

1. Aquaculture

1.1 INTRODUCTION

World fish farming was first practiced as long ago as 2000 B.C. in China. Fish ponds and ornamental fish ponds appear in paintings from ancient Egypt. European aquaculture began sometime in the middle Ages and transformed the “art” of Asian aquaculture into a science that studied spawning, pathology, and food webs. One of the most significant developments was the invention of culture methods for trout, which were being introduced into natural waters by the mid-1800s. Aquaculture is a form of agriculture that involves the propagation, cultivation, and marketing of aquatic animals and plants in a controlled environment

Fish culture is the growing of fish in ponds. Growing fish in ponds, from which they cannot escape, allows feeding, breeding, growing and harvesting the fish in a well-planned way. Fish culture is one form of aquaculture. Aquaculture is the science which deals with the cultivation/growing of aquatic organisms (fish, mollusks, crustaceans, other vertebrates, unicellular organism, microalgae and higher plants) using extensive or intensive method in order to increase the production or yield per unit area or volume to a level more than can be obtained naturally in a particular aquatic environment. Aquaculture, a type of agriculture, is also the practice of cultivating aquatic animals and plants in managed aquatic environments. Aquaculture in salt-water or marine environments is called maricultures. Fish culture, or pisciculture, refers to the husbandry of finfish. The most popular aquaculture species are finfish grown in fresh waters, accounting for over 40% of total aquaculture production

Aquaculture has been defined in many ways. It has been called as the rearing of aquatic organisms under controlled or semi controlled condition - thus it is underwater agriculture. The other definition of aquaculture is the art of cultivating the natural product of water, the raising or fattening of fish in enclosed ponds. Another one is simply the large-scale husbandry or rearing of aquatic organisms for commercial purposes. Aquaculture can be a potential means of reducing over need to import fishery products; it can mean an increased number of jobs, enhanced sport and commercial fishing and a reliable source of protein for the future.

Fish is a rich source of animal protein and its culture is an efficient protein food production system from aquatic environment. The main role of fish culture is its contribution in improving the nutritional standards of the people. Fish culture also helps in utilizing water and land resources. It provides inducement to establish other subsidiary industries in the country.

The continuous decline in fishery harvests and an effort to meet seafood consumption, aquaculture has become the world's fastest growing sector of food production, increasing nearly

60-fold during the last five decades. The success of aquaculture is closely dependent on aquatic ecosystems and a range of other natural resource inputs that require continuous support from the natural resource base. On the other hand, aquaculture has a great potential to damage the natural resource base, diminishing environmental quality and societal benefits. The success of aquaculture, therefore, depends upon its ability to produce quality sea food as well as to maintain the sustainability of its resource base. Tremendous developments have been achieved in this sector especially in the uninhabited zones of coastal deserts of countries in Middle East, Africa, America and Australia. Sustainable aquaculture has emerged as a key issue of farming systems, research and development, and the concept of sustainability includes the notion of conservation of natural resources. Though the impact of aquaculture activities to the environment were considered, the impact of total amount of waste discharged from aquatic farms on ecosystem sustenance were not recognised, particularly from the sustainability point of view.

The most common species used for fish farming globally are common carp, Nile Tilapia and Catfish. However, species selection for fish farming depends on: - Consumer preference, feed availability and market price

1.2 Types of aquaculture

Based on the type of water, there are three aquaculture systems: - **fresh water aquaculture (a)** where the culture take place in fresh water bodies, **brackish water aquaculture (b)** where the culture takes place in brackish water and **mariculture (c)** where culture takes place in sea water. Aquaculture includes the culture of aquatic organism of food, culture to improve the natural stocks, culture of ornamental fish and sport fish, integrated farming etc.

Based on Stocking Organism, there are about four culture systems, these are:

1. Monoculture: Rearing of a single species of fish is called Monoculture, it is called monospecies culture. E.g. Culture of Nile tilapia in a pond.
2. Monosex culture: Rearing of only sex of species is called Monosex culture E.g. Tilapia.
3. Polyculture: Rearing of different species in a water body is called Polyculture. It is also called composite culture, e.g. culturing of Nile tilapia, catfish and common carp together
4. Integrated fish culture: Culturing fishes along with other forms of agriculture such as, poultry, dairy etc., is called integrated fish culture. E.g. Integrated Nile tilapia with horticulture (Papaya) as shown below



Note: In aquaculture, site selection is very important before starting the project. Soil types, water quality and quantity and climate of the area are very important factors to consider.

1.3 Guidelines for pond design and construction

Size, Shape and depth

Square and rectangular shaped ponds are easiest to build, but your pond can have a different shape to fit the size and shape of the land. An area of 300 m² is a good size for a family pond, which you can build without the use of machinery. Ponds can be much larger than this, but for family use it is better to have several small ponds rather than one large one. Also, if you have more than one pond you will be able to harvest fish more often. The water depth is usually 30 cm at the shallow end and 1 metre at the deep end. The pond can be deeper than this if the pond is used as a water reservoir in the dry season. It is important that the water can be completely drained for harvesting.

Types of ponds

The type of pond you need to build depends on the land contours (topography). Different types of ponds are suitable for flat and hilly areas. Excavated ponds are built in flat areas by digging out an area as big as needed for the pond. The water level will be below the original ground level side of the pond is dug out and used to build up a dam on the lower side. The dam must be strong because the water level in the pond will be above the original ground level

Building the fish pond

Building a pond can be the most difficult and most expensive part of fish farming. A well built pond is a good investment that can be used for many years. The steps in building a fish pond are: Site selection, Prepare the site, Build a clay core Dig the pond and build the dikes, Build the inlet and outlet, protect the pond dikes, Fertilize the pond, Fence the pond, Fill the pond with water and Stock the fish

Site selection

Proper selection of a site is probably the most important factor for success. However, if the ideal site is not available, you may have to compromise. There may also be conflicts concerning land and water use that need to be resolved. You should decide on which species to rear, based on the available feeds (e.g. agricultural by-products) and possible fertilizers (e.g. compost or animal manure). Site selection will depend on the type of fish farm you plan to run. For pond construction you need to consider the following factors: soil type and quality and quantity of the water available.

A. Soil

The quality of soil influences both water quality and productivity in a pond. The soil must also be suitable for dike construction. To determine soil suitability the two most important properties to examine are soil texture (particle size composition), and porosity or permeability (ability to let water pass through). The pond bottom must be able to hold water (have a low porosity, like clay) and the soil should also contribute to the fertility of the water by providing nutrients. The best soil for pond construction should contain a lot of clay. The three methods one should follow to predict whether the soil will be suitable for pond construction are: The 'squeeze method', the ground water test and the water permeability test

I. Squeeze method: the steps are, a. Wet a handful of soil with just enough water to make it moist b. Squeeze the soil by closing your hand firmly. If it holds its shape after opening the palm of your hand, the soil will be good for pond construction

II. Ground water test: the steps are, a. Dig a hole to a depth of one metre b. Cover it with leaves for one night to limit evaporation c. If the hole is filled with ground water the next morning, a pond could be built but take into account that you will probably need more time to drain the pond. This is due to the high ground water levels that will refill the pond. d. If the hole is still empty the next morning, no problems will occur as a result of high ground water levels and the site will probably be suitable for pond fish farming. Now you should test the soil permeability to water

III. Water permeability test: the steps are, a. Fill the hole with water to the top b. Cover the hole with leaves c. The following day the water level will be lower due to seepage. The dikes of the hole have probably become saturated with water and might hold water better now. d. Refill the hole with water to the top e. Cover it once more with leaves. Check the water level the next day. f. If the water level is still high, the soil is impermeable enough and is suitable for pond construction. g. If the water has disappeared again, the site is not suitable for fish farming, unless the bottom is first covered with plastic or heavy clays.

B. Water sources

Water supply is the most important factor in selecting the proper location for an aquaculture facility. Aquatic organisms depend upon water for all their needs. Fish need water in which to

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breathe, eat, grow, and reproduce. Large quantities of water must be available year-round. If water is not available all the time, but there is some way to store it, then that site still may be suitable. The key, of course, is that water must always be available and in good supply. Water sources can be classified as: wells, springs, groundwater, streams, rivers, lakes, and municipal. Of these seven possible sources, wells and springs rank the highest in terms of overall quality. Wells and springs are usually uncontaminated and have no unwanted fish or fish eggs. The only drawbacks to well and spring water are their low concentrations of dissolved oxygen (which fish need to breathe), and their high concentrations of dissolved gases such as carbon dioxide, and metals such as iron. These problems can be overcome. Groundwater sometimes is used where ponds are dug into the existing water table. This type of pond is generally less productive than ponds filled from other sources because of the low productivity of the surrounding soil. Streams, rivers, and lakes also can be used to produce aquatic organisms, but they are subject to any contaminants that could wash in from the surrounding watershed. In addition, unwanted fish or fish eggs must be filtered from these existing water bodies

Water quality

To great extent water quality determines the success or failure of a fish farming operation. Physical and chemical characteristics such as suspended solids, temperature, dissolved gases; pH, mineral content, and the potential danger of toxic metals must be considered in the selection of a suitable water source. Of these many water quality characteristics, only temperature, dissolved oxygen, ammonia, pH, and alkalinity will be discussed. In existing systems, a close watch should be kept on these critical characteristics.

Temperature

Fish are cold-blooded organisms and assume approximately the same temperature as their surroundings. Metabolic rates increase rapidly as temperatures go up. Many biological activities such as spawning and egg hatching are geared to annual temperature changes in the natural environment. These temperatures vary according to the particular species. Generally, for good fish growth, 20-30°C water temperature is required. Ideally, species selection should be based partly on temperatures of the water supply. Any attempt to match the fish with improper water temperatures will involve energy expenditures for heating or cooling to within the desired range. This added expense will subsequently reduce the farmer's profits.

Dissolved oxygen

Like humans, fish require oxygen for respiration. Dissolved oxygen (DO) concentrations are expressed in parts per million (ppm) or milligrams per liter (mg/l). Both methods are the same since 1 mg/l is equal to 1 ppm. Some fish such as tilapia and carp are better adapted to withstand periodic low DO concentrations. However, concentrations greater than 4 to 5 ppm are required for good growth in fish. The oxygen that fish need to breathe also is consumed by the breakdown of fish wastes and uneaten feed. Oxygen enters the water in three ways:

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(1) Through air diffusing into the water at the surface, (2) through the photosynthesis of microscopic plants (algae) in ponds. (In this process carbon dioxide is converted into food by plants and oxygen is released as a by-product.) (3) through mechanical means. (The levels of oxygen can be increased.)

Ammonia, nitrites, and nitrates

Fish excrete ammonia and a lesser amount of urea into the water as wastes. Two forms of ammonia occur in aquaculture systems: ionized (NH_4^+) and un-ionized (NH_3). The un-ionized form of ammonia is extremely toxic to fish; ionized ammonia is not. Both forms are grouped together as “total ammonia nitrogen.” Through biological processes, toxic ammonia can be degraded to harmless nitrates. In natural waters, such as lakes, ammonia may never reach critically high levels due to the low densities of fish. But the Aquaculturist must maintain high densities of fish and therefore runs the risk of ammonia toxicity. Un-ionized ammonia levels rise as temperature and pH increase. Toxicity levels for un-ionized ammonia depend on individual species; however, levels below 0.02 ppm are generally considered safe. Dangerously high ammonia concentrations usually are limited to water reuse systems, where water is continually recycled. However, the intermediate form of ammonia – nitrite – has been known to occur at toxic levels in fish ponds.

pH, alkalinity, and hardness

The quantity of hydrogen ions in water determines whether it is acidic or basic. The scale for measuring the degree of acidity is called the pH scale, which ranges from 1 to 14. A value of 7 is neutral, neither acidic nor basic; values below 7 are considered acidic; above 7 basic. The acceptable pH range for fish culture is normally between pH 6.5 and 9.0. Alkalinity is a system by which wide pH fluctuations are prevented or “buffered.” It is a measure of the carbonates (CO_3^{2-}) and bicarbonates (HCO_3^-) as expressed in terms of equivalent calcium carbonate (CaCO_3). An example of this type of buffering system is the addition of agricultural lime to prevent decline in pH. Hardness is the measure of the calcium and magnesium portion of the buffering system. These two elements can be absorbed by the fish’s gills and, in addition to other uses; they help with the bone development in fish. Fish will grow over wide ranges of alkalinity and hardness, but values of 120–400 ppm are considered optimum.

The type of aquaculture, fish farming highly depends on the fish species used and site selected for implementing the selected aquaculture type. Therefore, before we learn the different types of aquaculture based on different criteria, we will see species criteria

Species Selection

The following should be considered when selecting a species for culture:

- Market demand: A species should only be cultured if it can be sold.
- Profitability: The species should fetch a sufficiently high price; farmers should get profit.
- Ease of culture: The species should be hardy, resistant to disease, and fast growing.

- Supply of seed stock: If the species does not breed readily, there should be a reliable supply of juveniles for grow out.
- Feeding habits: The species should readily accept artificial feeds.
- Legal aspects: In some countries, there are restrictions on the culture of certain species, for various reasons

Note: Very few fish species are suitable for aquaculture. Some of the common aquaculture species are Nile tilapia, common carp and catfish as shown in figure1 (left to right)

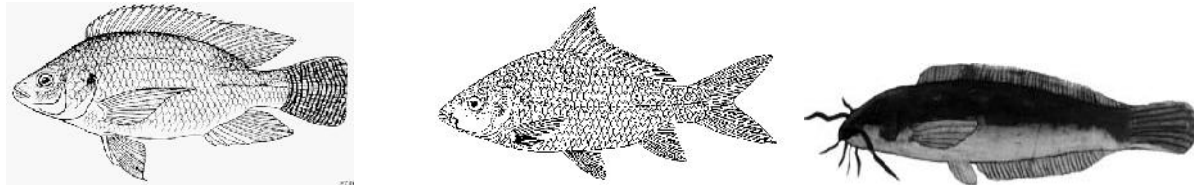


Figure 1: Common fish species used in aquaculture

Methods of Culture

Fish can be culture in water based systems such as cage and pens and land based systems such as earthen ponds, concrete ponds etc.

Pond Culture

A pond is an earthen, or sometimes concrete, impoundment that holds water (figure 2). Water is added only to fill the pond or to replace water lost by seepage or evaporation. Sometimes ponds are subject to water changes, but this water change does not usually exceed one complete change in a 24 hours period. Pond culture is perhaps the simplest way of practicing aquaculture. Most of the aquaculture production in the world is carried out in ponds. Earthen ponds are the most widely used structures, mainly due to their relatively low cost. The advantages include low technology requirements; ease of stocking and harvesting, and less risk from climatic conditions. Pond culture also allows cultured species to utilize natural sources of food. A major disadvantage is water quality deterioration. Ponds can be used for extensive, semi-intensive or intensive aquaculture. Extensive ponds may be several hectares in size, while semi-intensive ponds usually do not exceed half a hectare.



Figure 2: Fish ponds made of plastic, earthen and concrete (left to right)

Pond Construction

A large part of the world's fish culture production relies on the use of freshwater ponds which hold and exchange water, receive fertilizer or feed, and allow for holding, rearing and harvesting of fish. The proper preparation and construction of such ponds and their associated structures are essential for successful fish farming. Good ponds should be inexpensive to construct, easy to maintain and efficient in allowing good water and fish management.

Features of a fish pond

Although there are many kinds of fish ponds, the following are the main features and structures associated with them in general:

- ✎ pond walls or dikes, which hold in the water;
- ✎ pipes or channels, which carry water into or away from the ponds;
- ✎ water controls, which control the level of water, the flow of water through the pond, or both;
- ✎ tracks and roadways along the pond wall, for access to the pond;
- ✎ harvesting facilities and other equipment for the management of water and fish

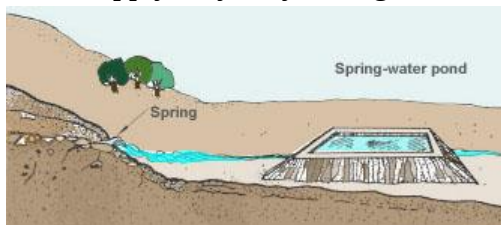
Different kinds of pond

1. Freshwater fish ponds differ according to their source of water, the way in which water can be drained from the pond, the material and method used for construction and the method of use for fish farming. Their characteristics are usually defined by the features of the landscape in which they are built. Ponds can be described as follows.

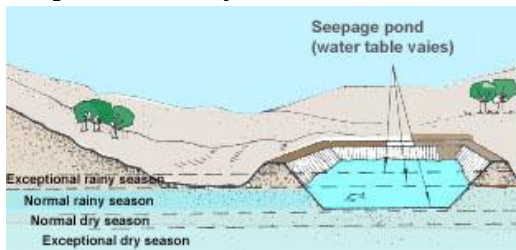
I. According to the water source

✎ Ponds can be fed by groundwater:

(a) Spring-water ponds are supplied from a spring either in the pond or very close to it. The water supply may vary throughout the year but the quality of the water is usually constant.

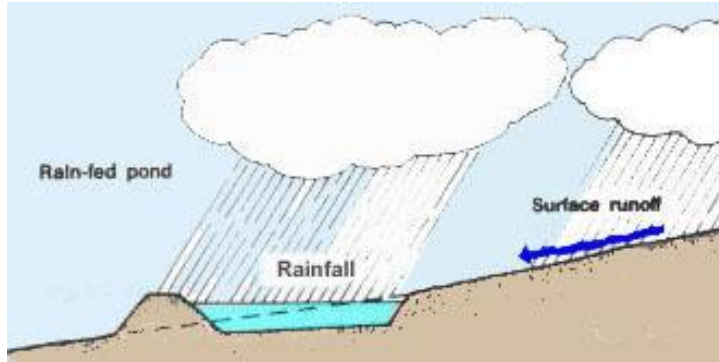


b) Seepage ponds are supplied from the water-table by seepage into the pond. The water level in the pond will vary with the level of the water-table

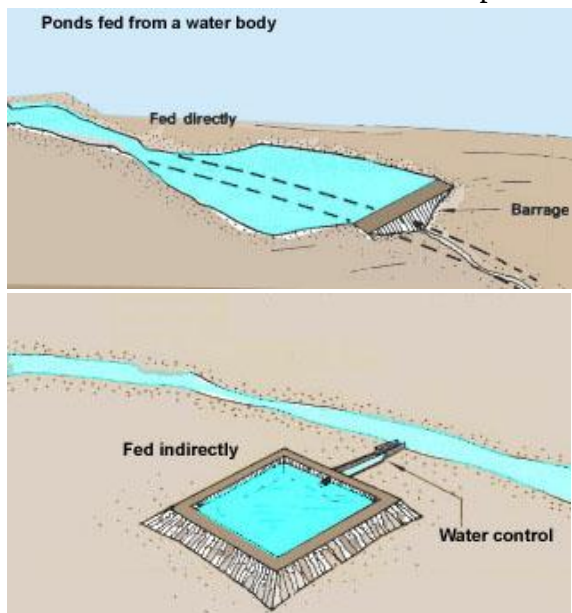


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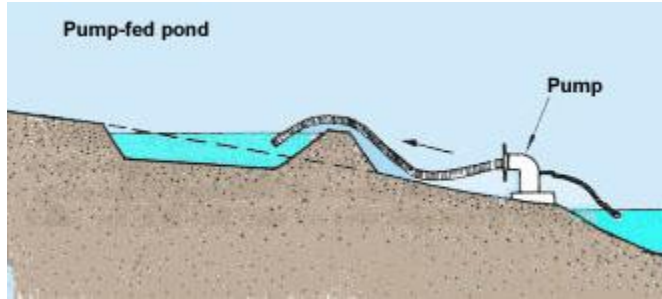
3. Rain-fed ponds are supplied from rainfall and surface runoff. No water is supplied during the dry season. These ponds are often small depressions in impermeable soil, with a dike built at the lower side to retain more water



4. Ponds can be fed from a water body such as a stream, a lake, a reservoir or an irrigation canal. These may be fed directly (e.g. barrage ponds), by water running straight out from the water body to the ponds, or indirectly (e.g. diversion ponds), by water entering a channel from which controlled amounts can be fed to the ponds



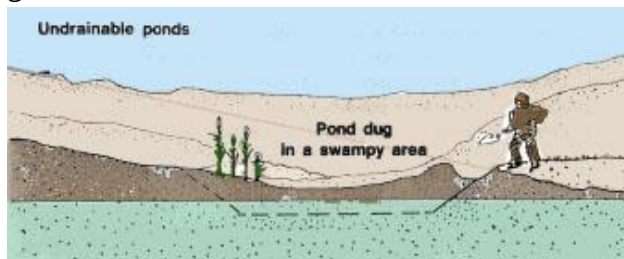
5. Pump-fed ponds are normally higher than the water level and can be supplied from a well, spring, lake, reservoir or irrigation canal, by pumping



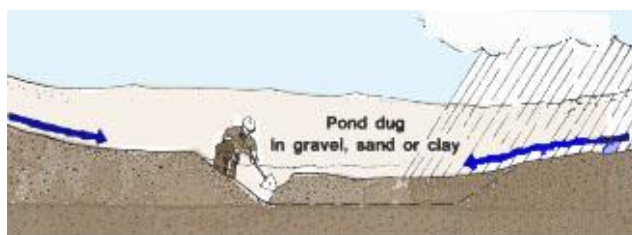
II. According to the means of drainage

1. Undrainable ponds cannot be drained by gravity*. They are generally fed by groundwater and/or surface runoff, and their water level may vary seasonally. Such ponds have two main origins.

(a) They may be dug in swampy areas where there is no source of water other than groundwater. (b) They may result from the extraction of soil materials such as gravel, sand or clay.

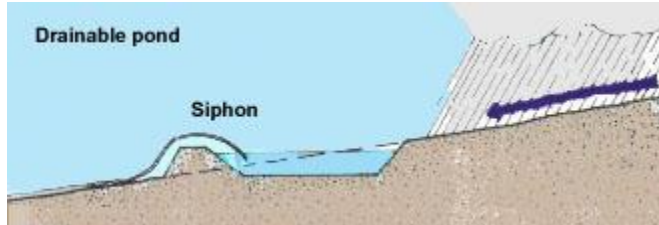


a



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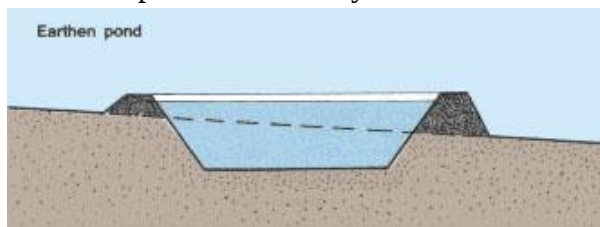
2. Drainable ponds are set higher than the level to which the water is drained and can easily be drained by gravity*. They are generally fed by surface water such as runoff*, a spring or stream, or are pump-fed.



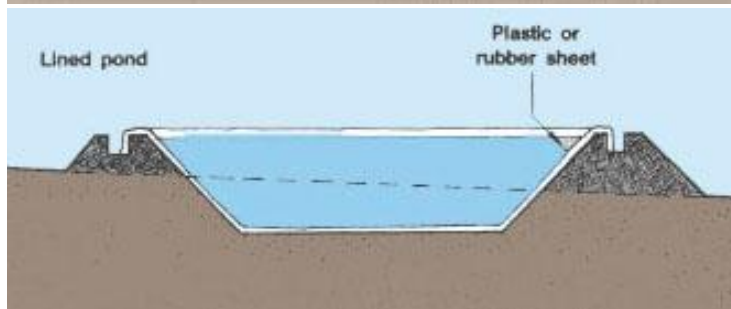
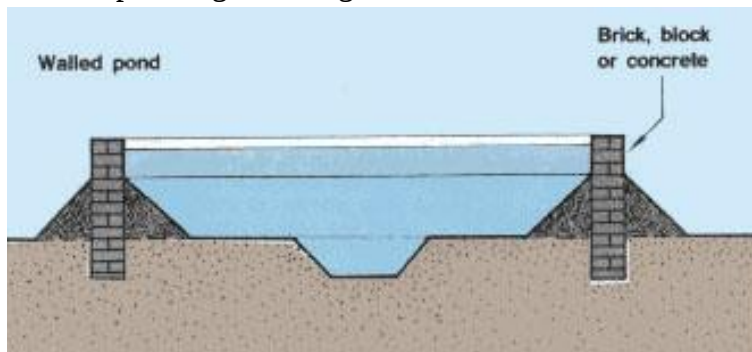
Pump-drained ponds may be drainable by gravity to a certain level, and then the water has to be pumped out. Other ponds, similar to undrainable ponds, must be pumped out completely. These ponds are only used where groundwater does not seep back in to any extent.

III. According to the construction materials

1. Earthen ponds are entirely constructed from soil materials. They are the most common.



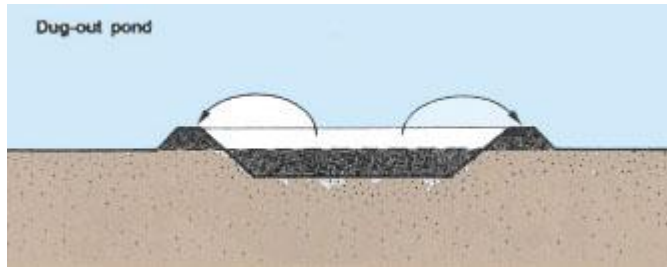
2. Walled ponds are usually surrounded by blocks, brick or concrete walls. Sometimes an impervious material such as a plastic or wooden planking or corrugated metal is used.



IV. According to the construction method

1. Dug-out ponds are constructed by excavating soil from an area to form a hole which is then filled with water. They are usually undrainable and fed by rainfall, surface runoff or

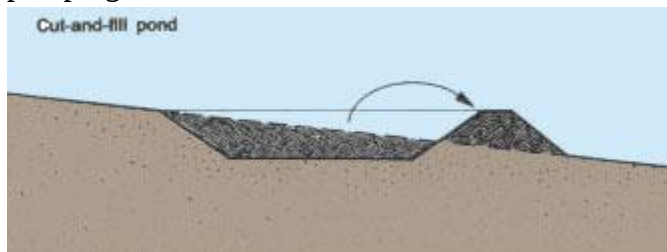
groundwater.



2. Embankment ponds are formed without excavation by building one or more dikes above ground level to impound water. They are usually drainable and fed by gravity* flow of water or by pumping.



3. Cut-and-fill ponds are built by a mix of excavation and embankment on sloping ground. They are usually drainable, and water, which is impounded within the dikes, is fed by gravity or by pumping



V. According to the use of the pond

There may be different types of pond on a fish farm, each used for a specific purpose:

- spawning ponds for the production of eggs and small fry;
- nursery ponds for the production of larger juveniles;
- brood ponds for bloodstock rearing;
- storage ponds for holding fish temporarily, often prior to marketing;
- fattening ponds, for the production of food fish;
- integrated ponds which have crops, animals or other fish ponds around them to supply waste materials to the pond as feed or fertilizer;
- wintering ponds for holding fish during the cold season

1.4 Cage Culture

Cage culture is the practice of rearing fish in cages. It can be applied in existing bodies of water that cannot be drained or seined and would otherwise not be suitable for aquaculture. These include lakes, large reservoirs, farm ponds, rivers, cooling water discharge canals, estuaries and coastal embayment. Generally speaking, large, deep bodies of water which contain very little nutrients are used for cage culture. Cages have a rigid framework, and a bag suspended below the water surface, in which the culture species are retained. The upper surface is provided with flotation devices, which can be manipulated to raise or lower the cage in the water. Cage culture requires the use of complete feeds, which makes it a part of semi-intensive or intensive culture.



Figure: Cages used for fish culture

1.5 Pen Culture

Pens are similar to cages, except that the species is allowed to access the bottom of the water body. Pens are generally built in large open waters such as lakes, reservoirs and rivers. However, waters used for pen culture are relatively shallow when compared with cage culture, and usually possess a medium to high level of dissolved nutrients. Fish therefore have access to natural food. In some cases, supplementary feed is supplied, making pen culture suitable for either extensive or semi-intensive aquaculture. Pen culture is especially characterized by good water exchange, high dissolved oxygen level, fast growth rate, low feed conversion ratio (FCR), less disease and better economic return. Therefore, pen culture is one of the important strategies for fishery development in open waters.



Figure: A pen made of bamboo used for fish culture

1.6 Nutrition, Feeding Habits and Feeds of Fish

Fish nutrition

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In the aquatic ecosystem, fishes can occupy the niches for phytoplankton-feeder, zooplankton feeder, carnivore, and bottom-feeder. The major components of feeds are moisture (=water), protein, lipid (=fat), carbohydrate, minerals and vitamins. Fish obtain the energy they need by eating protein, lipid and carbohydrate (these nutrients are called the **macronutrients**). Small (or trace) amounts of minerals and vitamins are also essential. These are called **micronutrients**.

Lipids are composed of fatty acids and some of these are also essential for some species of fish. Carbohydrates include fibre, starches and sugars and while not usually considered essential, they can be an effective source of energy and improve food conversion efficiency when included at moderate amounts. Carbohydrates are usually the cheapest sources of energy although different species of fish differ in their ability to use carbohydrates. Carbohydrates can also help to bind a diet together (i.e. the pellet will not crumble easily). Minerals are important for normal skeletal development of fish but some also have a vital role in the functioning of enzymes and other metabolic functions. The ash content of an ingredient is the total amount of minerals (or inorganic matter) present within a food.

Vitamins are complex organic compounds required in small amounts for normal growth, reproduction, health and general metabolism. Diets lacking adequate levels of vitamins and minerals can result in growth and development disorders and death in severe cases of deficiency. Many vitamins and especially Vitamin C (ascorbic acid) are easily damaged by heat, light and humidity and this reduces their usefulness to fish. Vitamins and minerals are contained in some feed especially where fish or prawns are stocked at high densities or are obtaining most of their nutrients from the added feed rather than natural food

Good nutrition in animal production systems is essential to economically produce a healthy, high quality product. In fish farming, nutrition is critical because feed represents 40-50% of the production costs. Fish nutrition has advanced dramatically in recent years with the development of new, balanced commercial diets that promote optimal fish growth and health. The development of new species-specific diet formulations supports the aquaculture (fish farming) industry as it expands to satisfy increasing demand for affordable, safe and high-quality fish products.

Prepared or artificial diets may be either complete or supplemental. Complete diets supply all the ingredients necessary for the optimal growth and health of the fish. In contrast, supplemental diets are intended only to help support the natural food normally available to fish in ponds. Even when the natural feed forms the main source of nutrition, supplemental feeding with artificial feed is necessary to obtain increased production in ponds.

Supplementary feeding plays an important role in intensive and semi-intensive fish culture. It also offers the best means of fish production within shortest possible time in ponds. Supplementary feeding increases the carrying capacity of culture systems and can enhance fish

production by manifold. Commercial fish diets are manufactured as either floating or sinking feeds. Both floating and sinking feeds can produce satisfactory growth, but some fish species prefer floating feed and others sinking feed. Most fish species can be trained to accept floating pellets. Most of supplementary feed in sinking pelleted form goes waste as it sinks to bottom and fish cannot consume it. Although floating feeds are more expensive, usually, it is advantageous to feed floating feed, because fish can consume it from the surface or column of water and the farmer can directly observe the feeding requirements of fish and adjust feeding rates accordingly. Determining whether feeding rates are too low or too high is important in maximizing fish growth and feed use efficiency.

Since feeds cost is one of the highest recurring cost in intensive and semi intensive aquaculture. So it is necessary to formulate low cost fish feed from locally available feed ingredients that are economically beneficial for fish farmers. The present level of fish production can be increased by formulation and commercial production of pelleted fish feed that meet nutritive requirements of the fish. Cultured fish require protein, lipids, energy, vitamins and minerals in their diet for growth, reproduction, and other normal physiological functions. These dietary requirements vary somewhat among species and within species relative to stage of life cycle, sex, reproductive state and environment. Nutrients for cultured fish may come from various food sources, such as plankton, insects and other fish from within the aquaculture ecosystem, and/or from organic matter and processed feeds added to the ecosystem. Foods are defined as natural sources of nutrients produced in the environment, and feeds are natural and manufactured sources of nutrients produced elsewhere and added to the environment. In this respect grains and certain food industry byproducts widely used in semi-intensive pond systems - can be considered as supplemental feeds. Supplemental feeds (feeds supplementing foods), which are usually rich in protein but nutritionally incomplete, may be used to expand production in aqua cultural ecosystems where foods are a major source of nutrition. Supplemental feed may be a single ingredient product such as rice bran or multi-ingredient processed feed. Nutritionally complete feeds are required where foods are absent or are a minor source of nutrition. Nutritionally complete feed will typically be a multi-ingredient pelleted feed produced through either a steam pelleting or extrusion process. Fish with highly specialized feeding habits, such as micro-filterers (e.g. silver carp), herbivores (e.g. grass carp) and piscivores (e.g. pike), may primarily or entirely depend on food while less specialized omnivores (e.g. common carp) readily take manufactured feeds and do not require any food in their diets.

Food and Feeding Habits in Fish

There are four basic eating groups among fish: carnivores, herbivores, omnivores and limnivores. Each group of fish needs to be fed in a particular way.

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1. Carnivores are meat-eating fish. Whilst they will never damage your plant life, you will be lucky if you do not find any of the smaller fish disappearing mysteriously. If there are smaller fish in the aquarium with a carnivore, sooner or later the smaller fish will end up in the carnivore's stomach. Carnivores need at least 45% of protein in their food, without which they become severely malnourished. Although many of the prepared foods are spiked with extra protein to help such fish, carnivores are happiest when they are fed live food like worms.

Recommended food for the carnivores would be:

- ✎ Earthworms, Red worms, Tubifex worms and Daphnia.
- ✎ Larvae of mosquitoes or fruit flies.
- ✎ Oysters, shrimps, clams and other fish.
- ✎ Supplements in the form of flakes or granules and pellets for added nutrition.

2. Herbivorous fish are those that will eat only plants. These fish need to graze very often, and whether they are fed regularly or not, they will nip at your plant life. It is a good idea to feed these fish with fresh veggies.

- ✎ Recommended foods for Herbivorous fish
 - Cucumber, peas and potatoes. These can be kept frozen and be chopped into tiny pieces at mealtime.
 - Vegetable flakes come in a variety of flavors.
 - Algal flakes will also be a favorite among this kind of fish.

3. Omnivore fish will eat pretty much anything, and that makes them dangerous to plants as well as to other smaller creatures in your aquarium. They are also voracious eaters and aquarists can sometimes mistake their eating frenzy for hunger. It is a common tendency to overfeed these species, and they do tend to pile on the fat very quickly if overfed.

4. Limnivores are also known as mud-eaters. Limnivore fish feed mainly on algae and on the microorganisms in your aquarium. These kinds of fish are constantly eating, and can be given pellets and algae based foods. Proper feeding practices are a matter of habit. They require some amount of patience, observation and consideration. Understanding your fish and appreciating the differences between the different species help a lot when you feed them.

The type of food, the culture conditions and the individual fish will all affect the quantity of food you should provide. In nature, there may be times when an adult fish starves for a day or two, or even for longer periods of time. The younger fish need more frequent feedings than the older ones. The fry have their own feeding needs. Most feeding problems arise due to overfeeding. More food also means more waste. The excess food will putrefy and degrade the water quality. Under gravel filters can get clogged with uneaten food wastes. Frequent water changes along with cleaning of decorations, rearranging of plants etc will help to control the debris collection in

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the aquarium. Catfish and other common bottom-feeding fish will help keep the aquarium clean. Deficiencies in vitamins can cause stunted growth, loss of appetite, cloudy eyes, weakness or tumors in fish. For this reason, it is advisable to give your fish vitamin supplements from time to time. No supplement should be left too long in your water. Adding any unnatural substance into your aquarium should be followed up by a water change in a day or two. This will keep the fish as well as the beneficial bacterial colony thriving.

Categories of food digestion processes

There are a number of processes that feed undergoes in the body of fish. These include ingestion, digestion, absorption and elimination.

Feeding habits and stomach presence

There are two major groups fish based on presence or absence of stomach: cyprinids (carps) haven't stomach while catfish, Nile tilapia and other pure predator fishes have stomach

Common fish feeds

Fish Meal

Fish meal made from good quality whole fish that is properly processed is the highest quality protein source commonly available to fish feed manufacturers. It is a rich source of energy and minerals, is highly digestible, and is highly palatable for most fishes. Fish meal made from whole fish contains 60% to 80% protein which is 80% to 95% digestible to fishes. It is high in available lysine and methionine, the two amino acids most deficient in plant feedstuffs. Marine fish meal contains 1% to 2.5% n-3 fatty acids, which are essential in the diet of many fishes. Fish meal made from fish parts, such as waste from fish processing and canning plants, is lower in percentage and quality of protein. It is also high in ash and should be used prudently in fish diets to prevent mineral imbalances which could cause in availability of certain minerals.

Soybean Meal

Soybean protein has one of the best amino acid profiles of all protein-rich plant feedstuffs for meeting the essential amino acid requirements of fish. Soybean protein is not deficient in any essential amino acid for channel catfish. Some fish find soybean meal unpalatable. Canadian research showed that soybean meal could comprise the major protein source in rainbow trout diets and produce satisfactory growth, but if the level of fish meal were reduced below approximately 18%, diet palatability was reduced. Channel catfish satisfactorily consume all-plant diets in which solvent-extracted soybean meal comprises 60% to 70% of the formula. When commercially processed soybean meal replaces fish meal or other animal byproduct proteins in the diet, the losses in energy, minerals, and lipids should be considered. Soybeans contain several anti-nutritional factors, namely a trypsin inhibitor. Heating during commercial oil extraction destroys most of these factors

Other Oilseed Meals

Fisheries and Aquaculture (Biol.3092) Handout One

Meals from peanut (groundnut) and sunflower seed have been used in fish feeds in the United States. Compared with soybean meal, these are deficient in lysine and methionine. Peanut meal produced in the United States contains around 48% crude protein, is highly palatable, and contains no toxins or anti-nutritional factors. It also has better binding properties for pelleting than soybean meal. Sunflower meal is also palatable, but relatively fibrous.

Grains and Byproducts

The primary nutritional contribution of grains is carbohydrate. Whole grains contain 62% to 72% starch, which is about 60% to 70% digestible by warm water fish but less than 40% digestible by salmonids. Heating increases digestibility 10% to 15%. Starch in grains is a valuable binding agent in fish feeds. Rice bran, which usually includes polishings, contains approximately 12% protein, 12% fiber, and 12% fat. It is often available at reasonable cost in developing countries where other ingredients may be prohibitively expensive. It is a good nutrient source, but does not pellet well because of the high fat and fiber contents. Wheat is usually too valuable for human foods to feed to fish; however, small amounts of ground wheat are often used in fish pellets because of binding quality. Wheat gluten (protein) is an excellent binder. Wheat bran and middlings are commonly used in salmonid feeds because they contain more protein and less starch than whole grains.

Animal Byproducts

Meat and bone meal is a product of partially fat-extracted, dried slaughterhouse waste. It usually contains about 50% to 55% crude protein, with a significant amount of the protein coming from bone and other nonmuscle tissue. The quality of the protein is less than that of whole fish meal and varies considerably with the composition of the waste material. It is high in ash and therefore should not be used in unlimited quantity in fish feeds. It is a good source of energy, phosphorus, and trace minerals. Flash or spray-dried blood meal is highly digestible and rich in protein (80-86%). It is deficient in methionine but rich in lysine. It is not as good a mineral supplement as fish meal or meat and bone meal because of absence of bone. Blood meal is unpalatable to some species. Poultry byproduct meal, without feathers, is a good source of animal protein for fish feeds; however, this product is usually recycled back into poultry feeds. Feather meal is a highly concentrated source of protein (80%), but quality is poor and digestibility is low unless the feathers are thoroughly hydrolyzed during processing.

Crustacean Meals

Shrimp waste meal is a useful feed ingredient if the heads are included. The exoskeleton is primarily chitin and has limited nutritional value; thus the visceral organs in the head section are most valuable nutritionally. In addition to supplying protein, shrimp waste meal is a source of n-3 fatty acids, cholesterol (essential for crustaceans), and astaxanthin (for red pigment in

salmonids). It is highly palatable and may serve as an attractant in feeds for fishes and crustaceans.

Fats and Oils

Fats and oils are used as energy sources, to provide essential fatty acids, and to coat the outside of pelleted feeds to reduce abrasiveness (resulting in less fines) and minimize dustiness. Fats from livestock and poultry processing (animal fats) are highly saturated, but are effective sources of energy for warm and coldwater fishes. Marine fish oils are used in feeds for trout, salmon, and cultured marine fish because they are a source of essential (n-3) fatty acids. Marine fish oils contain on the average 20% to 25% of the long chain (over 20-carbon) n-3 fatty acids. Animal fats and vegetable oils do not contain fatty acids beyond 18 carbons and, except for soybean and linseed oils, most are low in n-3 fatty acids. Catfish oil, which is recycled back into catfish feeds, is similar to livestock and poultry fat in fatty acid composition.

Feed formulation

Two main types of feed are available: nutritionally complete and supplementary. Nutritionally complete feeds have been developed and sold especially for intensive farming. They are designed to meet all the nutrient requirements of the fish and are formulated to meet the requirements of different species. Often the requirements quoted are approximations. If the requirement is unknown, then the rule is to use the nearest related species. Supplementary feeds are feeds developed and sold for semi - intensive farming, or for intensively stocked fisheries. More is known about the dietary requirements of aquaculture species than those found in most recreational fisheries.

Aims of formulation

The overall objective of formulation is to maximize production at lowest cost. This involves a compromise between what is ideal and what is actually practical in the formulation of any diet. Considerations might include things like the price and availability of ingredients; the acceptability and palatability of the formulation; whether the ingredients are dry or moist; the ease with which the formulation can be formed into pellets for feeding; the keeping qualities and ease of storage; and any anti - nutritional factors that will reduce digestibility.

Feeding Rate

Correct delivery of food is important to reduce feed waste. Underfeeding can result in loss of production while overfeeding results in feed wastage and can lead to deterioration in water quality. A serious decline in water quality can result in loss of stock and the need for corrective measures. Although the total quantity of feed needed will increase as fish grow, the amount of feed added as a percentage of total fish biomass needs to decrease over time. Feeding rates for tilapia fingerlings of approximately 5-10 g are 10-5% of biomass; for sub-adults of approximately 40 g the daily feed required is from 8 – 3.2 % biomass. Feed twice a day

preferably after sunrise (around 7-9 am) and before sunset (around 4-6 pm). Sample the animals every 2 weeks or once a month and recalculate the amount of feed to be given.

Generally in fish culture, the major factors affecting fish growth are:-**stocking rate, stocking density the water temperature, the quantity (adequacy) and quality of feeds and the feeding method and frequency .**

It can therefore be seen that foods and feeds availability and the feeding practices used by farmers will determine to a large extent the success or otherwise of a fish culture enterprise. Recommended dietary crude protein (CP) requirements for fast and healthy growth of fish vary with fish species. Generally, requirements are: -

- ✓ semi-intensive culture with natural foods (20-25%CP),
- ✓ intensive culture for fingerlings (40-48%CP)
- ✓ and juveniles/adult fish in intensive culture (30-35%).

Water transparency as fertility indicator

Water transparency is measured by Secchidisc shown in figure below. Transparency is inversely related with turbidity, which is a function of the amount of natural food or suspended particles in the water. Turbidity is measured with the secchi disc. If the secchi disc disappears at 30-50 cm. the water is productive in nature. If it is not visible at a depth less than 25 cm, a dissolved oxygen problem could arise during the night. If it is more than 50 cm, the plankton produced is less in the pond water



Figure: Secchidisk for transparency measurement

Health and Disease

Disease control

Aquaculture is still the fastest growing food production sector in the world. It provides a significant supplement to, and substitutes for, wild aquatic organisms and creates employment, generates income and provides opportunities for human development. However, disease is a primary constraint to the growth of many aquaculture species, and is now responsible for severely impeding both economic and socio-economic development in many countries of the world. Addressing health questions with both pro-active and reactive programmes has, thus, become a primary requirement for sustaining aquaculture production and product trade.

What causes diseases?

Infectious diseases caused by: pathogens (virus, bacteria and parasites) and are capable of spreading through the movement of infected host species.

Non-infectious diseases caused by: ubiquitous opportunistic agents or other biotic and abiotic conditions. For example, inadequate management, poor water quality, inappropriate nutrition, aquatic environmental degradation. So we can control disease in different ways such as prevention and control methods.

Prevention:

- (I) Control of movement of animals onto the farm/site (quarantine)
- (II) Sanitary measures, such as disinfection (aquaculture equipment and the pond itself)
- (III) Checking the source of juveniles or brood stock

Control method:

- (I) Destruction of clinically sick animals
- (II) Emergency harvest of clinically healthy animals
- (III) Drain the pond, cull all fish, dry the pond and disinfect it then finally restock it.

Harvesting the fish

Fish can be harvested from culture system (Fish Ponds) using fishing gears. The harvesting type are complete harvesting (collect all stocked fish in pond) and Partial harvesting (Select the marketable sized fishes using selective gears)

1.7. Maintenance and monitoring

Land, water and climatic conditions are probably the most important natural factors that need to be assessed. When developing a site for fish farming you should consider the effect it may have on the environment. Important natural areas (e.g. fish nursery grounds like mangrove forests) should not be used for fish farming. One of the most essential requirements is water availability, in terms of quality and quantity. The type of aquaculture farm and species of animals or plants that you will be able to culture will depend largely on the properties of the site. The risks involved in fish farming should also be stressed. Fish need protein in order to grow and reproduce. This means they can become Competitors for products, which could otherwise be used directly for human consumption. Furthermore, the cost of production is fairly high and therefore fish grown in ponds are not always able to compete financially with fish caught in the wild. Setting up a fish farm involves high initial investment and high production costs as well as

Fisheries and Aquaculture (Biol.3092) Handout One

economic risks. Therefore, there are some very important factors a prospective fish farmer should consider before embarking on fish farming

1. Gathering information:

Future fish farmers can often get assistance with starting up a fish farming enterprise in the form of technical advice from extension services. In some cases even financial support is provided.

2. Finance:

A cost estimate should include the cost of land as well as capital expenditures for fish stock, pond construction, labor, production and harvesting.

3. Site:

The soil must be able to retain water. Good water quality and sufficient quantity should be available at a reasonable cost. The site should be close to home and potential losses from stealing should be estimated. The ownership of the land, as well as the state or federal permits required, should be known and obtained. The site and roads should be passable and not subject to flooding.

4.Fish stock:

You need to decide whether to breed your own fish stock or purchase it from others. If you plan to buy from others you must have a reliable source of good quality fish stock. If you choose to breed on-site, then you must have adequate space for maintenance of brood stock and production of young fish.

5. Production:

Will the feed available for the selected fish species match these species preferences?

6.Harvesting: Enough people should be available to harvest the fish. Find out what is the most economical method for harvesting. You may need storage facilities for harvested fish.

7.Consumption: Will the fish be used for your own consumption or for selling? Selecting the site and type of fish farm