A Guide to Milkfish Culture in the Western Indian Ocean Region

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Cover Photo: A milkfish pond at Chongoleani, Tanga, inaugurated in July 2008 by His Excellency, Jakaya Kikwete, the President of the United Republic of Tanzania. © Lugazo Zuberi

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Preface

In 2004, the Coastal Resources Center (CRC) at the University of Rhode Island was awarded by the United States Agency for International Development (USAID) a five-year Leader with Associates Cooperative Agreement to implement a program entitled "Sustainable Coastal Communities and Ecosystems" (SUCCESS). This program is implemented in collaboration with the University of Hawaii Hilo, Western Indian Ocean Marine Science Association (WIOMSA), Institute of Marine Sciences, EcoCostas and Universidad Centro America. Other partners are: Conservation International, The Nature Conservancy, World Wildlife Fund and Sea Grant Network. The overall objective of the SUCCESS program is to assist coastal communities in selected countries in Eastern Africa and Latin America improve their quality of life (health), income, education and their physical environment through good governance.

Working towards this goal in the Eastern Africa, the program is initiating a number of sustainable mariculture activities for seaweed, milkfish and half-pearls. Since many of these are unfamiliar to most coastal communities, it is critically important to produce publications that provide step-by-step details on how to undertake these activities. Currently, such publications are not widely available, particularly in the Western Indian Ocean Region. Furthermore, implementation of these activities has generated interesting results, which are important to share widely within and outside the region.

Milkfish is a marine and brackish water species that is locally caught and eaten, but rarely has it been cultured commercially in ponds in the Western Indian Ocean Region. Milkfish farming is considered to have great potential to provide additional livelihood and food production opportunities for coastal communities in Western Indian Ocean Region. This guide provides an overview of low-cost, low-impact milkfish farming methods based on emerging lessons in adapting Asian production methods to the Western Indian Ocean context. New information presented in this guide is based on experience gained through trials aimed at developing commercial milkfish farming methods in Tanzania. The emphasis is on methods which are simple, locally appropriate and environmentally friendly.

Comments and suggestions are most welcome. The authors, the SUCCESS program, WIOMSA and the other participating institutions believe this guide will be useful to the region at large.

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1. Introduction

Milkfish culture had been practiced for over a hundred years in Asia, particularly in the Philippines, Indonesia and Taiwan. Much has been learned about proper milkfish culture over this period and how milkfish culture can be a sustainable mariculture practice. Milkfish culture can help supply much needed requirements of dietary protein for growing populations as well as contribute to poverty alleviation in coastal communities if developed and managed appropriately.

In the Western Indian Ocean (WIO) Region, mariculture is not widely practiced except for seaweed farming. However, the potential within the region is great and many forms of mariculture are under trial and development. Milkfish (Chanos chanos) is an indigenous species within the WIO region but has not been widely cultured. Since its culture is well known from Asia, it represents an important mariculture opportunity whereby existing technology can be readily transferred to the WIO region. Tanzania is pioneering locally appropriate methods of milkfish farming by adapting and learning from the Asian experience.

This manual is based on the emerging milkfish farming experience in Tanzania. The manual provides guidance to extension workers and small scale entrepreneurs who may be interested in developing milkfish farms as a food production and income generating opportunity. It provides information on the ecology and biology of milkfish in addition to information on pond site selection, construction, stocking, rearing, harvesting and marketing. Milkfish farming is not a simple aquaculture practice and requires individuals with the desire to learn, adapt and pay close attention to their farm management on a daily basis. In addition, it requires a good deal of upfront investment, especially for pond construction, so should not be considered without a source of financial capital as well as an available labor pool for construction and management. However, preliminary indications are that good economic returns can be made from milkfish farming in the region.

1.1 Environmental Considerations

Aquaculturists need to be responsible for the conservation, protection and sustained management of fisheries and aquatic resources. Irresponsible milkfish farming and development practices in Asia have led to the widespread destruction of mangroves, and have given aquaculture a bad reputation in the eyes of many environmentalists, as well as others concerned about environmental degradation. The WIO region needs to avoid many of the early mistakes made in Asia and promote milkfish farming in a responsible way. There are several areas in particular that need to be given consideration by farmers and policy makers. For instance, one key area of concern is selecting farming areas that will not have an impact on surrounding environments such as mangroves, and other fragile ecosystems. Preferred sites for milkfish pond development are found in areas that were formerly used for salt production or in salt flats behind the mangrove zone. Extensive placement and construction of milkfish ponds in mangrove areas should be avoided. Milkfish farmers have a responsibility for conscientious farming practices that are environmentally sustainable. However, government must also play a role in the early stages of development of this form of mariculture practice to protect and regulate the industry in a way to avoid mistakes learned from other places, so that they will not be repeated.

1.2 Regulatory Framework for Mariculture

In Tanzania, there are policies and strategies on environment, fisheries and aquaculture already in place that support responsible and sustainable mariculture practices. Of particular importance are guidelines established by The National Environment Management Council for the development of mariculture in Tanzania (TCMP 1999; TCMP 2001a, 2001b). The guidelines discuss many aspects of mariculture development including approval procedures, water rights, environmental impact assessments, and site selection, as well as gaps in current policies especially in the approval processes.

From an environment stand point, milkfish ponds should not be built in mangrove areas but behind the mangroves in the salt pans by replacing salt production ponds or conversion of abandoned salt production ponds. Long term leases or permits also need to be sought before any construction is started. While the general regulatory framework for mariculture in Tanzania is fairly strong, the challenge will be in applying it appropriately to milkfish farming. In other countries in the region, milkfish farming promoters will need to look carefully at the national context, and policy development may be needed prior to development of widespread milkfish farming.

1.3 History of Milkfish Farming in Tanzania and Lessons Learned

There have already been a number of attempts at experimental and pilot culture of milkfish in Tanzania (Dubi et al 2004; Rice et al 2006) by a number of academic institutions. The Institute of Marine Sciences (IMS) for example, has been involved in milkfish pond aquaculture since 1996 (Mmochi et al 2005). However, milkfish farming has not taken off on a commercial scale by private operators for several reasons.

First, more attention needs to be paid to economics and marketing considerations. The mean weight of the market-size adult milkfish caught in the wild in Tanzania is 12 kg and therefore many people are not familiar with the smaller sizes that are typically produced from aquaculture. Accordingly, there are worries on the marketability of the farmed fish. However, initial milkfish sales trials have demonstrated marketability to restaurants and city markets in Tanzania, fetching approximately US$ 2 / kg.

Milkfish is a delicious food fish, but it has a large number of intermuscular bones in the tissues that make some people avoid it, especially Europeans, but people on the coast of Tanzania are familiar with milkfish from the wild fishery. The intermuscular bones are therefore not considered a problem. Eating trials conducted by IMS did not reveal any preferences of other local species over milkfish. In Asia, de-boned processed milkfish is gaining in popularity and de-boning may also be a post harvest processing method in the WIO region as well.

Transportation infrastructure is another challenge. In some areas it has proven inadequate to move a large volume of harvest from commercial farms to urban population centers. In such instances “backyard” farms geared more to local household or village consumption may be more appropriate.

Careful attention needs to be given to pond construction. Poor pond construction doomed several pilot operations to failure from the onset. Proper construction is critical to ensure appropriate tidal flows for water management and allow for drying of pond bottoms between growing cycles. This is a more complicated process than is often assumed by prospective farmers, and more technically challenging compared to freshwater pond construction. Construction is also the most costly phase of milkfish farming and may therefore constrain the poor from attempting milkfish farming. Subsidizing pond construction via development projects may be justified as a means of getting the industry started and a critical mass of ponds operating.

Current approaches to piloting milkfish farming include working directly with interested farmers rather than on research stations. For instance, one approach has been to work with salt pond operators. Salt pond operators can start by experimenting in a simple way by converting a few active or abandoned salt ponds for small-scale low risk trials first, before considering any larger scale conversion or development. This approach also helps keep start-up costs low.

Another constraint discovered in early milkfish trials was that not much attention was paid to sorting fry or fingerlings so in some instances, the predator fish “tenpounder” (Elops machnata), were unintentionally stocked along with milkfish leading to very low and unprofitable production levels. Fingerling availability and methods of fingerling collection in sufficiently large numbers for commercial operation are other challenges being faced. Proper pond preparation and good water management are also essential. None of these issues are insurmountable and the outlook for milkfish farming in Tanzania and the WIO region seems very promising. Proper technical support and training of prospective farmers will be essential for success. That is one issue this manual hopes to address.

2. Biology and Ecology of Milkfish

Milkfish is a marine species of finfish that has a wide tolerance to variations in salinity . Fry and juvenile stages occupy estuarine environments and the adult form lives in the open ocean. They can live as long as 15 years and grow to a maximum weight of 14 kg. Milkfish is a desirable species for aquaculture for a number of reasons:

- Milkfish fry supply from the wild is abundant because of the high fecundity of spawners;
- Milkfish fry are hardy and easy to handle; with a high tolerance and adaptability to salinity change;
- Milkfish are herbivorous, thus benthic algae grown from fertilization of pond bottom is a suitable food;
- Growth rate of milkfish is much faster than other herbivorous fish;
- Milkfish are not cannibalistic, thus stocking density can be high; and
- Milkfish has high resistance to diseases

2.1 Identification of Milkfish and Milkfish Fry

Milkfish is scientifically known as Chanos chanos (Figure 1). In Tanzania, there are several local names. In Zanzibar it is called mwatiko, but in some parts of the mainland, such as in Mkuranga is referred to as mkuyui. Ironically in Zanzibar mkuyui or kihalua is the name used for tenpounder, which is a predator and should not be in the same pond with milkfish. In Mkuranga the tenpounder is called mwatiko. Another name used for milkfish in the coast region in the mainland is kowazi. Many people in the mainland however call the milkfish mwatiko and the tenpounder kihanisi or hanisi and these are the names that appear in the FAO field guide for marine and brackish water species in Tanzania (Bianchi, 1985).

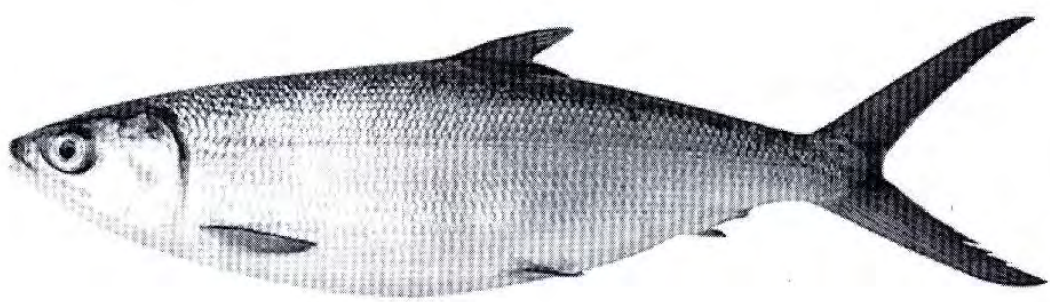


Figure 1. Market-sized milkfish, Chanos chanos, from ponds in Bagamoyo, Tanzania. ©E. D. Requintina,Sr.

Milkfish are similar in appearance to many other species of fish but can be distinguished through a number of distinctive features (Figure 2):

- Body elongate, moderately compressed, smooth, and streamlined
- Body color silvery on belly and sides grading to olive-green or blue on back
- Dorsal, anal, and caudal fins pale or yellowish with dark margins
- Caudal fin large and deeply forked
- Pelvic fins abdominal in position, with auxiliary scales
- Scales small and smooth
- Mouth small, terminal, without teeth
- Lower jaw with a small tubercle at tip, fitting into a notch in the upper jaw
- Only 4 branchiostegal rays support the underside of the gill covers
- Intermuscular bones long and numerous

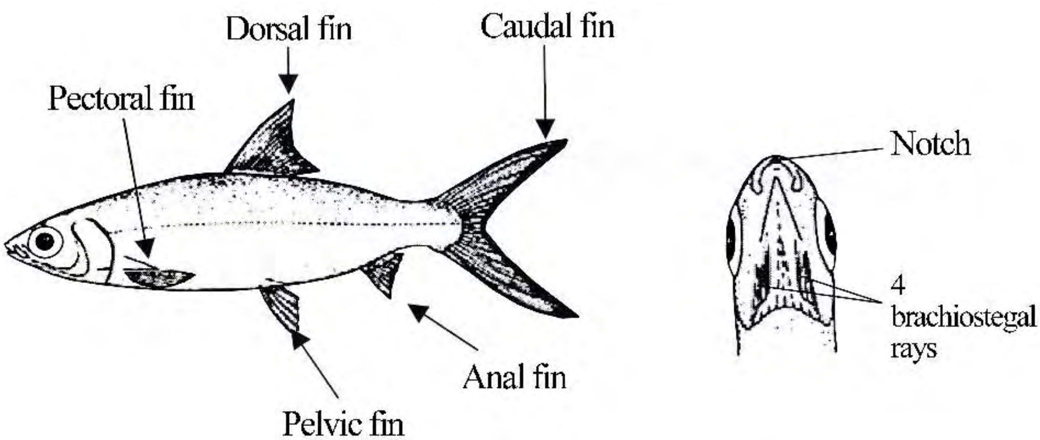
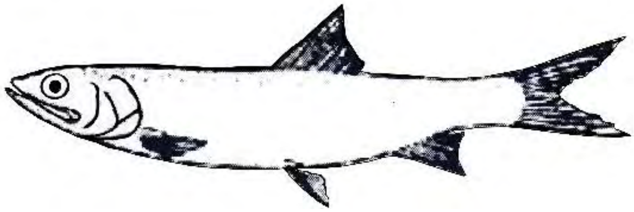


Figure 2. The shape and the front lower head of the milkfish showing the main features. (SOURCE: Bagarinao, 1999)

Milkfish are similar in appearance to several other types of finfish (Figure 3) that are often mistaken as milkfish. In particular, it is often mistaken with the tenpounder (locally known as mkuyui in Zanzibar and mwatiko in Mkuranga). It is very important to distinguish between milkfish and tenpounders since tenpounders are carnivorous. If care is not taken to exclude these predators of milkfish during pond stocking, a pond owner can wind up with a few well-fed tenpounders and no milkfish, rather than a large number of milkfish at harvest time! The distinguishing features of milkfish fry are illustrated in Figure 4. Other fry that can be mistaken for milkfish fry, including the tenpounder, are shown in Figure 5.

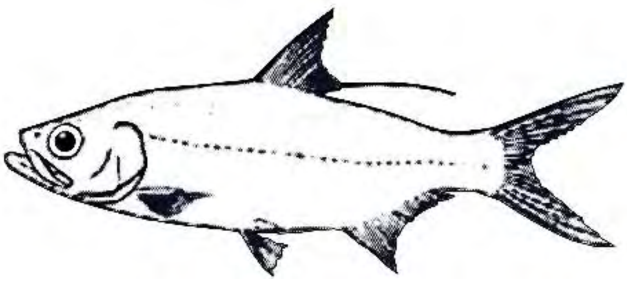
Characteristics of milkfish fry include:

- Large black eyes
- Elongated transparent bodies and a single line of black pigments on the ventral edge
- Energetic schooling and circling behavior
- They are very hardy compared to other fry species and can be easily kept alive for transport to ponds with proper handling procedures.



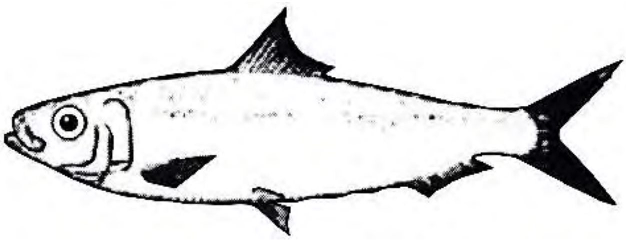
Tenpounder, *Elops hawaiiensis* or *Elops machnata*

- Mouth much larger, maxilla reaching back behind eye
- A bony gular plate present between arms of lower jaw
- The fish is carnivorous and should be avoided in milkfish ponds



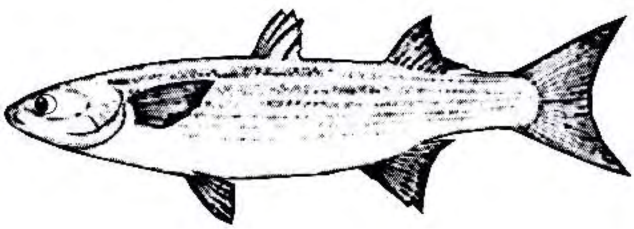
Tarpon, *Megalops cyprinoides*

- Has a bony gular plate
- Last dorsal fin ray filamentous
- Scales large, 30-40 in lateral line



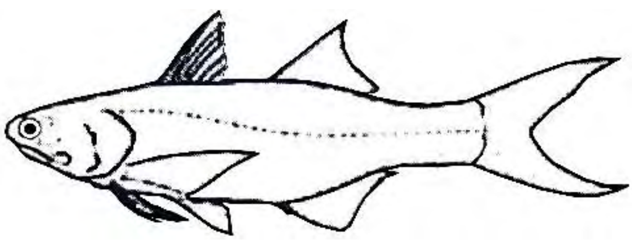
Sardine, *Sardinella* spp.

- Size much smaller, usually 6-7 branchiostegial rays (only 4 in milkfish)
- No lateral line
- Scutes usually present along belly



Mullet, *Lisa* spp., *Mugil cephalus* or *Valamugil*

- Two short dorsal fins, the first one with 4 spines
- Pectoral fins set high on body
- No lateral line
- Can be farmed with milkfish in polyculture



Threadfin, *Eleutheronema tetradactilum*

- Snout projects forward of inferior mouth
- Two dorsal fins
- Pectoral fins with separate rays

Figure 3. Distinguishing features of fishes commonly mistaken for milkfish. SOURCE: Fisher and Whitehead, 1974

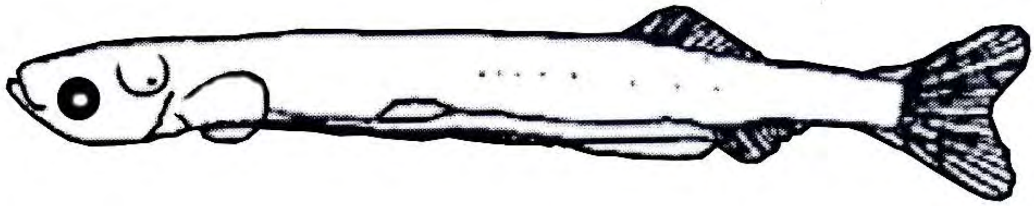
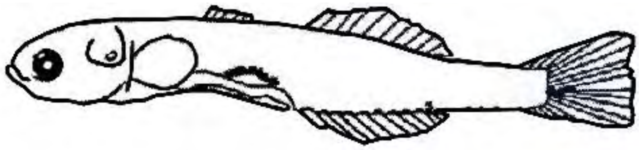
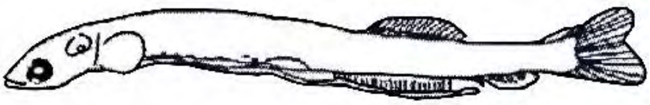


Figure 4. Milkfish fry. SOURCE: Bagarinao and Kumagai, 1987



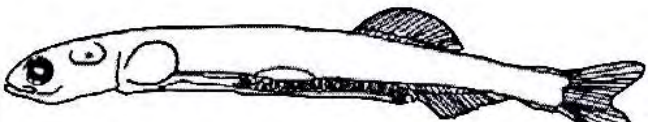
Goby fry

- Goby fry maybe shorter or longer than milkfish fry
- Two short dorsal fins and a prominent inflated swim bladder



Sardine fry

- Transverse foldings in the gut



Anchovy fry

- As with sardines, anchovy fry also have transverse foldings in the gut

Tenpounder fry

- Longer (25-35mm), deeper, flatter, ribbon-like, slightly amber bodies, smaller eyes than milkfish fry

Tarpon fry

- Longer (25-35mm), deeper, flatter, ribbon-like, slightly amber bodies and smaller eyes than milkfish fry

Figure 5. Larvae of other fishes often confused with milkfish fry. SOURCE: Bagarinao and Kumagai, 1987

2.2 Life Cycle, Habitats and Geographical Distribution of Milkfish

Milkfish is a large, long-lived species, and its habitat, behavior, and food habits change with size and stage in the life cycle. Milkfish in the wild migrate from one place to another. Adults spawn at sea, the larvae migrate to shore, juvenile settle in shallow-water habitats, and large juveniles and sub-adults return to sea. Accordingly, to ensure the survival of milkfish populations in the wild, coral reefs, beaches, mangrove swamps, estuaries, rivers and lakes must be protected. The life cycle of milkfish generally consist of several stages as illustrated in Figure 6 the eggs, larvae, fry, juveniles and adults. Fry congregate along coastal shorelines searching for estuary areas which are the preferred nursery grounds. This is important as sandy beach shorelines are often prime areas for collection of fry for pond stocking. The larger sized juveniles often referred to as fingerlings, are found in estuary areas. These can also be collected and stocked in ponds. However, as they increase in size they become harder to catch and more difficult to find in the numbers required for commercial farming.

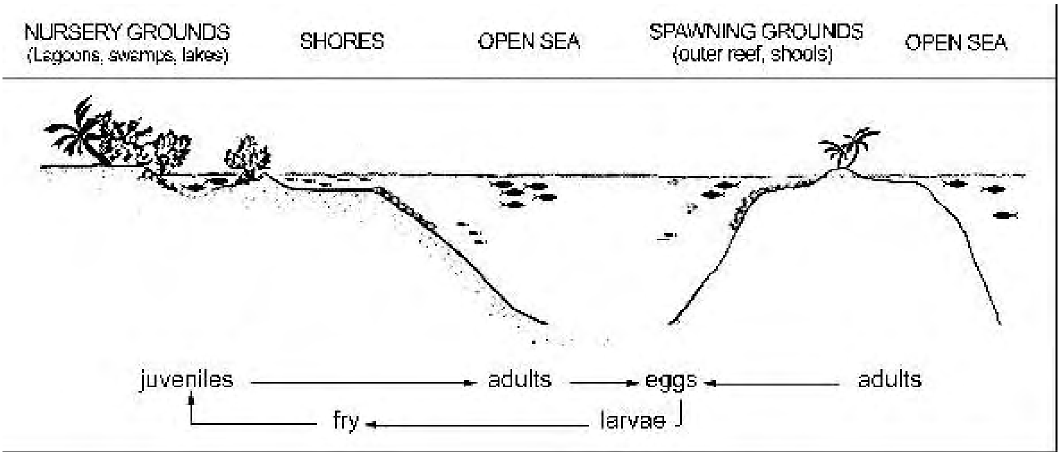


Figure 6. Habitats of milkfish at different stages in the life cycle. SOURCE: Buri et al 1981

Milkfish have a large bio-geographic distribution within the Pacific and Indian Oceans as illustrated in Figure 7. The Philippines, Indonesia and Taiwan are the center of geographic distribution. Milkfish have been recorded as far north as Japan and as far south in eastern Australia. They extend eastwards to America and are common in the bays and lagoons of Mexico.

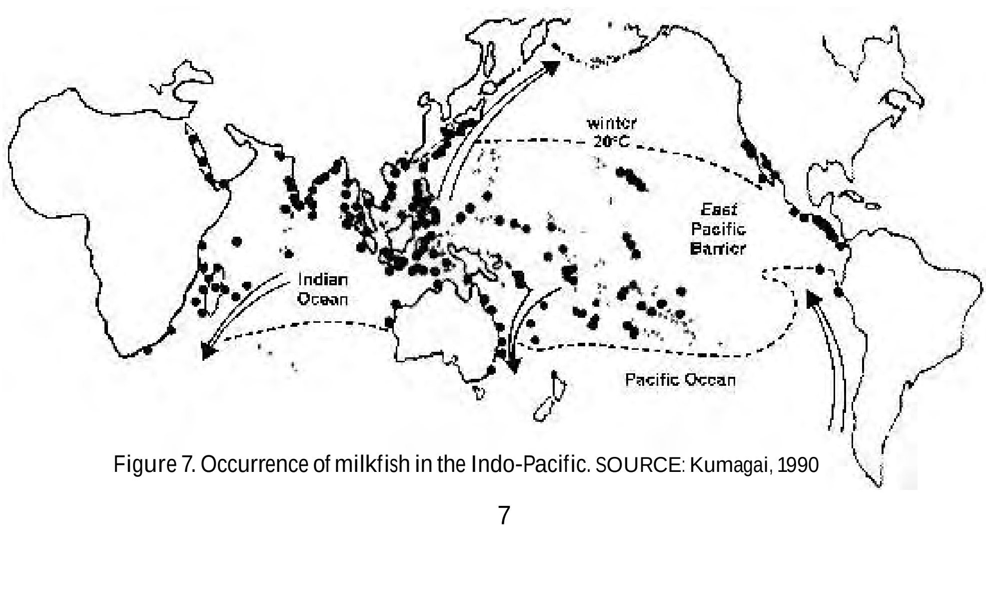


Figure 7. Occurrence of milkfish in the Indo-Pacific. SOURCE: Kumagai, 1990

They also occur in the Indian Ocean and along the East African continental shoreline. Milkfish are not found in tropical waters affected by cold ocean currents. The geographic range is limited to winter water temperatures greater than 20°C. Such warm waters extend to temperate latitudes where there are major warm ocean currents, but do not exist in tropical latitudes affected by cold ocean currents (Kumagai 1990; Bagarinao 1994).

3. Milkfish Pond Engineering and Construction

Fishpond engineering is the science of planning, designing and construction of fishponds, including water control structures. It plays an important role in attaining efficiency in farm management so that better farm production can be realized.

3.1 Site Selection and Evaluation

Several factors need to be considered in selecting appropriate sites for milkfish ponds. Poor siting of ponds have resulted in many farms failing and eventually being abandoned. Site selection should start with an initial field survey that evaluates the area for a number of criteria described in more detail below.

3.1.1 Water Supply

Water supply is the first and most important factor to consider in the suitability of a fishpond site. Usually, water supply comes from a river, creek or sea. It must meet the quality and quantity of the pond requirements throughout the year. It would be futile to develop a site if the source of water is polluted and / or the volume is inadequate.

3.1.2 Tidal Characteristics and Ground Elevation

The suitability of a tide-fed site for a milkfish pond depends on the relationship between the tidal characteristics of the area and its ground elevation. Areas with ground levels that are too high or too low in reference to Mean Lower Low Water (MLLW) also called “0-datum” (see Section 3.2.2 for more information) are not economically suitable for it will require too much and costly excavation or filling. Suitability of a pond construction area relative to 0-datum and ground elevations are illustrated in Figure 8. Areas reached only by the high spring tides should be ruled out as it is too costly to excavate the large quantity of earth that would be required to allow water to reach the pond at other times. Pond sites with areas much lower than the 0-datum on the other hand, will require filling of pond bottoms, otherwise full draining and drying cannot be accomplished. This is an unnecessary and extra expense. The best elevation for a pond bottom would at least be 0.2 meter from the 0-datum plane or at the elevation where 0.6 meter depth of water can be maintained inside the pond during ordinary tides. Maintaining a water level of 0.6 meters depth will satisfy the requirements of both fish and natural fish food. Water of this depth is deep enough that sunlight can reach the bottom of the pond so that photosynthesis should still be able to take place to produce the benthic algal mat (called “lablab”), a natural food for milkfish, yet be deep enough so that fish can survive.

3.1.3 Soil Properties

Most fishponds are constructed on tidal lands consisting of alluvial soils, which are adjacent to rivers or creeks near the coastal shores and estuaries at or near sea level elevation. It is made up of mineral and organic particles of varying sizes. The mineral particles are either clay, silt, and sand while the organic particles are plant and animal matter at various stages of decomposition. Table 1 shows classifications of soil by particle size (soil texture).

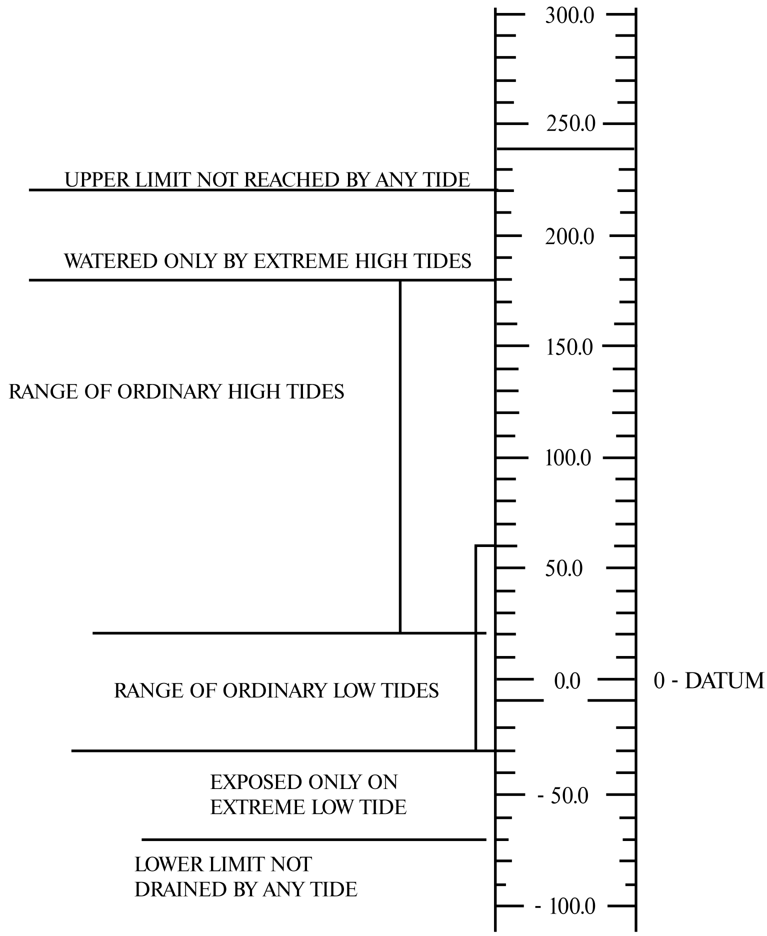


Figure 8. Suitability of a fishpond site based on tidal characteristics and ground elevation.
SOURCE: BFAR/FAO/UNDP, 1980

Table 1. Classification of soil by particle sizes (SOURCE: BFAR/FAO/UNDP, 1980)

GENERAL TERMS				
	Common Names	Texture	Basic Soil Textural Class Names	
1	Sandy	Coarse	Sandy	
			Sandy Loam	
2	Loamy Soils	Moderately Coarse	Sandy Loam	
			Fine Sandy Loam	
		Mediam	Very Fine Sandy Loam	
		Moderately Fine	Loam	
			Silty Loam	
			Silt	
3	Clay Soils	Fine	SandyClay	Clay Loam
			Silty Clay	Sandy Clay Loam
			Clay	Silty Clay Loam

3.1.4 Soil Classification

Soil texture is important in determining how well suited the area is for fishpond development. Finer textured soils are superior for fishpond purposes because of their good water retention properties. Ideally, dikes constructed with clay soils are preferred over dikes with sandy soils (Figure 9). Figure 9a shows a solid clay core whereas Figure 9b shows a mixture of clay and sand, which is more susceptible to water leakage and dike failure. Clay or sandy clay is best for dike construction but not as good as clay loam or silty clay loam in terms of growing natural food. Table 2 shows the suitability of the different soil classes in pond constructions.

Table 2. Relationship of soil classes and suitability for dike material (SOURCE: BFAR/FAO/UNDP, 1980)

Class	RELATIVE CHARACTERISTIC		COMPACT CHARACTERISTIC	SUITABILITY FOR DIKE MATERIAL
	PERMIABILITY	COMPRESSIBILITY		
Clay	impervious	medium	fair to good	excellent
Loamy	impervious	high	good	good
Silty	semi-pervious to impervious	medium to high	good to very good	poor
Sandy	pervious	negligible	good	poor
Peaty				very poor

Figure 9. Cross section of two dikes showing a good solid clay core (A) and poor core of mixed clay and sand (B). ©: B. Crawford

There are various ways of identifying different classes of soil, especially using texture as described below.

Sand - Soil has a granular appearance. It is free flowing when in a dry state. A handful of air-dried soil when pressed will fall apart when released. It will form a ball that will crumble when lightly touched.

Sandy Loam - Essentially, it is a granular soil with sufficient silt and clay making it somewhat coherent. Sand characteristics predominate. It forms a ball which readily falls apart when lightly touched or when air-dried. It forms a ball, which bears careful handling without breaking.

Loam - A uniform mixture of sand, silt, and clay. Grading of sand fraction is quite uniform from coarse to fine. It is soft and has a somewhat gritty feel, yet is fairly smooth and slightly plastic. When squeezed in hand and pressure is released, it will form a ball which can be handled freely without breaking.

Silty Loam - It contains a moderate amount of finer grades of sand and only a small amount of clay; over half of the particles are silt. When dry, it may appear quite cloddy; it can be readily broken and pulverized to powder. When air-dried, it forms a ball which can be freely handled. When wet, soil runs together and puddles. It will not ribbon but has a broken appearance; it feels smooth and maybe slightly plastic.

Silt - It contains over 80% of silt particles with very little fine sand and clay. When dry, it may be cloddy; it is readily pulverized to powder with a soft flour-like feel. When air dried, it forms a ball which can be handled without breaking. When moist, it forms a cast which can be freely handled. When wet, it readily puddles. It has a tendency to ribbon with a broken appearance; it feels smooth.

Clay Loam - Fine texture soils break into lumps when dry. It contains more clay than silt loam. It resembles clay in a dry condition. Identification is made on physical behavior of moist soil. When air dried, it forms a ball which is freely handled without breaking. It can be worked into a dense mass. It forms a thin ribbon which readily breaks.

Clay - Fine texture soils break into very hard lumps when dry. It is difficult to pulverize into a soft flour-like powder when dry. Identification is based on cohesive properties of the moist soil. When air-dried, it forms long thin flexible ribbons. It can be worked into a dense compact mass. It has considerably plasticity, and can be molded.

Organic Soil - Identification is based on its high organic content. Much consists of thoroughly decomposed organic materials with considerable amount of mineral soil finely divided with some fibrous remains. When considerable fibrous material is present, it maybe classified as peat. Soil color ranges from brown to black. It has high shrinkage upon drying.

It is recommended that soil samples be taken from different spots in the proposed site. Identification of different soil types in different areas in the site is important so that the most suitable type will be used for appropriate purposes. Thus, clay soils can be moved to construct dikes while the organic soil can be used to line the pond bottom as they would be most appropriate for growing organic food for the fish.

3.1.5 Flood Hazard

Flooding is considered to be one of the most destructive natural disasters in the fishpond industry. Floods cannot be controlled completely, but it is important to know how a fishpond can be free to some extent from flood hazard. It is necessary to know the weather conditions in the area and find out the highest flood that occurred. High tide plus the highest flood level on record should be considered so proper diking and drainage can be planned. In Eastern Africa, the main rainy season is March to May when fingerlings are more abundant (Dubi et al 2005). In addition to dike construction elevation considerations, farmers may want to consider harvesting before the rainy season that coincides with flooding from land and the highest spring tides in the year with greater possibilities of breaking the pond walls. Then, restock the ponds just after the rainy season has passed reducing the risk of flooding and just at the time when the greatest abundance of fingerlings can be caught.

3.1.6 Climatic Conditions

Seasonal climatic changes are important in scheduling and managing fishpond operations. The climatic elements that concern most operators are rainfall, temperature and prevailing wind direction because they greatly affect fish production directly or indirectly. Data on rainfall and wind direction are necessary in planning the layout and design of a pond system. Knowing the past rainfall records can help you decide on dike heights or whether to include drainage canals.

Wind direction may not be so critical for small ponds; however, if the pond area is big, winds can be very destructive since they generate wave action that can destroy the sides of the dikes. By knowing the wind direction, the dikes can be positioned such that the wind will only have to travel across the ponds in the shortest possible distance, thus reducing the potential wind damage to the dikes and to the ponds in general. Dikes that are most likely to be hit by strong winds can be made wider and stronger to stand up to such wind. Heavy rain can suddenly change the salinity and temperature of pond water, which can be detrimental to fish. It is also important to know the period of the rainy season as this will affect pond preparation and stocking cycles. Drying of pond bottoms cannot be accomplished during rainy seasons but is a necessary step prior to stocking to reduce likelihood of disease outbreaks.

3.1.7 Type and Density of Vegetation

Type, size and density of vegetation and the root system of individual trees, greatly affect the method of clearing, procedure of farm development and construction cost. Thickly vegetated areas will take longer to clear and therefore cost more money. The clearing cost will depend on how much vegetation is present and the labor cost, whether the charge is per tree or per area. It is highly recommended that pond sites be selected that are sited primarily in salt flat areas behind mangrove stands. Large scale clearing of mangroves is not recommended as it increases construction costs and is environmentally destructive.

3.1.8 Support Infrastructure and Labor

Other factors that can affect the selection of a good fishpond site are:

- Accessibility to market
- Availability of fast and good transport facilities for marketing of fish
- Availability of fry for stocking
- Availability of skilled labor
- Availability of ice and cold storage facilities
- Availability of fertilizers (organic and inorganic) and supplementary feed
- Availability of construction materials
- Availability of financial institutions
- Peace and order conditions in the locality

3.2 Site Survey for Pre-Construction

3.2.1 Survey Equipment

Pond construction requires the following equipment:

Measuring Tape - Used for measuring straight distances between points and made of flat steel or fiberglass bands marked in various ways. These can be obtained in different lengths but 50 –100 m long are the most convenient size to use.

Water-filled Transparent Hose - An inexpensive tool to transfer an elevation from one point to another based on the principle that water seeks its own level. It is a transparent hose (of about 1–2 cm inner diameter) filled with water. One end of the hose will be held in one reference point, positioned in a way that the water level is aligned to a desired elevation like for example a stake with a marking that is 0.5 m above 0 datum. The other end should be positioned in the area where you want to determine the elevation (Figure 10). Drive a stake and place the other end of the hose beside it, then mark the water level and that will tell you exactly that the mark is 0.5 m above 0 datum.

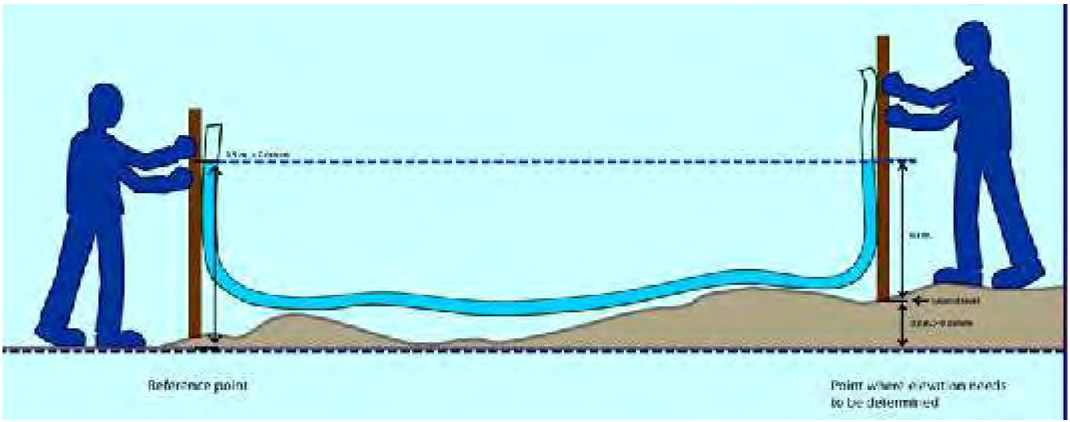


Figure 10. Illustration of using the water in a transparent hose to transfer elevations. © E. Requintina, Jr.

Hand Level - Used for rough measurements of differences in elevation. It is used by standing erect and sighting through the eyepiece, holding the tube and moving the objective end up and down until the image of the spirit level bubble on the mirror is centered on the fixed cross wire. The point where the line of sight in this position strikes the rod or other objects is then noted. The vertical distance from the ground to the surveyor's eye is used to determine the height of instrument and ground elevations. A rough line of levels may be carried out with the hand level for distances of 10 –15 m.

Level Transit - Is a more accurate instrument for measuring the difference in elevations. The height of the instruments line of sight is well established and rotational movement is stable. As do all sighting instruments, it operates on the principle that any point along a level line of sight is exactly level with any point along that line. Self-Leveling level Transit - The self-leveling level automatically levels its' line of sight with great accuracy. There is no tubular spirit level and no tilting screw. It levels itself by means of a compensator after the circular spirit level is centered approximately. It is precise as well as simple and quick to operate and can be used for any type of level survey.

Engineer's Transit - This instrument is used primarily for measuring horizontal and vertical angles, prolonging or setting points in line, measuring approximate distances by stadia principle, and for leveling operations. It can also be used as a compass when equipped with a compass needle.

Tripod-A three adjustable legged stand where the transit is mounted for a stable support.

Leveling Rod - Stadia rod and the range pole are two kinds of leveling rods which are commonly used in conducting a site survey. Stadia rods are calibrated extension rods where you can read the elevations and sometimes distance if you are using an engineers transit.

Marker Stakes - These are use to mark elevations by transferring the stadia reading on them. These are also used to mark proposed locations of dikes and gates.

Meter Sticks - Convenient instrument to measure short distances.

3.2.2 Locating the 0-Datum

0-datum is defined as Mean Lower Low Water (MLLW). Determining the location of the 0-datum is the most important task in site selection and for design. The datum plane of reference for land elevation of fish farms is called 0-datum. It is the average water height of all the lower of low waters or mean lower low water (MLLW). It can also be called 0.00 elevation. The most accurate way to do this is through tidal observation at the proposed site of the main gate for at least one-month duration or one lunar cycle. You can also get a rough estimate using just a few tidal cycles. This can be done by erecting a calibrated tidal pole in the deepest area near the proposed site of the main gate. Observe and record all the low tide readings that occurred for future calculations. Pick out the data from the range of ordinary low tide readings and add to the data of extremely low tide ones (neap tide) and get the average. This is where your datum plane (0-datum) will be set. Also observe and record all the high tide readings including the extremely high tides (spring tide) for the reference in the minimum height of the perimeter dike and the main gate to prevent flooding. An example of tidal readings, determination of 0-datum, and suitability of an area for pond construction are shown in Figure 11.

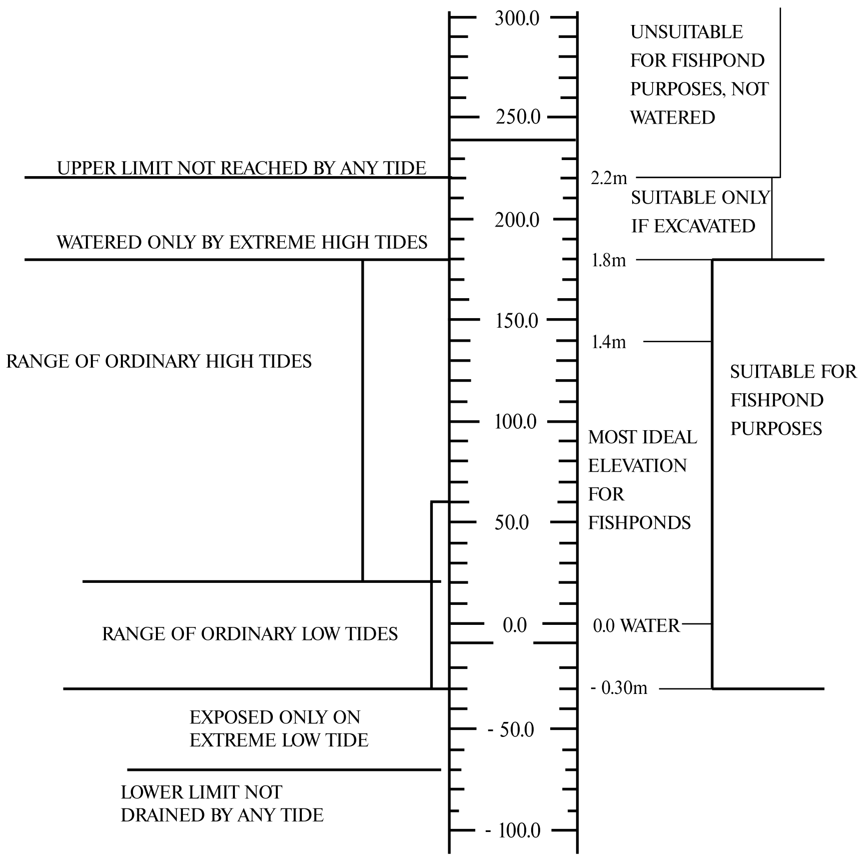


Figure 11. Sample of tidal readings and the location of 0-datum (MLLW). SOURCE: BFAR/FAO/UNDP, 1980

3.2.3 Setting up a Bench Mark

Several temporary or permanent bench marks should be set up in the site. These are based on 0-datum or MLLW. They are used as references for elevations during construction and therefore should be well marked and secured. A main Bench Mark at the site is needed to gauge elevation based on 0-datum. Secondary bench marks should also be established in different locations in the site based on the construction plan.

The following steps describe this process:

- Plan to be at the site when the tide is low
- Somewhere halfway between the tide pole where 0-datum had been established and the proposed bench mark, set-up the level transit
- Set the bottom of the stadia rod aligned to 0-datum and take a backsight (BS) reading (Figure 12)

- The backsight (BS) reading is the height of the level transit in reference to the 0-datum
- Set up a bench mark (BM) by driving a wooden stake onto the ground
- Distinguish the bench mark stake from other stakes by a distinctive paint. Set the stadia rod on top of the bench mark and take the foresight reading (FS)
- Calculate the elevation by subtracting the height of the foresight (FS) reading from the height of the instrument (HI). HI-FS=BM elevation

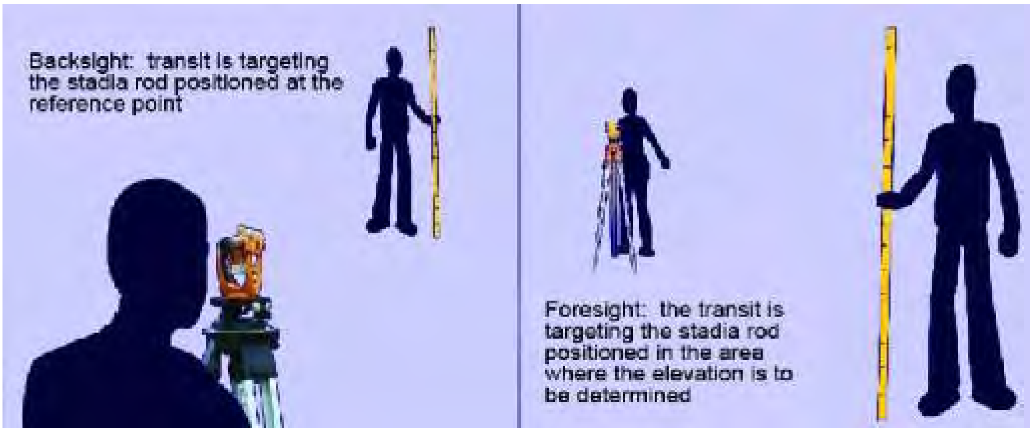


Figure 12. Illustration of the transit and the stadia rod being used to measure the backsight (BS) and the foresight (FS) readings. © E. Requintina, Jr.

3.2.4 Determining Elevations of Different Ground Locations

Drive some marker stakes at the locations where you want to know the elevations and identify each stake with a number. Set up the level transit at a location where you can spot the bench mark (BM) and the marker stakes. Place the bottom end of the stadia rod on top of the bench mark (BM) and take a reading. Place the bottom end of the stadia rod on the ground level (GL) where the marker stakes are located and take a reading. Ground level (GL) reading minus the bench mark reading (BM) will give you the elevation in reference to the bench mark. GL reading - BM reading = GL elevation in reference to BM elevation.

3.2.5 Setting Up Marker Stakes for Dike, Canal, and Gate Locations

Using a measuring tape, measure the distances between points where you want to construct your dikes, canals and gates. At every point where you have located the proper placement of the dikes, canals and gates, drive a primary stake in the ground. From these primary stakes, measure on both sides to mark the proposed width of the dikes, canals and gates and drive in the secondary stakes. Check if the set up is done as planned and adjust if something is not quite right before doing the actual construction.

3.3 Backyard and Commercial Pond Systems

No one standard type of pond system is likely to satisfy all site conditions and socio-economic contexts within a nation or region. In Tanzania, two basic types of pond systems are emerging that seem to have the widest degree of applicability: (1) commercial ponds systems whereby a large volume of uniform-sized fish can be produced, harvested and sold at any one time to a sizable commercial market, usually wholesale, and (2) backyard ponds which are small in size, simple in construction and can be community-managed or managed by a single household with a one time or continuous harvest for household consumption or for direct local retail sale within a village.

Figure 13. Backyard mariculture pond in Buyuni, Tanzania. ©B. Kalangahe

3.3.1 Backyard Ponds

This type of pond farming system is mainly for household purposes but some direct sales are also possible on a small scale. The pond sizes range from 0.1–0.2 ha. Pond construction and management costs are minimal. The small pond size means that they can be hand dug and managed directly by household members without the need to employ outside labor. In this type of pond, fish are stocked and harvested continuously. The harvesting in this case can be selective whereby only the larger size individuals are taken for consumption, then allowing smaller fish to grow before they are in turn harvested. There are several ponds in Tanzania operating at this scale including the recently developed at Buyuni, Saadani in Pangani District, and in Tanga, Tanzania (Figure 13).

Rather than using wooden or cement gates that are expensive to construct, PVC pipes (construction gauge PVC used for water supply, not electrical conduit gauge) can be used for water inflow and drainage (Figure 14). This is the main material that needs to be purchased with cash. Pipe thickness should be quite wide from 6–9 inches in diameter. Site selection, dike construction, and pond preparation are similar to the commercial scale operations, except for the absence of a gate. PVC piping which is used for water regulation must be laid at the bottom of the pond and through one of the dikes in order to allow full drainage of the pond without having to break open the dike. An elbow attachment on the inside portion of the pipe followed by a 1 m extension allows the pond to be drained, or for water exchange, by turning the pipe extension from an upright position to sideway. Metal screening should be placed over the top of the pipe extension so that fingerlings and adult fish do not escape during draining or water exchanges.

3.3.2 Commercial Pond Systems

Commercial pond systems range from 1 ha in size and upwards. They are more capital and labor intensive. They have elaborate construction, management and marketing strategies. There are several examples of this scale of operation (1ha) in Mkuranga and Bagamoyo districts in Tanzania. These are designed as semi-intensive pond systems, that require few inputs, primarily just fry or fingerlings, some organic fertilizer in the form of composted dung or chicken manure, possibly lime, but no supplemental feeds. While supplemental feeding is possible in such systems, this guide does not cover feeding as we are recommending very simple and low cost models for the region at the time being. As the industry grows and farmer skills develop, supplemental feeding could be developed at a later stage of evolution. In addition, this type of

Figure 14. Backyard ponds showing PVC pipes for water control. ©B. Kalangahe

commercial system, reduces potential impact on adjacent water bodies by minimizing the risk of excess nutrient loading and also lessens the likelihood of disease problems. This system is dealt with more elaborately in other sections of this book.

3.4 Fishpond Layout and Design

A well-designed fishpond can make water management and fish handling simple and efficient. Operational expenses are also lowered. It is a matter of proper location, sizing and elevations of dikes, canals, gates and compartments. A semi-intensive milkfish pond design is the best design approach for the WIO region as it is a simple design and easily managed. A typical layout of a conventional pond system is shown in Figure 15. Typical features include the following:

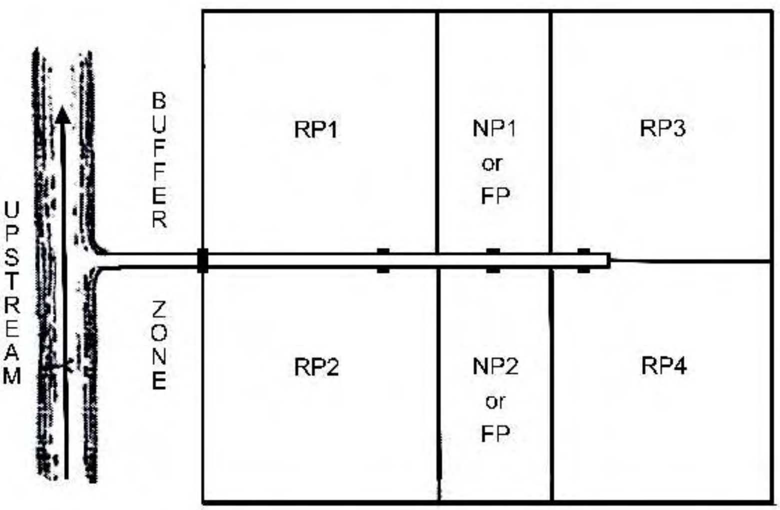


Figure 15. Sample design and layout of a conventional milkfish pond system. RP = rearing ponds; FP= feeding ponds and / or NP= nursery ponds

3.4.1 Fry/Fingerling Pond

The fry/fingerling pond comprises about 10-20% of the total area. The most suitable place is where it can be easily supplied with fresh unpolluted water at all times and at elevation where it can be readily drained even during ordinary low tides. Water depth should be 15–25 cm. Fry/fingerling ponds are located adjacent to the rearing ponds in order to have an effective and easy transfer of fry and fingerlings. It is in this compartment where fry or fingerlings are nurtured before they are transferred to the rearing pond. The pond bottom elevation is a little bit higher than the rearing pond. A manageable area ranges from 0.01 to 1.5 ha. After the fry/fingerlings are transferred to the rearing pond, this compartment can then be prepared to grow lablab and be used as a feed pond. If lablab in the rearing pond gets depleted, this compartment can be opened to give access to the fish to feed. This procedure can minimize the need for further fertilization of the rearing ponds towards the end of the culture period.

3.4.2 Rearing Pond

The rearing pond is the largest compartment in the pond system. It is about 70–80% of the total area. It is in this pond where the fingerlings are raised to marketable sizes. It is desirable that the pond bottom elevation should be 15 cm lower than the nursery pond. The water depth should be 30 – 50 cm deep. A manageable size ranges from 2.0 – 5.0 hectares.

3.4.3 Feed Pond

A feed pond is optional. In fishpond areas where natural food does not grow well and supplementary feeding is a necessity, one extra compartment could be constructed as a “Feed Pond”. The main purpose of this pond is to produce supplemental natural fish food or for fattening fish before they are harvested. The ideal size of a feed pond is about 20% of the rearing pond.

3.4.4 Dikes and Canals

Dikes and canals comprise about 5% of the total area. Dike construction is described in section 3.6.1.

3.5 Water Control Structures

Water management is an important part of the overall farming practice. Ponds need to be periodically filled and drained both prior to stocking and for harvesting. In addition, water in the ponds must be exchanged from time to time while fish are stocked to manage salinity and dissolved oxygen levels. Water control gates (or a PVC pipe as used in the “backyard” pond design) are the main way that water is managed in the pond system.

3.5.1 Gates

A gate is a sluice, culvert, or pipe which is used to control water flow. The most commonly used is the sluice gate (see Figures 16 and 17). A conventional milkfish pond has a main gate which is the main entrance of water that supplies the whole fishpond system. Secondary gates control water supply to the rearing ponds and a tertiary gate can be used to control water supply in the nursery pond. Other important structures that must also be built to withstand water current and pressure are screens and the slabs. Screens are placed within the gate to filter incoming and out-going water. Double screening is best because you can have two sizes mesh, the coarse to filter out big debris and a fine mesh to hold out other types of fish or their eggs including predator species. Slabs are pieces of wood placed in the gate and to regulate water flow into the ponds as well as water elevation. Double slabs are good because you can seal the gate well and prevent leaking by filling the space in between the slabs of wood with mud. The cost of gate construction

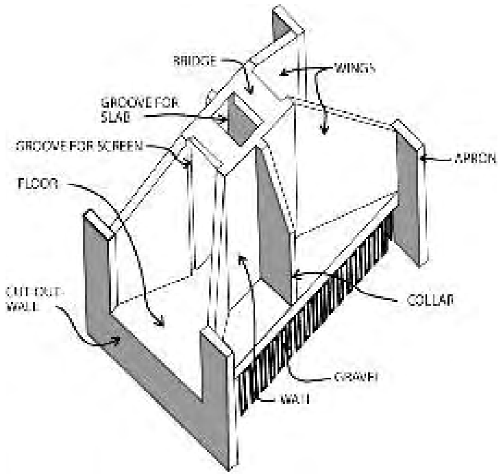


Figure 16. Concrete gate
SOURCE: BFAR/FAO/UNDP, 1980

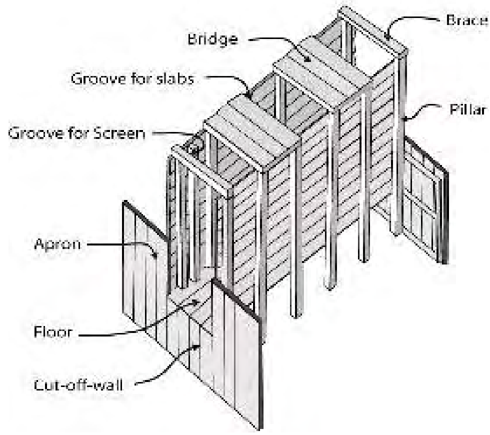


Figure 17. Wooden gate
SOURCE: BFAR/FAO/UNDP, 1980

will vary on the size of the gate, type of materials used and the price of the construction materials. Concrete gates last longer than wooden gates but are typically more expensive to build. A typical gate consists of the following parts as shown in the sample illustrations of a concrete (Figure 16) and a wooden gate (Figure 17). An actual wooden gate built at the Mkadam farm site in Mkuranga is shown in Figure 18.

3.6 Earth Work

3.6.1 Dikes

The dikes are the main structures that hold water in the pond. They are built out of soil materials that are present on the farm site. The top is called the crown and the bottom is called the base. The side slope (ratio of horizontal length to vertical rise) or steepness (Figure 19) is determined by the height of the dike and the quality of soil material used. Dikes less than 3 m high can have a slope ratio of 1:1 unless the soil material is of poor quality. Dikes that are higher than 3m need to have a 1.5:1 to 2:1 ratio (Table 3). There are three classifications of dikes:

Perimeter Dike - The main dike that protects the whole fishpond from the outside environment. It has to be high and big to withstand flooding and erosion.

Secondary Dike - The dike that is used for the main supply canal and for the rearing pond compartments. They are a little lower and smaller than the perimeter dike.

Tertiary Dike - The smallest and lowest dike. It is used for the nursery compartment.

Figure 18. Wooden gate under construction at Mkadam farm, Mkuranga, Tanzania. ©E. Requintina Sr.

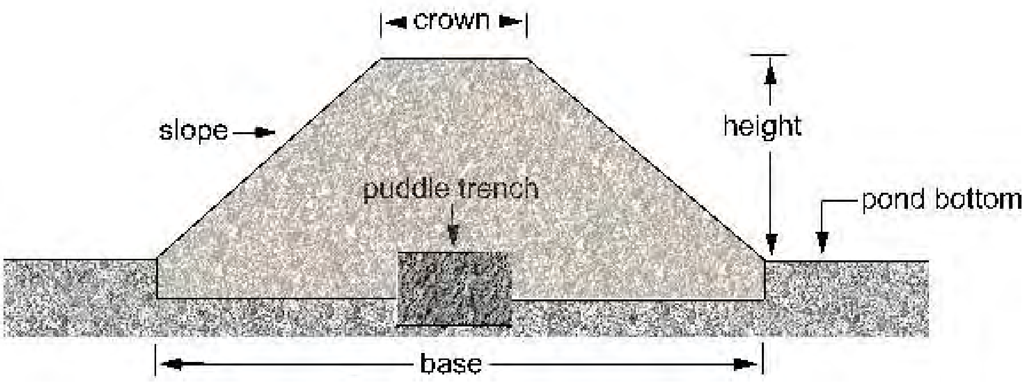


Figure 19. Cross-section of a typical earthen dike. SOURCE: BFAR/FAO/UNDP, 1980

Table 3. Relationship of the top and bottom widths and height of dike with side slope

Height (m)	Top width of crown (m)	Bottom width at given side slope (m)		
		1:1 ratio	1.5:1 ratio	2:1 ratio
1.5	1	4	5.5	7
2	1	5	7	9
3	2	8	11	14
4	3	11	15	19

The width of the bottom of the dike relative to the slope and width of the surface are important in determining the stability of the dike which is also related to the type of soil. The bottom width is calculated as follows:

Bottom width= Height x 2 (ratio) + Top width of crown

The volume of the soil to be moved is important in determining the size of the labor force and the cost involved. The volume of soil for dike construction can be computed by first computing the cross-sectional area and multiplying it by the length of the dike.

Formula for computing the volume of soil for dike construction:

Area = Height X (Crown + Base) / 2

Volume = Area X Length

Example: Height=2.0 m, Crown=1.0 m, Base=5.0 m, Length=50.0 m

Area = 2.0 m X (1.0 m + 5.0m) / 2 = 6 m^2

Volume = 6 m^2 X 50.0 m = 300.0 m^3

To determine the cost of dike construction, you should know how much the contractor charges per cubic meter. Then multiply the price per m^3 to the total volume calculated.

3.7 Excavation and Leveling

Manual excavation can be more efficient with at least four people working as a team. Manual excavation is normally done with the use of a blocking blade (Figure 20). Shovels and digging tools are also needed (Figure 21). Part of the excavation is done during dike construction, so you should take note that you don't need to pay for the digging of certain areas. But for areas that need to be excavated, the price of labor should also be per cubic meter with a simple formula of length x width x depth. The depth of excavation will always depend on the elevation of the pond bottom relative to 0-datum and tidal range. An example of a main supply canal is shown in Figure 22.

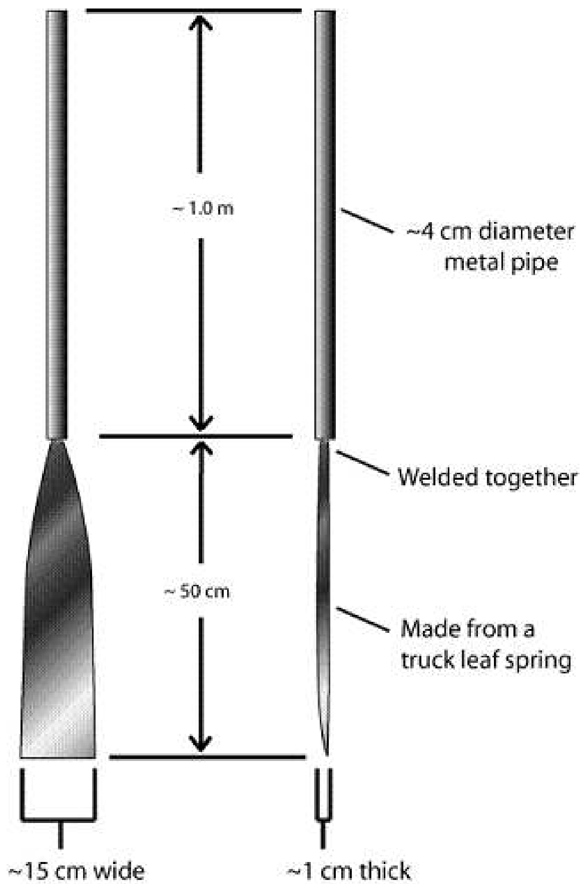


Figure 20. A blocking blade ©E. Requintina Jr.

Figure 21. Manual excavation and dike construction. © WIOMSA

Figure 22. Main canal, dike and main gate at the Mkadam farm, Mkuranga, Tanzania. ©WIOMSA.

4. Stocking, Management, Marketing and Book-Keeping

Managing a milkfish pond is not that different from managing other businesses. To run a business, one would expect sufficient profit so further production can be encouraged. Production can be increased by good management. Furthermore, by keeping expenses low, a larger margin of profit will be realized.

The best way to start milkfish pond culture is to start small and simple. Then, expand later when you are comfortable with the whole operation. Use the cheapest source of energy, such as tidal energy or solar energy and organic fertilizers that come from animal manure or rice bran. As rule of thumb, never spend what you cannot afford to loose.

Tanzania is blessed with a good tidal range to fill up milkfish ponds, good sunny days to energize the natural food production in the pond and plenty of animal manure to fertilize pond bottoms. Milkfish, which is one of the best species to culture in coastal areas, is also present. All the ingredients to operate a milkfish aquaculture system are present.

An important point to make is that raising milkfish takes a certain degree of knowledge and attention just like any other animal husbandry or farming operation on land. If farmers think they can just build any sort of pond, throw in any number of any type of fingerlings, walk away and come back to harvest in several months, they will be very disappointed with the results. Milkfish farming requires commitment to learning the technical knowledge and skills necessary to do it right as well as a commitment of time and labor to make it profitable.

4.1 Pond Preparation

Before stocking fish in the pond, good preparation is needed to ensure success. All pond compartments should be prepared and this is done a month or two before filling the pond with water. It involves the following steps:

4.1.1 Draining and Drying the Pond Bottom

The pond bottom is drained and dried by completely draining the water and allowing the pond to dry for a week or two, depending on the weather. The purposes of draining and drying are to:

- Eradicate pests, predators and competitors
- Hasten the chemical decomposition of organic matter deposited so nutrients will be available for the growth of natural fish food
- Totally harvest the fish stock from previous culture
- Kill organisms that may cause some diseases (Avoid use of chemical pesticides for they are harmful to the environment).

4.1.2 Tilling-Cultivation of the Pond Bottom

The pond bottom is prepared by cultivating with shovels and rakes. The purposes are to:

- Make the sub-surface nutrients available at the surface for the growth of natural fish food
- Eradicate burrowing fish and crustaceans that can cause pond seepage
- Eradicate fry predators such as mud skippers which otherwise are capable of surviving underground for some time
- Eliminate and destroy pond weeds that are not desirable in the ponds

4.1.3 Leveling

This is done so bottom surface irregularities, such as mounds, depressions and holes are leveled. The natural fish food (“lablab”) grows better with a good-leveled surface. This is done with the use of shovels and rakes.

4.1.4 Pest Control

Complete drying of the pond bottom and picking-up of obvious pests found on draining the pond is the safest and the most economical way to control pests. However, there are several other management actions needed to keep pests out of ponds. At the stocking stage of fingerlings into nursery ponds, care must be taken to examine fingerlings and eliminate any tenpounders from the nursery ponds (see Section 2.1 to distinguish milkfish from tenpounders), otherwise, there will be high mortality of milkfish, lower production and less profit. Lastly, screens placed in the water gates also serve to keep pests out of ponds.

4.1.5 Fertilization

Organic fertilizers are highly recommended for conventional milkfish culture. Sources of organic fertilizers are chicken manure and cow dung. These are best for growing a benthic algal mat (“lablab”) that milkfish feed on.

Steps in the pond preparation for lablab growth are as follows:

- Allow the bottom to sun-dry until it cracks
- Refill the bottom with water to 5–10 cm depth, and allow it to evaporate until completely dry
- The process is repeated 2 –3 times
- Spread organic fertilizer over the pond bottom (500–1000kg./ha/crop)
- Add fresh brackish water to a depth of 10 –15 cm.
- After several weeks, benthic algae (lablab) will grow to about 1.0 –3.0 mm.
- Apply lime if the pond turns acidic (optional)

Organic fertilizer application ranges from 500–1000kg./ha/crop. Most of the application should be during pond preparation. Fertilizer application at the pond preparation stage should be to a dry cracked bottom (Figure 23). Additional application of fertilizer is necessary if fish food (lablab) growth is slowing down, especially close to the end of the culture period when food consumption is at a higher rate. However, organic fertilizer should be applied by putting it in sacks strategically located in the ponds, allowing nutrients to slowly diffuse. This will prevent milkfish from directly feeding on the organic fertilizer, thus avoiding the foul smell of the gut during harvest. The amount of fertilizer applied is dependent on how fertile the soil in the area is, that is why there is a range, and farmers need to use their best judgment as to the proper amount of fertilizer to apply for their ponds.

Figure 23. Dried chicken manure being applied at Mkadam farm, Mkuranga, Tanzania.

What is Lablab?

Lablab (Figure 24) is one of the most important natural fish foods in the ponds. It is a benthic mat with various components including unicellular, colonial and filamentous blue-green algae or cyanobacteria, a great variety of diatoms, some unicellular or very fine threads of green algae, bacteria, protozoans, minute worms, copepods and other small crustaceans. Cyanobacteria dominate in fertilized ponds, but diatoms take over in unfertilized ponds. Under some conditions, the benthic mat can detach and float. Lablab is about 6–20% protein, and is preferred by all sizes of milkfish. Fingerlings, 2.5 grams in body weight, consume 60 % of their body weight per day. Juveniles, 100–300 grams in body weight, eat about 25% of their body weight per day. Lablab has been cultivated and used in milkfish farming in the Philippines since the 1920s. A hectare of nursery ponds with a good growth of lablab can support 300,000–500,000 fry for 4–6 weeks until they reach 4–5 cm. A fertilized grow-out pond with lablab can support 500–700 kg/ha total fish weight over 2–3 months. About 25,000 kg/ha of lablab is needed to produce 2,000 kg/ha of milkfish. Clay–loam and loam soils with a pH of 7–9 and more than 3% organic matter are favorable for the growth of lablab in milkfish ponds. Shallow ponds allow the growth of lablab.

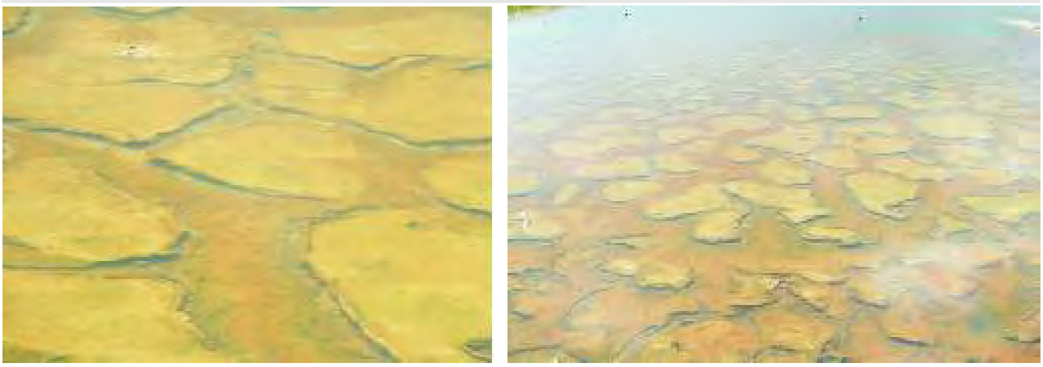


Figure 24. Lablab in Makoba Bay ponds in Zanzibar, Tanzania. © A. J. Mmochi

4.2 Fry Collection

As the ponds are being prepared for stocking, fry collection should be started so enough can be accumulated for the intended stocking rate of the pond. Normally, in places where milkfish culture has been practiced extensively, there are individuals or communities that are specialized in fry collection as a separate business from the actual fish farming.

This kind of separate fry collection industry has not yet developed in Tanzania so fishpond operators buy milkfish fry and fingerlings directly from local collectors or do the collection themselves. Fingerling prices range from 5–10 TSH per piece. Fry occurrence in the wild is seasonal and only present in certain locations. Thus, in order to accumulate a substantial amount of fry, there should be enough collectors to stock enough fry in a period of a few weeks. It is therefore very important that pond preparation start prior to the occurrence of abundant supplies of fry and that the start of the culture period coincides with peaks in fry abundance.

4.2.1 How to Locate Milkfish Fry

Seasonality in the abundance of milkfish fry varies for different regions of the world. In the WIO region there are two peak seasons of fry occurrence coinciding with the long and short rainy seasons. In Zanzibar, studies indicate peak abundance in February–May and October–

November periods (Dubi et al 2004). Lunar cycles also influence the occurrence of fry in the coastal waters. Milkfish spawn in the wild during the first and last quarter moon, so fry are abundant in coastal waters during full and new moons. Fry catches increase when the wind direction is towards the shore. They are normally caught along sandy shores, or in estuary and mangrove areas.

4.2.2 Methods and Gears Used in Milkfish Fry Collection

Methods of fry collection have evolved through the years. The different collection gears vary according to structure, materials and methods of operation, with modifications made to suit the behavior of the fry and the conditions of the milkfish fry grounds as well as the capability of the fry collectors. Fry collection could be passive or active filtration. Illustrations of active fry collection gears used in Asia are shown in Figure 25. In Tanzania, fry collection gear has not yet been well developed as there is not yet a large enough industry to generate market demand for fry as exists in the Philippines and Indonesia. Pond operators at present typically catch their own fry or fingerlings in nearby estuarine areas. Hatcheries for milkfish fry are possible, but milkfish breeding and larval rearing are complicated and costly. The WIO region is not ready yet for hatchery development until the industry reaches a certain critical size in the future where it may become economically feasible. While capture of, and dependence on wild fry is a concern from an environmental standpoint, the scale of the industry is not yet of sufficient size to result in any significant environmental impact. Different types of gear for fry collection are shown in Figure 26. They include:

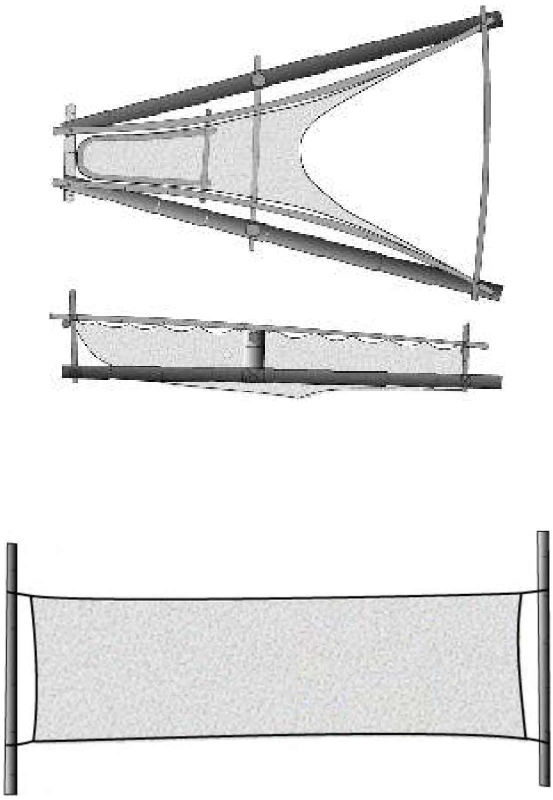


Figure 25. Types of milkfish fry collection gear used in the Philippines. SOURCE: Villaluz, 1986

Skimming nets are gears that have triangular or semicircular frames. Nets may be made of abaca cloth or fine mesh nylon netting. It works by filtering milkfish fry from the water when the operator pushes it forward.

Push nets are gears consisting of a V-shaped bamboo frame with detachable fine mesh netting and a bag net located at the narrow end. The wings and bag net are weighed down with lead sinkers. The top portions are tied to the frame above the water line, while the lower parts are 5–15 cm below the water surface. Usually they are operated along the shore or river bank by two people, one pushing the gear and scooping the fry from the bag net and another shuttling and sorting the fry on the shore. Push nets can be used as a stationary gears along the shore or river mouth. An example of how to use a push net is shown in Figure 26.

Figure 26. Collection of milkfish fry using a push net, Mlingotini, Bagamoyo. © E. D. Requintina, Sr.

Tow nets with bamboo floats are gears that consists of wings made of fine mesh netting and a cylindrical bag made of sail cloth. A float is attached at the upper mid-portion of the bag net's opening while the lead sinkers are placed at the lower edge. They are used in areas with steep shore profiles, high waves and stormy winds. Typically, they are operated by two people, each pulling on the bamboo pole at the end of one wing.

Double stick net gears consists of rectangular netting material suspended between bamboo poles. It is towed along the shore or at a river mouth by two people. The netting at the wings is made of fine-mesh nylon and the center is made of finer netting or cloth where the fry is concentrated and scooped.

Passive fry collection gears can also be used and may be appropriate for many estuarine areas in Tanzania (Figure 27). These can be used for larger size fingerling collection. A Floating tidal set net is one form of passive gear. The gear consists of V–shaped floating wings made of coconut leaves tied to bamboo poles and connected to a bamboo frame. The sides are made of fine mesh nylon netting and the catching chamber is made of an even finer netting or cloth. The offshore side of the wings is longer (30–30 m) than the near-shore side (6–8 m). The opening between the two tips of the wing is from (20–30 m). This is set against long-shore currents. This is operated during flood tide but also can be used when wind or current direction is towards the gear.

Fingerling collection using mosquito net is so far the most common method in Tanzania (Figure 28). The net is used for catching fingerlings of approximately 5g in weight from tidal pools and trapped waters in estuary areas and abandoned ponds.

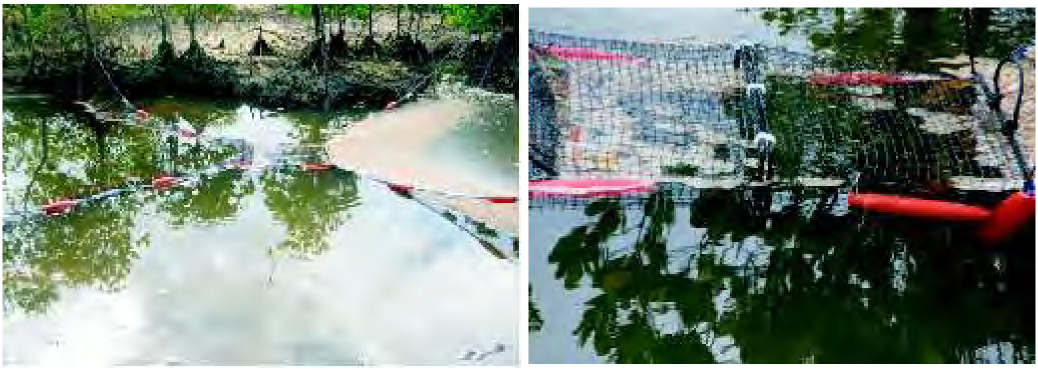


Figure 27. A passive tidal set net at Regent Enterprises, Bagamoyo, Tanzania. © A. J. Mmochi

4.3 Sorting and Counting

The whole catch, which may include other fish fry and crustacean species, is brought ashore after capture. It is easy to see and sort if they are placed in a white plastic basin. A small white bowl is used for sorting and counting (Figure 29). The sorted and counted fry are placed in an earthen jar or another plastic container for storage and the rest of the unwanted species should be returned to the water where they were caught. This is very important because these unwanted species are part of the larger ecosystem and therefore should be preserved. Actual counts of fry can be done with the aid of pebbles. For instance, one small pebble represents 100 fry, while a bigger one represents 1,000 fry.

Figure 28.Collecting milkfish fingerlings by mosquito net at Mkadam Farm, Tanzania. © S. Nundwe

The fry are not fed overnight after they are caught. Storage water is generally diluted with one part freshwater and three parts seawater and the storage containers are about 20–30 litre capacity. For longer storage, water is further diluted to approximately 18–25 parts per thousand (ppt). Containers are covered to minimize fry activity and to prevent dirt from getting in.

Milkfish fry are fed with yolk of hard boiled eggs, pulverized rice, or dried wheat flour once a day for one or two days. The stored fry are checked twice a day and the excess food, feces, dead fry and debris are removed by scooping or siphoning out the potentially hazardous waste.

4.4 Transport of Milkfish Fry

Transport is done using oxygenated plastic bags with a capacity of 16–20 litres each. Seawater in the bag should be diluted to a salinity of about 10–22 ppt, filling the bag to about one-half its capacity. Fry are placed inside the bag. The ambient air is then flushed out as oxygen is added to fill up the remaining half of the bag volume. Oxygen should be bubbled through the water if possible to increase the oxygen saturation of the water and the total amount of oxygen in the bag and water. The bags are then sealed tightly with a rubber band and placed inside woven palm bags, cardboard boxes, or styrofoam boxes. Each bag holds about 4,000–8,000 fry. It is important to keep the bags at a low temperature (about 20°C) during transport to lower oxygen consumption and metabolic rate. Low temperature also decreases fish activity, thus, preventing physical injuries to the fry.

4.5 Stocking Techniques

Upon delivery to the fishpond, milkfish fry should be transferred to another container (20–30 liters capacity) for conditioning, final counting and sorting. The water in the conditioning container is gradually diluted with pond water every 2 hours, adding a quarter of the container volume with pond water each time until the salinity comes close to that of the pond water. To reduce temperature shock to the fry, the conditioning container is floated in the pond for 10–15 minutes before the fry are set free in the pond. The best time for stocking the fry in nursery ponds is during the cooler time of the day - the early morning or late afternoon.

4.6 Pond Stocking Density

Milkfish fry are grown in the nursery pond for 1–2 months until they reach the fingerling stage. The fingerlings are then transferred to the transition pond for 1month, and finally, to the rearing pond for 3–4 months. The stocking densities for all the different stages are shown in Table 4. Having different compartments for different growth periods ensure enough fresh lablab for the different stages of fish growth, helping to provide for optimal growth conditions.

Table 4. Stocking densities at different stages of growth

Pond compartment	Growing stage (g)	Culture period (days)	Growth rate (g/day)	Stocking density (per m^2)	Harvest size (pc/kg)
Fry/Fingerling pond	0.02 to 50	30-60	0.016-1.0	40 fry - 5 fingerlings	100 - 2000
Rearing pond	50 to 275	90-120	2-3	1 fish	3-4

4.7 Water Management

Water quality in ponds should be within parameters that are most favorable for milkfish to attain optimal growth and survival. It is therefore necessary that water quality parameters be monitored regularly. The optimum water quality conditions for milkfish farming are shown in Table 5.

Table 5. Optimum water quality conditions for milkfish farming

Parameter	Optimum
Dissolved Oxygen	3-5 ppm
Temperature	22-35°C
pH	6.8-8.7
Salinity	18-32 ppt
Turbidity	0.5 m

To avoid disastrous occurrences of high mortality due to unhealthy water quality, ensure a sufficient supply of clean water. Change water in the ponds as often as possible, at least every two weeks. Install a stand-by water pump, if available, to maintain desired water depth when water management through tidal fluctuation is not possible (optional). Anticipate adverse weather conditions and be ready for occurrences such as sudden changes in water temperature and salinity. Adverse weather conditions can also cause dike wash-out and/or flooding. Always stock good and healthy fry. Monitor survival rate, biomass, growth and health.

A common error made by new milkfish farmers is to maintain water levels in ponds by simply adding new water, but not exchanging (removing) water in the ponds to maintain salinity. Water in the ponds will evaporate making the remaining water highly saline. If water is only added and none removed, ponds become hypersaline with salinities well above 30 ppt and as high as 60 ppt or even more. To avoid shock to the fish, only 10–20% of the water volume should be drained and replaced at a time. At high salinity levels, milkfish can survive but start to become stressed and growth rates can be reduced or even stopped. At very high salinities above 60 ppt, mortalities can be expected. Salt farmers turned milkfish farmers often make this error of failure to maintain proper salinity levels. Salinity can be measured using an optical salinometer (expensive) or with a hydrometer (cheap). If no instrumentation is available, farmers can roughly gauge salinity from taste. In East Africa where precipitation rates are low compared to Southeast Asia, hypersalinity in ponds is a constant threat. If no instruments to measure salinity are available, it is good practice to exchange water in the ponds every two weeks as a general practice. Wooden slabs and mud fill is removed from the center of the gate so that during low tide, water is released from the ponds through the gates (remember to keep screens in the gates so milkfish do not escape), and then during high tide, new water is let in to re-fill the ponds (remember to screen the gates so predators do not come in). This is typically done through 2–3 tidal cycles to ensure a thorough water exchange process. Furthermore, this process brings fresh nutrients to the ponds. The slabs are then placed back in the gate and mud is filled in between the slabs to stop water flow.

4.8 Harvesting

The most commonly used method for harvesting milkfish that have reached marketable size is the “water current” method. This method takes advantage of the tendency of the fish to swim against the current. The method is carried out by introducing water, creating a strong water current, into the rearing pond with the harvestable fish, to induce the fish to swim through the gate into the main canal or to an adjacent empty compartment. The gate is then closed when all the fish have transferred. Harvesting can also be done by the use of seine nets (Figure 29). Gill netting is usually employed as a harvesting technique if selective harvesting is done, especially for the “backyard” pond system. The size of the net mesh would determine the size of the fish harvested and allows smaller fish to remain and grow larger until the next harvest period. Another method is the complete draining method. Complete harvesting is done by manually collecting or picking the remaining fish from the pond bottom.

Harvesting from commercial ponds should take place as early as possible in the morning. Temperatures are lowest at this time of day and help to maintain the quality of the fish being sold. After the harvest, fish are prepared for marketing. Typically, harvested fish are placed in fish boxes or bins and mixed with ice to maintain freshness and quality while being transported to market. Use of ice and early morning harvesting is particularly important if markets are located more than one hour away from the pond site.

Figure 29. Harvesting of milkfish using a seine nets.

4.9 Marketing and Distribution

Fishpond operation includes the packing and transporting of fish to the market. Since fish spoilage is largely controlled by temperature, enzymatic and bacterial activity, fish must be packed with sufficient ice and must be handled with care to ensure they stay fresh until they reach the consumers.

How to pack fish for transport: Wash the fish with pond water prior to icing and sort them according to size. Immerse the fish in a tank filled with ice water immediately after harvest to keep them from losing their scales. Spread a layer of crushed ice about 15 cm thick at the bottom of the transport box. Lay approximately 100kg of fish on top of the crushed ice with their head facing one direction. Spread another layer of crushed ice about 5 cm thick on top of the fish. Repeat the process until the last layer of fish is about 15 cm below the top of the box. Place the last layer of crushed ice about 15 cm thick on top of the fish. Cover the top, and the fish are now ready for transport. The boxes of fish should be loaded to the transport vehicle carefully and if possible, done early in the morning when the temperature is cooler. Make sure fish are taken to market without unnecessary delays and sold at a good price to ensure profit.

4.10 Summary of Pond Management for One Growing Cycle

Pond management can be made easier if the farmer knows the seasonality of the area. Thus, schedule the drying of the pond bottom during the dry season, making sure that each part of pond preparation is finished before the onset of the rainy season. Also, planning should be done such that stocking of the ponds with fry or fingerlings will coincide with just after the rainy season when the collection is greatest. Harvest of the fish should be timed before the heavy rains come when the threat of pond flooding and loss of stock is greatest.

The steps involved in one growing cycle are complicated and difficult to remember. Table 6 is a quick reference guide and checklist of the main steps that must be undertaken for each growing cycle after ponds are constructed. This quick reference guide is useful for extension agents to keep on hand, and for farmers to keep available on each pond system unit. This helps in planning when management actions will be required and when certain labor or inputs will be needed. A laminated form of this table can be kept by farmers and check marks made with a marker pen when each step is completed. Harvesting of fish should be done before heavy rains when the threat of pond flooding and loss of stock is greatest.

5. Economics of Milkfish Farming and Book Keeping

Although it does not have the complexity of other business ventures, milkfish farming is still considered a business. You need to understand the financial situation to guide you for the future operation. To know the expenses incurred for the development and operation of the milkfish pond you need to record everything. This is called book keeping. This is important because your records are the basis of determining how much you have spent to run the whole operation. This information is needed to determine whether you have gained or lost after these costs have been deducted from the total sales of fish harvested (gross revenues). Gross revenues less total expenses are your net profit or loss for that growing period.

The budget in table 7 shows that capital costs of pond construction are the greatest expense. While this may appear large, it should be noted that this is an initial non-recurrent capital investment. Once the ponds are constructed, and with proper periodic maintenance, they will remain operational for many years. The only other costs that one may incur will be for maintenance and other operational/running expenses. It is useful to break out one-time capital costs from recurrent operational costs of the farm for calculating cash flow and estimating how long it will take before the farm turns a profit, when all capital and operational costs have been recouped. In the example described below, it will take approximately three growing cycles before the pond breaks even and starts to turn a profit. Once the initial costs are fully recuperated, the annual estimated profits in this example after three growing cycles are TSH 1,286,700 (1US$ = 1200 TSH).

Table 6. Timetable and checklist of pond management activities

Week	Activity	Duration (Days)
Week 1-2	Drain pond, level and repair pond bottom	1-2
	Dry pond until bottom cracks. Till the pond to further kill organisms below the surface	7-14
Week 3-4	Add lime if soil pH is low (<7)	1
	Fill pond with water, 10 cm	1
	Drain pond	1
	Dry pond	7-14
Week 4-5	Add organic fertilizer (500–1000 kg/ha)	1
	Fill pond with water, 10 cm depth	1
	Dry pond	7-14
	Fill pond with water, 10 cm depth	1
Week 6-7	Allow lablab to grow	7-14
Week 1-7	Fry/fingerling collection	30-50
	Stock fingerlings (3 fingerlings/m^2) in nursery ponds	1-2
	Add water to maintain depth at 10–12 cm, increase the depth up 30 as the fish grow	1
	Monitor water depth, salinity, pH and dissolved oxygen frequently, especially during adverse environmental conditions or fish mortalities	1
	Refresh water (at least 15%) for 3 days during each spring tide - every 2 weeks	3
	If the lablab is consumed (usually in six months) add inorganic manure, or shift the fish into another pond with lablab or harvest	
	You may put wooden stakes with plastic or cloth stripes to chase away birds. The stakes also discourage thieves using nets in the ponds	
Week 24-32	Harvest	7

Capital costs include labor costs for dike construction, the purchase of pond construction and clearing equipment such as a shovel, machete, etc. and purchase of materials for main and secondary gate construction. If the ponds are constructed directly by the owner or are managed as a community or group pond, the community or group can organize themselves to provide the labor without direct pay. While this may seem to be a cost savings measure, there are opportunity costs for anyone providing labor for construction (they could be earning money from another form of employment if not constructing the pond). Hence, while this may require less direct capital in the form of cash required up-front for construction, owners or communities or groups would be wise to consider this labor as a cost. Individuals who work on construction can then be paid at a later date for their time as revenues are generated. This may take longer to get pond construction completed as payment or the return on individual labor is deferred.

If pond construction and initial operating expenses are provided through a loan, the total amount for construction and development can be paid through a loan over 5 to 10 years of operation depending on the actual costs and earnings calculated for a particular site. In such cases, the loan amount (principal and interest) needs to be amortized as an annual cost and included as an operating expense (not shown in this example).

Table 7. Milkfish pond capital costs for construction and development[1]

Item	Amount (TSH)
Materials:	
Clearing equipment (shovel, machete, saw)	82,500
Materials for the six secondary gates (wood)	1,484,400
Materials for the main gate (wood)	264,000
Total Materials	1,830,900
Labor:	
Clearing the area	200,000
Perimeter dike construction (400 meters @ 1000 TSH/meter)	400,000
Main gate construction	50,000
Main canal construction (200 meters @ 1000 TSH/meter)	200,000
Compartment dikes construction (200 meters @ 1000 TSH/meter)	200,000
Excavation and leveling of pond	200,000
Secondary gate construction @ 20,000/gate X 6 gates	120,000
Total Labor	1,370,000
TOTAL POND CONSTRUCTION COSTS	3,200,900

[1]Expenses for 1 ha. pond system formally used as saltpan with 4 grow out ponds covering 80% and two fingerling ponds covering 20% of pond area, based on actual 2006 costs in Mkuranga District. (1US$ = 1200 TSH)

The construction budget may appear large but it should be noted that the initial capital investment for pond construction will last for approximately 20–30 years. Once the ponds are constructed the dikes will remain there in perpetuity with minor maintenance costs annually. The annual operational or running costs will be much lower than these initial up-front costs once the ponds are already constructed. Labor makes up the large share of pond construction costs. If labor is provided by the fishpond owner, family or community group, then the actual cash outlays needed for construction are only for the purchase of the clearing equipment and gate materials. The total amount for construction and development can be paid or depreciated over a few years of operation depending on the amount of yearly revenues and net income. If cement gates are used, initial construction costs will be higher but they will not need to be replaced every few years as is the case with wood gates. The capital costs in the example above assume no purchase of land.

Table 8. Example of operating costs, total costs, revenues and net profits for a one hectare pond for one production cycle

Item	Amount (TSH)
Expenses:	
Purchase of chicken manure (750 kg @ 10 TSH/kg)	7,500
Purchase of lime 2 bags at TSH 2000/bag	4,000
Purchase of 12,000 fry at TSH 10 per fry	120,000
Purchase of net for harvesting (1 meter X 15 meters, mesh size of 2.5 cm)	300,000
Wages for pond management, maintenance (260 TSH/hr X 180 hrs)	46,800
Wages and labor for harvest 6 people @ 2,000/person	12,000
Purchase of ice for harvest and marketing (500 kg ice X 250/kg)	125,000
Transport of fish harvest to market	100,000
Total Operating Expenses	715,300
Capital Costs (assumes 5 year payback period and no interest: 3,200,900/5)	640,180
Total Costs	1,355,480
Revenues:	
Sale of fish: 1 fish per square meter, 4 fish/kg (2000 kg @ 1000 TSH/kg)	2,000,000
Total Revenues	2,000,000
NET PROFIT	644,520

(Note: the above figures are example amounts and are not intended for actual application).
(1US$ = 1200 TSH)

As shown in the above example, the net profit for the first culture period of operation is TSH 646,520. This assumes that capital costs for construction expenses are paid over 5 growing seasons, resulting in a small net profit for the first several growing seasons. Depending on the length of time to get fish to marketable size, there could be 1–2 growing seasons per year. After construction costs are paid back, net profits would increase substantially. In this simplified example, interest on a loan for construction and initial operating costs are not factored into costs. For a multi cycle cash flow, inflation should also be factored in. The cash flow projection shown in Table 9 indicates that total investment payback will occur after the third growing cycle. Assuming 6–8 month growing cycles or 1–2 crops per year, total payback and start of profits will take from 18 months to 3 years

Table 9. Cash flow over 5 growing cycles

Cycle	Expenses	Revenues	Annual Net Revenues	Cumulative Net Revenues
1	3,914,200	2,000,000	-1,914,200	-1,914,200
2	715,300	2,000,000	1,284,700	-629,500
3	715,300	2,000,000	1,284,700	655,200
4	715,300	2,000,000	1,284,700	1,939,900
5	715,300	2,000,000	1,284,700	3,224,600

The initial investment for milkfish farming in Tanzania may seem high compared to average incomes of rural coastal households. The profitability overall, however, seems quite good. The construction costs are the primary up-front expenses needed, but then recurring expenses per crop are much lower. Since capital costs occur in the beginning of the operation, a key issue for households interested to invest in milkfish farming may be how the initial capital for construction is acquired. As previously mentioned, if local labor is used either from the household or community group, it may be possible to defer payment in order to spread labor costs out over time. Additionally, using concrete gates will make a more permanent pond system and would require less maintenance, but it is more expensive initially. Alternatively, wood gates could be used which are cheaper to construct and would keep initial capital costs down, but then they would need to be replaced every few years. If loans could be acquired from either formal or informal lending institutions, cement gates are recommended, but the time to break even and profitability will be lengthier and dependent on the interest rate or fees charged for such loans.

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