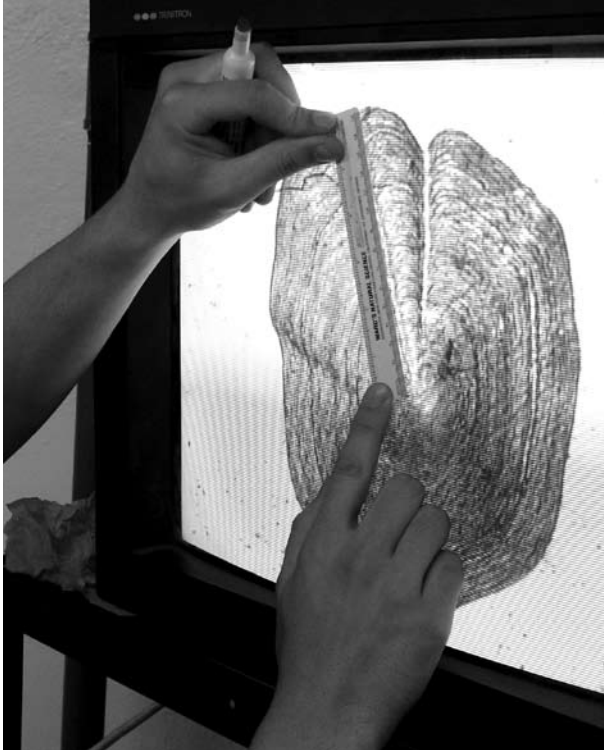
Fig. 5–7. Age-frequency distribution, growth, condition, and other fisheries measures are determined from analysis of growth rings on scales. (CREDIT: JOHN FOSTER)

how well fish within a species have grown throughout their lifetime, comparisons can be made with average growth rates for that region.

Table 5–2 shows average sizes at different ages for natural populations of fish growing in New York State. This table can be used to determine if fish in a particular lake are growing better or worse than average. It can also be used to determine how long it takes a particular fish species to attain legal size. Largemouth bass, for example, average four years to attain the legal size of 12 inches in New York State. The table can also be used to determine if growth in a particular lake is slow during certain life stages or ages.

Managing fish populations

Relatively few choices are available for direct management of fish populations compared to the number of choices available to manage fish habitat or to manage the angler. Two choices, population manipulation and lake rehabilitation, have been used extensively in the past, but are not used as frequently today. Stocking is now the most frequently used

	Age in Years										
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Warmwater Fish											
Largemouth Bass	.0	.5	9.0	11.0	12.0	13.0	14.5	15.5	17.0	18.0	19.0
Smallmouth Bass	2.0	4.5	7.0	10.5	12.0	13.5	14.5	15.5	17.0	17.5	19.0
Rockbass	1.5	3.0	4.5	6.5	7.0	7.5	8.0	8.5	9.0		
Bluegill	2.0	3.0	5.0	5.5	6.0	6.5	7.0	8.0			
Black Crappie	.5	3.0	7.0	7.5	8.5	9.0					
Coolwater Fish											
Walleye	5.5	8.5	12.0	15.0	17.0	19.0	20.0	21.0	22.0	23.5	25.0
Yellow Perch	1.9	2.8	3.4	4.9	5.6	6.7	8.4				
Whitesucker	2.0	4.0	5.5	7.5	9.0	11.0	12.0	13.5	14.0	16.5	18.0
Coldwater Fish											
Lake Trout	2.0	6.0	9.5	12.0	15.0	18.0	20.0	23.5	24.0	26.0	28.0
Brook Trout	2.5	4.0	5.5	7.0	9.0	12.0					
Rainbow Trout	3.0	5.5	7.5	10.0	19.0	21.5					

Table 5–2. Average sizes at different ages for natural populations of fish in New York State. (CREDIT: JOHN FOSTER)
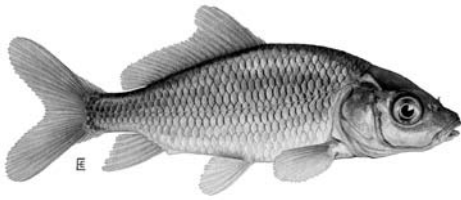
Fig. 5–8. Common carp (Cyprinius carpio)
(Credit: DEC)

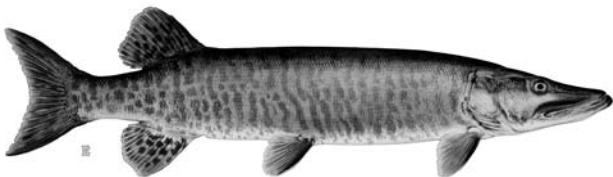*Fig. 5–9. Northern pike (Esox lucius)*
(Credit: DEC)

Fig. 5–10. Tiger muskellunge
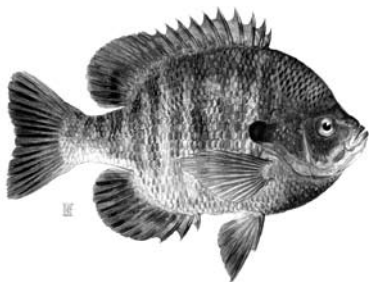*(Esoc lucius cross Esox masquinongy)* (Credit: DEC)

Fig. 5–11. Pumpkinseed sunfish (Lepomis gibbosus)
(Credit: DEC)

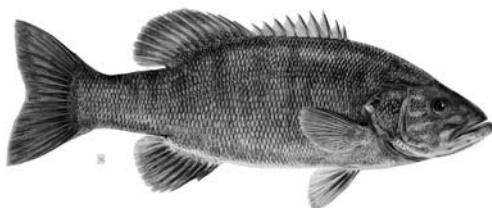*Fig. 5–12. Bluegill (Lepomi macrochirus)*
(Credit: DEC)

Fig. 5–13. Smallmouth bass (Micropterus dolomeiui)
(Credit: DEC)

method for managing fish populations. Financial support for fish hatcheries and stocking programs in most states accounts for more than half of the monies spent on fisheries management.

Fish population manipulation involves removal of undesirable species or sizes. Stunted sunfish, for example, can be netted and removed from a lake. This approach to fisheries management is often labor intensive and not cost effective. Fish culling can also be accomplished by having a fishing derby or bow-fishing tournament in which an undesirable species, such as carp, is targeted. Similar results can be accomplished by manipulating the habitat so that undesirable fish have difficulty spawning or surviving.

Lake rehabilitation is focused on killing all fish in a lake, and then restocking with desirable game fish and pan fish. Fish are poisoned with rotenone, a natural chemical that will break down into carbon dioxide and water in a few weeks. Rotenone suffocates fish and gilled invertebrates by preventing their use of dissolved oxygen. It is harmless to other aquatic organisms and to wildlife that eat the dead fish.

Lake rehabilitation may be suitable for restoring the ecological balance in very small, cut-off lakes that lack tributary streams and a surface outlet, but it seldom results in a long-term solution. Game fish are easily poisoned but some undesirable fish, such as carp and bullheads, are extremely hard to eliminate completely. Significant populations of the targeted fish often return within ten years.

Fish stocking in New York State has improved fishing and enhanced fisheries in hundreds of lakes. Stocking has helped restore brook trout, Atlantic salmon, lake trout and walleye to lakes where they had been eliminated. It has also been used to create fisheries, such as tiger musky and tiger trout that would not otherwise exist.

Most state hatchery systems are focused on rearing game fish for stocking, but forage fish or invertebrates may also be stocked to improve the forage base for game fish. The species of fish present in a small lake is generally due to chance, so adjustments to the fish community by professional fisheries biologists can improve the fishery. Opossum shrimp (*Mysis relicta*) is often stocked because it provides a good forage

base for many game species such as lake trout, Atlantic salmon, walleye and musky. In coldwater lakes, ciscoes and rainbow smelt are often stocked to support Atlantic salmon populations, while sculpins, alewives and whitefish have been stocked as forage for lake trout.

Stocking can be used to control stunted fish populations. Many small lakes have limited fishing opportunities, but support a large forage base of stunted pan fish such as bullheads, sunfish and yellow perch. This situation may develop when game fish are over-fished, but pan fish are ignored. Stocking the appropriate predator species, such as walleye, largemouth bass, lake trout or salmon, can restore the ecological balance between predator and prey. Predation by these game fish will reduce the pan-fish population, thus making more food available to the remaining pan fish and increasing their growth and size.

Fish production is defined as the increase or decrease of fish biomass through time. It is usually measured in pounds-per-acre-per-year. Using stocking to increase production in a lake is tricky, since a lake can only support a certain biomass of fish. This level, called the lake's **carrying capacity**, is based primarily on its size, depth and fertility. There is no practical means of making a lake hold more fish. Stocking more fish than the carrying capacity of the lake allows will simply overpopulate some segment of the fish community and there won't be enough food to sustain growth.

Fisheries surveys and stomach analysis can indicate that there are empty niches available. If a lake has an area of rocky substrate and shoals, but no shoal-living fish, then stocking smallmouth bass and rock bass will not only increase production but will also create new fisheries. Rock bass and smallmouth bass will prey on crayfish and aquatic insects that had not been adequately preyed on before.

Stocking can only increase production if the stocked fish fills an empty niche, and there is enough habitat, food and shelter to support them. Otherwise, stocking a new fish species will displace an existing fish species and its population will decline. If the stocked fish supports a fishery and the displaced fish did not, some folks would call that progress.
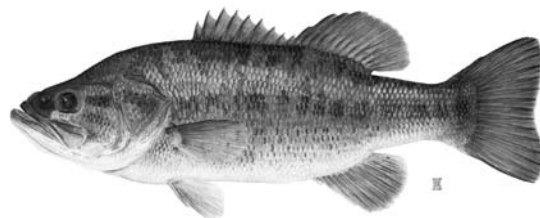

Fig. 5–14. Largemouth bass (Micropterus salmoides)
(CREDIT: DEC)

Fig. 5–15. Yellow perch (Perca flavescens)
(CREDIT: DEC)

Fig. 5–16. Lake trout (Slavelinus namaycush)
(CREDIT: DEC)

Fig. 5–17. Atlantic salmon (Salmon salar)
(CREDIT: DEC)

Fig. 5–18. Brown trout (Salmo trutta)
(CREDIT: DEC)

Fig. 5–19. Walleye (Sander vitreus)
(CREDIT: DEC)

Stocking can enhance an existing fishery. The single most important factor affecting the size of game-fish populations is *year-class* strength. The number of fish in a year-class usually depends on the number of spawners and environmental conditions in the spawning and nursery habitat. In some lakes, catastrophic winter- or summer-kills could also be a determining factor in survival or failure of some year-classes.

A new *year-class* or generation is born each year. After four or five years, fish from a given year-class will have grown to a size to enter the fishery. Fishing will be fantastic if these fish were part of a strong year-class. It will even be better if two or three strong year-classes occur consecutively. Conversely, fishing will be lousy if several weak year-classes entered the fishery consecutively. Lakes that have strong natural reproduction produce the most successful year-classes and thus maintain a large enough population of catchable fish to offset a few weak year-classes. In lakes where reproduction is spotty, however, stocking can be used to even out year-class variability and maintain or enhance a fishery.

Requests to DEC from anglers, clubs and associations are the greatest single factor in determining whether a lake will be considered for stocking. After receiving such a request, a fisheries biologist will survey the lake and determine if it is suited for the kind of stocking requested. If the lake in question is shallow and eutrophic, it would be futile to stock coldwater trout, even if that is what the public requests. Another important factor that will be evaluated is the forage base. Yellow perch, for example, is the best forage base for walleye. If a large population of yellow perch exists, stocking of walleye would be supported.

After a stocking plan has been devised and implemented, the fisheries biologist must periodically re-evaluate the effect of stocking to see where it might be improved. The critical question is whether stocking is improving the fishery. If stocking is not benefiting anglers, than it will probably be discontinued. Another reason to discontinue stocking occurs when natural reproduction of the stocked species reaches a level that is self-sustaining.

Fisheries biologists initially use standard rates for determining how many fish should be stocked in a lake. Standard rates for stocking are based on the size or surface acreage of a lake, lake productivity and the amount of available prey. Follow-up surveys will evaluate the success of the stocking. Data are collected on the growth and survival of the stocked fish, its effect on the forage base, and the amount of natural reproduction. Based on the survey information, stocking levels will be increased, decreased or eliminated altogether.

Fish can be stocked as eggs, fry, fingerlings or adults. Stocking of juvenile fry and fingerling are most popular. Stocking of adults occurs in some put-and-take trout fisheries, where it is expected that fish will be caught and removed before food conditions in the lake deteriorate. Stocking fry has some significant advantages. It is cheap and more likely to result in self-reproducing fish populations, but fry are very vulnerable to predation. If a lake contains alewives, stocking tiny three-day old walleye fry in May would simply feed the alewives. Stocking two-inch pond fingerlings in July, however, lets the walleye avoid predation by adult alewives, and at the same time provides the walleye with abundant alewife fry to feed on.

Managing fish habitat

Fisheries management has traditionally focused on the top of the food chain, dealing primarily with anglers and game species. Management plans are aimed at stocking a specific game species or regulating the angler. Many fisheries problems, however, are best solved through habitat management. If the lake trout fishery is collapsing because of summer die-offs due to oxygen depletion in the profundal zone, stocking more lake trout or reducing the catch will not do much to protect the fishery. The only sure, long-term management of this coldwater fishery is managing the coldwater habitat. This entails watershed or shoreline management to reduce nutrient input, or aeration to add oxygen to the habitat.

The absence of critical habitat, such as trout-spawning habitat, can be overcome by stocking. Usually, however, habitat improvements are cheaper in the long run than continued stocking. Habitat protection and restoration efforts are the best solution

to the gradual loss of important habitat. For more detailed information on watershed management, see Chapter nine, "Watershed management." Small lakes are especially vulnerable to fish habitat loss. As lakeshore development increases, naturally vegetated lakeshores are dredged for docks, covered with stones to prevent erosion, and converted into lawns and sand beaches. The water gradually becomes murkier from the increased nutrient input of septic systems, fertilizer runoff, shoreline erosion and boat traffic. Fish production is reduced because inshore places for fish to hide, feed and grow are gone due to the removal of emergent bulrushes and woody debris, and the lack of sunlight to submergent plants caused by murkier water. The great fishery and recreation that first drew families to the lake gradually deteriorates with continued growth, use and development.

The first step in reversing habitat deterioration is realizing that altering the lakeshore habitat will cause alterations in fish populations. Lakeshore owners seldom realize that the aquatic "weeds" and deadfalls they remove are essential for maintaining healthy fish populations. Fewer still are willing to give up their lawns. Fish habitat cannot be managed without understanding aquatic ecology. A simple rule is that lakes with the best fisheries have the healthiest fish habitat.

State, university or private fisheries biologists, working with local fishing clubs or lake associations, can develop a management plan to improve and protect fish habitat. They can review proposed shoreline development plans to insure that no damage is done to lake fisheries. Fisheries biologists can provide suggestions to developers and landowners for plan revisions to reduce the damage to fish habitat and populations. It is easier to protect fish habitat beforehand than it is to restore it after the damage is done.

Methods of improving fish habitat and fishing need not be expensive. Construction of artificial reefs and cover, planting lakeshore buffer strips, stabilizing shorelines, or transplanting aquatic plants to reduce erosive wave action can be easily carried out by individual lakeshore owners, conservation clubs, or public service groups such as scouts. Restoration of native lakeshore vegetation and the corresponding reduction of lakeside lawns and beaches can have significant benefits to a landowner, such as cutting maintenance costs, attracting wildlife, and improving fish habitat. See also Chapter nine, "Watershed management."

Winter-kills are massive fish die-offs that occur periodically in many small lakes. When thick ice and snow prevent light from reaching underwater plants, they stop producing oxygen and eventually die. As the dead plants decompose and surviving plants continue to respire in the absence of sunlight, dissolved oxygen in the water is depleted and fish die. The largest fish are often the most vulnerable to winter-kill. It may take four years or more for the surviving young-of-the-year to grow to a size that will restore the fishery. Winter-kills are most common in highly fertile lakes and the solution is to add oxygen via an **aeration** system. Aeration prevents ice from forming, lets in light, facilitates gas exchange, adds oxygen, mixes the water column and cools the lake. Fisheries biologists can make recommendations to lake associations or conservation clubs on the placement and types of systems that would work best for a particular lake.

A high nutrient level does not always translate into high fish production. Lakes can actually be too fertile to support good populations of game fish. The phytoplankton and plants fertilized by nutrients, which usually provide food and oxygen to the lake, consume oxygen on sunless days or when they die and decompose. Decomposing plankton and plants in deep lakes can eliminate production of coldwater fish such as lake trout, whitefish and salmon. Very fertile, shallow lakes can have massive fishkills when plant respiration depletes oxygen on cloudy, windless summer days.

Excessive nutrients fuel massive algal blooms, which deplete oxygen needed by fish and aquatic invertebrates. The best long-term solution is identify nutrient sources and then to control nutrient input. Common nutrient sources are eroding lake or stream banks, runoff from lawns and farms, and leakage from septic systems.

Some fish species such as carp and bullheads aggravate habitat degradation by stirring up deposited sediment loaded with nutrients. While control of these fish can result in a short-term fix, the long-term

solution to improving fishing in lakes with excessive nutrients is the reduction of nutrient inputs to the lake. Frequently, reducing these inputs requires a watershed-wide approach. Definitions and testing techniques for nutrients are discussed in Chapter four, "Problem diagnosis." Input control is discussed in Chapter nine, "Watershed management."

Maintaining brushy, tree-lined stream banks can help filter out sediments and reduce nutrients. The added benefit of shade to keep the water cold is essential to maintaining brook-trout or brown-trout populations in most small lakes. The addition of **riparian** or shoreline vegetation, woody debris and boulders will reduce streambank erosion and siltation and the deepening and scouring of streambeds, and will provide shelter for spawning fish and fry.

Turbidity interferes directly with sight-feeding fish, clogs their gills and smothers their eggs. It also limits the habitat available to littoral-zone fish by reducing the depth at which submergent plants can occur. Turbidity reduces water clarity, blocks sunlight, and limits the production of plankton and submergent plants, reducing the production of invertebrates and fish. If the source of the turbidity is tributary streams, improvement in water clarity can only be accomplished by developing and implementing a watershed management plan. If the source of turbidity is lakeshore erosion, then planting riparian and emergent lakeshore plants has been shown to be the best solution.

Increased shoreline development, and waves from wind and boat traffic also causes shoreline erosion. If banks are steep, construction equipment can be used to create a gentle slope before planting trees and shrubs. Boulders and rip-rap stones can be placed at the base of an eroding bank to anchor the soil until plantings can become established. Planting emergent vegetation along the edge of the lake can also help stabilize eroding banks, and buffer strips of trees help filter out nutrients as well as hold soil in place.

Moderate levels of aquatic vegetation are essential to most fish communities. Aquatic vegetation shelters young fish and provides food and substrate for prey organisms. Excessive vegetation, however, interferes with fishing, upsets predator-to-prey balance, and causes dissolved oxygen problems. Aquatic plants can be controlled by stocking herbivorous organisms such as grass carp, snails and crayfish. Carp and bullheads uproot plants and increase turbidity, thus reducing plant growth. Other solutions include herbicides, water-level manipulation, or cutting and harvesting. See Chapter six, "Aquatic plants" for detailed information on aquatic vegetation management.

Most forage species use inshore weedy areas as spawning and nursery habitat. Some unwanted species such as carp, also spawn in shallow water. Dropping lake water levels during spawning of carp or sunfish in early summer can expose their eggs and reduce their reproductive success. Dropping water levels in the early fall can force forage fish from cover, increasing their vulnerability to predation by game species such as walleye and bass.

Most small lakes have limited spawning habitat, and reproduction for important game fish because of the size or quality of the available habitat. If lake trout and walleye spawning habitat is limited, adding gravel on a shallow offshore shoal may be all that is needed. Emergent wetlands are the spawning and nursery habitat for pickerel, pike and muskies. Emergent wetlands are also critical to the survival of forage species such as killifish. The addition of bulrushes may be all that is needed to increase production of these species.

Tributary streams provide spawning habitat to trout, smelt, walleye and other lake species. If dams, and culverts obstruct access to the spawning habitat, inexpensive fish ladders can be installed to provide safe fish passage.

Fish habitat can be limited by a lack of oxygen in deep waters. If deep waters become anoxic, or oxygen-depleted, destratification or aeration will significantly increase fish habitat. Enlarging the profundal zone area with sufficient dissolved oxygen increases the available habitat for deep-water species. This process can bring bottom nutrients to the surface where they can be utilized by phytoplankton and rooted plants, which also encourages fish production.

The critical habitat requirement for shoal-living fish, such as rock bass and smallmouth bass, is structure or cover. Many other fish, such as walleye, yellow perch and largemouth bass, are also attracted to these habitats. They can easily be constructed or restored in

the winter by piling field stones or boulders on the ice above 10 to 15 feet of water. Sunken trees also restore natural structure. Periphyton (aufwuchs) will grow on these artificial reefs increasing production of food for fish, and provide habitat for fish and invertebrates. The term *aufwuchs* refers to the fuzzy-looking, slimy, green coating of algae, diatoms, protozoans, bacteria, and fungi seen on underwater objects.

Managing the angler

A major approach to fisheries management is to manage the angler. This usually takes the form of education and regulation. Education about the fisheries ecology of a particular lake can be provided by state, academic and private fisheries biologists. This is best accomplished through formal reviews and question and answer sessions at meetings of local lake, angler or conservation associations. State fisheries management agencies, such as DEC, have a range of angler management regulations that can be offered to local anglers, or conservation and lake associations seeking ways to improve fishing.

Education to adjust expectations

Anglers, lakeside property owners, and other stakeholders often have their own, very different expectations of a fishery. Anglers prefer deep, cold-water lakes containing game fish, such as trout and salmon, and pan fish, such as ciscoes and whitefish that require considerable equipment and expertise to catch. In many deep, coldwater lakes, however, most property owners would simply like to take their family out for a few hours of fishing, or to catch dinner. A shallow, productive, warmwater lake would be better suited to this expectation. Through knowledge of the ecology of the fishery, stakeholders can better match their expectations to the reality of the basic ecology of their lake.

The expectations of the typical angler also need to be adjusted to the local fishery. Some anglers get grumpy when they don't catch their limit of game fish, when the fact is that their expectations are too high. On a typical day of fishing, few anglers will even catch a game fish. When interviewed, the majority will indicate that fishing was poor. In most cases, fishing is not poor. Most game fish are simply more difficult to catch and fewer in number than pan fish. That is the nature of fishing.

Otsego Lake, for example, has one of the top ice fisheries in Central New York for lake trout. On any given day, however, 95 percent of lake-trout anglers do not catch their two-fish limit, and 75 percent do not even catch a lake trout. This might be annoying to many ice anglers, but from a broader perspective, it is not a negative outcome. There simply aren't enough fish for everyone to catch their limit. If every ice angler caught their limit on a typical weekend, the entire population of keeper-sized lake trout in Otsego Lake could be wiped out!

Ecology

Anglers seldom understand their role in maintaining the ecosystem balance of a small lake. As fishing increases and anglers remove more game fish, the number of predatory fish, such as lake trout decrease. As lake trout decreases, zooplankton-eating prey fish such as alewives increase, because fewer lake trout are feeding on them. As zooplankton-eating fish increase, zooplankton decrease. As zooplankton decrease, phytoplankton increase and the lake turns greener and greener. Lake water can also turn green from imbalances that start at the bottom of the ecosystem. If nutrient input from runoff increases, nutrient levels in the lake increase. This provides food for phytoplankton, increasing their population, and turning the water green.

Fisheries programs often become very focused on game fish, disrupting the ecosystem balance of small lakes. We know that changes in one part of a food chain will affect other parts. If only bass are removed from a small warmwater lake, bass populations decrease, while sunfish populations increase because of reduced predation. Sunfish populations overrun their food supply, their growth stunts, and they become so numerous that they successfully prey on bass eggs and fry. To maintain ecosystem balance, fisheries biologists have determined that anglers should harvest four to five pounds of sunfish for every pound of bass harvested.

Fisheries regulations

Fisheries regulations focus on the major areas of seasonal access, types of fishing gear allowed, and species harvest limits. Regulating fishing seasons is the most commonly used method for limiting access, and enables fisheries managers to limit access when fish are most vulnerable. Protection during spawning seasons is the most common use of this type of regulation. Season regulation can also be used to protect fish during migrations, or when water temperature is stressful to fish. One example is prohibition of trout fishing in the Beaver Kill, from Iron Bridge at Horton downstream to the first Route17 overpass from July 1st through August 31st when trout are under stress during the hottest part of the summer and vulnerable to over-fishing. For a similar reason, a no-ice-fishing regulation eliminates access to this same fishery during the winter. Both regulations protect trout at times of the year when they are most in danger from over-fishing.

Access to small lakes is often regulated by the surrounding property owners who are able to limit physical access. A common example is a boat-launch facility owned by a marina or lake association that will only allow member boats, or only allow a daily limit of transient boats on the lake. If access is too restricted, however, DEC could decide that the lake is no longer "public" and no longer warrants expenditure of public funds for surveys and stocking.

A *no-boats regulation* may confine the fishery to shore fishing, which limits access to offshore habitats that then become a refuge for the fish. This type of regulation also protects the lake from the introduction of exotic species such as zebra mussels and plants that often hitch a ride on boats and trailers.

A *no-motor regulation* confines the fishery to inshore waters and reduces access to offshore areas, and portions of the lake far from the boat launch. This regulation also eliminates troll fishing and provides some protection to walleye and salmon stocks.

Regulating gear is another tool for managing the angler. While it is not readily obvious, all fisheries are subject to gear limits. Public fisheries are limited to angling with a specified number of hooks except for collecting bait, and some are for specialized fisheries such as smelt (see Fig. 10-1).

Fly-fishing-only is the most restrictive regulation in terms of allowable fishing gear. The intent of this regulation is to protect fish where pressure is heavy, to spread the harvest over a longer period of time, and to allow more fish to grow to a larger size. Fly-fishing-only regulations are sometimes placed on a body of water for aesthetic reasons. This type of regulation is also used on lakes where the philosophy of catch-and-release is encouraged but not required.

Baitfish use or possession is prohibited in some lakes, such as Trout Pond and Huggins Lake, Town of Colchester, Delaware County. Baitfish regulations were recently upgraded by DEC. They include a list of approved "green" baitfish, the only species that can be purchased or used in New York State. The regulations also include a number of restrictions and prohibitions concerning the possession, use and transportation of prohibited baitfish (DEC, 2008. See also Appendix F, "Internet resources"). This type of regulation protects the lake from bait-bucket introductions of non-native or invasive species of fish, plants or diseases.

Harvest regulations

Harvest limits are the focus of the vast majority of fishery regulations. A multitude of regulations govern the harvest of fish, but only the most common are described below:

Catch-and-release regulation allows recreational fishing, but eliminates the harvest of fish. It protects targeted fish species. In the case of health advisories, it also protects the angler.

Bag or daily-limit regulation restricts the number of fish an individual can possess both on and off the water. The public perception of these regulations is that they serve to prevent over-harvesting. This would only be the case if most anglers could catch their limit each trip. Since

relatively few anglers catch their limit on a given trip, bag limits generally do little to protect fish populations from over-harvesting. The primary purpose of bag limits is to distribute the catch among anglers, and to prevent a few anglers from commercially fishing a game species.

Minimum-size limit regulation insures that fish smaller than a particular length will be released. The statewide minimum size limit for largemouth bass is 12 inches. This means that, except under special conditions, you may only creel bass 12 inches or longer. This regulation allows fish to mature and spawn at least once before becoming part of the fishery. It is only effective when applied to slow-maturing species.

One-over-limit regulation allows an angler to keep only one fish over a set length. The limit in Otsego Lake, for example, is two lake trout 21 inches or longer, but no more than one lake trout longer than 27 inches. This regulation limits the harvest of trophy fish and spreads the catch of large fish among anglers.

Protected-slot-limit regulation protects fish within a size range or slot. In Lake Ontario, for example, lake trout greater than 25 inches and less than 30 inches must be released. There are two purposes for having a protected-slot limit. It allows fish within that slot to grow to a larger size that might be preferred by anglers. It also protects the most successful spawners in those species where medium-sized fish produce the most offspring.

Fishery regulations can be used to develop a trophy bass or walleye fishery. Fishing pressure can be very heavy on popular small lakes near population centers. These lakes often have bass and walleye populations made up of large numbers of sub-legal fish, since fish are removed from the population as soon as they become legal size. Lakes can only produce a fixed number of pounds of fish per year and anglers may decide to impose regulations that would shift the bass or walleye populations toward larger fish. These regulations reduce the quantity of fish harvested, but can improve the quality of the fishery. Protected-slot-limit, one-over-limit, or minimum-size

limit regulations that protect or reduce the harvest of midsize fish will increase the number of larger fish available for harvest in a few years.

Summing it up

New York State is blessed with many small lakes that provide convenient angling opportunities for millions of anglers of all ages. Poor fishing in some of these lakes generally results from a lack of understanding of basic fish management concepts and an unwillingness to alter practices that degrade fish habitat. Because of their size, it is unrealistic to expect small lakes to be all things to all people. The desires of local anglers and property owners must be matched with the ecology and production capabilities of the lake and its surrounding watershed to establish a realistic management plan for the fisheries.

With proper management, small lakes can provide annual crops of harvest-sized fish commensurate with their fertility and ecology. Several useful options are available to fisheries biologists, lake associations and anglers for implementing management procedures designed to achieve this result. Successful angling opportunities can be provided in small lakes with minimal effect on other uses provided the lake is properly stocked and managed.