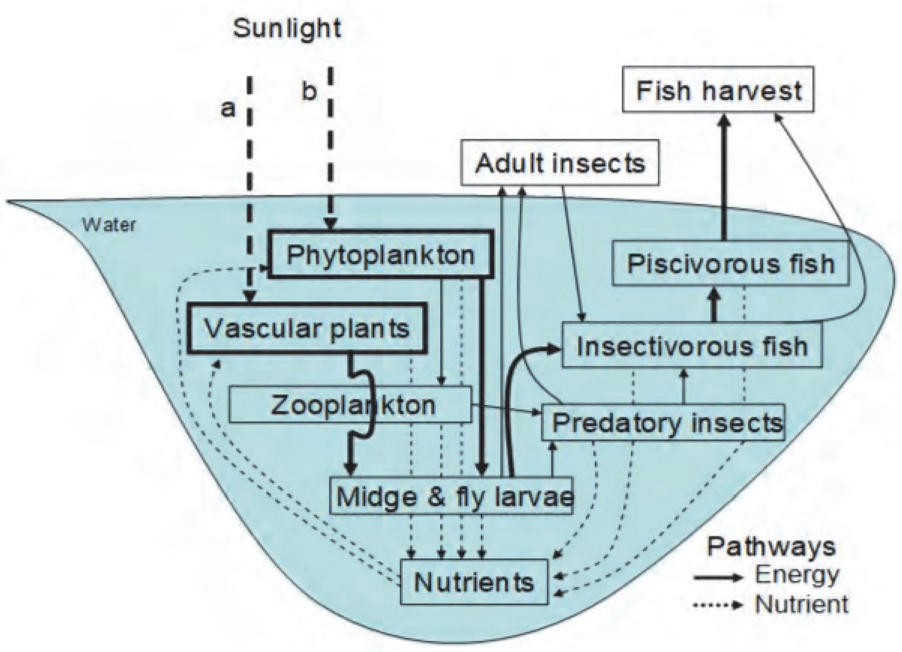
1.2 Impact of Invasive Aquatic Plants on Fish

Eric Dibble: Mississippi State University, Mississippi State MS (emeritus); e.dibble@msstate.edu

Introduction

Many species of fish rely on aquatic plants at some point during their lives and often move to different habitats based on their growth stage. Young fish use the cover provided by aquatic vegetation to hide from predators and their diets may be dependent on algae (Section 2.18) and the microfauna (e.g., zooplankton, insects and larvae) that live on aquatic plants. Mature fish of some species move to more open waters to reduce foraging competition and also include other fish in their diets. Also, different fish prefer different types of habitats and will move to a new area if foraging conditions in their preferred location decline due to excessive growth of aquatic weeds.

The energy cycle



The energy that supports all life on earth – including life in lakes – originates from sunlight. Vascular plants and phytoplankton (algae) capture light in the chloroplasts of their cells and convert it to energy through photosynthesis (Section 1.1). Aquatic plants and phytoplankton use this energy to subsidize new growth, which is consumed and used as an energy source by aquatic fauna. For example, phytoplankton is eaten by zooplankton, or vascular plant tissue is eaten by insect larvae. The zooplankton and insect larvae are then eaten by larger insects and/or insect-eating fish. This energy cycle continues with ever-larger organisms consuming smaller ones and provides a vivid illustration of the "trickle-up economics" of energy cycling. As this example demonstrates, the vegetated aquatic habitat that is essential for insects and small fish can be a critical component in the process that fosters growth of harvestable fish.

The relationship between fish and aquatic plants

The abundance of some fish declines with increased plant densities. For example, populations of white bass (*Morone chrysops*), gizzard shad (*Dorosomoa cepedianum*) and inland silverside (*Menidia beryllina*) generally decline where heavy vegetation is present. In contrast, many juvenile and some adult fish prefer habitats with aquatic vegetation; in fact, over 120 different species representing 19 fish families have been collected in aquatic plant beds. Sites with vegetation generally have higher numbers of fish compared to non-vegetated areas. In fact, densities of greater than 1 million fish per acre have been reported in areas containing a diversity of aquatic plants. Very few of these fish, however, survive to become large adults, so high numbers of small fish do not always result in populations of large mature fish. Excessive growth of aquatic plants promotes high populations of small fish in contrast to more diverse and balanced plant populations. Reduced plant densities due to weed management activities, boat traffic and/or natural senescence may change or cause the loss of invertebrate food sources. However, studies of lakes where invasive plants were treated with early applications of herbicides to allow native plants to reestablish have revealed that removal of exotic weeds has little impact on invertebrate populations and no measurable effect on fish communities.

Fish and their affinity for plants

Fish	Plant affinity	Life stage			Relationship		
		Larvae	Juvenile	Adult	Spawn	Forage	Predator avoidance
Bluegill sunfish	High	X	X	X	X	X	X
Common carp	High	X	X	X	X	X	X
Largemouth bass	High	X	X	X	X	X	X
Muskie	High	X	X	X	X	X	X
Northern pike	High	X	X	X	X	X	X
Black crappie	Moderate		X	X	X	X	X
Smallmouth bass	Moderate		X	X		X	X
Yellow perch	Moderate	X	X			X	X
White crappie	Low		X			X	
Salmon, trout	Low		X				X
Shad	Low	X					
Walleye	Low			X		X	

Bluegill sunfish (*Lepomis macrochirus*) are often referred to as the “kings” of plant-loving fishes and strongly prefer vegetated habitats throughout much of their lives. There are many different types of small sunfishes, but the bluegill is likely one of the most popular freshwater fish in North America. The bluegill is the most intensely studied freshwater fish in the US and is considered to be a “lab rat” by fish biologists. In addition to its popularity with scientists, the bluegill has been widely stocked, carefully managed and regularly harvested in natural and artificial systems throughout the US. Bluegill is a premier food fish and is called “pan fish” in the North and “bream” in the South.

Similar to other sunfishes, bluegill often move to new habitats as they age. Bluegill sunfish spawn and nest in colonies near areas of submersed vegetation, where soft sediment and plants are cleared. Bluegill larvae are transparent and can safely move from shallow shoreline habitats to open water where they feed on plankton. As the larvae grow larger and develop color, they become more attractive to predators and seek refuge among aquatic vegetation where they feed on insects, midges and small crustaceans. Juveniles and small adult fish remain among shoreline plants and feed on the food they can capture; as they grow, they may shift to feeding on larger crustaceans, insects and amphipods. As fish mature, grow larger and change color, their chances of being eaten by predators decrease and they shift to more optimal feeding grounds. Bluegill continue to feed in vegetated habitats where they can avoid larger predators until they reach approximately 8 inches in length. Fish of this size are large enough to escape most of the risk of predation, so these mature bluegill will venture away from the complex structure provided by plants and move to feed in open water. This reduces feeding competition among bluegill and provides access to larger fish that bluegill consume to supply the energy needed for continued growth. Bluegill are not considered herbivores, but they do consume plant material, most likely by accident as they forage for insects and crustaceans living on aquatic plants. Aquatic plants thus play a critical role in the growth of bluegill sunfish by hosting insects, crustaceans and invertebrates that are eaten by young fish and by providing cover that allows young fish to hide from predators.

Fish populations in lakes with a diverse assemblage of phytoplankton, aquatic plants and habitats tend to be stable. This is a general ecological principle that applies to wildlife, fish and other organisms. However, the bluegill sunfish illustrates why it is unwise to make specific "ironclad" statements regarding the habitat requirements of fish. As noted above, bluegill sunfish have very close associations with aquatic plants but can also become quite large and develop robust populations in managed fish ponds that lack aquatic plants. This apparent conflict is partially explained by the concept that bluegill food webs may be based more on phytoplankton in ponds where the predator-prey relationship has been simplified.

Largemouth bass (*Micropterus salmoides*) are stocked throughout the world and are among the world's top freshwater game fishes. Largemouth bass are plant-loving and are closely associated with aquatic plants, spending much of their lives in or around vegetated habitats. Adult largemouth bass diligently protect their nests and offspring from predators. The structure provided by moderate densities of submersed plants improves nesting success, but an overabundance of plants can reduce nesting success. Larvae of largemouth bass feed mostly on microcrustaceans and juveniles consume larger (but still small) crustaceans, whereas mature largemouth bass primarily eat aquatic insects and small fishes (e.g., bluegill, shad and silverside). Aquatic plants serve as critical habitats that support the prey that largemouth bass rely so heavily on through their lives. These prey resources directly or indirectly influence growth and the ability of largemouth bass to overwinter and survive adverse conditions. Therefore, the abundance of largemouth bass is strongly correlated with the abundance of submersed vegetation in its habitat. However, this correlation varies based on the types and densities of the plant species in the habitat.

Smallmouth bass (*Micropterus dolomieu*) prefer deeper, cooler waters with rocks and/or woody cover and generally avoid shallow water that is dominated by aquatic plants. However, like the largemouth bass, young smallmouth bass prey on the insects, crustaceans and other microfauna that are hosted by aquatic plants. More mature smallmouth bass consume crayfish, larger insects and other fishes (including shad). Shad feed primarily on phytoplankton and detritus and avoid aquatic vegetation, so the diet of adult smallmouth and largemouth bass may be dependent on prey fish that do not prefer a vegetated habitat, especially in reservoirs. Smallmouth bass protect their nests and offspring but are less selective of nesting location and will choose nesting sites in shallow water if the water has some form of cover. This cover may be provided by aquatic plants, but most sites have cover in the form of rocky outcrops or overhanging woody debris. Because young smallmouth bass consume microfauna associated with aquatic plants and sometimes use aquatic plants to avoid predators, their relationship with aquatic plants is moderate.

White crappie (*Pomoxis annularis*) have a low affinity for aquatic plants since they typically spawn in nests away from vegetation and spend much of their time as adults and juveniles in open water. However, aquatic plants can directly affect spawning and indirectly influence the diet available to young white crappie. Research suggests that excessive amounts of aquatic plants may reduce spawning success of a nesting colony of white crappie. In addition, the presence of aquatic plants may deter nesting altogether. Eggs of white crappie have been found in aquatic vegetation; however, this is most likely incidental drift of eggs from nearby nesting sites. Larval white crappie feed primarily on microfauna, whereas juveniles feed on insect adults and larvae (i.e., midges and water boatmen) that frequently inhabit vegetated habitats.

Black crappie (*Pomoxis nigromaculatus*) are more closely associated with aquatic plants than their cousins, the white crappie, and have a moderate affinity for plants. Adult black crappie prefer sites with plants – including submersed, emergent, flooded and even inundated terrestrial species – for nesting and spawning and are more likely than white crappie to care for nests and offspring. Like white crappie, they also rely on many of the insects that live in aquatic vegetation. In fact, young black crappie rely heavily on insect larvae and other microfauna that are strongly associated with vegetated habitats.

Gizzard shad (*Dorosoma cepedianum*) are small fish that are widely distributed and are frequently stocked in reservoirs as prey for fish-eating fishes such as crappie and striped, largemouth and other bass. Gizzard shad are not usually considered to be associated with aquatic plants; as larvae, they may rely on food resources from vegetated habitats but their affinity for these habitats is low. Larvae of gizzard shad feed on algae, protozoans and microfauna, whereas adults are more herbivorous and consume phytoplankton in the water column and detritus (decomposed vascular plants) in the sediment. Gizzard shad usually spawn at or near the surface of the water and broadcast their eggs. Eggs drift on the water and can attach to any surface, but it is not uncommon to find egg masses attached to aquatic vegetation. In fact, some egg masses are so large that stems of emergent aquatic plants may collapse under their weight.

Common carp (*Cyprinus carpio*) are invasive, exotic, nuisance species that are detrimental to many aquatic systems. Common carp are frequently found in reservoirs and natural lakes and are associated with shallow areas that have soft sediments and abundant submersed vegetation. Common carp are omnivorous bottom feeders whose diets are composed primarily of organic detritus (mostly in the form of dead plant material) and benthic organisms, including insect adults and larvae, crustaceans, snails, clams and almost anything else organic that they encounter. The mouth parts of common carp are specialized for foraging for hard items (i.e., plants and animals) within soft sediments and among the roots of aquatic plants. Adult fish typically spawn in shallow water inhabited by aquatic plants, where plant stems and leaves serve as attachment sites for fertilized eggs after spawning. Eggs require oxygen to survive; egg attachment to plant structures prevents eggs from settling into soft sediments that lack the oxygen needed for egg survival.

Salmon and **trout** are not usually associated with aquatic plants and their affinity for vegetated habitats is typically thought to be low. However, some trout species may develop indirect relationships to aquatic plant habitats after the fish are introduced into cool reservoirs and natural lakes. For example, the diet of trout in these systems is often dominated by adults, nymphs and larvae of caddisfly, stonefly, cranefly and mayfly, all insects that are frequently associated with aquatic vegetation. This observation, along with reports that navigation and migration of adult salmon and trout may be hindered by dense beds of invasive aquatic plants, suggests that the relationship of salmon and trout to aquatic vegetation may be complex.

Aquatic plants play an important role in the foraging and reproductive strategies of **northern pike** (*Esox lucius*), which typically avoid strong currents and have strong affinities for dense beds of aquatic plants during feeding and spawning. Northern pike primarily feed on other fish by using "ambush" foraging strategies—they wait and strike at prey with a burst of swimming energy. Northern pike are among the first fish to spawn in early spring and broadcast their adhesive-coated eggs on shallow weedy areas. After being released, the eggs drift and settle on submersed vegetation, where they attach and are well-oxygenated.

Muskellunge or **muskie** (*Esox masquinongy*) are rarely found far from aquatic plants during any stage of their life. They rely heavily on prey resources (i.e., fish, young ducks, frogs and muskrats) that live in vegetated habitats. Muskie spawn later than northern pike, but utilize similar spawning tactics and rely on plants to successfully reproduce. Eggs of muskie also have an adhesive coating and adhere to plant structures after being broadcast.

Walleye (*Stizostedion vitreum*) are not classified as having a strong affinity for aquatic vegetation, despite reports that walleye are sometimes caught near vegetation. However, vegetation in flooded marshes can provide a substrate for spawning, and populations of some species used by walleye as prey (e.g., yellow perch) do rely on vegetated habitats. Walleye are not tolerant of increases in turbidity or suspended sediment. Therefore, aquatic plants may play an indirect role in improving the walleye habitat in some systems by filtering sediments and decreasing water turbidity.

Adults of **yellow perch** (*Perca flavescens*) are typically found in open waters with moderate levels of aquatic plants, but when young their affinity for plants is relatively high. Yellow perch are frequently associated with rooted aquatic vegetation. Successful spawning sites typically contain some form of structure, most often in the form of submerged aquatic plants. Like bluegill, young yellow perch switch habitats as they mature. As clear larvae, they feed in open water on zooplankton; once they become pigmented, they return to shallow water with vegetation where they feed on small fishes and insects along the bottom.

Plants provide critical structure to aquatic habitats

The shade created by leafy plants is important to many visual feeders because shade can improve visibility for both selecting prey and avoiding predators. Vegetated aquatic habitats also provide food for young and small fish of many species while protecting them from predators. The abundance and diversity of aquatic fauna eaten by small fish are higher in vegetated habitats than in areas with no plants because leaves and stems provide a surface for attachment; also, small gaps among plants can provide a place for fauna to escape and hide from predators. As vegetated habitats become more complex, the risk of small fish becoming prey may be decreased. However, the ability of fish to forage declines as vegetated habitats become more complex as well. Visual barriers created by leaves and stems may make it more difficult for fish to find and capture prey, whereas swimming barriers that result from dense vegetation can increase search time by reducing maneuverability and swimming velocity. For example, the rate at which sunfish successfully capture prey declines with an increase in structurally complex vegetated habitats. Some fish have developed tactics to address the negative aspects (i.e., reduced food availability accompanied by increased efforts to capture prey) associated with densely vegetated areas. The largemouth bass, for example, changes foraging tactics in complex habitats and switches from actively pursuing prey to ambushing them as they drift or swim by.

Plants influence growth of fish

Studies have shown that aquatic plant abundance affects the growth and health of fish, especially plant-loving fish such as the sunfishes. Habitats with moderate amounts of aquatic vegetation provide the optimal environment for many fish and enhance fish diversity, feeding, growth and reproduction. Conversely, both limited and excessive plant growth may decrease fish growth rates.

High densities of plants can reduce the growth and health of largemouth bass and of black and white crappie, most likely by reducing foraging efficiency. Fisheries scientists have predicted that largemouth bass growth significantly declines in systems with > 40% coverage of aquatic plants and that maintaining plant beds at an average standing crop of 5 tons of fresh weight per acre (4 ounces per square foot) would improve foraging efficiency of largemouth bass. A total removal of plant biomass exposes forage fish and can, at least temporarily, increase growth of predator fish species (i.e., largemouth bass, black and white crappie, bluegill and other sunfishes) that rely heavily on the prey that inhabits vegetated habitats.

Rapid removal of aquatic plants can alter foraging behaviors and encourage young largemouth bass to switch to eating fish sooner in life, which results in more rapid growth. Conversely, young sunfish grow most quickly in vegetated habitats because when plants are absent or sparse, competition for forage sources increases among these fish; less food resources are available to them and growth slows. However, growth of these fish can also be slowed when plant density is too high, especially in shallow-water areas where plants form monotypic beds.

Plants influence spawning

Studies suggest that the structure provided by plant beds is important to fish reproduction. In fact, many fish in North America are “obligate plant spawners” that directly or indirectly require aquatic plants in order to successfully reproduce. At least a dozen fish families use vegetation as nurseries for their young and reproductive success of nest spawners is improved when they have access to sites with aquatic vegetation and/or some form of structure. Fish can derive a number of benefits from nesting near aquatic plants. For example, vegetation can protect nest sites from wave action and sedimentation that can harm eggs and small fish. Also, parents often use aquatic plant patches or edges as “backing” to protect nests from predators. In addition, many fish that live among aquatic plants are visual feeders and the shade produced by overhanging leaves and plant canopies improves visual acuity so fish can find prey – and avoid becoming prey – with greater success. The shallow areas preferred for spawning by nesting fish are not static and can change over time so that a formerly ideal nesting site can become less than perfect. These areas can become overgrown with aquatic plants, which can hinder optimal spawning. Also, nesting fish can change the composition of the littoral zone by disturbing or altering plant growth, which could affect future nesting success.

Plants influence the physical environment

Aquatic plants can change water temperatures and available oxygen in habitats, thus indirectly influencing growth and survival of fish. The amount of oxygen a fish uses during the course of a day is referred to as daily oxygen consumption rate. High numbers of large fish are not usually found in warm-water habitats that are low in dissolved oxygen because larger fish in warmer water need more oxygen; however, smaller fish are more tolerant of such conditions. Shallow areas where aquatic plants are present and water temperatures increase quickly are inhabited by small fish more frequently than large fish because small fish have lower oxygen consumption rates and can tolerate the reduced oxygen available in these habitats. Dense monotypic beds of weeds in shallow-water habitats can negatively impact fish habitats. The structure resulting from dense growth of stems and leaves can interfere with water circulation and surface exchange of atmospheric oxygen, resulting in high water temperatures and low dissolved oxygen. These conditions can seriously impact fish health; in fact, it is not uncommon to have localized fish kills in areas with extremely dense aquatic weeds. Dense plant beds sometimes have relatively open areas that allow water circulation and oxygen exchange to occur. These areas are usually temporary, but they can serve as important refuges for fish during periods when oxygen levels are low in the rest of the weed bed. Plant beds that are managed for fish habitats should include open areas such as patches and/or lanes to improve the water circulation and oxygen exchange that are important to fish health.

The "perfect" lake: artificial and natural systems

Before determining the optimal amount and type of aquatic plants needed to create "perfect" conditions for fish growth, it is important to recognize that the two types of water systems – artificial and natural – differ from one another and present different challenges for management of aquatic plants. Both types of system can be found throughout the US; as a result, the species of fish that inhabit them (and angler goals) vary by location and contribute to management challenges. As noted above, most fish require some sort of structural habitat at some point in their lives. A diversity of structures provides a diversity of habitats, which can support many different types of aquatic organisms, including numerous species of fish. Therefore, a critical goal in managing artificial and natural water systems should be the maintenance of diverse habitats within the littoral zone, which can be accomplished by ensuring that a variety of plant species are available.

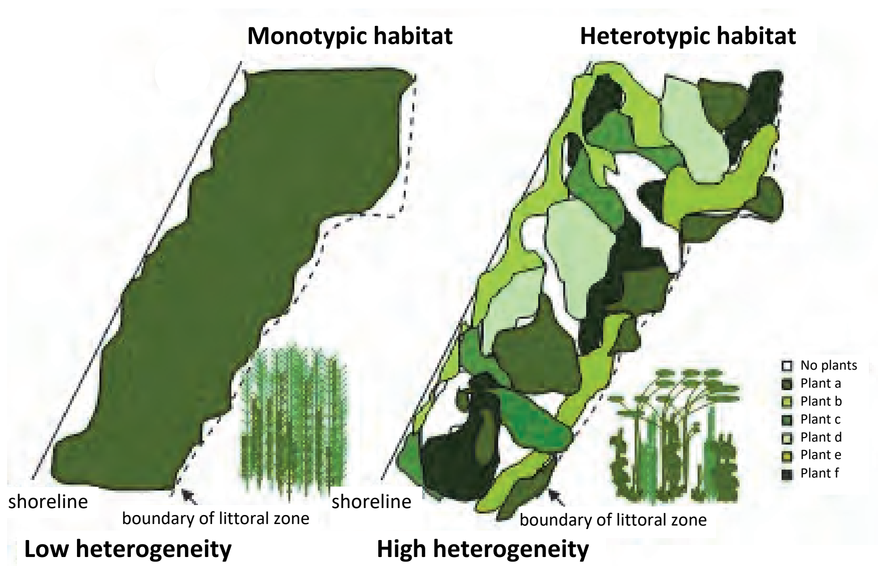
Reservoirs

Reservoirs are typically young (< 100 years old) artificial systems constructed to prevent flooding, generate electrical power and/or provide navigation for barge traffic. Much of a reservoir is an artificial basin on a flooded – but formerly terrestrial – site; therefore, few reservoirs have naturally occurring populations of native aquatic plants. The sediments of many reservoirs hold seed banks of terrestrial plants that will not germinate under flooded conditions. As a result, the sediment is often a barren benthic mud that provides ideal conditions for invasion by exotic plants. In fact, many reservoirs in the US have been taken over by invasive aquatic weeds and plant diversity is typically very low.

Fish may naturally inhabit reservoirs, but providing fish habitat is often a byproduct of the reservoir's construction and is rarely intentional. Reservoirs in the southern US are typically stocked with a variety of plant-loving fish, including largemouth bass and bluegill sunfish. As noted earlier, aquatic plants play a critical role in the growth of these fish by hosting prey such as insects, crustaceans and invertebrates and by providing cover that allows fish to hide from predators. However, dense monotypic beds of aquatic weeds can restrict the benefits associated with a vegetated habitat by reducing fish foraging ability. This results in a fish population with high numbers of small individuals that fail to grow large, a condition sometimes referred to as a "stunted population." Such populations consist of many individuals feeding in dense habitats which provide better forage resources for smaller individuals, but which restrict foraging opportunities for larger fishes. A plant density that results in coverage of 20 to 60% of the surface area within the littoral zone generally provides the best fish habitat and recreational opportunities in reservoirs.

Natural lakes

Many lakes form as a result of natural events such as flowing water, earthquakes and animal activities like dam building, but most natural lakes in the northern US are the result of glacial disturbance. These systems were formed many years ago (most recently ten thousand years ago) and are often vegetated by diverse collections of native and endemic aquatic plants. Therefore, management of natural lakes differs significantly from methods used in reservoirs, which are usually dominated by monocultures of invasive species.



Natural lakes are diverse in both aquatic plants and fish. Like reservoirs, most of the fish in natural lakes require a structural habitat at some point in their lives. In fact, many are plant-loving fish that choose to spend much of their life feeding and growing in vegetated habitats. The diversity of native and endemic aquatic plants furnishes the littoral zone with a wide variety of structures that differ in size and plant composition, a condition referred to as habitat heterogeneity. This diverse habitat is home to a number of fishes adapted to this environment, including largemouth bass, bluegill, crappie, northern pike, muskie, young perch and walleye.

Summary

Most freshwater fish rely on aquatic plants at some point during their lives and prefer specific habitats based on their growth stage. Young fish use aquatic vegetation as a food source – both by directly consuming plants (in most cases incidentally) and by foraging for the microfauna associated with the plants – and as cover to hide from predators. Mature fish move to more open waters to increase foraging success and consume other fish to supplement their diets. Nesting, growth and foraging success of plant-loving fish are influenced by plant composition and density. While many fish require some aquatic vegetation for optimal growth, excessive amounts of aquatic vegetation can negatively impact growth by reducing foraging success. Also, different fish prefer different types of habitats and will move to a new area if foraging conditions in their preferred location decline due to excessive growth of aquatic weeds.

An “optimal”, one-size-fits-all fish habitat is impossible to describe, which leads to confusion and often erroneous conclusions. For example, a crappie fisherman has a different idea of a perfect habitat than does a bass fisherman. The parameters of an ideal habitat change based on the size and species of fish, the type of lake, structures present in the lake and numerous other factors. However, the “optimal” habitat that provides a beneficial environment for most animal populations is one that contains a large diversity of native plants.

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Page 10 lower: Common carp; Richard A Bejarano, Florida Museum of Natural History
Page 11 upper: Northern pike; Robin West, US FWS
Page 11 lower: Yellow perch; Duane Raver, US FWS
Page 13: Low vs. high heterogeneity; Eric Dibble, Mississippi State University