A Review of Some Basic Principles in Fishpond Management

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Abstract: A review of some basic principles in fishpond management was reviewed to educate fish culturist, private and public sector to effectively manage culture fisheries. Successful pond management requires more than just stocking fish. It is also important to maintain the proper environmental conditions, to monitor fish harvest and growth, check for successful fish reproduction, and to keep out unwanted fish. This is the science of fish management, the solid basis for ensuring good fishing. Good fish management begins with an understanding of your pond’s physical, chemical, and biological features. Pond ecology, fish biology, site selection. Construction, liming, fertilization, brackish water pond management, culture species, stock management, managing fish population, management system, harvesting, fresh water pond management, fish species selection, fish stocking in fresh water ponds, stocking density, feeding, pond testing, diagnosing problems in pond, correcting muddy ponds, fish kills, aquatic weed control, managing other animals, habitat, pond renovation, fish harvesting in fresh water ponds, marketing and legal considerations are other important fish pond management principles the fish culturist need to know.

Keywords: Brackish and fresh water, legal consideration, marketing, pond ecology, pond management, pond renovation

INTRODUCTION

Good fish management begins with an understanding of your pond’s physical, chemical, and biological features. Many new ponds continue to be constructed each year. While most ponds are found in southern Indiana, they are widely distributed throughout the Hoosier state. Besides fishing, ponds provide many important and practical benefits: erosion control, fire control, livestock watering, irrigation, swimming, and picnicking and wildlife enhancement. Successful pond management requires more than just stocking fish. It is also important to maintain the proper environmental conditions, to monitor fish harvest and growth, check for successful fish reproduction, and to keep out unwanted fish. This is the science of fish management, the solid basis for ensuring good fishing (USEPA, 2002).

If you are planning to construct a pond, contact the local Natural Resources Conservation Service office at the county seat. The NRCS can provide the technical engineering advice you need to properly design and construct a pond. But remember, there may be some legal aspects of pond construction that you should consider. Contact your county surveyor, planning commission, or the Department of Natural Resources prior to pond construction to obtain any necessary permits. The NRCS office can also help in making sure your pond meets the legal qualifications. Since you are interested in managing the pond for fishing, several factors should be considered when planning a new pond. Fish ponds should be at least one surface acre in size. Ponds smaller than one acre seldom support a satisfactory fish population over many years. They usually require much more intensive fish management and may not justify the costs (Hill, 1976). Fishing ponds should have a drain line so the pond can be completely drained. The additional construction cost will result in dollars saved over the years. A pond that can be drained is more easily and economically managed for good fishing (RPI, 1985).

Water-level draw downs can be effective in controlling overabundant small fish. Because few ponds provide high quality fishing indefinitely, it may become necessary to eliminate a poor fish population. Some pond owners believe that a deep pond provides better habitat (living space) for fish. This is seldom true. Most deep ponds in Indiana don’t contain enough oxygen for fish in water greater than 15 feet deep during the summer (Prygiel et al., 2000). Only during the spring and fall months, when the water temperatures are changing, does the pond water circulate enough to supply oxygen to the
A pond is like the land around it. There is a limit to what it can produce. While a certain field can produce 100 bushels of corn per acre or a pasture can support two cows per acre, a pond also has a limit to the pounds of fish it can support (Welch, et al., 1977). Just like the land, the upper limit or “carrying capacity” of a pond is influenced by fertility (nutrients available), climate and the type of crop being grown. In a detailed study of 14 Indiana ponds, the total weight of fish ranged from 109 to 703 pounds per acre. The average pond supported 320 pounds of fish per acre. This “standing crop” consisted of 224 pounds of bluegill, 36 pounds of largemouth bass, and 60 pounds of miscellaneous fish per acre. A standing crop of 320 pounds might consist of 320 one-pound fish, or any combination totaling 320 pounds. The important fact is that each pond has a limit to the pounds of fish that it can sustain. The pond owner who understands the concept of carrying capacity will be better able to manage and use the fish crop that the pond produces (USEPA, 2002).

This article is prepared for pond owners who wish to make the most of their pond’s fishing potential. Unfortunately, many ponds do not provide the kind of fishing they are capable of producing. Good fishing does not just happen. It’s the result of proper fish management. By managing your pond wisely, you can look forward to many enjoyable hours of good fishing.

Pond ecology, fish biology, site selection, construction, liming, fertilization, brackish water pond management, culture species, stock management, managing fish population, management system, harvesting, fresh water pond management, fish species selection, fish stocking in fresh water ponds, stocking density, feeding, pond testing, diagnosing problems in pond, correcting muddy ponds, fish kills, aquatic weed control, managing other animals, habitat, pond renovation, fish harvesting in fresh water ponds, marketing and legal considerations are other important fish pond management principles the fish are reviewed in the article to educate culturist.

POND ECOLOGY

Fish culture involves adequate management practices. This depends on the nature of the environment (marine, brackish or fresh water). Pond enrichment involves management practices geared towards increasing the productivity of the abiotic environment (Nwadukwe, 1989). The biotic community in ponds refers to plants and animals that are resident in the pond. The abiotic factors refer to the basic inorganic and organic compounds in the pond environment from which the producers manufacture food (Abowei and Sikoki, 2005). The biotic communities in a pond can be classified as follows: Producers (autotrophs): These are mainly green plants (planktonic and benthic algae), which manufacture food through photosynthesis from inorganic substances (Lim and Kiu, 1995).
The older they get, the more eggs they produce. A four-year-old female produces about 20,000 eggs. Bluegills lay their eggs in shallow depressions, called “beds,” fanned in sandy areas. Bluegills will spawn over most types of bottom and often throughout the summer. Eggs hatch in three to four days. The tremendous reproductive ability of bluegills can cause problems for the fish pond owner. Bluegills often produce more young than the pond can support. When this happens, bluegill growth is very poor and few fish reach sizes desired by the pond owner. Corrective management is then warranted. Bluegills not only provide good fishing and eating, they are a major food item for largemouth bass. In a well-managed pond, bass abundance should remain high enough to control bluegill overabundance (Ajayi and Talabi, 1984).

Largemouth bass: Largemouth bass are the major predators in Indiana fish ponds. Largemouth bass are dark olive-green on the back with green sides shading to a white belly. A dark horizontal band extends on each side from the eye to the tail. The most distinguishing characteristic is its large mouth with the upper jaw extending past the rear margin of the eye. Largemouth bass usually eat smaller fish, primarily bluegills. But often, when crayfish, tadpoles and other minnows are abundant, bass may switch to these food items. On occasion, bass are cannibalistic. Because they are predators, bass bite well on artificial lures that resemble small fish and crayfish. Like bluegill, food availability determines how well they grow (Nwadukwe, 1989).

If forage items are plentiful and accessible, bass grow rapidly. However, many Indiana ponds contain too much cover (aquatic plants usually) that prohibits bass from catching ample food. When this happens, bass growth may decline and prey species become too abundant. Corrective fish management is then needed to increase the efficiency of bass predation. Bass grow about three inches each year for the first four years in northern Indiana ponds and about four inches each year in southern Indiana ponds. They usually live to be six years old with some reaching 10 years and measuring over 20 inches long. Some largemouth bass spawn at age two, but most begin spawning at age three. Three and four year old bass usually produce the most viable eggs, averaging about 10,000 eggs per female. After age six, the number of eggs declines (Atabatele et al., 2005).

Bass spawn once a year when the water temperature reaches 620 F. Bass also build nests, but slightly deeper than bluegill beds. They prefer to spawn in more protected areas than bluegills, usually around aquatic plants. After the eggs hatch, the male keeps young bass schooled for about a week to 10 days. Bass reproduction in Indiana ponds is influenced by environmental conditions much more than bluegill reproduction. Increases in turbidity (muddiness) and rapid changes in water temperature reduce spawning success. Since bass produce fewer eggs and are more susceptible to

Consumers: These are mainly animals, which feed on other organisms or depend on producers for food. Examples are zooplanktons, benthic invertebrates, carnivores, and herbivores.

Decomposers: These are bacteria and fungi, which break down dead organic matter, absorb some of the decomposition products and release inorganic substances such as phosphates and nitrates utilized by the producers. These organisms constitute the pond biota and are present either in the water column or pond bottom. Their abundance, depend on the water quality and soil condition. Pond fish depends on these organisms for food. There is therefore the need for increasing their population. These animal and plant production constitute the natural food for fish in the pond. In fish culture, liming and fertilization are two management techniques employed to generate natural fish food production in ponds (Literathy and Csanyi, 1994).

The application of lime and fertilizer improves the pond condition through increased mineralization. Nutrients are therefore made available for the growth of the natural food: plankton, periphytic and benthos organisms.

FISH BIOLOGY

Bluegill: Bluegills are generally dark olive-green along the back and lighter along the side. They have five to nine dark vertical bars on each side, blue cheeks, and a dark spot at the rear of the dorsal fin. Bluegills do not have a margin on the opercular, “ear”-lobe. Bluegill feed primarily on insects, both aquatic and terrestrial. However, they will often eat snails, small crayfish, zooplankton (microscopic animals), and other fish and fish eggs. Because of their varied diet, bluegills can be caught on many different kinds of baits, including insect larvae (bee moths, spikes, mousies), crickets, grasshoppers, and worm (Ajao and Fagade, 1991). Bluegills avidly hit on artificial flies that resemble aquatic insects. The amount of food each bluegill eats determines how fast it grows. If food is abundant and bluegill numbers are low, they grow rapidly. If food is scarce and numbers are excessive, they grow poorly, or even not at all. Slow growing bluegill populations are the most serious problem in Indiana fish ponds. The simplest pond management techniques focus on maintaining good bluegill growth. Bluegills grow more rapidly in southern Indiana ponds than northern Indiana ponds. This is a result of regional differences in the length of the growing season (climate). They usually reach six inches by age four and their typical life span is six years (Mclusky and Eliot, 1981).

Some bluegills begin spawning in their first year. However, most don’t spawn until they are two years old. The older they get, the more eggs they produce. A four-year old female produces about 20,000 eggs. Bluegills lay their eggs in shallow depressions, called “beds,” fanned in sandy areas. Bluegills will spawn over most types of bottom and often throughout the summer. Eggs hatch in three to four days. The tremendous reproductive ability of bluegills can cause problems for the fish pond owner. Bluegills often produce more young than the pond can support. When this happens, bluegill growth is very poor and few fish reach sizes desired by the pond owner. Corrective management is then warranted. Bluegills not only provide good fishing and eating, they are a major food item for largemouth bass. In a well-managed pond, bass abundance should remain high enough to control bluegill overabundance (Ajayi and Talabi, 1984).
environmental changes, bass reproduction fluctuates dramatically from year to year (Barnes and Hughes, 1988). Weak year-class can trigger population explosions among other fish, especially bluegills. As bluegill numbers expand, they eat bass eggs and fry, further limiting bass recruitment. The pond manager is once again required to initiate corrective management to restore balance in the fish population. While bass are popular to catch, a pond owner must work to keep ample numbers of bass in the pond to control bluegill. In many cases, a bass in the pond is worth two on a stringer (Nwadukwe, 1989).

Channel catfish: “Mr. Whiskers” traditionally found in slow-moving rivers, is equally at home in Indiana fish ponds. Channel catfish are characterized by the lack of scales, their deeply forked tail, and 24-29 rays in their anal fin. They can easily be distinguished from bullheads (see section on Problem Fish) since bullheads have blunt tails. Channel catfish grow well in Indiana fish ponds, usually 3-4 inches per year. They may reach over 20 pounds and are excellent tasting. Unfortunately, reproduction and survival of young channel catfish are severely limited in many Hoosier ponds. Young catfish make easy prey for other fish. You should not expect channel catfish to maintain good fishing without restocking. Channel catfish are “omnivores”. That is, they eat about anything they find. They usually feed on insects, crayfish, and fish, including dead fish. They feed primarily near the bottom and can be caught using worms or “stink baits” (chicken liver). Although channel catfish eat small bluegills, don’t expect them to control bluegill overpopulation (Atabatele et al., 2005).

The channel catfish begins its life in a nest constructed by the male in a secluded, dark, quiet retreat. This may be under a bank or mass of vegetation, or in old tires, tiles or large cans sunk in the water. Spawning occurs in June and July in Indiana when water temperature exceeds 750 F. The female catfish produces up to 4,000 eggs per pound of weight. During their early development, the fry stay packed in a tight ball. This strong schooling instinct is their downfall. Often, the entire school can be consumed by a single bass as the entire school can be consumed by a single bass as the school regroup after each attack. If you want to keep a large channel catfish population, periodic restocking will probably be necessary (Atabatele et al., 2005).

Site selection: The first step in selecting a pond site is to determine why you want or need a pond. If you plan to use a small pond for fishing and irrigation or livestock watering, these uses will often conflict with each other. Pond uses that are more likely to work well together are fishing, swimming, boating, wildlife watching, and fire protection. If you need a pond as a water source for crops or livestock and you want a pond for fishing too, you may want to build separate ponds for each use (Allem, 1989). In general, there are two types of ponds, embankment ponds and excavated ponds. Embankment ponds are constructed by damming a small stream. Excavated ponds are constructed by digging out an area fed by springs and runoff. Embankment ponds can be economically constructed on stream sites where the slope is steep enough to limit the size of the dam. Excavation ponds can be used in a variety of situations, but are typically constructed in flat areas where dams are not practical. Because excavation is very expensive, most ponds over one acre in size are embankment ponds (Nwadukwe, 1989). A good pond site contains all of the following:

- Topography (lay of the land) that allows for economical construction
- Soil with enough clay content to hold water
- A water supply that is adequate, but not excessive, for the intended uses of the pond

It is best to have several site options that are appropriate for the planned uses of the pond. Ponds with dams over 20 feet in height are costly to construct and do not typically provide higher fish production due to the loss of oxygen in the deepest part of the pond in midsummer. In Virginia, ponds should have dams high enough to provide a depth of 6 to 12 feet. Productive fishing ponds usually have 20 or fewer acres of watershed for each acre of pond. The water quality in your pond will vary according to the land uses and geology in the area from which the pond receives runoff (the watershed). If your pond's watershed is used for grazing or crop production, or if it is a dense urban area, poor water quality can result if runoff from the watershed is not filtered before it reaches the pond. A vegetated buffer strip at least 50 feet wide surrounding the pond can serve as a natural filter. If your pond is fed by a stream, the stream should have a vegetated buffer strip along both banks. Livestock must be fenced out of streams above ponds and out of the pond itself. If the pond is being developed for livestock watering as well as fishing, create a livestock water source downstream of the dam (Nwadukwe, 1989).

Construction: The best fishing ponds have a surface area of at least 1 acre. Ponds less than 1 acre in size are more difficult to manage because the fish populations, especially largemouth bass, can be easily overharvested. Small, shallow ponds are more likely to have problems with aquatic vegetation, unbalanced fish populations, and low water levels caused by droughts. Ponds less than 1 acre in size are probably best managed by stocking only channel catfish. The average depth for a fishing pond should be between 6 and 8 feet, with maximum depth not greater than 10 to 12 feet. An average depth less than 6 feet increases the chances of aquatic vegetation problems, and depths greater than 12 feet are not necessary for good

fish production. Pond banks should be a minimum of 3 feet deep at the waterline (Allem, 1989). This bank shaping will help prevent the growth of nuisance aquatic plants (Fig. 1).

An important feature of a fishing pond is the water control structure or drainpipe. This structure will allow you to drain the pond to make repairs, manage the fish populations, and control nuisance aquatic plants. A drainpipe that has a bottom draw maintains good water quality by drawing stagnant water from the bottom of the pond. A trash rack over the standpipe will help prevent structural damage. Another necessary feature for water overflow from a pond is an emergency spillway. While the drainpipe carries water during normal runoff, an emergency spillway carries flood runoff away from the pond so the dam is not damaged or destroyed. Your pond construction advisor will be able to recommend an appropriate emergency spillway for the size of your pond (Allem, 1989).

When constructing a fishing pond, remove all brush, trees, and vegetation from the site before the pond is filled. Fish populations in ponds with structure removed are easier to keep in balance. In addition, if you ever need to use seines to remove excess sunfish, no obstructions will be in your way. If needed, some type of structure can be added to the pond at a later date. New ponds should be constructed in time to fill them during late summer or early fall, which is the best time period to stock sunfish. Immediately after construction, establish permanent grassy vegetation on the top and sides of the dam. Sow the grass seed with lime and fertilizer and then mulch it with straw. Once the vegetation is established, regular cutting on the top and sides of the dam will keep trees from growing, thus preventing weak spots in the dam (Allem, 1989).

**Liming:** This is the act of introducing lime in the pond. Liming is the key. It is so important that if you need lime you have to use it. Get help. Contact your County Extension Agent, your local Soil Conservationist, or your State Universities Aquaculture Department. Get a soil sample from the pond and get it tested. This is a must. If you need lime and do not get it you will never have good pond. Luckily it’s not real expensive. I cannot over emphasize the importance of lime to your pond’s water quality. It is the key to unlocking everything in the pond. If unsure of your need for lime, get help.

Lime is considered as fertilizer, since; it supplies calcium, which is an essential nutrient. The importance of lime application in fish ponds include:

- It increases the alkalinity of water thereby increasing the availability of carbon (iv) oxide for photosynthesis.
- It increases the pH of pond bottom mud and water, which enhances the availability of nutrients like phosphorus.
- The increased alkalinity values after liming provides a buffering capacity to pond water against drastic pH fluctuation resulting from eutrophication.
- Through the increased nutrient availability, the production of benthic organisms increases.
- Humus strains of vegetative origin restrict light penetration into the pond water and are cleared by lime treatment.
- Destroys bacteria as well as, fish parasites in their various life history stages.

**Type of lime:** The four common types of limes used are:

- Agricultural limestone (CaCO₃)
- Slaked lime (Ca(OH)₂)
- Quick lime (CaO)
- Calcium cyanide

Limes differ in their ability to neutralize acid. Agricultural limestone is used as a standard for other limes. The neutralizing value of CaCO₃ is 100%, Ca (OH)₂ is 136% and CaO is 179%. Calcium cyanide is seldom used. Agricultural limestone is the most commonly used lime in fishponds. When Ca (OH)₂ and CaO are used, enough time should be allowed before stocking the pond. This allows an appreciable reduction in the pH raised by the lime. Otherwise the fish dies.

**Application of lime:** When the pond is new, lime is spread evenly on the pond bottom before filling with water. The lime requirement of pond bottom soil is determined before liming. Nursery ponds are limed to eradicate predatory organisms, parasites and other disease causing organisms. Older ponds containing water can be limed by spreading lime over the entire pond surface. For small ponds, broadcast lime from the dykes while in large ponds, construction of platforms or use of boats become necessary (Dulbin-Green, 1989).
The dosage depends on the soil type in the pond bottom. The aim of liming is to bring the pH to neutral value. This can be achieved through a careful study of soil type and the pH. For example, more lime is required for clay soils than sand soils. Acid sulphate soils have greater lime requirement (Dulbin-Green, 1989). Table 1 shows the recommended lime dosage for different soil types based on the pH.

<table>
<thead>
<tr>
<th>pH range</th>
<th>Soil condition</th>
<th>Dose of lime (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0-4.4</td>
<td>Highly acidic</td>
<td>1,000</td>
</tr>
<tr>
<td>4.5-5.4</td>
<td>Medium acidic</td>
<td>7,000</td>
</tr>
<tr>
<td>5.5-6.4</td>
<td>Slightly acidic</td>
<td>5,000</td>
</tr>
<tr>
<td>6.5-7.4</td>
<td>Near neutral</td>
<td>200</td>
</tr>
</tbody>
</table>

Dulbin-Green (1989)

Fertilization: Pond fertilization is based on the notion that the addition of nutrients to the water will increase the production of plankton (microscopic plants and animals). This increase in the amount of fish food then results in increased fish production (pounds of fish per acre). While fertilization may increase fish production and help control aquatic vegetation due to water clouding caused by dense plankton blooms, the disadvantages of fertilization usually outweigh the advantages.

There are many things to consider in deciding to fertilize your pond. Do you want to grow bigger fish? Do your want to catch fish when you go fishing? Do you want your pond to look good? A fertilized pond can produce three to four times as many pounds of fish per acre each year than a non-fertilized pond. A well-managed pond will usually produce 300 to 500 pounds more fish per acre each year. With a fertilized pond, you have more fish and your fish will have more to eat; in return you have bigger fish to catch. It takes very little time or money to have a good fertilized pond or lake. The secret is knowing what to do, how to do it, when to do it and why you are doing it. Why is simple, to grow bigger fish, to catch more fish and to have better time fishing. You have spent probably thousands of dollars in building a pond and now you want to enjoy it, so fertilized it.

Fertilization can promote aquatic vegetation growth rather than plankton. Increases in aquatic vegetation can increase chances of summer and winter fish kills as the vegetation decays. Plankton blooms can also occur, damaging the appearance of your pond by making it a soupy, green color. Once fertilization is started, it must become a permanent part of your management program or your pond’s carrying capacity is reduced, often resulting in over-crowded, slow-growing fish. Because of these many disadvantages of fertilization, it is not recommended that you initiate a fertilization program.

Pond fertilizers are available in liquid, granular, or powdered forms. All of them are good. Consider your preferences to find the one that’s right for you. Liquid is heavier than water and will half to be diluted before it can be applied. Some times special equipment is needed to apply this liquid fertilizer. Large lakes require you to apply over a larger area, boat and spray equipment should be used. First if your pond is small you will have to shake up the liquid to get it to mix properly. If all is not used, then dilute it. I like to use at less three gallons of water for one gallon of liquid fertilizer used and apply with a sprayer. Try to apply as much as you can evenly over your pond. Liquid takes more time to apply and it might not be to your advantage to use that type. But it does act a littler quicker than granular fertilizer.

The liquid does cost a little more to use. Granular fertilizer is a little less expensive but it will have to be kept off the mud. This is very important. You will have to put something under the granular, to keep off the mud. You can use visqueen or any kind of plastic or a platform. For every 3-5 surface acre of water you would need to apply your granular. I like to place my granular fertilizer in about 3-6 inches of water near the pond bank. Do not take you granular and broadcast it into the water or pour it behind you boat. You just wasted your money. Power fertilizer should be use as the instructions say. There are several different kinds of powder fertilizer. What little I have used has not work in my commercial operation. But some of my clients like the powder and it work well for them, so you might try it. The Suttle Fish Farm test on the use on Water Soluble Pond Fertilizers (12-52-4) has show's its not only work but you get a deeper blooms quicker requires no premixing or agitation because its dissolves rapidly on contact with water. We use 6 pound per acre Application can be made by hand or aquatic applicator in a lot less time than with granular or liquid pond fertilizer.

Begin fertilization in the dry season when water temperatures have stabilized at 60° Fahrenheit. Then stop when water temperatures cool down to 60° in the fall. A simple method of knowing when to fertilizer is to examine your water clarity. If the sunlight penetrates the water 18 inches or more, a fertilization program should be implemented. The depth of light penetrating into the pond
Table 2: Recommended quantity of inorganic fertilizers for soils with different levels of nitrogen and phosphate

<table>
<thead>
<tr>
<th>Urea</th>
<th>Ammonium Sulphate</th>
<th>Sodium Nitrate</th>
<th>Nitrogen levels (kg/ha)</th>
<th>Single Super Phosphate</th>
<th>Triple Super Phosphate</th>
</tr>
</thead>
<tbody>
<tr>
<td>335</td>
<td>750</td>
<td>940</td>
<td>High</td>
<td>375-470</td>
<td>165-190</td>
</tr>
<tr>
<td>345</td>
<td>1000</td>
<td>1250</td>
<td>Medium</td>
<td>500-625</td>
<td>220-250</td>
</tr>
<tr>
<td>670</td>
<td>1500</td>
<td>1870</td>
<td>Low</td>
<td>750-940</td>
<td>330-375</td>
</tr>
</tbody>
</table>

Allem (1989)

is a measurement of algae density or bloom. Once a program is started, it needs to be continued all rainy season. In order to effectively utilize and maintain the productivity of the pond, the nutrients utilized by organisms in the pond must be replenished continuously. The productivity of natural food in the pond can be facilitated with fertilizers. This provides the essential nutrients and minerals required for the production of the aquatic biota. Fertilization is aimed at enhancing all primary, secondary and tertiary levels of productivity towards maximum yield of fish. There are two categories of fertilizers.

- Inorganic fertilizers
- Organic fertilizers (Manure)

**Inorganic fertilizers:** The major constituents are phosphorus, nitrogen, potassium and calcium. Inorganic fertilizers have a definite and constant chemical composition of nutrient elements. They are usually expressed as percentage of available nitrogen (N), phosphoric acid (P₂O₅) and potash (K₂O). The commonly used ones are:

- **Phosphate fertilizers:** These exist in the form of single super phosphate, triple-super phosphate and ammonium phosphate

- **Nitrogen fertilizers:** These exist as urea or ammonium nitrate

- **Potassium fertilizers:** These exist as potassium nitrate or Potassium sulphate

- **Mixed fertilizers:** This is a combination of nitrogen, phosphorus or Potassium

Phosphate fertilizers are commonly used in fishponds because phosphorus facilitates plankton growth in fish ponds. The most commonly used are mixed fertilizers. These fertilizers are expressed as percentage of the constituent element. The constituents elements and their respective proportions are: N.P.K 15:15:15 and N.P.K 20:20:5. The figures denote the percentages of nitrogen phosphorus and potassium in the order as contained in the fertilizers.

**Application of inorganic fertilizers:** Inorganic fertilizers are applied at least two weeks after flooding a limed pond. This is to prevent the reaction of phosphate available in the fertilizer with lime, because this can hinder the availability of phosphate. Table 2 presents recommended rates of inorganic fertilizer application.

Campbell et al. (1986) reported on the use of inorganic fertilizer to enrich brackish water ponds. The ponds were fertilized at an initial rate of 125 kg/ha with N.P.K 15:15:15 and boosted at 45 days interval with urea (250 kg/ha) and TSP (50 kg/ha). Inorganic fertilizers are most effective when applied at short intervals and in small quantities. This provides more nutrients for phytoplankton. Large doses at long intervals are wasteful, because the phosphorus can be absorbed in the mud.

Inorganic fertilizers are used together with organic manure. In this case, the fertilizers are alternated. When tobacco dust or mahua cakes are used in eradicating weed fish in the pond, the dose of the fertilizer is halved. This is because the feeds poison and kill weed fish while acting as fertilizers.

Inorganic fertilizers are applied by broadcasting over shallow areas of the pond. It is advisable to dissolve the fertilizer pellets or granules in water before application. So that, the nutrients are made available to the plankton in water column as they are being added. Otherwise, the fertilizers sink to the bottom mud and the nutrients may become adsorbed.

**Organic fertilizers:** These consist of various manures or plant wastes. The organic materials may serve as direct food source to fish. When they decompose, the inorganic nutrients released are used to generate plankton blooms. To achieve good results, large quantities of manures are applied. When they decompose, there is a reduction in dissolved oxygen level.

Organic manures add detritus to the pond and this stimulates the heterotrophic food chains, producing more bacteria and zooplankton. They enrich the organic matter content of the soil and water, release carbon (iv) oxide on decomposition and sustain the fertility of water. Their merit lies in imparting a comparatively slower rate of release of nutrients to the water over a larger period of time as decomposition proceeds. The disadvantage lie in the fact that they deplete dissolved oxygen during decomposition and reduces the aesthetic value of a pond. Organic manures can also transmit parasites and diseases to fish in fishponds.

**Types of organic fertilizers:** There are different types of organic fertilizers. These include the following:

- Cow dung from cow husbandry
- Chicken manure from poultry farms
- Pig manure from piggery farms
Cattle dung: 672 kg/ha/week

Poultry manure: 112-224 kg/ha/week

Pig manure: 560-1630 kg/ha/week

Household scraps from human wastes

Oil cakes from feed meals

Plant leaves from grasses and mangroves

Sludge from bottom of tanks

Sewage from human wastes

Table 3: Lime applications to brackish water pond in accordance with the pH values of the soil

<table>
<thead>
<tr>
<th>pH value of soil</th>
<th>Carbonate of lime/Hectare</th>
<th>Slaked lime/Hectare</th>
<th>Caustic lime/Hectare</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0</td>
<td>1690 kg</td>
<td>1610 kg</td>
<td>1130 kg</td>
</tr>
<tr>
<td>4.5</td>
<td>1500 kg</td>
<td>1430 kg</td>
<td>1020 kg</td>
</tr>
<tr>
<td>5.0</td>
<td>1130 kg</td>
<td>1050 kg</td>
<td>720 kg</td>
</tr>
<tr>
<td>5.5</td>
<td>750 kg</td>
<td>720 kg</td>
<td>530 kg</td>
</tr>
<tr>
<td>6.0</td>
<td>380 kg</td>
<td>340 kg</td>
<td>270 kg</td>
</tr>
<tr>
<td>6.5</td>
<td>Little</td>
<td>Little</td>
<td>Little</td>
</tr>
</tbody>
</table>

Allem (1989)

- Sewage from human wastes
- Sludge from bottom of tanks
- Plant leaves from grasses and mangroves
- Oil cakes from feed meals
- Household scraps from human wastes

Application of organic fertilizers: Organic fertilizers can be spread all over the pond surface. They can also be at the different corners of the ponds. It is good to put the manure heaps near the inlet pipe to wash nutrients into all parts of the pond by incoming water. Cribs can also be used. These are constructed at pond corners and composite materials heaped in them. The recommended manure rates in fishponds are:

- Pig manure: 560-1630 kg/ha/week
- Poultry manure: 112-224 kg/ha/week
- Cattle dung: 672 kg/ha/week

To effect organic stabilization of the pond, manures are added simultaneously with lime. The combination of organic and inorganic fertilizers resulted in high yields in many culture trails.

The quantity of manure applied is related to the organic carbon content. Cow dung of 20-30 tons/ha/year can be used. The first installment is usually one-sixth of the total quantity applied a forth night before stocking and the rest in equal parts of monthly installments for the culture period. The quantity is reduced if the soil contains organic reserve or tobacco dust and mahua cake are used. When used with inorganic fertilizers, organic fertilizers are alternated with the former.

No two ponds are alike, and with our present knowledge, it is impossible to predict the rate of fertilizer to use in everyone’s pond or lake. The types of soil in your pond will determine the amount of fertilizer you use. Try these rates for the various types and find out what work best for you. Liquid fertilizers include 10-34-0 and 13-37-0 or 13-38-0. The key ingredient is phosphorous (middle number). Try one gallon per surface acre and wait 7 days for a bloom. If there is no bloom, add 10 pounds a week until you get a bloom. Another granular fertilizer such as Triple Super Phosphate (0-46-0) is the most economical. Try 12 pounds per surface acre. Wait 7 days and if no bloom appears, add 10 pounds a week until you get a bloom. Another granular fertilizer is 0-20-0. Use twice the amount recommended for 0-46-0. Try 24 pounds per surface acre and wait 7 days. If there is no bloom, add 20 pounds a week until you get a bloom. 16-20-5 is also a granular fertilizer that can be used. You would need about 40 pounds per surface acre of this type. If there is not a bloom within 7 days after application, add 20 pounds per week until the water turns light green in color. 18-46-0 is a good granular fertilizer that requires about 18 pounds per surface acre. Wait seven days and check for a bloom. If there is not a bloom, add 9 pounds per week until the bloom appears.

After fertilizing, pond water will turn a light green color. The reason for this color change is plankton. Plankton is present when the water is filled with tiny plants and animals, called plankton. A good bloom is light green water, dark enough where you can not see more than 12-18 inches deep. A good fertilization program will keep the water a light green color all summer long. Fertilizer will turn water light green in color with plankton. Water insects and other organisms use the plankton for food. Small fish feed on these insects and organisms. When plankton production is increased with fertilizer, fish production also increases. Fertilizer can be applied to stimulate plankton growth and increase fish production in all ponds.

Phytoplankton blooms can be closely monitored to avoid the depletion of oxygen. Rough estimation of plankton can be used to measure pond water transparency and can also be used in monitoring blooms. Excessive phytoplankton blooms in fishpond causes the stocked fish to come to the air-water interface to obtain dissolved oxygen. This anoxic condition results from rapid depletion of dissolved oxygen in pond water by the phytoplankton. The behavior of fish in the pond is therefore an indication of stress factors in the pond. When blooms are excessive, part of the water is drained and new water is added. Phytoplankton blooms may not occur even after a proper fertilization programme. This could be as a result of low alkalinity, presence of humic acid in the water, low pH and turbidity. Addition of lime may be necessary here. An adequate fertilization programme is accompanied by water quality assessment. This enables the assessment of fertilizer impact on the water quality. When excessive blooms are observed, fertilization is discontinued. Discourage the use of ammonium fertilizers when the water pH is high. This is because unionized ammonia is toxic to fish at high pH.
A combination of organic and inorganic fertilizers is very good in poly culture. In which case, the benthos and plankton can develop side by side. So, the fish species have different feeding niches to exploit. It is pertinent to note that no fertilization rate can be rigidly adhered to. Rather, adjustments based on the environmental response should be made from time to time. Therefore, for any environmentalist, a fertilization program based on modifications of existing ones can be worked out in order to effect a proper enrichment of the pond.

Brackish water pond management: Brackish water fish pond can be distinguished from fresh water ponds with the following features:

- The pond is sited in the inter tidal estuarine areas.
- Freshwater with enriched drainage from land mixes with the sea water in the inter tidal estuarine areas.
- Salinity in the brackish water environment ranges from freshwater to seawater.
- The pond is supplied with water from the tide.
- The water control gates and canals supply and drain water from time to time.
- The lime requirement of the pond is high because most of the ponds are situated on acid sulphate soils.
- The surrounding vegetation is made up of mangrove forest.
- The concrete and wooden sluice gates are, constantly fouled by sepulid worms, barnacles and oysters.
- The metallic farm equipments such as shovels, spades and wheelbarrow rust easily in salt water.
- Dykes need constant repair to prevent wild fishes from entering the pond.

Brackish water pond is managed with meticulous care during pond preparation. Apart from the normal repair of dykes, sluice gates and screens to insure effective water control and prevent the entry of pests and predators, the pond bottom is exposed to dry, until the soil cracks. A series of fertilization and water management follows. The common procedure followed by most fish farmers is presented in Table 3.

- The lime is sprinkled evenly on dried pond bottom. In an area with acid sulphate soil, the pond dykes are treated separately with lime at the rate of 2.5 kg carbonate lime per meter of dyke.
- Chicken manure is applied to the dried pond bottom at the rate of 2 ton/ha. This dose is reduced to 300-500 kg/ha in fairly old ponds to maintain organic matter content level at 3-4% in the soil.
- Water is allowed gradually to a depth covering the pond bottom and allowed to dry. Apply urea (0-0.46) the chicken manure. Water is allowed to evaporate.
- Water is allowed to a depth of 5 cm and fertilized at the rate of 10 kg of triple super phosphate/ha.
- Water depth is increased gradually over a period of two weeks until it reaches 50 cm at which the fish are stocked.
- Half of the initial dose of the inorganic fertilizer is applied to the pond every 15 days.

Culture species: Major species presently cultured in brackish water ponds are inherently euryhaline. Others considered for culture in brackish water ponds are endemic or can easily adapt through acclimation to the estuarine environment. These species include: *Tilapia guinensis*, *Sarotherodon melanotheron*, *Mugil cephalus*, *Mugil grandisquamis*, *Lisa falcipinis*, *Chrysichthys nigrodigitatus*, *Lutjanus goreensis*, *Elops lacerta*, *Megalops atlanticus* and the pink shrimp *Pennaeus notialis*.

Some freshwater fishes such as *Tilapia zilli*, *Oreochromis niloticus* and *Clarias gariepinus* can also be cultured in brackish water ponds. This is because these fish species can easily adapt to brackish water conditions.

Stock management: After you have a properly constructed pond and a basic understanding of its features, it is time to stock your pond. You must consider what kinds of fish you want, how many and what size of fish you need to stock, when and how to stock, and potential stocking problems. Proper stocking can make a world of difference in fishing quality in years to come.

The stocking strategy you choose should be geared to the kind of fishing you want. If your chief interest is to raise an annual food crop, then channel catfish or common carp would be best. If you simply want something in the pond to catch, just about any stocking combination will do. For sport and table fare, the largemouth bass-bluegill-channel catfish combination is hard to beat. Other combinations involving smallmouth bass, walleye and northern pike can be used if the pond owner is willing to pay for periodic and expensive restocking. A few deep, well-oxygenated ponds may be able to support trout. However, this is a “put-grow-and-take” proposition as with walleye or northern pike. There are many other species of fish that will live and grow in Indiana fish ponds. However, many of them require specialized management that most pond owners can’t afford. The use of hybrid sunfish in combination with largemouth bass is a popular technique. Hybrids are fast-growing and do not overpopulate as bluegill often do.

In fact, so few hybrids reproduce, regular restocking is required. One important drawback to hybrids is that they will crossbreed with other sunfish (bluegill, red-ear, green sunfish). When this occurs, hybrid identity and vigor are soon lost. Where other sunfish are present or there is a good chance they may enter a pond, a hybrid stocking program will have little success. The best al-
around stocking combination for Indiana ponds has proven to be largemouth bass, bluegill and channel catfish. All three provide excellent sport in addition to fine eating. Occasionally, red-ear are substituted for bluegill because they seldom overpopulate. However, red-ear is caught less frequently and may disappear altogether from small ponds.

Considerable effort has been made over the years to determine the best stocking rates for new fish ponds. Stocking too many fish leads to poor fish growth and is a waste of money. Stocking too few fish promotes fast growth initially, but increases the risk of initial over harvest, especially bass. Both problems can lead to an unbalanced fish population and corrective fish management may be needed.

The initial stocking ratio widely successful in Indiana consists of five bluegill fingerlings to one largemouth bass fingerling, not to exceed 1,000 bluegill and 200 bass per acre. For a low fertility pond, it is advisable to maintain the 5:1 ratio but reduce the number stocked to 500 bluegill and 100 bass per acre. The desirable stocking size for bluegill is one to two inches and three to four inches for bass. Four to six inch channel catfish should be stocked at a rate of 100 fish per acre. If red-ear are desired, replace one-fourth of the bluegill fingerlings with one to two inch red-ear fingerlings. If hybrid sunfish are desired instead of bluegill or red-ear, a 10:1 ratio of sunfish to bass would probably be more suitable. In this case, the maximum stocking rates would be 1,000 sunfish and 100 bass per acre. For ponds larger than five acres, you may stock as if the pond was only five acres in size: 5,000 bluegill, 1,000 bass, and 500 catfish.

If costs are not prohibitive, stocking more fish will provide better fishing sooner. Once again, be sure to maintain the 5:1 ratio and do not exceed 1,000 bluegill and 200 bass per acre. For ponds smaller than a half acre, hybrid sunfish or channel catfish only may be stocked at a rate of 500-1,000 fish per acre. Stocking size in this instance is not as important as when the fish are stocked in combination with largemouth bass. Simply stocking a few adult fish to populate a new pond is risky and not advised. First-year production of young fish from these adults is unpredictable. For example, bluegill may spawn more successfully than bass and the pond will immediately be “out of balance”. Fishing quality will become poor in a hurry and will probably stay that way.

After you have decided what to stock, the next step is to locate a good source. While catching adult fish from a nearby pond or creek and stocking them in your pond may be inexpensive and convenient, it can lead to several problems. Fish identification can be difficult, particularly of small sunfish. Stocking green sunfish that you thought were bluegill, or bullheads that were supposed to be channel catfish, will certainly make for unpleasant surprises later on. Other problems include difficulty in catching the proper number and size of fish, as well as increasing the chances of introducing unhealthy fish that may be diseased or injured. To invest a lot of money into the proper construction of your fish pond and follow it with poor stocking practices won’t give you the return on your dollars that you expect.

Fish for private ponds are no longer available from federal hatcheries or from Indiana state fish hatcheries. All fish raised at these facilities are used for stocking public waters that have guaranteed public access to all Hoosier fishermen. The best source of fish for private ponds is a reputable commercial fish hatchery. Several hatcheries are located in Indiana as well as in surrounding states. A list of commercial fish hatcheries is available from the Division of Fish and Wildlife. Getting your fish from the hatchery to the pond in good shape is extremely important. Avoid rough handling and large temperature changes. If water in the hauling container differs by more than 10ºF from the pond water, the fish should be carefully acclimated. Place the hauling container (plastic bag) into the pond water or gradually exchange the water in the container with pond water until the temperatures are similar.

Stocking should not be delayed once a new pond has filled. As soon as the pond has adequate water in it, contamination by unwanted fish is possible before a good fish population develops. Some pond owners believe unwanted fish eggs are carried into their pond attached to birds’ feet or within a bird’s digestive system. This is simply not true. However, many good fish ponds have been ruined through indiscriminate stockings by others or by emptying unused bait minnows into the pond. The time of year a pond is stocked is not important. However, most commercial fish hatcheries are geared to growing fish during summer for stocking during autumn. If you plan to stock fish in your pond during the fall and the pond is not completely filled, you should consider water depth. Unless the pond has at least five feet of water, you may risk fish loss during winter.

Properly managed, the initial stocking of bass and bluegill is the only stocking you should ever have to make. However, regular re-stockings of channel catfish are usually necessary. This species requires a darkened enclosure such as a hollow log or undercut bank in which to spawn. Since this type of habitat is lacking in most ponds, channel catfish seldom reproduce. By placing milk cans, sections of large diameter field tile or culvert in the pond at depths of three to four feet, catfish can be induced to spawn. However, small catfish are a preferred food item for bass so even this will not guarantee more catfish. In most cases, it is necessary to add catfish from time to time. These should be at least six and preferably eight inches or longer so they’re not simply a free meal for your bass. Depending on how fast you remove the initial stocking, a second stocking of catfish should not be needed for two or three years.
In the nursery ponds, fry are stocked at the rate of 30-50 fry per square meter. Soon after stocking, the fry feed voraciously in the natural food. The natural food in the nursery pond can be exhausted within 2-3 days. The fry can be fed with powdered oil cakes and wheat bran at 10% biomass daily. Fish biomass are monitored at 5-days interval.

This can aid the adjustment of feeding schedule. Fish are harvested and transferred to holding tanks/ponds when fingerling sizes are attained. The stocking rate in the holding ponds is 10 fish/m². Adequate feeding is necessary for good fish wellbeing.

Culture methods in grow-out ponds vary considerably with farm. However, fish farmers mostly stock fish fingerlings at 2 fish/m². The fish are initially fed with protein rich diet at 5% biomass of the fish.

Managing fish populations: The purpose of fish management is to provide good fishing. Pond owners must decide what they want from their pond and tailor their management to meet their goal(s). Ponds less than 1 acre in size are difficult to manage for bass and sunfish. For ponds larger than 1 acre, a largemouth bass/bluegill fishery is the most popular option for Virginia ponds. Other options for ponds larger than 1 acre may include managing for trophy bass, trophy bluegill or trout. Consult your local fisheries biologist to discuss them.

All ponds have a maximum weight of fish the pond can support. In unfertilized ponds, you should be able to harvest up to 40 pounds of adult bluegill (about 120 fish) and 10 pounds of adult bass (about 8 to 10 fish) per acre per year. In fertilized ponds, you can harvest 160 pounds of bluegill (600 to 700 fish) and 35 to 40 pounds of bass (30 to 35 fish) per acre per year.

In new or reclaimed ponds, do not allow bass harvest for at least 2 years after stocking to let the bass mature and reproduce. Bass are easy to catch, and in small ponds it is possible to harvest 70-80% of the bass in 1 weekend of fishing. Harvest 5 to 10 pounds of bass per acre per year. Restricting bass harvest will help keep the fish population balanced (the proper ratio of predator and prey fish). In a balanced pond, 40-60% of the bass should be 12 inches or longer, while 20-40% of the bluegill should be 6 inches or longer. A good rule of thumb for maintaining balanced bass/bluegill populations is to remove at least 4 to 5 pounds of bluegill for each pound of bass removed. Keep all bluegill caught. Most overpopulation problems are caused by small bluegill, and returning them only adds to the problem.

Removing too many bass usually causes bluegills to become overpopulated and stunted. Overpopulated ponds are full of 3 to 5 inch bluegills that are thin and slow growing. Management options to correct this problem include:

- Winter water level draw downs to increase bass predation on bluegills
- Stocking additional predators
- Draining the pond and re-stocking
- Applying rotenone (fish toxicant) to kill a portion of the population
- Seining to remove excess stunted bluegills

Catfish and trout can be harvested without limits in ponds because their populations are maintained by stocking, not reproduction.

Record keeping keep accurate records of numbers and sizes of fish caught; The records will help you evaluate the status of your fish populations. Fish population balance can also be checked using a 15 foot long minnow seine 4 to 6 feet deep with ¼-inch mesh. Seine 3 to 4 shallow areas of the pond in June or July. The areas seined must be clear of brush and weeds.

MANAGEMENT SYSTEM

The management system adopted in most fish farms varies as follows:

Monoculture: This involves the culture of single fish species or mono-sexed individuals. Mono sex culture is commonly used for tilapia to control its breeding and over population in ponds. Most fish culturist prefers all-male culture of T. guineensis because male T. guineensis attains marketable size within a short time.

Poly culture: This involves the culture of two or more fish of different species in the same fishpond. This culture technique increases the carrying capacity of the pond. In poly culture, fast growing compatible fish species of different ecological niches and feeding habits are cultured together because different species occupy different trophic levels and do not compete with each other. This can increase fish yield from the pond.

Mono-size culture: In this culture technique, the pond is stocked with fingerlings of uniform size and cultured for a given period of time. The duration of time depends on the initial size, stocking rate, desired size at harvest and the type and abundance of food. The culture period also depends on the age of the fingerlings.

Multi-size culture: In this case, the pond is stocked with at least 3 different sizes of fingerlings averaging 5, 20 and 80 g, respectively. Fish is harvested as so on as the largest size reaches marketable size. It can be approximately 45 to 60 days after stocking, depending on the growth rate of the species. The second and third largest sizes are sequentially harvested in a similar time period. Carnivorous fishes are excluded in multi-size culture.
Harvesting: There are two ways of harvesting fish. These are the, single and multiple harvests. In single harvest, the ponds are drained slowly. The fish follow the water and gather in catchments areas. They are scooped out or seized with a small drag net. Harvesting can be carried out when the weather is cool. Morning or cloudy weather conditions are preferable. Multiple or partial harvest involves the use of various fishing devices or equipment. These include lines, trap nets, seines, dragnets, cast nets, and bamboo lattice. The mesh size of the nets suit the size of fish harvested. For instance, tilapia fry are harvested from spawning ponds with mosquito nets.

Biologists and pond fishermen commonly talk about “pond balance” or “population balance.” They are simply talking about the relationship between the abundance of predators (largemouth bass) and the abundance of prey (bluegill). When bluegill overpopulates and become slow-growing, the pond is said to be “out of balance”. In a “balanced pond”, bass remain abundant enough to prevent overpopulation of bluegill. A balanced pond fishery can be established with the initial stocking. The pond owner is required to manage the harvest to maintain the balance. This is usually the most difficult part of pond management. After the cost and effort of pond construction and fish stocking, the owner is understandably anxious to begin reaping the initial fishing benefits. Too often this leads to bass overharvest within the first two years.

When too many bass are removed, bluegills are free to overpopulate. The excessive numbers of small bluegill that survive in the absence of adequate bass predation quickly outstrip their own food supply. The result is a horde of small, very slow growing bluegill and not much else. This is an extremely common occurrence in ponds. To correct this situation, it is usually necessary to renovate the pond completely and start over with a balanced re-stocking. However, this can all be prevented by conservatively managing the bass harvest. Channel catfish and bluegill can be harvested as soon as they reach a desirable size. However, no bass should be removed during the first two years after stocking. This doesn’t mean you shouldn’t catch bass. With gentle handling, you can enjoy many hours of catching and releasing these fish with virtually no harm to them. bass will normally spawn for the first time during their second spring in a new pond. If bass harvest has been prohibited up to this point, the pond should still contain 60 to 80 percent of the bass originally stocked.

A new and sizable generation of bass will be produced to maintain the fishery balance as well as to provide enjoyable bass fishing. The bass originally stocked have to provide most of the bass fishing for the first five years. It takes two seasons to grow them to maturity and it will be three more years before their first progeny reach sizes of 10 to 12 inches. If bass harvest is prohibited during the first two years and carefully managed thereafter, your pond can provide many years of quality fishing. Although there are no hard and fast rules for managing bass harvest, the key is to practice a conservative harvest. One way is with a minimum size limit of 14 inches. Another helpful guideline is to remove no more than 20 to 25 bass per surface acre each year (after the first two years).

This approach emphasizes the quality rather than the quantity of pond fishing. The dividends are large, spunky bluegill, plenty of bass fishing action including some “lunkers” and an occasional bass for the frying pan. But perhaps the greatest dividend of all is to see your management efforts translated into good fishing year after year. When catching and releasing largemouth bass, there are a few simple rules to follow that improve the chances of the bass surviving. These are:

- Don’t overplay the bass. Retrieve and release it quickly.
- Don’t put it on a stringer and then decide to let it go.
- Carefully remove hooks so excessive bleeding doesn’t start.
- If the hook cannot be removed, cut the hook or line and release the fish.
- Keep the bass out of sunlight and in the water.

Fresh water pond management:

Pond preparation: The pond can be drained and allowed to dry for a number of days before being fertilized. Certain ponds are waterlogged and cannot be drained completely. In some cases, ponds are located in areas with limited water supply. The water in such ponds is not completely removed. Therefore the presence of predatory and unwanted fish species and aquatic weeds cannot be ruled out in such fresh water ponds. Thus, there is need to eradicate these predators and pests before stocking the pond.

The first step to remove the predatory and weed fishes is to drag the pond with a net. This method cannot remove a predatory weed fish because the fry (Tilapia zilli) produced can pass through the net. The mudfish, Clarias can dig into the bottom mud in order to escape from the net. The use of toxicants or poisons to eradicate pond pest seem to solve the problem. Several fish poisons or biocides are available. However, fish culturists have to be very careful in their selection of a suitable fish poison. Some examples of recommend biocides are; Rotenone, aldring, endrin, malathion, saponin and tobacco waste. The characteristics of a suitable fish poison include:

- Can easily be obtained at a relatively low cost
- Should not be toxic to man and farm animals
- Can be easily degraded in water, leaving long-term adverse effects on aquatic biota
Derris powder contains 5% rotenone and when applied at 4-10 ppm can kill any unwanted fish. Fishes with accessory organs are not excluded. The toxicity can last in the pond for 4-12 days depending on the dosage used. Endrin can kill most fishes at 0.001 ppm. The toxicity can last for 2 days. At 0.01 ppm, all fish can be killed. The toxicity can last for 2 weeks. Tobacco waste can be applied as a toxicant in fishponds at a dosage of 25 ton/ha.

Three main categories of aquatic insects are common in fresh water ponds. Remove all dangerous aquatic insects from the pond. Such insects include:

- The basic swimmers (Notenecta sp.) the giant water bugs (Belostoma sp.) and the water scorpions (Nepa sp)
- The predaceous diving beetle (Cybister sp.) and the whirling beetle (Gyrinus sp.)
- The dragon fly nymphs

Teepol 13-300, a detergent emulsified with oil is commonly used to spread on the pond surface to control these insects.

Many aquatic plants are desirable and can only be controlled when they become pests in fishponds. In fresh water fishponds, the common types of weed are:

- Floating weeds such as Pistia, Lemma, Eichornia and Wolfia.
- Emergent weeds which are usually rooted at the ponds bottom. For example, grass plants and water lily
- Submerged weeds that are either or not rooted; for example, Hydrialla
- “Scums” of algae that are filamentous, for example, spirogyra and microcystis
- Marginal weeds that fring the pond dykes, occasionally choking the water body e.g., Ipomea cyperus

After the eradication of any predatory or weed fishes as well as aquatic weeds, liming and fertilization follows. For newly constructed freshwater ponds, a range of 500-1000 kg/ha dose of agricultural lime is adequate for a soil pH range of 4-6.5. A few days after liming, a little water can be let into the pond.

Organic manures like chicken or cow dropping can then be added at the rate of 750 or 1500 kg/ha, respectively. The pond water level can be increased slightly. After an interval of 5 to 7 days, inorganic fertilizers can be added to the pond. The commonly available fertilizers are urea, NPK, Triple Super Phosphate (TSP) and Single Super Phosphate (SSP). A combination of urea and TSP can be applied at a dose of 50 and 20 kg/ha, respectively on separate days (2-3 days interval). The pond water level can be increased slowly to approximately a meter water level. A green phytoplankton bloom appears in 3-5 days after application of last dose of inorganic fertilizer. Fish can be stocked 2 weeks after post lime application.

**Fish species selection:** Certain fish species can be selected for culture. This is based on:

- Objective of culture
- Desired quantity of fish
- Consumer acceptance and marketability
- Cost of production

A good culture fish species exhibits the following characteristic;

- Fast growth
- Efficiency in food conversion
- Resistance to disease and poor water quality
- Adaptation to changes in physical and chemical Characteristics of water
- Good table quality
- Easy to breed in captivity

A good number of species are presently cultured in Nigerian fresh water ponds. Among these are the Tilapias, Oreochromis niloticus, Sarotherodon galilaeus, the catfishes: Clarias gariepinus, Hetrobranchus and Chrysichthys nigrodigitatus. Others include the mullets, Mugil sp., Heterotis niloticus, Lates niloticus and Chana chana. Fish fingerlings of required species are either collected from wild or from hatcheries. They are transported in oxygenated polythene bags. An average of 1 kg of fish can be transported in 5-6 L of water. When polythene or plastic bags are used, they are placed securely in transportation boxes.

The inside of the boxes are lined with a foam insulation material. This can reduce splashing and heat transmission. Anaesthetics or sedatives are introduced to the fish during transportation. This tranquilizes the fish. Two common sedatives are quinaldin applied at 5 ppm; and Tricaine methane sulphonate (Ms 222-sandoz) applied at 50 ppm.

Pond owners should be aware of potential problem fish species. These fish, once established in a pond, can harm good fishing and cause the pond to fall far short of its fishing potential. Fish that are considered problem species are bullhead, common carp, buffalo, sucker, crappie, perch and miscellaneous sunfish species.

**Bullheads:** Bullheads, often called “mudcats” or “yellow-bellies”, are not desirable in ponds because they often overpopulate and roil the bottom, making the water muddy. Overabundant bullhead populations produce few bullheads of desirable size. In addition, their presence often limits the success of channel catfish.
Carp, buffalo and suckers: Introduction of these three fish species into fish ponds is a serious mistake, unless you are only interested in growing fish to eat. They compete directly for food with small bass and bluegill, destroy bass and bluegill habitat, and can only be removed by totally draining or chemically treating the pond. Because of their bottom feeding habits, common carp make the water extremely muddy. Common carp reproduce quite successfully in ponds.

Crappies: Although both black and white crappies do well in large lakes, they usually do not do well in small ponds. Once crappies become established, they prey on small bass, compete for food with adult bass and bluegill, and tend to overpopulate. This produces a pond full of small bass, compete for food with adult bass and bluegill, and usually don’t grow well. Perch are much more suited to large lakes and should not be stocked in ponds.

Miscellaneous sunfish: Many pond owners have difficulty identifying the seven sunfish species commonly found in Indiana. These include bluegill, red-ear, long-ear, warmouth, pumpkinseed, green and orange spotted sunfish. Only bluegill and red-ear are suited for Indiana ponds. When stocked into fish ponds, the other sunfish usually produce an undesirable fish population. Green sunfish and warmouth are aggressive feeders and compete with bass and bluegill for food. If they get big enough, they even eat small bass. The pumpkinseed, long-ear and orange spotted sunfish do not grow big enough to interest fishermen and they overpopulate easily.

Fish stocking in fresh water ponds: The ponds are prepared and fertilized. Fingerlings are discharged from the transportation van and gently transferred into open plastic basins or tanks. The fingerlings are left to rest for several hours. During this period, the dead ones are removed. The water from the pond is slowly mixed with the water in the basins or tanks containing the fish. This is the process of acclimation and can last for two days. The live fingerlings can then be stocked directly into the ponds.

Stocking density: This depends on the culture technique. The recommended stocking density of fish in production ponds for fish species that does not breed in captivity is 2 fish/m². This means that, for a pond area of 0.1ha, a total of 2,000 fish fingerlings can be stocked in a monoculture. In practice only 70% of the stocked fish can be recovered. It is therefore advisable to stock the fingerlings at a rate of 2.5 fish/m² in order to meet the expected target at harvest. This means that 2,500 fingerlings can be stocked in a 0.1 ha pond. For fish species like tilapia that breed profusely in captivity, the recommended stocking density is less than one fish/m² for mixed sex stocking and 2 fish/m² for mono sex (male) culture.

Poly culture takes advantage of the various feeding habits of the different fish species cultured. This reduces competition for food and space among the species. Tilapias are omnivores and are highly prolific. Heterobranchus, Clarias and Channa are predators. The tilapias can be cultured in a poly culture. The tilapias can be stocked at a ratio of 2 fish/m² and the predator at 1 fish/m², resulting to a total stocking density of; 3 fish/m² in the same pond.

Feeding: Feeding and fertilization are management tools in fish culture. Fertilization enriches the pond and maintains the production of natural food for the fish. Fish culturist commonly uses pellets because it contains 35% protein content. Pfizer’s feed is also adequate. In recent times, fishmeal is scarce because of the high cost of fish. Fish culturist use one or more feed ingredients in addition to fertilization.

The feed ingredients commonly used include: Groundnut cake, Soya bean meal, cotton seed cake, rice brain, wheat bran, cooked or steamed corn, brewery wastes, mill sweeping etc. The feeding rate and frequency of artificial feed given is based on a percentage of the fish. The quantity of artificial feed given is based on a percentage of the total fish biomass in the pond. Feed quantity ranging from 7 to 10% of the fish biomass is adequate for young fish. The biomass of 5% is given to fish of 4 months and above.

The feeding rate of brooders can be reduced to 2-3% of the fish biomass. Feeding rate is therefore inversely proportional to the age of fish. Feeding frequency influences the growth rate of fish. It is therefore necessary to feed at 3-4 h interval. This means that fish can be fed at least 4 times a day. The total weight of feed given per day is shared equally into 4 parts and fed. Feeding can be done daily until harvest.

Pond testing: The best way to tell how well your fish are doing is to go fishing. By catching fish, you can check on how well your fish are growing, how well your fish are reproducing, or whether unwanted fish are now in the pond. You should fish your pond frequently, not only to learn how well your pond is producing, but also to harvest the crop of older, larger fish before they succumb to natural mortality. Most Indiana ponds are capable of producing many big bluegill. These fish should be harvested to reduce competition for food among the remaining fish. Bluegill fishing can begin within one year following stocking. Keep a record of the fish you harvest from your pond. This will aid you in determining whether
additional management is needed. Record the kind and size of fish you catch. Then, periodically review your catch records. Ask yourself these questions:

- Is the average size of bluegill declining?
- Is the largest size of bluegill you catch getting smaller?
- Do you catch fewer big fish per hour or more little fish per hour?
- Are bass more difficult to catch?
- Is crappie, common carp or other non-stocked fish showing up in the catch?

Answers to these questions can form a “common sense” approach to fish management in your pond. You may also wish to purchase a minnow seine, about 12 feet long and four feet deep. By dragging the seine along some shallow, shoreline areas, you can sample your fish population. Seining is especially effective in catching small bass and will aid you in determining how successfully the bass are reproducing. Another effective method of catching fish is using wire-mesh cylindrical traps. A wire funnel should be attached to one end of the trap while the other end is closed. These traps work best at catching bluegill and red-ear. By placing one or two traps at various locations and depths throughout your pond for 24 to 48 h, you can usually catch enough fish to judge their size range. Once you have examined your fishing records and the seine or trap catches, you can judge how “balanced” the fish community is and whether any problems exist.

Diagnosing problems in pond: There are three basic reasons why your pond may not produce the quality of fishing you want: your pond may contain the wrong kind of fish, the wrong size of fish, or the wrong number of fish. Remember, many kinds of fish found in Indiana lakes and streams are not suited for ponds. Corrective fish management to eliminate undesirable fish usually focuses on completely draining the pond or chemically eradicating all fish in ponds that cannot be drained. Most pond owners who are not satisfied with the size of bluegill usually complain of catching only “little ones”, mainly in the three to five inch range, and seldom any bluegill larger than six to seven inches. By far, this is the most common problem in Indiana ponds. It usually means too much of the pond’s standing crop (fish population) is tied up in overcrowded, slow-growing bluegill. Corrective management of this problem centers on removing many of the small bluegill by seining, trapping or fishing and reducing bass harvest to allow the predator (bass) population to increase.

Occasionally, fish pond owners complain about catching only small bass and that no “hawg-bass” are present in their pond. These problems result either from overharvest of bass before they grow to large size or from inadequate forage to sustain good bass growth. If your bass grow at normal rates, merely reducing the number you harvest should allow the remaining bass to grow big. If the bass are growing slowly, simply harvesting more small bass should thin their numbers so those left in the pond grow faster. Aligned closely with the problem of having the wrong size of fish in your pond is the problem of having the wrong number of fish.

Too many fish usually means not enough food is available for each fish to grow at a normal rate. Consequently, only small fish are present. And of course, too many little fish means not enough big fish. The same corrective fish management techniques that address the problem of having the wrong size fish will also correct the problem of having too many fish. Throughout this discussion of testing and diagnosing your pond’s fish problems, one common symptom related to each problem is fish growth. How rapidly fish grow is the best indicator of how well-balanced your fish population is. If your fish grow rapidly, chances are that they are not too numerous and overcrowded. Therefore, if you know the age and growth rate of fish in your pond, you will be more able to diagnose and correct problems.

Correcting muddy ponds: A muddy pond does not provide good habitat for fish. Muddy water can adversely affect fish reproduction. Mud also prevents sunlight from penetrating the water and reduces microscopic plant (phytoplankton) growth. Phytoplankton release oxygen into the water during photosynthesis for fish to breathe. Phytoplanktons also serve as the first link in the pond’s food chain. If your pond is muddy much of the time, look for the cause of the problem and try to correct it. Some common causes of muddy ponds include:

- Soil erosion due to poor land management practices in the watershed
- An abundance of bottom feeding fish such as common carp or bullheads
- Wave action along an unprotected shore
- Livestock trampling the pond banks
- Suspended clay particles

Maintain a buffer strip of terrestrial vegetation around the pond to hold the soil and reduce silt and nutrient inputs. To reduce bank erosion caused by wave action, you may wish to place large rocks or gravel along the shore. Allowing some aquatic vegetation, such as cattails and lilies, to grow in areas where wave action is greatest can also reduce bank erosion. If muddy water is caused by common carp or bullheads, complete pond draining or chemical eradication may be warranted. Livestock should be kept out of ponds. Muddy water caused by suspended clay particles can sometimes be corrected by spreading broken bales of high quality hay around the shoreline. As
Fig. 2: Pond water stratified to layer

the hay decays, a weak acid is formed which causes clay particles to settle. Approximately two bales of hay per surface acre should clear the water.

**Fish kills:** Nothing is more disheartening to a pond owner than a fish kill. Fortunately, they are rare in most ponds, but no pond is completely immune to them. Fish kills can be partial or complete and are caused by a variety of factors including low dissolved oxygen, pollutants, disease, temperature extremes, or natural mortality. It's not always possible to avoid a fish kill, but in most cases there are warning signs that the pond owner can look for and correct before it's too late.

Low dissolved oxygen is the most common cause of fish kills in ponds. Contrary to popular belief, fish kills are never caused by natural over-population. A pond will naturally stay within its capacity to support fish under normal conditions. Low oxygen levels usually result from combinations of weather conditions and pond characteristics that fall into one of the scenarios described below. The most obvious sign of an oxygen problem is fish gasping at the surface, particularly in the early morning. Once the problem has reached this point, aeration is the only suitable option a pond owner has to prevent a fish kill. To prevent the problem from recurring, determine which of the scenarios listed below describes your situation and correct it as soon as possible.

At moderate levels, aquatic vegetation is beneficial to fish populations. But when it covers more than ½ of the pond, the potential for a fish kill is greatly enhanced. Plants produce oxygen during the day when there is sunlight, but not at night. During the night, plants, fish, insects, and naturally occurring bacteria use oxygen for respiration. If the oxygen produced during the previous day is insufficient to carry pond life through the night, a fish kill will result. As long as the weather is sunny, oxygen production is usually adequate. However, several consecutive calm, cloudy days can reduce the pond's oxygen level to a point where fish may not survive the night. These types of kills usually occur during warm weather. The best way to avoid this problem is to prevent weeds from covering more than ½ of the pond. See Aquatic Vegetation section for more information.

Excessive plant growth must be controlled gradually. Treating too much of a pond with herbicide at one time creates too much decaying plant matter, providing an abundance of food for bacteria. The bacteria grow and reproduce quickly and can easily deplete oxygen in the water. To avoid this problem, never treat more than one-third of a pond (less is better) at a time with herbicide. If multiple treatments are necessary, wait at least 2 weeks between treatments to allow for complete plant decomposition.

As discussed in the water quality section, microscopic phytoplankton are the base of the food chain, and their abundance determines a pond's capacity to produce fish. The phytoplankton population is directly proportional to the fish populations. But like anything else, you can have too much of a good thing. If your pond receives excessive nutrients from runoff, phytoplankton can become overabundant and cause some of the same problems as rooted plants. Phytoplankton are overabundant when pond water becomes so green that water clarity is less than 12 inches. This can cause the same type of extreme oxygen cycling described above for rooted plants. If the phytoplanktons suffer a sudden die-off, rapid decomposition can cause oxygen depletion and a fish kill. If your pond receives excessive nutrients and suffers from excessive phytoplankton blooms, take care of the problem before a fish kill occurs. The best solution is to reduce nutrient inputs from the watershed.

In residential areas where landscaping (and thus lawn fertilization) is extensive, excessive nutrients commonly enter neighborhood ponds. The best solution is to reduce fertilization and increase the use of xeriscaping. Xeriscaping is the use of landscaping techniques that minimize fertilization and irrigation requirements. It emphasizes the use of drought tolerant native plants that are adapted to local soil conditions. Planting and annually cutting native wetland plants such as cattails can also reduce the availability of nutrients to the plankton. However, some folks may consider these plants a nuisance. A diversion ditch could work here, but remember, this will reduce water flow to the pond.

During summer, the heat and relatively calm weather causes pond water to stratify into layers (Fig. 2a and b).
There is a less dense, warm, upper layer that is exposed to the sun and atmospheric oxygen (epilimnion), a very thin layer where temperature and density changes rapidly (metalimnion), and a cold, denser, lower layer that receives little sunlight and does not mix with the upper layers (hypolimnion). Because it does not mix, the hypolimnion has no incoming oxygen to replace what is used by bacteria that are decomposing dead animals and plants on the bottom of the pond. As the summer progresses, the hypolimnion usually loses its oxygen. If a storm carrying cold rains causes the pond to turn over (mix suddenly), the de-oxygenated water in the hypolimnion can reduce the oxygen level of the pond enough to cause a fish kill. Ponds with the proper maximum depth (6-12 feet) are less likely to have this kind of kill because they have a smaller hypolimnion. In ponds with a vertical standpipe (also called a riser), an easy way to reduce the size of the hypolimnion is to install a pipe over the existing standpipe so that pond overflow is drawn from the bottom of the pond instead of the top. Aerators or anti-stratification pumps can also be used to prevent or reduce stratification and associated fish kills, but electricity costs can be prohibitive.

Fish kills caused by pollution in ponds are rare. Aside from livestock wastes, which were discussed earlier, the most common pollutants that cause fish kills in ponds are pesticides. Pesticides can enter a pond with storm runoff from an agricultural field, orchard, golf course, or residential landscaping. They can also reach a pond by drifting through the air during crop dusting or spraying. Because pesticides are extremely toxic to fish, great care must be taken to keep them well away from ponds. If there is a farm in your ponds watershed, discuss your concerns with the farmer and watch the pond closely when pesticides are being applied. If you use pesticides yourself, be careful to clean your mixing and spraying equipment in an area where runoff will not enter a pond. Although less common, herbicide pollution can cause an oxygen depletion by killing phytoplankton, rooted aquatic plants, or both. Pollution can contaminate living fish and make them unsafe to eat, but this is rare in private ponds. Unless your pond is impacted by industrial pollution, livestock wastes, acid mine runoff, or golf course drainage, it is highly unlikely to have a problem of this nature. If you think you have a pollution problem, consult with the Virginia Department of Environmental Quality. If they can't provide direct assistance, they can provide you with a list of private consultants.

Fish kills resulting from disease usually only occur when fish are overcrowded. Although overcrowding can occur naturally during a drought when water levels are low, it's usually the result of overstocking by man. Follow the recommended stocking rates in this brochure and you shouldn't have a problem. If necessary, diseased fish can be treated with a medicated feed (if you feed your fish), but the improvement will only be temporary if the underlying problem is not addressed. Parasites generally do not cause fish kills. They are common in fish and usually cause them little harm. Because parasites have complex life cycles, attempts to control them are usually futile. Parasites often form cysts (commonly called grubs) in the fillets and make them unappealing for eating. However, properly cooked fish cannot transmit any bacteria or parasite to people who eat it.

Except for ponds with trout, water temperatures rarely cause sport fish kills in Virginia. Temperatures are usually not low enough to allow ice to cover ponds and cut off oxygen for extended periods.

The most common cause of fish kills in Indiana ponds is suffocation. Suffocation occurs when aquatic plants do not produce enough oxygen for fish to breathe. This may occur during heavy snow and ice cover in winter, during rapid plant die-offs after a cold rain or several days of cloud cover, or following aquatic plant die-offs from herbicide applications. Once fish suffocation starts, it is too late to stop it. Fish kills in general can be best prevented by properly controlling nutrient inputs and overabundant aquatic vegetation. Winter kills can be prevented by removing snow from the pond. Three inches of ice covered by five inches of snow will shut out 99% of the incoming sunlight. To prevent or reduce the severity of winter kills, remove snow from at least 50% of the pond surface. Drilling holes in the ice will not help.

Additional action that can be taken to prevent winterkills includes artificially aerating and circulating the water either by motor-driven air compressors or wind driven baffles. When using an air compressor system, do not allow the air stone (diffuser) to lie on the bottom. This will usually stir up organic materials and result in more oxygen consumption as the materials decay. Suspend the diffuser at least two feet off the bottom. Summer-kills can be prevented by making sure no fertilizer, herbicides, insecticides or organic run-off (silage, manure) enter the pond. Chemically treat aquatic vegetation early in the growing season according to the label and avoid treatments in late July and August. Avoid treating large amounts of aquatic vegetation throughout the pond by treating one area at a time.

Aquatic weed control: Aquatic plants are essential members of the pond community. They are beneficial to fish and wildlife. Rooted plants provide living areas for fish and fish food organisms such as aquatic insects. Certain plants offer shade to fish from bright sunlight and provide natural fish attractors to larger fish. Some kinds of aquatic vegetation never cause problems in ponds. Control is not recommended if the vegetation covers less than 20-25% of your pond’s surface area. This level of aquatic
vegetation is generally accepted as optimal for sport fish populations and the ecology of the pond. Aquatic vegetation can cause problems when in excess (covering more than 20-25% of the pond). Excessive aquatic vegetation detracts from the pond's appearance and makes swimming, boating and fishing difficult (Chinda et al., 2003).

Aquatic vegetation also uses nutrients that could go into producing fish food organisms. Excessive aquatic vegetation offers unneeded protection to small fish from predators and often results in pan fish overpopulation. On cloudy, hot summer days or under ice cover, excessive vegetation can lead to fish kills by using up the available oxygen. There are several ways to control aquatic vegetation in ponds. Hand pulling, cutting or raking aquatic vegetation may be the simplest and least expensive. Placing permeable filter fabric on the bottom can control vegetation in specific areas of the pond (Chinda and Braide, 2003).

Some Indiana pond owners control vegetation with registered and approved aquatic herbicides. Another alternative may be biological control. The first step in chemically controlling aquatic vegetation is to correctly identify the problem plants. There are four basic types of vegetation found in ponds: emergent plants, submerging plants, floating plants and algae. Your choice of herbicide will depend on the types of problem plants you want to control. Filamentous algae are perhaps the most common vegetation problem in Indiana ponds. It is a stringy, hair-like plant (sometimes mistakenly called “moss”) that can completely cover a pond’s surface.

Algae can be difficult to control and may require several treatments. If you are unable to correctly identify your problem plants, enclose a damp sample in a plastic bag and mail them to your District Fisheries Biologist. After your problem vegetation has been identified, the next step is to determine the acreage and water volume of the area to be treated. To prevent killing too much vegetation, you may wish to treat the pond in sections. In this case you will need to calculate the area and the volume of only the section you want to treat (Chinda and Braide, 2003).

Carefully read the entire label to ensure the herbicide will do the job in the manner you expect. Especially note the precautionary statements and directions before using the product. Be sure to wear any safety equipment such as gloves or eye protectors as stated on the product label. The method(s) of herbicide application is dictated by the formulation and the product label. Liquids are usually sprayed from shore or a boat. Some liquids can also be injected from a boat mounted tank into the prop wash of an outboard motor with a simple device called a boat bailer. If the vegetation is very thick, spraying may be easier than bailing. Granular herbicides can be broadcast by hand or hand held spreaders (Chinda and Braide, 2003). Powders might be dissolved in water and sprayed or poured along the shoreline as a paste or slurry.

Licensed and certified commercial aquatic pesticide applicators are available to treat pond vegetation for a fee. A list of licensed commercial applicators is available from your District Fisheries Biologist. Do not apply aquatic herbicides to your pond on rainy or cloudy days or if the weather forecast calls for a period of rainy or cloudy days or else you may cause a fish kill.

Important points to remember when treating aquatic vegetation are:

- Identify the problem plant and select the appropriate herbicide
- Use only registered, approved herbicides
- Carefully read and follow all herbicide label directions
- Distribute the herbicide evenly, covering all areas in the treatment zone
- Do not over treat or apply the herbicide to an area larger than needed
- Treat submerging vegetation and algae early in the growing season
- Properly dispose of empty containers and unused herbicide

**Example:** Plants are growing from the shoreline to a depth of 10 feet around the entire pond. An easy way to calculate the area (acres) and/or volume (acre feet) to be treated is to divide the pond into five treatment zones. Before you apply the chemical to a treatment zone, you need to know the area (acres). To determine the area, measure the length and width in feet. Multiply the length by the width and divide by 43,560 (the number of square feet in one acre).

**Here is the formula:** Length (m) X Width (m) = Area in acres (43,560 m²)

You may also need to know the volume (acre feet) of the treatment zone. To calculate the volume in the treatment zone, determine the average depth in feet and multiply the average depth times the acres. Here is the formula:

Acres of treatment zone X Average depth (meter) of treatment zone = Volume in cubic meter.

**MANAGING OTHER ANIMALS**

**Beavers:** Beavers are rodents that build lodges on land, along a pond bank, or in open water. The lodge is usually dome-shaped and is built of sticks and mud. Lodges usually have two or more underwater entrances. The den is above water and is used to raise families, for sleeping, and some food storage. Most of the damage caused by beavers is a result of dam building, tree cutting, and bank burrowing. Their burrowing activity weakens dams,
which may cause failure during major storm events. Beavers prefer trees such as poplar, sweet gum and pine. However, they eat the bark, twigs, and leaves of most woody plants growing near water. They also eat corn, soybeans, and other crops (Ajao and Fagade, 1991). Beavers often plug drainpipes in a pond, resulting in loss of water level control and damage to the emergency spillway. Rip-rap above and below the water surface along the face of the dam will discourage beaver digging activity. The use of traps is the most effective, practical and environmentally safe method of controlling beavers. Trapping should be done in the late fall or early spring. You do not need a license to trap on your property. However, if you give permission or hire someone else to trap, they must have a trapping license.

**Muskrats:** Muskrats construct their homes (burrows) by digging tunnels into the dam and along pond banks. These tunnels are dug both above and below the water surface to get to the burrows. The tunnels threaten the integrity of a dam. In a dam with muskrat burrows, rising and falling water levels could eventually cause the dam to leak and possibly fail. Muskrats can be discouraged by eliminating sources of food such as cattails, bulrush, reeds, and arrowhead. Keeping the pond banks mowed also limits their activities. Placing rip-rap along the face of the dam, extending 2 feet above and 3 feet below the water surface will discourage digging. Wire screening (1 inch mesh) is also effective along the dam. Trapping is the most practical method for controlling muskrats. Traps should be set in runways or den openings during the winter (Ajao and Fagade, 1991).

**Crayfish:** Crayfish are not harmful to fish populations. Some crayfish species build burrows that may cause leaks in a dam. Crayfish overwinter in their burrows in the bottom muds or pond banks. They become active when water temperatures are above 40º F. Crayfish are active at night, and traps should be set in late afternoon and left out all night. Crayfish traps can be made with ½-inch mesh chicken wire shaped like minnow traps. The funnel openings should be at least 2 inches in diameter to allow for easy entry. Traps can be baited with fish heads, meat scraps, dog food, or soybean cakes. Crayfish are eaten by trout, bass, and catfish. A balanced fish population is one of the best ways to control crayfish numbers.

**Snakes:** Snakes do eat fish, but do not pose a threat to pond fish populations. Water snakes are harmless and should not be destroyed without reason. Clearing debris and mowing the pond edges reduces hiding places for snakes and will reduce their numbers.

**Turtles:** Turtles are common in ponds, but are not harmful to fish populations. Turtles are scavengers that feed on aquatic plants, insects, and dying fish (fish on a stringer are an easy meal!). Snapping turtles may capture small ducklings. Like snakes, turtles should not be killed without good reason. Turtles can be easily captured with handmade traps. Traps should be set in shallow weedy areas and baited with fish heads, watermelon rind, or fresh meat. Turtles may be trapped in spring, summer and fall. Another collection method for snapping turtles is a baited trot line (Ajao and Fagade, 1991).

**Habitat:** Quality habitat is essential for healthy fish populations. Habitat includes all of the physical, chemical, and biological characteristics that affect the pond environment. Water quality, depth, bottom type (mud, gravel, etc.), vegetation, watershed type (forest, grass, etc.), and climate are all habitat characteristics. The pond owner has control over most of these and can manipulate them to benefit fish populations (Abowei and Sikoki, 2005). Fish need quality water to survive, grow, and reproduce. Quality water has no pollutants, is high in dissolved oxygen, and does not have excessive organic matter or silt. Fencing a pond to prevent access by livestock is extremely important for maintaining good water quality (see Aquatic Vegetation section). Livestock trampling erodes pond banks, which causes pond shallow, muddy water, and loss of fish habitat. Livestock wastes promote algae and other plant growth, increase organic content, and increase the chances for fish kills. Livestock fences should be 50 to 100 feet from the pond bank and completely enclose the pond, including the dam and spillway (Abowei and Sikoki, 2005).

Every pond should have a vegetated border. Forested or grassy areas at least 50 feet wide will reduce soil erosion and reduce the amount of fertilizer and pesticides entering the pond with runoff. Trees along the shoreline (not the dam) are desirable for shading and nutrient uptake.

Oxygen in water is produced by microscopic plants (phytoplankton) and other larger plants during photosynthesis, and by wind and wave action mixing the air and water. Most fish need at least 5 parts per million (ppm) of dissolved oxygen for good health. Oxygen levels below 3 ppm stress fish and most will die when dissolved oxygen levels fall below 2 ppm. Mechanical aeration may increase dissolved oxygen levels in ponds with poor water quality. Some fish have strict habitat requirements. For example, trout are very sensitive to temperature and dissolved oxygen levels. To survive, trout typically need water less than 70ºF, and dissolved oxygen levels greater than 5 parts/million (Abowei and Sikoki, 2005).

Muddy water directly influences the health of a pond. Sight feeding fish like largemouth bass and bluegill need reasonably clear water to find their food. Water clarity is necessary for plankton production, the basic component of the food chain. Water clarity should be at least 18 inches throughout the year. Clarity can be measured using...
a Secchi disk, which is an 8 inch disk made of wood, metal, or plastic. The disk is marked into quarters alternately painted black and white. Attach the disk to the end of a yardstick or pole (right). Ponds that receive excessive sediments from heavy rains may need a diversion ditch to channel water away from the pond (Abowei and Sikoki, 2005).

Ponds that stay muddy may need lime to reduce acidity and to settle suspended clay. Contact your local county extension office or DGIF office for help with muddy water problems.

The primary purpose of fish attractors is to congregate fish for the angler. Bluegills, minnows, and other prey fish use the attractors to hide from predators. Larger fish seeking an easy meal gather at these attractors. Brush piles, Christmas trees, stake beds, and rock piles all make good fish attractors. In ponds 1 acre or less, one attractor is enough. In larger ponds, one shelter for every 2 to 3 acres is appropriate. Attractors should be placed at depths exceeding 2 feet, and within casting distance of the shoreline. Do not place fish attractors in your pond if sunfish or crappies are overabundant and stunted, because you will provide more hiding places for them to escape from bass.

In Virginia, most warm water species such as largemouth bass and bluegill are generalists and will spawn on practically any bottom material. Channel catfish spawn in hollow tree stumps, root wads, or holes in the bank. In catfish-only ponds, reproduction is undesirable because the catfish tend to overpopulate and stunt when no predators are present. Therefore, nesting structures should not be provided. Most (not all) minnows spawn on rocky substrate, and a gravel bed (½ to 1 inch diameter, 4 to 6 inches deep) makes a good spawning area. Bluegills are attracted to these areas as well. Gravel beds can be added anytime, although locating potential sites before pond construction or during draw downs is preferred. Do not locate gravel beds in sites prone to heavy erosion. Floating boards (1×6, 1×8, etc.) and cinderblocks make good spawning substrate for minnows that do not spawn on rocky substrate. Because they require flowing water to keep their eggs oxygenated, trout do not typically spawn in ponds (Abowei and Sikoki, 2005).

**Pond renovation:** Ponds that contain large numbers of rough fish such as bullheads, carp, perch and suckers must be renovated. These species compete with bass and bluegill for food, cover, and spawning sites. Nuisance fish tend to overpopulate and ruin sport fishing. The best strategy in this situation is to destroy all the fish in the pond and restock with desirable species (Allem, 1989). The least expensive method of renovating a pond is to drain it dry, or partially drain it and kill the remaining fish with rotenone. Rotenone comes in liquid or powder formulations. Powdered rotenone is usually available at local feed and seed stores. Liquid formulations are available through mail-order from aquaculture chemical suppliers. Contact your county extension office or DGIF for sources of liquid rotenone. Be aware that you must be a Certified Pesticide Applicator in Virginia to purchase and use rotenone.

Rotenone should be applied when water temperatures are above 65°F, usually in late summer or early fall. A concentration of 2 ppm will cause a complete fish kill. This equates to 5.4 pounds of granular rotenone or 0.65 gallons of liquid rotenone for each acre-foot of water. The volume of your pond measured in acre-feet can be calculated by multiplying the surface area in acres by the average depth in feet. For example: if you have a 2-acre pond with an average depth of 6 feet and you treat with 0.65 gallons of rotenone per acre-foot, you need 7.8 gallons of rotenone (2 acres × 6 feet × 0.65 gallons per acre-foot = 7.8 gallons). Apply the rotenone uniformly over the entire pond using buckets, sprayers, or pumps. Deep areas (over 4 feet deep) should be treated by pumping the rotenone through a hose that is weighted at one end while motoring back and forth across the pond. One of the drawbacks to using rotenone is that thousands of dead fish will be floating on your pond (Literathy and Csanyi, 1994). They must be picked up and discarded. Rotenone generally stops killing fish within 10 days, depending on water temperature and weather conditions, but it may last as long as 1 month in water temperatures below 60°F. The pond should be restocked soon after the rotenone has stopped killing fish. Refer to the stocking section to determine the species and sizes to restock.

Water fertility determines pond productivity. A more productive pond will support more fish and a larger harvest than a less productive pond. Fertilizer increases pond productivity by stimulating the growth of microscopic plants (David et al., 1981). These are eaten by bluegill, which are in turn eaten by bass (George et al., 2010). Fertilization makes the water turn green, shading the bottom and preventing growth of nuisance aquatic plants. Adding too much fertilizer can cause unsightly algal blooms with unpleasant odors. Algae die-offs during summer months can cause low oxygen levels, which may result in fish kills. Contact your local fisheries biologist to help you decide if a fertilization program is appropriate for you (George et al., 2010). Once fertilization is started, it should be continued. Fertilization causes the fish populations to expand because of the enhanced food supply. Stopping fertilization drastically reduces the food supply. The result is stunted, slow growing fish that are in poor health.

Fertilizers used in ponds are similar to those used for agricultural crops. However, most agricultural fertilizers do not have the best combination of nutrients for ponds. Fertilizers high in nitrogen such as 21-53-0 or 10-34-0 should be used. Liquid formulations are preferred because...
they go directly into solution and are more economical. Liquid formulations are applied at the rate of 1 gallon per acre, 4 to 6 times a summer. Applications should begin in spring when the water temperature reaches 60°F, and every 2 weeks until visibility decreases to 18 inches. During the summer months add fertilizer as needed to maintain 18 inches visibility. In the fall, stop fertilizing when water temperature drops below 60°F. Before beginning a fertilization program, have your pond water tested to be sure the lime content is adequate (Ajayi and Talabi, 1984).

Ponds with soft, acidic water (typical in much of Virginia) sometimes require the addition of lime to improve fishing. Check the total alkalinity of the pond water to determine if liming is necessary. If alkalinity is below 20 ppm, add agricultural limestone to neutralize the pond bottom. A mud sample (taken from several areas of the pond bottom) should be analyzed to determine the amount of lime needed. Combine the mud samples and spread them out to dry. After the samples dry, take them to your local County Extension Agent for analysis. The agent will recommend the proper liming rate. Lime should be applied evenly over the entire pond bottom. Common methods of application include shoveling or washing it from a plywood platform mounted on a boat. The best time to apply lime is in late fall or early spring. Typically, ponds require liming every 2 to 4 years. Do not use hydrated (builder's) lime. It will cause a rapid pH change that may cause a fish kill, and it is hazardous to handle (Mclusky and Eliot, 1981).

Aquatic plants supply oxygen, provide cover, and can be food for insects that are eaten by fish. Plants protect shorelines from wave erosion and serve as feeding and nesting habitat for waterfowl (ducks, geese, etc.). Aquatic plants are desirable and beneficial to fish communities but can cause problems with fishing by interfering with angler access. Largemouth bass and bluegill function best when aquatic plants cover 20 to 30% of the pond surface during the summer. Plant densities greater than 30% can cause fish kills. Fish kills can occur when overabundant vegetation dies and decays, causing oxygen depletion. Aquatic plant problems usually do not occur in properly constructed ponds (Atabatele et al., 2005).

Aquatic plants are grouped into four general categories: algae, floating, submerged, and emergent. Pond owners should either obtain a plant identification key or have a qualified person identify the plants in their ponds. In Virginia, the Cooperative Extension Service or your local fisheries biologist can assist with plant identification. If you have more than one kind of plant, make sure the plant you bring in for identification is the problem plant. Aquatic plants can be controlled by manual, chemical, and biological methods. Manual control refers to physically pulling, raking, cutting, digging, shading, or mowing nuisance plants. Manual control of species like cattails is practical when their abundance is low. Manual control should be done in the spring when the plants are first emerging (Chinda et al., 1999).

Chemically treating a pond with herbicides approved for aquatic use can be effective for many types of vegetation. Chemical treatments can be very effective in controlling vegetation in small areas of a pond such as swimming areas or boat ramps. Herbicides generally provide quick results, but plants often return and several applications may be necessary to maintain control. Protect yourself and others by strictly following all label directions when using pesticides. Certain herbicides can be purchased and used only by Certified Pesticide Applicators, so herbicide treatment may not be possible without paying someone to do it for you (Barnes and Hughes, 1988).

One of the most effective long term controls for aquatic plants is stocking triploid (sterile) grass carp. Because grass carp have specific food preferences, accurately identifying the plants in your pond is very important. Grass carp consume many vegetation types and have a life span as long as 15 years. They will not reproduce in a pond, will not muddy a pond, and will not disturb the nests of other fish. Triploid grass carp grow rapidly and will control most submerged (underwater) plants. They will consume as much as 40% of their body weight in plants every day during the summer months. The best way to prevent aquatic plant problems is proper pond construction. Shoreline depths of 2 to 3 feet with bank slope ratios of 3:1 are ideal. In deeper waters, aquatic plants cannot easily establish themselves because sunlight does not penetrate to the bottom (Chinda et al., 1999).

Muddy water detracts from the pond appearance, reduces the pond ability to produce fish food (microscopic plants and animals), and restricts sight-feeding fish such as largemouth bass and bluegill from effectively capturing prey. Muddy water also reduces oxygen production by reducing photosynthesis. Water in new ponds is often muddy because of pond construction, and from erosion of pond banks by wave action. Muddy water in new ponds should clear up as pond banks become vegetated. Rip-rap can be used to stabilize pond banks and reduce muddy waters (Allem, 1989).

Muddy water in established ponds may be caused by livestock wading along the shoreline, pond sediments that are continually suspended, or nuisance fish such as carp or bullheads. Livestock can be fenced from the pond, as discussed in the Construction section of this handbook, and nuisance fish can be removed with rotenone as discussed in the Renovating Ponds section. Suspended clay particles can be cleared by spreading 50 pounds per acre of agricultural lime. Using lime is a temporary cure and will probably need to be done annually. Hay can also...
Fish harvesting in fresh water ponds: This involves the capture of fish from the pond. It can be done in various ways. Feeding of the fish can be suspended 1-2 days prior to harvesting. Cool water is convenient for fish harvesting. This can take place early in the morning. Harvesting can be partial through netting, especially when the pond cannot be drained completely. In the absence of drainage system, pumping can only do bailing. Pumping is expensive because it involves the use of energy (Nwadukwe, 1989).

Complete draining of the pond seems to be the best method. The pond can be drained to allow all fish move with the water current. Suitable screens are kept in the groves in the monk or sluice gates to retain the fish in the pond while the water is being drained out. The fish can be handpicked or collected with suitable nets. This can be done either in front or behind the monk, depending on the type of structure built (Nwadukwe, 1989). Harvested fish can be transported in tanks or open buckets and basins into temporary tanks near the ponds. Here, the fish are allowed to remain in clean water for 24 to 48 h before being restocked. The marketable fish are transported in aerated tanks parked in cartons, iced or other preservation method applies to preserve fish before marketing (Nwadukwe, 1989).

Marketing: Fish culturists negotiate with fish wholesalers who can buy the fish in bulk. The fish can be marketed live, smoked, frozen, salted, canned, fishmeal or silage. Marketing women play an important role in fish market. Women gut and clean the fish before smoking. Fish farmers prefer fish wholesalers or middlemen buying the fish in bulk. The unsold fish are returned live into holding tanks without stress. This is important because dead fish looses its market value faster than live fish.

Legal considerations: Pond owners have unique responsibilities in terms of stocking, maintenance, and liability requirements (Dance and Hynes, 1980). Consult with your local Soil and Water Conservation District Office and/or the Natural Resources Conservation Service when selecting your pond site and during construction. Depending on the site, watershed size, and the purpose of the pond, federal and state permits may be necessary for construction. For example, streams are considered wetland areas, and if you build a dam on a stream or affect a wetland in other ways, you are required to obtain a permit from the USACOE.

Dams need periodic inspections and repairs to ensure their integrity and safety. Who may access the pond and when it may be used are considerations the pond owner must address. Will swimming and boating be allowed? If so, where, when, and under what conditions (swim at own risk, power boats or electric motors, etc.)? Stocking non-native or exotic fish species requires a permit. Raising and selling fish for bait and/or consumption may require permits from the ministry of environment. As the pond owner, you are responsible for obtaining these permits. Pond owners are also responsible for the well-being of habitats downstream of their property. If too much rotenone is applied during a pond renovation and it causes a fish kill downstream, the owner is liable for replacement costs associated with the clean-up. Determining if threatened or endangered species live in your area is extremely important. Warm water (or no water) released from your pond could push a sensitive aquatic animal closer to extinction! (Conides and Parpoura, 1997).

Another consideration in site selection is dam failure liability. You must consider what would happen downstream if the dam failed and flooding or loss of life and property resulted (Conides and Parpoura, 1997). Dams over 25 feet in height that hold more than 50 acre-feet of water are regulated by the Ministry of environment. This agency requires annual safety inspections and emergency action plans. If your stream is in a watershed known to support anadromous fish (shad, herring) spawning, you may be required to construct a fish way on your dam (Esu, 1999). Consult the ministry of environment for more information on fish passage requirements.

CONCLUSION

Pond ecology, fish biology, site selection, construction, liming, fertilization, brackish water pond management, culture species, stock management, managing fish population, management system, harvesting, fresh water pond management, fish species selection, fish stocking in fresh water ponds, stocking density, feeding, pond testing, diagnosing problems in pond, correcting muddy ponds, fishkills, aquatic weed control, managing other animals, habitat, pond renovation, fish harvesting in fresh water ponds, marketing and legal considerations are other important fish pond management principles the fish are very important pond management principle the culturist need to know.

REFERENCES
