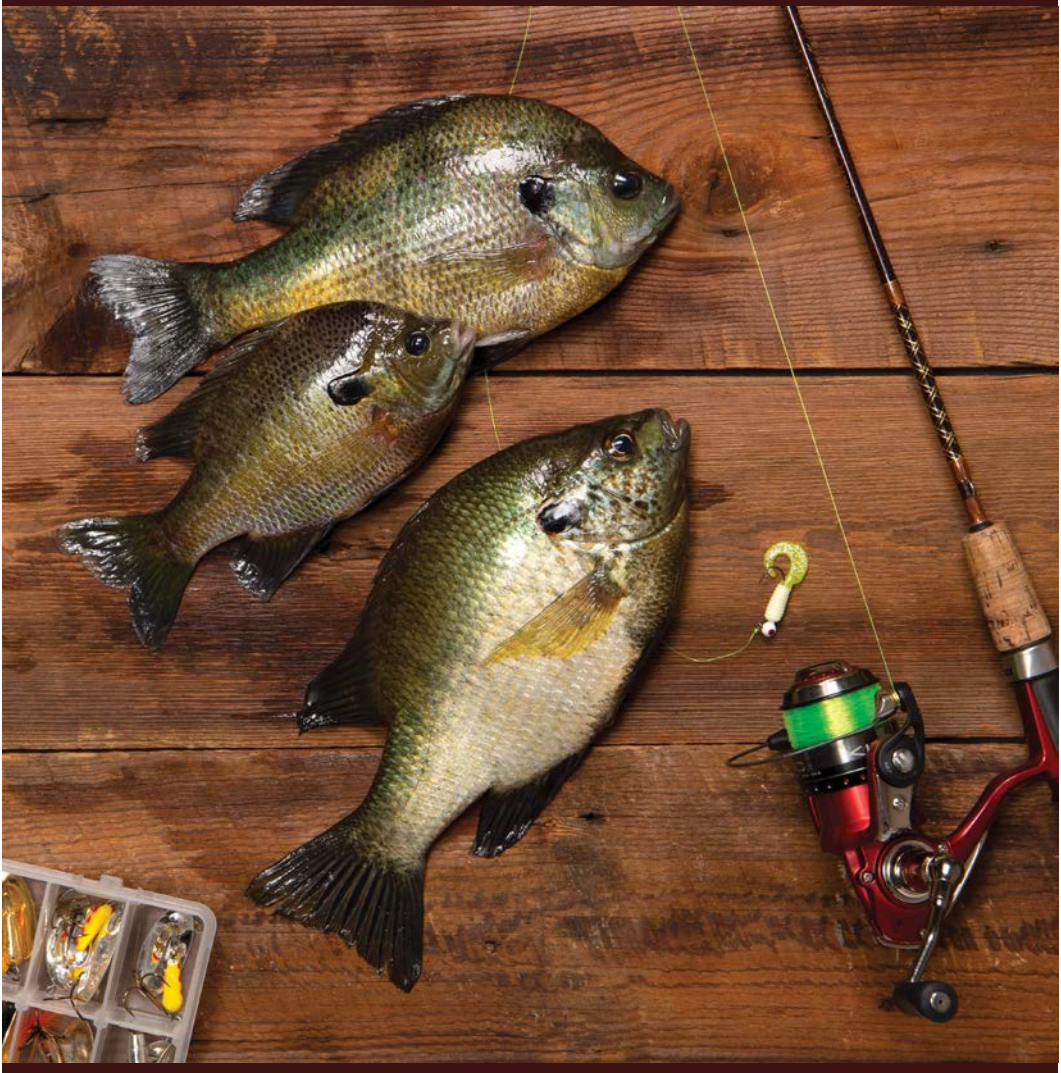
Pond Management Guide



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Introduction

North Carolina ponds offer excellent fishing for Tarheel anglers and represent a significant portion of the state's water resources. Properly managed ponds can provide excellent fishing opportunities to many anglers at a reasonable cost. However, careful planning and wise management are necessary to maintain high-quality fishing in a pond year after year. To maintain a healthy, productive fish population, you must select the site carefully, construct the pond properly, maintain good water quality, and stock and harvest the pond correctly. Often the difference between a productive pond and an unproductive one is the ability of the owner to obtain sound pond management advice and carry out the recommended practices.

Before constructing a pond or implementing any management actions, you should determine your objectives and priorities for the pond. The best management strategy depends upon your objectives. Will the pond be used primarily for irrigation, livestock watering, waterfowl, or recreation? Not all pond uses are fully compatible, so some compromises may have to be made. Do you want the pond to produce trophy largemouth bass or large quantities of average-sized bass? Do you want big bream (bluegill) or channel catfish? How heavily will the pond be fished? How much money can you devote to achieving your chosen objectives? You must answer these important questions during the initial planning stages so you can develop an appropriate management plan for the pond.

This publication presents the basic principles of managing recreational ponds and the requirements for producing and maintaining high-quality fishing in a pond. Some common mistakes in pond management and ways of solving pond problems are discussed. This information should allow you to develop and carry out a pond management plan that provides maximum benefits.

Bluegill photo by James Rice

1 Site Planning and Pond Construction

Perhaps the most important aspect of pond management is deciding where and how to build your pond. Many problems can be avoided if the pond is properly designed and constructed. The Natural Resources Conservation Service (NRCS) publication *Ponds – Planning, Design, Construction* (Agriculture Handbook 590) contains detailed information on design surveys, site selection, drainage area, pond layouts, soil analysis, and spillway construction. Contact your county NRCS office to obtain a copy, or you can access it online at nrcs.usda.gov/Internet/FSE_DOCUMENTS/16/stelprdb1246427.pdf. Your county NRCS staff can provide additional information on cost estimation and other aspects of pond construction or refer you to a reputable engineer for assistance. To take advantage of these services, contact the NRCS during the initial stages of pond planning.

There are two general types of ponds:

- Watershed or embankment ponds, which are formed by constructing a dam to collect water from surface runoff, a spring, or a stream,
- Excavated ponds, which are formed by digging down into the water table in an area that is relatively flat.

The type of pond that is best for your site will be determined to a great extent by the topography of the land and the principal use of the pond. It is usually necessary to move more earth to construct an excavated pond than a watershed (embankment) pond. Excavated ponds, which are most common in the coastal plain, often have very low fertility and are subject to significant water level changes throughout the year, especially during droughts. Watershed ponds, however, are more likely to have problems with muddy water, high siltation rates, rapid fluctuations in flow rates, aquatic weeds, temperature fluctuations, and wild fish invasions. Large watershed ponds can benefit from construction of a small settling pond immediately upstream to reduce turbidity, sedimentation, and weed problems in the large pond. If possible, watershed ponds should be constructed off-channel to reduce negative impacts from pond construction on instream and wetland habitats.

Permits

After choosing a site, contact a representative of the U.S. Army Corps of Engineers (USACE) to make sure that the site is not located in a stream or wetland area. If pond construction would involve placing a dam across a stream or would affect a wetland, you are required by law to obtain a 404 permit from the USACE and a 401 permit from the North Carolina Department

of Environmental Quality (NCDEQ) Division of Water Resources before starting construction. To find 404 permit information and contact information for your regional USACE field office, visit www.saw.usace.army.mil/Missions/Regulatory-Permit-Program/Contact. Information and application forms for the 401 permit are available from the Division of Water Resources website at deq.nc.gov/about/divisions/water-resources/water-resources-permits/wastewater-branch/401-wetlands-buffer-permits. A Coastal Area Management Act (CAMA) permit may be required for pond construction in coastal counties. For more information, consult the CAMA website at deq.nc.gov/about/divisions/coastal-management/coastal-management-permits. A permit from the North Carolina Wildlife Resources Commission (NCWRC) is required to stock fish in any pond with a direct connection to a stream or other public water body (see Stocking section below). The application for this permit is available at ncwildlife.org/stocking-permits.

Additional forms or permits may be required for some ponds. If the dam height will exceed 25 feet and impounded water volume (at the dam crest) will exceed 50 acre-feet, or if the dam is deemed to be a high hazard structure that would cause significant property damage or loss of life upon failure, you are required to submit a construction document set that includes project drawings, specifications, and a report by a professional engineer to the NCDEQ Dam Safety Program. To ensure that your pond will conform to all state laws, visit the NCDEQ Dam Safety Program website at deq.nc.gov/about/divisions/energy-mineral-land-resources/energy-mineral-land-permits/dam-safety where you can locate the nearest regional NCDEQ office before beginning construction. The agency may also require that you prepare a sediment and erosion control plan. More information is available at deq.nc.gov/about/divisions/energy-mineral-land-resources/erosion-sediment-control. Trout streams and streams in some river basins have special buffer requirements that may have to be addressed. For information on buffer requirements, see deq.nc.gov/about/divisions/water-resources/water-resources-permits/wastewater-branch/401-wetlands-buffer-permits. Also check to see if local county or municipal ordinances require additional permits.

Drainage Area

An important factor in deciding where to build a pond is the nature of the surrounding watershed or drainage area. Generally, a watershed pond built in pastureland requires 5 to 20 acres of watershed per surface acre of pond, whereas a pond constructed in woodland requires 20 to 40 acres. If the drainage area is too large, it may be necessary to construct a diversion ditch to channel some water around the pond to prevent excessive flushing. If the

drainage area is insufficient, the pond will not fill adequately and will be subject to water-level fluctuations and vegetation problems.

Water Source and Quality

Potential water sources for a pond include surface runoff, streams, springs, shallow groundwater (in excavated ponds), and wells. Each source has advantages and disadvantages; the type chosen will depend to a large extent on where the pond is located. *Surface runoff* is rarely a source of disease or wild fish problems but can lead to fluctuations in pond level during spring and fall. Water quality from surface runoff is best when the watershed is forested or contains grasslands. *Streams* are usually high in dissolved oxygen, but they also tend to fluctuate rapidly, are a source of silt, and are a potential source of diseases and wild fish invasions. *Groundwater* may have poor water chemistry, and levels may drop during droughts.

Springs are considered the most desirable water source because they have a constant temperature and flow rate, are inexpensive to divert, are rarely a source of disease or wild fish problems, and are less likely to be affected by pollution. However, they may contain high concentrations of undesirable gases (hydrogen sulfide and carbon dioxide), and the high clarity of the water from most springs encourages vegetation problems. *Wells* offer good quality water and can be placed where convenient but are expensive to drill and operate and may also contain undesirable gases.

It is also important to consider land uses within the watershed where the pond is located, as these may degrade the water quality. Runoff from cropland can increase the amount of sediment reaching the pond and may cause turbidity. It may also contain potentially toxic agricultural chemicals, as well as fertilizers that can cause algal blooms and resultant fish kills. Runoff from livestock pastures and holding areas is rich in nutrients (animal wastes) that can also cause noxious algal blooms and fish kills. Residential, urban, and industrial runoff may contain substances (such as industrial waste, chemicals, oils, and sediment from construction activities) that can adversely affect a pond's water quality. When planning a pond, be sure to consider the quality of the water source and factors that may affect it.

Site Preparation

During construction of ponds to be used primarily for fishing, remove all brush, trees, and vegetation from near-shore areas of the pond before it is filled, so the pond can be seined to assess pond balance or remove excess sunfish (bream) if necessary. If desired, habitat structures like stumps, logs, brush

piles, or standing bushes can be left in some areas of the pond to provide cover for small fish and attract larger fish for anglers. To prevent soil erosion, vegetate the dam and pond banks as soon as possible after construction has been completed. Dams that are used for motor vehicle traffic should have a minimum width of 12 to 16 feet, regardless of the dam height. New ponds should be filled by early to mid-fall to coincide with the best period for stocking sunfish.

Size

The size of the pond will be determined by the water resources and land available, as well as the specific goals of the landowner. The best fishing ponds have a surface area of at least 1 acre. Ponds of less than 1 acre are difficult to manage because the fish populations, especially largemouth bass, are easily overharvested. In addition, small, shallow ponds are susceptible to vegetation problems that usually result in overpopulation of sunfish. These problems ultimately result in stunted growth of both bass and sunfish. Fish populations in ponds of less than 1 acre are also adversely affected by drought. If you have a small pond and cannot afford to enlarge it, the best management tactic is to stock it with channel catfish or hybrid sunfish (or both) and begin a feeding program (discussed in a later section). A larger pond will have greater potential for an enhanced fishery although it is typically more expensive to construct, stock, and manage.

Depth

The average depth for a 1-acre or larger fish pond should be between 6 and 8 feet with a maximum depth not greater than 10 to 12 feet. An average depth less than 6 feet greatly increases the probability of aquatic vegetation becoming established in the pond and does not allow for fluctuations in water levels during periods of drought. Depths greater than 12 feet are not necessary for good fish production and increase the chance of fish kills from summertime oxygen depletion. Pond banks should be cut to allow a 1-foot drop for every 2 or 3 feet toward the center of the pond (2:1 or 3:1 slope) and should be a minimum of 3 feet deep (Figure 1). This shape will help prevent growth of nuisance aquatic vegetation and will also discourage muskrats, which can burrow into and compromise pond embankments and dams.

Water Control Structure

An important feature that should be incorporated into the design of all fish ponds is a water control structure (drainpipe). A drainpipe enables you to drain the pond to make repairs, fix leaks, and control nuisance aquatic vegetation. It also makes it possible to treat and remove undesirable fish species chemically

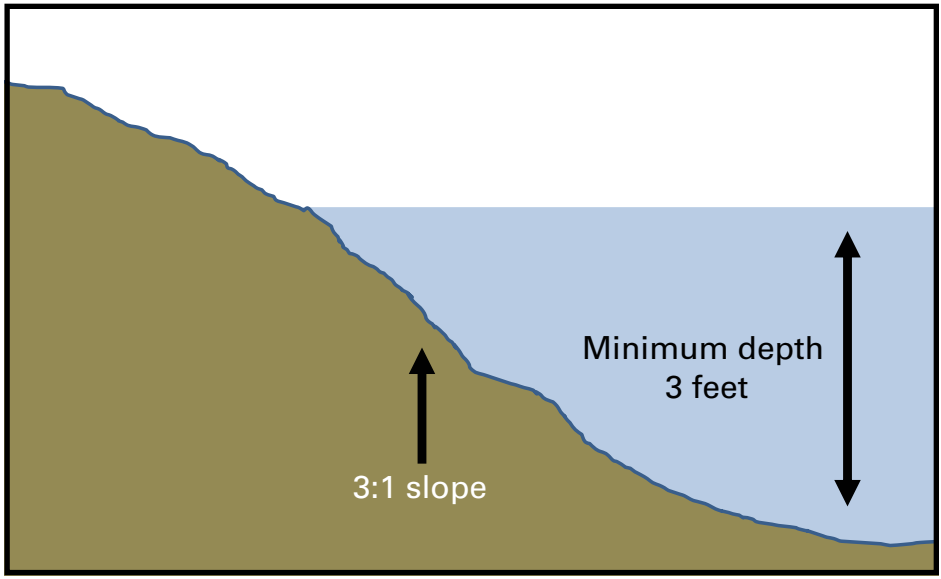

Figure 1: Slope of pond.

and to manage the fish population more effectively. The drainpipe should include a grate or trash rack to keep turtles, large fish, and debris from entering the pipe and potentially clogging it. A drainpipe that incorporates a bottom draw-off device (Figure 2, page 6) serves this function. A drainpipe ensures good water quality and reduces the chances of a fish kill by removing stagnant water from the bottom of the pond. Ponds tend to stratify during the summer, resulting in a stagnant bottom layer that is low in dissolved oxygen and may contain high concentrations of toxic gases such as carbon dioxide, hydrogen sulfide, and ammonia. A bottom draw-off device also serves as a coldwater release, which is important for mountain ponds to minimize increases in the temperature of downstream waters.

Another important feature that you should incorporate is a well-designed and maintained emergency spillway. An emergency spillway prevents loss of the dam during periods of extremely high water by rerouting excess water through a low spot around the dam. It should be kept free of trees, brush, and structures (other than a grass carp barrier, if necessary). To meet individual requirements, it is best to ask your county NRCS office for advice about this aspect of pond design.

Contacting the appropriate agency when first considering construction of a pond can prevent many costly mistakes.

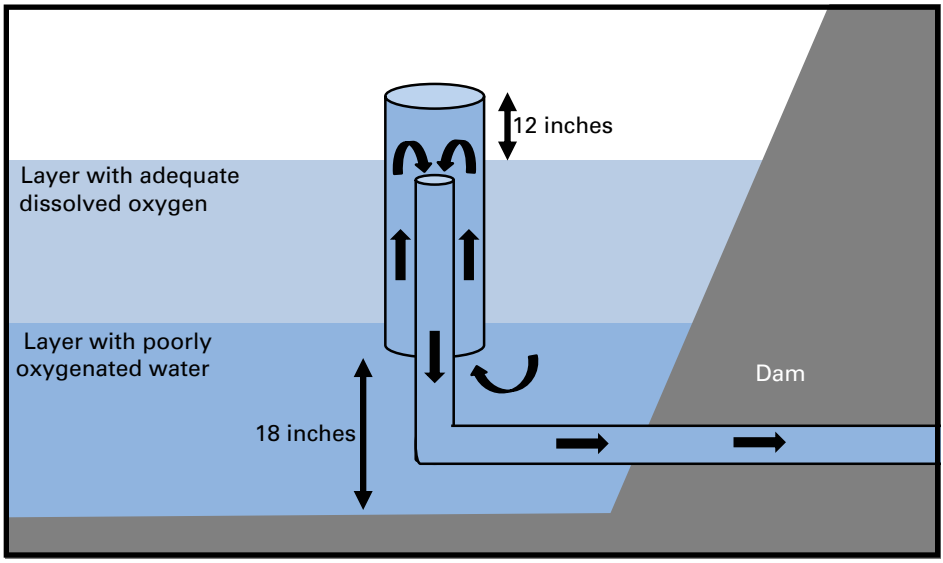

Figure 2. Drainpipe incorporating a device for drawing water from the bottom of the pond (note: dam slope is not to scale).

Restoring Old Ponds. Sometimes renovating an old existing pond is more feasible than constructing a new pond. Older ponds can become less productive, fill in with sediment, and experience aquatic vegetation problems. If given enough time, most ponds will fill in with sediment, become shallow wetlands, and eventually dry land. The most economical method for removing excess sediment in a pond is to drain it and allow the bottom to dry before removing the sediment. There are methods of removing sediment without draining the pond, but these are much more expensive.

2 Stocking and Harvesting

Prestocking Procedures

New Ponds. Plan construction so the pond is completed and filled by September or early October.

Existing Ponds. Restocking a pond may require first eradicating existing fish populations (a process known as pond reclamation). Contact your Cooperative Extension center or the NCWRC to determine if reclamation is necessary; sometimes the problem may be solved by other means. Pond reclamation may be required if undesirable species, such as crappie or bullheads, are creating problems in the pond. Occasionally, pond reclamation is necessary when fish populations become too unbalanced (for example, when there are too many

sunfish and no bass). Undesirable fish populations are eliminated by using a fish toxicant called rotenone. Rotenone formulations labeled for fish removal may only be purchased by a certified pesticide applicator, and must be applied by, or under the direct supervision of, a certified applicator.

Follow these steps when reclaiming a pond with rotenone:

1. Plan the reclamation for August or September. The water is warm at this time, and rotenone will detoxify quickly. This will also allow time for the pond to refill by fall when sunfish are normally restocked.
2. Prepare the pond by lowering the water to its lowest level. This reduces the amount of rotenone needed and concentrates the fish in a smaller area, ensuring a complete kill. Close the overflow pipe and check daily for leaks so that treated water will not escape and kill fish downstream.
3. Follow all label instructions regarding rotenone application (remember, the label is the law). After treatment, most fish will die and come to the surface within 24 hours, although fish may continue to appear for several days. Rotenone is not approved by the Food and Drug Administration for human consumption, therefore the poisoned fish should not be eaten by humans or livestock. Bury them to prevent odors and pest problems.
4. Allow at least 10 days for the rotenone to break down (detoxify) naturally. In warm water (65° to 70°F) the rotenone should be gone in about four days. The treated water should not be used for watering livestock for at least 10 days and should not be released from the pond for at least two weeks after application. Fish may be stocked two weeks after treatment.

Selecting the Proper Fish

Largemouth bass, bluegill, redear sunfish and channel catfish are generally the only fish that should be stocked in a warmwater pond. Research has proven that various combinations of these fish produce the best pond fisheries. Except for specific situations described below, stocking the pond with any other species of fish can make it difficult to manage, usually resulting in poor fishing and an unbalanced fish community. Stocking healthy, disease-free fish from a reputable fish supplier will help reduce the chances of disease outbreaks and subsequent fish kills.

A fish stocking permit issued by the NCWRC is required before stocking fish into any pond that is not self-contained. This refers to all ponds with a direct connection to a stream or other public water body (if water drains from your pond, you will likely need this permit). Fish stocked in ponds that are not

self-contained have the potential to escape, and in many cases undesirable fish species can invade public waters and possibly harm native species. The application for this permit is available at ncwildlife.org/stocking-permits.

The following paragraphs briefly describe the desirable fish species and their characteristics to help you better understand fish populations.

Largemouth Bass. This species is recognized by its large mouth and dark stripe or blotches down its side (Figure 3). Young bass feed on microscopic animals (zooplankton) and insects until they are about 2 inches long, when they start feeding on fish as well. Adult bass eat mostly fish, but they also eat large insects, frogs, and crayfish when available. Although their growth rate varies across North Carolina, most bass reach a harvestable size (12 inches) in two to three years when food is abundant. Largemouth bass spawn once a year when the water temperature is 63° to 68°F, usually beginning in late March in eastern counties and as late as June in western counties.

Figure 3. Largemouth bass.

Bluegill. This species of fish, also called bream (or brim), is recognized by its small head and mouth and an irregular black spot located at the base of the soft dorsal (top) fin (Figure 4). Broad, dark vertical bands can sometimes be seen on the sides of the fish when it is in the water. Bluegill prefer to eat zooplankton and insects, but they also sometimes feed on small fish. Their growth rate depends on the amount of food available and the number of fish in the pond. It usually takes three years to produce fish of harvestable size. Bluegill spawn frequently from May through October when the water

temperature is 67° to 80°F. Because they produce such large numbers of young fish, they are the primary food source for largemouth bass.

Figure 4. Bluegill.

Redear Sunfish. Also known as the shellcracker, the redear sunfish has a small mouth and head and is shaped much like a bluegill (Figure 5). The opercular (cheek) tab of the redear sunfish is black with a red-orange or cream-colored border, and breeding males have a bright orange border. The redear sunfish is primarily a bottom feeder, eating mostly snails and insects. Its growth rate is similar to that of the bluegill, but redear sunfish typically reach a larger size because they are harder to catch. Redear sunfish typically spawn once a year when water temperature is 70° to 75°F and will not produce enough small fish to support good largemouth bass growth on their own.

Figure 5. Redear Sunfish.

Hybrid Sunfish. This fish is a cross of two different sunfish species, usually bluegill and green sunfish (Figure 6). The hybrid sunfish resembles the bluegill but has a much larger mouth. It is an active feeder and is generally easier to catch than other sunfish. Because of their voracious feeding and hybrid vigor, hybrid sunfish can reach a harvestable size in about two years. Hybrid sunfish are not sterile, but a high percentage of them are males so spawning is limited, and any offspring produced have slower growth rates than the first generation. Hybrid sunfish will not provide sufficient forage to support a largemouth bass population and should not be stocked in largemouth bass-bluegill ponds as they will spawn with bluegill and reduce the overall productivity of the bluegill population. But they are an excellent choice for small ponds maintained by stocking.

Figure 6. Hybrid Sunfish.

Channel Catfish. This type of catfish can be recognized by its scaleless body, chin barbels (whiskers), dark spots scattered on the body in smaller fish, forked tail, and barbed spines on the dorsal and pectoral (side) fins (Figure 7). Channel catfish will eat almost anything, but they prefer insects, small fish, and crayfish. They readily adapt to an artificial (pelleted) diet, which increases their growth rate. They are capable of spawning in ponds, but because of egg predation by bluegill and fingerling predation by bass, very few young channel catfish survive. Spawning success of these cavity spawners may be

improved by placing 2-foot sections of terra-cotta pipe (≥12 inches in diameter) perpendicular to the bank in 2 to 4 feet of water.

Figure 7. Channel Catfish.

Except as noted elsewhere in this publication, the five species described in this section are the only ones recommended for warmwater pond stocking.

Crappie (both black and white) are popular game fish throughout North Carolina. Although they can thrive in reservoirs and larger rivers, crappie are not suitable for stocking in most ponds. They can prey on young bass, compete with bass and bluegill for food, and tend to overpopulate a pond, resulting in stunted crappie, bluegill, and largemouth bass. In severe cases, pond reclamation is the only way to remedy this problem. The smaller a pond is, the greater the risk that crappie will overpopulate. Typically, crappie may be safely stocked in ponds larger than 30 acres, but consult a biologist to see if this is appropriate. If crappie do become established in a pond, the chances that they will overpopulate can be reduced by maintaining a relatively high density of bass to increase predation on their young and aggressively harvesting adult crappie.

Threadfin shad may be stocked to enhance growth of largemouth bass. They can negatively affect juvenile bluegill, so they should only be stocked in ponds managed for trophy bass after bluegill have become established. They are not cold tolerant and can die off during the winter if water temperature falls below 42°F. Thus, frequent restocking may be required. Gizzard shad are not recommended because they can grow too big for a largemouth bass to eat and

can overpopulate a pond. It is never recommended to collect shad from the wild because of the risk of introducing undesirable species.

Fathead minnows are often recommended by fingerling suppliers as supplemental forage for newly stocked largemouth bass. These fish are readily eaten by bass and may provide an initial boost to growth, but they are typically eaten before they can reproduce and will not establish a self-sustaining population. The addition of fathead minnows is not necessary if the recommendations in this guide are followed regarding stocking species, rates, and timing.

Triploid grass carp are herbivorous fish that can be stocked to control many kinds of aquatic vegetation. They are discussed in detail in the section on aquatic weed control.

Bullheads are not recommended to stock because they become overpopulated and can keep a pond muddy.

Common carp are not recommended to stock because they do not effectively control algae or aquatic vegetation and can keep a pond muddy by stirring up the bottom.

Many pond owners are curious about the benefits of stocking genetic strains of largemouth bass and bluegill that may grow faster or are more aggressive feeders. The Northern and Florida strains of largemouth bass are native to North Carolina. The Florida strain largemouth bass has the potential to grow larger than the Northern strain but tends to be less aggressive for anglers and is less cold tolerant. The first-generation hybrid cross between these two strains (called F1 hybrids) may exhibit enhanced growth rates, but their offspring will likely have reduced growth rates that may be less than those of a pure strain largemouth bass.

The two most common strains of bluegill that can be stocked are the native bluegill and the coppernose bluegill. The coppernose bluegill is from Florida and has a golden band that runs across its head, which is very distinct in spawning males. It is more tolerant of low pH than native bluegill and may be more appropriate to stock in coastal ponds with low pH. There is some debate whether coppernose bluegill grow more rapidly than common bluegill or are easier to train to take feed.

The bottom line for a pond owner is that although selecting a strain of fish that has the potential to grow faster or larger can be beneficial if these are your management goals, it is much more important to actively manage your pond

through harvest to achieve these results. You will not get the desired results you are looking for if you just rely on stocking the fish and expecting them to meet your management goals (for example, trophy bass).

Stocking Options

Except for supplementary stocking of hybrid sunfish or channel catfish, stocking a pond that already contains fish is normally not recommended. Before stocking a new or reclaimed pond, contact your local Cooperative Extension center or the NCWRC for assistance in selecting a stocking regime best suited to your management plan for the pond. Stocking the pond with the proper species and numbers of fish at the proper time, combined with good management practices, is necessary to maintain good fishing. Sunfish fingerlings should be stocked in the fall, usually in October or November, so they can grow large enough to avoid predation by largemouth bass, which are stocked the following June. The fish stocking combinations given in the accompanying tables usually produce a successful fishery. The stocking rates, which depend on whether or not the pond will be fertilized, are given as a general guide. In some cases, the stocking rate should be altered depending upon the pond management plan, extent of fishing, water quality, and other uses of the pond.

Option 1: Largemouth Bass and Sunfish Fingerlings in a 1-to-10 Ratio.

	Number Per Acre			
Species	**Fertilized**	**Unfertilized**	**Size (inches)**	**When Stocked**
Bluegill	700	350	1 to 2	Oct. to Nov.
Redear sunfish	300	150	1 to 2	Oct. to Nov.
Channel catfish	100	50	2 to 4	Oct. to Nov.
Largemouth bass	100	50	2 to 4	The following June (after sunfish)

Option 1 is an economical and most commonly recommended stocking plan for establishing a fishery of largemouth bass and bluegill. However, harvesting must not occur until the second year post stocking for sunfish and the third year for largemouth bass or when they reach 12 to 14 inches in length. Supplementary stockings of channel catfish may be necessary after several years; if so, 8- to 10-inch fingerlings should be stocked to reduce predation by largemouth bass. These rates should be used for ponds of 10 acres or less. Ponds larger than 10 acres should be stocked with 3,500 bluegill, 1,500 redear sunfish, 500 largemouth bass, and 500 channel catfish

(if desired). If redear sunfish are not desired, they can be replaced with additional bluegill.

Hybrid sunfish should not be stocked in a pond when managing for largemouth bass and bluegill. They may hybridize with the bluegill, and reproduction and growth of subsequent generations will be diminished. This will result in less food availability for largemouth bass and affect growth rates.

Option 2: Largemouth Bass and Sunfish Adults.

Species	Number Per Acre	Size (inches)	When Stocked
Bluegill	70	3 to 5	April
Redear sunfish	30	3 to 5	April
Largemouth bass	20	8 to 14	April

Stocking adult fish (Option 2) usually costs more than stocking fingerlings, but it will provide fishing sooner. Catch-and-release fishing can begin immediately, with modest harvest beginning after one year for sunfish and after two years for largemouth bass or when they reach 12 to 14 inches in length. As with Option 1, hybrid sunfish should not be used. If redear sunfish are not desired, they can be replaced with additional bluegill.

Option 3: Sunfish Adults and Largemouth Bass Fingerlings.

Species	Number Per Acre	Size (inches)	When Stocked
Bluegill	60	3 to 5	April
Redear sunfish	15	3 to 5	April
Largemouth bass	100	2 to 4	June

Option 3 may be necessary when adult largemouth bass are difficult to find. This option still gives the sunfish time to spawn that summer, providing fish prey for the fingerling largemouth bass. If redear sunfish are not desired they can be replaced with additional Bluegill.

Before stocking a new or reclaimed pond, contact your local Cooperative Extension center or the NCWRC for assistance in selecting a stocking regime best suited to your management plan for the pond.

Option 4: Channel Catfish and Hybrid Sunfish Fingerlings.

Species	Number Per Acre	Size (inches)	When Stocked
Channel catfish	100	2 to 4	June or July
Hybrid sunfish	300	1 to 2	June or July

Option 4 yields an excellent fishery for avid catfish and sunfish anglers and is the best option for ponds much less than 1 acre. These species can be stocked together or separately. They grow quickly when fed a commercial fish diet. Since their reproductive potential is limited, periodic restocking will be necessary. A few bass may be added to control any reproduction by hybrid sunfish, as their offspring will have undesirable traits.

A list of fish suppliers in North Carolina that sell fish for stocking private ponds is maintained by the North Carolina Department of Agriculture & Consumer Services (NCDA) at www.ncagr.gov/markets/aquaculture/hatcheries.htm. We recommend contacting several commercial facilities to obtain the best pricing and delivery arrangements. Also ask about guarantees or replacement policies in case your fish die shortly after stocking.

Mountain Trout Ponds

Most North Carolina ponds are best suited for the warmwater species described above. However, some ponds in western North Carolina stay cold enough to support trout year-round. Before you stock trout in your pond, it is critical to determine that conditions will be acceptable. Generally, ponds with sufficient flow that are above 3,000 feet in elevation will be cool enough for trout year-round. Water temperatures that exceed 70°F for more than a few hours can be harmful or lethal to trout. Many ponds in western North Carolina exceed 70°F during the summer due to their elevation or inadequate water flow, or both. Spring and fall are excellent times to stock trout in recreational ponds. However, stocking trout without knowing if the pond is suitable can be disastrous. A fish kill can result either immediately or in the future without an understanding of specific pond and fish species characteristics. Stocking healthy fish from a reputable supplier will also reduce the chance of a fish kill.

Sterile (triploid) rainbow trout are recommended for stocking ponds and are available from commercial suppliers. Brown and brook trout are only produced by a few suppliers and will cost about twice as much or more as rainbow trout. Stocked trout should be sterile; this improves growth and survival and reduces risks of negative impacts on native species. It is best not to stock any other species of fish with trout. To apply for a stocking permit, visit ncwildlife.org/stocking-permits.

Suitable stocking rates vary depending on water flow, pond size, and management preferences, but they typically range from about 300 fingerlings that are 5 to 7 inches per acre if the trout are not fed to 500 per acre if fed. A good rule of thumb is to stock no more than 10 to 15 trout per gallon of water flow per minute. Trout will not successfully reproduce in ponds, so periodic supplemental stocking will be necessary, usually about every three years. When supplemental stocking is performed, it is best to use fish at least half the length of any larger trout already present in the pond to minimize predation losses.

In ponds known to exceed 70°F in the summer months, trout can be stocked in the fall when water temperatures consistently fall below 65°F to support a winter fishery. However, the trout must be harvested or removed before the water temperature exceeds 70°F in the spring, typically in April or May. If largemouth bass are present, trout should be at least 9 to 10 inches when stocked to minimize predation losses.

Due to natural food limitations trout in ponds usually should be fed a high-protein, pelleted trout feed (preferably floating). Only feed as much as the fish will eat in a few minutes; overfeeding can cause water quality problems. Do not feed when water temperature is above 68°F or below 38°F. Trout ponds should not be fertilized, as trout are especially sensitive to low nighttime dissolved oxygen concentrations that sometimes occur in fertile ponds.

When building or stocking a trout pond take steps to avoid potential negative impacts on wild populations. North Carolina's native brook trout are particularly sensitive to competition and hybridization with non-native rainbow and brown trout and cultured (non-native) brook trout, warm water temperatures, and impacts from sediment inputs. These effects have eliminated or altered native brook trout populations across much of their range. Potential introduction of whirling disease or gill lice parasites from some hatchery trout has emerged as another threat to wild trout populations. Check with your NCWRC District Fisheries Biologist to find a reputable hatchery when stocking trout.

Instream ponds (those built by damming a stream) pose the greatest risk of negative impacts on wild trout populations and should be avoided, but care must be taken with off-channel ponds as well. Hatchery trout of any species should not be stocked into ponds where accidental escape may result in their introduction into a brook trout stream. The temperature of surface water flowing out of some ponds can become high enough to degrade downstream habitat for trout and other coldwater species. This can be a problem in both instream and off-channel ponds. A bottom draw-off device (or coldwater

release) should be used to reduce the temperature of water leaving such a pond and minimize warming in the receiving stream.

Before stocking or building a trout pond near a trout stream, contact your NCWRC District Fisheries Biologist for an evaluation of any possible risks and advice on how best to minimize them. More information on managing recreational trout ponds is available from your local Cooperative Extension center or online at ces.ncsu.edu/troutinformationandlinks/#recreation, under Recreational Pond Management.

Harvesting

Proper fish harvesting is one of the more important factors in pond management. You may fish the pond after the first year, although largemouth bass should not be harvested until the third year or when they reach 12 to 14 inches in length. Overharvesting, particularly of bass, may easily occur when a pond is first opened to fishing, and it can ruin a pond that is becoming established. The bass originally stocked must support the bass fishery for at least three to four years from the time of stocking. Bass growth and subsequent harvesting rates are different for each pond. As a general rule, unfertilized ponds receiving runoff from agricultural lands can support a harvest of about 10 to 15 pounds of largemouth bass per acre each year. In excavated or infertile ponds, which are common in the coastal plain, about 10 pounds per acre is a safe rate. These harvest rates may be doubled if the management plan includes a fertilization program.

Once a pond has become established, the most common mistake a pond owner can make is under-harvesting bass. Largemouth bass less than 12 inches are aggressive feeders and help maintain the proper population balance between bass and sunfish, so they should not be overharvested. However, practicing strict catch-and-release bass fishing typically leads to an overcrowded population and stunted bass. Usually harvesting about 10 to 20 bass per acre, per year that are 10 to 12 inches long (less than 14 inches if managing for trophy bass) maintains a good balance. Note that private ponds are not regulated by the NCWRC, so rules limiting the number and sizes of fish that can be harvested in public waters do not apply here. If you are unsure if your pond is considered private or public water, contact your NCWRC District Fisheries Biologist.

Remember to spread the harvest throughout the fishing season. If too many adult bass are removed, particularly in the spring, bluegill may become overcrowded. Keep a record (number and length or weight of fish harvested) and ask others fishing the pond to record the number of bass removed from

the pond. When the annual quota is reached, fishing may continue but any bass caught should be released. All fish to be released should be handled carefully and returned to the water as quickly as possible.

Sunfish growth and harvesting rates are also different for each pond. As a general rule, you may remove up to 40 pounds of harvestable-size sunfish per acre annually from an unfertilized pond. This rate may be doubled for ponds with high basic fertility and those in which a fertilization program is used. Harvest of sunfish is not essential if an adequate bass population is maintained.

Fish that are maintained by stocking rather than natural reproduction, such as channel catfish and hybrid sunfish, may be harvested at will. However, if large numbers are removed soon after fishing begins, restocking may become necessary earlier than anticipated. Keeping a record of the number of fish harvested can be helpful in planning for restocking.

Determining Balance

When is a fish population in balance? How can I determine if a balanced condition exists in my pond? These are two questions often asked by pond owners. Actually, a truly balanced condition never exists in a pond. Fish populations continually change and never reach the state of equilibrium, or general stability, referred to as balance. Fisheries biologists sometimes use the term to describe satisfactory relationships between the predator (largemouth bass) and prey (bluegill) populations of a pond. Generally, a balanced population must provide three things:

- Fish of harvestable size.
- Annual reproduction.
- A combination of fishes, including at least one predator species.

The two methods described in the accompanying table may be used to determine balance in a pond of largemouth bass and bluegill. The first method, using angler harvest information, is based on a correctly stocked largemouth bass-bluegill combination. The seine method, using a minnow seine 20 feet by 4 feet with ¼-inch mesh, is effective during July and August in ponds containing a bass-bluegill population at least two years old. Sampling four or five shoreline locations around the pond should yield results in one of the population condition categories. If the results from one or both of these methods indicate an overcrowded or undesirable condition, contact your local Cooperative Extension center or the NCWRC for advice. The Extension agent

or fisheries biologist will usually recommend a corrective measure described for the following population conditions.

Overcrowded Bass. If a bass population is overcrowded, the situation can usually be corrected by harvesting the surplus bass. Harvest 20 bass per acre and assess the results the following year; if bass size and condition have not increased, repeat the bass removal treatment. If possible, selectively remove smaller-than-average bass and leave the larger ones. Higher harvest rates may be needed in severely overcrowded ponds. Harvest up to 30 bass per acre in unfertilized ponds and up to 50 bass per acre in fertilized ponds.

Overcrowded Bluegill. In severe cases, correcting this condition may require removal of 100 pounds of sunfish per surface acre of pond. If adequate harvest is not feasible, a shoreline marginal rotenone application in the fall can be used to selectively remove small sunfish. This approach involves application of rotenone in several 300-foot transects about 25 feet from the bank along a shallow shoreline. Consult a professional fisheries biologist for detailed advice before attempting this method. If few bass are present, restock the pond with 50 advanced (6- to 8-inch) bass fingerlings or 20 adult bass (10+ inches) per acre. If overcrowding is not too severe, winter drawdown may correct the problem by concentrating the stunted sunfish, allowing bass to consume the surplus fish. Drop the water level in mid to late October to reduce the pond surface area by 30 to 50 percent. Begin refilling the pond in time to ensure that it is full before spawning season; usually February 1 is a safe date. If overcrowding persists, the pond should be drained, treated with rotenone (reclaimed), and restocked with the correct bass-to-bluegill ratio.

Undesirable Fish Population. Fish removal or drawdowns are rarely effective in eliminating populations of undesirable fish species. Corrective stocking or largemouth bass harvest management to maintain high bass density can help control crappie or other species prone to overpopulation. Otherwise, the last resort is pond reclamation and restocking to establish a successful bass-bluegill fishery. Colonization by unwanted fish species is unavoidable in ponds connected to streams or swamps, or subject to flooding by rivers. Otherwise, establishment of unwanted fish populations is most often due to introductions by people.

Methods for Determining Pond Balance

I. Angler Method

Harvest Data	Population Condition
Bluegill 6 inches and larger. Bass average from 1 to 2 pounds, although smaller and larger sizes also caught.	Balanced population.
Bluegill average more than 1/3 pound. Bass average less than 1 pound and are in poor (skinny) condition.	Unbalanced populations with bass overcrowded. (May be desirable if large sunfish are preferred.)
Principally small bluegill, 3 to 5 inches long. Very few bass are caught, and those caught are larger than 2 pounds in size.	Unbalanced populations with bluegill overcrowded and stunted (May be desirable if trophy bass are the primary objective.)
Small crappie, sunfish, bullheads, carp, suckers, or other undesirable fish of any size.	Undesirable fish population.

II. Seining Method

Fish Collected by Seining	Population Condition
Young bass present. Many recently hatched bluegill. Few 3- to 5-inch bluegill.	Balanced population.
Young bass may or may not be present. Many recently hatched bluegill. No or few 3- to 5-inch bluegill.	Unbalanced populations with bass overcrowded.
No young bass present. No recently hatched bluegill. Many 3- to 5-inch bluegill.	Unbalanced population with bluegill overcrowded.
Young bass present. No recent hatch of bluegill. No 3- to 5-inch bluegill.	Unbalanced population. Bluegill absent.
No game fish species present. Few to many carp, suckers, bullheads, shad, or other undesirable species.	Undesirable fish population.

3 Pond Management

Liming

Some ponds benefit from the occasional addition of lime. Ponds with very soft, acidic water (less than 20 parts per million total alkalinity) will not be very productive, and also may not respond to fertilization, unless they are limed. Ponds with acidic waters (water having a low pH value) are common in many areas of North Carolina especially in the coastal plain. Fishing will usually be poor if the pH is below 6.0. A pH value between 6.5 and 9.0 is considered optimum for fish ponds. If alkalinity is maintained above 20 parts per million, pH will stay in the desirable range. Water pH and alkalinity can be measured with inexpensive water testing kits (look for kits with 5-ppm resolution). You can also send a water sample to the NCDA Solution Analysis Laboratory for analysis, for a small fee. More information on this service is available at www.ncagr.gov/agronomi/uyrsoln.htm or call 919-733-2655.

However, a soil test from the NCDA Soil Testing Laboratory is the best way to determine how much lime your pond needs. For more information see www.ncagr.gov/agronomi/sthome.htm or call 919-733-2655. There is a small fee during peak season. For existing ponds, randomly collect six soil samples per acre throughout the pond from a boat using a can nailed to the end of a pole to form a scoop or collect soil plugs using a PVC pipe. Combine and mix the samples thoroughly, spread the sediment on a piece of plastic and allow it to dry. Then place the sample in a shipping box available from your local Cooperative Extension center, label it as a pond sample, and mail it. The soil analysis you receive will indicate how much lime your pond needs.

The lime should be distributed as evenly as possible over the entire pond. A common method for applying lime is to shovel it or wash it from a plywood platform while moving around the pond in a boat. Late fall or early winter is the best time to apply pulverized lime, so it will dissolve sufficiently before the next growing season. A typical pond requires retreatment with lime every three to four years, although ponds with high rates of inflow and outflow require more frequent applications.

New ponds are easiest to lime while they are still empty. Before the pond is filled, collect soil samples for analysis following the procedure described above. Lime, if required, can be spread over the bottom of the pond and disked in before the land is flooded. Hydrated or builder's lime (calcium hydroxide) is generally not recommended, as it is caustic and has the potential to increase pH too quickly, killing the fish.

In some situations, "liquid" limestone may be a useful alternative to pulverized limestone. Liquid lime (not to be confused with hydrated lime) consists of extremely finely ground limestone suspended in water. Its small particle size allows it to dissolve rapidly and completely, so it can quickly increase the alkalinity and can be applied in the spring or during the growing season. Liquid lime is heavier than water, so it should be mixed with water and spread evenly over the pond surface. Liquid lime may not be as efficient as pulverized lime for treating ponds with a high lime requirement.

Fertilization

As with land and crops, the fertility of the water determines the productivity of a pond. A typical pond supports 100 to 150 pounds of fish per acre. Proper fertilization can double or triple this production by stimulating the growth of microscopic plants (phytoplankton) and animals (zooplankton), which comprise the base of the food chain (Figure 8). These organisms are fed upon by insects and small fish, which provide forage for larger game fish.

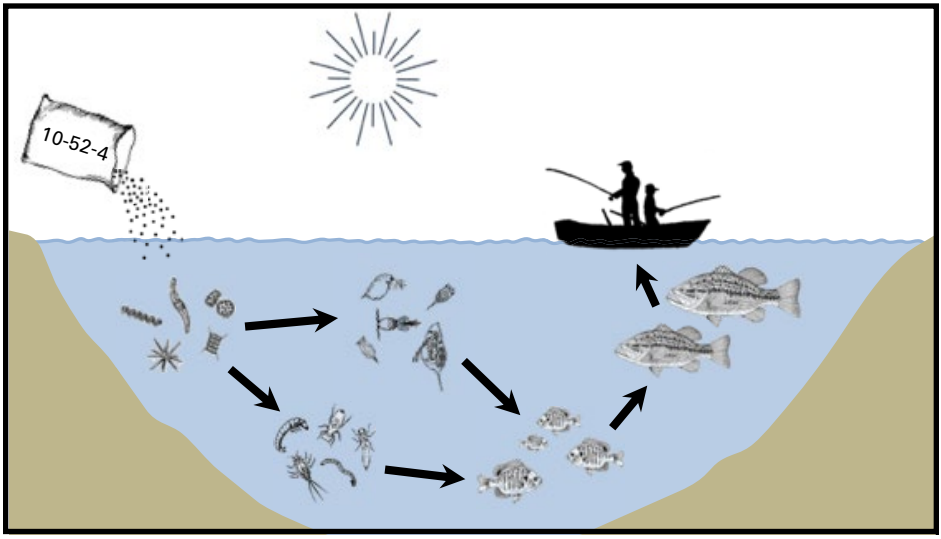

Figure 8. The aquatic food chain.

Pond fertilization can, however, have negative side effects. Excessive fertilization can create noxious algal blooms. In addition, the decomposition of dead algae during summer months can cause low oxygen levels, which may cause fish kills during extended periods of cloudy weather.

Fertilization is an advanced pond management option that is not recommended for everyone. Ponds that are naturally fertile, have high flow rates, or don't

get heavy fishing pressure should not be fertilized. Fertilization can increase productivity, but it takes time and money, and must be done correctly to avoid problems.

Fertilization should only be considered for ponds that have adequate alkalinity, low suspended clay turbidity, and no weeds or filamentous algae. If these criteria are met and a light-colored or shiny object, such as your hand or a small (6-inch) pie tin or lid, can be seen clearly more than 18 inches under water, fertilizing is an option.

Before beginning a fertilization program, measure the pH and alkalinity of the water, or have the pond soil analyzed, as described above. Ponds with alkalinity below 20 parts per million usually don't respond to fertilization and need to be limed first. Apply lime at least two weeks (preferably several months, if using pulverized limestone) before fertilization. For many ponds, liming as necessary may support adequate pond productivity without fertilization.

Once begun, fertilization should be continued from year to year. Discontinuing fertilization will affect fish populations by reducing the food supply and will encourage the growth of filamentous algae and other undesirable aquatic vegetation. *It is better not to fertilize at all than to do so in a random manner*. Do not fertilize ponds that have extensive shallow areas. *Do not apply fertilizer to ponds with weeds already present, as the fertilizer will promote weed growth and compound the problem*.

Begin fertilization in spring when water temperatures reach 60° to 65°F. The number of applications of fertilizer needed per year may vary. Usually two to three applications, spaced two weeks apart, are required for a plankton bloom (greenish color) to develop. After the initial application, apply additional fertilizer whenever water clarity exceeds 18 inches to maintain a bloom through July.

Fertilization may not be effective in ponds with high flow rates, muddy water, or stained water. If a bloom does not develop after the third application, consult your Extension agent or NCWRC District Fisheries Biologist.

Several types of soluble powder, liquid, and granular pond fertilizers are available. Search online for local suppliers of pond fertilizers in your area. Most fertilizers are sold with three main nutrients, nitrogen-phosphorus-potassium (N-P-K), and the values given are the percentage of each nutrient. Of these, phosphorus is usually the most important nutrient in ponds. Most agricultural fertilizers do not have the best combination of nutrients for ponds. They include components that are unnecessary and may stimulate an undesirable type of algae. Application rates vary depending on chemical composition and

type of fertilizer, taking into account the amount of phosphorus that actually enters the water and becomes available to the phytoplankton. Ponds with higher alkalinity will require somewhat higher application rates. The following types of fertilizers and application rates are recommended.

Fertilizer Type	Application Rate (low alaklinity to high alkalinity)
Water-soluble powder (10-52-4, 12-49-6 or similar)	4 to 8 pounds per acre
Liquid (10-34-0, 11-37-0 or similar)	1/2 to 1 gallon per acre
Granular	
20-20-5	13 to 26 pounds per acre
0-20-0	8 to 16 pounds per acre
0-46-0	4 to 8 pounds per acre

Generally, water-soluble powder and liquid pond fertilizers are the easiest to apply and most economical. Soluble powder fertilizer requires the least labor because it goes into solution immediately and can be applied directly to the pond without mixing with water first. Because liquid fertilizer is heavier than water, it should always be mixed with water (one part of fertilizer to five parts of water) before application. Otherwise it will sink to the bottom where the nutrients may be chemically bound up by the pond mud. It is best to siphon or pour diluted liquid fertilizer from a container while moving over the pond in a boat. If this method cannot be used, the diluted fertilizer can be sprayed or splashed around the edge of the pond, although this sometimes encourages the growth of undesirable algae and weeds.

Granular fertilizer should not be applied directly to the pond bottom because contact with the pond mud can bind the nutrients, and fertilizer on the pond bottom can encourage weed growth. Instead, it should be spread on a platform 12 to 18 inches below the surface so that it will be dissolved and dispersed by water currents. The platform should be located 10 to 15 feet from the bank. In watershed ponds, it should be placed in the upper two-thirds of the pond, away from the drainpipe. For ponds of 3 acres or less, a platform with 9 square feet of surface area is adequate. Ponds of more than 3 acres require a platform for every 4 to 5 acres. As an alternative to using a platform, you can make an X-shaped cut on the front of the fertilizer bag and carefully sink it in shallow water with the opened side facing up. Granular fertilizer can also be mixed thoroughly with water to dissolve the nutrients and the solution can be spread around the pond from the bank or by boat.

Supplemental Feeding

Supplemental feeding can be used to increase the growth of fish and harvesting rates of ponds. Feeding is not necessary for most ponds, as an adequate quantity of natural food organisms (insects, worms, and crustaceans) is present to support fish populations. In small, infertile ponds, supplemental feeding may be preferable to fertilization for increasing productivity. Heavy feeding is not recommended for fertilized ponds. Moderate to light feeding can be used to attract fish.

Bluegill, hybrid sunfish, and channel catfish will readily take feed, whereas largemouth bass usually do not. However, some commercial hatcheries sell "trained" bass that have been conditioned to consume artificial feed. Note that grass carp will also eat pelleted feeds, which may reduce their effectiveness controlling aquatic vegetation.

Feed only between spring and fall when the water temperature exceeds 65°F. Stop feeding if the water temperature is greater than 90°F as fish will generally not feed at higher temperatures. It is best to place the feed in the pond daily at one location for every 5 to 10 acres. Feed only the amount that the fish consume in about 10 to 15 minutes and no more than 10 pounds per acre, per day. Excessive feeding can cause fish kills because the decomposition of uneaten feed depletes the oxygen supply. Ponds receiving substantial feeding may benefit from installation of an aeration device to minimize risk of a fish kill. Discontinue feeding if the fish stop accepting the feed. Automatic and demand feeders are commercially available. Be sure to continue a feeding program once you have started it. If feeding is discontinued while the fish are still accepting feed, there may be more fish than the natural food supply can support, resulting in stunted fish of poor quality. Occasional feeding will do little to increase fish growth but will attract fish to an area.

Several commercial feed preparations for fish are available in either floating or sinking varieties. Floating feed is usually the best choice as it will allow you to observe the extent and duration of feeding and minimize waste. Fish have different nutritional requirements than other animals, so choose a commercial feed specifically formulated for fish, with 28 to 32 percent protein. Feeds with higher levels of protein are available but are generally more expensive and do not perform better than lower protein formulas. If feeding bluegill, a mixture of fingerling and grow-out size pellets is recommended. Floating feed can be placed in floating plastic rings that prevent the pellets from washing ashore. Moldy feed should not be used, as it can be toxic to fish.

Habitat Improvement

Various structures can be used in ponds to concentrate fish and improve fishing. Best results are obtained in ponds that are devoid of natural cover such as stumps, tree tops, and aquatic vegetation. The structures should be located within casting distance of the shoreline or piers. Floats can be used to mark the location of the structures. Tall attractors will be more effective than short ones. These structures generally do not increase productivity but will concentrate fish where anglers can find them. Remember that more habitat is not always better. Typically, structural habitat should not exceed 25 percent of the pond bottom. Too much structural habitat can create conditions where predatory fish cannot capture prey because they can hide in the habitat.

Brush Piles. Any available woody material can be used to make a brush pile. The more vertical the pile, the better. Cedar and discarded Christmas trees can be set into cement blocks, secured with polypropylene rope, and set upright on the pond bottom. Several trees located together work better than single trees. Brush piles generally have to be replaced every few years. Simply cutting a tree and dropping it in from the shoreline can create an instant fish attractor.

Stake Beds. Any type of untreated wooden stakes can be driven into the pond bottom or nailed to a weighted frame and sunk. The stakes should be placed 6 to 8 inches apart, and the bed should cover an area of about 200 square feet. One good strategy is to place stakes so they extend from the shoreline into water that is 6 to 8 feet deep. The tops of the stakes should extend out of the water so they can be located easily. Pieces of plastic pipe can also be used as stakes (Figure 9).

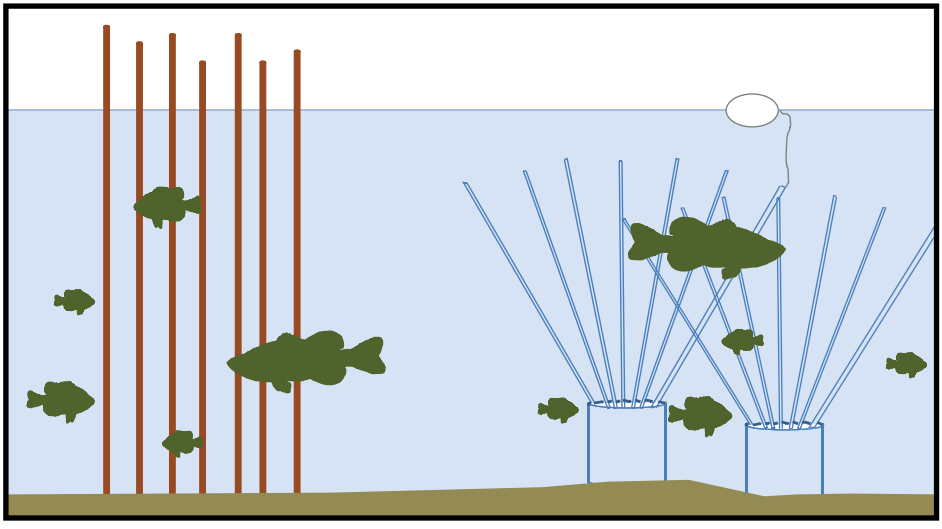

Figure 9. Stake bed (left) and artificial structures (right).

Artificial Structures. Effective fish attractors can be made with artificial materials such as PVC pipe or flexible plastic tubing. These structures will last much longer than brush or wood and are less likely to snag fishing lures. Pipe or tubing of various lengths can be embedded vertically in several inches of cement in the bottom of a plastic tub or barrel. Prefabricated plastic fish attractors of various designs are also commercially available (Figure 9, page 26).

Automobile Tires. Tires are no longer recommended for construction of fish attractors in ponds, as degradation of the rubber can result in leaching of chemicals that may be harmful.

Aquatic Vegetation. Aquatic plants can provide habitat structure for fish, and some species may attract other wildlife such as waterfowl or increase the abundance of invertebrates fed upon by small fish. However, aquatic vegetation is not necessary for good fish production; excellent fisheries can readily be maintained in ponds with no vegetation at all. Aquatic vegetation can overtake a pond and cause major management problems, so carefully consider the risks before introducing any plants. If you decide to establish vegetation in your pond, use only native species and never exotic species. Many of the plants sold for use in water gardens can become major pests in ponds. Keep in mind that even native species of aquatic vegetation can become a nuisance in pond environments. In addition, planting material may be contaminated with invasive hitchhikers that could be introduced to your waterbody. If you do decide to establish vegetation, be extremely careful with source material and cleanliness of the planting stock.

When selecting plant species, consider the physical makeup of your pond. Emergent plants like pickerelweed that are restricted to shallow water are the best choices. Free-floating species should never be used because they will spread over the entire pond, and it can be difficult to detect expansion of submersed species until it has already become a problem. Before introducing any plant species to your pond, make sure you know what it is and what control options you will have if it becomes a problem. Remember, it is much easier to keep vegetation out of your pond than to manage or remove it once established. Contact your local Extension agent or NCWRC District Fisheries Biologist for more information or visit aquaticweeds.wordpress.ncsu.edu.

To find a NCWRC District Fisheries Biologist visit:
ncwildlife.org/Portals/0/Fishing/documents/fisheries_NC_map.pdf

4 Solving Problems

Fish Kills

Fish die from a variety of natural causes. Observing a few dead fish in a pond is not uncommon and is no reason for concern unless it continues for several days. When fish die in large numbers, however, there is reason for concern.

The most common cause of fish kills is oxygen depletion. This condition usually occurs during summer in very fertile ponds as a result of pond turnover or the die-off of an algal bloom but can occasionally occur at other times of the year. During hot weather, most ponds have a layer of cooler, denser water near the bottom that contains little or no dissolved oxygen (Figure 2, page 6). When high wind or cold rain causes this water to mix with the warmer, less dense upper pond water, oxygen levels often drop low enough to kill fish. Oxygen depletion also occurs when dead algae or other plants decay in the pond after herbicides have been applied to control weeds.

Preventing oxygen depletion is difficult, but the following suggestions may help:

- If fertilizing, follow the prescribed guidelines and **do not overfertilize**!
- Do not allow livestock to wade in the pond or animal waste to enter the pond.
- Do not treat aquatic weeds with herbicides during the summer months without consulting a weed control specialist, fisheries biologist, or Extension agent. If herbicide application is necessary, treat no more than one-fourth to one-third of the pond at a time and wait 5 to 7 days between treatments to prevent oxygen depletion and a resulting fish kill. Aerating the pond (see below) can also help reduce the chances of an oxygen-depletion fish kill.
- During extremely hot, cloudy weather, check your pond regularly at sunrise for signs of stressed fish. If fish are observed at the pond's surface gulping for air, stop feeding the fish and aerate the pond immediately. In an emergency, oxygen can be added to the pond by circulating the water with an irrigation pump or by running an outboard motor in the pond. If using a pump, pick up surface water and spray it out horizontally near the water surface to create as much surface water movement as possible. Aeration is most important at night, as this is when oxygen becomes most depleted.

For ponds that are prone to fish kills or are heavily managed, installation of an aeration system may be worthwhile. Commercial aerators vary widely in

design and effectiveness. The most effective systems create a circulation pattern that brings water from the bottom to the surface; this breaks down stratification and keeps the whole pond oxygenated. Diffuser systems create this circulation pattern by generating a column of bubbles that can both oxygenate and circulate the water. Surface aerators that draw water from just below the surface efficiently add oxygen to the upper layer of the pond and are good for shallow ponds. They do not break down pond stratification or oxygenate the bottom water in deeper ponds but can provide an oxygenated refuge during low-oxygen events. Fountains that spray water high in the air are relatively inefficient as aerators.

Although fish kills caused by pesticides, herbicides, or other chemicals are not as common as those caused by oxygen depletion, some do occur. If you suspect that your fish were killed by a pesticide or herbicide, try to determine what chemical was involved and call the NCDA Pesticide Section in Raleigh, North Carolina (919-733-3556). For fish kills caused by other chemicals or animal waste spills, call the NCDEQ Division of Water Resources in Raleigh, North Carolina (800-858-0368).

Be very careful when spraying herbicides or other pesticides near ponds, as many are highly toxic to fish. *Always read and follow label instructions!*

Fish kills resulting from low pH (acidic water) are even less common than chemical kills. Usually pH kills occur when heavy rains wash tannin (an acidic substance found in leaves) from wooded areas. Low pH can be increased by applying agricultural limestone. The amount of lime required can be determined by sending samples of the soil from the pond bottom to the NCDA Soil Testing Laboratory for analysis. (See previous section for liming procedures.) Contact your local Cooperative Extension center for assistance in sending soil samples.

Fish kills caused by diseases usually occur when fish are already stressed by poor water quality or overcrowding. In most situations little can be done once a disease strikes except wait for it to run its course and see what is left. Remove as many dead fish as possible during an outbreak to reduce reinfection of other fish and minimize oxygen depletion. Here again, prevention is the key: fish the pond properly, maintain good water quality, and watch for signs of problems such as poor fish growth, thin fish, and excessive numbers of small fish.

Fish Parasites

Wild fish normally carry a variety of parasites, and usually show no negative effects unless the infection is extremely heavy. Few freshwater fish parasites

can be transferred to humans, mainly via consumption of raw or undercooked fish. While parasites are aesthetically unappealing, the flesh of infected fish is still edible when fully cooked or frozen at -4°F for seven days.

The parasites most frequently observed by anglers are the yellow grub and the black grub or black spot parasite. The yellow grub is the larval stage of a trematode worm. It forms small whitish or yellowish cysts in the flesh and near or just beneath the skin. Black grub parasites are also the encysted larvae of trematode worms and appear as a small black spot about the size of a small pinhead, in or just beneath the skin. Both parasites have a complex life cycle involving snails, fish, and fish-eating birds such as herons or kingfishers. The adult worms live in the mouth and throat of fish-eating birds and shed their eggs into the water as the bird feeds. The eggs hatch and the free-swimming larvae infect snails. Later, advanced larvae emerge from the snail and penetrate the skin of a fish. When the fish is eaten by a bird, the cycle is completed.

There are no chemical treatments available to eliminate parasites in pond situations. However, snails are a preferred food of redear sunfish, so establishing a good population of these fish in the pond may help disrupt the life cycle of parasitic trematodes.

Poor Fishing

Most complaints about poor fishing stem from crowded or stunted bream (bluegill) or bass populations. The best way to prevent these problems is to fish the pond properly. Correcting an unbalanced fish population is a lot more trouble than keeping it in balance from the start. If a fish population becomes unbalanced with too many small bream, it may be possible to correct the problem by removing excess bluegill, or by stocking 20 largemouth bass (10+ inches) per acre up to 50 per acre in extreme circumstances. This solution may be prohibitively expensive, however, as bass in this size range are costly. Stunted bass populations can be corrected by removing excess bass (see earlier section).

Sometimes poor fishing can result from competition of game fish with undesirable fish such as wild sunfish, shiners, bullheads, and crappie. These fish may enter the pond via feeder streams or be purposely stocked by anglers with good intentions. Again, prevention is much easier than the cure. When building a new impoundment, make sure that all wild fish are eliminated before stocking the pond with hatchery fish. Also, do not place wild fish in the pond or use minnows as bait.

Aquatic Weeds

Healthy ponds often contain some aquatic vegetation. However, an overabundance of aquatic weeds often causes serious problems in ponds, interfering with fishing, boating, swimming, and irrigation. In addition, when vegetation is dense, bream often become overcrowded and stunted because the weeds prevent bass from adequately reducing their numbers. Extremely dense growths of filamentous algae and submersed weeds may also cause fish kills as a result of nighttime oxygen depletion. It is best to control aquatic weeds before they become problematic. Most aquatic weed problems stem from excessive nutrient inputs. Vegetation control methods treat the symptoms but do not address the underlying causes. For persistent problems, long-term control may require actions to reduce nutrient loading.

Just as for terrestrial weeds, it is critical to accurately identify the species of aquatic weeds or algae to determine the proper control measures. For assistance identifying aquatic vegetation and appropriate control alternatives, contact your local Cooperative Extension center. More information is available on the NC State University Aquatic Plant Management website at aquaticweeds.wordpress.ncsu.edu.

Weeds that root to the bottom or begin forming on the bottom are usually a problem only in ponds that are shallow or have shallow areas (water less than 24 inches deep). Any time sunlight can penetrate to the pond bottom, rooted aquatic weeds and filamentous algae may become established. Once established, many weeds can spread to deeper water.

Problems with planktonic algae and floating weeds, such as duckweed, usually develop in very fertile ponds. Ponds that receive runoff from livestock operations or other nutrient-rich areas are prime candidates for duckweed and algal problems. The following methods have proven effective in North Carolina for controlling aquatic vegetation.

Triploid Grass Carp. These vigorous, fast growing, reproductively sterile, herbivorous fish can be used to control unwanted aquatic vegetation under certain conditions. They are an effective biological control agent for submersed weeds such as hydrilla, chara, elodea, widgeongrass, bladderwort, fanwort, coontail, pondweed (Potamogeton), and naiads. Grass carp do not consistently provide control of duckweed, Eurasian watermilfoil, variable leaf milfoil, parrotfeather (except at a high stocking density of 25 per acre), and some types of algae, so they are not usually recommended for these species. They are not effective in controlling watermeal, eelgrass, smartweed, American lotus, yellow waterlily, fragrant waterlily, maidencane, dollarweed,

alligatorweed, torpedograss, and cattails. Grass carp grow large and provide effective control for five to eight years. Recommended grass carp stocking rates are generally 10 to 15 fish per acre in small ponds and 10 to 20 fish per vegetated acre in larger impoundments. Stock large fish (10 to 12 inches long) to reduce losses from predation by largemouth bass and wading birds. Given the opportunity, grass carp will try to move upstream or downstream. To protect your investment and prevent damage to native vegetation downstream, make sure that grass carp cannot readily escape from your pond.

Only grass carp that have been genetically manipulated to make them triploid (unable to reproduce) are allowed. A permit is required to stock grass carp in North Carolina. The receipt from a licensed triploid grass carp distributor can be used as the stocking permit if all four of these criteria are satisfied:

- your pond is less than 10 acres
- your pond is solely owned by you or a single entity (for example, a neighborhood association)
- you intend to stock no more than 150 grass carp
- your pond is self-contained (no direct connection to a stream or other water body)

If your situation does not meet all of these requirements you must apply for a permit from the NCWRC. For more information and a permit application, visit ncwildlife.org/ Stocking-Permits or contact your District Fisheries Biologist.

More information is available in Extension publication AG-456, *Using Grass Carp for Aquatic Weed Management,* available online at content.ces.ncsu.edu/using-grass-carp-for-aquatic-weed-management-in-north-carolina. Be sure to purchase your grass carp from a licensed grass carp supplier; the NCDA maintains a list of licensed suppliers in North Carolina at: ncagr.gov/markets/aquaculture/grasscarp.htm.

Chemical Treatment. Weeds can be killed by treating the pond with one of the herbicides labeled for aquatic use. To determine which herbicide to use, get an accurate identification of the plant(s) from a Cooperative Extension agent or other qualified individual. Unfortunately, herbicides only treat the symptoms and do very little to cure the problem. Weeds frequently return soon after treatment if no action is taken to deepen the pond or eliminate the nutrient source. Be sure to apply the chemical according to label instructions and follow any restrictions on fish consumption, irrigation, swimming, livestock watering, or other uses.

Winter Drawdown. Reducing the surface area of a pond by one-third to one-half from mid-November to the first of February helps control many submersed rooted aquatic plants by exposing them to drying and freezing. A side benefit in bass-bluegill ponds is improved fish population balance resulting from increased predation by bass on bluegill forced out of cover. Unfortunately, some weed species, such as hydrilla, cannot be controlled by winter drawdown because they produce tubers or other overwintering reproductive structures. Winter drawdown is not recommended in ponds of less than 1 acre.

Manual Weed Removal. Removing plants by methods such as pulling, raking, or chaining works best on small patches of plants that are rooted in shallow water. Manual removal is most effective if performed in late spring or early summer before the plants form seeds. Be sure to dispose of the vegetation properly, especially alligatorweed, which may root and grow on dry land.

Pond Deepening. Deepening all areas of the pond to a minimum of 24 inches will reduce weed infestations. Most pond owners use this method as a last resort, but for shallow ponds it is often the only lasting solution.

Pond Dyes. Adding a non-toxic pond dye to your pond is another way to help prevent weed problems. Pond dyes turn the water a bluish-green color and help control weeds by shading the bottom so plants can't get established. They should not be used in ponds that are fertilized, because they will interfere with plankton bloom development.

Barley Straw. Many private companies market barley straw for algae control treatment in water gardens or ponds. Anecdotal reports range from success to failure; however, results of scientific testing in the United States have not been favorable. Small-scale tests have been inconsistent and field tests have generally been negative or inconclusive, so this treatment is not recommended.

Nuisance Animals

Several kinds of animals can cause problems in your pond. Descriptions of the most common ones are given below and, in some cases, removal is necessary.

Mammals. There are several species of mammals that can cause physical damage to the dams and banks of ponds or have negative impacts on fish populations:

Muskrats—Muskrats feed primarily on vegetation. These semiaquatic rodents dig burrows into the shoreline with a 6- to 8-inch diameter entrance below the

water line, often causing pond banks to collapse and dams to leak. Keeping the pond edge mowed and controlling emergent vegetation will discourage muskrats from taking up residence.

Nutria—These semiaquatic rodents introduced from South America are abundant along our coast and have spread throughout the eastern half of North Carolina. They feed primarily on aquatic vegetation, but also can cause damage to crops. Like muskrats, nutria burrow and can result in damage to banks and dams.

Beavers—Occasionally, beavers take up residence in ponds. When they do, they usually cause considerable damage. They girdle or cut down trees, block drain pipes and dam spillways, and dig dens in pond banks and dams.

Otters—Pond owners can be disappointed to find partially eaten fish or scat piles full of fish scales along the banks of their pond, which is a sign that otters may have taken up residence. A family of otters can eat a substantial amount of fish in your pond. Grass carp are among the first fish they will remove, reducing weed control and increasing expense. Fish populations in larger ponds are more resilient to the impacts of otter predation than smaller ponds.

If any of these species become established in your pond, they are best controlled by trapping. If you do not want to trap them yourself, contact a licensed trapper or wildlife damage control agent to do the job. For a list of licensed trappers visit the NCWRC webpage at: ncwildlife.org/Trapping/Contact-a-Licensed-Trapper. Muskrats, otters and, beavers should be trapped during the regular trapping season by a licensed trapper unless a depredation permit has been obtained from the NCWRC. Nutria may be hunted year-round with a hunting license and may be trapped year-round East of I-77 with a trapping license. Contact your District Wildlife Biologist for more information on controlling these animals if they become a nuisance.

Turtles. These slow-moving creatures are omnivorous, opportunistic feeders and scavengers, and they do not harm fish populations. They may, however, eat fish off a stringer, or in the case of snapping turtles, eat a few ducks or live fish. For most turtles found in North Carolina ponds, harvest or relocation of more than four individuals is not permitted. Holders of a Wildlife Collection License may harvest up to 10 snapping turtles per day and 100 per year, and they must exceed 11 inches in shell length. Snapping turtles can be caught on large set hooks baited with scrap meat or fish, or they can be baited into wire baskets.

In general, turtles recolonize ponds quickly and removal is only temporary. Turtle harvest regulations can be found at the NCWRC website ncwildlife.org and in the Inland Fisheries, Hunting, and Trapping Regulations Digest.

Snakes. Most snakes seen in and around ponds are nonvenomous water snakes. Snakes do not pose any fishery management problems for pond owners. However, they can be unsettling to some individuals. The best way to control snakes is to keep the pond banks mowed, which eliminates their hiding places.

Waterfowl. Resident waterfowl such as domestic geese and ducks may cause problems if they become too abundant, especially in small ponds. They can cause turbidity and algal problems, damage shoreline vegetation, leave unsightly droppings on pond banks and piers, and cause unsafe levels of fecal bacteria in the water. They may also become aggressive during nesting season. If it becomes necessary to remove waterfowl, contact a licensed wildlife damage control agent. A list of agents by county is available at ncwildlife.org/Trapping/Wildlife-Damage-Control-Agent.

Double-crested Cormorants. These fish-eating birds consume 1 pound of fish per day on average, so a flock that takes up residence on a pond can significantly impact fish populations. Lethal control methods require federal and state depredation permits, but these are not issued for control on recreational fishing ponds. A variety of noisemaking and pyrotechnic devices have been used with varying success to disperse cormorants. Live ammunition fired near the birds often is the least expensive and most readily available form of frightening device. Harassment is most effective before birds have become habituated to a location. For assistance, contact a licensed wildlife damage control agent.

Muddy Water

The first step in clearing a muddy pond is to eliminate the source of the turbidity. Common causes of muddy water are runoff from nonvegetated acreage in the watershed, livestock wading in the pond, or some undesirable fish species (such as common carp or bullheads) stirring up the bottom of the pond. After the source of the turbidity has been eliminated, the water will usually clear naturally, but this may take from several weeks to several months, depending on the soil type in the watershed. However, some ponds may not clear naturally because their water chemistry keeps the clay particles from settling out. To determine if this is the case, collect some pond water in a clear jar and allow it to settle for a week. If most of the sediment settles to the bottom, then the source of turbidity is likely physical. If the sediment stays

suspended in the jar, then the water chemistry of the pond is causing the clay particles to stay suspended.

In moderate cases, liming may effectively clear the pond. Given the other benefits of liming, this is often a good first option. Chopped hay or cottonseed meal can reduce turbidity in a pond but is not optimal because uniform application is difficult, and as these organic materials decompose, reductions in dissolved oxygen can be harmful to fish. The methods described below have proven successful in clearing persistently muddy ponds.

Gypsum. Gypsum (land plaster) dissolves slowly but works well to clear muddy water and also adds beneficial micronutrients and increases hardness. In ponds that already have hard water (calcium hardness ≥ 50 ppm), gypsum is not effective. The gypsum should be finely ground and spread over the pond's surface. Application rates will vary depending on the average pond depth, water chemistry, and how turbid the pond is. As a general rule for ponds with moderate turbidity (visibility less than 12 inches) apply 1,000 pounds per acre. Ponds that are more turbid (visibility less than 6 inches) may require up to 2,000 pounds per acre. More precise application rates of gypsum can be determined to reduce cost while maintaining effectiveness based on the average depth of the pond and preliminary testing. This can be achieved by testing different application rates in 5-gallon buckets of pond water. These instructions are derived from the Southern Regional Aquaculture Center publication number 460, available online at appliedecology.cals.ncsu.edu/wp-content/uploads/SRAC-0460.pdf. Fill four 5-gallon buckets with pond water leaving 3 inches of head space from the rim. Measure out the amount of gypsum indicated in the table below (2, 3, 4, or 5 grams) and pour into each bucket. Stir for 1 to 2 minutes and then briefly every 5 minutes for up to 30 minutes. Observe the clarity of the water and determine the smallest dose that achieves the desired level of clarity. Next determine the average depth of the pond by taking 10 to 20 depth measurements throughout the pond and averaging them. Use the amount of gypsum in grams and the average depth in the table below to determine the application rate per acre. To estimate the total amount of gypsum needed to effectively treat the pond, multiply the pounds per acre value in the table below by the total surface acres in the pond. Applications are more effective during periods of calm weather as wind action can keep particles suspended.

Gypsum application rate (pounds per acre) based on bucket test and average depth of pond.

Bucket	Gypsum added to Bucket (grams)	Average Pond Depth (feet)						
		2	2.5	3	3.5	4	4.5	5
1	2	600	750	910	1,060	1,210	1,360	1,510
2	3	910	1,130	1,360	1,590	1,810	2,040	2,260
3	4	1,210	1,510	1,810	2,110	2,420	2,720	3,020
4	5	1,510	1,890	2,260	2,670	3,020	3,020	3,370

Buffered Alum. Alum (aluminum sulfate) also effectively clears muddy waters. Compared to gypsum less alum is required per treatment, but it is more expensive, removes more phosphorus from the water, and it should not be used repeatedly to avoid aluminum toxicity. Application of unbuffered alum can cause a sharp decrease in water pH that may be harmful to fish, so buffered alum should be used. If buffered alum is not available, you can add hydrated lime at a ratio of 0.5 part hydrated lime to 1 part alum to achieve the same results. As for gypsum, application rates will vary depending on the average pond depth and how turbid the pond is. For ponds with moderate turbidity use 150 pounds of alum per acre. For more turbid ponds use up to 250 pounds per acre. To determine a more accurate application rate of alum, use the table below and follow instructions for the bucket test as described earlier for gypsum.

Alum application rate (pounds per acre) based on bucket test and average depth of pond.

Bucket	Alum added to Bucket (grams)	Average Pond Depth (feet)						
		2	2.5	3	3.5	4	4.5	5
1	0.2	60	75	91	106	121	136	151
2	0.3	91	113	136	159	181	204	226
3	0.4	121	151	181	211	242	272	302
4	0.5	151	189	226	267	302	340	377

5 Sources of Additional Information

Information on pond stocking, fingerling and grass carp suppliers, pond management, and aquatic weed control is available from NC State Extension. Contact your local Cooperative Extension center or visit the NC State Fisheries Extension web site: cals.ncsu.edu/applied-ecology/extension/fisheries.

Information on application rates, effectiveness, and water-use restrictions for aquatic herbicides may be found in the *North Carolina Agricultural Chemicals Manua*l, available for purchase at go.ncsu.edu/ncagchem and online at: content.ces.ncsu.edu/north-carolina-agricultural-chemicals-manual.

The NCWRC also can provide information on pond stocking, pond management, reclamation, and grass carp permits. Contact your District Fisheries Biologist or visit the NCWRC webpage at ncwildlife.org. To find the biologist for your county, visit ncwildlife.org/Portals/0/Fishing/documents/fisheries_NC_map.pdf. Further information on pond planning, design, and construction is available from your county Natural Resources Conservation Service office.

Permit information and requirements for pond construction that may affect streams or wetland areas can be obtained from:

U.S. Army Corps of Engineers, Wilmington District Regulatory Division, P. 0. Box 1890, Wilmington, NC 28402-1890 (phone: 910-251-4511, fax: 910-251-4025). www.saw.usace.army.mil/Missions/Regulatory-Permit-Program/Contact (404 permits)

Division of Water Resources, deq.nc.gov/about/divisions/water-resources/water-resources-permits/wastewater-branch/401-wetlands-buffer-permits (401 and buffer permits)

Division of Coastal Management, deq.nc.gov/about/divisions/coastal-management/coastal-management-permits (CAMA permits)

Division of Energy, Mineral and Land Resources, deq.nc.gov/about/divisions/energy-mineral-land-resources/erosion-sediment-control (sediment and erosion control plans)

NCDEQ Division of Energy, Mineral and Land Resources, Dam Safety Program, deq.nc.gov/about/divisions/energy-mineral-land-resources/energy-mineral-land-permits/dam-safety (Information on dam safety and permit requirements)

Natural Resources Conservation Service (advice regarding soil and site suitability for pond construction). To find your local county office, visit offices.sc.egov.usda.gov/locator/app.

Managing Your Pond for Better Fishing

NC State Extension produced a 23-minute pond management video designed to complement this pond management booklet. This video is oriented primarily toward landowners who have a pond, or are planning to build one, and want to manage it for recreational fishing. It illustrates all the key aspects of good pond management, including pond design, fish stocking, harvesting, maintaining pond balance, liming, and fertilization, as well as how to deal with common pond problems such as aquatic weeds, fish kills, and muddy water. Interested individuals can view the video at: appliedecology.cals.ncsu.edu/extension/fisheries/pond-management-guide/pond-management-video. You may also purchase a DVD copy by sending a check for $15.00, payable to NC State University, to:

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