ACF INTERNATIONAL

Subsistence fish farming in Africa: a technical manual

Yves FERMON

In collaboration with:

Cover photos:

- Top right: *Tilapia zillii* - © Anton Lamboj
- Top left: Pond built by ACF in DRC, 2008 - © François Charrier
- Bottom: Beneficiaries in front of the pond they have built. Liberia, ASUR, 2006 - © Yves Fermon

OBJECTIVES OF THE MANUAL

⇨ **The objective of this manual is to explain how to build facilities that produce animal protein — fish — using minimal natural resources and minimal external supplies. These fish are being produced for the purpose of subsistence.**

⇨ **It is possible to produce edible fish in a short time and at a low cost in order to to compensate for a lack of animal protein available in a community and to do so sustainably. However, facilities must be adapted to the environmental context.**

This manual is a guide for:

- Program managers and their technical teams;
- Managers at headquarters who are monitoring program success.

This manual covers:

⇨ ***The different stages of starting of a «fish farming» program***

As soon as teams arrive on the ground, they must evaluate the resources available, the needs of the population, and existing supplies. This assessment is followed by the technical work of installing fish ponds. When this is done, the next stage is to manage and monitor the ponds and the production of fish.

⇨ ***Constraints on field workers***

The determination of whether fish farming is appropriate in a particular location and if so, of which type, will depend upon many environmental variables. These include available resources, geomorphology, climate and local hydrology. But they also include social and cultural factors, such as beliefs and taboos, land issues and laws. The success of different methods will vary depending on the region of intervention as well as the concerns of ethnic and social groups.

WHY ANOTHER HANDBOOK?

Several organizations have published fish farming manuals for Africa.

The first books described systems in place during the colonial period, with the aim of producing fish for food self-sufficiency. However, after many trials, the majority of these methods proved to be unsustainable over the long term, for a variety of reasons.

Studies undertaken by various national or international research agencies, such as the World Fish Center (formerly ICLARM), CIRAD, IRD (ex ORSTOM), Universities of Louvain and Liège, etc. have investigated these failures, proposed solutions, and contributed technical, social, and biological information.

However, the following generalizations hold for most existing literature:

✓ Most handbooks are concerned with the production of fish for sale, implying:

- A substantial investment in time and commercialisation of the enterprise. These systems are technologically advanced and require training of technicians on the reproduction, nutrition or health of fish, so that they can put into place systems to produce food to feed the fish. Such an enterprise requires external inputs that may present a barrier for small producers.
- Substantial financial investment in land, pond building, hiring of workers and qualified technicians, etc.

✓ These handbooks did not take account of local biodiversity. Indeed, farmers were encouraged to move or introduce many species into new areas, causing significant ecological damage.

- ✓ Although the documents present supposedly universal solutions, they fail to adequately take into account the great variation in geomorphology, hydrology and climate across Africa that necessarily dictates what kind of fish farming implementation is possible.
- ✓ Few existing manuals take into account socio-ethnological factors such as differences in education, beliefs and culture that will influence acceptance of fish farming installations.
- ✓ Most of these guides are designed for development projects that have a long timeline.

LIMITS OF THIS HANDBOOK

This handbook is primarily a guide to steps and procedures for workers to follow. However, these steps and procedures must be adapted to function in the context in which the project will be implemented. Considerations include:

- ✓ **Social, cultural and political perspectives**
  - ➢ **Culture and belief**

Food taboos exist to varying degrees in all cultures. Beliefs about food, the basic element of subsistence, often include distinctions between allowed and forbidden, pure and impure. These distinctions may be fundamental to health, morality, or symbolic systems in a particular culture.

- ➢ **Local law**

Every country has enacted laws concerning wildlife protection and movement of species from one region to another. These laws can be enacted at the regional level and at all administrative levels, down to the village itself. They may also be related to land issues.

- ✓ **Environmental perspectives:**
  - ➢ **Biodiversity and available resources**

There are over 3200 identified fish species in inland Africa, belonging to 94 families. However, not all of them can be exploited. Distribution of species is not uniform across the continent and some species exist only in limited areas. For example, the majority of species in the African Great Lakes are endemic to them. Field workers should have extensive knowledge of the local fish fauna, not just traditionally exploited species that are often be exotic to the area of implementation. They should also understand the ecological risks of fish farming.

- ➢ **Geomorphology, climate and hydrology**

The diversity of wildlife across the continent is a result of historical and geological events that occurred over millions of years. In that time, there have been major hydrological changes. On a smaller time scale, climate variations are crucial for the viability of fish. The availability of water, and the different uses to which it is put (drinking, domestic use, agriculture, etc.) limits viability and can be a source of conflict. The type of terrain and the nature of the soil in the region will present technical challenges to establishing ponds.

STEPS

This first manual is intended for internal use within the Action Against Hunger network, so distribution will be limited. If interest warrants, a manual with corrections and revisions may be published at a later time for wider distribution. For space considerations, only the most important sources of information used in preparing this manual are listed.

ACRONYMS

ACF/AAH: Action Contre la Faim / Action Against Hunger

AIMARA: Association of specialists working for the development and application of knowledge about fish and man-nature relationships

APDRA-F: Association of Pisciculture and Rural Development

ASUR: Association for Agronomy and Applied Sciences for Vulnerable Populations

CIRAD: Center for International Cooperation in Agronomic Research for Development

CNRS: National Center for Scientific Research (France)

FAO: Food and Agriculture Organisation of the United Nations

IRD: Institute for Development Research (France)

MNHN: National Museum of Natural History (Paris)

UNO: United Nations Organization

NGO: Non-Governmental Organization

GIS: Geographic Information System

BDC: Biological Diversity Convention

IBI: Index of Biological Integrity

DRC: Democratic Republic of Congo (ex-Zaïre)

Association of specialists working for the development and the application of knowledge about fish and Man-Nature relationships

The management of water and aquatic environments represents one of the major challenges for the future.

Fish are a source of good quality protein for human consumption and also a source of considerable income for developing as well as developed countries.

However, population growth, urban development, dam installations, industrialization, climate change, and deforestation have irreversible consequences on inland waterways and the biodiversity — including our own species — that depend on them.

⇨ *Goals*

Research

✓ To improve ichthyological knowledge — systematic, physiological, ecological, ethological — on freshwater, brackish and marine species.

✓ To highlight knowledge and practices relating to fishing and management of biodiversity and their modes of transmission.

Diffusion of knowledge

✓ To disseminate the results of these studies to local populations, the general public and the scientific community by publications, exhibitions, and via the media and Internet.

Sustainable management of environment and resources

✓ To foster sensitivity to the social, cultural, culinary, economic and patrimonial values of local communities with the aim of effective conservation and management of biodiversity;

✓ To collaborate with the local actors in the durable management of their aquatic resources.

⇨ *Scope of activities*

- Studies of the characteristics of environments and human impacts.
- Studies of the biology, biogeography, ecology and behavior of species.
- Studies of anthropological and socio-economic factors in man's relation to the Biosphere.
- Ecosystem modeling, statistical analysis.
- Development of databases.
- Consulting and faunistic inventories.

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⇨ Children fishing for fingerlings in river for the ponds, Liberia, ASUR, 2006 - © Yves Fermon

Chapter 01
FISH FARMING: AIMS AND ISSUES

I. WHY FARM FISH?

Fishing and aquaculture contribute to food security in three primary ways:

- Increases food availability,
- Provides highly nutritious animal protein and important micronutrients,
- Offers employment and income that people can use to buy other food products.

Worldwide, a little more than 100 million tons of fish are consumed each year, providing 2.5 billion people with at least 20% of their average intake of animal protein (Figure 1 below), and up to 50% or more in developing countries. In some of the areas most affected by food insecurity — in Asia and Africa, for example — fish protein is essential as a large proportion of the animal protein consumed, although these levels remain low. Approximately 97% of fishermen live in developing countries, where fishing is extremely important.

Fish production in Africa has stagnated over the past decade, and the availability of fish per capita has decreased (from 8.8 kg in the 90s to about 7.8 kg in 2001; Table I, p. 4). Only in Africa has this happened, despite the fact that there are no good alternative sources of protein available to most people. For a continent where food security is so precarious, the situation is alarming.

Even though Africa has the lowest per-capita fish consumption in the world, marine and inland water ecosystems are very productive and sustain important fisheries, which reported rising production in some countries. With production at 7.5 million tons in 2003 and similar levels in previous years, fish provides 50% or more of animal protein for many Africans — second only to Asia. Even in sub-Saharan Africa, fish provide nearly 19% of the animal protein consumed by the population. This is an important contribution in a region afflicted by hunger and malnutrition.

Although fish production levels have stabilized, the population continues to grow. In view of UN population forecasts, fish production needs to increase by more than one third over the next 15 years. The situation has been aggravated further by a significant increase in exportation of fish, as

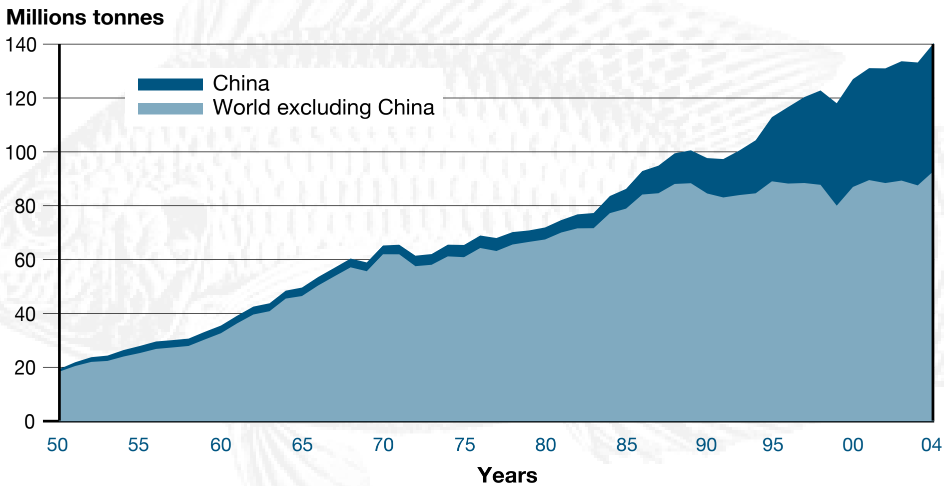


Figure 1. Global capture and aquaculture production (FAO, 2007).

Table I. World fishing and aquaculture production and utilization, excluding China (FAO, 2007).

		2000	2001	2002	2003	2004	2005
Production		(million tonnes)					
Inland	Capture	6.6	6.7	6.5	6.6	6.8	7.0
	Aquaculture	6.0	6.5	7.0	7.6	8.3	8.8
	Total	12.6	13.3	13.5	14.2	15.1	15.8
Marine	Capture	72.0	69.8	70.2	67.2	71.3	69.7
	Aquaculture	4.9	5.3	5.6	6.1	6.6	6.6
	Total	76.9	75.2	75.8	73.3	77.9	76.3
Total	Capture	78.6	76.6	76.7	73.8	78.1	76.7
	Aquaculture	10.9	11.9	12.6	13.8	14.9	15.4
	Total	89.5	88.4	89.3	87.5	93.0	92.1
Utilization							
Human consumption		63.9	65.7	65.7	67.5	68.9	69.0
Non-food uses		25.7	22.7	23.7	20.1	24.0	23.1
Population (billions)		4.8	4.9	5.0	5.0	5.1	5.1
Per capita food fish supply (kg)		13.3	13.4	13.3	13.4	13.5	13.4

well as fish harvesting by non-African fleets operating in areas under fishing agreements.

Because coastal fisheries are already heavily exploited, even large investments may do little to increase production in them and reducing exports seems unlikely in these countries which need foreign currency.

After a slight downturn in 2002, the total world catch in inland waters increased again in 2003 and 2004, reaching 9.2 million tons during the past year. Africa and Asia represent approximately 90 percent of the world total and their respective shares are relatively stable (Figure 2, p. 5). European fisheries, however, seem to be in crisis, as the total catch has dropped by 30% since 1999. Recreational fishing represents a substantial part of the catch. The statistics on catches in inland waters in developed countries, published by FAO, are generally based on information provided by national correspondents, and the total catch may vary significantly depending on whether they include leisure fishing in the count.

In Africa — as in the world in general — aquaculture must play an important role. Globally, aquaculture accounts for about 30% of the supply of fish. African aquacultural production accounts for only 1.2% of the world total (Figure 3, p. 5). Aquaculture in Africa today is primarily a secondary, part-time, subsistence activity, limited to small-scale farms.

This African production primarily includes tilapia (15,000 T), catfish (*Clarias*) (10,000 T), and common carp (5,000 T). It is thus still an embryonic activity that has been supported by development programs for approximately half a century. Aquaculture still contributes only marginally to the supply of water-sourced protein for the African continent, in which total fish production (marine and inland) was estimated to be 5,000,000 T in 1989. Nevertheless, fish are a large component of the protein supply (23.1%) — slightly less than in Asia (between 25.2 and 29.3%), but far ahead of North America (6.5%), Western Europe (9.4%), or the world average of 16.5% (Figure 4, p. 6).

Thus, aquaculture in Africa remains limited. There are several reasons for this, but the most important is that the sector is not treated as a business enterprise. Even where not commercialized, aquaculture in Africa can still benefit from good fisheries management practices that will help safe-

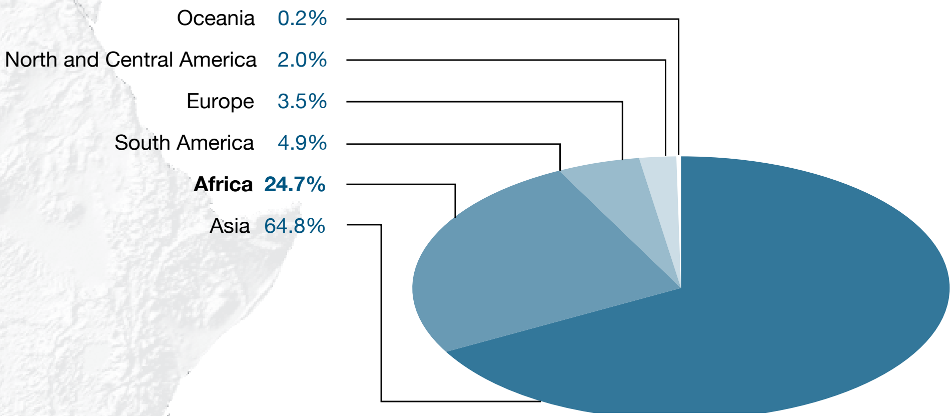


Figure 2. Inland capture fishing by continent, 2004 (FAO, 2007).

guard these important sectors of food production. Aquaculture is not intended to replace fisheries, but to supplement supplies of animal protein.

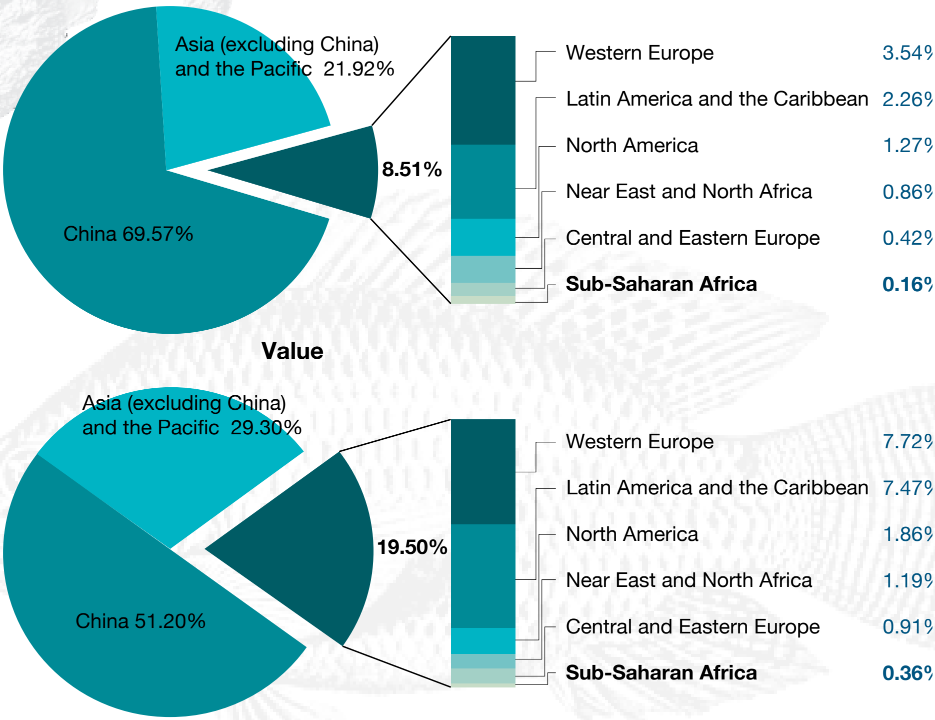


Figure 3. Aquaculture production by regional grouping in 2004 (FAO, 2007).

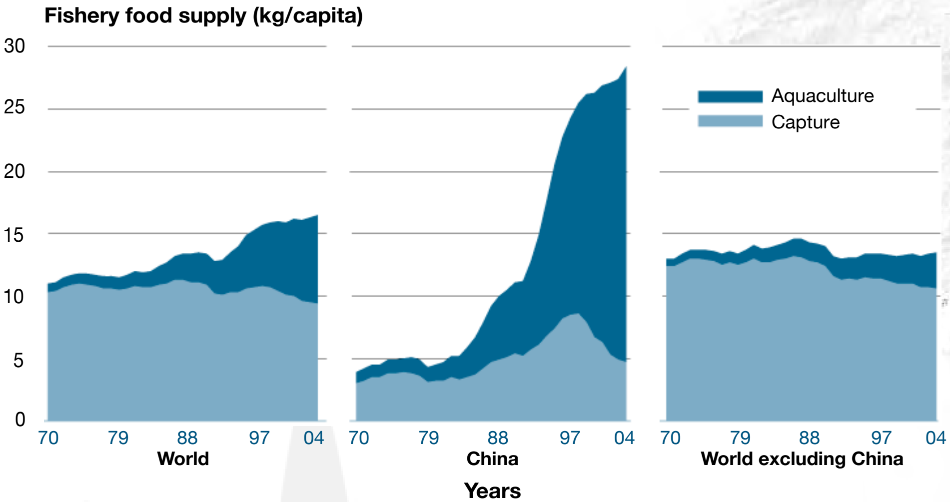


Figure 4. Relative contribution of aquaculture and capture fisheries to fish consumption (FAO, 2007).

II. PRESSURE ON RESOURCES

Human activities such as dam building and other water development projects, pollution, over-fishing, and voluntary or involuntary introduction of non-native species often drastically alter aquatic environments. The consequences, amplified by increasing population and pressure on natural resources, endanger the fish fauna native to every continent. Africa suffers from these effects as much as do other continents.

II.1. HABITAT MODIFICATION

Habitat alteration is one of the most dangerous threats to aquatic life. These changes have two distinct origins:

- ✓ Climate change, with its impact on water balance and functioning of hydrosystems.
- ✓ Man-made changes in the aquatic environment and its catchment areas.

II.1.1. CLIMATE CHANGE

Continental aquatic environments are critically dependent upon rainfall. Thus, any change in climate will have major consequences for water balance that can cause the increase or reduction of aquatic habitats. One spectacular example is the Lake Chad area, which shrank significantly in the 1970s during a dry period in the Sahel.

We know that the climate has never been stable on a geological scale and aquatic environments have always fluctuated with or without man-made influences. (The «El Niño» phenomenon provides a good example.) But we also know that humans can act indirectly on the climate, either on the local level by, for example, deforestation, or at the global level through the emission of greenhouse gases. It is now generally accepted by the scientific community that the planet is warming due to increased emisson of carbon dioxide, methane and chlorofluorocarbons (CFCs), from industrial activities. The extent and speed of warming if not yet clear, but it is feared that over the coming decades these temperature changes will result in altered rainfall patterns in some regions of the world. Aside from changes in local rainfall, we can also expect increases in solar radiation, changes in the distribution of vegetation, and elevation of sea levels. Although it is still impossible to assess the consequences of these changes at the local level, it seems clear that whatever the magnitude of the phenomenon, aquatic fauna will be the first affected.

II.1.2. DEVELOPMENT

The need for water for agriculture, energy production, transportation, and domestic use motivates the modification of hydrological systems. These projects affect the water balance as well as, directly or indirectly, aquatic habitats.

■ Dams

Large hydroelectric dams are expensive, while their economic benefit is often controversial. However, their environmental impact is substantial.

Blocking a stream to create a dam causes numerous changes to the aquatic environment and to fish habitat and disrupts the movements of migratory fish.

■ Development of rivers

The development of rivers, including construction of dykes, re-routing of water courses, construction of locks for navigation, etc., is still limited in Africa, but there are many examples of projects that have caused substantial changes in natural systems.

For example, much work has been done to facilitate management of the Senegal River for the sake of agriculture. The Diama Dam was constructed downstream, near the estuary, to prevent salt water from backing up into the lower course of the river during the dry season. Meanwhile, the Manantali Dam, located upstream, was built to store large quantities of water during floods, which could then be used to irrigate large areas as needed. All the water resources in the valley of Senegal are now partially under control, but managing these resources becomes complex when there are conflicting demands for its use.

■ Reduction of flood plains and wetlands

Wetlands are often considered to be fertile areas that are favorable for agriculture. Everywhere in the world, development projects, particularly dam construction, have had significant impacts on hydrosystems by reducing, sometimes substantially, the surface area of the flood plains. These floodplains are often critical nurseries for juvenile fish.

■ Land use changes in catchment areas

The quantity and quality of the surface water in aquatic ecosystems depend on the nature of the catchment area and its vegetation. However, changes such as the disappearance of forests, whether cut down for agriculture or lumber for domestic or commercial use, increases soil erosion and water turbidity and alters the hydrology, with heavier runoff causing shorter but more intense flood regimes.

Deforestation has had an impact across Africa, and the available information shows that the scale of the phenomenon is a concern. In Madagascar, for example, the deforestation rate was 110,000 ha per year for 35 years, and erosion rates of 250 tons of soil per hectare have been reported. In the Lake Tanganyika drainage area, deforestation is massive as well and erosion on the slopes has resulted in significant increases in lake sediment and changes in the type of wildlife found in some particularly vulnerable coastal areas. If current trends continue, 70% of forests in West Africa, 95% in East Africa, and 30% in the Congo basin will disappear by the year 2040.

Increased amounts of suspended solids in water, and silt deposits in lakes and rivers, have had many effects on aquatic life. These include reduced water clarity, which has implications for planktonic and benthic photosynthesis. Suspended elements may seal the branchial systems of fish or cause irritation, and muddy deposits reduce the quality of substrates in breeding areas.

II.2. WATER POLLUTION

Although water pollution has long been a secondary consideration in Africa, the problem has become much more noticeable in recent years. In general, however, there is a lack of data on the extent of water pollution in Africa.

II.2.1. WATER EUTROPHICATION

Nutrients such as phosphates and nitrates are generally present in limited quantities in aquatic environments. They constitute «limiting factors», meaning that these elements are quickly assimilated into the environment and stimulate primary production. When the natural cycle is disturbed by human activities, particularly by run-off from manure, detergents, or waste water, excess phosphates (and nitrates to a lesser extent) are responsible for a phenomenon callled eutrophication, which is a proliferation of algae and/or macrophytes, as well as a reduction in water transparency. The decomposition of this abundant organic matter consumes so much oxygen that other animal species die off from asphyxiation. Eutrophication also causes wide variation in oxygen concentration and pH levels. In lakes, the phenomenon of "bloom" (or "fleur d'eau" in French) is a manifestation of eutrophication.

Eutrophication in Lake Victoria over the last 25 years is fairly well documented. The increased nutrient concentration in the lake results from increased urbanization, agricultural use of fertilizers and pesticides, and the use of pesticides for control of tsetse flies, etc.

II.2.2. PESTICIDES

In the second half of the twentieth century the use of chemical pesticides became widespread in Africa, as elsewhere in the world, to fight major diseases as well as crop pests. There is a large range of products, and while some are not very toxic for aquatic organisms, many are xenobiotics, or substances that have toxic properties even when present at very low concentrations. This is particularly true for pyrethroids (permethrin, deltamethrin) and organochlorines (DDT, dieldrin, endrin, endosulfan, malathion, lindane). In addition to their immediate toxicity, these chemicals build up over time and become concentrated in food webs.

II.2.3. HEAVY METALS

The term "heavy metals" includes several families of substances:

- ✓ Metals with high atomic mass and high toxicity, whose presence is not necessary to life, including cadmium, mercury, lead, etc.
- ✓ Metals with lower atomic mass, which are essential for life in trace amounts, but quickly become toxic in high concentrations, such as copper, zinc, molybdenum, manganese, cobalt, etc.

Heavy metals are usually present at very low concentrations in natural ecosystems, but pollution from human activities has caused them to increase. Heavy metals come from agricultural land and water systems through intentional input of trace elements and pesticides, discharge from refineries or factories treating non-ferrous metals (nickel, copper, zinc, lead, chromium, cadmium, etc.), discharge from tanneries (cadmium, chromium) or paper pulp (mercury). Atmospheric pollution related to human industrial activities and domestic and urban effluents (zinc, copper, lead) also have an impact. Mercury pollution can originate in industrial activity (including the paper industry), exploitation of gold deposits, and use of organomercury fungicides. Heavy metals can accumulate in organisms until they reach toxic levels.

II.2.4. BIO-ACCUMULATION

Bioaccumulation is an alarming phenomenon where certain contaminants, including heavy metals and pesticides, accumulate in an organism and can reach concentrations much higher than those observed in the natural environment.

Organisms with these high levels of contiminants may enter the food chain. If the pollutant is not degraded or removed, concentrations will increase with each link, from algae to fish-eating birds. This phenomenon is called biomagnification, and shows that environmental pollution through small quanitities of substances in water can have unexpected consequences on consumers higher up the food chain.

II.3. IMPACT ON FISHERIES

The impact of fishing on fish populations appears first as selective pressure on certain species, either on adults or on juveniles. It is frequently assumed that fishing alone with traditional gear is not the reason for the disappearance of fish species. Indeed, it is hard to imagine that a population can be completely elminitated by indiscriminate capture rather than through hunting. However, pressure associated with changes in habitat can cause species to decline fairly rapidly.

Large species with low reproductive capacity are particularly sensitive to the effects of fishing. Consider, for example, the quasi-disappearance of the catfish *Arius gigas* in the Niger Basin. In this species, the male is buccal incubator of a few large eggs. Records show that, in the early 20th century, 2 meter-long specimens of this species were captured, but since 1950 the species has become very rare.

The effects of fishing are clearly obvious in population demography, as the average size of species has decreased and large individual specimens have disappeared. Indeed, if fishing began with large mesh gear, the size of the gear has decreased as it became more difficult to catch large individuals. In some cases, mesh size is so small that it catches immature individuals, so that the species cannot reproduce and collapses dramatically. In Lake Malombe, for example, *Oreochromis* (*O. karongae*, *O. squamipinnis*) was fished with gillnets. As the use of small mesh seines increased in the 1980s, there was a parallel collapse of the *Oreochromis* fishery. Such overfishing is also responsible for the disappearance of nine endemic species of large Cichlidae.

II.4. INTRODUCTIONS

People have been intoducing new fish species into non-native areas in order to improve fish production for centuries, but in recent decades this practice has become a subject of controversy among scientists and managers of aquatic environments. Indeed, the introduction of new species can have significant effects on indigenous fish populations.

New species introduced into an ecosystem can compete with indigenous species for food, and may cause the elimination of either native species or the introduced species. But additional, less, obvious, indirect changes to the food chain may also occur. Introductions can occur at several different levels, which have different impacts. These include:

- ✓ Transplantation of a species from one location in the same catchment area to another;
- ✓ Introduction of a species that is alien to the basin but from the same biogeographic zone;
- ✓ Introduction of a species from a different biogeographic zone, or even a different continent.

II.4.1. COMPETITION WITH INDIGENOUS SPECIES

Introduced species may compete with or eliminate native species. There is a particular danger of this when the introduced species is a predator. One of the most spectacular examples is the introduction of the Nile Perch, *Lates niloticus*, into Lake Victoria. The perch is a piscivorous (fish-eating) fish that can grow to more than 100 kg. Some scientists think that this predator fed on and caused the decline and likely extinction of several species of small Cichlidae.

II.4.2. EFFECTS ON THE AQUATIC ECOSYSTEM

Introduction of a predator into an aquatic ecosystem can affect the system's biological functioning through food chains. In Lake Victoria, for example, in the 1980s, the Nile perch caused the virtual disappearance of detritivore/phytoplanctivore group of haplochromines (Cichlidae endemic), as well as a group of zooplanctivores, which comprised, respectively, 40% and 16% of the biomass of demersal fish. Detritivores have been replaced by the indigenous shrimp *Caridina Nilotica*, and by the pelagic zooplanctivores Cyprinidae *Rastrineobola Argentea*. These latter two species became the Nile perch's main food after the haplochromine disappeared.

II.4.3. HYBRIDIZATION

The introduction of related species that do not normally live together into the same body of water may result in hybridization. Different species of tilapia, in particular, are known to hybridize, which can cause genetic changes in the suriving species. For example, in Lake Naivasha, *Oreochromis spilurus* was introduced in 1925 and remained abundant in the years 1950 to 1960. In 1956, *O. leucostictus* was introduced, and the two species hybridized. Evenutally, *O. spilurus* disappeared. Similarly, the disappearance of the species *O. esculentus* and *O. variabilis,* endemic to Lakes Victoria and Kyoga, could have been caused by hybridization and/or competition with the introduced species *O. niloticus* and *T. zillii*). The hybrids *O. niloticus* and *O. variabilis* were found in Lake Victoria.

Fish species have been introduced and moved throughout Africa; everything and anything has been done (Annexe 02, page 197, Table II, p. 10 and Table III, p. 11). First, the colonialists introduced trout and carp. Then, many species, particularly tilapia, were transplanted from country to country in Africa to see if they were appropriate for fishfarming. These introductions included the strange practice of introducing strains of Nile Tilapia (*Oreochromis niloticus niloticus*) or Mossambic Tilapia (*O. mossambicus*) in areas that already had their own native species of tilapia. For example, Ivory Coast's famous "Bouaké" , which was, actually, a mix of several broodstocks, was introduced into several countries with native populations of *O. niloticus*. The same thing happened with the Butare, strain in Rwanda, where the stock was brought to the United States by a research institution and then re-introduced in Rwanda!! (Lazard, *pers. com.*).

Information on the distribution of species is provided in Appendix 05, page 255.

⇨ **It is important to note the provenance of the fish used for farming as well as the location of the watershed in which the fish farming operation is located because of the risks incurred by the introduction of fish species as well as national and international legislation concerning biodiversity.**

⇨ **The fact that a species has already been introduced in the intervention area does not necessarily mean it should be used again.**

III. INTERNATIONAL ASPECTS

The Convention on Biological Diversity (CBD), known informally as the Biodiversity Convention, is an international treaty that was adopted at the Earth Summit in Rio de Janeiro in June 1992. The Convention has three main goals:

1. **Conservation of biological diversity (or biodiversity);**
2. **Sustainable use of the components of biodiversity;**
3. **Fair and equitable sharing of the benefits arising from genetic resources.**

In other words, the Convention's objective is to develop national strategies for the conservation and sustainable exploitation of biological diversity. It is often considered the key document on sustainable development.The Convention was opened for signature on 5 June 1992 and entered into force on 29 December 1993. As of that date, it had been signed by 168 countries. Of the 53 African countries, Somalia is the only one that has not signed.

The convention marked the first time that a document of international law recognized that conservation of biological diversity is «a common concern of humankind» and an integral component of development. The agreement covers all ecosystems, species, and genetic resources, and it links traditional conservation efforts to the economic goal of sustainable use of biological resources.

At a meeting in Buenos Aires in 1996, the focus was on local knowledge. The interests of key actors, such as local communities and indigenous peoples, must be considered by states with sovereignty over the territories where they are protecting biodiversity. The convention established principles for fair and equitable sharing of benefits arising from the use of genetic resources, including commercial use. It also covered the area of biotechnology through the 2001 Cartagena Protocol on Biosafety, which addressed issues of technological development, benefit-sharing and biosafety.

The convention reminds decision-makers that natural resources are not infinite, and sets up a philosophy of sustainable use. While past conservation efforts aimed to protect specific species

Table II. Origin and number of fish species introduced in Africa.

Coming from	Number
Africa	206
North America	41
South America	3
Asia	58
Europe	92
Unknown	*128*
Total	**528**

Table III. Introduced species that have had a negative ecological effect.
ENE= Number of countries that have recorded an Ecological Negative Effect.

Order	Family	Species (n = 39)	French common name	English common name	ENE
Clupeiformes	Clupeidae	*Limnothrissa miodon*	Sardine du Tanganyika	Lake Tanganyika sardine	3
Cypriniformes	Cyrpinidae	*Aristichthys nobilis*	Amour marbré, à grosse tête	Bighead carp	3
		Carassius auratus auratus	Poisson rouge	Goldfish	9
		Carassius gibelio	Carpe de Prusse	Prussian carp	4
		Ctenopharyngodon idella	Carpe herbivore	Grass carp	5
		Cyprinus carpio carpio	Carpe commune	Common carp	22
		Hemiculter leucisculus	Vairon	Sharpbelly	3
		Hypophthalmichthys molitrix	Carpe argentée	Silver carp	9
		Pimephales promelas	Tête de boule	Fathead minnow	3
		Pseudorasbora parva	Pseudorasbora	Stone moroko	12
Siluriformes	Ictaluridae	*Ameiurus melas*	Poisson chat	Black bullhead	8
		Ameiurus nebulosus	Poisson chat	Brown bullhead	3
	Clariidae	*Clarias batrachus*	Poisson chat marcheur	Walking catfish	5
		Clarias gariepinus	Poisson chat nord africain	North African catfish	6
	Loricariidae	*Pterygoplichthys disjunctivus*	Pléco	Vermiculated sailfin catfish	3
Esociformes	Esocidae	*Esox lucius*	Brochet	Northern pike	5
Salmoniformes	Salmonidae	*Oncorhynchus mykiss*	Truite arc-en-ciel	Rainbow trout	21
		Salmo trutta trutta	Truite de mer	Sea trout	12
		Salvelinus fontinalis	Saumon de fontaine	Brook trout	5
Atheriniformes	Atherinopsidae	*Odontesthes bonariensis*	Athérine d'Argentine	Pejerrey	4
Cyprinodontiformes	Poeciliidae	*Gambusia affinis*	Gambusie	Mosquitofish	9
		Poecilia latipinna	Molly	Sailfin molly	3
		Poecilia reticulata	Guppy	Guppy	8
		Xiphophorus hellerii	Porte-épée vert	Green swordtail	4
Perciformes	Percidae	*Gymnocephalus cernuus*	Grémille, Goujon-perche	Ruffe	3
		Perca fluviatilis	Perche commune	European perch	3
	Centrarchidae	*Lepomis gibbosus*	Perche soleil	Pumpkinseed	9
		Lepomis macrochirus	Crapet arlequin	Bluegill	6
		Micropterus dolomieu	Black-bass à petite bouche	Smallmouth bass	3
		Micropterus salmoides	Black-bass à grande bouche	Largemouth bass	13
	Gobiidae	*Neogobius melanostomus*	Gobie à taches noires	Round goby	6
	Odontobutidae	*Perccottus glenii*	Dromeur chinois	Chinese sleeper	4
	Latidae	*Lates niloticus*	Perche du Nil	Nile perch	4
	Cichlidae	*Oreochromis mossambicus*	Tilapia du Mozambique	Mozambique tilapia	21
		Oreochromis niloticus niloticus	Tilapia du Nil	Nile tilapia	16
		Parachromis managuensis	Cichlidé de Managua	Guapote tigre	3
		Sarotherodon melanotheron melanotheron	Tilapia à gorge noire	Blackchin tilapia	3
		Tilapia rendalli	Tilapia à ventre rouge	Redbreast tilapia	3
		Tilapia zillii	Tilapia à ventre rouge	Redbelly tilapia	3

and habitats, the Biodiversity Convention recognizes that ecosystems, species and genes can be used for the benefit of humans, but in a way and at a rate that does not cause biological diversity to decline over the long term.

⇨ **Above all, the Convention is legally compulsory; states that have joined are obligated to implement its measures.**

⇨ **Projects in the field must respect these measures, avoiding as much as possible any actions that could impact biodiversity. If there is an effect, there could be consequences for the organization responsible for the interventions, regardless of their intentions and the tacit approval of local and regional authorities.**

IV. OBJECTIVES OF FISH FARMING

It is not necessary for fishfarming to occur at the expense of natural environments. However, fish farming that causes the discharge of organic matter or involves introduction of an alien species can cause serious ecological changes that have substantial effects on the availability of animal protein. Indeed, there is a major risk that fishing catches will decline, and **fish farming is expected to contribute to supplies rather than replace available resources**, assuming they exist.

As shown in Figure 5, p. 13, with the exception of desert zones, where, for lack of water, fishfarming can be difficult, it is possible to produce fish almost everywhere in Africa.

⇨ **The objective of fish farming is not to replace fisheries, but to supplement them in order to maintain current levels of fish consumption as the world's population increases. However, this goal must be pursued with respect to the environment, the health of consumers, and bioethics.**

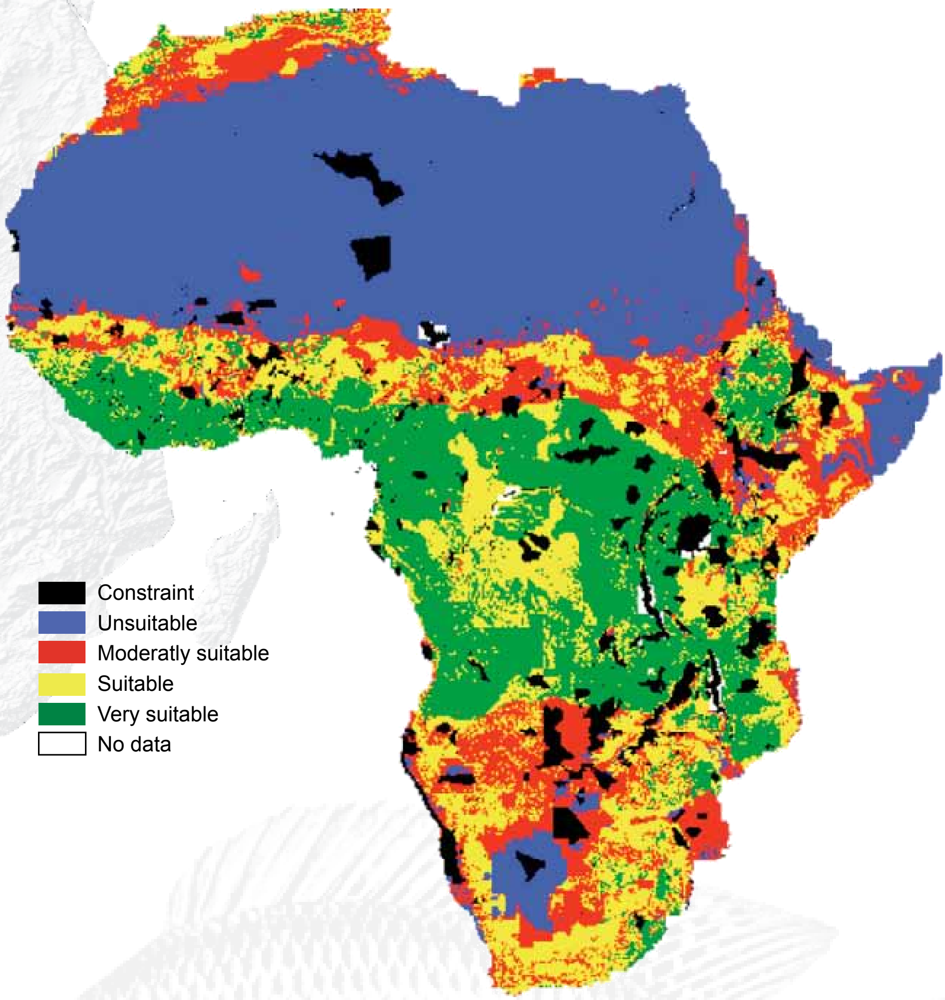


Figure 5. GIS assessment of potential areas where fish farms could be established in Africa (Aguilar-Manjarrez & Nath, 1998 - FAO).

Chapter 02
TYPES OF FISH FARMING

The FAO (1997) defines aquaculture as:

« *The cultivation of aquatic organisms including fish, molluscs, crustaceans and aquatic plants. The term culture implies some form of intervention in the rearing process to enhance production, such as restocking at regular intervals, feeding, protection against predators . . .This cultivation also implies individual or legal ownership of the breeding stock. From the viewpoint of statistics, aquatic organisms harvested by an individual or legal person who owned them throughout their breeding period are products of aquaculture. On the other hand, aquatic organisms that are exploited publicly while they are common property resources, with or without appropriate licenses, are to be considered products of fishing*.»

In this manual we are concerned with the cultivation of fish, or **fish farming**.

I. TYPES OF FISH FARMING

Types of fish farming are distinguished mainly by the amount of investment necessary, the quantity of fish produced per unit of area, and by the product's destination. They are generally characterized by their degree of intensification, which is defined by feeding practices. In intensive systems, external food supplies generally represent more than 50% of the total cost of production. However, the degree of intensification is also determined by many other factors of production, such as water, land, capital and labor.

The various types of fish production systems are presented in Table IV, p. 16, by degree of intensification. A preliminary classification can be established in the following manner:

✓ **Extensive** fish farming systems are based on the natural productivity of the environment or the structure built for cultivation, using few if any external inputs. Generally, fish are cultivated in basins or medium to large ponds. Food for the growing fish is provided by organisms that are already living or reproducing in the water, with, possibly, some supplementation. External inputs are limited, costs remain low, keeping funding capital low as well, and only small quantities of fish are harvested per unit of area. In short, there is a low level of control over the factors of production. Systems that integrate rice cultivation and fish farming are included in this extensive category, since the fish benefits from inputs added for rice cultivation.

✓ **Semi-intensive** fishfarming systems depend on fertilization or complementary feeding for the fish, although a large proportion of nourishment is still provided by natural food. Poultry-fish or pig-fish farming typically belong in this category.

✓ In **superintensive** and **intensive** systems, all of the fish's nutritional needs are provided through external inputs, and organisms naturally growing in the basin or water (lake, river, etc.) where the fish grow, provide very little nutrition. The food that is used in these systems is generally rich in proteins (25 to 40%), and is consequently expensive. Intensive fish farming systems produce a lot of fish per unit of area, but factors of production (food, water quality, quality of fingerlings) must be controlled. The production cycle requires permanent monitoring; the system will not survive without continual external inputs. The principal infrastructure for this type of fish farming includes the enclosures or cages, which require a high rate of water renewal.

The evolution from extensive systems to intensive systems is linked to increasing global investment.

An alternative classification of fish production systems is based on differentiation between the sources of food for the fish.

✓ In the production fish farming model, food is derived essentially (or only) from the ecosystem (such as the pond ecosystem). Management tasks for this type of farm include fertilization or provision of complementary food, and the implementation of polyculture farming. There is a strong

Table IV. Levels of intensification of fish farming systems.

Density of fish at stocking	< 0.1 m^{-2}	0.1 to 1 m^{-2}	1 to 5 m^{-2}		5 to 10 m^{-2}	10 to 100 m^{-2}
Farming structure	Pond, small dam, pool		Pond		Pond, cage	Ponds, pools, raceways, cages
Yield (t/ha/year)	0 - 0.3	0.3 - 1	1 to 5	5 to 15	15 to 50	50 and more to 200 $kg.m^{-3}$
Fish intitial stock	Mainly polyculture		Polyculture		Generally, monoculture	Monoculture
Inputs	Low or no inputs		Fertilizers, macrophytes, simple food (bran, oilcake)		Composed food	Equilibrate food with fish meal, extruded, antibiotic
Dayly rate of water renewal (%)	Natural contribution		Compensation for losses		Ventilation, water circulation	Ventilation/oxygenation
	None	Sometimes < 5	< 5		5 to 30	> 30
Intensification level	Extensive		Semi-intensive		Intensive	Super intensive
Models	Semi-fishfarm		Production fishfarm			Transformation fishfarm

correlation between the density of fish, the growth rate and final weight of individual fish, and the yield, which must be managed carefully. Thus, in this system, managers recreate an ecosystem with the fish at the top of the food chain.

✓ In the transformation fish farming model, food is entirely exogenous. Fish eat only artificial food, usually in the form of granules containing a very high proportion of fishmeal. Farms that follow this model are usually monoculture systems, which produce high densities of fish and uses protein-rich artificial food.

The choice between these different types of fish farming depends on many factors, which are presented in Table V, p. 17.

Under another classification system, African pisciculture can be classified into four categories, on the basis of socio-economic criteria rather than the level of intensity of production.

✓ Subsistence or **self-consumption** farming: The product is meant for consumption by the fish farmer and his family. Under this category, farmers implement extensive techniques at a low technical level.

✓ **Artisanal** or small scale fish farming: This technique is implemented primarily in suburban zones and offers the best environment for the supply of inputs and the marketing of fish.

✓ «**Channel**» fish farming: Characterized by the segmentation of different phases of development, principally in cages and enclosures.

✓ **Industrial** fish farming: Characterized by very large production units, and by strictly economic objectives, whereas, in the three preceding forms, fish farming is considered to be a tool of development as well as production.

For a long time it was believed that fish farming for production required only low-tech methods, compared to systems that depended on external food supplies. In reality it is not so simple.

Intensive fish farming models based on advanced technologies are perhaps easier to transfer, as their main components are well defined and the farmer works in an environment where there is little (in cages in lakes and rivers) or no (in raceways and vats) interference from uncontrolled natural components. Production costs are higher in intensive systems, but so is the yield. But there are important initial obstacles:

- There is a higher level of risk that fish farmed under intensive systems will contract disease,
- The initial investment for intensive systems is very high, and the venture does not become productive for several years. Thus, these systems require:

Table V. Factors of production for the two main models of farming. The symbol – means that the production factor is a constraint for the establishment of fish farming; the symbol + means it is an asset.

Production factor	Transformation fish farming	Production fish farming
Land	+	–
Water	discharge	surface
Environnemental impact	–	+
Working capital	–	+
Labor force (per kg of produced fish)	+	+
«Food»	–	+
Technical know-how	–	–
Risk	–	+
Production costs	–	+
Yield	+	–
Plasticity (ex: Juveniles production)	–	+

- Training of technicians, who take time to become professionals,
- Establishment of a chain of sale, which must include a fish processing facility and other provisions for preservation and transport.

In this context, the concepts of intensive and extensive are particularly significant. Thus, the fish industry, which was long considered a way to concentrate food production and achieve economies of scale geographically, is more aligned with intensive techniques and privatization. It now appears that all such projects implemented on the African continent have failed in their original purpose of producing fish for sale at a lower cost.

Thus, the intensive model requires that both a system of production and a system for marketing the product be established. The marketing system, in turn, requires a good feasibility study. All of these activities take too much time in areas where demand for animal protein is high and supply is low, so production must happen quickly. On the other hand, an intensive system can be developed after a production system has already been implemented.

II. SOME HISTORY

Although the tilapia *Oreochromis niloticus* was raised in ponds by the Egyptians nearly 4,000 years ago, the fact remains that the African continent, unlike Asia, has no tradition of fish farming. At the beginning of the century, aquaculture was still totally unknown on the continent. Initial studies on tilapia date from the nineteenth century, and the first attempts to develop aquaculture occurred in the 1940s.

Around 1950, there were attempts to introduce aquaculture in Africa in order to diversify sources of animal protein and promote food self-sufficiency among rural populations. In 1949, early tests with tilapia in the Kipopo station, in the former Belgian Congo, yielded promising results, and the colonial government began outreach to the local population. In 1957, a research and training station, Kokondekro, was created near Bouaké in Côte d'Ivoire. The first tests were conducted on species, such as *Tilapia zillii, Tilapia rendalli* and *Oreochromis macrochir,* that have since been abandoned because of poor yields under intensive farming conditions. It was not until the 1970s that research with *Oreochromis niloticus* (formerly *Tilapia nilotica*) yielded results that significantly exceeded those of most other tilapia. Also during this period, researchers began to focus on identifying other species with high potential for aquacultural production. However, despite massive promotion of family farming, as in Asia, results were disappointing.

III. SUBSISTENCE FISH FARMING: GOALS AND PRINCIPLES

In the framework of humanitarian NGOs, the goal of fish farming is, above all, to expand access to animal protein at a low cost and within a short time.

So **extensive** to **semi-intensive, low-tech fish farming** is preferable. At the same time, the system should produce a sufficient quantity of fish of consumable size (80 to 100 g in many countries) in a short time. Thus, these farms do not need to produce fish of 300 g or more, which takes more time. This is artisanal fish farming for self-consumption.

Important points:

- ✓ The system should require a minimum of technical know-how so that beneficiaries can appropriate methods easily,
- ✓ The system should reduce its impact on the environment by using local species,
- ✓ Fast, low-cost production,
- ✓ The system should require a minimum of intervention from beneficiaries, who have other major activities,
- ✓ Live or material inputs should be kept to a minimum.
- ✓ There should be a potential for Income Generating Activities (IGA): Depending on the size of the fish farming operation and the number of ponds, the system can allow IGA by employing people to provide maintenance and care of the ponds while maintaining an extensive system of production, which does not require extensive technical input.

Extensive fish farming requires minimal work for the people involved, since there is an important contribution from the natural environment, which should be developed as well as possible. This practice is common in rural areas in poor countries, where the average socioeconomic status of small producers is such that they cannot afford external inputs.

The accepted meaning of "extensive" aquaculture is only perceived paradoxically by its degree of intensification, that is, on the producer's level of intervention in the life cycle of water organisms (Table IV, p. 16). Investments and production costs increase as the method evolves from extensive to intensive (Figure 6, p. 19). Collection of animal material (larvae, juveniles or subadults) in the wild, which will be grown in captivity, through farming techniques, until reaching a marketable size, constitutes fish farming that depends on existing fisheries. These kinds of semi-fish farming practices include low-input fish farming, which is practiced by the majority of small fish farmers in sub-Saharan Africa. These practices are based on the use of space in the shallows in forest areas. Social aspects take on more importance in this case, particularly for community management of larger fisheries. Fish farming, in this case, makes it possible to supplement the protein available from fishing. The association of the two systems, when they are both present, also reduces pressure on fishing resources.

In terms of land needs, for a given level of production, ponds require more land surface (or water surface) than more intensive systems, which, however, require frequent water renewal. In general, fish ponds have only a small negative impact on the environment, unless exotic species are being used and they escape, in which case they can have a catastrophic effect on the natural environment. The ponds can be used to directly or indirectly recycle various types of waste such as domestic or livestock effluents, through stocked watershed stabilization and maturation (pond) where fish is the ultimate link.

This approach will be emphasized in this manual.

IV. POLYCULTURE VS MONOCULTURE

Monoculture is the practice of producing only one species in fish farming structures.

The logic of polyculture is similar for fish and for crops. Keeping fish with different diets in the same space increases the net yield of the pond and the value of production. Polyculture allows for more intense production per unit area; without it, the value of labor may decrease. The principle of a subsistence pond is to recreate a semi-natural ecosystem that feeds on itself. This is an intermediate situation between monoculture, where the flow of energy is concentrated on one species, and a natural system with a diversity of specifies benefitting from the flow of energy. Target species are generally those at the bottom of the food chain, which tend to reproduce at small sizes. Predator species can then be added to control the population and ensure that the fish invest more energy in growth than in reproduction.

In Africa, fish farms use tilapia (often Nile tilapia, or *Oreochromis niloticus*) as a main species and

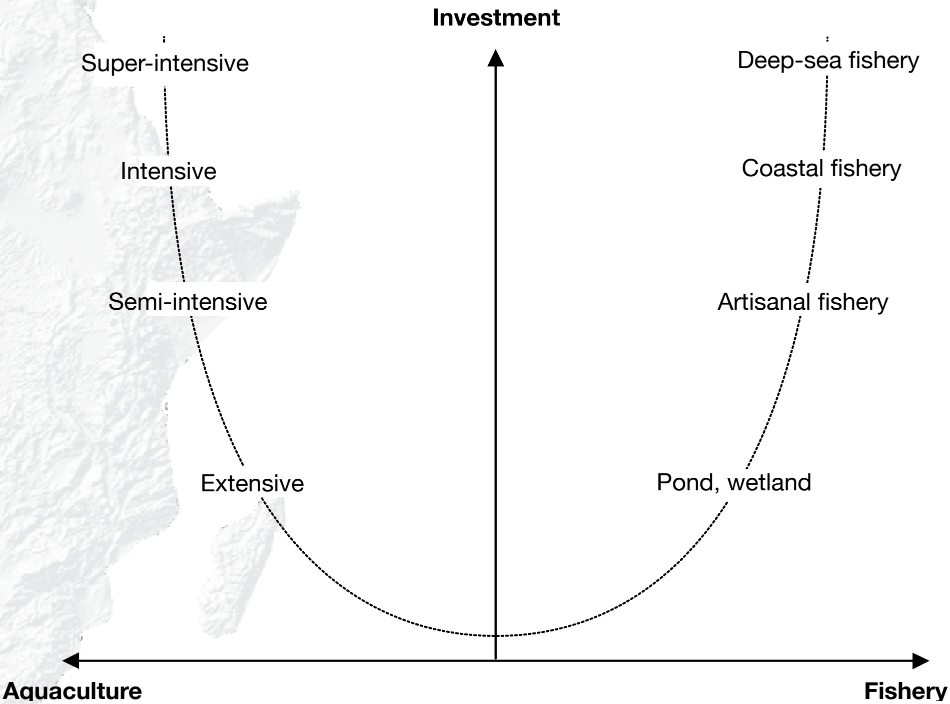


Figure 6. Aquaculture continuum: Fisheries in relation to intensification of investment. (Mikolasec *et al., pers. com*)

add Siluriformes (*Heterobranchus isopterus*, *Clarias* spp.), Osteoglossidae (*Heterotis niloticus*) and the predator *Hemichromis fasciatus* (to remove unwanted fry). Under these conditions, the secondary species may increase the total yield by over 40%. Whatever species of tilapia is used, as the number of age classes in a farm enclosure increase, competition may inhibit the growth of the fish that were first stocked.

A growing number of Africans farming tilapia are using predators to control undesirable reproduction. Within this framework, Siluriformes (*Clarias* or *Heterobranchus* sp.) often have a double function: predation and polyculture. The results of farming *Clarias* with Tilapia show that a large number of *Clarias* are necessary to totally control reproduction of *O. niloticus. Clarias also* competes with *O. niloticus* for food. A population of 260 *Clarias* with an initial mean weight higher than 150 g is necessary to control a population of 1,200 tilapia in a pond of 10 ares, and the tilapia grow more slowly than those on an identical farm where *Clarias* is replaced by the strict predator *Hemichromis fasciatus*. It was also noted that, in the presence of a predator, tilapia tend to invest more energy in growth before they reproduce, possibly because they can defend their young more effectively if they are bigger.

Polyculture has a variety of advantages:

✓ **Natural foods are used more effectively, and more efficiently**, since any one species never consumes all the food resources in a pond, even if it eats a broad spectrum of food.

✓ **«Dead ends» on the food chain are avoided.** No fish will consume every type of organism in a pond. For example, certain small crustaceans that the fish do not eat can grow. The polyculture farmer can then control the population of this invader by introducing a species that either will reduce its food supply, or directly eat the organism.

✓ **Polyculture stimulates the production of natural foods.** Fish that dig for food can suspend particles and, thus, aerate the sediment, oxidizing organic matter and improving recycling of nutrients that stimulate production of natural food.

✓ **Double fertilization can occur.** The waste products of herbivorous fish are so "rich" that they have a fertilizing effect, similar to fertilization in terrestrial farming. This effect is sometimes called "double fertilization", since chemical fertilization is much more effective when these fish are present in mixed-farming systems. For example, double fertilization can increase carp yields from 14 to 35%, compared to normal fertilization in a monoculture pond.

✓ **Water quality improves.** In a pond, tilapia improve oxygenation by consuming organic matter on the bottom, which would otherwise be mineralized by bacteria that consume oxygen.

✓ **Organisms are controlled more effectively**. For example, it is possible to control molluscs in ponds using *Heterotis niloticus*, while proliferation of small wild fish or shrimp can be controlled with carnivorous fish.

There are also disadvantages to polyculture, particularly when competition between species causes an imbalance. Moreover, when fish population densities are very high, the pond's natural productivity becomes less important for the fish's diet, since naturally-available resources must be allocated among all the individuals in the food chain. Profits from polyculture systems are relatively limited, whereas the work necessary to sort the various species at the time of harvest is considerable and can limit productivity.

Thus, monoculture is the only method used in intensive systems where the contribution of natural foods is very limited. Fish densities are not very high in these ponds, since oxygenation and accumulation of toxic substances such as ammonium and nitrites limit population growth.

⇨ **For most applications in Africa, a semi-intensive, artisanal fishfarming operation for self-consumption, that employs polyculture and requires a limited degree of external inputs and maintenance will prove to be the most satisfactory.**

Chapter 03
BIOGEOGRAPHY AND FISH SPECIES

I. GEOGRAPHY

Fish faunas have assembled and evolved together with the aquatic systems they occupy. They are far from homogeneous throughout Africa.

The existence and survival of aquatic habitats depend on two main factors: their morphology, which can be modified over the long term by erosion or tectonic movement; and water balance, which depends on precipitation, evaporation, and seepage. Over the short- or medium-term, small changes in hydrological balance can cause an aquatic environment to either shrink or expand, depending on the conditions within the basin. Drainage basins can interact with each other. Over various time periods, some basins have been engulfed or captured by other basins, and these colonizations have been followed by selective extinctions resulting from climatic and/or geological events. While basins have changed over time, populations of species isolated in separate basins often evolve into separate species; such speciation often explains the presence of areas of endemism.

The African continent can be separated into several great ichthyofaunal regions, or ichthyoregions, (Figure 7, p. 22), defined by the affinities between fish faunas. Each region includes several catchment areas of different sizes. For example, the nilo-sudanic region includes several large basins, such asthe Nile, Niger, and Senegal.

Political divisons between countries do not correspond to ichthyoregions. A country may be included completely in only one ichthyoregion (e.g. Gabon), or overlap with several (e.g. Cameroon). Table XLV, p. 244, shows ichthyoregions for each African country, while Table XLIV, p. 240 provides geographical information for each African country.

⇨ One must consider the country and the ichthyoregion when choosing species for fish farming. Tables in the annexes list species, particularly tilapia, that may be used in aquaculture.

II. SPECIES

Of the 292 farmed species listed by FAO (1995) and for which data are available, the first 22 represent 80% of total production. Practically all of these 22 are filterers, herbivores, or omnivores. Only one species, the Atlantic salmon, is carnivorous, and it is clearly a minor species in terms of production volume. The most important group is fresh water fish, which accounts for 12.7 million tons, compared with 1.4 million tons for amphihaline fish and 0.6 million tons for marine fish.

Fresh water fish are dominated by Cyprinidae (carp) and Cichlidae (tilapia). Cyprinidae present a certain number of comparative advantages: they can eat food with limited protein and fish meal content; they can be raised as part of a polyculture system, allowing optimal use of the natural productivity of ponds and pools; and they are a growth market in Asian countries, because of tradition as well as their relatively low price.

In Africa, aquacultural production focuses mainly on two groups of indigenous species: tilapia (12,000 tons annually) and catfish (7 000 tons), and on carp (2,000 tons), which have been introduced into the area. Historically, tilapia were the subjects of Africa's first aquacultural experiments, mainly in DRC (ex-Zaire) and Congo, particularly because they reproduce easily in captivity. Thereafter, a variety of species were tested for their fish farming potential. At the beginning of the 1970's, in Central African Republic, the high potential for farming of catfish (*Clarias gariepinus)* was proposed. In the 1980s, other species were identified, particularly in Ivory Coast, based of the appreciation of consumers and their performance. The biological cycle of some of these species is now completely controlled, so that they can be produced on fish farms.

Figure 7. ichthyoregions (yellow-green borders) and countries (red borders) (Paugy *et al.*, - Faunafri, 2008).

II.1. CICHLIDAE

In Africa, the main fish farming species are from a group of Cichlidae called the Tilapiines. They are commonly called tilapia and are mainly herbivorous/microphagous. The parents care for their young. Tilapia are sometimes called "aquatic chickens," and have biological characteristics that are particularly suitable for fish farming:

- ✓ They grow fast, even when their food contains little protein;
- ✓ They tolerate a broad range of environmental conditions (oxygenation, water salinity, etc.);
- ✓ They reproduce easily in captivity and are not very sensitive to handling;
- ✓ They are very resistant to parasitic diseases and infections;
- ✓ They are appreciated by consumers.

More than a hundred species of «tilapia» have been described. More than 20 species have been recorded in some countries (Annexe 04 page 239). Some are endemic to specific lakes or very circumscribed areas. Their maximum sizes vary considerably, from less than 5 cm to more than 60 cm Total Length (TL). Tilapiine species are separated into various genera, but the three principal ones are *Oreochromis*, *Sarotherodon* and *Tilapia*. Distinctions are based mainly on species' mode of reproduction. *Oreochromis* are maternal mouthbreeders (females keep the eggs and juveniles in their mouths to protect them), *Sarotherodon* are also mouthbreeders, but biparental, (both parents can incubate the young), and *Tilapia* are substrate spawners. Maximum growth is 3 grams per day.

Oreochromis niloticus was one of the first species to be cultivated, and remains the most common. However, many other species have also been used, including *O. aureus, O. macrochir, O. mossambicus, Tilapia rendalli, T. guineensis, and Sarotherodon melanotheron.* This last, which is often found in West African estuaries and lagoons, seems to be better adapted to farming in brackish water. Many of these species are now widespread throughout the world, having been either introduced into natural environments to improve fishing, or used for fish farming.

Between 1984 and 1995, the proportion of farmed tilapia to total supply increased from 38% (198,000 tons) to 57% (659,000 tons). Four species or groups of species dominated production between 1984 and 1995, comprising 99.5 % of total Cichlidae supply. The Nile tilapia represented 72% of total production; its annual growth rate between 1984 and 1995 was 19%. In 1995, the principal producers of tilapia were China (315,000 tons), Philippines (81,000 tons), Indonesia (78,000 tons) and Thailand (76,000 tons)!

Other Cichlidae were used to control tilapia populations in the ponds. These were predatory species of the genera *Serranochromis* and *Hemichromis*.

II.2. SILURIFORMES OR CATFISH

Siluriformes are, in fact, catfish. They are separated into several families.

The interest in farming of African fish species is recent. Some species of Siluriformes are very suited to fish farming because they are robust and grow rapidly. Currently, there are three species whose potential for domestication has been well-studied: *Clarias gariepinus*, *Heterobranchus longifilis* and *Chrysichthys nigrodigitatus*. *Heterobranchus longifilis* is present in most river basins in intertropical Africa, and has biological characteristics that are particularly favorable to fish farming, including an air breathing apparatus that allows it to survive in hypoxic conditions, an omnivorous diet, high fertility, quasi-continuous reproduction, and remarkable growth potential (10 g per day). Reproduction of these species in captivity is controlled, but the larval growth phase is the most constraining phase of farming. The farming potential of other catfish, such as *Clarias isheriensis*, *Bathyclarias loweae*, *Heterobranchus isopterus* or *H. bidorsalis*, has also been studied. Tests on *Auchenoglanis occidentalis* were completed in Ivory Coast.

Some species of Siluriformes are strictly piscivorous and were tested for their ability to control tilapia populations in polycultural systems. In addition to *Heterobranchus longifilis*, Schilbeidae, like *Schilbe mandibularis*, *S. mystus* and *S. intermedius* and Bagridae, *Bagrus docmak*, and *B. bajad* can be used.

II.3. CYPRINIDAE

There are more than 500 identified species of Cyprinidae in African inland waters, but despite this abundance and diversity, none have been domesticated so far. Yet some species, such as *Labeobarbus capensis* (99 cm TL), and *Barbus altianalis* (90 cm TL) reach very large sizes. There were some attempts to introduce Asian Cyprinidae as common carp (*Cyprinus carpio*), silver carp (*Hypophthalmichthys molitrix*), mottled carp (*Hypophthalmichthys nobilis*) and grass carp (*Ctenopharyngodon idella*). The common carp was first introduced to Madagascar and then scattered in a dozen other countries including Kenya, Cameroon, Malawi, Ivory Coast and Nigeria. *Labeo victorianus* (41 cm TL) and *Labeo coubie* (42 cm TL) were also tested. However, these species often live in running water, and this can be a problem in pond farms, where water is almost stagnant.

II.4. OTHER FAMILIES AND SPECIES

A FAO list of species produced commercially through African fish farming is provided in Annex 02, (p. 193), listed by country.

Other species, which may or may not be produced, have been researched. These include the

Nile Perch (*Lates niloticus*, Latidae, 167 cm SL), the predator introduced into Lake Victoria for production and control of tilapia populations.

Other species have been tested, but the results of this research are old and cannot be found easily in the bibliography. Other African species being considered for domestication include *Gymnarchus niloticus* (in Nigeria, Gymnarchidae, 167 cm SL for 18.5 kg), *Parachanna obscura* (Channidae, 50 cm SL for a maximum weight of 1 kg), and *Distichodus niloticus* (Citharinidae, 83 cm TL, for a weight of 6.2 kg).

The osteoglossid *Heterotis niloticus* (100 cm SL, for a weight of 10.2 kg), is used regularly in polycultural systems in Ghana, Nigeria, Gambia, Guinea, and Congo.

It is clear, however, that people quickly focused on fewer than 10 species. However, the potential of many others has not been tested. Considering the damage that has been caused by the introduction of non-native species, it would be a good idea to begin developing farms for indigenous species.

One step toward identifying suitable indigenous species would be to focus on neglected and little-known species whose potential is better than that of a sister species or a similar genus that has been used already. Another consideration is to avoid the introduction of foreign species. Examples of such substitutions include *Chrysichthys nigrodigitatus* for *C. maurus,* or *Heterobranchus longifilis* for *Clarias gariepinus*. Such substitutions could also help with diversification.

⇨ **We should agree that 'what is found elswhere IS NOT necessarily better than what is found at home.'**

Summary

FISH FARMING: AIMS AND ISSUES

WHY FARM FISH?

Fisheries and aquaculture contribute to food security in three primary ways:

- ⇨ They increase food availability,
- ⇨ They provide highly nutritious animal proteins and important trace elements,
- ⇨ They offer employment and income that people can use to buy more food.

PRESSURE ON RESOURCES

Continental aquatic ecosystems are particularly affected by human activities through:

- ✓ Habitat modification,
- ✓ Water pollution,
- ✓ Impact on fisheries,
- ✓ Introduction of alien species.

INTERNATIONAL ASPECTS

The Convention on Biological Diversity (CBD), known informally as the Biodiversity Convention, is an international treaty that was adopted at the Earth Summit in Rio de Janeiro in June 1992. The Convention has three main goals:

1. Conservation of biological diversity (or biodiversity);
2. Sustainable use of its components;
3. Fair and equitable sharing of benefits arising from genetic resources.

⇨ **Above all, the Convention is legally compulsory and the member states are forced to implement its mesures.**

⇨ **This means respecting its provisions when implementing field projects and avoiding changes to the environment that may affect biodiversity. If ignored, consequences could accrue to responsible agencies regardless of their intentions and the tacit agreement of local and regional authorities.**

OBJECTIVES OF FISH FARMING

⇨ **The objective of the fishfarming is not to replace fisheries but to supplement its contribution to the current level of fish consumption in response to increasing world population. However, this goal must be pursued while respecting environmental laws, consumer health and bioethics.**

TYPES OF FISH FARMING

TYPES OF FISH FARMING

Types of fish farming are categorized mainly by the size of the investment required, the quantity of fish produced per unit of area, and the destination of the product. Farms are generally characterized by their degree of intensification.

SUBSISTENCE FISH FARMING: GOALS AND PRINCIPLES

A fish farm using **extensive** to **semi-intensive production methods, which** require minimal technical knowledge, is preferable. At the same time, the farm should produce a good quantity of fish of consumable size within a rather short time. This is artisanal fish farming for self-consumption.

Important points:

✓ Necessary technology should be minimal for appropriation by beneficiaries,

✓ Impact on the environment should be reduced by using local species,

✓ Production should be fast and low-cost,

✓ There should be a minimum of work necessary on the ponds, since beneficiaries have other major activities,

✓ Live or material inputs should be kept to a minimum.

✓ Potential for Income Generating Activities (IGA): depending on the size of the fish farm and the number of ponds, the system may allow IGA's, employing people to provide maintenance and care for the ponds while maintaining an extensive system of production, which does not require a high level of technology.

POLYCULTURE VS MONOCULTURE

Monoculture systems cultivate only one species in each fish farming structure. In polyculture systems, fish with different diets are kept in the same structure, increasing the net yield and value of production.

⇨ **We therefore describe in this manual a fish farming system for production that is semi-intensive, artisanal, meant for self-consumption, and that utilizes polyculture rather than monoculture. Adequate production under this type of system requires external food inputs and more intensive monitoring and maintenance.**

BIOGEOGRAPHY AND FISH SPECIES

GEOGRAPHY

Fish faunas were established and have evolved with the aquatic systems where they live. They are far from homogeneous across Africa.

The African continent can be separated into several great ichthyologic regions or ichthyoregions. These regions are defined by affinities among fish faunas.

⇨ **It will be necessary to know the icthyoregion for the locality where an intervention will take place.**

SPECIES

Aquaculture production primarily works with two groups: Cichlidae, or **tilapia,** and Siluriformes, or **catfish**.

No single species of tilapia or catfish species is distributed over the entirety of Africa, although both of these *groups* are represented by one or more species in most watersheds.

⇨ **It is important to note both the provenance of the fish and the watershed, because of the risks incurred by the introduction of fish species as well as national and international legislation concerning biodiversity.**

⇨ **The fact that a species has already been introduced in the intervention area does not mean it should be used again.**

⇨ **We should agree that "what is found elsewhere IS NOT better than what we find at home."**

Part II
PRACTICAL ASPECTS

Contents

- The initial pre-project assessment
- Village and site selection
- Characteristics of ponds
- Pond construction
- Biological processes
- Handling the fish
- Maintaining and managing ponds

CONTENTS - PART II

Cover photo:
⇨ Villagers working on the pond, Liberia, ASUR, 2006 - © Yves Fermon

On the next page, the reader will find a complete implementation plan for establishing ponds (Figure 8, p. 32).

The chapters follow the plan. As the manual progresses, phases of the plan will be referenced at the beginning of each chapter.

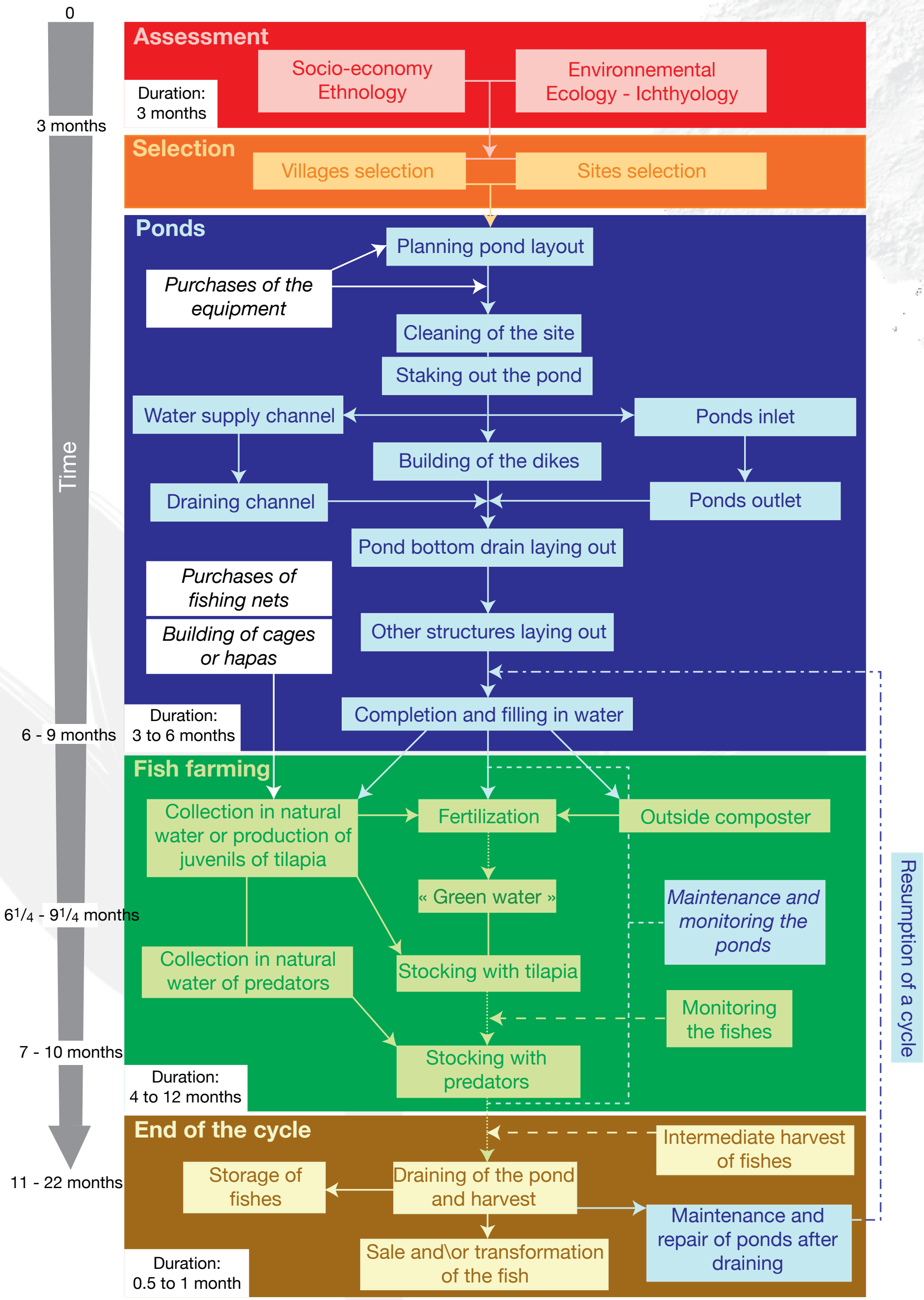


Figure 8. General implementation plan.

Chapter 04
THE INITIAL PRE-PROJECT ASSESSMENT

The initial evaluation helps to determine whether a project will be useful and relevant for the beneficiary population. It should take into account:

- ✓ **Beneficiaries' requests;**
- ✓ **Available resources and environment**.

As a first step, we will discuss the environment and **ecosystems**. Then we will discuss aspects of evaluation. The evaluation phase will take at least three months, and possibly longer depending on the size of the program and the geographical area being assessed (Figure 9, p. 34).

I. THE ECOSYSTEM

An **ecosystem** is a dynamic, complex system that includes plants, animals, microorganisms and inert environment, that is subject to complex interactions as a functional entity. Ecosystems vary greatly in size, lifetime duration and operation. A temporary pool in the hollow of a tree and an ocean basin are both examples of ecosystems.

The interacting organisms (plants, animals and microorganisms) that live in a particular habitat and interact with each other form an ecological community, or «**biocoenosis**», characterized by a **food chain**. At the bottom of this food chain are plants (**primary producers**) that build organic matter with energy from light, CO_2 from the air, and mineral ions from the ground. They are then consumed by other **producers**, from herbivores to super predators. At every stage, decomposed organic matter returns to mineral form in the soil. The inert environment is also known as the **biotope**. It includes all geographical and physicochemical characteristics of the ecosystem, including climate, soil, topography, water, etc. The concept of an ecological factor is used to analyze and describe a given ecosystem. Any element of the external environment which may affect the development of living beings is known as an ecological factor. There are several types of these:

- ✓ **Biotic** factors, related to biological components (biocoenose), interactions between live organisms, including intraspecific (within the same species) as well as interspecific (between two different species or more) interactions;
- ✓ **Abiotic** factors, related to the physicochemical conditions of the environment (biotope).

An ecological factor can determine an organism's success in its attempts to colonize an environment. Success can be affected by the absence of an ecological factor or by its excess. With respect to ecological factors, all living beings have a zone of tolerance, as well as an ecological optimum. The «ecological valence» of a species represents its capacity to support variations in ecological factors.

Ecological factors can thus affect the biocoenose in various ways. In particular, they will affect:

- ✓ A species' biogeographic distribution area;
- ✓ Population density;
- ✓ Occurrence of adaptive modifications (in behavior or metabolism).

Thus the presence of a specific species can be a **biological indicator**, providing information on the characteristics of the environment where it appears. Knowledge of what particular characteristics indicate for the presence or absence of biotopes allow zoning. It is possible to associate each type of ecosystem within these zones, which show its operating process, goods and services produced, known risks and threats, etc.

Human beings, as an integral component of ecosystems, benefit from the "**goods and services**" produced by their functioning. Services provided by ecosystems include services of deduction such as food and water; services of regulation for floods, dryness, disease and impoverishment of soil; services of self-maintenance such as ground formation, nutritional cycle development; and finally cultural benefits such as enjoyment, esthetic benefits and other nonmaterial benefits. These various "services" result from ecosystem functioning, that is, all of the biogeochemical reactions that affect

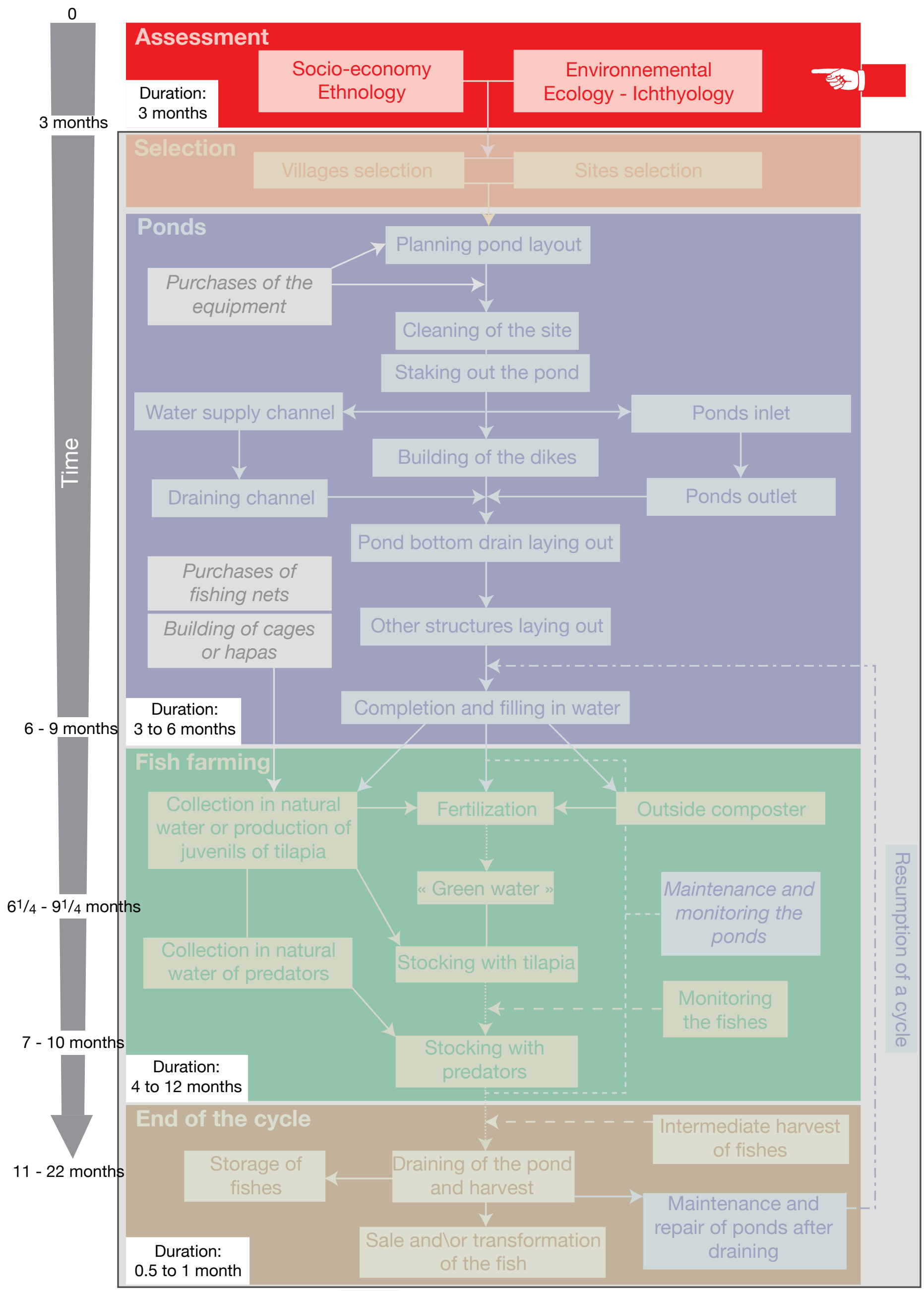


Figure 9. Setting up fish ponds: 1. Assessment.

the biosphere and are characterized by permanent exchanges of matter and energy along the various cycles (water, carbon, nitrogen, etc.), and along food chains.

Because of various cycles (like that for water, illustrated in Figure 10 below), each ecosystem is open to others. The more or less porous borders between them are called «**ecotones**». Examples of ecotones include the edge of a wood that separates it from an agricultural field, or a hedge that cuts the wind. Like any border, these zones are important places of transit and exchange. One of the best-known ecotones is the wetland, which is a transitional zone between terrestrial and water environments. Wetlands constitute a vast inter-connected network of exchange that includes lakes, rivers, swamps and coastal regions.

A human community's living conditions and production capacity always depend, either directly or indirectly, on «services» provided by local ecosystems (water, food, wood, fiber, genetic material, etc.). For example, exploratory studies undertaken under the "Millennium Ecosystem Assessment" found that the demand for food could grow by 70 to 80% over the next 50 years. Which ecosystems will supply the food to satisfy this growth? This increasing demand will make it even more difficult for communities to access the resources they need and will increase the cost of food security for all. This is where the concept of territorial vulnerability becomes important.

Because all ecosystems are interconnected, the same territory is subject to forces that operate at different spatial and temporal scales.The global environment (climate, major biogeochemical cycles) evolves over a long period, local environment (biomass production) over a medium period, and human communities over a short period. For the time being, it is difficult to estimate the impact that climate change will have on the global environment, but continued study of this question is needed.

The landscape ecosystem approach is useful for understanding the interconnected and interdependent nature of temporal and spatial variables that operate in a region.

Thus we should remember that there is a direct and indirect relationship between the vulnerability of the ecosystems that exist in a specific region and the vulnerability of human communities that live there and depend on the «goods and services» these ecosystems produce.

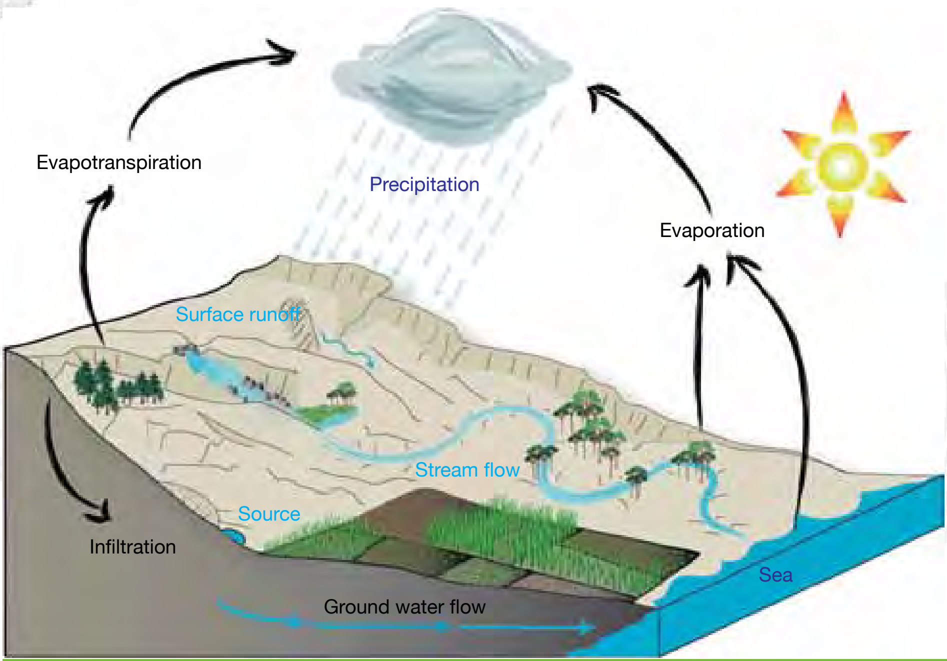


Figure 10. Water cycle.

> ⇨ **All components of an ecosystem, including human beings, must be taken into acount in order to propose interventions that will promote "quality of life," with regard to food security issues and also with regard to health, water and sanitation.**

II. THE ASSESSMENT

The three components of an assessment are:

1. **Humans.**
2. **Resources.**
3. **Human effects on the resources.**

Analyzed through two grand themes (Figure 11):

(i) Biology and ecology: points 2 and 3.

(ii) Socio-ethnology: points 1 and 3

It would be ideal to evaluate these two issues at the same time.

For post-emergency interventions, there is a serious time limit. In this case, it will be necessary to carry out a «rapid evaluation», centering on the intervention.

III. PRINCIPLES

Rapid evaluation (or assessment) can be defined as:

"*A synoptic evaluation often undertaken in urgency, within the shortest possible time, in order to produce results that are reliable and applicable to the defined goal*".

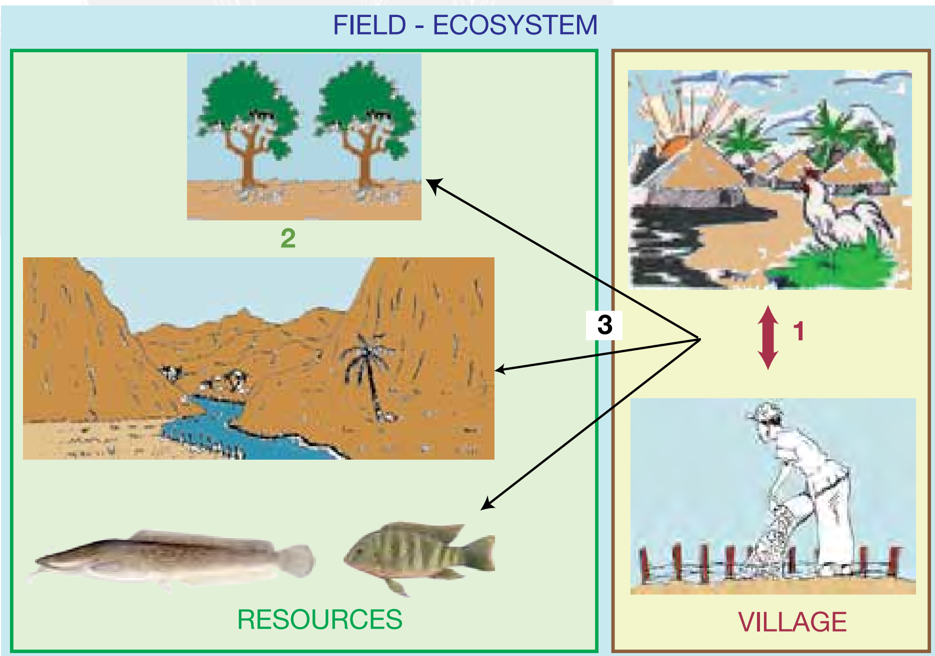


Figure 11. Contextual components of an assessment.
1: Humans; 2: Resources; 3: Human effects on resources.

Planning for rapid assessment should integrate the following nine points:

1. **Type** of rapid assessment: A rapid assessment can range from a theoretical study to a field study, with data collected through meetings of expert groups and workshops. It can include a compilation of existing knowledge and specialized data, including traditional knowledge and data, as well as field study methods.

2. Three stages of assessment: These include **design/preparation, application, and reporting.** Rapid assessments provide the necessary information within the shortest practical time, even if planning and preparation that precede the study consume a lot of time. In some circumstances (depending on seasonal factors, for example) time may run out between the decision to undertake the evaluation and its completion. In other cases (in the event of a disturbance or catastrophe, for example), the evaluation will be undertaken in an emergency situation and there will be minimal preparation time.

3. **Inventory, evaluation and follow-up**: It is important to distinguish between inventory, evaluation, and follow-up and the kind of data needed for each. The reference inventory for wetlands is used as a basis for the development of a suitable evaluation and follow-up. Inventories of wetlands, repeated at specific intervals, do not necessarily constitute "follow-up".

4. **Costs**: Costs increase, in particular, for assessment of isolated or large areas, for high topographical resolution and/or when multiple characteristics are being measured. The cost of a rapid assessment will also be higher, since it will be necessary to support large teams in the field simultaneously.

5. **Spatial scale**: Rapid assessments can be undertaken on areas of a variety of sizes. In general, for a large-scale rapid assessment, a standard method will be applied to a large number of localities or sampling stations. Obviously, the more an area is extended, the more time the assessment will take, depending on the number of people working; so costs will be higher.

6. **Compilation of existing data/access to data**: Before deciding to complete a new assessment of the area, it is important to compile and evaluate as much existing and available data and information as possible. This part of the assessment should determine what data exists and whether it is accessible. Data sources can include **geographical information systems (GIS)** and teledetection, published and unpublished information, traditional knowledge, and other data obtained from local populations and indigenous people. Compilation of this data will help to determine whether the goals of the assessment can be reached with existing information or if a new field study will be necessary. ***Well-done mapping of the area is essential for a high-quality assessment and for future project decisions.***

7. **Documentation**: All new data and information collected during a rapid field assessment must be permanently documented and available for future decision-making.

8. **Reliability of the rapid assessment data:** For all rapid assessments, information on confidence limits for conclusions is particularly important. A comprehensive assessment of confidence limits for the final results helps to avoid the propagation of error.

9. **Diffusion of results**: The fast, clear and open diffusion of results to a range of actors, decisionmakers and local communities is an important component of any rapid assessment. Information should be presented to each group in the appropriate form and with the appropriate level of precision.

Assessments of wetlands and their resources should simultaneously consider:

- ⇨ **Biological characteristics and resources;**
- ⇨ **Socio-ethnological characteristics of human communities.**

⇨ **Preferably, two specialists should be tasked with emphasize to the biological evaluation.**

IV. BIOLOGICAL AND ECOLOGICAL ASSESSMENT

The methods available for rapid assessment of biodiversity in a given waterway depend on the goals and results of specific projects. Limitations imposed by available resources are quite important, particularly because they influence the range of the assessment. Resources of time, money and expertise may also limit the methods available to a specific project. These resources define the project's range in the following areas: systems, geography, site choice, analysis, data, and sampling procedures. These are important components of an evaluation of wetland biodiversity, and the range or capacity of each varies depending on project needs and resource limitations.

It is important to establish the ecological health of the region.

⇨ **A country's hydrographic network is its "blood circulatory system." Damage caused by a problem at one point will diffuse through the system from that point, whether the damage emanates from chemicals, urban activity, or erosion. The phrase "water is life" is a well-known slogan, but for health, water and sanitation, as well as food security (agriculture, fish), it is a central truth. As an examination of the circulatory system of a human body can help establish a diagnosis, studying an area's rivers can facilitate an evaluation of the area's health and help to identify points where intervention will be necessary.**

Biological components of an aquatic ecosystem, including invertebrates (crustaceans, molluscs, insects, etc.), and vertebrates (fish) are excellent indicators of water quality. The diversity of species and communities is an indicator of water quality, hydrology, and the general health of particular ecosystems. "Biomonitoring" is often associated with this type of evaluation. Traditionally, it is defined as the use of biological indicators to monitor toxicity levels and chemical content. Recently, however, this approach has been more often applied to the monitoring of the overall health of a system rather than simply its physical and chemical characteristics. The presence or absence of specific chemical or biological indicators can reflect environmental conditions. Taxonomic groups, individual species, groups of species, or whole communities can be used as indicators. Usually, benthic macro-invertebrate, fish and algae are used as organic indicators. So, it is possible to use the presence or absence of species, as well as, in certain cases, the characteristics of the habitat, to evaluate the state of wetlands ecosystems. In temperate countries, the use of biological criteria to monitor river quality is a common practice, but this is not a widely-used method in tropical countries. The biological index of integrity (IBI) has been used for more than 10 years in Europe and North America. This index provides an estimate of the health of a river through analysis of fish populations. The maintenance of water quality is a major concern for human society, which must satisfy increasing water requirements while ensuring adequate quantity as well as quality.

The aim of resource evaluation is to determine the potential for sustainable use of living resources in a given area or aquatic system. The data provides information on the presence, state and condition of economic species, or species that provide the means of existence and/or have a potential commercial value. Logically, resource evaluation should facilitate ecologically sustainable development rather than destructive activities. Fish are important indicators because they provide animal protein. Evaluation surveys examine available resources in rivers that are close to targeted villages.

It is assumed that the objective of any rapid assessment is conservation and rational use. The increased knowledge and understanding gained from the assessment establishes a reference point for monitoring changes in ecosystems and ensuring the sustainable use of resources. In this context, there are five reasons to undertake a rapid assessment of wetlands:

1. To collect reference information on biodiversity of a given area and establish an inventory and hierarchy of species, communities, and wetlands ecosystems.

2. To gather information on the status of a target species (such as a threatened species) and gather data that is important to the conservation of a particular species.

3. To obtain information on the effects of natural or man-made disturbances in a particular area or on a particular species.

4. To obtain indications of the general health of an ecosystem or of the state of a particular wetland ecosystem.

5. To determine whether it is possible to sustainably use a wetand ecosystem's living resources.

Many rapid assessments do not provide a comprehensive evaluation of all the threats or pressures on biological diversity. Nevertheless, they can help to determine indicators for a future evaluation, or to make a provisional evaluation of categories of threats.

It is important to note that methods for rapid assessment of wetlands generally do not integrate variations in time and ecosystems' seasonal characteristics into the analysis. However, some methods can be (and are) used in iterative studies as elements for integrated follow-up, in order to incorporate temporal variations. Rapid assessment techniques are appropriate particularly at the specific level of biological diversity and the evaluations discussed here should be done on this level. «Rapid» approaches generally cannot provide evaluations of genetic biological diversity.

Because nature is so complex, and wetlands ecosystems vary so widely, there is no universal method of rapid assessment that is applicable to the entire range of wetlands and assessment goals. Moreover, possible methods in particular cases depend on the resources available and the abilities of the evaluators.

The general goal is to gather as much information as possible on a wetlands ecosystem through a wide sampling of biological elements and their associated characteristics that is as complete as possible. Identification of existing species and habitats will probably be most important, but other relevant data could include: species richness, abundance, relative population size, population distribution and the area of distribution, and cultural importance of resources, in addition to water quality, hydrology and the health of the ecosystem, which is important for biodiversity. Data on geography, geology, climate and habitats are also important. For the majority of studies, it would be good to measure indicators of water quality, including temperature, electric conductivity (EC, a measurement of dissolved total salts), pH (acidity or alkalinity of water), chlorophyl A, total phosphorus, total nitrogen, dissolved oxygen and water transparency (which can be measured with a Secchi disc). These measurements can be taken with individual instruments or with a combination of instruments, including several types of probes. Macrophytes can be visually monitored. Fish can be sampled through many methods, but the choice of method may depend upon applicable legislation. Working with local fishermen and examining their catches can provide invaluable information.

A specialist must be involved, since a generalist will be limited by his or her knowledge of aquatic organisms and the functioning of ecosystems.

It is essential to collect the following data:

- Number of species,
- Number of individuals of a specific species in a given sample,
- Presence/absence of focal species,
- Physicochemical quality of the water (rate of nitrates/phosphates, pH, oxygen, conductivity, turbidity).

Once the species have been identified, it is easy to see which are available for fish farming.

Local communities can be an important source of information on the richness of a species in a given habitat. For example, studies of communities and their consumption can provide information in very little time. Thus it is important to combine analysis with a socio-ethnological approach.

V. SOCIO-ETHNOLOGY

V.1. SOCIO-ECONOMIC AND CULTURAL CHARACTERISTICS

While information on the socio-economic and cultural characteristics of biological diversity are important, a complete economic evaluation is, generally, not possible during a rapid assessment. Nevertheless, within the framework of a rapid assessment of inventory or risk evaluation, it can be useful to look at indicators of socio-economic and cultural characteristics important to the site, as they may provide an idea of probable changes in the natural resource base and identify characteristics that should be examined in a more detailed follow-up evaluation.

To be taken into account are:

1. Paleontological and archaeological artifacts;
2. Historical buildings and building sites;
3. Cultural landscapes;
4. Traditional systems of production and agro-ecosystems, such as rice plantations, saltworks, and estuaries;
5. Collective water and land management practices;
6. Self-management practices, including customary property rights;
7. Traditional techniques of wetlands resource exploitation;
8. Oral traditions;
9. Traditional knowledge;
10. Religious beliefs and mythology;
11. “Arts”, including music, song, dance, painting, literature and cinema.

In addition to the customary evaluation of the nutritional and medical state of the local population, it would also help to consider several questions when one arrives in an inhabited area.

V.2. HUMANS’ RELATIONSHIP TO RESOURCES

➢ *Are there taboos or beliefs governing relationships among humans, fish, and the river?*

Food taboos exist, to various degrees, in all cultures. Since food is a basic element of the subsistence of humans (and of other living beings), distinctions between allowed and forbidden, pure and impure, are fundamental, for medical, moral or symbolic reasons. These taboos can have religious, medical, moral, psychological and emotional justifications, or a combination of all of these. There may also be other customs related to eating fish that pertain particularly to women and children. These may be taboos against eating fish, although often people who are not accustomed to eating fish will say they do not like it simply because it “smells bad” or “resembles a snake”. In some communities, the range of taboos for pregnant mothers was formerly so wide that it was almost impossible for them to eat a balanced diet. For example, some of the Bahaya people, who live close to Lake Victoria, prohibited eggs, milk, fish, and meat for pregnant women. The assessment should also ascertain whether there are fish known as “patrimonial”, which have a symbolic importance.

In other cases, fishing may be prohibited in some areas of a village. Some of these prohibitions were put in place to avoid excessive predation and manage resources in an area rich in fish.

➢ *How is fishing perceived?*

In some ethnic groups, fishing is considered an activity for lower castes. To be a fisherman and live off fish is considered unworthy.

➢ *What resources are being used?*

The share of fish in the daily diet can be ascertained by examing what women prepare for meals, or by visiting the market. In Ethiopia, for example, fish is consumed mainly during Lent. If fish is being eaten, it is important to learn its source and availability. For example, in Liberia, villages near rivers did not have any problemwith fish supplies in spite of an interest in fish farming, but 10 km further away, another village did have supply problems.

- *What resources are being produced?*

Visting the fields and conducting a census of cattle and animals will provide information on the diversity of food products available. It will be necessary, however, to separate «prestige» cattle from animals meant for human consumption.

- *How is the water supply?*

It is important to find out where the water points are (well, pump, river, etc.) and to assess their condition.

V.3. HUMAN INTERRELATIONSHIPS

- *Who does what? What are the roles of women and of men? What are their uses and tasks?*

There is a division of labor between men and women. Among fishing people, most of the time, the men go fishing but the women collect the fish for processing and sale. In other communities, fishing is practiced by women and becomes a social act. For example, in Liberia, the women go to the river with the children during the afternoon to capture fish with large scoop nets, and take the opportunity to exchange the latest news from the village.

- *What is the social structure?*

It is particularly important to know how a village is structured and to learn who the key and notable people are. Groups and their operations are key to program success.

- *What is the system of land division?*

It is also important to understand the system of land division, membership, and land rights, as fish farms may be established in privileged areas. Water rights and management are also important.

Most of the time, this information can be collected through investigations that humanitarian NGOs like ACF do routinely. It is, however, important not to stop collecting information after discussions with villagers.

In some cases, communities may already have experience with fish farms that have failed. This may be particularly true with systems developed in countries with old fish farming traditions and ancestral knowledge. The many attempts to transfer these fish farming models into countries without fish farming traditions have failed.

Many explanations for the difficulties encountered in the development of fish farming in Africa have been proposed, including:

- **Social constraints: rural populations do not have traditions or knowledge of fish farming;**
- **Technical constraints: recently, fish farming techniques have not been controlled perfectly, and have resulted in inadequate production quality and quantity;**
- **Economic constraints: fish farming developed as a family subsistence activity, and was not profitable.**

Therefore, the assessment should also include a search for former sites of fish production ponds. ***If such constraints exist, the population will first have to unlearn before relearning.***

- ⇨ All of this collected information will allow us to ascertain:
  - ⇨ The area where the intervention should take place;
  - ⇨ Available resources, and their current use;
  - ⇨ Communities and social structures.
- ⇨ The goal of this assessment is to collect the information you need to propose a program that the population will be able to take over and manage themselves, assuming the assessment shows that fish farming is an appropriate intervention for the area under consideration.

Chapter 05
VILLAGE AND SITE SELECTION

If findings from the initial assessment justify an intervention, the first stage can begin: choosing villages for the project, making sure that there are adequate sites in the vicinity (Figure 12, p. 44). This choice may have already been more or less defined by the preliminary assessment and field visits that took place during the assessment.

I. VILLAGE SELECTION

As with all development or post-emergency interventions, the choice of villages, communities, and beneficiaries is particularly delicate. In the majority of cases, the project targets populations that are considered the most vulnerable.

Considerations dictating the choice of villages will include:

✓ The first consideration, under NGO operating procedures, will be the presence or absence of vulnerable populations.

✓ Projects usually last a fairly short time. The number of villages targeted should therefore depend upon the **duration** of the project and **logistical considerations**. ***However, it is unrealistic to propose a fish farming project that will last less than 12 months.*** Indeed, the establishment of a 200 m^2 pond requires 20 people over 20 days. If the workforce is comprised of beneficiaries, planning should account for the fact that most of these people subsitst mainly on agriculture, and the time that they can devote to pond construction will be limited.

✓ Villages should not be too far apart to avoid **long transportation times** and logistical problems. Often, the presence of technicians is essential to **motivate** beneficiaries and to follow up. Moreover, roads are often damaged and not very practical. Thus, it is essential to make good maps of the area, which can be done during the assessment.

✓ There should be no large source of fish nearby (fishery). Indeed, the presence of considerable quantities of fish close to the village will prevent the development of fish ponds. Unfortunately, many times, villagers will seem motivated by a project while, in fact, they simply want to obtain something from international NGOs operating in the area. If this is true, the project will be a total fiasco; the village will not be invested in building ponds. It is thus important to assess whether fish protein is needed and unavailable in the area. Project requests that come from the villagers have more weight.

✓ There should be **water sources** or **rivers** near the village.

This is a crucial consideration in the choice of the villages, and will be discussed in more detail below (paragraph II, p. 45). It is essential that the village has a sufficient amount of running water nearby.

✓ The **villagers must be motivated.**

This is one of the more delicate considerations. At first, it is very difficult to judge motivation. Generally, it will be easier to tell if villagers are truly motivated when the work begins. However, the preliminary ethnographic study will provide information on motivation as well as whether the beneficiaries are in a position to take over the project. **Beneficiaries must understand that anything constructed through the project will belong to them and not to the NGO supporting the project. Similarly, the NGO will not implement the project at all if the villagers don't want it.** The NGO certainly will not impose anything. If possible, it is best to choose to work with family groups and avoid interfamily problems during the management and distribution of harvests. If perennial associations exist, it may be possible to work with them, depending on members' motivation and social cohesion.

Once villages have been selected, the project can move to the second phase: selection of sites within the village.

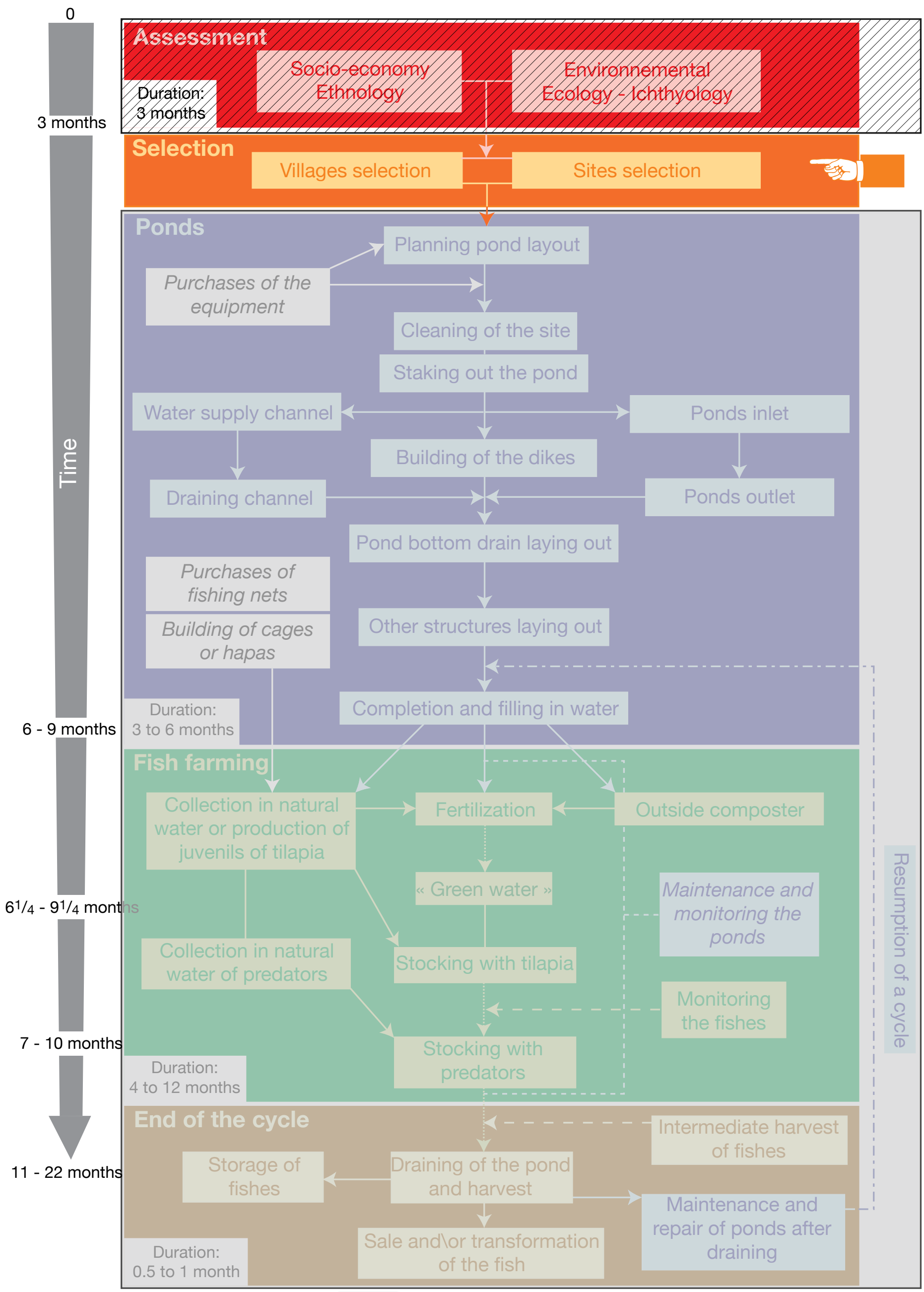


Figure 12. Setting up fish ponds: 2. Selections.

⇨ **The choice of village must take into account:**
- ⇨ **Vulnerability of the population,**
- ⇨ **Logistics,**
- ⇨ **Water resources,**
- ⇨ **Motivation of the villagers.**

II. SITE SELECTION

⇨ **This is the most important stage in a fish farm project.**

Ponds should be designed and constructed for maximum water control capability. The quality of the fish farming facility determines how follow-up, harvest and sorting can be done. In other words, they determine the feasibility of a fish farm. It is advisable to evaluate each potential site through a series of rapid feasibility studies to make sure that they meet the principal requirements.

In this chapter and the following one, most of the drawings and text present classic information that is drawn from various booklets, mainly from FAO.

II.1. WATER

II.1.1. AVAILABILITY OF WATER

It will be necessary to plan for inland water variations that occur over time, particularly variations in types of flow for a variety of inland water ecosystems, including:

✓ **Perennial** systems, which have surface water all year and do not drain during the dry season.

✓ **Seasonal** systems, which flow during the annual rainy season, but can be dry during several months of the year.

✓ **Episodical** systems (periodic or intermittent), which flow during one prolonged period, but are not predictable or seasonal. These systems are generally supplied by rainwater as well as subterranean water. Sometimes, surface flows can only occur in some parts, while the water flows underground in others.

✓ **Transitory** systems (short life), which flow briefly and infrequently and then dry up again. These systems are generally supplied only by precipitation.

A source that has running water continuously throughout the year (during the dry and rainy seasons) is best for fish farming ponds. Thus, the ponds should be located on perennial systems.

Such a system facilitates renewal of the pond water, however slight, ensuring favorable oxygenation and mitigating water loss.

The amount of water necessary will depend on the size of the pond, as well as the soil available and climate characteristic of the area.

■ WATER FOR THE BASINS

It is easy to calculate the appropriate amount of water for a basin; it is a simple calculation of volume:

volume = length x width x depth

as shown in the Figure 13, p. 46.

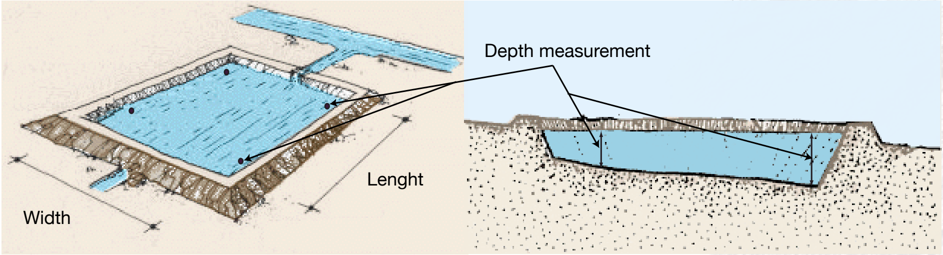


Figure 13. Volume of a pond.

WATER LOSS

In addition to a leak in the drain, water loss can occur through infiltration (seepage) into the substrate and through evaporation .

Evaporation

The amount of evaporation that occurs depends on wind, humidity, and sunshine: in other words, the area's climate. The rate of evaporation will be lower under a cloudy sky than under a sunny one (Figure 14 below). In equatorial areas, evaporation causes water loss of about 2 to 5 mm each day, which can be replaced by adding 15 to 35 liters of water per minute and hectare of pond. In an inter-tropical zone (25°N - 25°S), evaporation almost always exceeds 100 cm per year.

Infiltration

Water loss also occurs through infiltration (seepage into the soil) at the bottom of the pond and at dikes. If dikes are built well, the principal losses will occur at the bottom. Losses will also depend on the soil type. In general, loss is more of an issue when the pond is first filled (Figure 15, below).

STREAM FLOW

To get as much profit as possible, the pond should be in production for the entire year, and will thus need a water supply during the whole year. You will need enough water to fill the ponds and to maintain the water level. Water lost through evaporation and infiltration must be replaced. The most

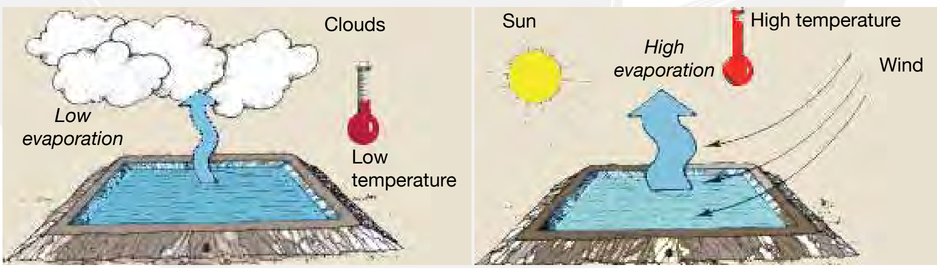


Figure 14. Water loss through evaporation casued by weather.

Figure 15. Water loss into the ground.

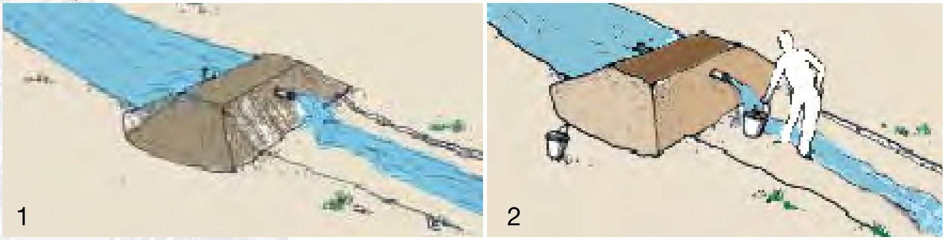


Figure 16. Measuring flow of small rivers.

loss occurs during the dry season, when there is little water. Maintainence of water levels on a one-hectare fish farm requires a flow of **2 to 5 liters per second**. Therefore, this flow must be controlled during the **dry season**.

On the other hand, it is also important to ensure that there is no risk of flooding. Local residents can provide information on this issue. They know if there is significant flooding and if water flows throughout the year. You can get more information from water level marks on riverbanks and bridges. A pond should not be built where there is a risk of flood, such as near the bottom of a slope. If there is a flood, there is a risk that all the fish will be lost, and dikes can be destroyed as well. Moreover, if there is a lot of vegetation on the banks, water flow will be lower than it will be near banks that have been cleared of vegetation.

The flow of a watercourse is measured in several ways.

For low flows, you need a stop watch and a bucket with a known capacity (Figure 16 above). Measure the rate of flow by seeing how long it takes to fill the bucket.

For stronger flows, or if appropriate measuring devices are not available, proceed as follows:

(i) Determine the wet cross section **S** in m^2 (Figure 17 below) with:

$$S = l \times p$$

Where **l** is the width and **p** the depth.

(ii) Use a stop watch and a half floating object to estimate the speed **V** in $m.s^{-1}$ of the flood in regular zone **AB** of the stream (Figure 18 below):

$$V = AB / t$$

Where **t** is the time taken for the floating object to travel AB.

(iii) Flow **D** in $m^3.s^{-1}$ of the stream is defined by:

$$D = V \times S$$

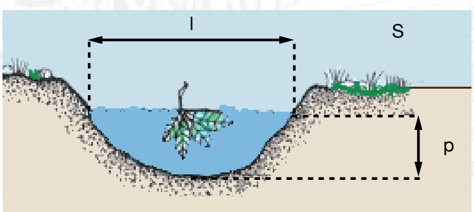


Figure 17. Measuring a section of a river.

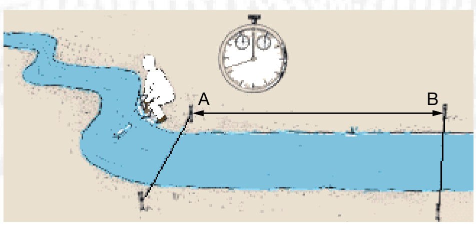


Figure 18. Measuring speed (V) of a river.

II.1.2. WATER QUALITY

Even if there is more water available than necessary, its physical and chemical characteristics must be appropriate for fish farming, or a fish farm cannot be established. An analysis of the water is thus critical to the choice of a site. You can also get an indication of whether the water quality is appropriate for fish farming by observing the amount of fish in the water over a long period of time (Figure 19 below).

Water is analyzed through both physical parameters (temperature, density, viscosity, color, turbidity, transparency), and chemical parameters (pH, conductivity, alkalinity, hardness, dissolved oxygen, phosphorus, nitrogen ammonia, nitrites, nitrates, carbon dioxide, etc.).

It is best to do the chemical analysis during the dry season, since the considerable amount of evaporation during this season allows the various components of water to become more concentrated, making it easier to detect extremes.

Some quick observations can be made without instruments. Water should not have a bad smell, a bad taste, or an unpleasant color, and it should not be too muddy. Avoid water that is very turbid or loaded with suspended particles (muddy water). Often, water becomes turbid because it is flowing too quickly over land that erodes easily. However, you can use this water if you install a settling tank upstream from the pond.

The proximity of factories should also be taken into account, since some industrial waste can contaminate good quality water and make it unsuitable for fish farming. Sources of effluents include:

- ✓ Metallurgy factories, which spew lead,
- ✓ Factories for electrolysis (manufacturing batteries, for example) which spew mercury,
- ✓ Refineries that contain carbolic acid,
- ✓ Agriculture and food factories, such as breweries, which can spew fertilizers, and which, in the extreme, can make water eutrophic and unfavorable for fish farming.

These effluents can kill fish or accumulate in their flesh, presenting a possible hazard for consumers.

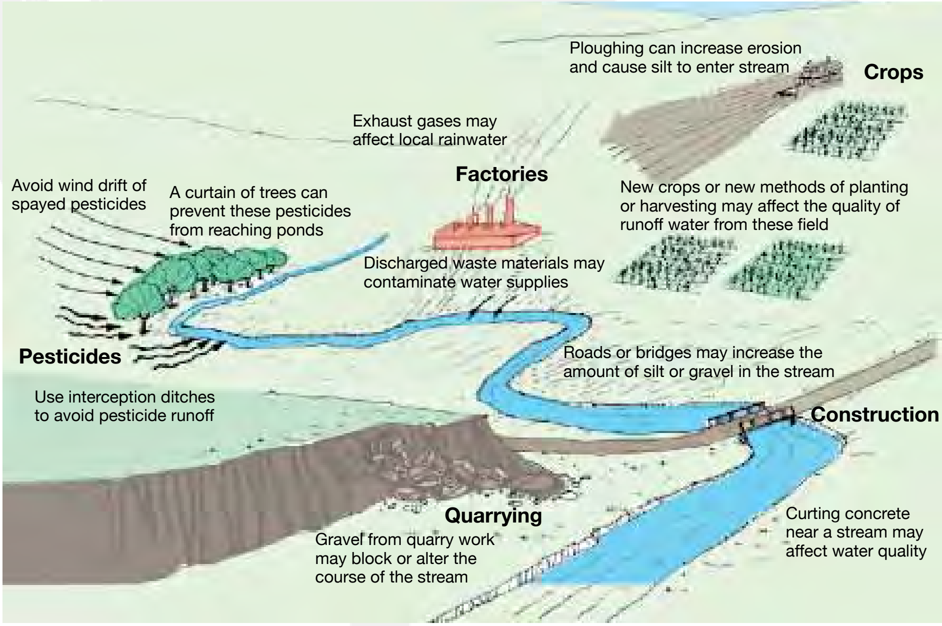


Figure 19. Examples of factors that may affect water quality.

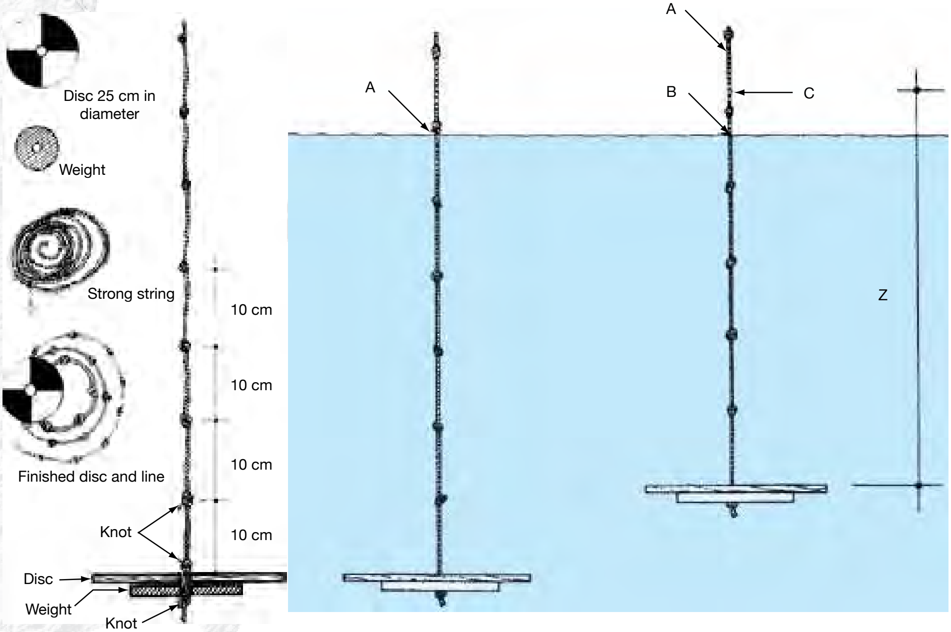


Figure 20. Secchi disk. On left: Composition. On right: Transparency measurement:
A = point at which the disk disappears at the descent; B = point at which the disk disappears at the lift; C = mid-point between A and B, and Z = distance.

The following characteristics of water are usually measured:

⇨ Physical characteristics: color, transparency and temperature;

⇨ Chemical characteristics: pH, rate of dissolved oxygen, total and carbonated hardness, and very often, total phosphorus, nitrates and nitrites.

A variety of devices can be used to measure these characteristics.

The Secchi disc (Figure 20 above) measures transparency, which is a function of the amount of natural food or suspended particles in the water. If this tool is not available, it can be made with a pole, a piece of white polyethylene paper, and a ruler (yardstick). Fix the white paper to the lower end of the pole, stick it into the water vertically, and measure the depth at which the white paper disappears from sight. Continue to immerse it. Then, lift the pole and note the depth at which the paper reappears. The depth is calculated as the average of the two readings.

Total hardness denotes the quantity of water soluble salts, particularly the ions calcium (Ca^{2+}) and magnesium (Mg^{2+}), which are important for the growth of phytoplankton. Water is considered «hard» if its salt concentration is high. Water is regarded as suitable for fish farming if its hardness ranges between 100 and 300 calcium carbonate Mg ($CaCO_3$). Thus water hardness denotes the water's capacity to precipitate certain alkaline salt ions, such as the ion sodium (Na^+) in soda (NaOH), which is used to manufacture soap. So, if you do not have the materials to perform a test for hardness, wash your hands with soap using the water you wish to test. The water is soft if it foams immediately and plentifully; it is hard if there is no foam or the foam disappears quickly. Moreover, dissolved salt traces will remain visible at the edge of a hard water stream when the water level is below its normal level.

PH is the concentration of hydrogen ions (H^+) in water, or, more simply, a measurement of the acidity or alkalinity of water. Thus, water is neutral at a pH of 7, acid if the pH is lower than 7 and basic if it is higher than 7. Most fish grow best in pH ranging from 6.5 to 9.0.

All these parameters directly affect the development of natural food. Water is for fish as soil is for plants. If its qualities are good or can be improved, it is favorable for fish farming.

II.2. SOIL

Soil is comprised of living organisms, organic matter and minerals, water, and air. Depending on texture, structure and consistency, there are different types of soils with more or less air and water.

The physical characteristics of the soil determine its permeability as well as its capacity to ensure the stability of dikes, and chemical characteristics influence the productivity of water. These include texture (grain-size distribution), structure (arrangement of particles in undisturbed soil), specific weight (concentration of particles), porosity (proportion of vacuums, or spaces between particles in the soil), permeability (soil's relative resistance to the passage of flowing water), compressibility (capacity to become deformed as volume decreases under pressure), shear strength (soil's relative opposition to shift), color, etc. Clay soils are often best, due to their capacity to retain water and their high shear strength. In theory, if a soil is good for making bricks, it is good for the construction of ponds. Soil areas that are clay-sand, silty-silto-clay, silty-clay, silty-sandy-clay and clay-silt are most desirable. Very sandy soils do not retain water, while pure clay soils are difficult to beak apart, and do not form very stable dikes. A soil that contains too much sand or gravel will not retain water (Figure 21 below).

The color of the soil provides an indication of its drainage capacity and composition. However, marbling can appear for other reasons (Table VI below). If marbling is in brilliant colors, it will not cause drainage problems. If the marbling is in matte colors, usually gray, there will be a problem with drainage for much of the year. A very bright yellow with an acid pH denotes a sulphatic soil.

Texture depends on the relative proportions of sand, mud, or clay particles of different sizes. Knowledge of texture helps to estimate how easily the work to be accomplished, as well as soil permeability, etc.

Soils of interest for the construction of ponds are sandy-clay soils because they retain water easily. Pure clay, laterite, black humus, and peat are not good soils for dike construction. Black humus, sandy peat and sand are too porous unless there is a clay core that can stop leaks. Pure clay, once it dries, can crack. Laterite soil (rich in iron and aluminum, usually with a rusty-red color) is too hard.

Simple tests can help to quickly ascertain soil texture.

For the first test, take a handful of soil from the surface and press it into a ball in your hand (Figure 22, p. 51). (A). Throw the ball in the air and catch it (B). The ball will disintegrate if the soil contains too much sand or gravel (C). If, however, it remains compact (D), it may be suitable for a pond. To be sure, you should carry out another test.

Table VI. Soil color and drainage conditions.

Soil color/mottling	Drainage conditions
Warm colours, browns, reds and oranges	Good drainage
Pale yellowish, pale and dark greys with rusty orange and/or grey mottling	Drainage seasonally poor. Water-table at 25- to 120-cm depth
Pale, dark and bluish greys, or pale brownish yellows with rusty orange, brown or grey mottling within the topsoil	Seasonally swampy soil. Water-table at less than 25-cm depth

Figure 21. Waterproof qualities of clay and of sandy soil.

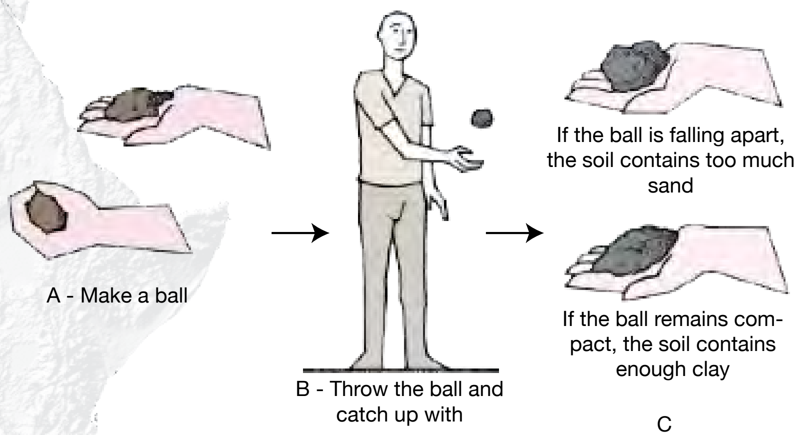


Figure 22. Test with a ball of soil (I).

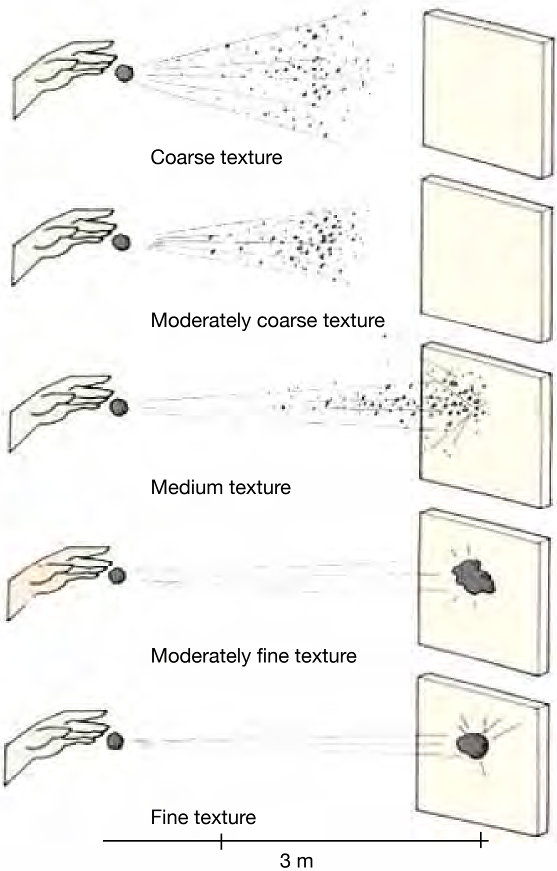
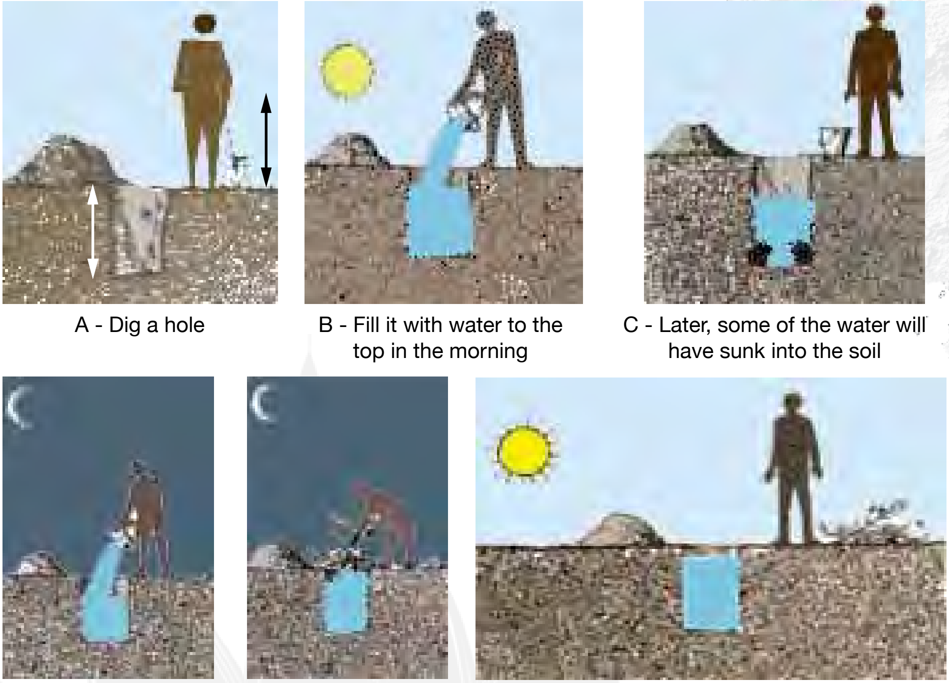


Figure 23. Test with a ball of soil (II).



A - Dig a hole

B - Fill it with water to the top in the morning

C - Later, some of the water will have sunk into the soil

D - Then fill the hole with water again to the top

E - Cover the hole

F - Result of the test the next morning

Figure 24. Test of soil permeability.

A second test is similar to the first (Figure 23, p. 51). Take some soil in your hand, knead it, make mortar and produce a ball out of it. Throw the ball at a vertical wall approximately 3 m away. If the ball adheres to the wall, the soil is suitable material for a pond dike. It is even better if the ball does not flatten much when it adheres to the wall. If the ball does not adhere, but bounces off the wall and falls to the ground, the soil is of bad quality and is not suitable for pond construction.

There is also a more conclusive test. In the morning, dig a hole that is waist-high (A). Then, fill it to the top with water (B). In the evening, some of the water will have seeped into the ground (C). Fill the hole to the top again (D), and cover it with boards or branches (E). Finally, the next morning, if most of the water is still in the hole, you know that the soil retains water well enough to dig a pond (F) there (Figure 24 above).

Whatever other conditions exist, the nature of the soil must allow for a permanent water reserve. It should contain enough clay to be as impermeable as the water supply is irregular or weak. The objective is to compensate only for evaporation. If the topography is favorable and the surface soil is sandy, however, it is not harmful, as long as a source of clay is available in the vicinity or in subsoil close to the surface. Indeed, even big hydroelectric dams are built on the principle of the "Clay Mask" covering of the ground of unsorted material. Therefore, sandy or humus-bearing soil can be sealed by a 30 cm clay surface layer. Rocky ground is often difficult to work without mechanical equipment, and is sometimes full of cracks that must be sealed with clay.

Chemical characteristics of soil depend on colloid concentration, degree of saturation in exchangeable bases, the capacity of cationic or anionic exchange, and the capacity to make a variety of biogenic salts. The soil must contain a certain amount of exchangeable mineral salts, which depend on a certain proportion of organic matter. The natural productivity of the water is generally related to the productivity of the soil that carries it. Acid soil should be avoided, because acidity can be transmitted to water and harm fish. Water that is too acidic requires a heavy investment in quicklime that will raise the water's pH so that it can be used for a fish farm.

The chemical composition of pond water depends primarily on the chemical characterstics of the soil and vegetation that it runs over. In general, water in the savanna is richer and less acidic than water that emerges from the forest, but the risk of pollution from sediment is greater through gullying or erosion. The more rock salt that is present in the river bed, the more naturally productive the water will be, as there will be a proliferation of phytoplankton and some higher plants.

II.3. TOPOGRAPHY

Viable ponds can only be constructed in favorable topography. Since one of our general principles is to minimize costs, it is best to have pond water supplied by gravity, similar to draining. Moreover, dikes must be built without much displacement of soil. Topography, as used here, denotes the forms and elevation of the land-- whether the ground is flat or rough, or in a narrow and boxed or broad valley, etc. An area's topography will determine whether it is possible to build ponds, as well as the number of ponds and their surface size (Table VII, p. 54).

Once the area is chosen according to water and soil requirements, you should also confirm that topographical parameters are favorable for construction. The area, the slope, the elevation and the distance from the water source should all be measured, while the best way to supply the basins and the simplest method of drainage should be investigated. These measurements will also help to

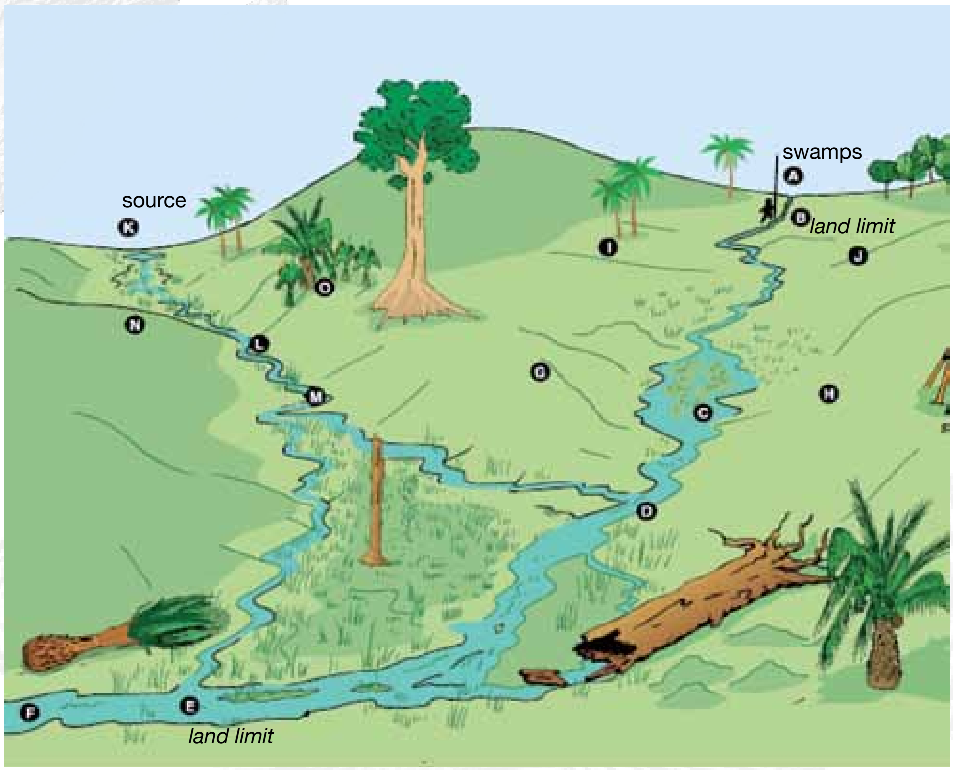


Figure 25. Identification of potential water supplies (A, K), drainage options (C, D, L, M, E, F), and individual valleys (M level compared to D); comparison of sites for pond installation (IG, GH, ON), view of the bottom (CIRAD).

Table VII. Topographical features of ponds.

Slope in length	Slope transverse	Pond	Cost
High	High	None	Too high
High	Weak	Diversion	Reasonable
Weak	High	Dam	Reasonable
Weak	Weak	Sunken	High

identify places to establish ponds (Figure 25, p. 53). If a site on rough ground is chosen, there may be a need for future excavation to keep the pond approximately balanced with the embankment.

Moreover, there should be a difference in height between the water supply and and the pond, to facilitate the water's use of gravity to drain the pond. Using gravity to pull the supply of water into the pond will simplify installation. The water source must be located above the pond so that water can run into the pond by itself (Figure 26, above).

A gentle slope will allow water to run off easily. The slope must be between 1 and 3% (that is, the horizontal to length ratio should be 3 cm to 100 cm). If the slope is too steep, runoff will be too fast. If it is too shallow, a dam will have to built to store the water, which may involve a considerable amount of additional work. If there is no slope, the water will not flow, and the pond will not drain (Figure 27 and Figure 28, p. 55).

Calculating a slope is a simple process, and does not require a lot of materials (Photo A, p. 56, Figure 29 and Figure 30, p. 57). Slope is expressed as a percentage. Place stakes at the top and bottom of the slope. Then tighten a horizontal rope between the two stakes using a plumb level. if you don't have a level, use a bottle filled with water. This device is particularly practical, since it allows you to proceed quickly, even on uneven, grassy ground, and ensures precision (the maximum error is lower than 6 cm by 20 m of distance). This method requires a team of three people. An observer installs a stake at the starting point A; the site is marked by the rope held on a grade corresponding to **h**. The observer at B also holds the rope on the same gradation, then moves the cord up on the second stake or to the bottom of the slope, until the person at the center indicates that the plumb level is horizontal on the rope. If a mason level is not available, a water bottle can be used. This method allows the team to determine **H**, and then the **H-h** difference can be measured.

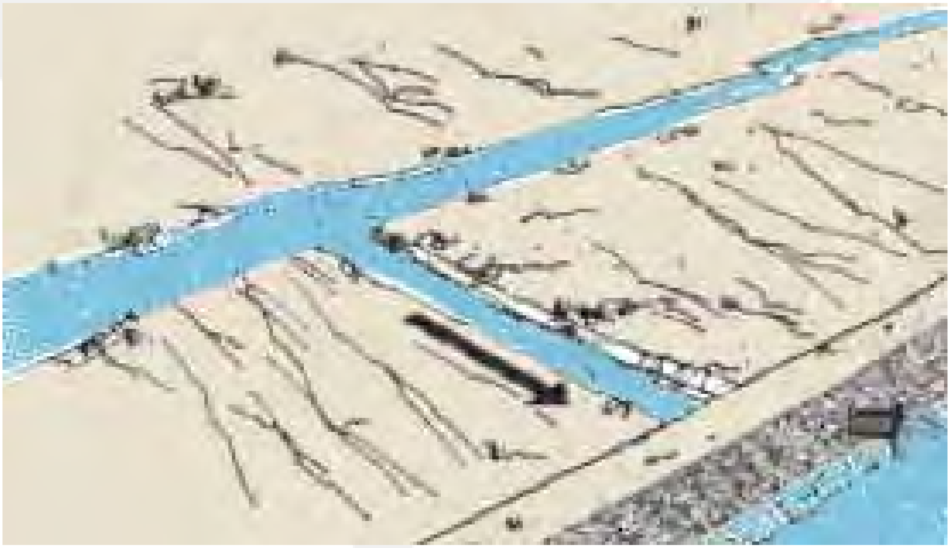


Figure 26. Water supplied by gravity.

A. Low slope (1 to 3%)
Suitable

B. No slope
How to empty the pond ?
Unsuitable

C. Strong slope
Unsuitable

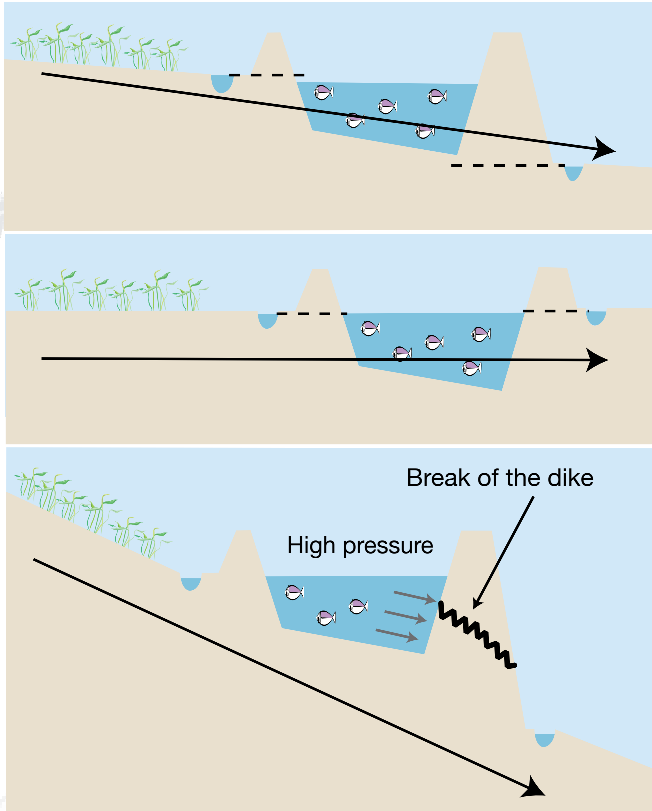


Figure 27. Types of slopes and constraints.

The slope **P** in % will be:

$$P = (H-h) \times 100 / D$$

With **D** = distance between A and B.

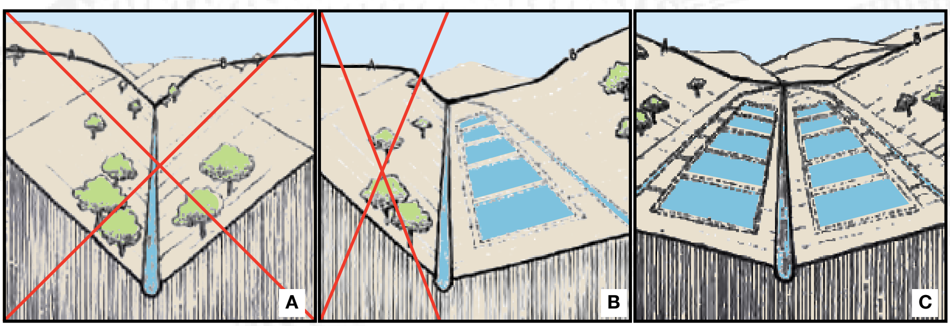


Figure 28. Hill slopes. A: Too high; B: Too high on one side; the second side is favorable; C: Both sides are favorable.

Photo A. Measuring a slope (DRC) [© Y. Fermon].

II.4. OTHER PARAMETERS

II.4.1. ACCESSIBILITY OF THE SITE

A good fish farmer will have daily control over the pond. He should go to the pond at last once every day, to monitor progress and feed the fish if necessary. Weekly activities include reloading compost, cutting grass on the dikes, etc. Thus, the pond should not be too far away from the fish farmer's house, and there should be no barriers between the pond and the house (such as a river that flows during the rainy season). The fish farmer should live as close as possible to the pond to guard against thieves (Figure 31, p. 58).

II.4.2. POSSIBILITY FOR LOWER-COST BUILDING

As already discussed, a pond should not be built where the slope is very steep because the downstream dike would need to be very large, increasing the cost of the project. For each task, the required effort should be compared with the benefit that will result.

If there is a choice, it is best to build on an open site, rather than one filled with tree trunks that must be removed, with their roots. It is also best to choose ground that does not have rocks or large stones.

II.4.3. LAND

It is important to know the owner of the site where the ponds will be established. You will have to do some prospecting. One solution would be to require the villagers to choose sites nearby. Then, sites should be evaluated according to the criteria described above.

At the margin of the ponds, maintenance or planting of trees and other plant species will make it possible to protect the ground against erosion, as well as to consider ways to profitably exploit the ground by integrating fish farming with other types of rural production (grass for bovines, fruits for food or fertilizer in the ponds, using wet areas to cultivate plants like rice, etc). The cleansing and drainage of water in most swampy areas is difficult, so if these areas are selected for fish pond construction, you should keep in mind that they will probably require more costs through future exploitation.

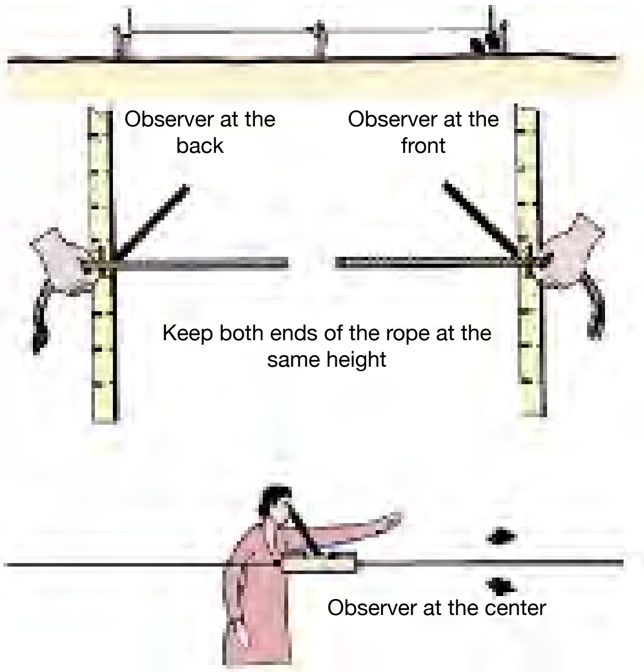


Figure 29. Measuring a slope: Device.

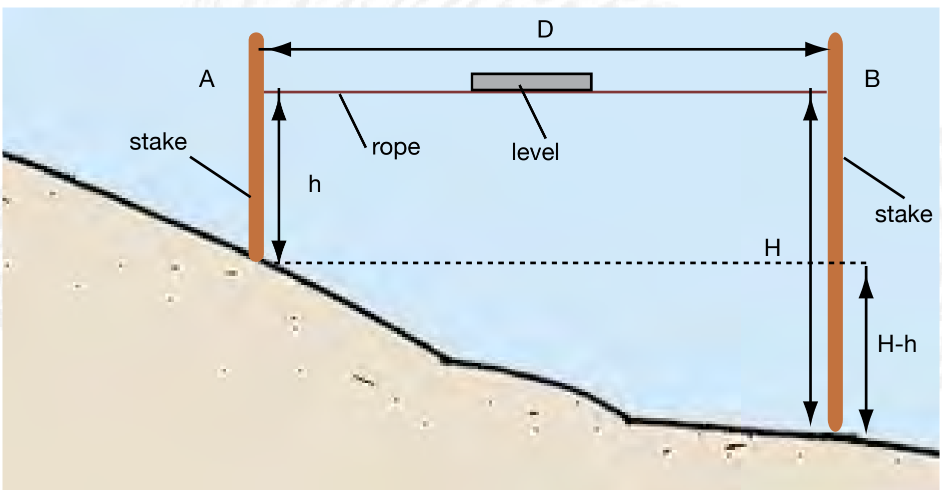


Figure 30. Measuring a slope: Calculation.

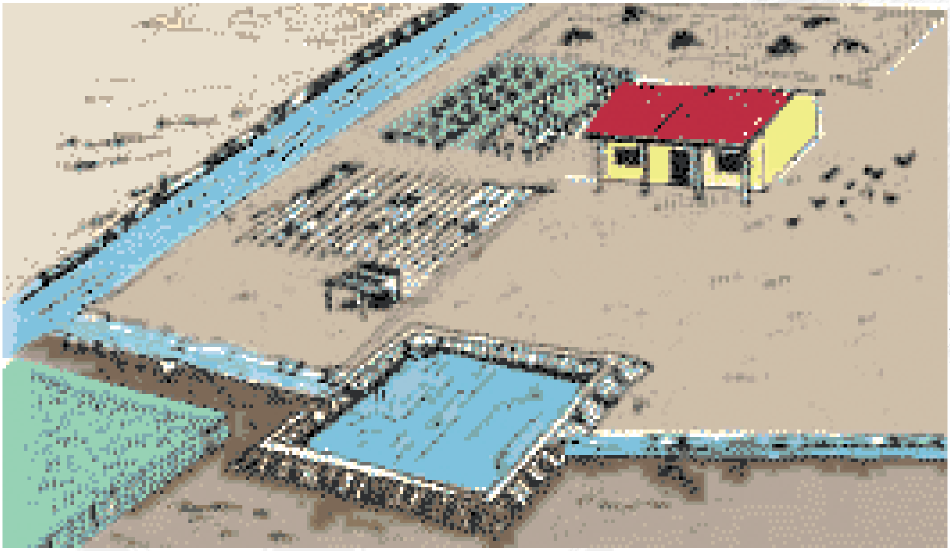


Figure 31. Example of the location of a pond in relation to a house.

- ⇨ Site selection should take into account:
  - ⇨ Water: quantity and quality;
  - ⇨ Soil: should be impermeable;
  - ⇨ Topography: the slope should be shallow, near where the water source emerges.

Chapter 06
CHARACTERISTICS OF PONDS

After the villages and pond installation sites have been chosen, the next step is to set up the ponds (Figure 32, p. 60).

Fish production requires earth ponds, which contain and renew fresh water, and can accommodate the storage, farming, and harvest of fish. Construction of the ponds and associated structures require specific preparations and tasks, which are essential for success. Moreover, the ponds must be inexpensive to build, easy to maintain, and tidy to ensure that the water and the fish are managed well.

I. DESCRIPTION

A fish pond is a shallow body of water, used for the controlled farming of fish. It is adapted to be easily and completely drained.

It includes (Figure 33 and Figure 34, p. 61):

✓ A **plate** that forms the bottom of the pond.

✓ **Dikes,** which surround the pond and form walls that contain the water. These walls must be solid, to resist water pressure, and impermeable.

✓ An **intake** structure that collects water to fill the pond.

✓ The **emissary,** a river or canal that allows for drainage.

✓ Canals that bring or evacuate pond water:
- The **supply canal** or **water inlet** brings collected water to the pond.
- The **draining canal** or **evacuation** allows drainage toward the emissary.

✓ **Regulation** devices control the water's level, flow, or both:
- The **water inlet** is the device that regulates water flowing toward the pond and stops water from flooding.
- The **water outlet,** preferably a monk, controls the water level and evacuation of the pond.

✓ The **outfall** or **overflow** allows evacuation of excess water, ensuring safety.

✓ **Filters**, if necessary, prevent animals and particles from entering or exiting the pond

✓ A **fence** surrounds the pond and keeps undesirable visitors out.

✓ Other **structures provide protection** against fish-eating birds, if necessary.

✓ **Access ways** and **roads** surround the pond and allow people to reach it.

II. TYPES OF PONDS

Piscicultural fresh water ponds differ by the origin of their water supply, their drainage method, construction materials and processes, and, finally, fish farming methods. These characteristics are usually determined by the characteristics of the site where they are built.

Ponds can be classified according to:

⇨ Water supply.

⇨ Drainage systems.

⇨ Building materials.

⇨ Use of the pond.

Concerning the utilization of a pond, the same pond can serve different purposes, depending on the specific moment and the evolution of the installation.

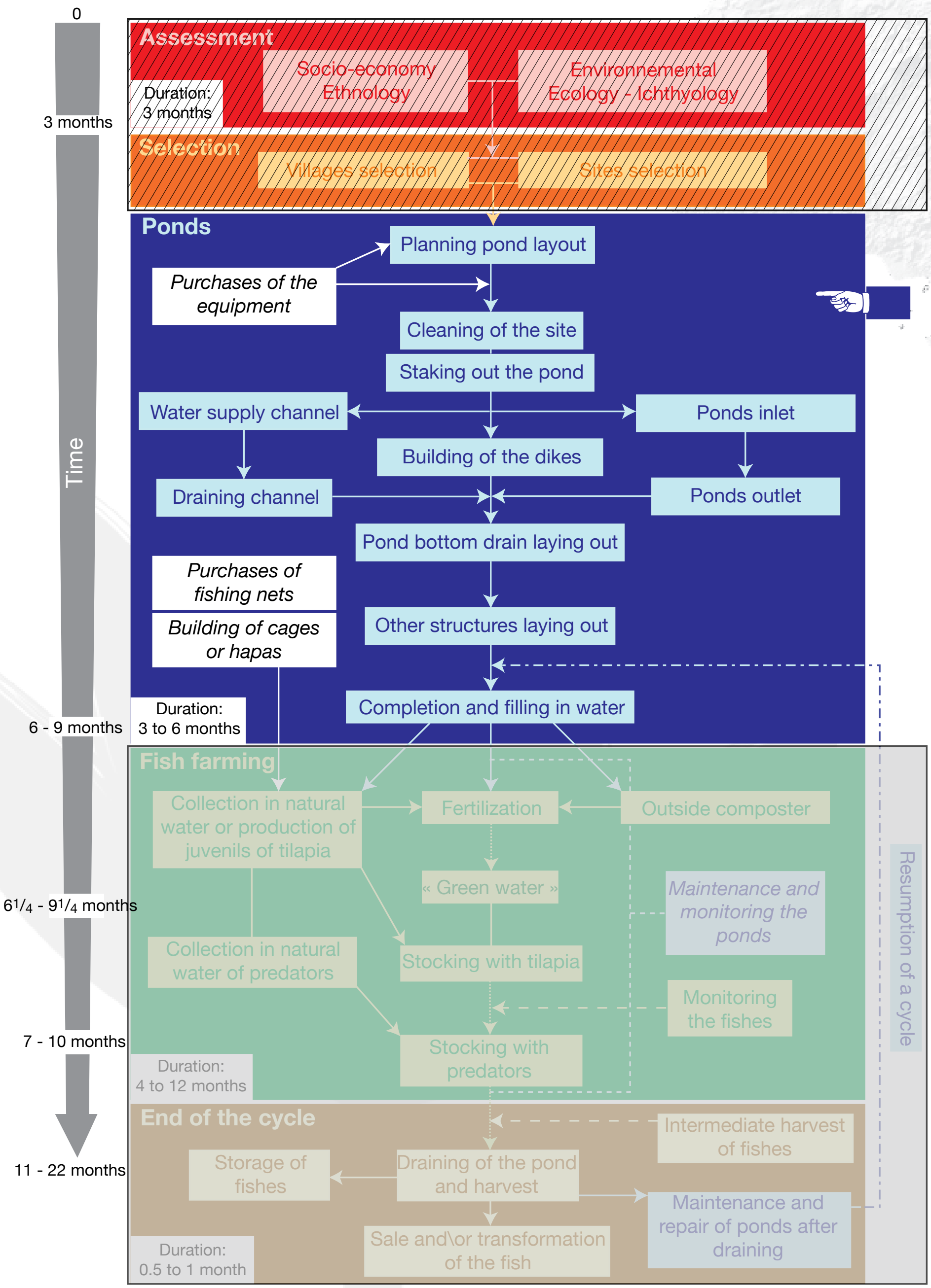


Figure 32. Setting up fish ponds: 3. Ponds.

One will find:

- ✓ **Spawning** ponds for production of eggs and small fry;
- ✓ **Nursery** ponds for production of larger juveniles;
- ✓ **Brood** ponds for rearing broodstock;
- ✓ **Storage** ponds for holding fish temporarily, often before they are sold;
- ✓ **Fattening** ponds, for the production of fish that will be consumed;
- ✓ **Integrated** ponds that include crops, animals or other fish ponds, which supply waste materials that act as feed or fertilizer for the pond;

This guide will only provide information on ponds that are viable and appropriate for subsistence fish farming. The principal characteristic will be that they can be completely drained, and have **running water available year-round**. We will not consider ponds collinaires supplied with streaming or rain water, or resurgent ponds that are supplied with ground water.

We will focus on two types of river-fed ponds:

- ✓ **Barrage** ponds.
- ✓ **Diversion** ponds.

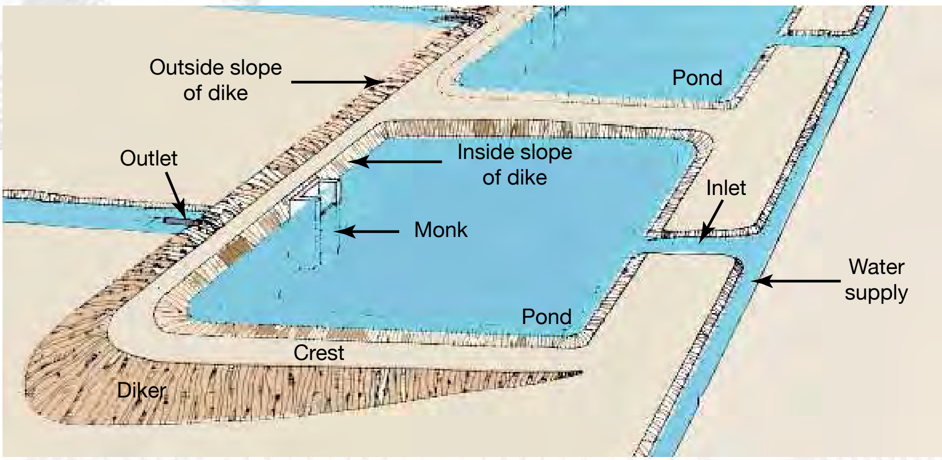


Figure 33. Main components of a pond.

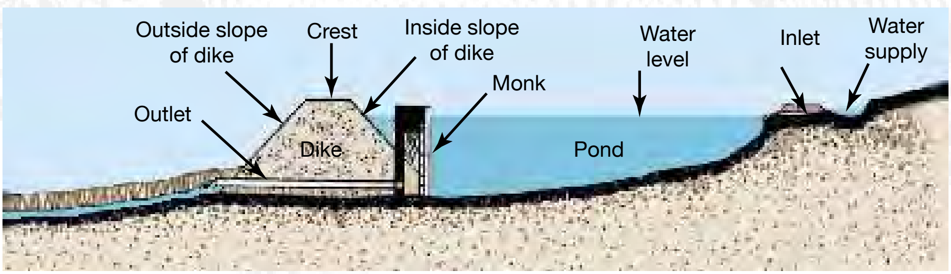


Figure 34. Cross section of a pond.

II.1. BARRAGE PONDS

In barrage ponds, all the water coming from the source passes through (Figure 35, p. 64).

A small river can be blocked so that water retained by the dam makes a pond. A monk is installed in front of the dam to drain the pond. One or more spillways are expected to drain excess water in case of floods or heavy rains. The spillways must be able to evacuate even in the worst flooding; if not the entire dam may be carrried away. The most important thing to know before beginning construction of a barrage pond is the river's maximum level and maximum discharge during the rainy season, after a heavy rain. On big rivers, which get much higher during the rainy season, it is better to build diversion ponds. In addition to this lack of control over the flow of water entering the pond, it is impossible to stop fish that live upstream from entering the pond. Nets cannot be put on the sipllways to prevent fish from escaping when the spillways works. Nets may be blocked by leaves, branches and mud suspended in the water. The water will rise and may break the dike.

One cannot correctly control the amount of water in the pond, so there is a significant risk of flooding (which will cause the loss of fish, food and fertilizer when the river flows high).

II.2. DIVERSION PONDS

Unlike barrage ponds, which retain all of the water from the stream, diversion ponds use only some of the water (Figure 36, p. 65). In these ponds, only a portion of the water passes through from the source, rather than all of it. The entry and exit of water from the pond are controlled.

Thus, part of the stream diverges into a supply canal that brings water to the ponds. Intake to the stream is usually built in front of a small deviation dam. This dam ensures that a constant water level is maintained in the supply canal. All of the surplus water that is not needed passes through the dam's spillway. Ponds that have a diversion canal can be built parallel or in a series.

Diversion ponds, which are derived from bypass ponds, are built on the slopes of a valley and are primarily composed of three dams. These ponds are generally inexpensive, have a low flood risk, and drain well.

II.3. COMPARISON

It is important to remember the following points:

⇨ If the water supply is well controlled, ponds will be easier to manage when you are, for example, fertilizing the water or feeding the fish.

⇨ Better drainage also makes the pond easier to manage during tasks such as harvesting farmed fish and preparing and drying the pond bottom.

⇨ Ponds with a regular shape and correct size are easier to manage and adapt to specific purposes.

⇨ The choice of a particular type of pond will largely depend on the available water supply and the topography of the site selected.

Practically, although it costs more, the increasingly intensive integrated management of fish production will be easier with diversion ponds (Table VIII, p. 63). Moreover, it is not possible to increase the number of ponds in barrage pond systems. This is important because avoiding the use of barrage ponds will eliminate the need to block water from rivers that is also used by villages located downstream, thus avoiding possibly violent conflict.

⇨ **Diversion ponds whose water supply flows through the force of gravity are the best approach proposed here.**

Table VIII. Advantages and disadvantages of barrage and diversion ponds.

Type	Advantages	Disadvantages
Barrage pond*	• Simple to design for small stream. • Construction costs relatively low unless there are flood defence problems. • Natural productivity can be high, according to quality of water supply.	• Dikes need to be carefully anchored because the risk of break down in case of flooding. • Need for a spillway and its drainage which be costly. • No control of incoming water supply (quantity, quality, wild fish). • Cannot be completely drained except when incoming water supply dries out. • Pond management difficult (fertilization, feeding) as water supply is variable. • Irregular shape and size. • Sociological problems due to possible water retention towards the people living downstream.
Diversion pond**	• Easy control of water supply. • Good pond management possible. • Construction costs higher on flat ground. • Can be completely drained. • Regular pond shape and size possible.	• Construction costs higher than barrage ponds. • Natural productivity lower, especially if built in infertile soil. • Construction requires good topographical surveys and detailed staking out.

* If the barrage pond is built with a diversion channel, some of the disadvantages may be eliminated (controlled water supply, no spillway, complete drainage, easier pond management), but construction costs can greatly increase if the diversion of a large water flow has to be planned.
** Relative advantages will vary according to the arrangement of the ponds, either in series (pond management is more difficult) or in parallel (both water supply and drainage are independent, which simplifies management).

III. CHARACTERISTICS

III.1. GENERAL CRITERIA

Depending on the need, it will be possible to build a series of ponds managed by shifted sowing, which allows for regular monthly harvests throughout the year.

Following the goal of limiting work and costs while optimizing the availability of water, basins should be laid out to align with the topography. Thus, development of a suitable site is a complex exercise.

Building terraces makes it possible to have a larger surface area, and water will be retained better (Figure 37, p. 66). Downstream dikes should be positioned across the flow of water in the basin in order to make more water available for storage at the site.

An overall design for the site, is essential to utilize the surface, the difference between the intake and draining areas and the availability of water as well as possible. Arrangement of the pond in the course of the water will not increase the suitable surface (B): as the surface in green is not utlized. This flow is parallel to the water course. On the other hand, in the diagram (C), water flowing perpendicular to the water course is blocked since all the ponds are on the same level. More water will then be stored in the basement above the level of the ponds, and will be available to fill the ponds again or to limit loss during the dry season.

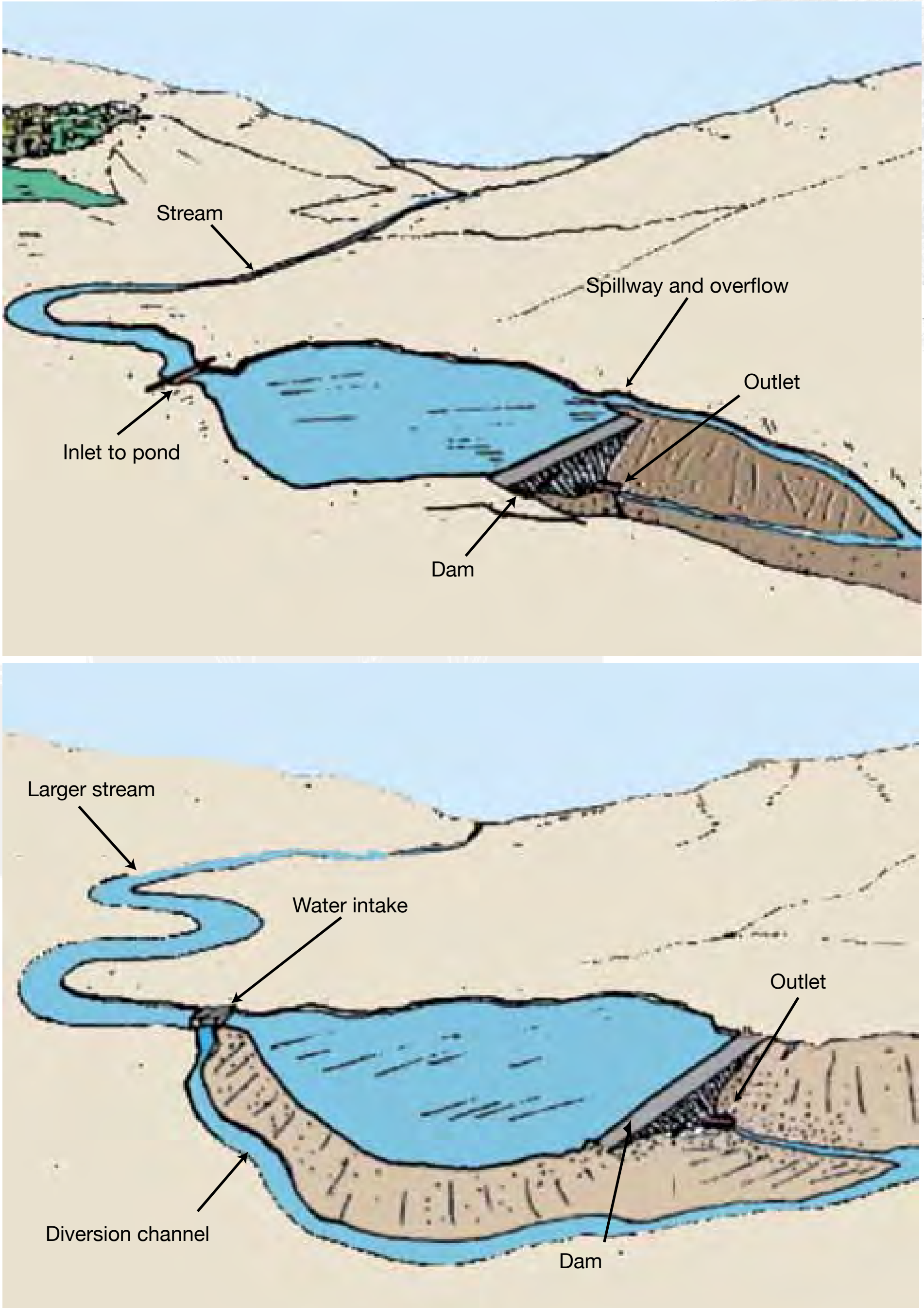


Figure 35. Examples of barrage ponds.

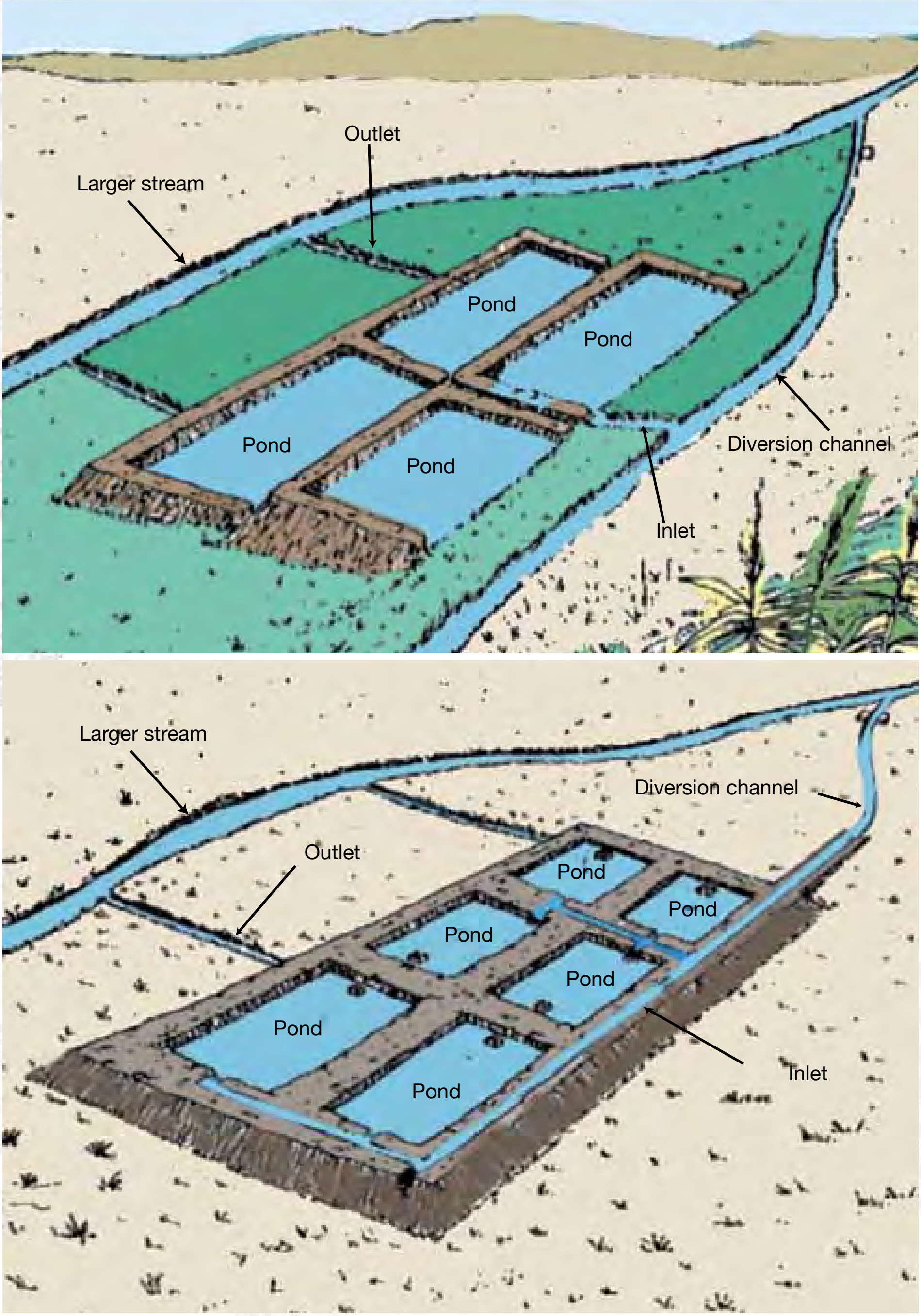


Figure 36. Examples of diversion ponds.

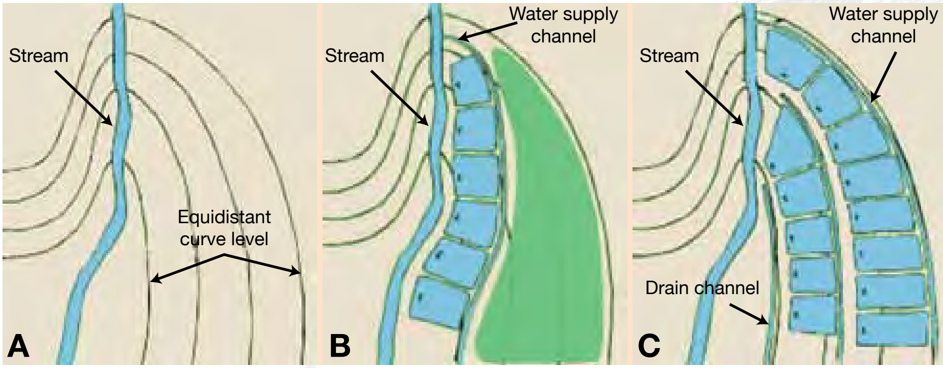


Figure 37. Disposition of ponds in relation to topography (CIRAD).

III.2. POND SHAPE

For an even water surface, the pond should be shaped in a way that minimizes the overall length of the dam (Figure 38 and Table IX below). For a pond of a given dimension, the overall length of the dike increases as the pond's shape deviates gradually from a square and becomes more elongated. At the same time, construction costs increase. The dikes that separate the ponds (intermediate dikes) are narrower than the downstream-dike. The square form extends the downstream-dike (A). If the rectangular form is too elongated, it will be reduced, but will considerably elongate the intermediate dikes (C). Moreover, in order to maintain the slope and guarantee that it drains adequately, it will be necessary to dig more deeply. These two forms (A and C) are not optimal. On regular ground, the pond shape that requires the least work is rectangular but not too elongated (B). This is the preferential form. In general, rectangular ponds are twice as long as they are wide. It is, also, better to use a standard width for ponds designed for the same use.

In some cases, it may be easier and more economical to adapt the shape of the pond to existing topography (Figure 39, p. 67).

Table IX. Proposed shapes for a pond of 100 m².

Pond shape	Width (m)	Length (m)	Dike length (m)
square	10	10	20 + 20 = 40
rectangular	7	14.3	14 + 28.6 = 42.6
	5	20	10 + 40 = 50
	2	50	4 + 100 = 104

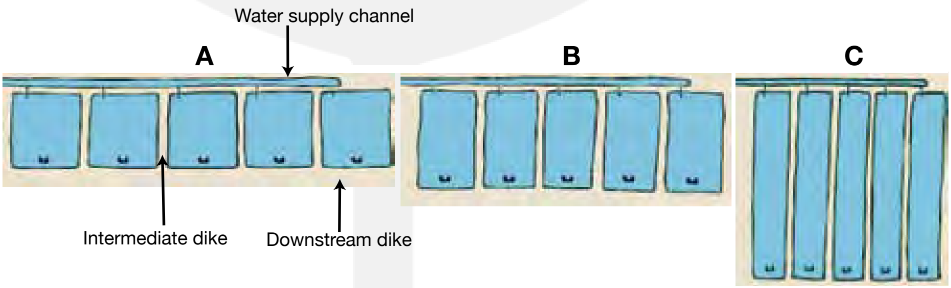


Figure 38. Optimization of surface / work (CIRAD).

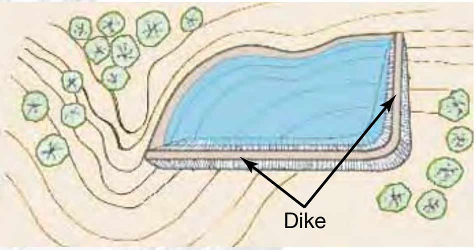


Figure 39. Example of a pond whose shape is adapted to the topography. Here, only two dikes are necessary.

III.3. ADAPTING THE SLOPE

The orientation of the ponds will vary depending on the angle of the slope, but should minimize excavation (Figure 40, below).

✓ **Slopes of 0.5 to 1.5%:** The long side of a rectangular pond must be perpendicular to the level lines. This means that ponds must be oriented in the direction of the bottom of the slope, following the natural slope. It is not necessary to dig in teh section that is deepest.

✓ **Slope greater than 1.5%:** The long side of a rectangular pond should be parallel to the level lines, so the pond must be perpendicular to the slope. The more the slope increases, the smaller the ponds should be.

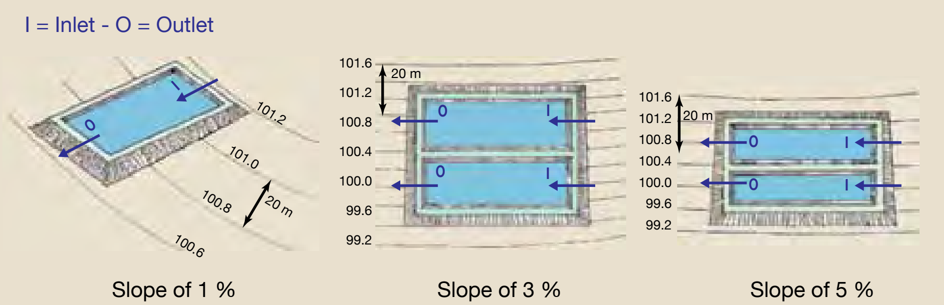


Figure 40. Disposition and shape of ponds with different slopes.

III.4. POND LAYOUT

When several ponds are being installed, they can be positioned in two ways (Figure 41 below):

✓ In a **series**: The ponds depend on each other for their water supply, as the water runs from the upper ponds to the lower ponds. This system has the advantage of limiting the number of draining and supply canals. However, since the same water is flowing through all of the ponds,

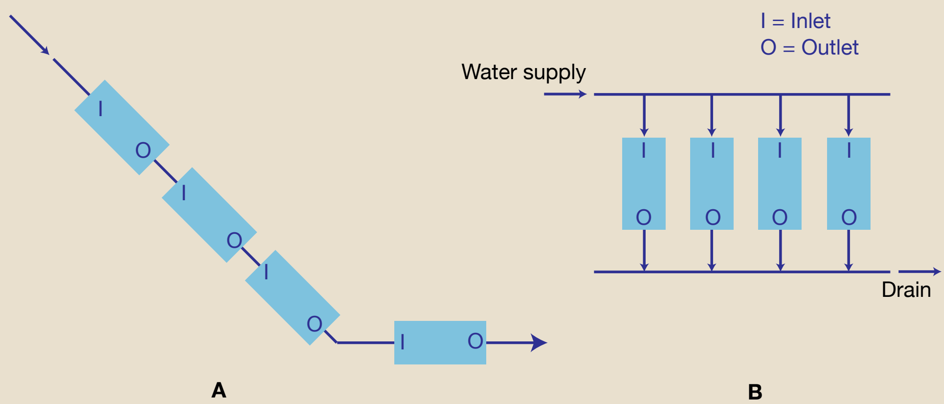


Figure 41. Layout of ponds. A: In series; B: In parallel.

Photo B. Example of parallel rectangular ponds under construction (Liberia) [© Y. Fermon].

there can be a problem with disease. Indeed, if a pond is contaminated, there is a higher risk that the others will become contaminated and all production will be lost. Draining the ponds will also be a problem. This layout also requires a steeper slope.

✓ In **parallel** (Photo B opposite): Ponds are independent from each other, and each gets its supply of water directly from the supply canal. Water is not re-used after flowing through one pond. Unlike ponds in a series, each of these ponds can be isolated, and limiting the risk of contamination. Each pond is drained independently and the slope is the same for each.

III.5.POND SIZE AND DEPTH

Ponds are characterized by their size, their form and their depth. Paragraph II, p. 45) showed the calculation of a pond's surface area and volume.

III.5.1. SIZE

The farmer can decide upon the individual size of sunken ponds and diversion ponds, as long as he considers the following factors (Table X and Table XI below):

✓ **Use:** A spawning pond is smaller than a nursery pond, which is in turn smaller than a fattening pond.

✓ **Quantity of fish to be produced:** A subsistence pond is smaller than a small-scale commercial pond, which is in turn smaller than a large-scale commercial pond.

✓ **Level of management:** An intensive pond is smaller than a semi-intensive pond, which is in turn smaller than an extensive pond.

✓ **Availability of resources:** There is no point in building large ponds if there are not enough resources to supply them, including water, seed fish, fertilizers and/or feed.

✓ **Size of harvests and local market demand:** Large ponds, even if only partially harvested, may supply too many fish for the local market.

Ponds for production fish farming should have a maximum surface area of 400 m^2.

Table X. Size of fattening ponds.

Type of fishfarming	Area (m^2)
Subsistence	100 - 400
Small-scale commercial	400 - 1000
Large-scale commercial	1000 - 5000

Table XI. Resource availability and pond size.

	Small pond	Large pond
Water	Small quantity	Large quantity
	Rapid filling/draining	Slow filling/draining
Fish seed	Small number	Large number
Fertilizer / feed	Small amount	Large amount
Fish marketing	Small harvest	Large harvest
	Local markets	Town markets

Table XII. Characteristics of shallow and deep ponds.	
Shallow ponds	**Deep ponds**
Water warms up rapidly Substantial temperature fluctuation Greater danger from predatory birds Greater growth of water plants Smaller dikes needed	Water temperature more stable Less natural food available Difficult to capture fish in deep water Strong, high dikes needed

Figure 42. Maximum and minimum pond depth.

III.5.2. DEPTH

Fish ponds are generally not very deep; their maximum depth does not exceed 1.50 m (Table XII and Figure 41 above). The shallowest part should be at least 0.50 m in order to limit the growth of aquatic plants. Deeper ponds are much more expensive to construct because the volume of the dams increases quickly with the depth of the pond.

However, it is sometimes necessary to use deeper ponds. In dry areas, it is essential to store enough water for the dry season.

III.6. DIFFERENCES IN LEVELS

In all cases, there are specific rules for constructing easily managed, completely drainable ponds that are filled using gravity (Figure 46, p. 72).

- Water flows down from the highest to the lowest point (A).
- The water surface in a pond is always horizontal, even if the ground below it is not (B).
- The bottom of the pond should be above the water table when the fish are harvested (C).
- The bottom of the main water intake should be below the minimum level of the water source (D).
- The bottom of the feeder canal should be at or above the pond's maximum water level (E).
- The pond inlet should be located at or above the pond's maximum water level (F).
- The beginning of the pond outlet should be at the lowest point of the pond (G).
- The end of the pond outlet should be at or above the water level in the drain (H).
- The end of the drain should be at or above the maximum water level in the natural riverbed (I).

For a diversion pond that is being filled from a stream through a main water intake and a feeder canal, it is easy to determine the difference (**x**) (cm) required between the minimum water level at the main intake and the maximum water level at the end of the drain (Figure 44, p. 70). As an example, consider a pond with a depth of 150 cm. Add the difference in levels necessary between the outlet of the pond's drainage device and the maximum water level in the drainage canal (**b**), and the difference in level between the pond's water supply canal and the pond's maximum water level (**c**), as well as the value between the entry and the exit of the pond's drainage device (**e**).

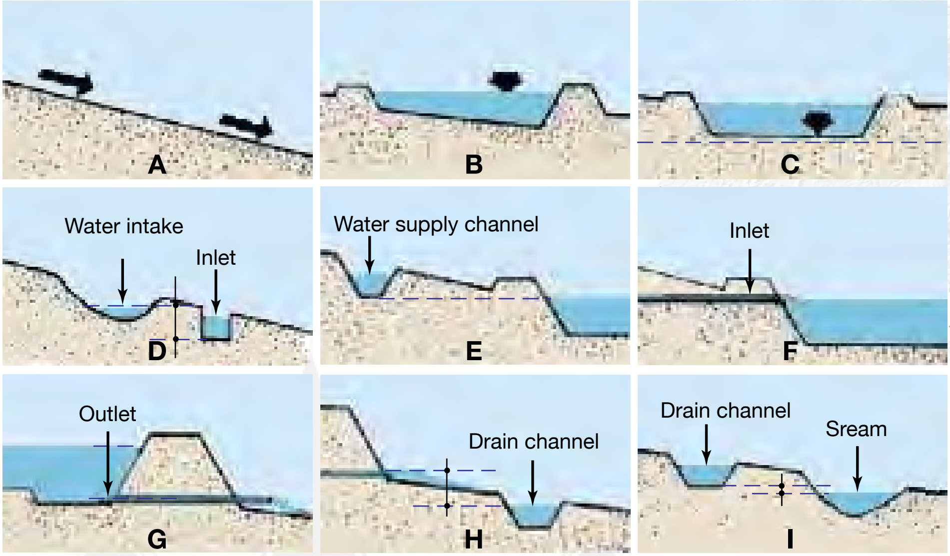
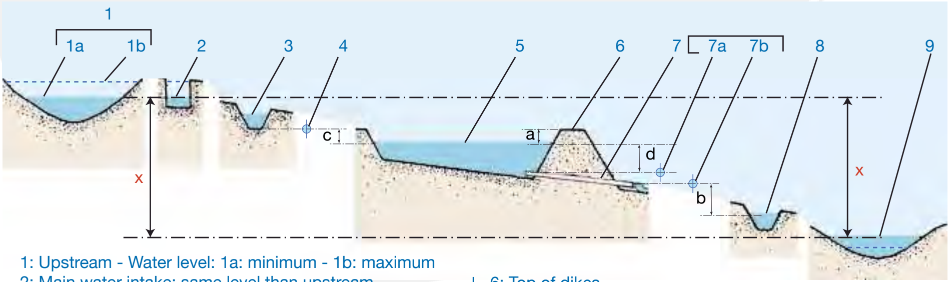


Figure 43. Different points for using gravity to manage water.
Explanations are provided in the text.

$$x > 150 + b + c + e$$

It is essential to reach this minimum difference in levels if the pond is going to be completely drainable.



1: Upstream - Water level: 1a: minimum - 1b: maximum
2: Main water intake: same level than upstream
3: End of intake channel
4: Pond inlet
5: Maximum water level in the pond
6: Top of dikes
7: Pond outlet - 7a: Start - 7b: End
8: Drainage channel
9: Downstream - Maximum water level

x = The difference in level required between the minimum water level at the main intake and the maximum water level at the end of the drainage channel
a = The difference in level required between the top of the dikes and the maximum water level in the pond
b = The difference in level required between the end of the pond outlet and the maximum water level in the drainage channel
c = The difference in level required between the pond inlet and the maximum water level in the pond
d = Maximum depth of the pond (150 cm minimum)

Figure 44. Differences in levels.

IV. SUMMARY

- **We will choose to build ponds that are:**
  - **Diversion ponds,**
  - **Rectangular,**
  - **Parallel to each other,**
  - **100 to 400 m^2,**
  - **Supplied with water by gravity.**

The ponds will thus be laid out in a pattern similar to the one depicted in Figure 45 below. Examples are provided in Figure 46, p. 72.

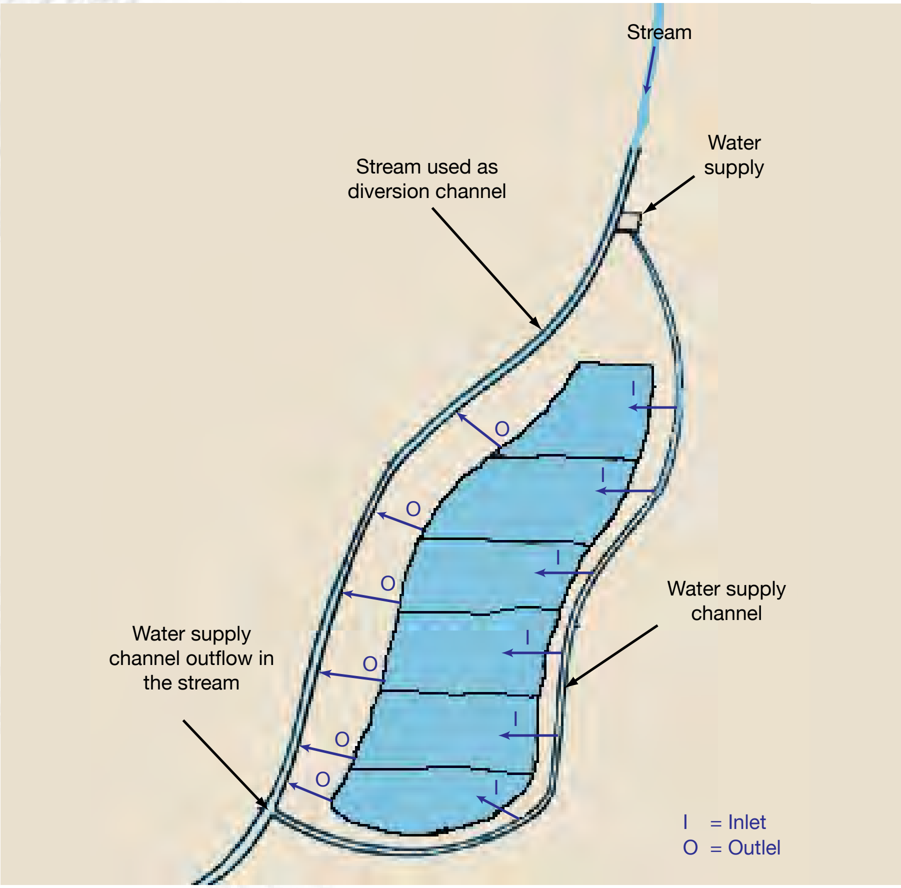


Figure 45. Classic plan for diversion ponds.

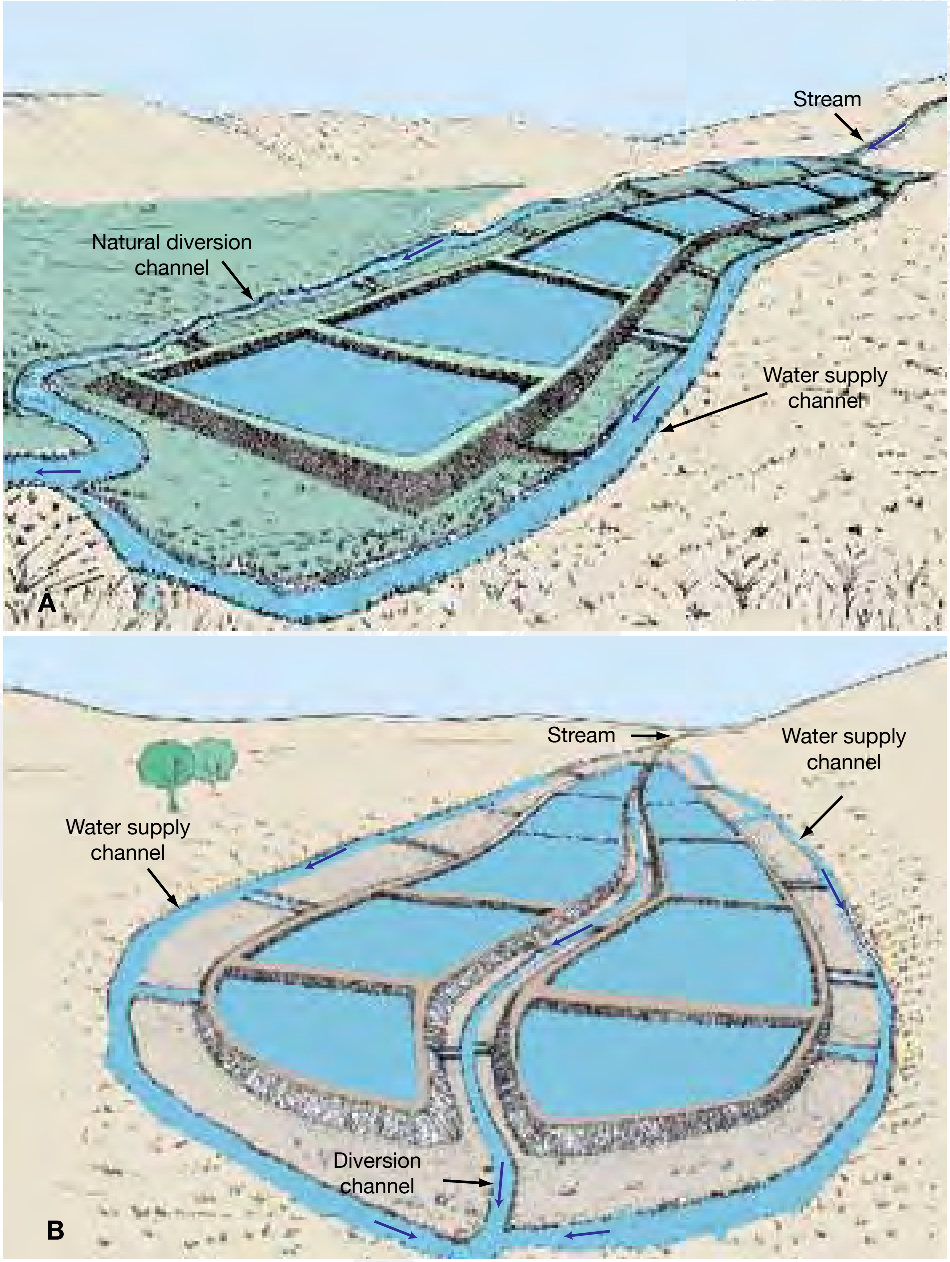


Figure 46. Examples of diversion fish farms.
- Water supplied by a stream
- One (A) or two (B) row(s) of parallel ponds
- Natural diversion canal
- Optimal water control

Chapter 07
POND CONSTRUCTION

Once the site is chosen, construction can begin on ponds and associated structures (Figure 47, p. 74). As discussed in the previous chapter, this manual will focus only on diversion ponds. However, these same steps can be applied to other types of ponds. **Pond construction should be completed during the dry season.**

For the highest-quality ponds, construction work should follow specific steps **in a strict order. Steps for a** diversion bypass pond are summarized below.

1. **Planning pond layout**
2. **Cleaning of the site**
3. **Water supply channel**
4. **Draining channel**
5. **Staking out the pond**
6. **Building the dikes**
7. **Pond bottom drain laying out**
8. **Building inlet, outlet and filtration**
9. **Decantation pond**
10. **Other structures: Erosion fight, biological plastic, fence**
11. **Filling and testing**

I. CONSTRUCTION PLAN

During this stage, possible locations for the ponds are studied. A primary goal is to minimize work in comparison to the surface cleared. The design is progressive: assumptions formulated on how the pond will be supplied and water diverted are progressively evaluated as construction continues.

Main criteria to observe throughout installation include:

- ✓ Rising water table;
- ✓ Whether the downstream dike is waterproof;
- ✓ The behavior of runoff and monks during floods;
- ✓ The feasibility of the work;
- ✓ Interactions with surrounding facilities (bins, gardens).

An initial plan is proposed (Figure 25, p. 53 and Figure 48, p. 75). This written plan should incorporate lower slope measurements as well as the locations of the structures to be built.

As an initial step, the ground should be partially cleared with a machete so that it is easier to visualize the layout.

Next comes the site survey. Generally, this survey is done systematically, with consistent spacing between measuring points. Each point is marked on the ground using a level stake. A letter corresponding to a letter on the topographic chart is written on the top of the stake. Spacing between the points will depend on the topography of the ground. If the ground is very uneven, the points will be very close. The first point will be made at the level of the collection point.

The line of the steepest slope may be determined as shown in paragraphe II.3, p. 53. First locate the highest point, then the lowest, and then calculate the slope between the two.

Using the line of steepest slope allows you to build fish farm structures that are as functional as possible, with the best possible drainage and water sanitation.

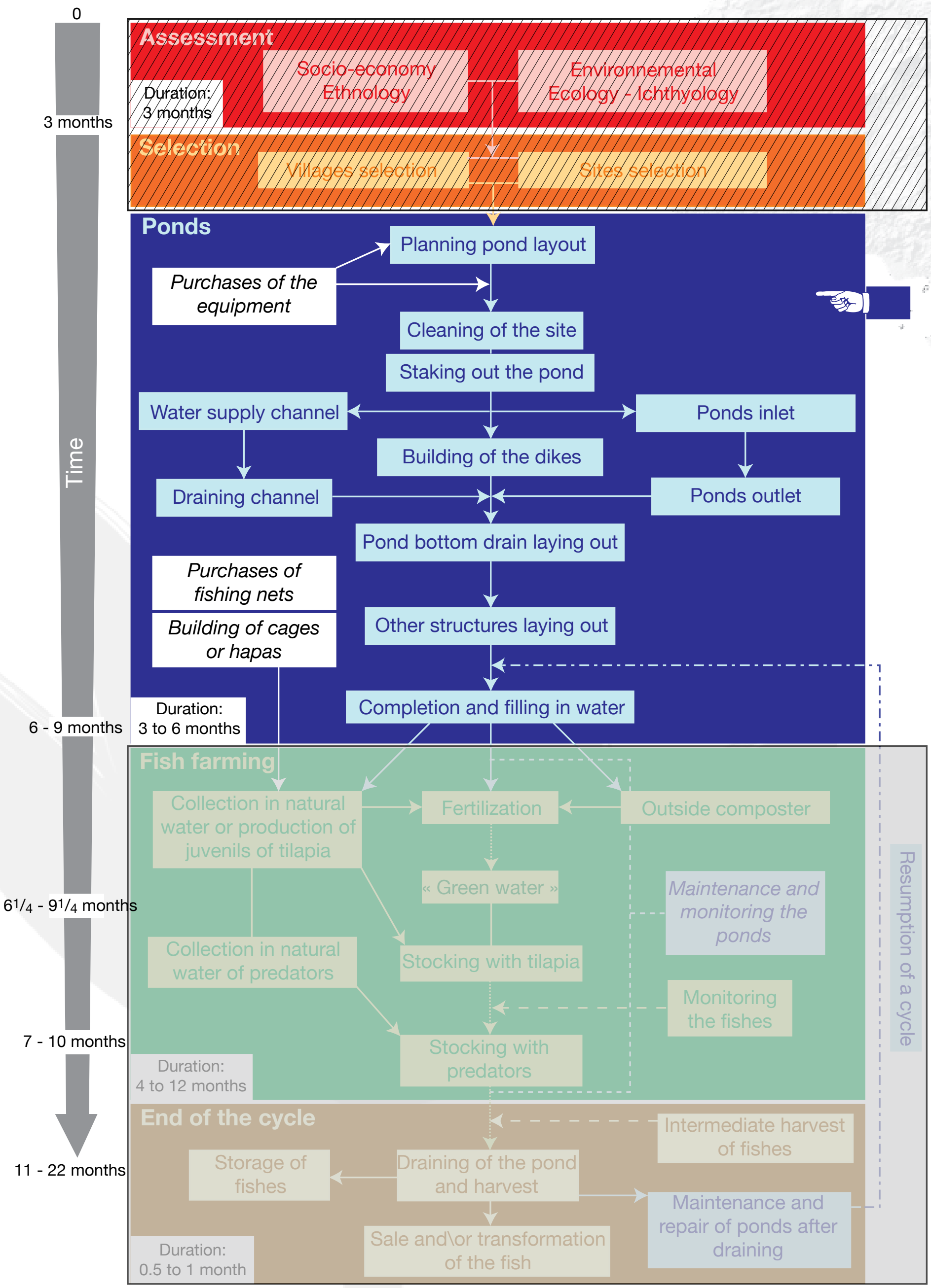


Figure 47. Setting up fish ponds: 3. Ponds.

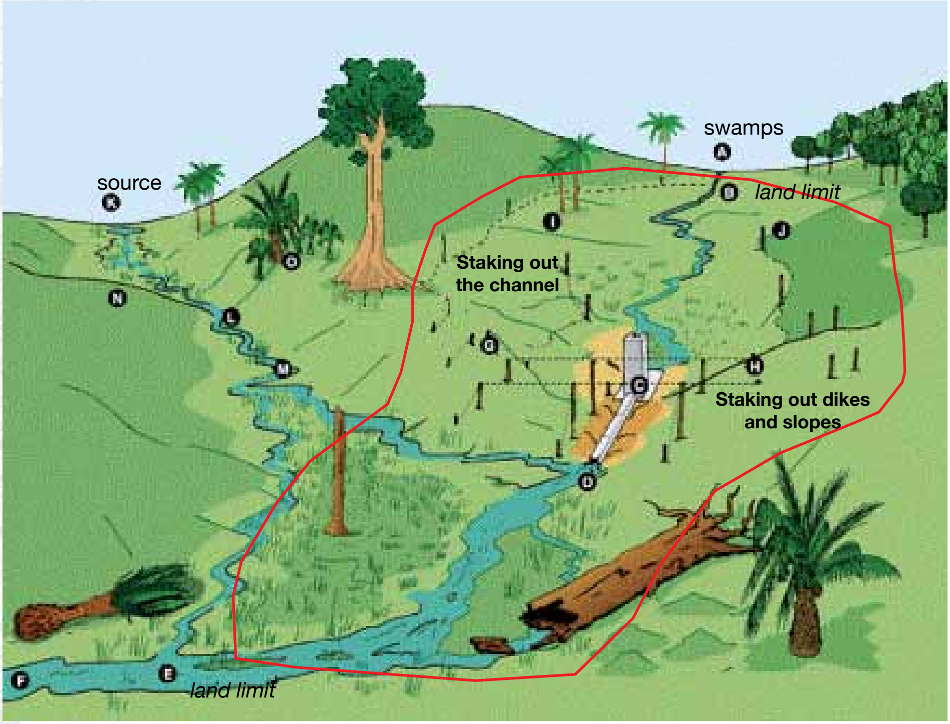


Figure 48. View of stakes for one plan for supplying water (A, K), including possible drainage schemes(C, D, L, M, E, F), in different valleys (level of M towards D), (Figure 25, p. 53) (CIRAD). In red, limits of work.

The arrangement of structures on the topographic map needs to incorporate the cost of farm construction and operation, safety requirements, and probable future extension of the farm into the overall plan.

II. CLEARING THE SITE

The first step in farm construction, after boundaries have been marked and the future site has been visualized, is to clear the area. The area must be defined precisely before it is cleared, and the outer corners of the ponds' surface area, which must include the surface area of the dikes, must be determined. The boundaries of this area can be marked using wooden stakes, ropes, or posts. Once this task is completed, an additional area should be marked that extends beyond the dikes and can serve as a passage and working area around the site. At this point, work can begin (Figure 49, p. 76):

⇨ Clear the zone, including the dikes, by removing all vegetation, shrubs, trees (including roots and stumps) and all large stones.

⇨ Clear the passage and working area around the dikes.

⇨ Clear all trees and shrubs in a area of 10 m around the dikes and the work site, and around the access roads, water supply, and drainage facilities.

Cut all grass, similar to what you would do for a farm. All trees must be cut and their roots removed. If roots are left behind, the pond will eventually seep. Grass, shrubs, all organic matter, and rocks

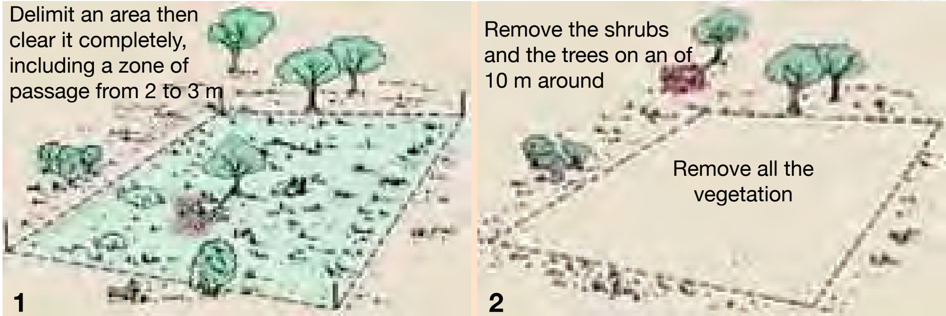


Figure 49. Preparation of the pond site.

must be removed; it can be burned if that is possible. The ground must be very well cleaned before construction begins. Elements to be removed include (Figure 50, above and Photo C, p. 77):

✓ Woody plants (A), whose roots can cause serious cracks in fish farm structures, such as water supply and drainage devices.

✓ Tree stumps (B), whose decomposition can weaken structures by leaving empty spaces in the soil.

✓ Large stones and rocks (C), whose extraction can turn out to be necessary.

✓ Termite mounds and animal burrows (D), which must be completely removed. The resulting hole should be filled with clay.

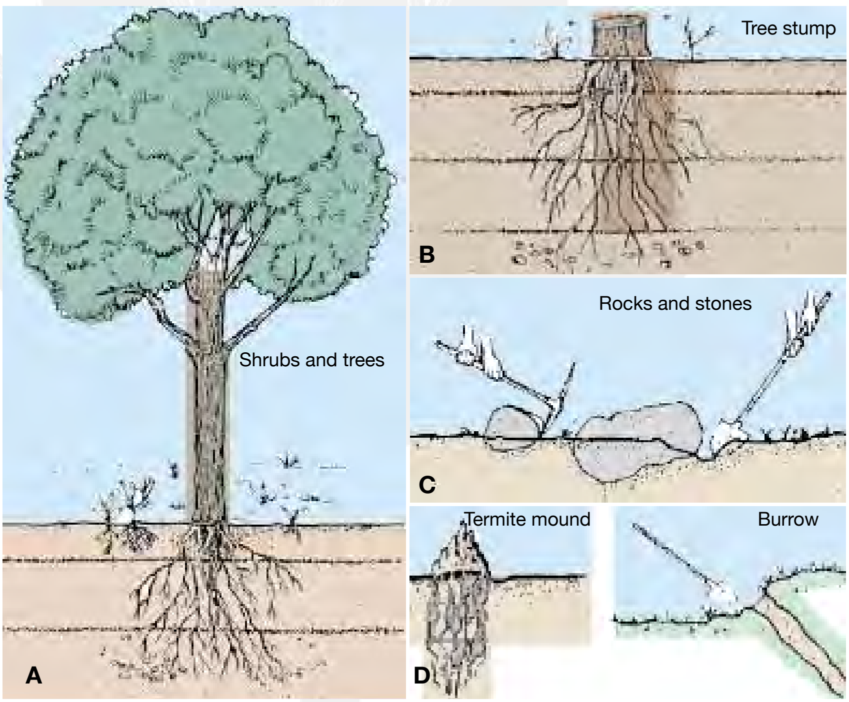


Figure 50. Clearing of the site. A and B: Trees; C: Rocks and stones; D: Animal habitats.

Photo C. Clearing the site. On left: Tree remaining near a pond in DRC (Avoid this); On right: Sites before they are cleared. (Liberia) [© Y. Fermon].

III. WATER SUPPLY: WATER INTAKE AND CANALS

The water supply includes water intake, the main supply canal and small canals that bring water from the main canal to the pond.

The principal water intake is used for overall regulation and to divert the water supply from a pond or group of ponds. The primary role is to ensure a consistent water supply, which may be regulated depending on present conditions.

Water inlets are installed, if possible, against the water current to prevent material in the river from being transported into the ponds. This canal, which is supplied, in theory, by a constant but adjustable rate of flow, is designed to bring water to the upper section of the pond, which is built so that **it can be completely drained no matter how high the water level is at the bottom of the valley**. This condition is very important and must be strictly respected. All too often when it is not, the ponds are nothing but a simple diversion of the water course, so flooding may demolish the dike and fish can enter and exit at will. Surveys should be completed to uncover any particular difficulties (such as the presence of rocks).

The main elements of a water intake are the following:

⇨ A **diversion** structure that regulates the water level and that is high enough to supply the water intake without flooding.

⇨ A device that **regulates** the level of entry (and flow) inside the structure, used to regulate the ponds' water supply. Such a device generally helps to transport water;

⇨ A structure, such as stilts, that will **protect** the entry way and prevent debris from entering and damaging the water intake.

It is best to use an open or free-level water intake that does not control supply levels but does capture water under all flow conditions. This system is simple and relatively cheap, but it generally requires a reliable, more or less consistent water supply.

Important points to take into account include the following (Figure 51 and Table XIIII, below):

- ⇨ The level of water at the source (river, small river, etc.) in comparison to the supply facilities and the ponds themselves.
- ⇨ The depth to which water will be collected (at the surface, at the bottom, or at all depths of the water source).

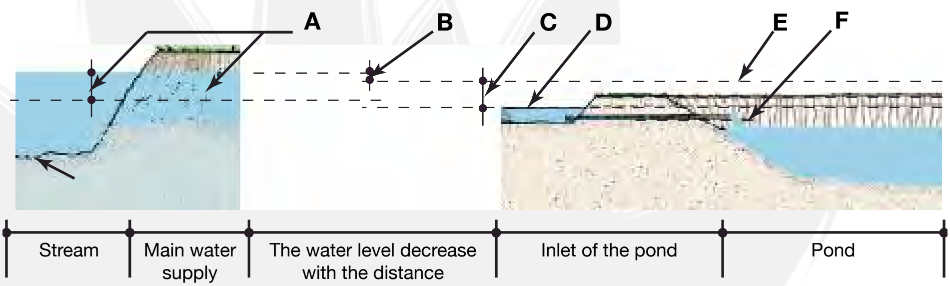
It is important to ensure that the water level at the source is always sufficient so that water can be drawn from the desired depth, and that the water intake is not likely to be flooded.

The wider the water intake, the less pressure loss there will be in the current which runs toward the ponds. This rule can be important if the water pressure is very weak.

In the majority of cases, however, the water intake is approximately as wide as the supply canal that is connected to it. The size of the supply canal is determined by the desired flow. If the supply canal is particularly wide, or if you want to increase pressure loss at the level of the water intake (for example, if the exterior water level is higher than what is required in the supply canal), the water intake can be narrower than the supply canal. In general, a narrower intake is easier to regulate with a simple structure that can be installed.

After selecting the water intake, the supply canal that will bring water to the ponds must be arranged (Figure 52, p. 79). This canal has a very weak slope and must be able to supply water throughout the year. The layout of the canal is designed by staking a contour line at the base of the water intake until reaching the site where the ponds will be built. Practically, after establishing the layout of the contour line, a definite layout can be adopted, contingent on the terrain.

It is important to avoid giving the canal too steep a slope and to anticipate, if necessary, rock falls



A: Minimum-maximum water level in the stream and in the first part of the channel
B: Charge loss
C: Minimum-maximum water level in the last part of the channel after the charge loss
D: The level of the inlet of the pond have to be lower than the minimum water level in the channel
E: The maximum water level have to be check to avoid flood
F: The release of the inlet is at 10 cm over the maximum water level of the pond

Figure 51. Differences in water levels.

Table XIII. Diversion structures that control water levels in streams.

Type of stream		Structures required	
Small	Flow less than 10 liters/ second	Diversion Not to be submerged	Dikes in the ground Wood/ropes/clay Wooden fence
	No significant flood conditions	No need	-
Large	Water flow at least twice the flow required	Diversion To raise water level	Wood or stone dikes, adjustable
	Significant flood conditions	No need	-

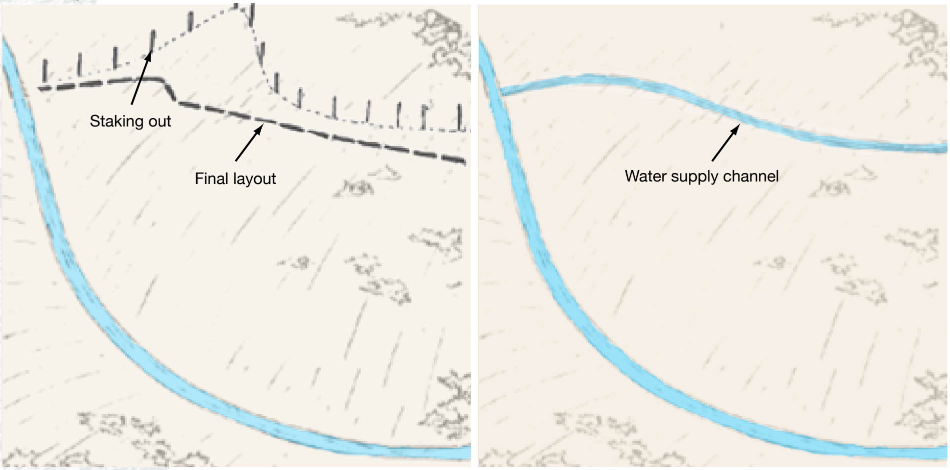


Figure 52. Setting up the water supply canal.

or concrete areas before completing the digging and sloping of the canal. Remember that the canal should be dug dry. Avoid the method of digging a canal as water seeps in, since this will result in a slope that is much too steep at the bottom of the canal.

Canals that are not sealed usually have a trapezoidal cross section, defined by the following elements (Figure 53 below):

- ✓ The horizontal width (**b**) of its bottom (or top);
- ✓ The slope (**z/l**) of the side walls;
- ✓ The maximum depth of water (**h**);
- ✓ Return (**f**) is permitted in order to avoid overflow.

The dimensions of the canal are illustrated in Table XIV, p. 80.

It is essential that the speed of the current in the canal does not cause the walls to erode. The maximum speed of water varies with the nature of the terrain: 0.15 m/s over fine ground and 1.00 m/s over stones.

If, for any reason, you cannot follow the contour line and need to reduce the level of the canal, you will have to plan a slanting slope or, better, use a pipe. However, never give the canal too steep a slope. If, despite these precautions, the water in the canal is turbid, you should plan to construct a sedimentation tank or widen the canal so that water is flowing slowly enough that the suspended matter will be deposited.

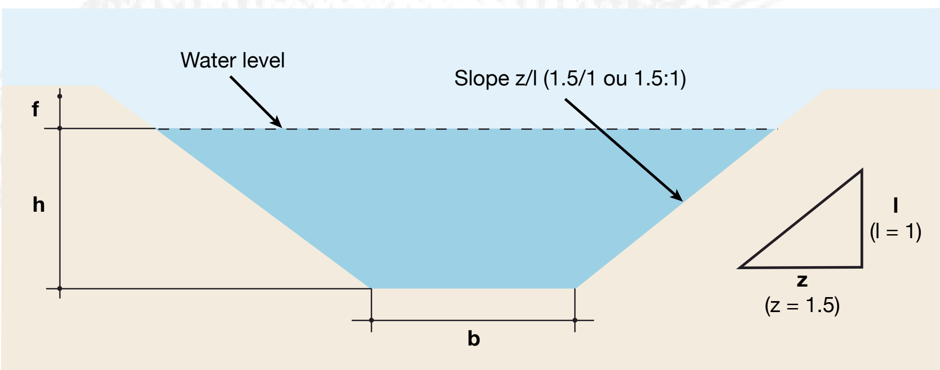


Figure 53. Transverse profile of the canal. Dimensions and slope of sides.

Table XIV. Canal dimensions.

	Small farm	Medium farm
	A few l/s	20-50 l/s
Bottom width	20 to 30 cm	50 cm
Water depth	20 to 40 cm	60 to 80 cm
Side slope	1.5:1	1.5:1
Top width	60 to 100 cm	150 to 180 cm
Bottom slope	0	1 ‰ (1 cm per 10 m)

Once the location has been verified, you can proceed with the excavation of the dry canal, starting wherever you want, depending on the needs of the moment. This operation is done in three phases (Figure 54, p. 80):

1. First, dig the central section with vertical walls. Adjust the slope lengthwise along the bottom, and proceed to the cut of the embankment.

2. Be careful to leave the stakes that provide depth reference marks in place (within the pond or at the edges), and to dispose of the excavated dirt below the site in order to avoid overflow during floods.

3. Adjust the slope lengthwise along the bottom.

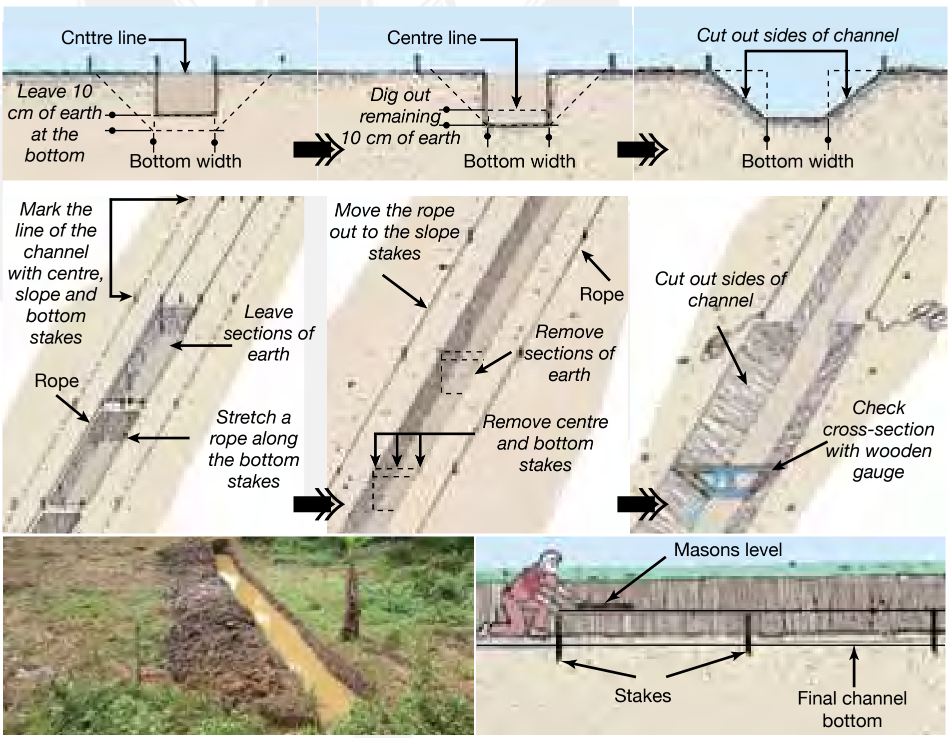


Figure 54. Canal digging.
Photo D. Canal during the digging (Liberia) [© Y. Fermon].

When, in certain sections of the course, the canals must be deepened, the same gauge should be used to check that the width of the surface and the regular slope of the banks was respected strictly in the deepest part of the canal.

Conversely, when the canal passes by high points and hillsides, it should be dug deeper and a berm should be installed at the edge of the canal. It should be built of well-compacted ground and the crest, which should be of a sufficient width, should be at the same level everywhere above the wet section.

Installation of waterfalls that will restore the slope of the canal to the acceptable maximum, must always be done before the pond is filled for the first time, in order to eliminate the risk of erosion. On the other hand, the installation of overflow areas, sedimentation tanks, and ditches for rain drainage, if necessary, are less urgent.

Finally, the canal can be dug backwards in small sections starting from the river. However, this method is not advised; if the canal is deep enough to allow the water to run into the canal, its slope will be too steep.

IV. DRAINAGE: DRAINAGE CANALS

The site and layout of the drainage canal is generally easier to determine (Figure 55 below). Ponds must be designed so that they can be completely emptied at any time during year. So the bottom of the drainage canal must be much lower than the bottom of the pond (Figure 56 below). This canal is usually built when the pond is finished. However, it is included here because the building method is the same as for the supply canal.

Using the bottom of the valley as a drainage canal is risky. During a flood, the water level in the valley may be higher than the bottom of the pond, so it would not work as a drainage canal. If, on the other hand, the water level at the bottom of the valley is permanently lower than the bottom of the pond, it can be used as a drainage canal. It is also preferable to set up a drainage canal around the pond area. In the next stage, the site of the ponds will be marked on the land between the supply and drainage canals.

V. STAKING OUT THE POND

On the land bordered by the drainage and supply canals, you can now mark the boundaries of the ponds. This operation is called picketing or staking. Stakes driven into the ground will represent the location of the dikes as well as their dimensions and heights, providing a guide for the excavation work (Figure 57 and Photo E, pg. 82).

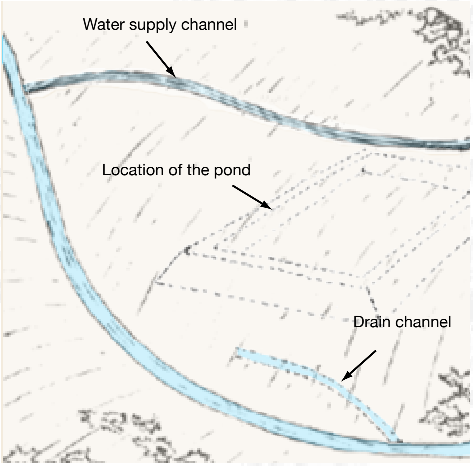


Figure 55. Setting up the drainage canal.

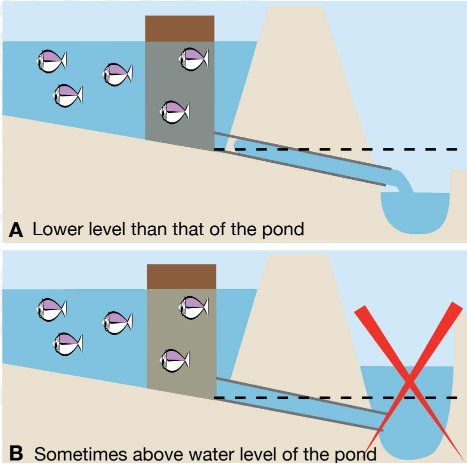


Figure 56. Level of drainage canal.

Stakes must be long enough to allow debris or subsequent backfill to occur without the risk of exposing buried ends or of covering the ends that are supposed to be exposed. There will be four rows of stakes for the main dike, two for the side dikes, and three for the upstream dike. These stakes will be spaced two meters apart in each row; spacing between the rows of stakes will depend on the dimensions of the dikes.

Photo E. Stakes put in while dikes are being built (Liberia) [© Y. Fermon].

VI. CONSTRUCTION OF DIKES

Digging a hole is only the first phase of establishing a pond. After establishing the pond site's boundaries, you need to carefully build watertight dikes around them. Dikes are essential components of the pond; the pond's solidity and capacity to retain water depend on them.

Remember that, initially, all debris must be cleared from the pond's base and the site of the dikes, including roots, plants, and stones. The surface layer of the ground, (i.e. the layer of cultivated earth), where the dam will be built, should also be removed, so that water cannot escape through the

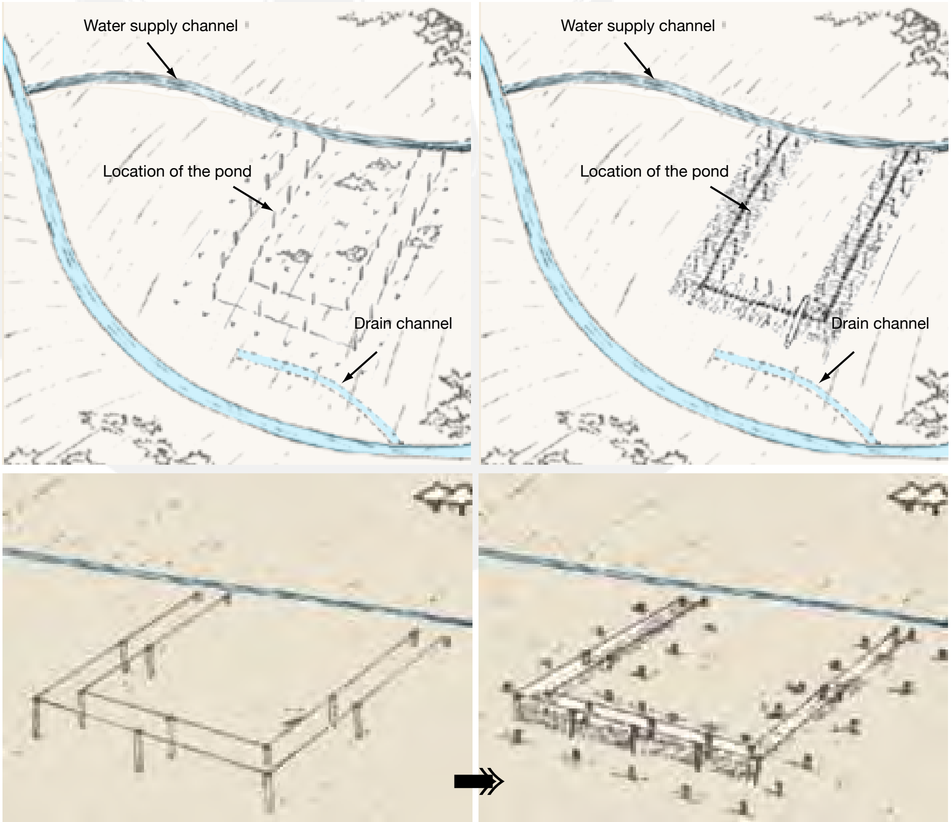


Figure 57. Picketing the pond and the dikes.

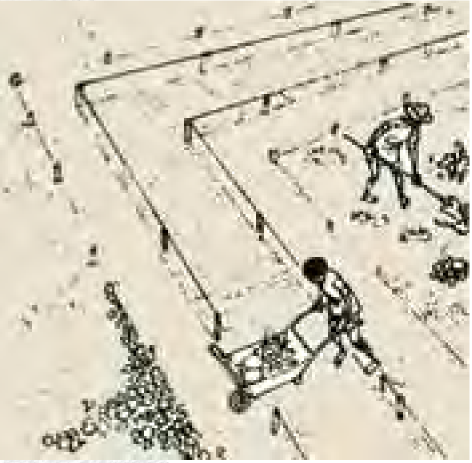


Figure 58. Cleaning the area where the dikes will be built.

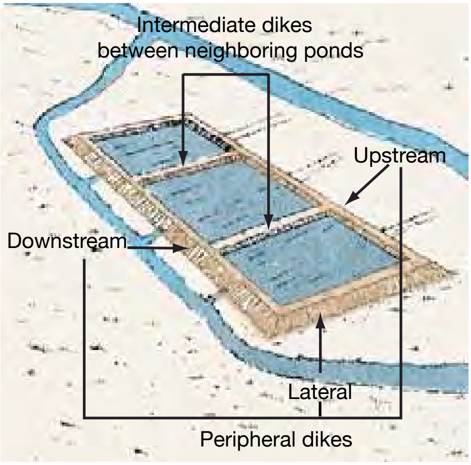


Figure 59. Definitions of different types of dikes.

base of the dike when the pond is full. **Often, people forget to strip the ground before constructing the dikes, which almost always means that a lot of water will escape and, eventually, the pond will need to be refilled** (Figure 58 above).

There are three types of dikes in a diversion pond (Figure 59, above):

- ✓ The **upstream** dike, parallel to the supply canal,
- ✓ **Lateral** dikes, which are perpendicular to the upstream dike and the main dike, with their walls supporting water pressure from two nearby ponds, and
- ✓ The main dike, which is **downstream,** whose embankment supports the greatest water pressure in the pond. This is the thickest and highest dike.

There are five principal components to a dike (Figure 60, below):

- ✓ **The foundation or base,**
- ✓ **The body,**
- ✓ **The bench, berm or top,**
- ✓ **The banks (embankments),**
- ✓ **The height.**

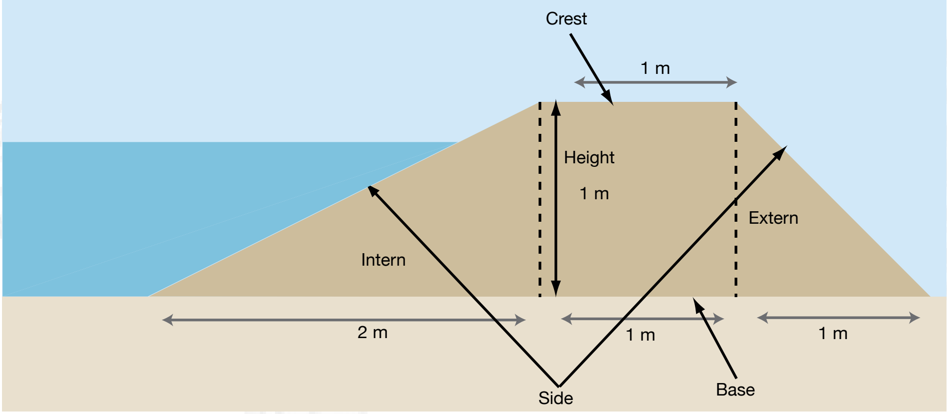


Figure 60. Description and proportions of a dike (1 m high).

Any dike must have the following properties:

⇨ It must be able to **resist water pressure** equal to the volume of water retained in the pond (Figure 61, below).

⇨ It must be **high** enough to stop water from flowing out, which would quickly destroy it (Figure 62, below).

⇨ It must be **impermeable**, allowing minimal infiltration through the dike.

If the soil is very sandy, a trench should be dug in the center, all the way through each dike, to the layer of impermeable ground, in order to replace the sandy and permeable ground with an impermeable clay core that reaches the top of the dike. Dikes built this way are tighter and more solid. This technique of anchoring the dike, which does not require too much work, is the best method of pond construction, whatever type of soil is being used (Figure 63, p. 85).

It is generally unnecessary to build an intermediate dike separating two ponds that are as solid as a peripheral dike, since the water pressure is practically equal on both sides. However, if one pond is emptied while the other remains full, the variation in pressure will be close to that observed on the peripheral dikes, and will require a more solid construction.

The dimensions of the dikes will depend on the pond's surface area. The foundation of the dike is a function of the depth of the water in the pond. The slope of the embankment is a function of the quality of the soil, so it can vary from 1 per 3 (33 %) for soft ground to 2 per 3 (66%) for soil that can bear more pressure. The bench or top of the dike must be wider than 1 meter to allow handling of the seine during fishing. Installation of the dike begins with the installation of the foundation.

Water pressure from the ponds is directed toward the downstream-dike that surrounds the fish farming site. Water saturates the soil at the bottom of the dike (Figure 64, p. 85). Thus the downstream-dike must be built in a way that will prevent infilatration, or seepage. The base needs to be broader in sandy soil than in soil that is mostly clay.

When water in the pond meets the ground water below it, the water at the bottom of the pond is in equilibrium with the water table. This is the best possible case, where there is no more infiltration once the soil is saturated with water.

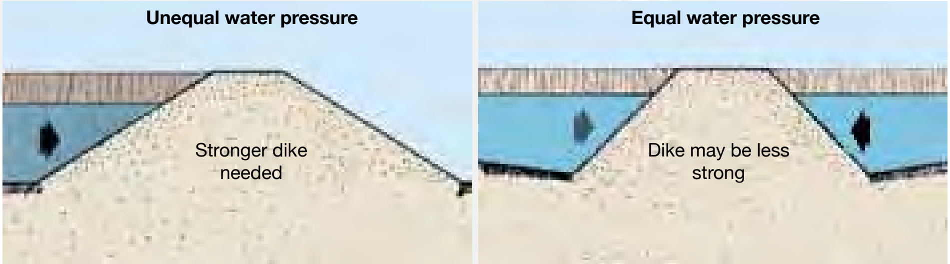


Figure 61. Dikes in different water pressure situations

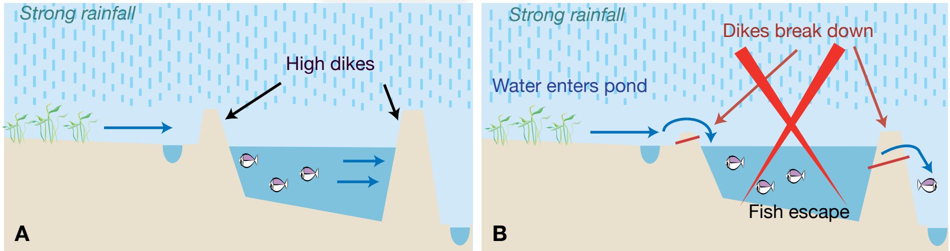


Figure 62. Dikes. A: Good height; B: Too small.

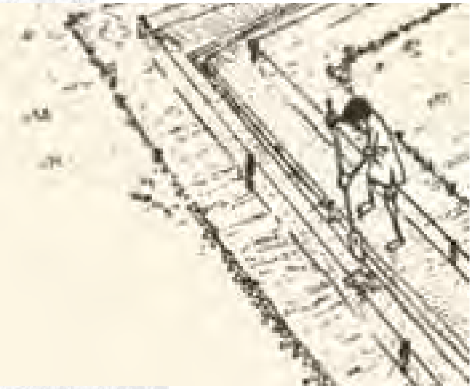


Figure 63. Digging a cut-off trench for a clay core.

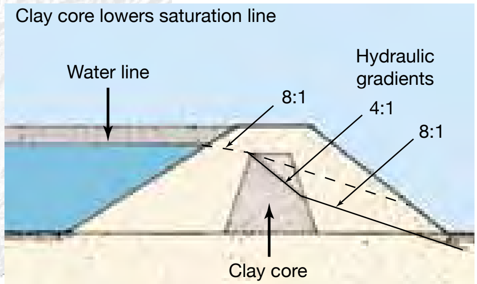


Figure 64. Clay core and saturation of the dike.

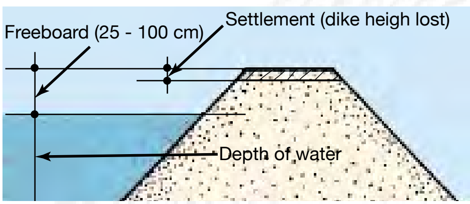


Figure 65. Height of a dike. Depth; freeboard; settlement.

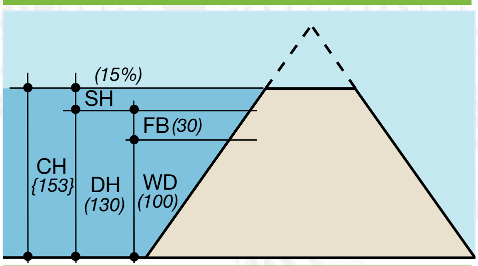


Figure 66. Height of the structure (definitions and examples in the text).

The calculation of the height of the dam should include the following variables (Figure 65 opposite):

✓ Desired **depth** of water in the pond.

✓ **Freeboard**, i.e. upper part of the dike which should never be immersed. It varies from 25 cm for very small ponds to 100 cm (1 m) for barrage ponds built without a diversion canal.

✓ Height that will be lost during **settlement**, taking into consideration the dike's compression of the subsoil and settling of fresh soil. This settlement allowance usually varies from 5 to 20 % of the dike's height when it was constructed.

Accordingly, there are two ways of calculating the depth of a dike (Figure 66 opposite):

⇨ The **design height DH**, which is the height the dike should reach after settling, which will safely provide the depth of water the pond needs. It is calculated by summing the water depth and the freeboard.

⇨ The **construction height CH**, which is the height the dike should reach when it has just been built, before settlement occurs. It is equal to the design height plus the settlement height.

The construction height (CH in cm or m), calculated simply from the design height (DH in cm or m) and the settlement allowance (SA in %) as follows:

CH = DH / [(100 - SA) / 100]

If the maximum water depth in a medium-size diversion pond is 100 cm and the freeboard is 30 cm, the design height of the dike will be DH = 100 + 30 = 130 cm. If the settlement allowance is estimated to be 15%, the required construction height will be:

CH = 130 / [(100 - 15) / 100] = 130 / 85 = 153 cm.

A dike rests on its base. It should taper upward toward the top of the dike, also known as the crest or crown. So, the thickness of the dike depends on:

⇨ The width of the crest, and

⇨ The slope of the two sides.

On the whole, the dike must have a base of 4 m for a minimum 1 m of height. The slope of the dike at the base of the slope of the pond is more important for limiting erosion and allowing easier access to the bottom of the pond (Figure 60, p. 83, Figure 66, opposite and Table XV, p. 86).

The width of the top of the dike is a function of the depth of water and the dike's role in circulation and/or transport:

- It should be at least equal to the depth of the pond, but not less than 0.60 m in clay soil or 1 m in sandy soil.
- It should become wider as the amount of sand in the soil increases.
- It should be safe for whatever method of transportation you plan to use on it.

In individual ponds, dikes have two sides: the wet side inside the pond and the dry or external side (Figure 67, below). These two sides should taper from the base to the top at an angle that is usually expressed as a ratio defining the change in horizontal distance (z in m) per metre of vertical distance as, for example, 2:1 or 1.5:1. In a dike with a side slope of 2:1, for each 1 m of height, the base width increases on each side by 2 x 1 m, or 2 m.

Table XV. Examples of dimensions for dikes.

Surface (m²)	200		400 - 600	
Quality of soil	Good	Fair	Good	Fair
Water depth (max m)	0.80		1.00	
Freeboard (m)	0.25		0.30	
Height of dike (m)	1.05		1.30	
Top width (m)	0.60	0.80	1.00	
Dry side, slope (SD) (outside)	1.5:1	2:1	1.5:1	
Wet side, slope (SW) (inside)	1.5:1	2:1	2:1	
Base width (m)	4.53	6.04	6.36	8.19
Settlement allowance (%)	20	20	15	15
Construction height (m)	1.31	1.31	1.53	1.53
Cross-section area (m²) / **Volume per linear m (m²)**	3.36	4.48	5.63	7.26

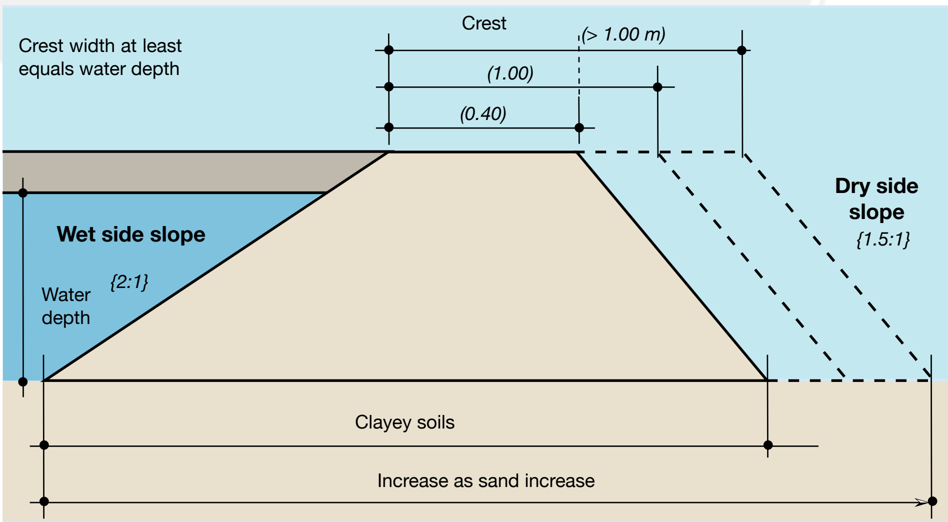


Figure 67. Dimensions of a dike.

Table XVI. Expression of slope values in different units.

Slope		
Ratio	**Percentage**	**Degrees**
1:1	45	100
1.5:1	34	66
2:1	27	50
2.5:1	22	40
3:1	18	33

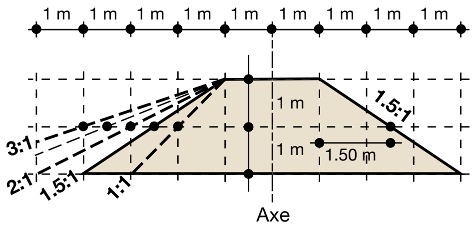


Figure 68. Calculating the slope for dikes.

The side slopes of each dike should be calculated bearing in mind that:

✓ The steeper the slope, the more easily it can be damaged;
✓ As the soil becomes sandier, it becomes weaker, so slopes should be more gentle;
✓ As the size of the pond increases, the size of its waves increase and erosion becomes worse;
✓ As the slope ratio increases, the volume of earthwork increases, and the overall land area required for the ponds increases.

Usually dikes' side slopes vary from 1.5:1 to 3:1, or 18° to 45° (Figure 68 and Table XVI, above), depending on local conditions for ponds of 100 to 600 m^2. The slope on the dry side can be steeper than the slope on the wet side.

Careful attention to dike construction is an essential component of construction that contributes to the pond's lifespan (Figure 69, Figure 70 and Figure 71, p. 88 and Photo F, p. 89).

To build dikes, start digging the ground for the main section of the pond and remove soil that is too sandy (A). The good argillaceous soil is transported and compacted wet, either using a compactor or by rolling a 200 liter barrel filled with water on the site of the dikes.

Each 10 cm-thick layer of good, wet argillaceous soil (which does not contain vegetable matter or large stones) is vigorously packed down (B). If a layer of soil is too thick, the ground will not be packed to a sufficient depth. Using the «staircase» technique will ensure that the ground is well-compacted and the dikes are well-sealed. This method requires a compactor, a barrel, or a roller for compacting each stair, one after the other. The majority of water leakage occurs because the soil is not compacted well, particularly above the outlet. The width of each stair decreases from the bottom to the top, and each is rammed and compacted vigorously (C). The dike should be assembled, step by step, to the desired height (0.6 to 1.2 m), which will depend on the type of pond (laying, stocking with fish, parent). It is also important to remember that the height of the freeboard should be 0.25 m. When construction is complete, the edges of the steps should be flattened with a wooden handle.

Soil with a high clay content is harder to work with, and it might be better to build the dikes with blocks of land divided in the soil. Sandy soil is easier to work, but it can be crumbled by hand, so it is very permeable and less appropriate for a fish farm (D). To build dikes on clay soil, proceed in the same way, (using the staircase method) but move the earth in cut clods, removing the vegetable matter on the top layer as well as large pieces of vegetable debris (E). With a little water, each clayey lump of earth sticks to neighboring clumps and forms a solid and impermeable paste, which adheres well to the clay soil the dike is built on. People often forget to strip the lump of topsoil, however, causing unnecessary leakage through the dikes. After depositing the clumps of dirt side by side along the area where the dike will be built, dampen and compress the entire length of each stair so that each lump of clay sticks to the one next to it (F). Then use a roller, or a 200 liter drum filled with water, or a compactor to compress the soil across the entire length of the dike.

If the pond's dikes are built well, using the appropriate soil, the pond will last more than twenty years, and require little maintenance.

Space can be left for inlet and outlet structures during construction, or they can be built at the same time. Instructions for buidling them will come later.

Once the dikes are built, construction on the base or bottom of the pond can be begun.

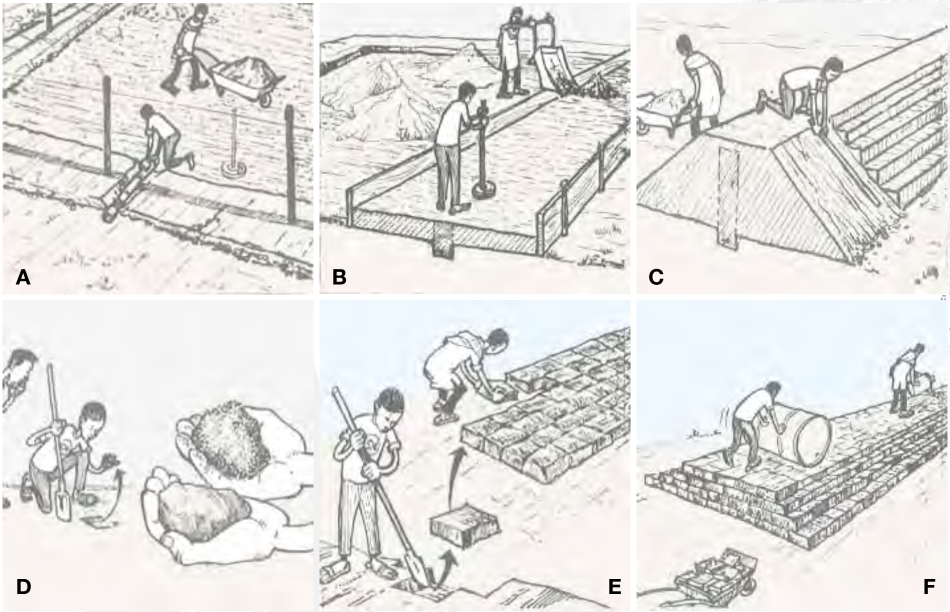


Figure 69. Dike construction (I). A, B and C: Traditional; D, E and F: Block construction

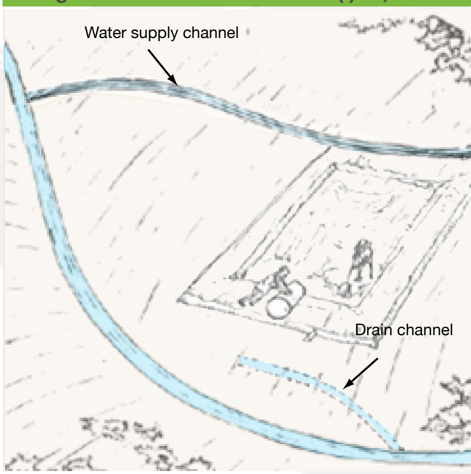


Figure 70. Dike construction (II).

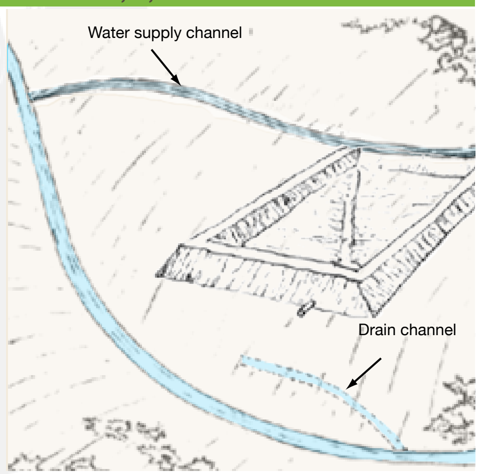


Figure 71. Preparing the bottom.

VII. CONSTRUCTION OF THE BASE (BOTTOM)

Since the pond must be completely emptied without any remaining water, the bottom or base should be arranged on a soft slope inclined toward the outlet (Figure 72 p. 89).

Construction is done by smoothing the bottom while remaining slightly above the projected dimensions. For the banks of the ponds, pay particular attention to the compaction and the choice of soil quality that will be used, since requirements are similar to those for the supply canal, which is permanently submerged.

For small ponds, the bottom should be built with a gentle slope (0.5 to 1.0%), from the water inlet

Photo F. Dikes. On left: Slope badly constructed, destroyed by erosion (DRC)[© Y. Fermon]; On right: Construction (Ivory Coast) [© APDRA-F](CIRAD).

to the outlet, to ensure that the pond can be easily and completely drained. The entry to the outlet should always be slightly below the pond bottom's lowest point.

For the bigger ponds (more than 4 ares, or 400 square meters), it is useful to install drainage ditches around the drain. To ensure complete drainage, it is best to use a network of shallow drainage ditches with a slope of 0.2 %, rather than try to create one slope across the entire pond bottom.

When the bottom of the base is entirely stabilized, dig drains with their edges converging toward the drainage area. The drains are small canals built to facilitate the total evacuation of water. All these operations are carried out with respect to the original data and the level stakes. The drains can be laid out (Figure 72, p. 89 below):

- ✓ **Radiating** from the outlet, or
- ✓ In a "**fish-bone**" pattern.

Drainage ditches must all be connected to a harvesting pit dug in the deepest part of the pond, usually in front of the outlet, where all the fish can be gathered for harvest (Figure 73 p. 90).

It is important to remember to anticipate the following differences in level (Figure 74 p. 90):

- ✓ Between the end of the drainage ditch and the bottom of the harvesting pit (at least 20 cm).
- ✓ Between the bottom of the harvesting pit and the bottom of the outlet (at least 10 cm).

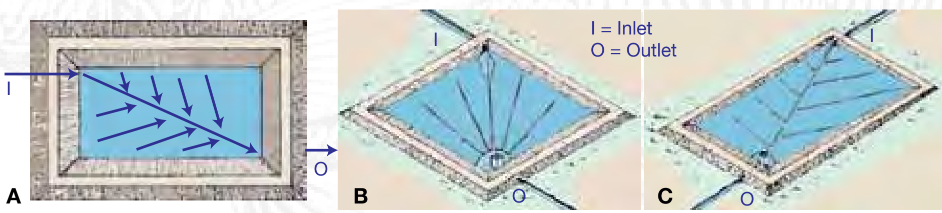


Figure 72. The bottom or base. Direction of the slope (A) and drain setting: In rays (B); As «fish bones» (C).

VIII. CONSTRUCTION OF STRUCTURES FOR SUPPLY AND DRAINAGE

We are concerned here with the devices used for supply and drainage of water. That is to say, how does water get into the ponds and how will they be completely emptied; how will the inflow and outflow be managed?

VIII.1. POND INLET STRUCTURES

Inlet structures are built to control the amount of water flowing into the pond at all times. There are three main types:

- ✓ Pipe inlets,
- ✓ Open gutter inlets,
- ✓ Canal inlets.

When designing and constructing an inlet structure, pay particular attention to the following points: (Figure 75, p. 91):

⇨ The inlet must be placed at the shallow end of the pond.

⇨ The bottom of the inlet must be at the same level as the bottom of the water supply canal, and ideally at least 10 cm above the pond's highest water level.

⇨ The inlet structure must be horizontal, with little or no slope.

⇨ The structure must be arranged so that water splashes and gets mixed up as much as possible when entering the pond.

⇨ The structure should be constructed to prevent entry of undesirable aquatic animals or fish.

VIII.1.1. PIPE INLETS

Pipe inlets can be constructed from various materials, depending on the water supply required and the diameter of the pipe interior (Figure 76, p. 91). Usually, pipe inlets extend for about 60 to 100 cm beyond the edge of the water when the pond is full, and they should be at least 10 cm above the expected water level. Usually, PVC pipe or plastic is utilized, since these materials are resistant and do not deteriorate easily. If they are not available, bamboo can be used.

Bamboo pipes make cheap, good inlets whenever the material is locally available (Figure 77, p. 91). They can be used to fill ponds in several ways, such as:

- ✓ Without modification, with water flow regulated upstream;
- ✓ With the inclusion of a mobile gate to

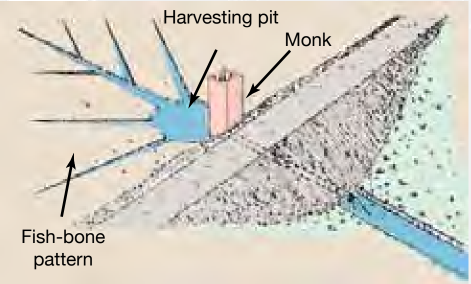


Figure 73. Bottom drain.

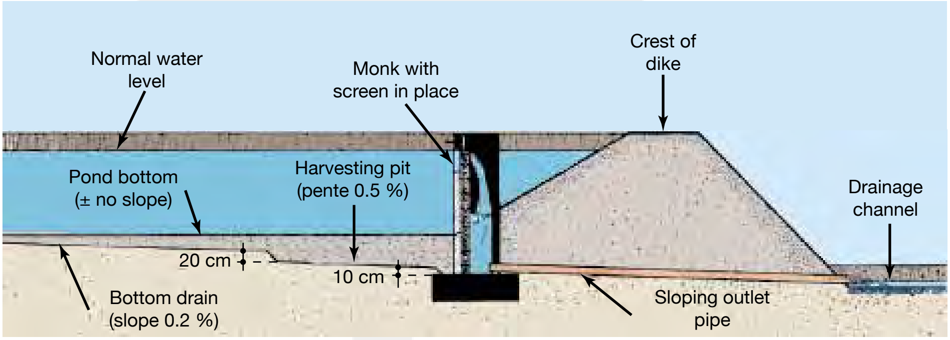


Figure 74. Cross section of a pond at the bottom drain.

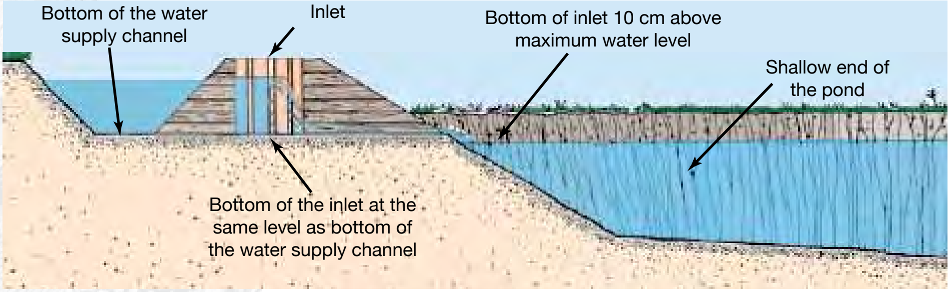


Figure 75. Cross section of a pond inlet.

regulate water flow;

✓ With modifications that will improve water quality.

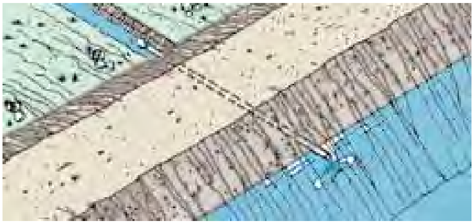


Figure 76. Pipe inlet.

VIII.1.2. GUTTER INLETS

Gutter inlets usually extend about 1 meter above the surface of the pond when it is full (Figure 78, p. 92). Construction is simple, and can utilize materials such as (Figure 79, p. 92):

✓ Bamboo: Cut a stalk of bamboo in half and clean out the partition walls. The diameter is usually 10 cm or less;

✓ Wood: Assemble three boards to form a rectangular gutter. A flow-regulating gate can easily be added;

✓ Metal: Bend a galvanized iron sheet lengthwise into a semi-circular gutter. The flow should be regulated upstream.

VIII.1.3. CANAL INLETS

A small open canal can be built to connect the water supply canal to the pond (Figure 80, p. 92). There are several possibilities, including:

✓ Digging a small earthen canal, with a trapezoidal section;

✓ Building a small, lined canal, with a rectangular section using wood, bricks or concrete blocks. Build two small parallel walls on a light foundation along the sides of the canal. If necessary, add two pairs of grooves,the first for thin boards to regulate water flow, and the second for a sliding screen to keep unwanted fish out.

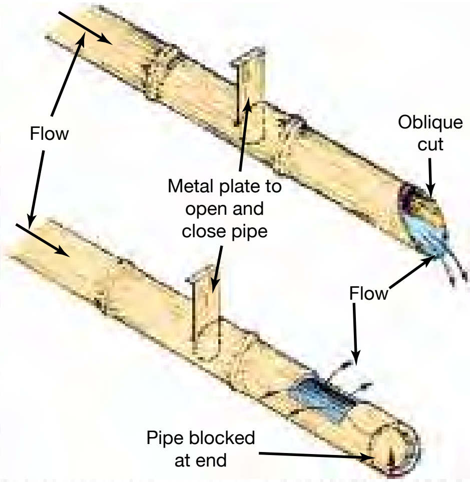


Figure 77. End of bamboo pipe.

VIII.1.4. SOME ADDITIONAL POINTS

■ OXYGENATION OF WATER

It is rather simple to increase the supply of oxygen in the water at a pond inlet at the moment that the water falls into the pond. The principle is to increase the surface area of contact between the air and the water. The ratio of atmospheric oxygen to water increases as:

✓ The height of the waterfall increases,

✓ The breadth of water and the surface area for contact with the air increases,

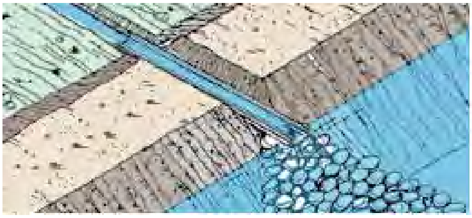


Figure 78. Gutter inlet.

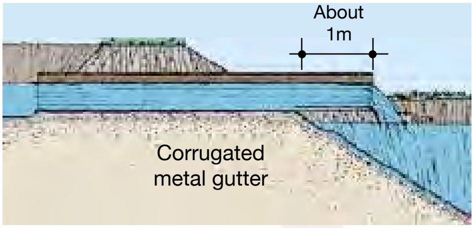
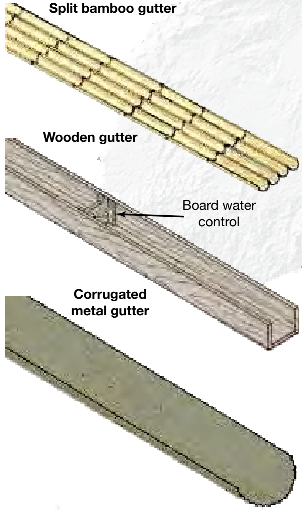


Figure 79. Different types of gutter inlets.



✓ The water laps and fragments into fine droplets.

If water enters the pond through a pipe, oxygenation can be improved:

✓ By bending the end of the pipe 90°, so that it opens upwards;

✓ By placing a perforated, vertical filter on the reverse end of the pipe;

✓ By fixing a horizontal perforated screen so that it curves around the end of the pipe and juts out slightly.

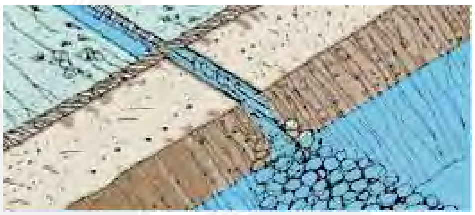


Figure 80. Canal inlet.

If the water supply falls vertically into the pond through an overhanging device, oxygenation can be improved by breaking the jet with a flat or corrugate horizontal panel placed under it.

■ LIMITING POND EROSION

It is essential to position blocks of stones that will not erode hollow under the water inlet.

VIII.1.5. FILTRATION

Water filtering devices are usually used at the inlet in order to:

✓ Improve water quality by reducing turbidity and eliminating suspended organic matter, such as vegetable debris.

✓ Limit the introduction of wild fish, which can take food, transmit infections and diseases, and reduce pond production. Carnivorous species can destroy the fish stocks, particularly if the fish are small.

There are a variety of more or less effective structures that are easy or difficult to implement. Initially, a crude barricade like a grid can be installed at the level of the supply canal or of the pond, to stop large debris from getting into the ponds. Finer structures will be necessary to stop aquatic animals. Often, a simple net, such as a mosquito net, has been used at the level of the inlet (Photo G, p. 93). However, these grids may either become filled very quickly and require daily cleaning, or be destroyed because they are not solid enough. More elaborate structures can be set up, but they often cost more. However, if the water is clear enough, it is possible to set up a simple system that is not too expensive and requires regular but limited maintenance, perhaps only once to twice a year. In this system, the water will pass over gravel, then a sand filter (Figure 81 and Photo H, p. 93).

If the water supply is too turbid and loaded with sediment, it can be directed through a settling filter before it arrives in the pond. The principle is simple: install a small basin upstream and direct slow-flowing water through it. The particles will settle to the bottom of the basin, which should be emptied when it is full. The water will then be clear when it arrives in the pond. This will be explained later on.

VIII.2. POND DRAINS

A well-built fish pond must be able to be emptied completely through a drain adapted to the dimensions of the pond.

Installation of draining devices should be planned before dike construction begins. Preferably, space will be left for the drainage devices when or before the dikes are set up.

There are two main reasons to construct drains:

Photo G. Example of inefficient screen at the inlet of a pond (Liberia) [© Y. Fermon].

- ⇨ **To keep the water in the pond at the optimal level**, usually the highest level designed for the pond;
- ⇨ **To allow the pond to be completely drained,** and the fish harvested, whenever necessary.

In addition to these major functions, a good drain should also ensure as much as possible that:

- ⇨ The pond can be drained completely in a **reasonable amount of time**;
- ⇨ When the pond is being drained, water

Photo H. Examples of filters at a pond inlet in Liberia [© Y. Fermon].

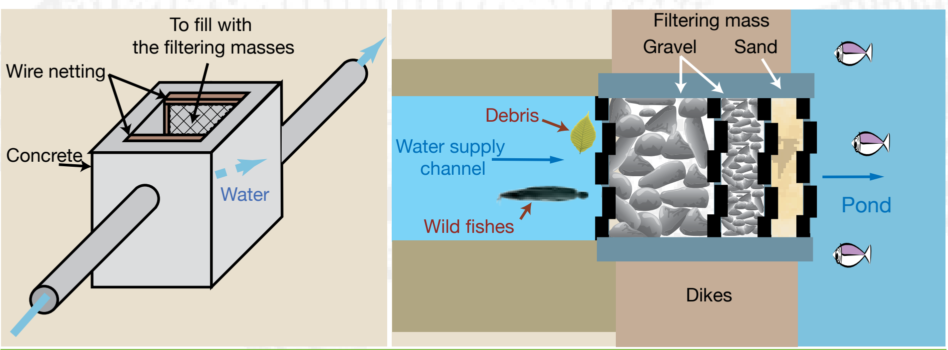


Figure 81. Diagram of a sand filter.

flow should be as consistent as possible, to avoid excessively disturbing the fish;

- ⇨ There is **no loss of fish**, especially during draining;
- ⇨ **Water can be drained** from the top, bottom or intermediate levels of the pond;
- ⇨ Any surplus water can be **drained off**;
- ⇨ The drain can be easily **cleaned** and **serviced**;
- ⇨ **Costs** for construction and maintenance are relatively low.

In most cases, drainage devices have three main elements:

✓ A **collecting area** inside of the pond, from which the water drains and into which fish is collected for harvest;

✓ The water **regulation device**, including drain plugs, valves, control boards, screens and gates;

✓ A device for draining water out of **the pond,** such as a pipe or an opening cut into the wall, and/or an overflow structure. In all cases, a protected area outside the wall must stop the draining water from scouring the walls of the drainage canal.

Pond outlets can be built in various ways, using materials such as bamboo, wood, bricks, cement blocks or concrete. There are four main types:

- ✓ Simple openings cut into the dike;
- ✓ Simple pipelines and siphons;
- ✓ Sluice dikes;
- ✓ Monks.

Several handbooks recommend that a simple pipe is enough; it can be made of bamboo, PVC, wood, iron or concrete and have a diameter of at least 100 mm for small ponds from 3 to 5 ares. The interior diameter of the drainage pipe will determine the structure's flow capacity. However, in practice, it appears that above 100 m^2, **a monk is most reliable** and allows better management of pond water. For the simpler ponds (storage, fish stocking), pipes can be used. Only these two prefered drainage methods will be discussed here.

VIII.2.1. PIPE DRAINS

The choice of pipe size and quality depends on the pond's surface area and the diameter required. A diameter of 5 to 10 cm is enough for ponds that are smaller than 100 m^2. Pipes can be made of bamboo, galvanized metal, or plastic (PVC). A drainage device can made of straight piping with a small diameter. It is important that pipes used for this purpose are installed at the lowest point of the pond, before the dike is built. Drainage structures made of rigid, angled pipe will control the height of water most effectively.

This type of pond drain is made of three parts, preferably with rigid plastic:

✓A slightly sloping base pipeline, made, for example, of one or more PVC pipes running through the dike,

✓A vertical pipe, which extends to the maximum water level;

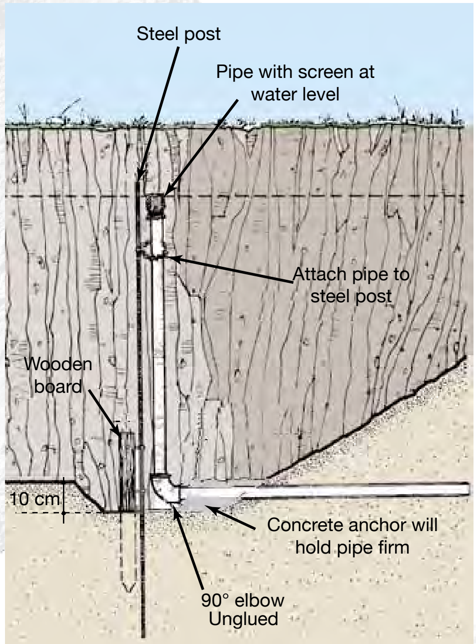
✓A 90°-bend, which connects these two pipes. It can be glued to the vertical pipe with plastic cement, but does not need to be unless the fit is very loose. The connection to the base pipe is not glued, but can be greased with a suitable material such as mineral grease, lard or palm soap.

This type of drain can be set up inside the pond, in front of the dike, or outside the pond, at the back of the dike, in which case a screen should be placed at the inner end of the base pipe. It is usually best to place the vertical pipe inside the pond to reduce the risk of blocking the horizontal pipe and to control leakage (Figure 82, p. 95).

If possible, the opening of the horizontal pipe should be at least 10 cm below the pond's lowest point. The vertical pipe can be carefully placed at a steel stake located in front, with a rope or a chain, which will stop it from moving accidentally. A closely-adjusted wire netting can be placed at the end of the vertical pipe.

To regulate the pond's water level, set the pipe at the required angle by turning it up or down. It should then be fixed into the set position with a chain or rope.

To drain the pond, turn the vertical pipe down steadily (gradually), following the dropping water level. When the pipe reaches the horizontal position, remove the bent pipe from the end of the horizontal pipe to stop the pond from draining anymore so that fish can be harvested.



This system can also be used to handle normal water overflow, since water that is above the selected pipe level will automatically drain.

VIII.2.2. MONK DRAINS

The monk sluice is one of the oldest and most common structures for draining ponds.

The monk is a drainage conduit that forms a U near the interior of the pond, and is extended at its base by a drain. Water is evacuated under the dike by this drain. The structure is built at the pond's deepest point, and includes two sides and a back. Two or three parallel grooves are arranged vertically on each side where small wood boards can be placed juxtaposed to each other and close the monk on the side that opens toward the interior of the pond. The space between the first two rows of small boards is filled with clay, making it watertight. In the third pair of grooves, grids serve as small boards and prevent fish from escaping while the pond is being drained. This third pair of grooves is very useful in practice, especially when drainage is almost finished. Indeed, when one reaches the

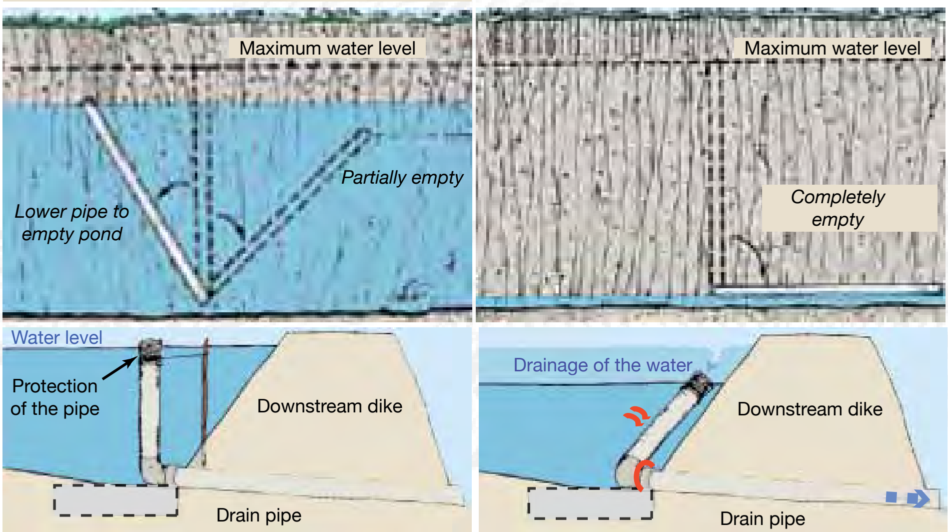


Figure 82. Turned-down pipe inside a pond drain.

last bit of water at the bottom of the pond, capturing fish gathered in front of the monk opening does not always leave time enough time to manage the first two pairs of small boards, and then presence of the grids in the third pair becomes useful.

The level of water in the pond is easily controlled and adjusted. It can function as overflow and simplify the fish harvest. In addition, a monk is easier to use, and more economical to build if the pond has a large dike. However, its disadvantage is that it is not very simple to construct, particularly if it is built with bricks or concrete.

The complete monk drainage system includes (Figure 83 below):

- ✓ A vertical three-sided tower (called the monk), usually built as high as the dike;
- ✓ A pipeline running through the dike, which is sealed to the back of the tower at its base;
- ✓ A foundation for the tower and the pipeline; and
- ✓ Grooves to fix the wooden boards and screens that form the fourth side of the monk.

Similar to any other drainage system, the monk is usually built on the side of the pond that is opposite the water inlet. It may be placed either in the middle of the dike or in the corner of the pond when the water drains into a catch basin shared by two adjacent ponds (Figure 84, p. 97).

The monk's foundation is built with consideration for subsequent water pressure on the structure, and especially for the levels at which gravitational drainage of the pond will be ensured. In any case, the base of the monk in front of the drainage pipe should be slightly lower than the lowest point of the base of the pond, and of course, higher than the maximum level of the drainage area.

The monk can either be built into the dike, or it can stand freely some distance into the pond (Figure 85, p. 97):

⇨ If the monk is built into the dike, water will leak through the dike more often and access to the outlet will be easier for poachers. To prevent soil from entering the monk, an additional protective wing will have to be built on both sides, but maintenance of the monk will be easier;

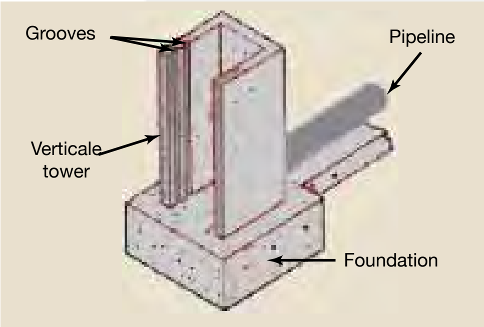
⇨ If the monk is built on the bottom of the pond in front of the base of the dike wall, a longer pipeline will be necessary. However,since the monk will be acessed through a removable catwalk, tampering with it will be much more difficult.

Monks can be built of wood, bricks or concrete, depending mainly on the materials available, their cost, local technical expertise, and the size of the structure.

A brick monk is the most difficult to build. It requires a very skilled mason to ensure that it is leak-proof. If it is not done properly, the mortar will have to be re-surfaced frequently, and maintenance costs will increase. Generally, wooden and concrete monks are cheaper and easier to build. Below are some points to remember when building a monk:

⇨ The pipeline should be laid down before the dike and the monk tower are built.

⇨ A solid foundation must be built to avoid future problems.



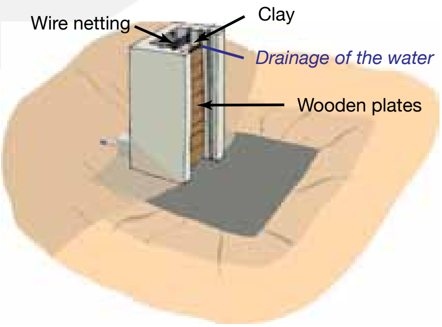


Figure 83. Composition of a monk.

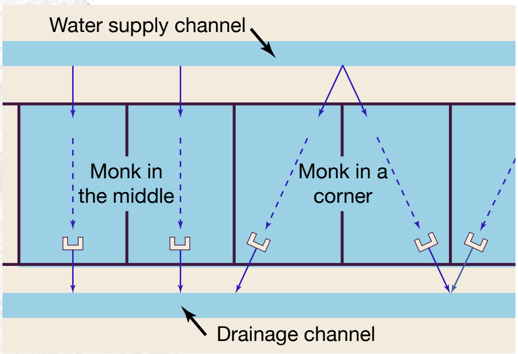


Figure 84. Position of a monk in a pond.

- The junction of the monk tower to its foundation, the junction of the pipeline to the back of the monk tower, and the finishing of the monk's grooves require particular attention.
- There should be a reasonable slope to the pipeline, preferably 1.5 to 2 percent.
- If several monks are built on the fish farm, their type and size should be standardized as much as possible; for concrete monks, strong forms should be prepared and re-used if possible.
- There should be a separate overflow area installed wherever it is possible that the entry of flood water cannot be controlled.

WOODEN MONKS

A simple monk can be built entirely of wood. This is the easiest and cheapest type of monk to construct, although it is important to ensure that it is watertight and durable. The height of a wooden monk should be limited to 2 m (Figure 86 below).

The monk should be built with a heavy and durable wood that is water resistant. Wood's durability can be improved through the application of discarded engine oil or a preservative. However, the wood must be washed before fish are put into the pond.

Small, 3 to 5 cm thick planks, without knots, should be used. So, approximately 0.4 m^3 of wood will be needed for a monk that is 2 m high.

In most cases, it is not necessary to plan foundations since monks are very light. However, if the ground is less stable, it may be necessary to use simple piles of wood for a foundation. Usually, a light foundation, such as paving flagstones, simple piles of wood, or broad boards placed flat on the bottom of the pond, is sufficient.

Both small- and medium-size monks are composed of boards nailed or screwed together, so that the side facing toward the pond is open. It is best to screw an anchoring post on each side of the column. These two posts should be inserted to a sufficient depth in the bottom of the pond, then screwed into the monk.

To make the structure more solid, it is possible to add a slanted brace to each side that will support the upper part of the column against the drain.

Instead of standard concrete or plastic, the drain can be built entirely of wood (Figure 87, p. 99). For this purpose, it is enough to assemble four boards from a rectangular box with nails or screws. A drain assembled this way can be carefully affixed to well-compacted soil and hidden under the dike.

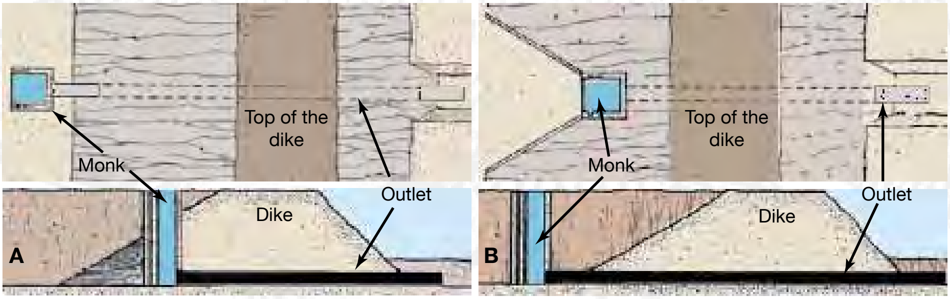


Figure 85. Position of the monk in relation to a dike downstream. A: Integrated into the dike; B: Inside the pond.

SMALL BRICK, CONCRETE BLOCK AND CONCRETE MONKS

Monks that are up to 1.5 m in height, fixed to pipelines up to 25 to 30 cm in diameter, can be built using single- thickness brick and mortar. Although taller and wider monks can be built, they require a double-width base and good bracing for stability and strength, so they are too heavy and expensive for most purposes.

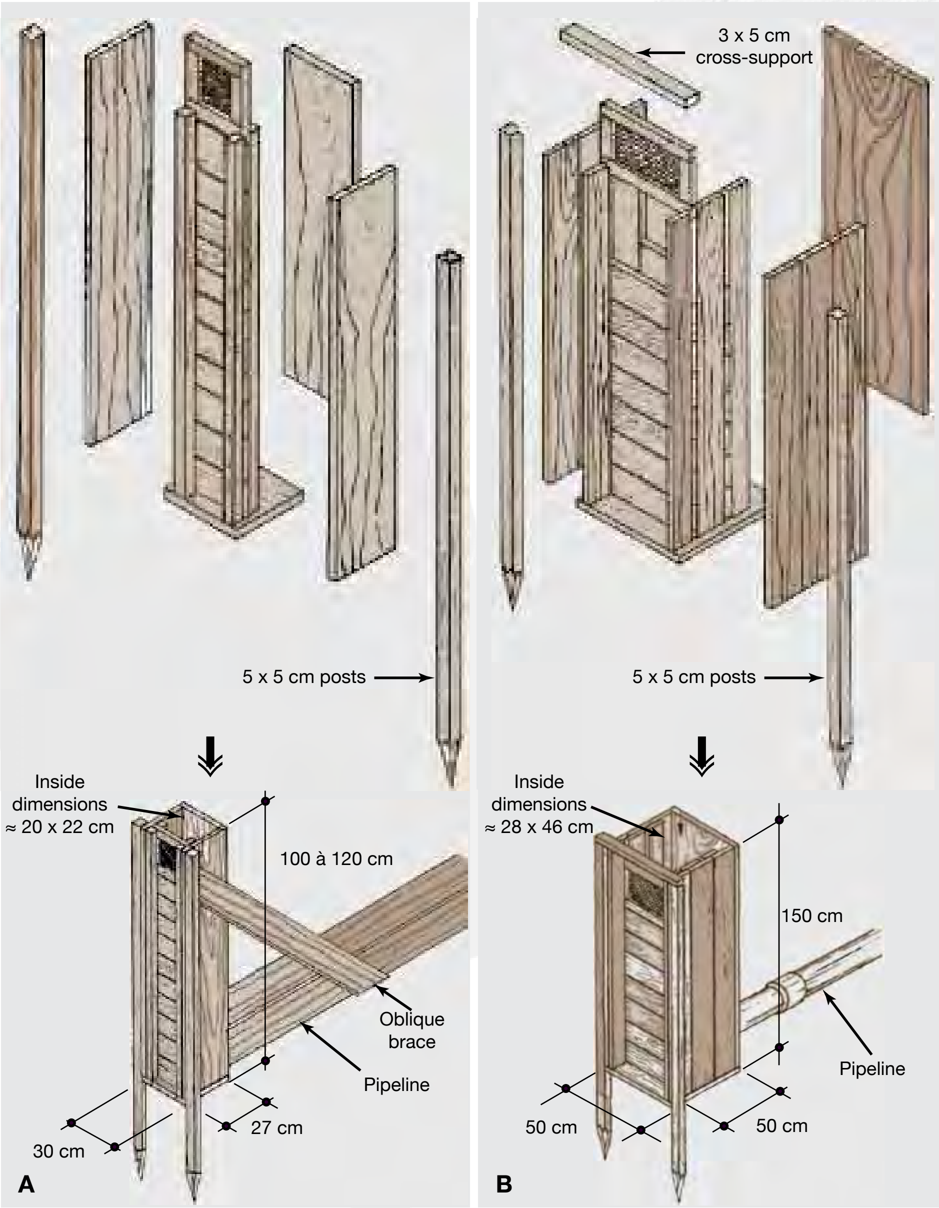


Figure 86. Wooden monk. Small (A) and medium (B) size.

Figure 87. Wooden pipe.

The rules of construction for small monks are:

⇨ Monks made of bricks and of cinder blocks must have interior surfaces that are carefully finished and coated. There are three major problems with this technique:

1. Cinder blocks are hollow and crumble quickly. Leaks, which are difficult to repair, appear on the aging monks.

2. The monk is often unnecessarily tall in proportion to the amount of flow that the pipe can drain off (so rather long and relatively expensive boards are required to close the monk).

3. It is impossible to construct two monks of the same width that can use the same grids or the same boards.

On the other hand, construction is not expensive.

⇨ For concrete structures, it is necessary to request the services of a qualified mason. The quality of the work must be excellent in order to guarantee its durability.

At the beginning, the construction of the frame was done on site, which made it possible to pour the concrete into the shape of a monk on release from the mould. This technique presented a difficulty at the time of implementation. The construction of the mould on the spot proved to be delicate, dismantling it sometimes hazardous, and recovery of the boards problemmatic. These problems significantly increased the cost of construction. The monks were generally of different sizes but were much more solid.

Since then a better solution has been found: reusable molds that can be dissassembled (Figure 88 and Photo I, p. 100). This solution guaranteed that dimensions would be standardized. However, the first moulds were rather heavy to transport. When fish farmers invested in the search for sand and gravel, these monks were in the end less expensive than ones made of cinder block. Then, this type of scaffolding underwent major changes. In particular, the mold can now be transported by just one person on foot or on a bicycle. The wooden scaffolding is coated internally with oil (such as waste motor oil from vehicles), and is constructed above the foundation in order to pour the wings and the back of the monk.

As an indication, the dimensions presented in Table XVII, p. 100 can be adopted, depending on the size of the pond. Thus, for a pond of 0.5 to 2 ha, the frame to be poured should have: 2 m of height, 0.7 m of width across the back, 0.54 m for the wings and 0.15 thickness. The mixture of the concrete to be used will be 1 volume of cement for 2 volumes of fine sand and 4 volumes of gravel. That is, for the monk described, 4 cement bags, 4 wheelbarrows of sand and 8 wheelbarrows of crushed stone will be necessary.

A monk's flow capacity is a function of the drain's internal diameter. The cross section of the monk increases with the drain's diameter (Table XVIII, Table XIX and Figure 899, p. 101).

The following points are important:

⇨ The interior width of the column must be equal to the diameter of the drain plus 5 to 10 cm on each side;

⇨ There must be a space of at least 8 to 10 cm in front of the first groove;

⇨ The two series of small boards must be separated by an interval of at least 8 to 10 cm;

⇨ The distance between the last series of small boards and the back of the column must all become larger as flow capacity increases, without, however, exceeding a maximum value of 35 to 40 cm.

To facilitate the operation of the small boards, it is best to limit the monk's interior width to a maximum value of 50 cm.

Maintenance of the mold requires minimal attention. It is best to store it assembled so that it does not become deformed, and to coat it as soon as possible with engine oil. If used well, a mould

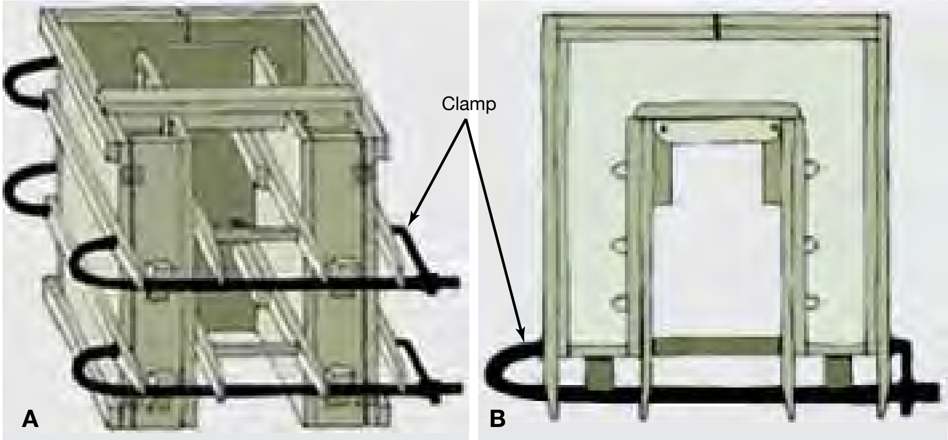


Figure 88. Mold for a monk. A: Front view; B: Upper view.

can make more than 20 monks.

If some iron rods are left in the fresh concrete to link it to the following stage, it is completely possible to build, by stages, a monk of more than 2 m (Photo I, below and Photo J, p. 102).

The soil used between the small planks to block the monk must be rich in organic matter in order to keep its plasticity. Clays that are too pure often crack on the side of the tube, so it doesn't take long for leaks to appear.

The amount of water in the pond is regulated by the monk, thanks to the small wooden boards

Table XVII. Information on the dimensions of a monk in relation to the size of the pond.

Surface of the pond	S < 0.5 ha	S > 0.5 ha
Height (m)	1.50	2.0,
Back width (mi)	0.54	0.70
Sides width (m)	0.44	0.54
Depth of concrete	0.12	0.15

Photo I. Mold and monks (Guinea). On left: The first floor and the mold; On right: Setting up the second floor [© APDRA-F] (CIRAD).

Table XVIII. Estimation of discharge and duration of pond drainage in relation to the diameter of the drain.

Diameter (cm)	Discharge (l/s^{-1})	Discharge (m^3/h^{-1})	Time for a pond of 4 ares (Mean depth: 1 m) to drain
10	8	28.8	13 h 53
15	18	64.8	6 h 11
20	31	111.6	3 h 35
30	70	252	1 h 35
40	130	468	52 mn

between which clay is packed (Figure 90, p. 102). Water is retained in the pond by this impermeable layer up to the level of the highest small board.

Netting at the top of the last small board prevents fish from leaving the pond over the highest small board of the monk. The netting's mesh should always be smaller than the fish raised in the pond.

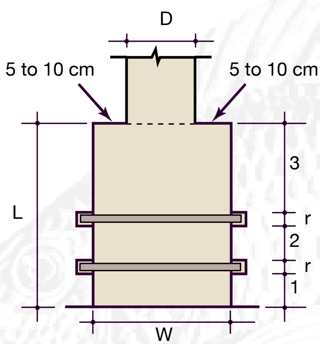
When the pond is filled to the last small board, all the water that enters the pond, crosses the grid above the impermeable layer and falls to the bottom of the monk. From here, it crosses the dike and leaves the pond, passing through the drain (Photo K, p. 102).

Once the monk has been built, it must be equipped with foundations called soles. The sole serves also as a hard surface from which remaining fish can be retrieved.

Monks of this type generally have drains, made either of PVC or of concrete tubes. For best results, the drain should have a strong foundation, constructed at the same time as the monk's column (Figure 91 and Photo L, p. 103). The drains must be carefully sealed to avoid leakage.

In wet environments, the abundance of water compensates for the risk of leakage, so concrete tubes are a good idea:

- They are cheap. Two bags of cement are enough for 10 m of tubing, plus half a bag for the seals;
- Their section allows a higher capacity than that of a pipe with a diameter of 100 or 120 mms;



W = Width
D = Diametre of the pipe
L = Lenght
r = Grooves

W = D + 2x (5 to 10 cm)
L = (1) + (2) + (3) + r + r
(1) = 8 to 10 cm
(2) = 8 to 10 cm
(3) = maximum 35 to 40 cm
r = 4 cm each

Table XIX. Interior dimensions of a monk in relation to the diameter of the pipe.

	Pipeline: interior diameter (cm)			
	10-15	15-20	20-25	25-30
Internal width	30	33-35	40	48-50
In front of groove 1	8	10	10	10
Gap between grooves 1 and 2	8	10	10	10
Distance between groove 2 to wall	16	16-20	26	34-37
Width for two grooves	8	8	8	8
Internal length	40	44-48	54	62-65

Figure 89. Monk. Upper view and example of size.

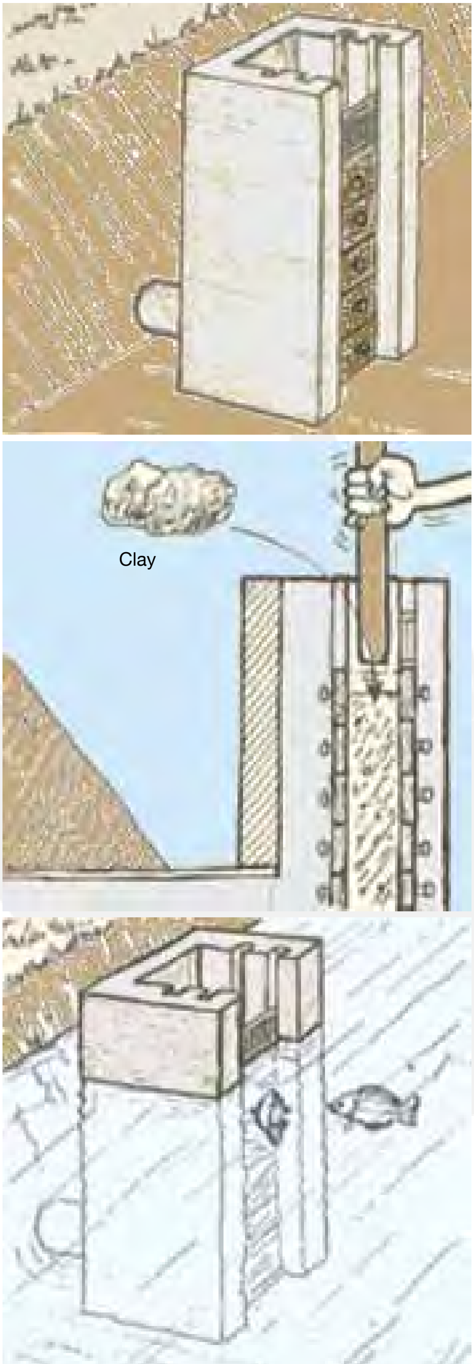


Figure 90. How a monk works.

Photo J. First floor of the monk associated with the pipe (Guinea) [© APDRA-F](CIRAD).

Photo K. Top of a monk (DRC) [© Y. Fermon].

⇨ The tube's flat bottom helps to accelerate final drainage, which is very practical;

⇨ It is easy to add a tube when you need to.

However, there are also some disadvantages to the concrete tubes, particularly in dry zones. Here are some recommendations:

⇨ The mold must be manufactured well and maintained correctly so that the junctions interlock and remain in place;

⇨ It is best to assemble the tubes before building the dike, since it will then be easier to divert the water. They can then be installed on dry, hard soil rather than in mud;

⇨ Tubes should be buried well under the slope so that when the fish farmer goes monitor his monk, the tube covers do not get loosened;

⇨ Along the tubes (as along the pipes) there is an area of weakness; earth should be carefully packed down around this area, If it isn't, there is a big risk of infiltration.

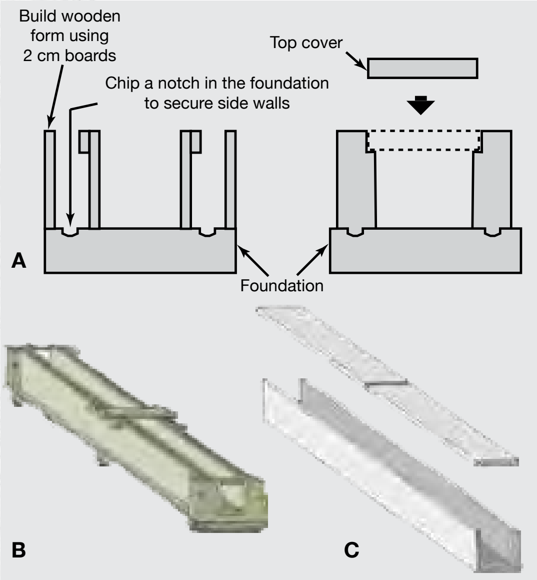


Figure 91. Concrete pipe. A: Cross cut; B: Mold; C: Final pipe.

Photo L. Building a pipe (Guinea) [© APDRA-F](CIRAD).

VIII.2.3. ADDITIONNAL OVERFLOW STRUCTURES

For safety reasons, pond water must always be prevented from exceeding its maximum level and flowing over the dike. Any excess water that enters an already-full pond - flood water or rain fun-off, for example - must be immediately and automatically drained. If a dike overflows most of the fish stock would be lost and major repairs would be required before the farm could begin to operate again.

In the case of a diversion pond, where most overflow is diverted at the diversion structure, a draining device such as an open vertical pipe or a monk will drain overflow automatically. However, it is important to keep all the grids clean. A monk also ensures the function of overflow. An additional pipe may be installed to compensate for a grid that has become blocked by detritus due to poor maintenance.

During heavy rains, there may be an excessive amount of surface runoff, particularly in barrage ponds or ponds built at the bottom of large sloping areas with little vegetation cover. In these cases, runoff water is often heavily loaded with fine soil particles that make it very turbid. If the runoff runs over cultivated areas, it might pick up toxic substances such as pesticides. To stop this water from reaching your fish farm, you will have to build one or more protection canals

If the pond is deprived of a free-flowing drainage device, or if this device is too small, and if the amount of excess water is always limited, you may install an overflow pipe of bamboo, PVC or galvanized iron (Figure 92, p. 104). It is best to use one-piece pipes that don't have any joints. If the pipe sags, or extends too far out from the side of the dike, you may need to put up some simple wood or bamboo pipe supports.

VIII.3. SEDIMENTATION TANKS

A sedimentation tank (or settling basin) is specifically designed to improve water quality by removing mineral and soil particles, such as fine sand and silt, that can be present in large quantities in highly-turbid water. Sedimentation tanks reduce the velocity of the water flow enough to allow the particles to settle.

There are different types of sedimentation tanks (Figure 93, p. 105):

- ✓ A simple small pond, constructed at the mouth of the water supply canal;
- ✓ A rectangular basin built on the feeder canal with bricks, cement blocks or concrete (Figure 94, p. 106).

If the sedimentation tank is a simple rectangular basin, the size will be determined as follows:

- ➢ **Minimum horizontal area**: Consider, for example, a particle with a diameter greater than or equal to 0.1 mm, in water flowing at 0.030 $m^3.s^{-1}$. To get these particles to settle, the sedimentation tank's minimum horizontal area will be 5.6 m^2. In these ideal conditions, 100 % of particles that measure 0.1 mm or larger should settle. A smaller proportion of smaller particles will also settle. The smaller the particles, the lower the percentage of them that will settle.
- ➢ The **minimum cross-section area** would be 0.3 m^2 in the preceding example.
- ➢ The **minimum width** would be 1.2 m in the preceding example.
- ➢ The **standard length** would be 4.6 m in the preceding example.
- ➢ The **depth**, which is the sum of the water depth (0.25 m), the freeboard (0.20 m) and the settling depth (from 0.10 to 0.20 m), would be 0.60 m in the preceding example.

The sedimentation tank could also be wider, and have a larger cross-section. In this case, the standard length could be shorter. As long as critical velocities are not exceeded, the basin can be shaped to fit local space and minimize construction costs. As a general guide, ratios of length: width are typically between 2:1 and 5:1.

The bottom of the sedimentation tank is built below the bottom of the water supply canal, so that soil particles become concentrated and can be removed from the arriving water.

The above design can be improved in the following ways:

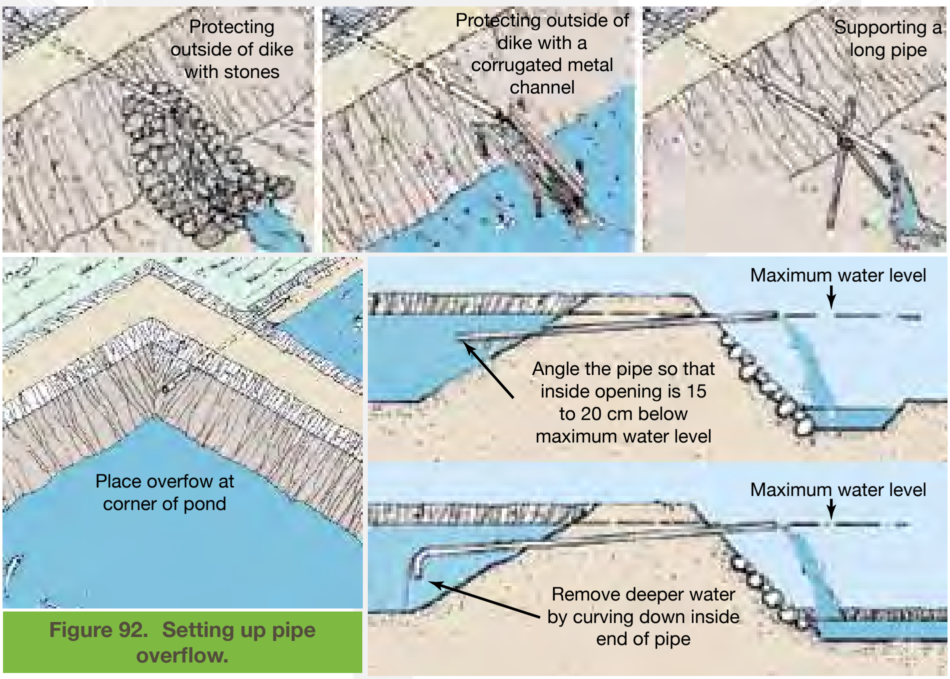


Figure 92. Setting up pipe overflow.

⇨ At the entrance, the water should pass over a wide edge near the basin's surface, to minimize disturbances.

⇨ Similarly, at the exit, the water can be spread over a wide edge near the basin's surface.

⇨ Exposure to cross-winds should be avoided, since they can agitate the water and make settled particles float again.

⇨ Inside the basin, deflectors can be added to slow the water down further and make it follow a longer, zig-zagging path. If these deflectors are installed, the length of the basin can be reduced by one third.

⇨ Water should flow evenly and quietly through the sedimentation tank. The creation of turbulent or rapid flow areas should be avoided.

⇨ The bottom should slope (slope = 2 percent) from the downstream end to the entrance of the basin.

The sedimentation tank must be regularly cleaned by removing accumulated soil from the bottom when the water supply has been cut off. This soil should be removed more regularly using a simple pipe or siphon. Usually, the soil is very fertile, and can be used to fertilize crops in gardens and fields.

IX. ADDITIONAL INSTALLATIONS

IX.1. EROSION PROTECTION

Once the pond has been dug and various structures are in place, the dikes must be protected from erosion, by planting grass across the upper part, at the top, on the dry side and on the wet side up to thepond's normal level of water (the freeboard) .

To do this, a 10 to 15 cm layer of topsoil should be spread over the area to be turfed (Figure 95, p. 106). Topsoil can be obtained either from soil extracted when the pond was dug, or in the nearby vicinity. Cuttings or turf should be planted in relatively close intervals. The area should be watered immediately after planting and in regular intervals thereafter. As soon as the grass is established, it should be cut short regularly, which will stimulate its growth over the entire surface.

If it rains heavily, the area should be covered with a temporary protective system, such as hay or other material, until it is completely covered with grass.

Space around the dikes (Figure 96, p. 107) can be used to grow kitchen gardens or fodder plants (A). However, species should be carefully chosen; they must ensure adequate ground cover and have a root system that penetrating too deeply into the ground, which would weaken the dike or alter its structure. Only small animals should be allowed to graze or circulate above the area (B). Finally, trees should not be planted on the surface or near the dikes, because the roots would weaken their structure (C).

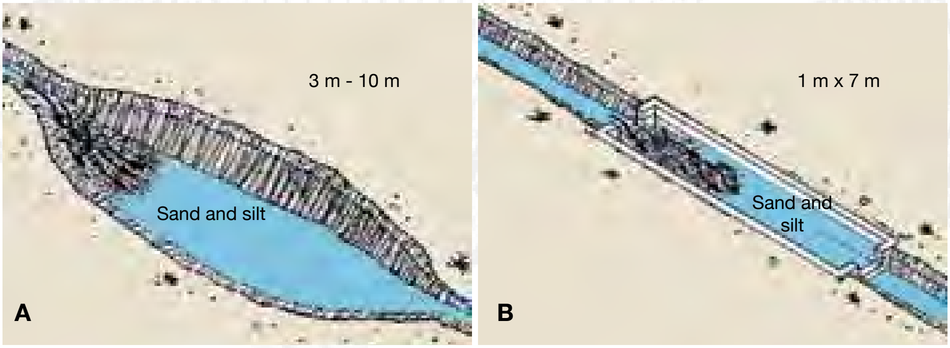


Figure 93. Types of sedimentation tanks. A: Natural; B: Concrete.

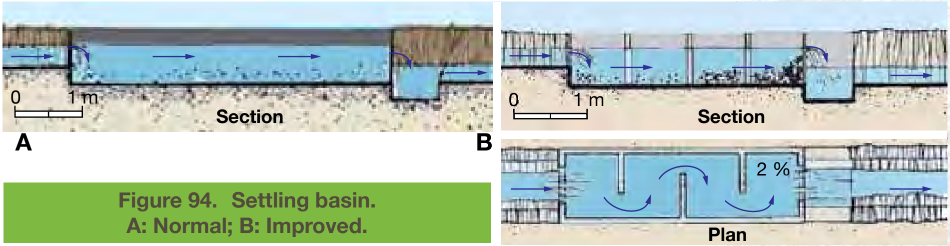


Figure 94. Settling basin.
A: Normal; B: Improved.

IX.2. FIGHTING EROSION

When ponds are installed, it is particularly important to know the risk of erosion in the catchment area. Soil erosion has negative effects on water quality and on fish farming facilities. When water runs down a slope, it picks up particles from the ground. The stronger and faster it flows, the more particles it picks up and carries away. Erosion can cause:

⇨ Serious degradation of the slope and soil properties, which reduces soil fertility;

⇨ Accumulation of turbid water at the bottom of the slope and problems with soil being deposited elsewhere.

As much as possible, erosion of the soil on slopes should be controlled to prevent turbid water from flowing into ponds (Figure 97, p. 107). This practice, called soil conservation, can generate significant advantages:

⇨ Richer soil on the slopes and increased production of products such as wood, fruits, fodder or food;

⇨ Higher quality pond water and greater production of fish.

Vegetation protects the ground against erosion. Plant roots stabilize ground particles and increase the permeability of the sub-base. The organic matter that vegetation adds to the ground, such as humus, increases resistance to erosion and makes water flow more slowly. It can also contribute to deposits of soil particles.

The correct arrangement of natural vegetation across the slope will guarantee greater resistance to erosion. In forest areas, ground cover should be maintained as much as possible through careful management of the exploitation of trees and protection of the forest against excessive grazing and fires. Forests that have good low-lying vegetation, well disseminated root systems and good leaf cover offer the best conditions. In savanna areas, use of fire for the regeneration of grazing grounds should be controlled, and fires should be used earlier in the season in order to guarantee sufficient new growth before the rains begin. Excessive grazing, particularly by sheep and goats, should be avoided. Rotation of pasture should be planned as soon as possible.

If you cannot fight erosion, you may have recourse to a protection canal that will collect and divert turbid water or, if necessary, use a sedimentation tank to improve the quality of the water supply (paragraph VIII.3, p. 103).

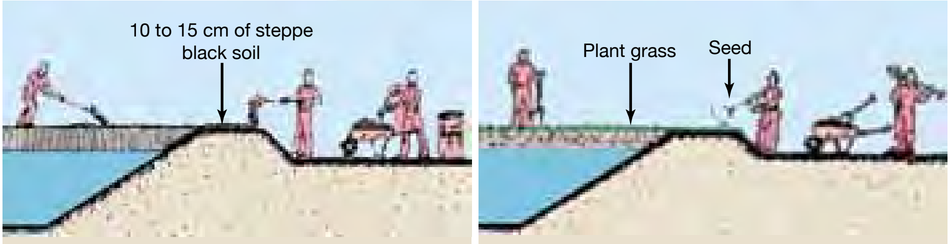


Figure 95. Planting vegetable cover on a dike.

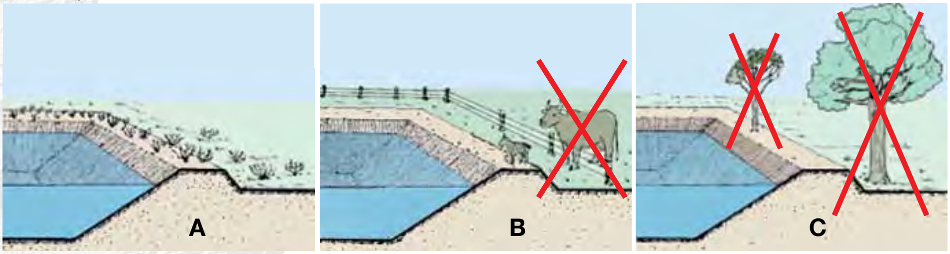


Figure 96. Planted dikes. A: Vegetable garden; B: Small animals; C: Trees.

IX.3. BIOLOGICAL PLASTIC

If the soil being used allows water seepage, it will be necessary to use "biological plastic" to reinforce the sealing at the bottom of the pond. This technique reduces leaks and infiltration by filling the base and the dikes of a pond that is built on soil that is not completely impermeable. Biological plastic is used in the following way:

1. After stabilizing the structures by removing vegetable debris and stones, the entire base and the water side of the dikes are covered with waste from a pigsty.
2. The waste is covered with banana leaves, straw or other vegetable matter.
3. A layer of dirt is spread over the whole thing and packed down well.
4. Two to three weeks later, the pond can be filled with water.

IX.4. FENCING

Fencing prevents all species of predators (snakes, frogs, otters, etc.) from entering the pond enclosure (Figure 98 and Photo M, p. 108). It can be composed of netting buried to a depth of at least 10 cm, with the higher end turned toward the pond. Stakes made of metal or wood that will not rot easily should be built with supports of 50 - 90 cm, and the grid is fixed to them with fastening wire. If bamboo is used in a tropical area, it should be replaced after no more than 18 months. Materials other than netting can be used.

There should never be holes in the fence's perimeter. The fence also serves to limit poaching, which is one of the main reasons that ponds are abandoned. Use of the access doors in pond enclosures must be controlled well.

If there are a lot of fish-eating birds in the area, a coarse net may also be installed on the ponds, or scarecrows can be used.

IX.5. FILLING THE POND AND TESTING THE WATER

It is best to fill the pond as soon as possible, in order to:

⇨ Check that all structures are functioning properly, including the water supply, the canals, and pond inlets and outlets;

⇨ Check that the new dikes are sufficiently strong and impervious;

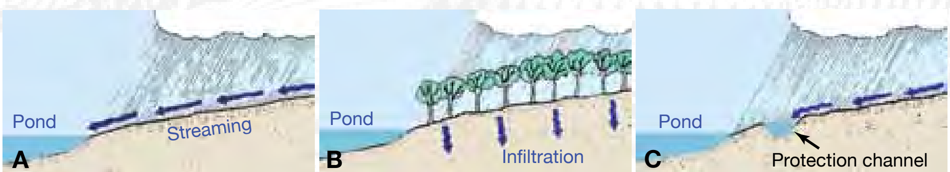


Figure 97. Types of erosion and soil conservation. A: Streaming; B: Infiltration; C: Protection canal.

⇨ Accelerate the stabilization of the dikes.

For maximum security and efficiency, proceed in the following way:

1. Fill the pond with water very slowly, to a maximum depth of 0.40 m at the outlet.
2. Shut off the water supply and keep the water in the pond for a few days. During this period, check the dikes carefully. Repair crevices and collapsed sections, making sure that the earth is compacted well.
3. Drain the water completely and leave the pond dry for a few days. Keep checking the dikes and repair them as necessary.
4. Fill the pond again very slowly, to a maximum level about 0.40 m higher than previously.
5. Shut off the water supply. Check the dikes and repair them as necessary. After a few days, drain the pond completely.
6. Repeat this process of filling/drying until the water level in the pond reaches its maximum level.
7. Check and repair the dikes as necessary.

X. NECESSARY RESOURCES

X.1. MATERIALS

The initial stage of prospecting and staking out the site requires the following materials:

- ✓ Stakes
- ✓ String and ropes
- ✓ Decameter
- ✓ Machete
- ✓ Sledgehammer
- ✓ Level or, if possible, a theodolite or automatic level
- ✓ Paper and pencils

Once the materials have been assembled, it is necessary to write out detailed descriptions of the work to be undertaken which refer to the topography and to the designs to be used. Separate sets of instructions should be written for excavation and structures, as indicated below:

Photo M. Setting up a fence with branches (Liberia) [© Y. Fermon].

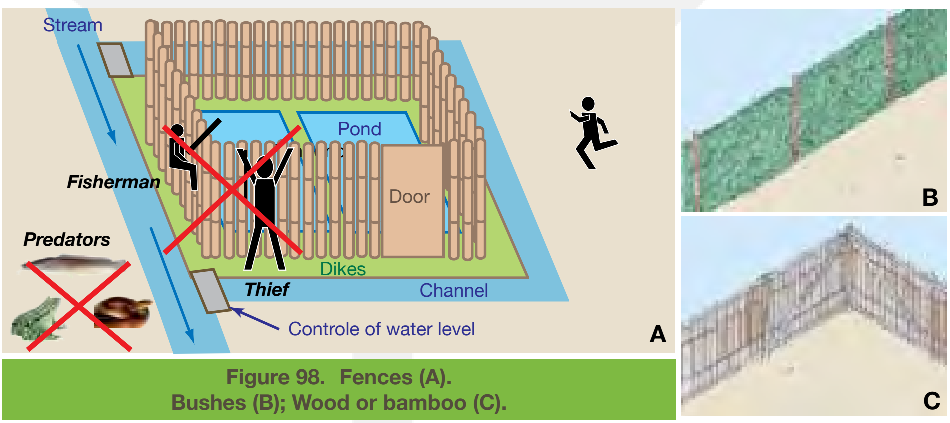


Figure 98. Fences (A).
Bushes (B); Wood or bamboo (C).

1. **Descriptions of excavation work**:

(i) Plan for preparing the ground of the site, particularly the complete clearing and uprooting of vegetation, and handling and placement of cleared vegetation;

(ii) Plan for removal of the topsoil layer, including indication of its surface area, its thickness, and where it will be stored;

(iii) Plan for construction of dikes, indicating the source and quality of the soil as well as its characteristics;

(iv) Plan for compacting the dikes, including instructions on the maximum thickness of layers, ground moisture, and the capacity and type of equipment to be used.

2. **Descriptions of the structures**, indicating the types and characteristic of materials that will be used in each case, such as:

(i) Reinforced concrete: type of proportioning, limits to observe during testing of settling, types of reinforcements, cleaning methods, scaffolding;

(ii) Wood: detailed list of species, treatment, relative humidity, conditions of storage;

(iii) Bricks or cinder blocks: quality, exterior finish, standard, weight, conditions of storage;

(iv) Pipes: type, material, storage, handling, fitting;

(v) Mortars and coatings, additives, water, etc.;

(vi) Painting: number of layers, type of paint.

For building work that will be carried out by hand, simple tools are necessary:

Hoe, shovel, machete, pickaxe, wheelbarrow and/or basket, coupe-coupe, buckets, axe, heel bar, spade, roll of wire, plumb level, compactor, hammer, sledgehammers, decametre, saw, screw clamp.

Materials that will be used and consumed:

- ✓ Planks of wood,
- ✓ PVC or galvanized iron pipe,
- ✓ Concrete,
- ✓ Sand,
- ✓ Gravel,
- ✓ Concrete-reinforcing steel,
- ✓ Stakes,
- ✓ Banana leaves,
- ✓ Waste oil,
- ✓ Paint.

In most cases, the only necessary resources will be PVC pipe and concrete. Since concrete may not be readily available, local brick or can be used, or wood that has been treated so that it can be immersed in water. Time between repairs can be reduced with concrete monks, which can last more than 20 years.

X.2. HUMAN RESOURCES AND TIME REQUIREMENTS

Work can be done by the beneficiaries and their family members, with the assistance of friends if necessary. To speed up construction time, day workers may also be contracted to dig the pond by hand for a fixed price based on the volume to be excavated. The surface area of each pond is usually no larger than 400 m2 of surface area. Knowing the volume to be excavated, you can estimate how much time each pond will require and, if necessary, calculate the price for sub-contracting this task.

Work standards for hand excavation will depend mainly on the nature of the ground. The harder it is to work, the lower productivity will be. If there is excess water, it will also reduce productivity, particularly if heavy, sticky clay is present.

Table XX, p. 111 provides estimates of the time it will take to complete each section of work. Estimates vary considerably and are presented only as an indication. For example, a pond of 200 m^2 took 20 people 20 full days to complete, or a total of 400 man-days (8 work hours per day) in Liberia. In Cameroon, complete development of 2 ha with 15 ponds of 400 m^2 each, an enclosure of

10 x 10 m^2, an office plus a store of 150 m^2, 5 hen houses and 5 pigsties, required 226 man-days per pond, or a total of 3,435 man-days for the entire project.

Work standards for excavation by hand are presented in Table XXI, p. 111. These estimates represent average output for excavation and throwing the dirt 1 m away that can be expected from an average worker excavating during one eight-hour day. Minimal values assume use of a hoe and maximum values assume use of a pickaxe and shovel under similar conditions. These outputs must be slightly reduced if throwing distance increases. For excavation and shaping of canals, the output of a qualified digger varies from 0.8 to 1.2 m^3 per day. You can estimate how long the work will take overall, but for each case, this estimate should be recalculated according to available resources (Table XXII, p. 111). If there are enough workers at the site, several stages can be done at the same time.

It is best that excavation be done when construction costs are lowest. The dry season is the most favorable time, particularly the end of the season for excavation. During this season, the soil's bearing capacity is better and swamps are not saturated with water. To schedule the work, design a calendar showing the scheduling of each task (Table XXIII p. 111).

Table XXXVI, p. 169, provides examples of management of 4 ponds constructed over approximately one month (400 men per day). Cleaning can take less time if there are enough laborers to cover several building sites at the same time.

Table XX.Examples of time estimates for building ponds (man/day).

	1 pond of 400 m²	2 ponds of 200 m²	4 of 400 m² and 2 of 100 m²
Main water supply	130	266	130
Water supply canal	50 (200 m)	50 (200 m)	70 (270 m)
Excavation/construction of dikes	600 (150 m³)	1600 (400 m³)	3600 (950 m³)
Inlet/Oulet	5	4	90
Total Time	**785**	**1920**	**3890**

Table XXI. Approximate output for excavation by hand.

Nature of the soil	Volume excavated (m³/j)	
	With hoe	With pickaxe / shovel
Soft (deposits, sandy soil)	2.5 – 3.0	3.5 – 4.0
Moderately hard (silt, light clay)	1.5 – 2.0	2.5 – 3.0
Hard (heavier clay)	1.0	2.0 – 2.5
Lateritic, moderately hard	0.5	1.0 – 1.5
Water-saturated	0.8 – 1.5	1.5 – 2.0

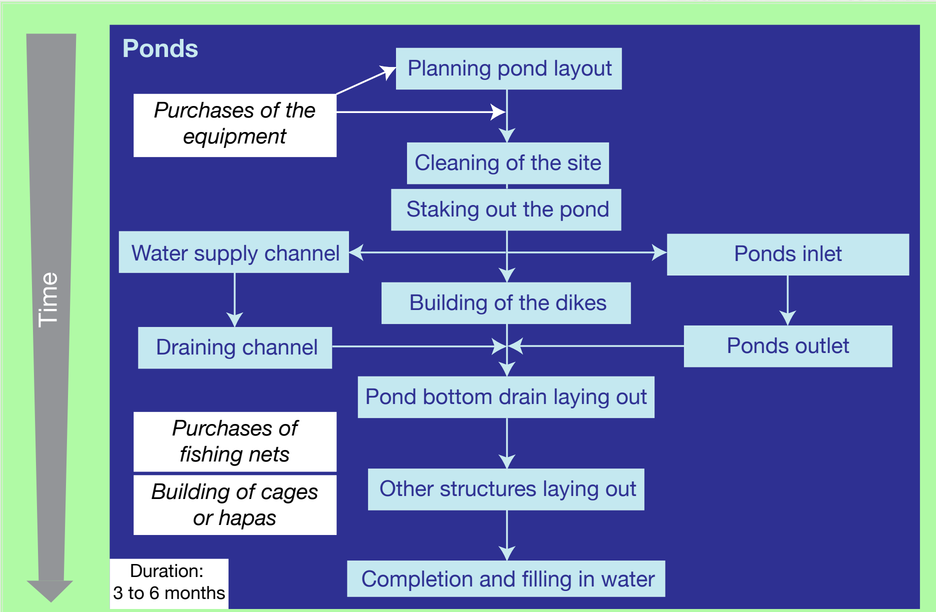
Table XXII. Example of a calendar of work for pond construction (400 workers per day). Activities shaded.

Activities/Week	For 3 or 4 ponds								For 1 or 2 ponds			
	1	2	3	4	5	6	7	8	1	2	3	4
Clear vegetation	■								■			
Remove topsoil		■							■			
Dig supply canal	■	■								■		
Build main water intake		■	■							■		
Build the main draining structure			■							■		
Build the outlet			■								■	
Build the inlet			■								■	
Build the dikes				■	■	■	■				■	
Finalise the pond								■				■

Table XXIII.Example of calendar following the seasons (15 ponds) in Cameroon.

Activity/Month	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept
Clear the site	■												
Topographic plan		■											
Design setting			■	■									
Water supply			■										
Excavation work				■	■	■	■						
Other							■	■	■	■			■

XI. SUMMARY



- **All necessary operations are summarized in the following figure:**
- **One should emphasize:**
  - ***Clearing* of the site, which must be done well**
  - ***Staking,* which must be precise for the slopes**
  - **Using canals to control and manage water**
  - **The importance of *dikes*, including their strength, size and compaction**
  - **The choice of a *monk* for draining ponds**
  - **Better control of ponds through t*otal isolation* from the outside**
  - ***Conservation of soil* upstream**

Chapter 08
BIOLOGICAL PROCESSES

Now that the pond is filled with water, biological processes can begin (Figure 100, p. 114).

A pond is a self-perpetuating environment-- it will feed on itself. However, the life cycle must be nurtured in order to begin and develop.

Once the pond is constructed, the next stages will be:

12. Fertilization

13. Waiting for « green water »

I. LIFE IN A POND

A pond is a small ecosystem encompassing several levels of the food chain, including microorganisms and algae, plankton, insects and their larva. At the top of the food chain are the fish, which, as the most important component, should be grown in the optimal way (Figure 99 below).

Photosynthetic plant organisms are the only living organisms that can transform mineral matter into organic matter. The development of complex molecules requires energy, which plants collect from sunlight. Organic matter is initially produced from minerals by photosynthetic plants. Thereafter, it can be assimilated and transformed by animals. Animals consume organic matter in order to grow, as they are unable to develop from minerals. By this process, organic matter (vegetable debris, waste matter, and animal cadavers), is decomposed, mineralized, and turned into mineral matter. It is estimated that 1 kg of phytoplankton is necessary to grow 10 g of fish such as tilapia (Figure 101, p. 115). The population of organisms at each level of the food chain must be larger than that of its consumers in order for it renew itself.

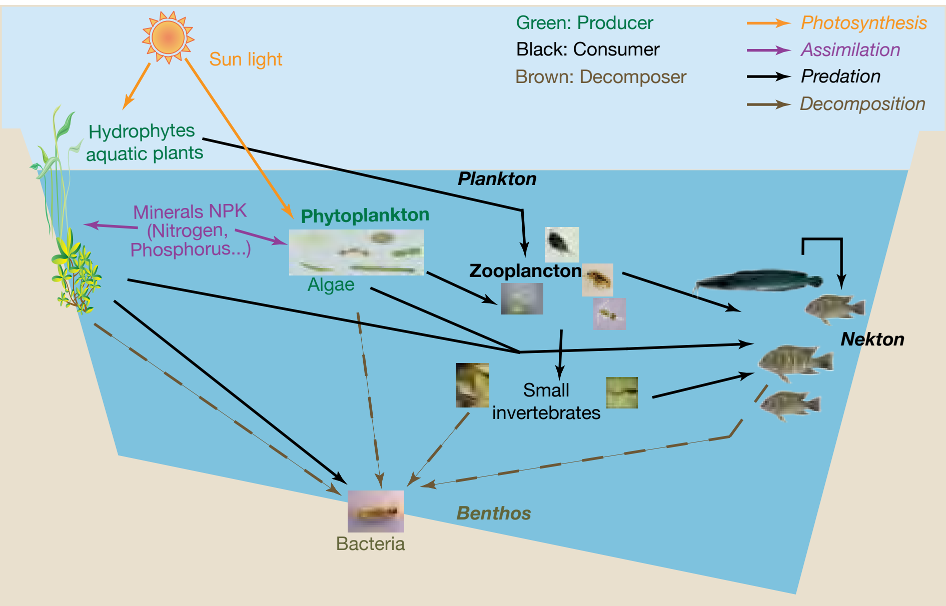


Figure 99. Schematic life cycle of a pond.

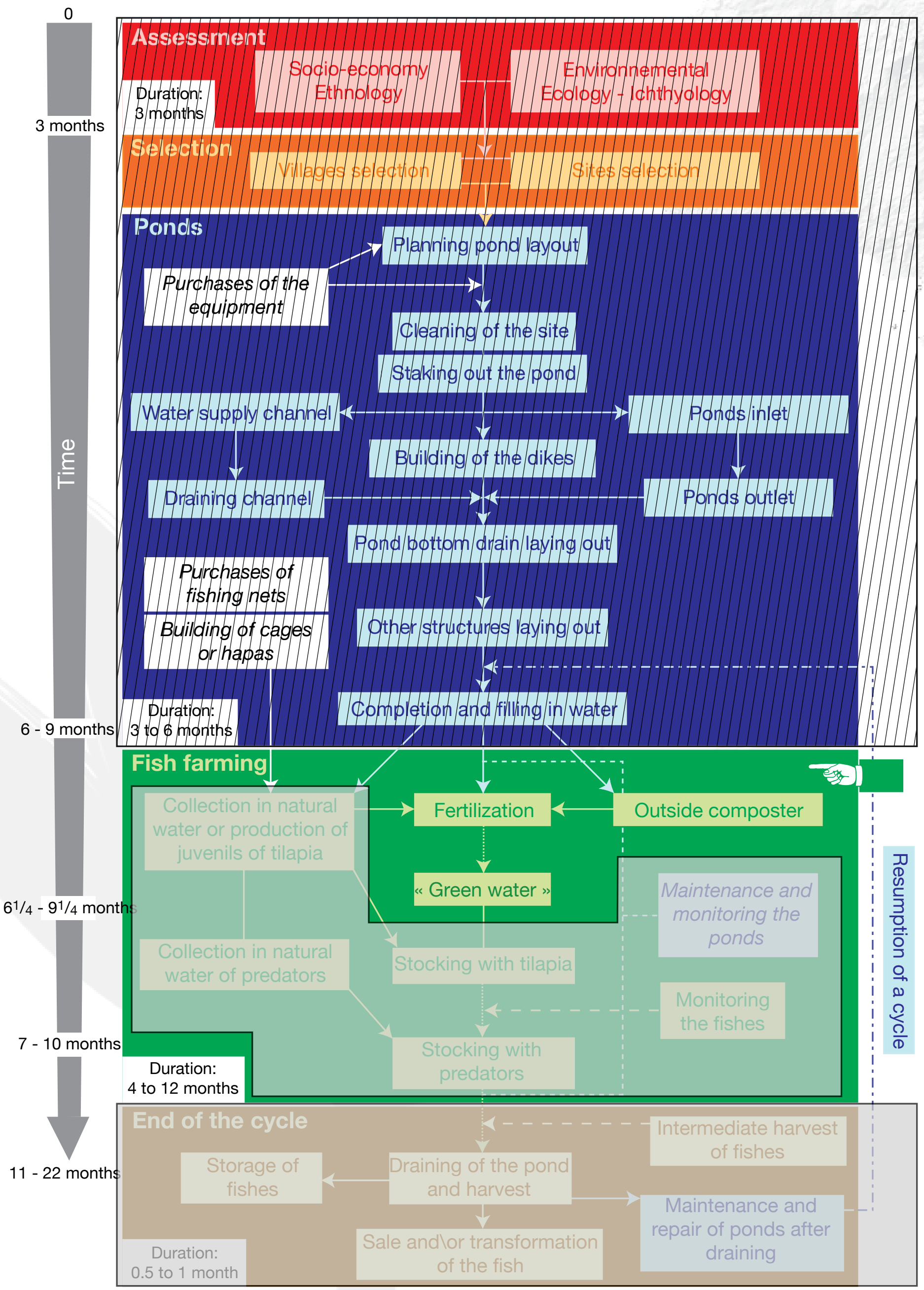


Figure 100. Setting up fish ponds: 4. Fish farming.

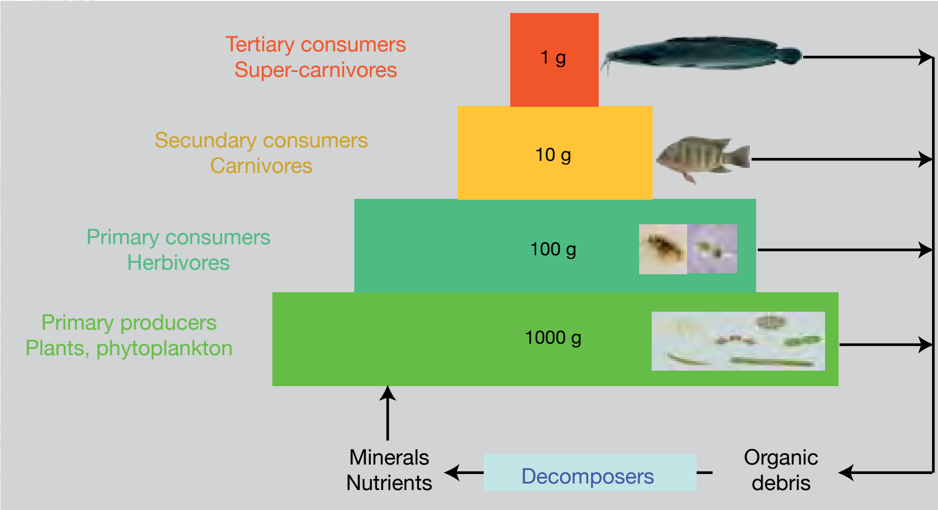


Figure 101. Trophic pyramids.

I.1. PRIMARY PRODUCERS

The most important group of vegetable organisms in a fish pond is **phytoplankton**. This group includes a wide variety of aquatic algae that move freely in water (without substrate). These algae are composed either of one cell (unicellular) or several cells (pluricellular; Figure 102 below). If there is a lot of algae in the pond, the water will have a blue-green to maroon-green color. Phytoplankton has two very important functions in a fish pond. First, it is an oxygen producer, and second, it is the first link in the pond's food chain.

Algae are photosynthetic organisms that convert light energy into chemical energy, while consuming carbon dioxide (CO_2) at night, and producing oxygen (O_2). This process occurs only during the day, in the presence of sunlight. These organisms live a relatively short time, and phytoplankton biomass varies with environmental characteristics such as temperature, presence of minerals,

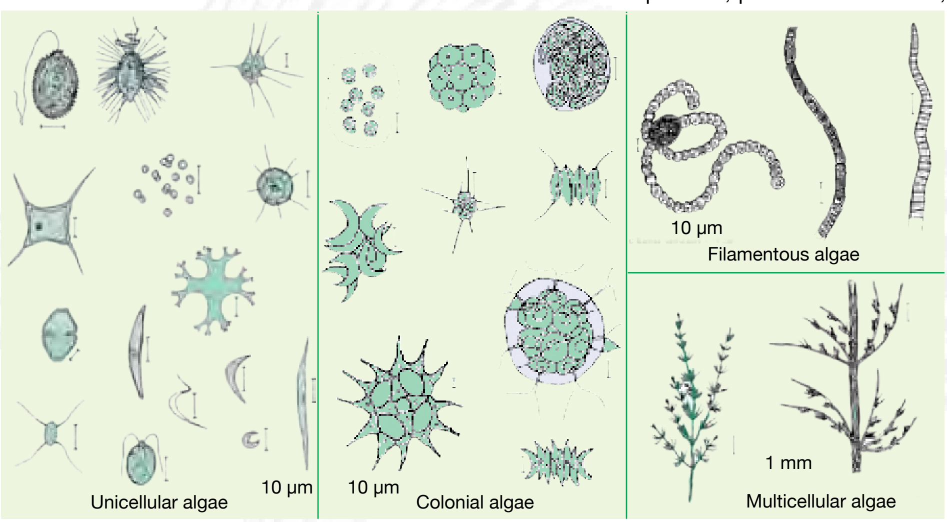


Figure 102. Different types of algae.

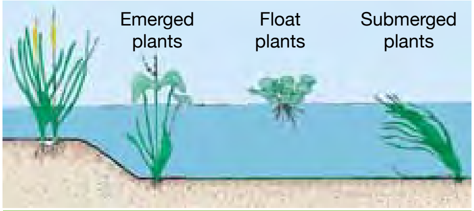


Figure 103. Aquatic plants that should be removed from ponds.

illumination, etc. If there is a great concentration of filamentous algae it should be removed from the pond.

If there are too many vegetable organisms (phytoplankton and aquatic plants) in the pond, their oxygen consumption may impede fish growth. If this is happening, fish may be observed at dawn coming to the surface of the water to seek oxygen. Sometimes, there may be a mass die-off from asphyxiation.

Higher-level plants can become serious indirect competitors of fish growing in the pond, either by respiration during the night, through consumption of minerals, or by offering shelter to predatory organisms. There are three kinds of these plants: immersed plants, emergent plants and floating plants (Figure 103 above). They are generally not useful in the pond unless you are farming herbivorous fish. They consume minerals that should be available for phytoplankton, the first link in the pond's food chain. In the same way, these higher plants provide cover that decreases light penetration into the water, reducing the phytoplankton's capacity for photosynthesis and hindering its development. If the pond is stocked with some herbivorous fish, they can limit the proliferation of these plants. If, in spite of such precautions, higher water plants appear, they should be removed as quickly as possible.

I.2. INVERTEBRATES

Algae provide food for microscopic herbivores, or *zooplankton*. Zooplankton, in turn, are eaten by second-order consumers-- carnivores. Zooplankton consume waste, phytoplankton, and bacteria, and the largest of them consume other zooplankton.

Organisms that live on or close to the bottom are known collectively as the benthos.

I.2.1. ROTIFERS

Rotifers are small organisms measuring between 50 µm and 3 mm, often shaped like a trumpet, cylinder or sphere. They have two wreaths of cilia around their mouths as well as a specialized organs with, notably, an alimentary canal. They are neither segmented nor metamerized (having repeated segments). Their bodies are covered laterally by a resistant sheath that sometimes becomes a true shell.

Rotifers live mainly in freshwater but some

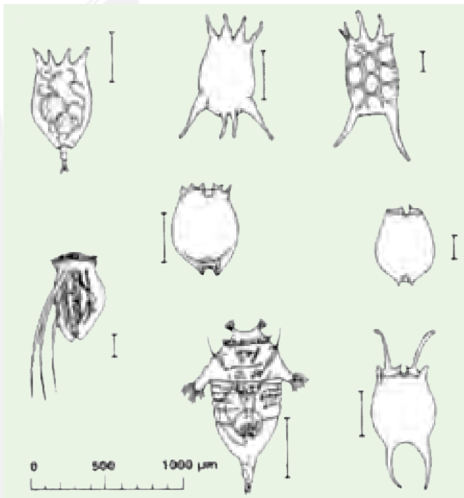


Figure 104. Rotifers.

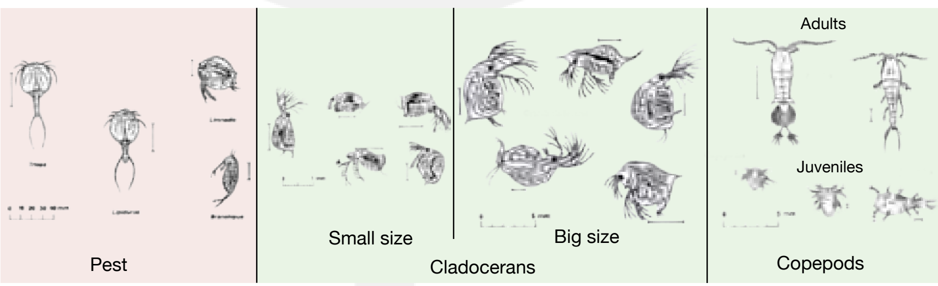


Figure 105. Crustaceans.

species occupy marine waters as well as wetlands. They feed mainly on microorganisms suspended in water. Some rotifers are parasites of crustaceans, molluscs and annelids. They compose most freshwater zooplankton and constitute an important source of food in freshwater ecosystems (Figure 104, p. 116).

I.2.2. CRUSTACEANS

Some of the organisms included among zooplankton are small crustaceans, which are mainly divided into two classes, cladocerans and copepods, in ascending sizes (Figure 105, p. 116). Zooplankton are excellent food for many fish species, especially during the larval stage. However, the largest copepods prey on eggs, larvae and even fry. It is important to know how quickly different groups of zooplankton will develop. It is possible to find, in the same water, crustaceans that are parasites of fish as well as predators. Crabs and shrimps may also still be present if they can pass through the filter.

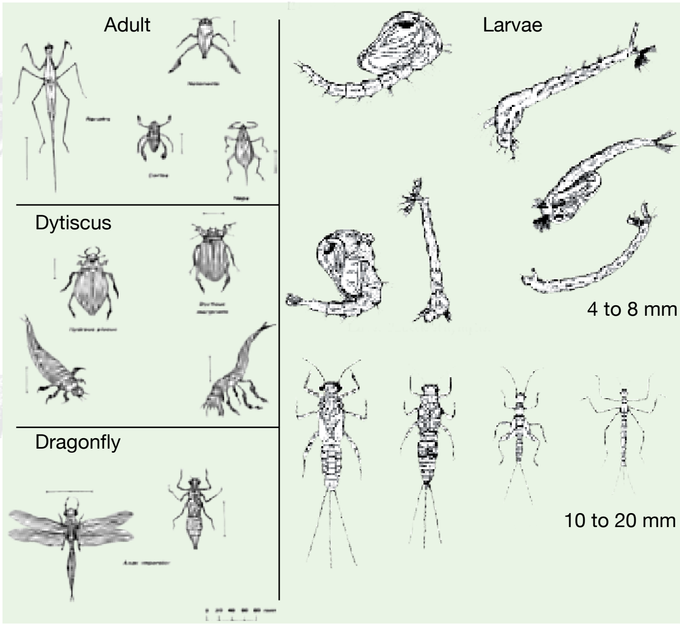


Figure 106. Insects.

During the first days after a well-fertilized pond has been filled, it is easy to see how well the population of the class of smallest zooplankton, the rotifers, are developing. After one week, the population of cladocerans reach their optimum size, and after ten days the population of copepods will reach their optimum size.

I.2.3. INSECTS

Many aquatic invertebrates are insects (Figure 106, above). Most of the time they are larvae of insects such as mosquitos, dragonflies, flies, ephemers, trichopters, etc., which go through a phase of aquatic larval life and, after emerging, also spawn in water. During this cycle, some are vectors of serious human diseases like malaria (mosquito) or onchocerciasis or river blindness (Simulis). Some also prey on fry.

Some insects, such as water beetles (Dytiscidae) and water scorpions (Nepidae) are aquatic in their adult stage. They also often prey on fry.

I.2.4. MOLLUSKS

There are a number of aquatic mollusks (Figure 107 opposite), including water snails and anodonta mussels, or freshwater mussels. Snails can prey on fish eggs. They may also spread a parasitic disease called schistosomiasis.

Figure 107. Mollusks.

I.2.5. OTHER INVERTEBRATES

Other aquatic organisms include hydras, parasitic worms (helminths, platyhelminths), leeches, sponges, and even jellyfish. Some of these prey on newly hatched fish (alevins).

I.3. VERTEBRATES

Fish are the largest group of vertebrates, with more than 10,000 freshwater species identified throughout the world. We will return to the biology of species used in fish farming.

Amphibians, such as frogs and toads, are another large group of vertebrates. These animals go through an aquatic larval phase (Figure 108 below). Many tadpoles are herbivores, but some are predators and can feed on small fish.

Reptiles include several types of snakes, such as grass snakes, and certain turtles that prey on fish.

Then, there are several species of birds, such as kingfishers, pelicans, cormorants, eagles, and herons, that are predators of juvenile and adult fish.

Finally, a mammal, the otter, preys on large fish.

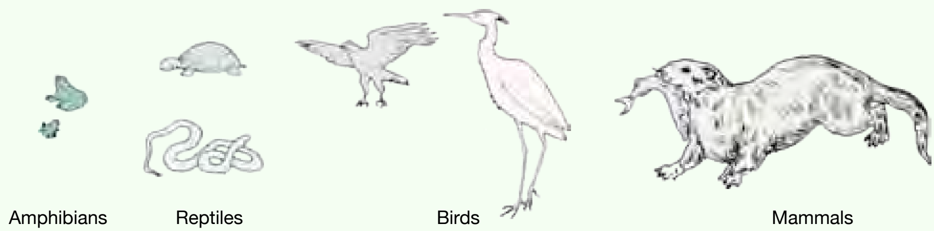


Figure 108. Vertebrates other than fish.

II. FERTILIZATION

Clear natural water does not contain food for fish. Pond water is like agricultural land: if the ground is fertile, the plants grow well. To make water fertile, fertilizing elements, particularly phosphorus, must be added. Water will respond much more readily to fertilization if its physical and chemical characteristics (temperature, pH, dissolved oxygen, etc.) are close to the optimal ranges for selected species. Fertilization increases the production of natural food in a pond, making it possible for fish to find more food. Fertilization provides food for the living organisms that then provide food for fish.

When manure is used to increase fish production in ponds, it will establish and maintain a dense population of phytoplankton and zooplankton, which should turn the water a beautiful green color.

II.1. FERTILIZER OR MANURE

The action of organic manure is a little more complex. It has at least three functions, which include (Figure 109, p. 119):

- ⇨ Use as fertilizer,
- ⇨ It directly provides food for some fish species, such as tilapia, and for some fauna (other animals) living in the pond,
- ⇨ Supports a range of microscopic organisms, which provide some natural food for the fish.

Organic manure's fertilizing function is progressive because the minerals it contains are made available to the phytoplankton as decomposition progresses, until it is completely mineralized.

Several kinds of organic matter, usually waste, can be used as organic manure. The following are the most common:

- ✓ Animal manure, mostly from farm animals;
- ✓ Waste from slaughter-houses;

✓ Fermented cassava;

✓ Natural vegetation;

✓ Compost, mixed from various kinds of organic matter.

II.1.1. ANIMAL MANURE

Animal manure constitutes an additional source of carbon gas (CO_2), which is very important for the effective use of nutrients that are present in water. The manure increases the amount of bacteria in the water, accelerating the decomposition of organic matter and providing food for zooplankton, which then also becomes more abundant. Manure has beneficial effects on the structure of the soil at the bottom of the pond, as well as on benthic fauna such as the larvae of chironomids. However, animal manure has some disadvantages; it contains a low amount of primary nutrients, it has a negative effect on dissolved oxygen content, and some fish farmers are reluctant to use livestock waste directly in fishponds. The chemical composition of organic manure varies considerably, depending on characteristics of the animal that it comes from--including its species, age, sex, and type of food - and depending on how the manure is treated, i.e. its relative freshness, storage conditions, and the rate at which it has been diluted with water. Chicken droppings are very rich in nutrients. Pig droppings are usually richer than those of sheep or goats. Cow and horse dung is poorer in nutrients, particularly when the animals eat nothing but grass. Their fiber content is relatively high. Buffalo excrement is the poorest manure of all.

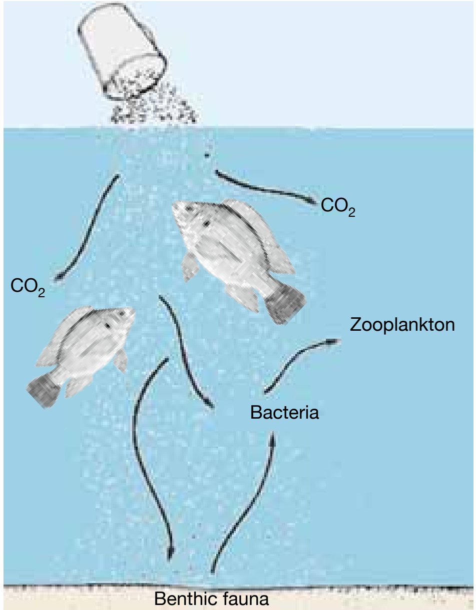


Figure 109. Beneficial effects of organic fertilizer.

Manure should be easy to collect. Animals in shelters or enclosures produce manure that is more concentrated than those that roam freely. Animal shelters can be designed to facilitate the collection and distribution of manure toward the ponds.

Sources of animal manure are rather numerous, but it is often available in rather small quantities (Table XXIV and Table XXV, p. 120). These include:

✓ In rural environments, droppings from chickens and other birds are often too dispersed to be used in large ponds.

✓ Pig manure is usable only by non-Muslims. Operations that combine pigsties with fish farming is very interesting for its yield and ease. Manure from a pigsty should be allowed to dry for two weeks before it is used.

✓ Manure from cows and other ruminants should be used with many precautions because it is too rich in cellulose and there is a risk that it will cause a lot of fermentation, which will cause a rapid decrease in the oxygen rate. It is better to apply this manure to the dry bottoms of ponds after they have been drained. Scarification of the base makes it possible to mix manure with the mud without turning over the soil.

✓ Liquid manure is an oozing heap of manure after a rain or watering, which is only found on a livestock farm where urine and manure are collected. It is an excellent fertilizer, helping to produce zooplankton at a rate of 2.5 liters/are/week. If there is an odor of ammonia, amounts should be reduced by half.

The amount of animal manure that should be applied in a given pond varies considerably depending on factors such as climate, water and soil quality, characteristics of the manure, and the type of agricultural system (type of fish, density of fish stock, length of the farming period). It is, however, impossible to recommend a treatment that works in all circumstances.

Manure must be spread in a uniform way to avoid detrimental concentrations. The choice of manure is limited by availability and price, and if possible, it should be obtained for free. All manure must be tested to verify that it is productive and not harmful. Manure should be spread by the weight of the droppings and expressed as a percentage of fish biomass. Recommended maximum values should not be exceeded, in order to avoid accumulation at the bottom of the pond, which would cause the oxygen rate to fall suddenly. The ideal frequency of provision follows the rule: **as often as possible**. Daily application is best. As an indication, in small rural ponds of 100 m² to 300 m², distribution is done once, or preferably twice, a week. If manure is not used every day, but only once per week, it is not necessary to spread seven times more of it on the pond.

II.1.2. OTHER ORGANIC MANURE

Several organic fertilizers other than animal manure are commonly used on small fish farms. These fertilizers are usually made of waste that can be obtained cheaply and locally. The most common organic fertilizers are:

⇨ **Slaughter-house waste**, such as the contents of bovine rumen, blood, bone and enriched waste water.

⇨ **Agro-industrial waste**, such as cotton and molasses seeds, oil cake seeds and residual palm oil mud (4 to 5 % nitrogen). Waste such as rice balls, fibrous residue (bagasse) from sugar cane stalks, and sawdust are rich in cellulose, which decomposes very slowly in a pond.

⇨ **Waste from cassava retting**: Bitter cassava tubers can be soaked in the ponds to remove hydrocyanic acid so that they can be consumed. This is an excellent, cheap way to fertilize small ponds. After retting, the cassava can be recovered and consumed, leaving behind juice that provides free fertilizer. It is recommended that a minimum of 10 kg tubers/are/day be used for this process. It is possible to use up to 200 kg/are/week, but no more.

⇨ **Vegetation** taken from the pond itself, from canals, or from other places that are filled with water. In some areas, harmful floating plants such as the water hyacinth (*Eichornia crassipes*), water ferns (*Salvinia* sp.) and water lettuces (*Pistia* sp.) can be used effectively.

⇨ **Compost** produced apart from the ponds can be spread over the bottom of a drained pond

Table XXIV. Maximum amount of fresh solid manure per day in a 100 m² pond.

Solid manure		Maximum amount (kg fresh/100 m² /d)
Poultry	Duck	2.8
	Chicken	4.8
Pigs	Pig	6.0
Small ruminants	Sheep/Goat	3.4
Large ruminants	Buffalo	6.3
	Cattle	6.0
	Horse	5.2

Table XXV. Quantity of each type of manure that should be used.

Source		Quantity (kg/100 m²)	For a pond of 400 m² (4 ares)	% fish biomass
Poultry	Poultry droppings	4.5	½ to 1 wheelbarrow/week	2 to 4
Pigs	Pig dung	6	½ to 1 wheelbarrow/week	3 to 4
Small ruminants	Sheep or goat dung	3		
Large ruminants	Cattle or horse dung	5		
	Cattle or horse stable-litter	15		
	Manure of large ruminants		1 ton/year	
	Liquid manure		10 l/week	

before it is filled, or be used regularly to fertilize the water. Vegetation such as cut grass, vegetable waste (scraps) and decomposed fruit can be used to make a simple compost in the pond.

The average quantities of these organic fertilizers that should be applied to small ponds are indicated in Table XXVI below. They should be used regularly, while avoiding overloading the pond, for several weeks. Water quality should be checked and, if necessary, quantities adjusted.

II.2. COMPOST

Composting is defined as intensive decomposition by microorganisms of organic matter, generally under controlled conditions. A whole range of waste can be used, including residues and natural vegetation, to produce a clean product that will be cheap, dry and rich in primary organic matter and nutrients. This product is called compost.

Compost is produced by various groups of microorganisms, including bacteria, fungi and protozoa, which need mainly carbon (C) and nitrogen (N) to grow and develop. They decompose available organic matter to obtain these substances. Compost includes relatively tender plants like leaves, grass and aquatic plants, mixed with feces (of birds, pigs, herbivores or humans).

Compost can be produced under anaerobic (in the absence of oxygen) or aerobic (in the presence of oxygen) conditions. Each type has specific characteristics (Table XXVII, p. 122). In some agricultural systems, both types of composting can be used. For example, external material can be prepared aerobically, and interior areas, where there is little oxygen, can use anaerobic preparation.

In fish farming, composting is usually practiced in two ways:

- Simple aerobic/anaerobic underwater composting, in a heap.
- Dry aerobic composting, either in a heap, or in pits.

It is easier to use the aerobic method to prepare compost on the ground (rather than under water) (Figure 110, p. 123). There should always be air in the pile of compost, in order to maintain rapid and total decomposition of organic matter. The stages of this process will include:

1. To begin a new pile of compost, lay down a layer of coarse vegetable matter, such as banana leaf stalks, straw or stems of sugar cane, at least 25 cm high. This layer should allow air to circulate while absorbing nutrient-rich liquids from the upper layers.

2. Cut organic matter that will be used for the compost into small pieces, from 3 to 7 cm long.

3. Pile up all the organic matter without packing it too tightly, leaving space between the layers. A pile of compost should never be compacted. The pile should also not be too high, so that organic matter will not become compacted under the weight of the pile.

4. Keep the pile moist but not wet. Too much water prevents air circulation. The pile should be protected from the rain (which would make it too wet) and the sun (which would make it too dry).

5. Turn the pile over from time to time in order to aerate it and ensure that the center is not producing too much heat. Introduce a stick into the middle of the pile and wait a few minutes before withdrawing it. If the stick is too hot or too dry, or smells too strongly, it is time to turn the pile over.

Table XXVI. Organic fertilizers commonly used in small-scale fish farming.

Organic fertilizer	Average amount applied at regular intervals
Animal manure	See Table XXIV and Table XXV, p. 120
Slaughterhouse waste	10 kg/100 m²/week
Agro-industrial waste	8 kg/100 m²/week
Cassava tubers	50 to 100 m³/week 10 to 25 kg/100 m²/day
Vegetation	20 to 25 kg/100 m²/week
Compost	20 to 25 kg/100 m²/week 50 kg/100 m² pond bottom

There are two ways of piling up materials:

⇨ In a heap above ground level, preferably during the heavy rain season. At that time, it will be easier to turn the pile over and keep it ventilated, but carbon and nitrogen losses will be high.

⇨ In pits dug into the ground, in a place that has been raised to avoid flooding. If necessary, pits should be protected by trenches. In dry climates, this method helps retain moisture. Under this method, carbon and nitrogen losses are lower.

II.2.1. LIMING

Earth ponds are conditioned by liming, preparing the ponds and treating them with various types of enriching limestones, which are chemical substances rich in calcium (Ca). Liming improves the structure of the soil in the pond, improves and stabilizes water quality, and facilitates manure's ability to efficiently increase the availability of natural food. One of the most important effects, which can be measured and used to regulate liming, is that it modifies the total alkalinity of water in a pond. Water's total alkalinity is the measurement of the total concentration of substances like calcium (Ca) and magnesium (Mg), which are typically alkaline, in carbonates and bicarbonates.

Liming of ponds is not always necessary. It can be done on a new pond or a pond that is already in use. However, in certain cases, it can be both a waste of money and harmful to the fish. Before a decision is made, specific characteristics of the pond's water and soil should be studied carefully. The following points should be considered:

✓ If the pH of the soil at the bottom of the pond is lower than 6.5, liming is justified.

✓ If the bottom of the pond is very muddy because it has not been emptied and drained regularly, liming will improve soil conditions.

✓ If there is a risk of contagious disease or if you need to fight enemies of fish, liming can help, particularly in drained ponds.

✓ If there is too much organic matter, either in the soil at the bottom, or in the water, liming is advised.

✓ If the water's total alkalinity is lower than 25 mg/l $CaCO_3$ liming is justified.

The effects on the soil at the bottom of the pond are:

⇨ Improved structure;

⇨ Accelerated decomposition of organic matter;

⇨ Increased pH.

All these factors will result in faster and more efficient exchange of minerals and nutrients between the soil at the bottom of the pond and the water, as well as reduced demand for dissolved oxygen.

Table XXVII. Characteristics of composting methods.

Characteristics	Aerobic composting	Anaerobic composting
Presence of oxygen	Necessary	No
Loss of nitrogen	Important	Reduced
Loss of carbon	Important	Reduced
Production of heat	Important	Very small
Destruction of pathogens	Yes	No
Moisture content	To be controlled, best 40-60%	Not important
Composting method	In heap, above ground level	In heap. deeper under water
	In pit, below ground level	In sealed heap, above ground level
	In heap, at water surface	In sealed pit, below ground level

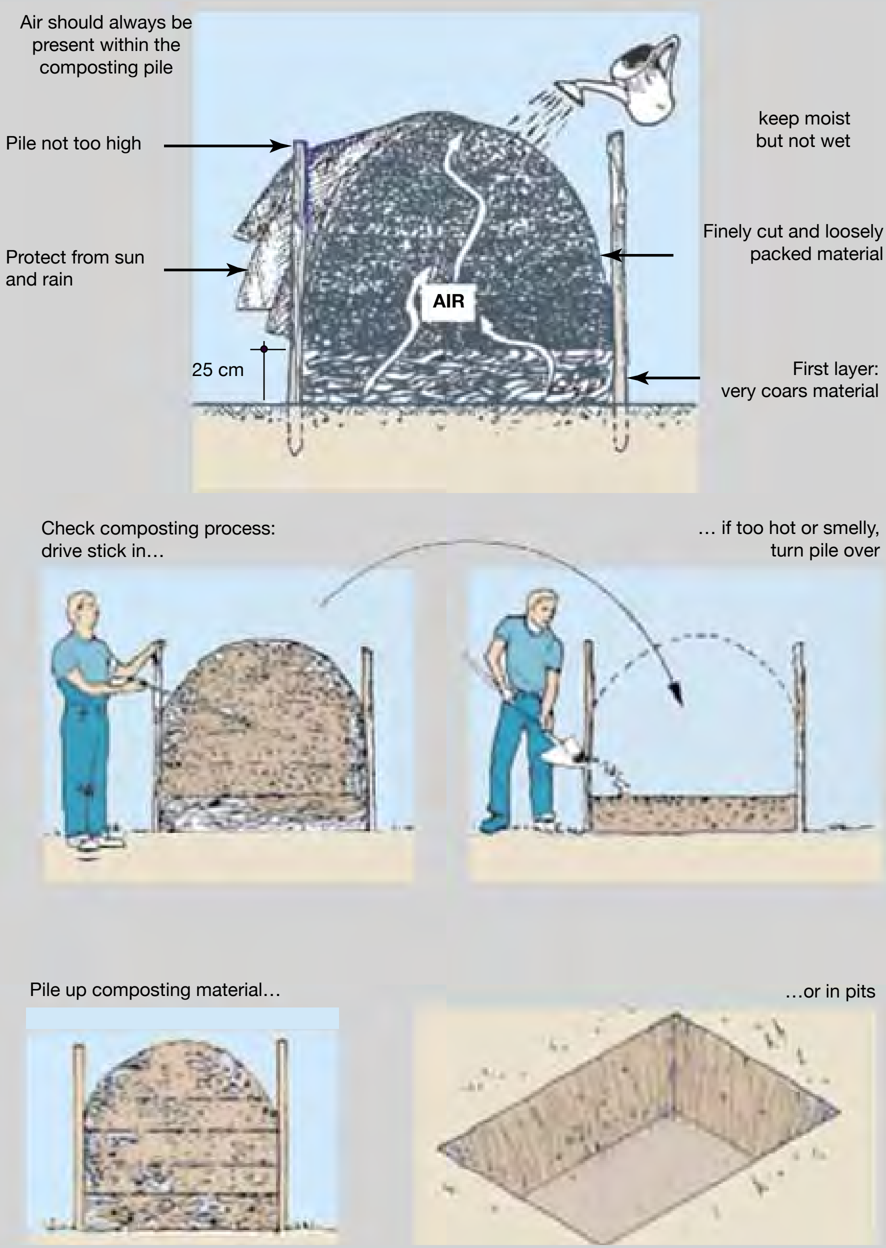


Figure 110. Preparation of dry compost.

Usually, limestone enrichment and fertilizer are applied separately. Liming should be done at least two weeks, and preferably one month, before any spreading of fertilizer. There are, thus, various times of the year that annual liming can be done, depending on the pond's management calendar. In tropical climates, it is better to lime the pond as soon as the fish are collected and at least two weeks before putting fish in again. Fertilizer is applied next, 15 to 30 days after liming.

However, measurements of pH and alkalinity will not necessarily be a simple matter to beneficiaries, who may have to seek assistance from local laboratories and institutes. For NGOs, analysis kits are easily available on the market, and are not very expensive.

II.2.2. SPREADING

Fertilizer can be spread either when the pond is dry, or when it is filled with water.

There are a variety of methods for the placement and distribution of animal manure (Figure 111, Figure 112 and Figure 113, p. 125). However, the illustrated examples are not specific, and must be adapted to local conditions (including the quality and quantity of manure available, water quality, weather conditions, etc.).

Except for slaughter-house waste and cassava tubers, organic manure is gathered into one or more piles in the water. An enclosure in a corner of the pond can also be used. Organic manure is piled up and compacted inside, beginning production of underwater compost. The method for making aerobic compost has already been described. You can also make anaerobic compost (paragraph II.2, p. 121).

To do this, arrange a bamboo or wooden compost bin to retain manure in each pond. Place it at an angle, in the main part of the pond (Figure 115 and Photo N, p. 126). The pile must be compacted well under water, which can be done by trampling each layer carefully (Figure 114, p. 125). But it should come slightly above the water surface, since it will slowly get smaller. Each week, new layers of organic matter should be added to reconstitute the pile. To obtain very good performance:

- Use at least a pile of compost for every 100 m^2 of pond.
- Ensure that the compost enclosures' total surface area corresponds to 10 % of the pond's surface area.
- Turn the piles over every two or three days.
- Place the compst piles in water that is sufficiently deep.

II.2.3. «GREEN WATER»

Once the ponds are filled with water and fertilized, wait until the pond's natural cycle begins. This will take several days during which, as long as the water has been fertilized well, it will turn green, meaning it is rich in phytoplankton. Use a Secchi disc to test whether the water is sufficiently green (paragraph II.1.2, p. 48), or, more simply, plunge your arm into the pond up to the elbow. If you can hardly see the end of your fingers, the water is sufficiently green.

The pond is now ready to be stocked with fish.

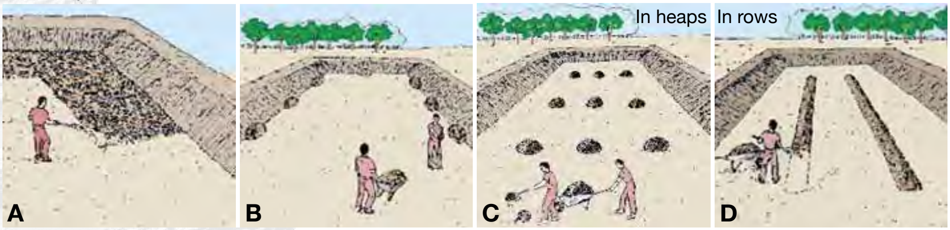


Figure 111. Applying animal manure to a drained pond bottom. A: New pond; B: Pond in which the water has not been controlled well; C and D: Pond in which the water has been controlled well (most common case).

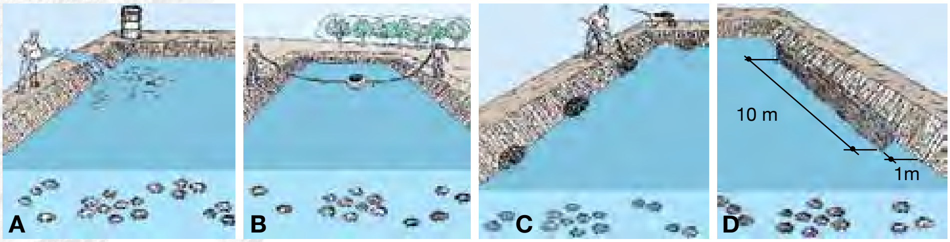


Figure 112. Applying animal manure to ponds that have been filled with water and stocked (I). A: Distribution of liquid animal manure from the bank; B: Distribution of animal manure using an inner-tube and basket; C: Disposition in piles along the banks; D: Detail of an elongated crib.

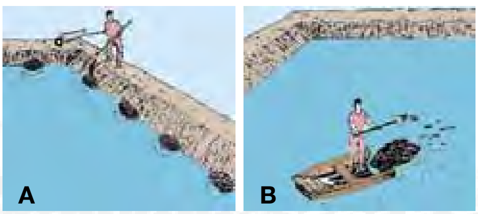


Figure 113. Applying animal manure to ponds that have been filled with water and stocked (II).
A: Stacking animal manure mixed with stable-litter in piles along the banks;
B: Applying pure animal manure from a boat.

Figure 114. Preparation of anaerobic compost.

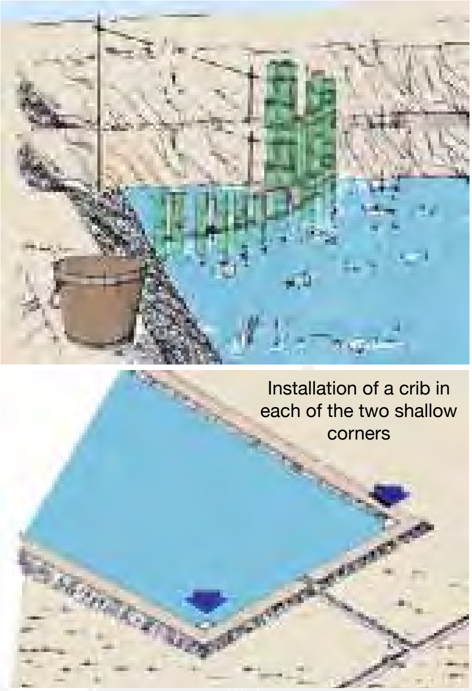


Figure 115. Compost heap in a crib in a pond.

Photo N. Compost pile. [Up, Liberia © Y. Fermon], [Down, © APDRA-F](CIRAD).

III. SUMMARY

- ⇨ **Two steps to complete before stocking the pond with fish are:**
  - ⇨ ***Fertilization*;**
  - ⇨ **Watching for « *green water* » which indicates that the pond is ready to be stocked.**
- ⇨ **This chapter focused particularly on:**
  - ⇨ **Preparation of aerobic and anaerobic compost**

Chapter 09
HANDLING THE FISH

Once the pond is ready, it can be stocked (Figure 116, p. 128).

Appendix 04, p. 239 provides information on fish species used in African fish farming, organized by ichthyoregions and countries. To restate the sequence of operations, activities will include, in the following order:

14. Collecting tilapia
    - In the field
    - By propagation
15. Juveniles storage
16. Transporting live fish
17. Stocking tilapia
18. Monitoring the fish
19. Stocking with other species
20. **Draining and harvesting**

In certain cases and areas, it is rather easy to obtain newly hatched tilapia (alevins) in the wild. Otherwise, alevins can be produced from broodstock collected in the wild. The assessment completed at the beginning of the project will indicate which usable species can be found near the selected sites, which will help:

⇨ To limit the loss of fish;

⇨ To limit costs. Long-distance transport may require costly logistics. Displacement should be avoided as much as possible.

Since most producers of alevins currently operating in Africa are not really practicing genetic management of broodstock and, moreover, are starting with introduced species, alevins should usually not be obtained from local producers. This approach may also limit costs.

I. CATCH METHODS

On a fish farm, live fish must be handled on many occasions, including during routine monitoring of growth and health, during transfer from one pond to another, and during final harvesting. Fish are usually handled with the aid of nets and other small pieces of equipment.

However, it is necessary to keep in mind some points mentioned above.

⇨ **If the beneficiaries themselves will collect the broodstock, it is important they understand that looking for fish close to home is preferred.**

⇨ **One of the main principles will be to use only non-destructive gear for the local wildlife.**

⇨ **Care should be taken to respect the laws relating to fishing. Where appropriate, permits have to be requested from the local authorities.**

Wild specimens can be obtained with the help of local fishermen, who may also be beneficiaries. They generally know where various species may be captured. If necessary, small fishing equipment can be manufactured.

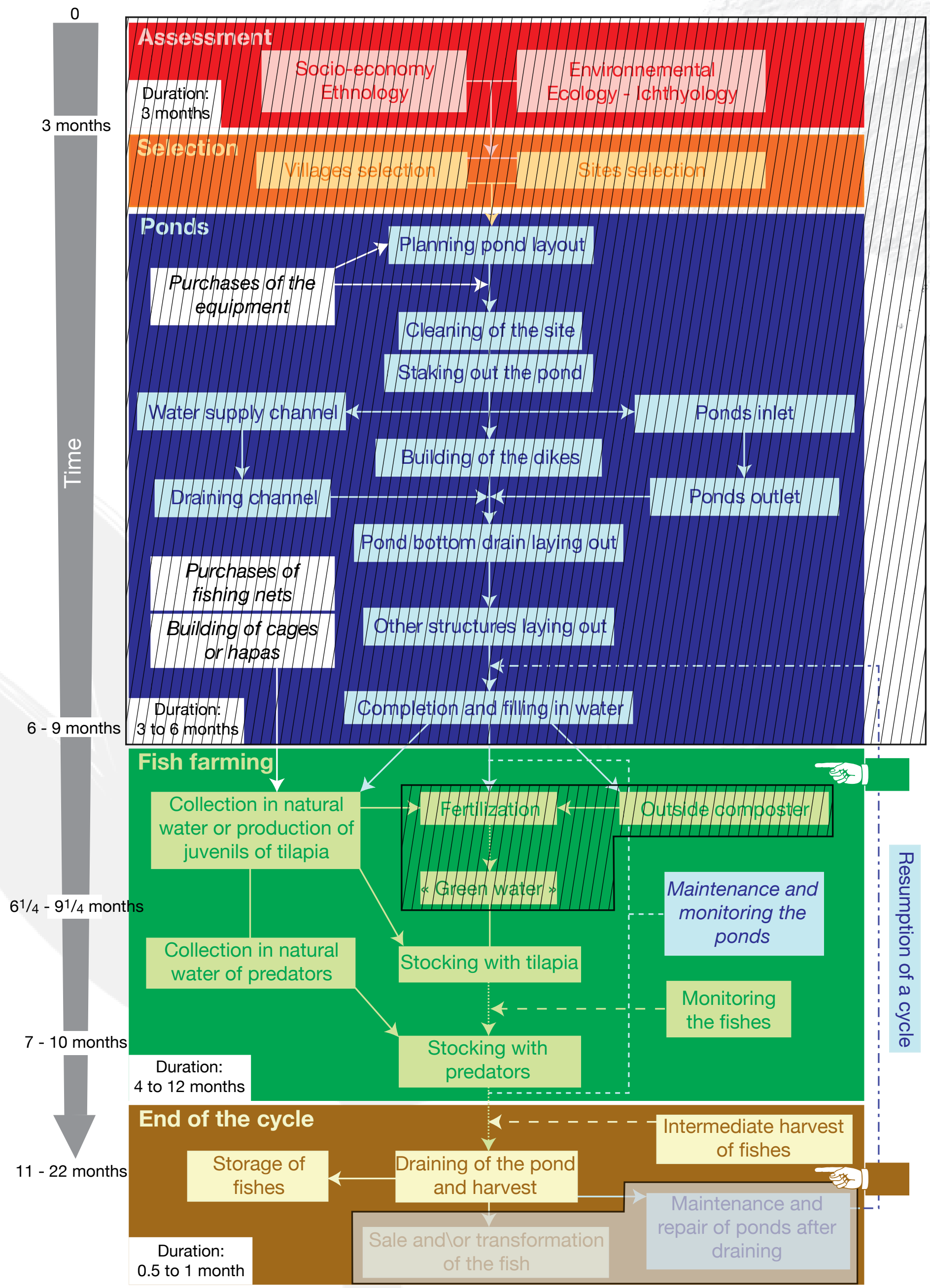


Figure 116. Setting up fish ponds: 4. Fish farming and 5. End of cycle.

I.1. SEINE FISHING NETS

One of the main pieces of equipment used to catch fish is the seine net.

This is the easiest way to catch alevins. If a seine net with mesh of approximately 1 cm is used, the fish that are caught will be at least 5 cm in length. Seines made with mosquito netting should be used to collect juveniles.

A seine net is the most common type used to harvest fish on fish farms. It is a long net with ropes at each end that is pulled along the pond to collect fish and then drawn into a circle to trap them and, most often, bring them back to shore.

A seine net consists of one or more pieces of mounted netting material (Figure 117 opposite):

✓ At the top, a head line is equipped with floats;

✓ At the bottom, a foot line is equipped with sinkers (or leads).

These head and foot lines normally extend beyond the netting to form pulling ropes.

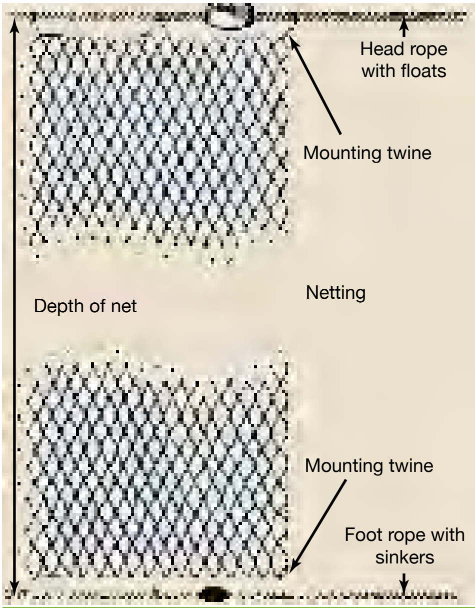


Figure 117. Diagram of a seine.

There are several kinds of seine. The two most commonly used designs are:

- A seine that is the same over its entire length. It consists of a simple rectangular net panel.
- A seine made of three parts:
  - One central, loosely mounted bag that collects the fish;
  - Two lateral wings that lead the fish toward the central part.

Various materials are needed to make a net (Figure 118, p. 130).

Rope can be made either of natural fibre (hemp, manila, sisal) or synthetic fiber (polyamide, polyethylene or polypropylene). Synthetic fibers are stronger and more resistant. The rope can be either twisted or braided.

Floats can be made of several materials such as cork, plastic, or light wood, which should be coated with paint or tarred to keep it from becoming saturated with water. In short, the material must float.

Sinkers are usually made either from earthenware or lead. The latter is available as thin lead sheets or in the form of olives of various individual weights. Recycled lead can be used. The total weight of the sinkers should be equal to 1 to 1.5 times the total floatability of the floats. Small stones can also be used, but they may break more easily.

During assembly, floats should be placed at intervals of 10 to 25 cm maximum. One sinker should be placed at every 3 intervals. There are various stages to assembling a seine (Figure 118, p. 130).

A small seine can be managed by as few as two people, one at each end of the net, holding it vertically with the wooden poles (Figure 119, p. 130, Figure 120 and Figure 121, p. 131, and Photo O, p. 132). If poles are not being used, the bottom rope should be kept slightly ahead of the top rope. If the pond bottom is muddy or if the seine is large and heavy, additional strength may be necessary. In this case, one person pulls at each end pole of the net while others assist by pulling on the extended ropes at the end. An additional person should stand near the middle of the seine to help whenever necessary, such as when it gets stuck on an underwater obstacle.

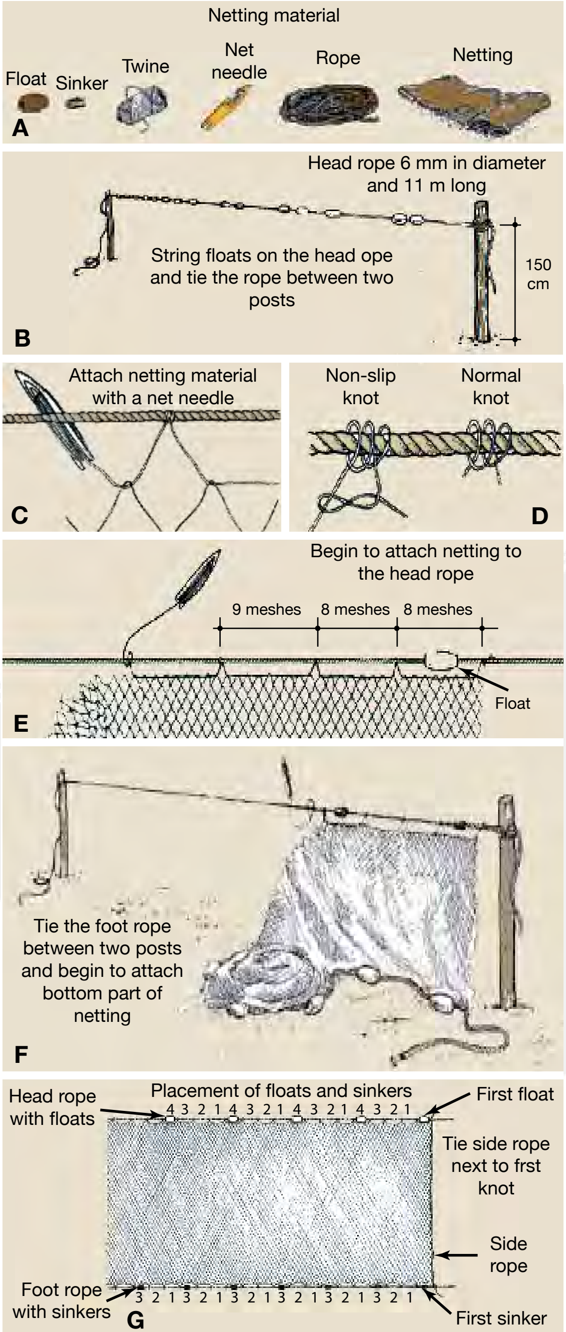


Figure 118. Steps for constructing a simple seine.

Seines can be rather expensive pieces of equipment. They should be kept in good condition. Users should watch especially for the following:

Protect them from direct sunlight and dry them in the shade.

After seining, clean and rinse the nets well, removing all debris, fish slime, scales, etc.

Protect them in a cool, dry place such as an open shed.

Protect them from rats and mice, possibly by hanging them on horizontal bars above ground level.

Repair them regularly. Replace sections of netting as necessary.

⇨ Note that the use of seines in the wild is generally prohibited. Even if they are not prohibited, seines can still only be used to harvest fingerlings or broodstock. If authorization is required, it should be obtained from the appropriate authorities.

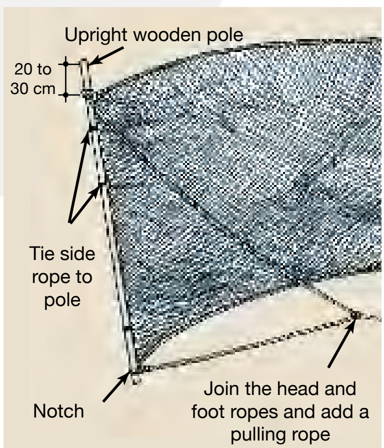


Figure 119. Setting up the pole to hold the seine.

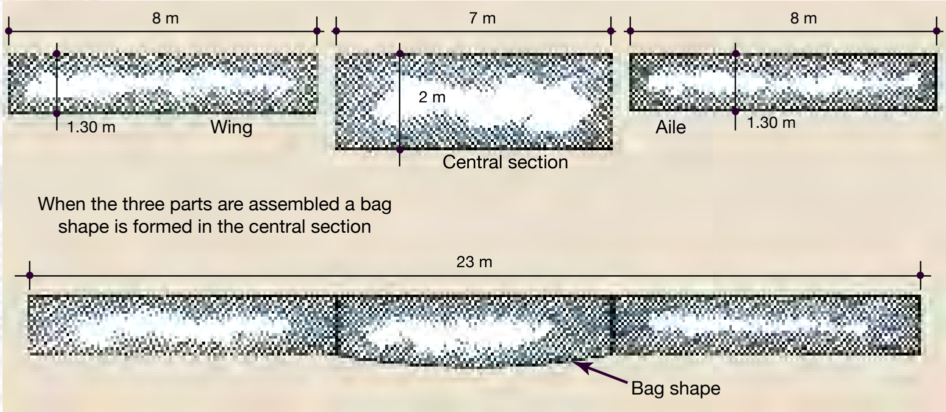


Figure 120. Construction of a central-bag seine.

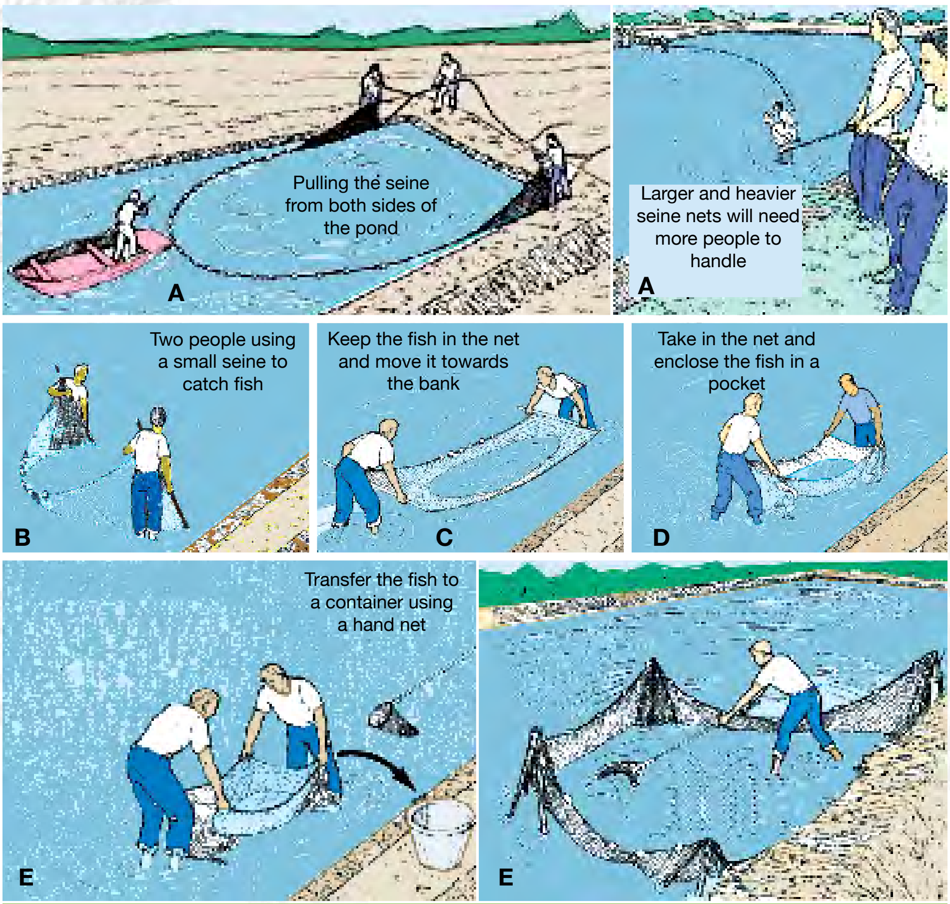


Figure 121. Manipulation of a seine.

Photo O. Use of small beach seine (Liberia, Guinea, DRC) [© Y. Fermon].

I.2. GILL NETS

The gill net is one of the most widely used nets in freshwater capture fisheries. It may also be useful on a farm for selective harvesting of larger fish for market.

In overall shape and design, a gill net is very

Photo P. Mounting, repair and use of gill nets (Kenya, Tanzania) [© Y. Fermon].

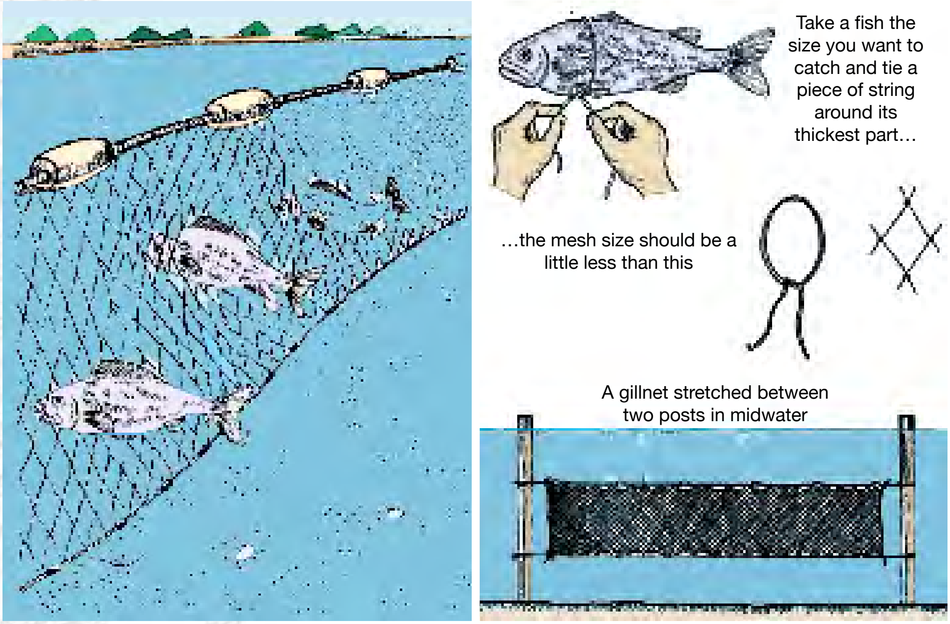


Figure 122. Gill nets.

similar to a seine net. The netting twine is thinner and usually made of a synthetic monofilament, such as polyamide monofilament, with a diameter from 0.12 to 0.25 mm, depending on the mesh opening. Mesh size is determined by the size of the fish being harvested.

Fish should be able to pass through the extended mesh just beyond their gill covers, but no further (Figure 122 above and Photo P, p. 132). When they feel caught and try to back out of the mesh, their gill covers should be caught by the mesh sides (which is where the name «gill net» comes from). Such nets are highly selective. The mesh size is calculated by measuring the body perimeter, or girth, of a few fish of the size that will be harvested. The stretched mesh size of the gill net should be about a quarter smaller than the fish girth. Avoid gill nets with a stretched mesh size of less of 4 cm, or 2 inches, so that you don't catch fish that are too small. **It is important to check and remove fish from a gill net every few hours at the most to ensure that harvested fish will remain alive and not suffer injuries.**

I.3. CAST NETS

The cast net is another type of non-destructive fishing gear that fishermen often use for capturing fish. It is a good tool for capturing large fish without damaging them.

A cast net is made of a flat circular piece of small-mesh netting, heavily weighted along its periphery with sinkers. Usually a series of strings runs from the outer edge through a central ring to join into a single pulling rope. A cast net is not very easy to make, but can be bought from a specialized store.

Handling of a cast net requires skill (Figure 123 and Photo Q, p. 134). When it is thrown, it should be open and horizontal to the surface of the water. The net sinks rapidly to the bottom, and is closed with a pull on the central rope that traps the fish inside the net.

A cast net can be used either from the banks, in the water, or from a boat.

Photo Q. Throwing a cast net (Kenya, Ghana) [© F. Naneix, © Y. Fermon].

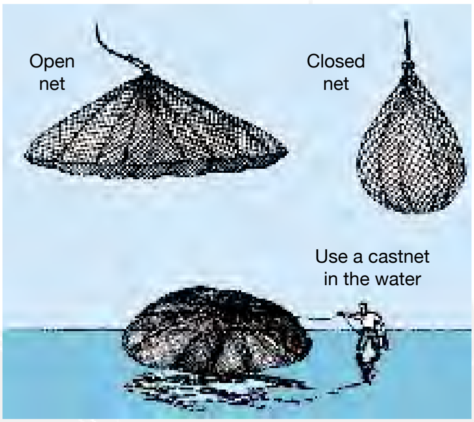


Figure 123. Using a cast net.

I.4. DIP OR HAND NETS

Dip nets are commonly used on fish farms to handle and transfer small quantities of fish. Farmers can buy completed nets, assemble them from ready-made parts, or make them themselves.

A dip net has three basic parts (Figure 124 and Photo R, p. 135):

✓ A bag, made of netting material suitable in size and mesh type for the size and quantity of fish to be handled;

✓ A frame from which the bag hangs, generally made from either strong galvanized wire or an iron bar (usually circular, triangular or «D» shaped, with fixing attachments for the handle);

Photo R. Dip net (Guinea) [© Y. Fermon].

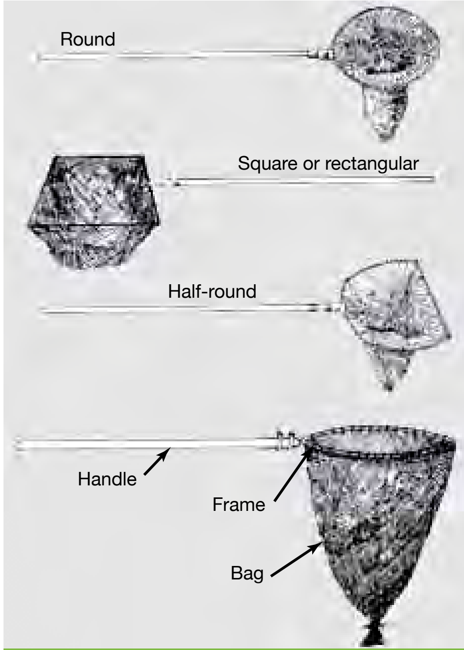


Figure 124. Different types of dip nets.

✓ A metal or wooden handle, 0.20 to 1.50 m long, depending on what the dip net will be used for.

The size and shape of dip nets vary greatly. It is important to keep the following guidelines in mind. Live fish should be handled with dip nets that have relatively shallow bags. They should not reach more than 25 to 35 cm deep. Select a size that is appropriate for the size of fish you are handling.

I.5. TRAPS

Many different kinds of traps can be used when fishing in lakes and rivers in the effort to capture broodstock or associated species such as catfish. Certain kinds of traps may be useful for simple and regular harvest of fish for food that does not disturb the rest of the pond stock.

These traps are usually made with wood, plastic pipe, bamboo or wire frames, and have surfaces made of netting, bamboo slats or wire mesh.

There are two main types (Figure 125 opposite and Photo S, p. 136):

✓ Pot traps, which are usually baited and have a funnel-shaped entrance through which fish can enter but cannot escape; and

✓ Bag or chamber traps, which usually have a guide net that leads the fish into a chamber and a V-shaped entrance that keeps them from escaping.

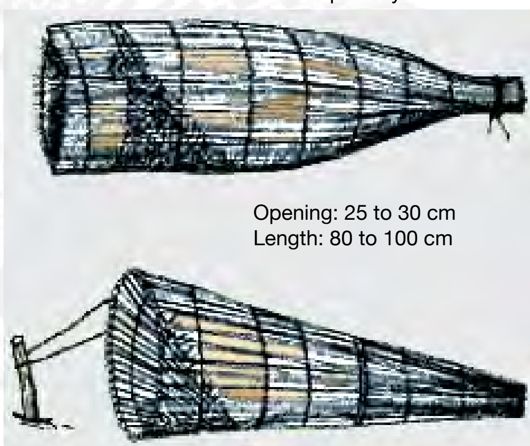


Figure 125. Differents types of local traps.

Photo S. Traps. At left and top right, traditional trap (Liberia); Bottom right, grid trap full of tilapia (Ehiopia) [© Y. Fermon].

I.6. HANDLINES AND HOOKS

One of the easiest ways to capture broodstock is to use a fishing handline. This selective gear allows the fisherman to capture fish such as tilapia and keep them alive without a problem.

It is important, however, to use hooks without barbs to the extent possible.

II. TRANSPORTING LIVE FISH

Transporting live fish is a common practice on many fish farms. It is done, for example:

⇨ After harvesting fish in the wild;

⇨ To take fish to short-term live storage.

The duration of transport varies, depending on the distance to be covered:

- ✓ From the river, transport time is usually longer, varying from a few hours to one or two days;
- ✓ On the farm, transport time is usually very short (from a few minutes up to a half-hour).

Some basic principles govern the transport of live fish:

⇨ Live fish are generally transported in water. Water quality changes during transport, as the concentration of chemicals changes.

➢ **Dissolved oxygen** (DO) is is essential for fish to breathe. Bacterial activity and oxydation processes also require oxygen that is present in organic matter.

- ✓ Oxygen consumption increases with temperature.
- ✓ Dissolved oxygen consumption by small fish up to 1 kg is higher than for larger fish.

✓ Oxygen consumption for resting fish is lower than for stressed or active fish.

- **Ammonia** is excreted by fish and produced by bacteria in different forms. The most toxic form, free or non-ionized ammonia (NH_3), increases as water temperature and pH increase.
- **Carbon dioxide** (CO_2) is produced by fish as a by-product of respiration. Bacteria also produce CO_2. Carbon dioxide exists in different forms; the most toxic form, free CO_2, increases as water pH decreases.

Other changes in water quality that may take place during transport include:

✓ Increasing water **temperature** in warm climates increases oxygen consumption and the content of toxic free ammonia.

✓ Increased carbon dioxide content and thus decreased **pH**, reduce the amount of toxic free ammonia but increase the amount of toxic free CO_2.

✓ **Suspended solids** from fish waste increase.

⇨ **Water quality**

- Water should be kept cool, so that fish and bacteria will be less active, consume less dissolved oxygen, and produce less ammonia and carbon dioxide. Ice may be used if necessary. Do not expose the fish to a sudden change in temperature.
- Water should be clear and free from silt or suspended solids, in order to reduce stress on fish's gills, reduce bacteria in organic solids, and reduce the risk of low oxygen levels that result from the decomposition of organic material.

As far as possible, avoid touching fish with your hands, since this will destroy the mucus on the fish's body, and avoid keeping them out of the water for too long.

For short and medium transport, use clay pots or barrels, buckets or basins, or inflated plastic bags. For transporting Clariidae, you will only need a small amount of water, since they can breathe ambient air.

For a long transport, use **plastic bags** inflated with oxygen, or with air if there is no oxygen (Figure 126 and Photo T, p. 138). You can get oxygen in a carriage-builder from a welder, either from a dispensary or a hospital. As much as possible, keep each breeder in his own bag and limit the density of juveniles. Although this will increase the volume of material to be transported, it will substantially reduce mortality risk. Do not put too much water in the bag. Bags should be filled to a level just above the fish. In general, bags should include 1/3 water for 2/3 air or oxygen.

For fish that have just been caught, change the water in the container every 5 minutes or when the fish pipe on the surface, to evacuate organic waste that the fish eject because of the stress of their capture, which consumes oxygen in the water very quickly.

Certain precautions should be taken and actions undertaken:

Before medium and long-term transport, fish should be kept in stables, or hapas, without food when they are taken from the ponds, and kept there long enough so that their digestive tracts are completely empty. This way, the water in which they are transported remains cleaner. The minimum duration of the fasting period depends on the water temperature and the species. In warm water, a fasting period from 12 to 12 midnight is sometimes sufficient. This period is not necessary for shorter transports.

As much as possible, the transport water should not be allowed to get dirty. The fish should be carefully cleaned with clean water before they are loaded into the transport container.

Place the containers in the dark and keep them safe from sudden noises in order to keep the fish quiet during transport.

Fish should be kept cool during transport, so it is best to transport them at night or early in the morning. Similarly, avoid putting containers in direct sunlight and place them in the shade. Containers can be covered with bags or wet tissues to increase the cooling effect of evaporation.

Photo T. Fish packed in plastic bags (Guinea, (Ehiopia) [© Y. Fermon, © É. Bezault].

Do not feed fish during transport.

During long stops, if the fish seem disturbed or start to come to the surface of the water to breathe instead of remaining calmly at the bottom, or when transport lasts more than 24 hours without oxygen being added, replace the water with fresh, well oxygenated water. If necessary, you can increase the amount of oxygen in the water by agitating it with your hand.

Fish should not be too crowded so that they will not run out of oxygen. Three or four 2 cm-long fish can be put into a half-liter bag, but that same bag can only hold one 8 cm fish. Moreover, fighting between individuals can cause wounds which may kill the fish.

If a fish dies in a bag or a container, it should be removed quickly.

After transport and before the fish are released into the water, the container should be placed in the new water to equilibrate the temperature between the water in the bag and the water in the pond. Then, water from the pond should be added to the container a little at a time to complete the fish's acclimatization before they are released.

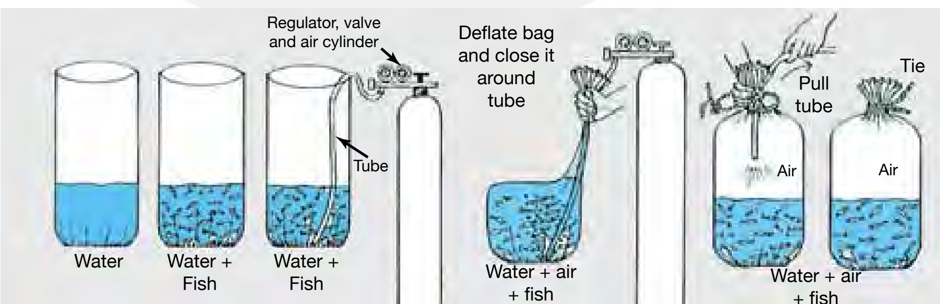


Figure 126. Packing fish in plastic bags.

III. PRODUCTION OF TILAPIA FINGERLINGS

Fingerlings can be produced from broodstock collected in the wild. Indeed, it is sometimes difficult to get a consistent number of fingerlings in the wild, such as during the rainy season. There are three possible ways of proceeding, which vary depending on the species. Fish can be reproduced in the following ways:

⇨ **Naturally**, by setting the water level depending on the behavioral needs and habits of the species being bred, and then adding the breeding fish,

⇨ **Semi-naturally, by** injecting hormones to start simultaneous production of gametes, and finally,

⇨ **Artificially,** where, after injection, ovocytes and sperm are extracted manually and fertilization is accomplished manually.

The reproduction and production of tilapia are currently carried out in farming systems of various intensities, depending on local topographic, physicochemical, and socio-economic conditions. The various techniques used until now are categorized by the environment where they are grown, namely:

- ✓ **Fish Ponds**,
- ✓ **Hapas** and **cages**,
- ✓ **Artificial tanks** (basins), "raceways" and arenas,
- ✓ **Hapas in tanks**,
- ✓ **Experimental aquariums**.

Ponds are the best choice for subsistence fish farming. If necessary, hapas and cages can also be used.

Tilapia's behavioral needs should be accounted for (Appendix 03 paragraph II, p. 216). They are territorial animals. Among mouthbrooders, males defend the territory. Among substrate spawners, both parents are territorial. Generally, the size of territories will be about 1 square meter of ground. This size will increase with the size of the individual. However, individual variability is very important among these fish.

Fingerlings from 10 to 15 mm length can be obtained every month. However, among mouthbrooders, it will be necessary to take care of the females, which suffer harassment from males at the end of the incubation period. If they are approached too often, they will guard their fingerlings for too short a time, increasing the risk of loss.

III.1. IDENTIFYING SEX

It is sometimes difficult to differentiate sexes among fish. In some species, like Alestidae, sexual dimorphism appears on the anal fin. In many species of mouthbrooding Cichlidae, males are more brightly colored. However, the coloring of some non-dominant males is similar to that of females. These fish, must be turned over so that the urogenital orifice can be seen (Figure 127, p. 140).

During breeding season, broodstock should be carefully selected. Only fish that are ready to spawn should be used. Fish with the following characteristics should be chosen:

- ✓ Males should release a few drops of milt when the abdomen is slightly pressed.
- ✓ Females should have a swollen and protruding genital opening, reddish/rose in colour, and a well-rounded and soft abdomen, showing that the ovaries are fully ripe.

When there is risk of male agression (for example, among catfish), fish of the two sexes must be kept in separate ponds after being selected.

III.2. NURSERY PONDS

If there is a central facility that can provide fingerlings to all fish farmers, you may propose to local officials that a station for stocking fish in a pond be installed. In this case, ponds should have a surface area between 100 and 500 m^2 and a depth from 0.4 to 0.5 m. Some authors recommend ponds of 400 m^2 , which allow higher production per unit of area, than ponds of 50 m^2. Others recommend using small ponds, from 9 to 12 square meters, and only introducing one pair into each. In these small ponds, it is easier to regularly harvest groups of alevins when their parents are no longer guarding them. Also, these small ponds do not require a monk. This latter system is preferred. For

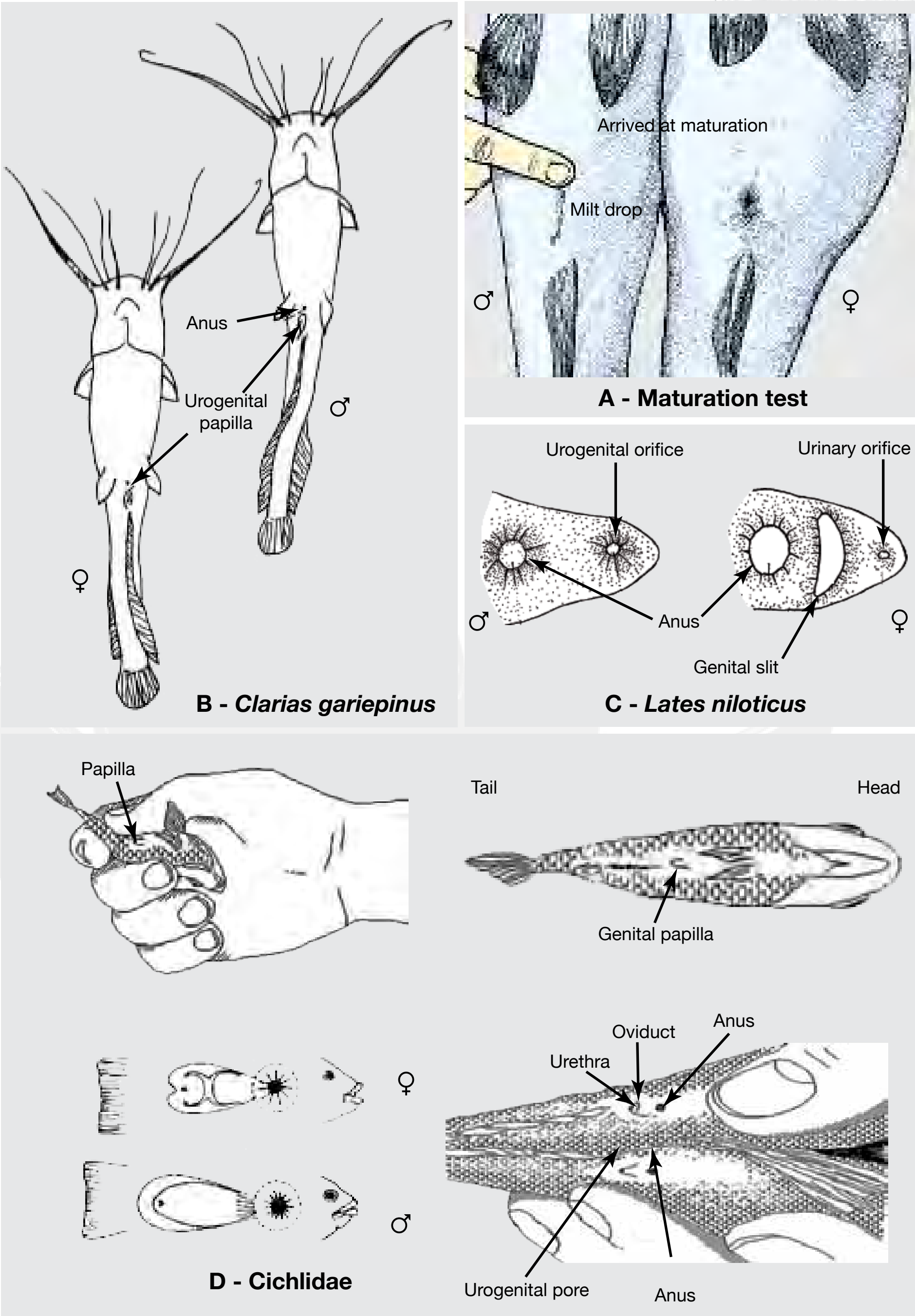


Figure 127. Sexual differentiation among different species.

mouthbrooders, this method will produce 200 to 300 alevins per parental pair per month. However, spawning frequency and alevin production may be significantly improved if ponds are stocked with 4 to 6 females and 2 to 3 males. In this case, even if one or another breeder is sterile, production will still occur. Ponds of 400 m^2 should be stocked with 200 females (average weight = 150 to 300 g) and 70 males (a.w. = 50 to 200 g), or **a density of 0.7 breeders/m^2 and a female/male sex ratio of 3:1** (Figure 128, Figure 129 and Table XXVIII, below).

Production of fingerlings per kg of female will decrease as the average weight of females increases. This occurs because of 3 factors:

- ⇨ Fertility decreases as weight increases.
- ⇨ Frequency of oogenesis decreases as weight increases.
- ⇨ Males reproduce less frequently with large, aggressive females.

Among substrate spawners, sex-ratios must be reduced.

There are two common harvesting techniques: first, ponds can be regularly drained every 60 days, which limits spawning frequency, and then breeders and fingerlings can be separated using nets of appropriate mesh size. Second, fingerlings can be harvested with seines or cast nets that collect all those that weigh more than 0.5 g. Exploitation begins 30 to 60 days after breeders are introduced into the pond and continues with a harvest every 15 days.

From a biological point of view, one of the main advantages of breeding fingerlings in a pond is that this method uses resources optimally, compared to breeding them in a more closed system. From a practical point of view, pond breeding also uses simple technology, requiring less regular control than breeding in artificial conditions. However, if the density of fish in the pond is high, conditions become more or less similar to those of a cage or a tank and the various phases of production must be followed up and monitored more closely:

Table XXVIII. Production of *Oreochromis niloticus* as a function of the number of breeders in a pond of 4 ares over 122 farming days.

Density of breeders (ind/m²)	Sex ratio (female / male)	Fingerling production	
		(ind/m²/month)	(g/m²/month)
0.35	3	33.1	60
0.50	1	27.5	49
0.70	3	54.0	86
1.00	1	45.0	112

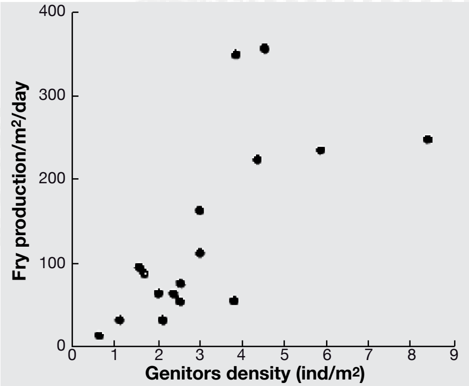


Figure 128. Fingerlings produced per fish density for *Oreochromis niloticus.*

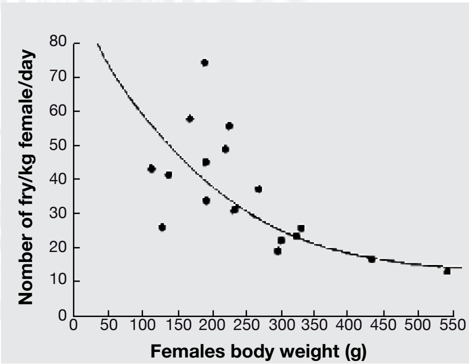


Figure 129. Fingerlings produced per female body weight for *Oreochromis niloticus.*

- ⇨ Control breeders' reproduction and harvest fingerlings frequently,
- ⇨ Fertilize the pond to improve productivity,
- ⇨ Feed the fish regularly,
- ⇨ Control water quality and renew it if necessary.

III.3.HAPAS AND CAGES

Under certain conditions, depending mainly on mesh size and breeder density, tilapia reproduction in a cage is feasible and can produce large amounts of fingerlings (Figure 130, below and Photo U, p. 143).

Hapas are small, fixed pockets (from 1.5×1×1 m to 3×3×1 m), made with nylon mosquito netting (mesh size of 1-3 mm) and attached to bamboo sticks, stakes, or wooden poles stuck into holes dug into the bottom of a shallow pond. The hapa is placed 10-20 cm from the bottom of the pond at a depth of about 0.6 m. It can also be placed in a basin.

Breeders are confined in an internal room bordered by nets with a mesh size of 30 mm, so that the fingerlings can be easily kept in the external room (with 1-3 mm mesh size) as they develop. The disadvantage to this device is that it limits water flow through the hapas, because the breeders do not have access to the walls of the external room. However, as the fish move and scrape algae and détritus, they facilitate renewal of the water within the hapas. As an alternative, breeders can be put in a half-hapas, which allows them to have better water circulation (Figure 131, p. 143).

The best results are obtained with densities from 2.5 to 5.0 breeders/m^2, and with a female/ male sex ratio of 5:1 to 7:1. Recently, however, ratios of 2:1 and 3:1 have yielded good results.

One of the advantages of using a hapas system is that it is easy to control spawning and recovery of fingerlings, since each unit can be easily handled by one or two people. Fingerlings can also be collected every day with a hand net. Ten to fourteen days is a good harvest interval for females that are one to two years old.

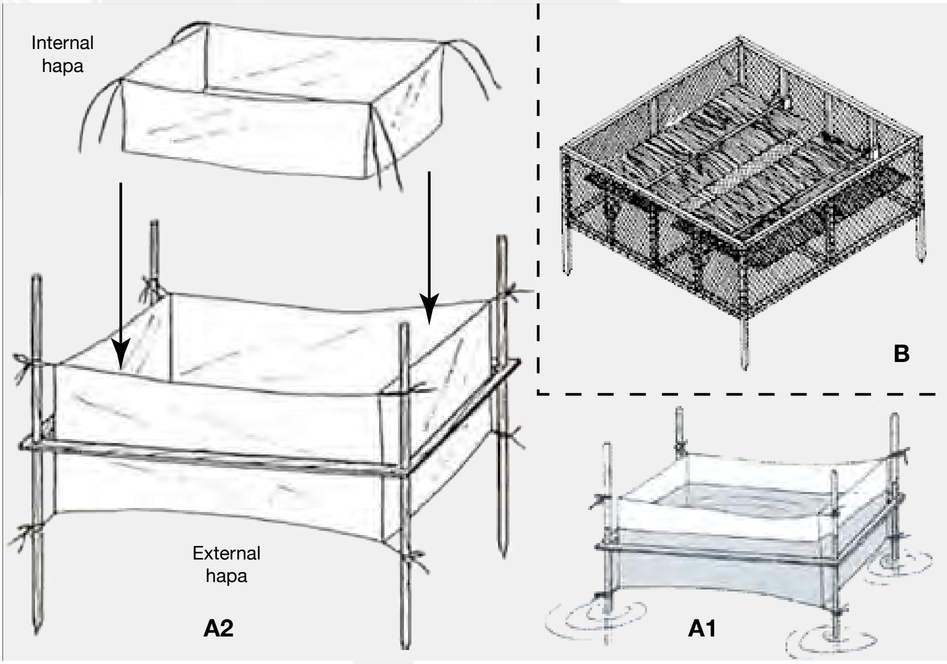


Figure 130. Hapas and cages. A: Hapas, A1: Simple, A2: Double; B: Cage.

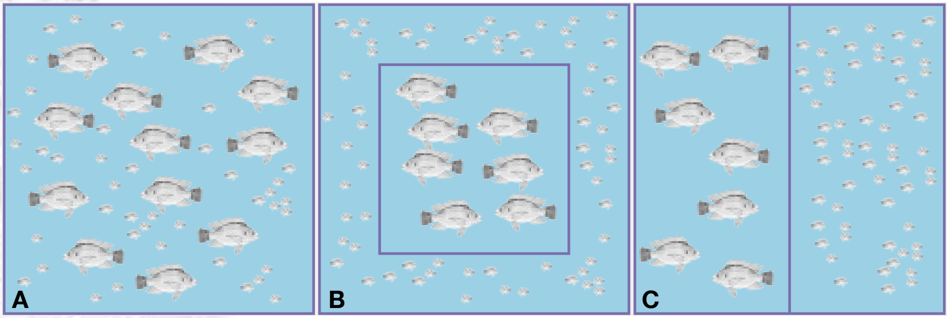


Figure 131. Different systems of tilapia reproduction in hapas and cages. A: Simple; B: Double with breeders in the middle; C: Breeders in one half.

Cages are generally made of a rigid wood or metal frame equipped with a synthetic net demarcating a volume of water and equipped with a system of floats attached to the upper framework or supported by stakes inserted into the lake or river at a shallow depth.

When establishing a cage breeding system, site selection is very important. Factors such as water quality and circulation, protection against floating débris and waves, site accessibility, safety, and distance from markets are important to consider. The possibility for sudden arrival of extremely turbid flood water must also be taken into account, since it degrades farming conditions and can prevent fish from feeding. A protective cover or net should be installed on the cage so that it can

Photo U. Hapas in ponds (Ghana) [© É. Bezault].

be submerged if necessary. Lastly, note whether there are water currents within the cage, with the reduction in dissolved oxygen concentrations following an increase in toxic gases, and variations in temperature during transitional periods.

Whatever model is used, the bottom of the cage must be at least 0.3 m from the bottom, where waste accumulates, causing a reduction in the concentration of O_2.

Cages for breeding and fingerling production are generally smaller than those for the production of fish for consumption, measuring from 0.5 to 1 m^3. The cage's depth can also affect tilapia growth and reproduction. To produce fish for consumption, cages of 20 m^3 generally have a depth from 0.5 to 1 m. A mesh size of 3 mm seems to be the upper limit for spawning of *O. niloticus,* since the average egg size is between 2.5 and 3.0 mms in diameter. The best fingerling production rate (53 ind/m^2/month) is obtained using a sex ratio of 3:1.

Breeders can be fed with rice, among other things.

The use of breeding cages can significantly increase the amount of larvae produced, if these larvae are harvested frequently. Repeated and complete harvests are all the more effective because they do not require draining of the pond or fishing with the seine, and thus limit the loss of offspring caused by these operations. Moreover, the double-net system reduces cannibalism by adults, thus increasing the number of larvae produced per female. Note that cages and hapas can be used to store the fish that are collected when ponds are drained.

Consequently, recommendations for fish farming are to keep parents aged 1.5 to 2 years at a density of 4 individuals/m^2, with males that are slightly larger than females and at a sex ratio of 1 male to 3 females.

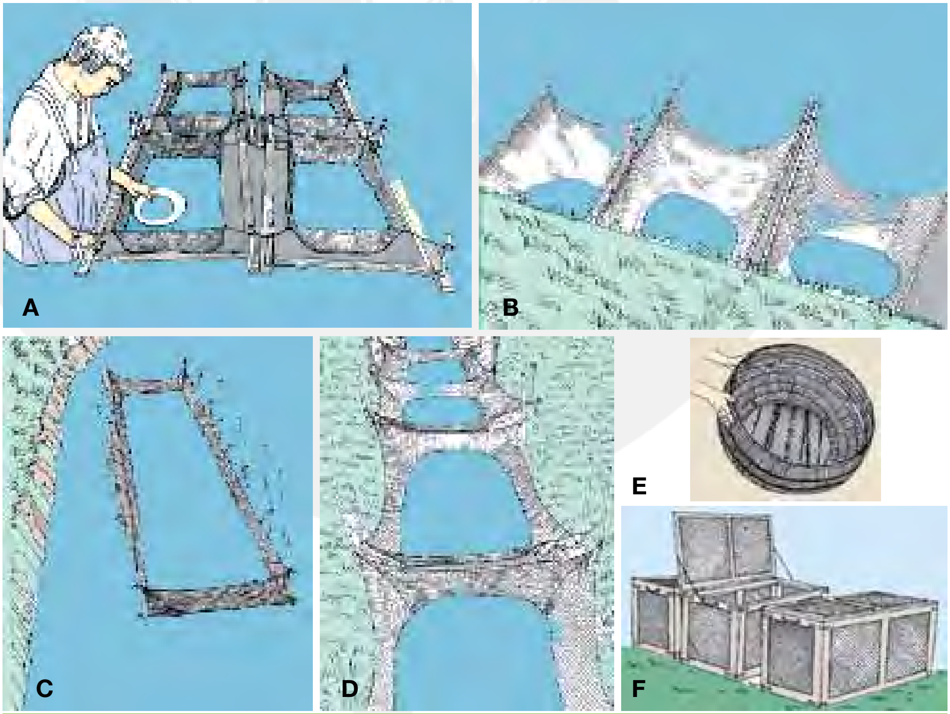


Figure 132. Live fish storage in hapas or nets. A: Wood frame and net bag; B, C and D: Hapas or cage in net in pond or in canals; E: Basket; F: Wood and mesh holding box.

These cages or hapas can be put directly into the water supply canal, or at other points where they will be protected. They can be used for several tasks:

- **Fingerling production**
- **Storage of fingerlings collected in the wild**
- **Storage of accessory species after they are captured in the wild**
- **Storage of fish after ponds are drained.**

Small nets or other materials can also be used to store fish (Figure 132, p. 144).

III.4. OTHER STRUCTURES

Other structures, such as concrete basins or aquariums, can be used to produce fingerlings. However, these structures are better for large-scale production in commercial operations. They are much more expensive and high-tech (Photo V, below).

Brick or cinder-block basins generally have an elongated shape, which makes water circulation easier.

Aquariums must be large (minimum of 200 liters for tilapia).

Photo V. Concrete basins and aquariums (Ghana) [© Y. Fermon].

IV. STOCKING THE PONDS

When the pond is filled with water and has been fertilized, the water is sufficiently green, and fingerlings are available, they can be introduced into the ponds.

The density of fish in the pond varies depending on the species and its behavior and is one of the key components of farming success. When herbivorous fish reach a size at which they can reproduce, predators should be added to the pond to control reproduction and prevent the population of fingerlings from getting too big. **The fish will not automatically do what you want them to do. Their development will depend on the conditions they are given.** So it is necessary to provide them with the optimal conditions that will allow them to invest their metabolic energy in growth.

The optimal density for fish stock at the beginning of the production period is whatever amount of fish will guarantee the highest income. Stocking density is one of the most important determinants of a fish farm's success. In fish farming systems, fingerlings grow at an almost maximum speed as long as they are not limited by a lack of food or by other environmental conditions. When fingerlings reach this limit, the biomass they have attained is called the critical charge (CSC). Growth rate decreases starting from this CSC, but it is not null. Thus, biomass continues to increase, until the population reaches the level of biotic capacity, or (K). After K is reached, population density will cause growth to stop and biomass to remain stable. Stocking density, and thus yield, can be increased as long as the stocking density rate of increase remains higher than the rate at which individual growth decreases. But, from the moment when the reduction in growth rate becomes higher than the increase in density, yield falls, as shown in Figure 133, below.

If the density of fish in the ponds is low and natural foods are abundant, fish will grow at the maximum speed allowed by the temperature. Supplementary feeding adds nothing at this stage since food is not a limiting factor. On the other hand, when stock density reaches the CSC, food does become a limiting factor. In this case, the growth rate will decrease unless management of the farm is intensified. If natural food production can be increased through fertilization, maximum growth begins again, until the stock reaches a new CSC at a higher level. At this stage, it may be necessary to provide complementary food to maintain the maximum growth rate. Then, again, CSC is reached when food or water quality becomes a limiting factor.

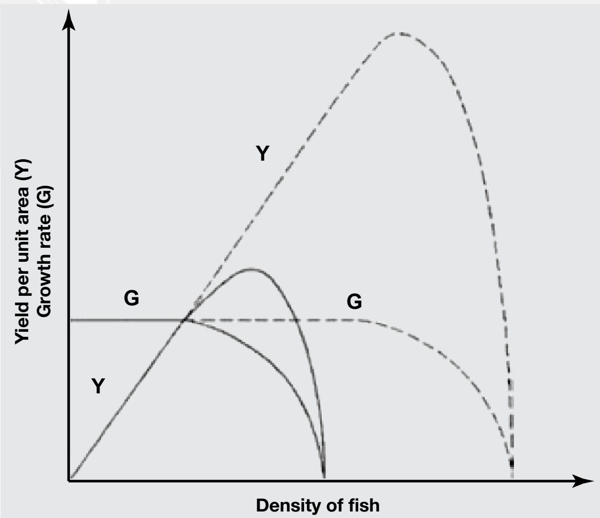


Figure 133. Diagram of the relationship between stocking density, instant growth rate (G) and instant yield per surface unit (Y) with (dotted) and without (solid) complementary feeding.

Density can be used to control the fish stock's average growth rate and consequently, the duration of the farming period. As we have already discussed, when stocking density increases, the stock will reach CSC at a lower individual weight and growth beyond the CSC is reduced. The average growth rate over the entire farming period is consequently lower. More generally, pond yield per unit area is positively correlated with density, while growth is inversely correlated with density. In other words, up to a certain threshold, the lower the density, the faster fish will grow and the lower the yield will become.

The pond fish farming

systems recommended in this manual are polyculture systems dominated by tilapia, particularly *Oreochromis niloticus* (or other tilapia). For some localities, catfish will be selected as the principal species. The clariid catfishes including *Clarias gariepinus*, *Heterobranchus isopterus* and *Heterobranchus longifilis* is the second group of fishes commonly farmed. The last of these species (*H. longifilis*) is used only in intensive farming systems with granulated food. Although it is often forgotten, *Heterotis niloticus* is probably the third most important fish.

Stocking the pond at a relatively low density will generate a better growth rate and a higher final weight, but a lower yield. But if the growth rate is higher, the entire cycle takes less time, which may result in higher benefits at the end of the year. Experiments in Ivory Coast showed that the optimal density for a compromise between yield and final average weight ranges from 4 000 to 7 000 tilapia/ha (Figure 134, below). For now, it is best to stock ponds at a density lower than that for low-input fish farming. The recommended density is 5 000 fish/ha, or **0.5 individuals/m²**. In earlier publications, recommended density was generally 2 individuals/m².

⇨ Tilapia density should be 0.5 individuals/m².

Most fish farming projects in Africa have used catfish (often *Clarias gariepinus*). The technique is very demanding: it is necessary to obtain, at the beginning of each cycle, catfish fingerlings of a size that will not attack the large tilapia in the pond. Moreover, if, for any reason, the growth cycle becomes longer, the catfish, which grow faster, will ignore the tilapia fingerlings and attack the large individuals. The value of production will then fall, since the large fish are more expensive than the small ones. Although catfish fingerlings are abundant in some seasons, they are difficult to find in the wild at other times of the year. In extended environments, *Clarias gariepinus* was a poor carnivore, unable to control the amount of fingerlings. On the other hand, some individuals grow so fast that they can attack large tilapia after 4 or 5 months. It is better to use *Hemichromis fasciatus*, or another fish-eating Cichlidae that is easy to manage. This small carnivore is definitely smaller than the tilapia, and can only attack fingerlings. The fastest growth of tilapia has been attained using this type of predator (Figure 135, p. 148). This provides a new advantage: it makes it possible to quickly obtain a larger product, which consumers will prefer. The eradication of tilapia fingerlings (which are the large tilapia's primary competition for food) allow the inputs to develop twice as well. Moreover, the presence of carnivores facilitates population control, making tiresome and hazardous fishing that will eliminate excess fingerlings unnecessary. Once the field is controlled by a predator, some catfish can still be judiciously introduced after the cycle begins, at a density where they will not influence the growth of the tilapia.

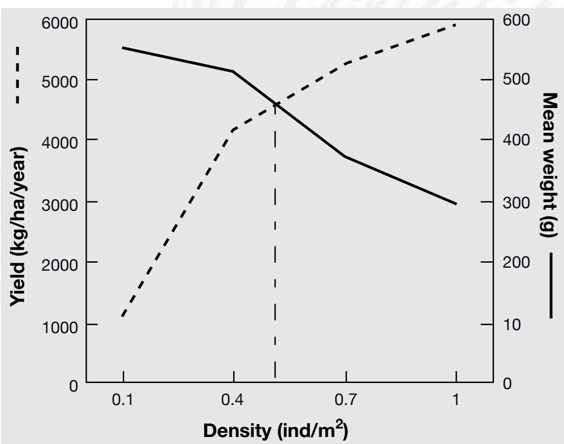


Figure 134. Yield and average weight of *Oreochromis niloticus* at harvest as a function of initial density.

Polyculture using *Heterotis niloticus* became important at the end of the 1980s. This species does not seem to reduce tilapia yield, but appears, instead, to be perfectly complementary. If a very limited number of *Heterotis* breeders (that are more than 1 and a half years old) are left to reproduce, they can be observed taking care of their young and, when the young appear large enough to be isolated (at the end of 1 to 2 months), they can be collected. In economic terms, partnering of *Heterotis* and tilapia allows for more intensive use of pond surface area.

Polyculture with Cyprinidae is still not used much in Africa, except with introduced species. This method can be developed with indigenous species.

As a principal species, tilapia (*Oreochromis niloticus* when it is available) can therefore be raised together with catfish (*Heterobranchus isopterus*, *Clarias* spp.), *Heterotis niloticus* and a predator (*Hemichromis fasciatus*, *Parachanna* spp. or *Serranochromis* spp.), which will eliminate undesirable fingerlings. The species ratio should be 0.03 for *Heterotis niloticus*, 0.04 for Siluriformes, 0.2 piscivorous for each tilapia.

The proportion of predators should be approximately 13% of the weight of introduced tilapia. On the whole, it is enough to have ten fish of approximately 7–8 cm per one hundred tilapia that have reached 6–7 cm. Predators should be stocked approximately one month after tilapia.

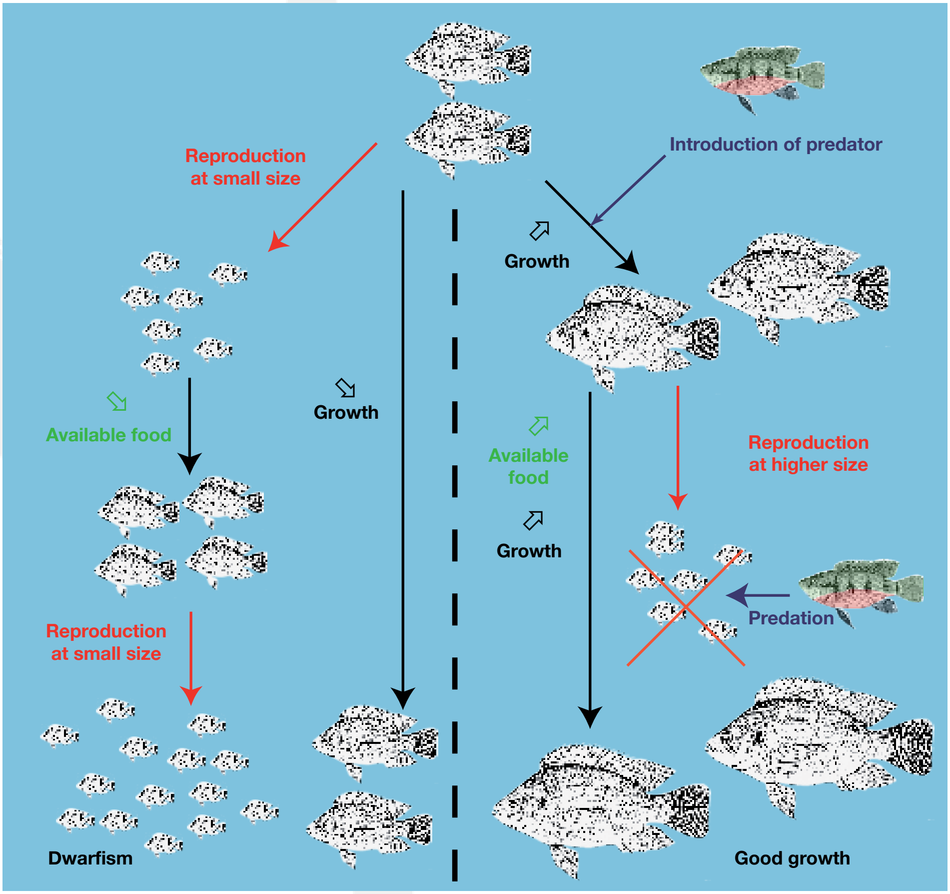


Figure 135. Impact of the presence of a predator (here, *Hemichromis fasciatus*) in a fish pond. On left: Without predator; On right: With predator.

V. MONITORING FISH

Proper management of fish requires regular verification of their size and rate of growth through measurement and weighing of a sample of fish from the pond.

It is always best to weigh live fish in clean water, as quickly as possible (Figure 136 below).

You can measure the total weight of a certain number of fish. For best results, put a batch in a container or a bag and weigh it. Then count the fish, and divide to obtain the **average weight** of each individual.

To measure the **live weight** of relatively large fish, such as a breeder, you can simply use a satchel or stretcher made of canvas (for example), slung from two wooden bars.

Length measurements are particularly quick and useful for medium to large fish and cause far less stress or damage to the fish. The easiest way to measure fish length is to use a fish measuring board. A simple one can be made out of wood. Fix a flat ruler marked with millimetres and centimetres on top of the horizontal board. Then fix a small perpendicular plank against the ruler at the «zero» mark. A coat of good waterproof varnish can help to ensure that the board is smooth.

To measure the length of a fish, place it on the horizontal board, with the end of its head against the small vertical plank, at the ruler's zero mark. The caudal fin should be well-extended and the length should be measured on a graduated scale. Often the total length or the fork length is used. However, it is better to use the **Standard Length** (SL) (Appendix 03, paragraph I, p. 207).

A fish's length and weight can be related mathematically, so weight can be estimated from length (Figure 137, p. 150). This relationship varies with the species and its environment, so it is necessary:

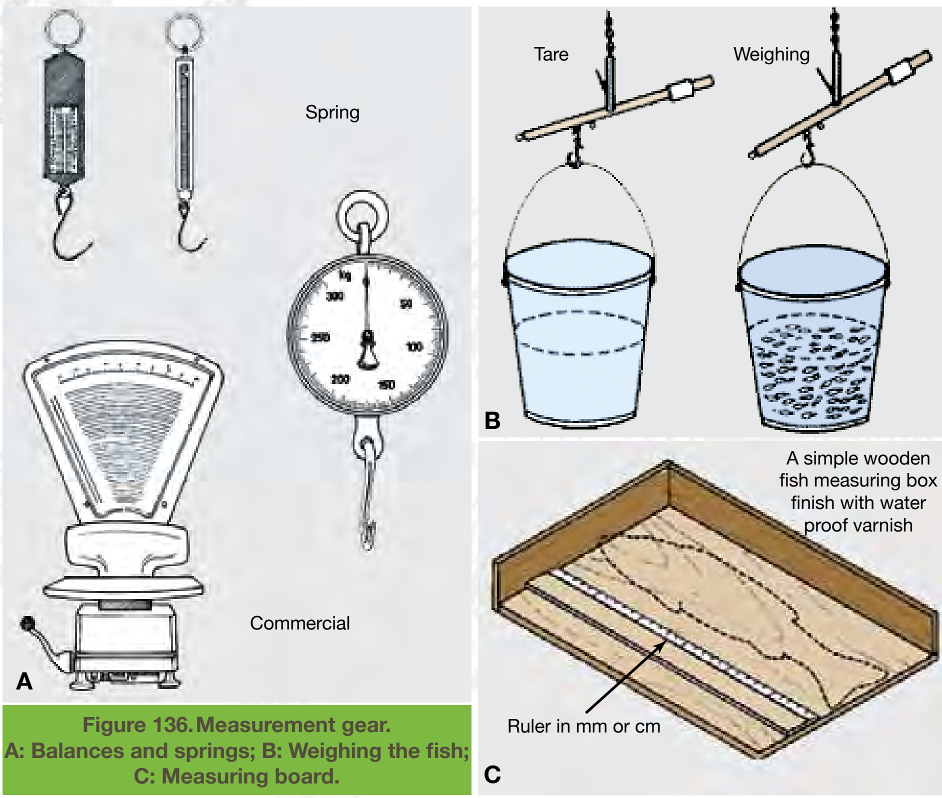


**Figure 136. Measurement gear.
A: Balances and springs; B: Weighing the fish; C: Measuring board.**

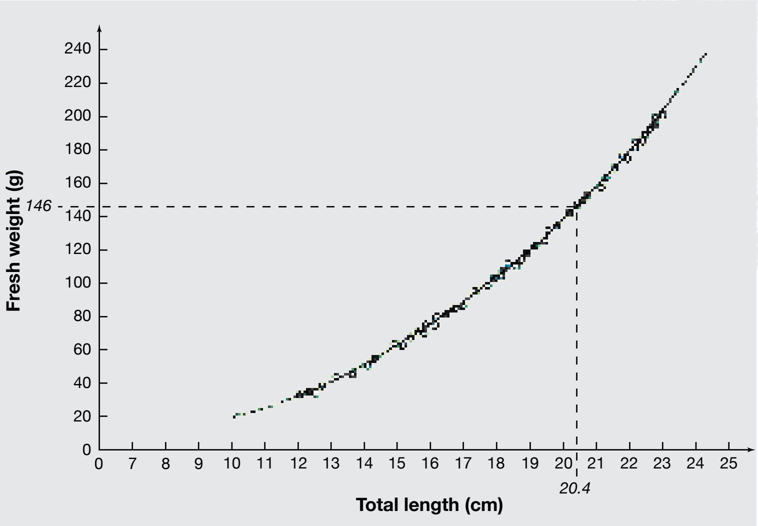


Figure 137. Length to weight relationships.

1. To take a fish sample from the pond.
2. To measure the standard length, preferably of each individual, then,
3. To weigh the fish individually.

The sample must include at least **20 individuals**, even if statistically a sample of 5 individuals would be enough.

If weighing the fish is difficult, the mean individual weight of the fish can be estimated from the relationship of length to weight.

To monitor growth, proceed as follows (Appendix 01, p. 189):

1. Take measurements from a sample of fish during stocking;
2. For fish that are less than 5 cm SL, proceed with the same manipulation twice a week during the first month. After that, measurements can be taken once every week.
3. If possible, growth should be monitored over a period of 3 months.

VI. DRAINING THE POND AND HARVESTING THE FISH

Farmed fish can be harvested in several ways. All the fish can be collected at once (complete draining) or harvesting can be done several times through intermediate fishing without emptying the pond, and then finally draining it completely.

VI.1. INTERMEDIATE FISHING

Using the intermediate fishing method, the farmer can harvest fish throughout the farming cycle. This can be done with a net, a cast net, traps or handlines. Alternatively, harvests can be timed to follow the growth of the fish. However, intermediate fishing should never be done too early; it should wait until the fish have reached a sufficient size for consumption. The size of fish to be harvested varies depending on the location. Sometimes, fish are consumed when they are smaller than 10 cm SL.

For each harvest, only a small amount of fish should be removed, especially if intermediate fishing will be done several times. Each time, the farmer should note the weight of the fish that are caught in the pond, in order to add them to production totals when the pond is finally drained completely. If intermediate fishing is done in a moderated way, total production will be higher than for ponds that are drained once at the end of the cycle. Fishing gear can be used to collect the fish (Chapter 09, paragraph I, p. 127).

VI.2. COMPLETE DRAINING

Draining is always done early in the morning, so that work can be completed during the coolest hours of the day, and the fish, especially the fingerlings, will suffer less. Material and necessary tools (shovel, basins, baskets, etc.) should be gathered the evening before. Fish that are not consumed or sold can be stored in cages or hapas. Fish can be sold either at the edge of the pond, in which case the neighbors should be informed, or at the village market, in which case a fast means of transport will be necessary.

When the pond is equipped with a monk, fish can be collected in two ways (Figure 138 below):

- Inside the pond, just in front of the monk;
- Outside the pond, after the fish have crossed the monk and the draining pipe.

To harvest fish inside the pond, remove the wooden boards from the monk one row at a time. Each time a row of boards is removed, be sure to put the screen back on top to keep the fish from getting out.

When the water is partly drained from the pond, some of the fish cnan be harvested from the water just in front of the monk. (Figure 139, p. 152). When it is time to harvest the rest of the fish, continue to take the boards out one by one. However, the screen should be put back each time until the pond is empty. When all of the water is out, the remaining fish can be harvested. Collect the baby fish first, and then the big fish. Muddy water is bad for baby fish. So, a little clean water should be allowed to flow through the pond to keep it from getting too muddy.

A number of fish will pass through the monk. A box or some baskets can be placed in the drainage canal outside the pond, at the end of the pipe coming from the monk (Figure 139, p. 152). The pipe should be well inside the box, so that the fish cannot escape.

So now we proceed to harvest the fish.

Figure 138. Harvesting fish. A: Inside, after complete draining; B: Outside, with a box; C: Inside, at the catch basin.

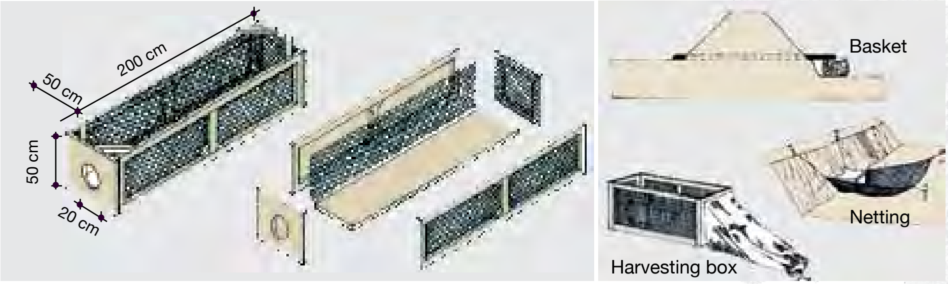


Figure 139. Examples of ways to collect fish outside the pond.

VII. SUMMARY

- After the pond is fertilized, the next steps are:
  - *Collect* specimens in the wild or produce tilapia fingerlings;
  - *Stock* ponds with tilapia;
  - *Monitor* growth;
  - *Collect predators* in the wild;
  - *Stock* the pond with predators;
  - *Monitor* and *partially harvest* fish;
  - After several weeks, *drain the pond* and *harvest all* the fish.
- This chapter focused on:
  - *Fishing methods* and precautions for keeping fish in good condition and avoiding problems and dealing with local legislation;
  - The *biology of the species* that produce high yields, breeding, feeding, and behavior, both for good growth and to influence choices about density;
  - T*ransporting* fish and providing care in order to avoid loss of some or all fish.

Chapter 10
MAINTAINING AND MANAGING PONDS

When the fish are harvested, the farming cycle is over (Figure 140, p. 154).This chapter will focus on remaining management tasks that will ensure the ponds' durability and, thus, continued production. These include:

- ✓ **Pond maintenance;**
- ✓ **Techniques for conserving and processing fish;**
- ✓ **Pond management;**
- ✓ **Ponds and health.**

I. POND MAINTENANCE

To ensure a high level of production over several years, it is advisable to implement a variety of procedures related to:

- ➢ **Diseases of fish,**
- ➢ **Nutrition of fish,**
- ➢ **Regular pond maintenance,**
- ➢ **Pond maintenance between periods of use.**

I.1. DISEASES OF FISH

Fish diseases may cause severe losses on fish farms through:

- ⇨ Reduced fish growth and production;
- ⇨ Increased vulnerability to predation;
- ⇨ Increased sensitivity to poor water quality;
- ⇨ Increased fish mortality.

While it may be difficult to avoid fish diseases completely, it is better to try to prevent them from occurring than to allow diseases to develop and attempt to cure them when they start to cause problems. In some cases surviving fish are so weakened that it is difficult to treat them effectively.

However, there are several simple and effective treatments, which will either prevent disease or control it before it becomes too serious.

There are several causes of disease that may affect fish directly or may continue to cause problems. Basically, any factor that causes stress or difficulty to the fish decreases their resistance to disease and increases the chance that complicatons will occur.

The three main causes of disease are:

⇨ **Inadequate feeding**. Nutritional diseases become more frequent as the cultivation system becomes more intensive and the fish are obtaining smaller proportions of their nutrients from natural food organisms.

⇨ Exposure to an extreme or toxic condition.
- ➢ Rough and/or excessive handling, such as during harvest or sorting/grading;
- ➢ Overcrowding and/or behavioural stresses, such as in storage or during transport;
- ➢ Unsuitable water temperature;
- ➢ Lack of dissolved oxygen;
- ➢ Changes in pH toward extreme values;
- ➢ Presence of toxic gases such as ammonia or hydrogen sulphide;
- ➢ Water pollution by agricultural or industrial chemicals, sewage effluents, heavy silt loads.

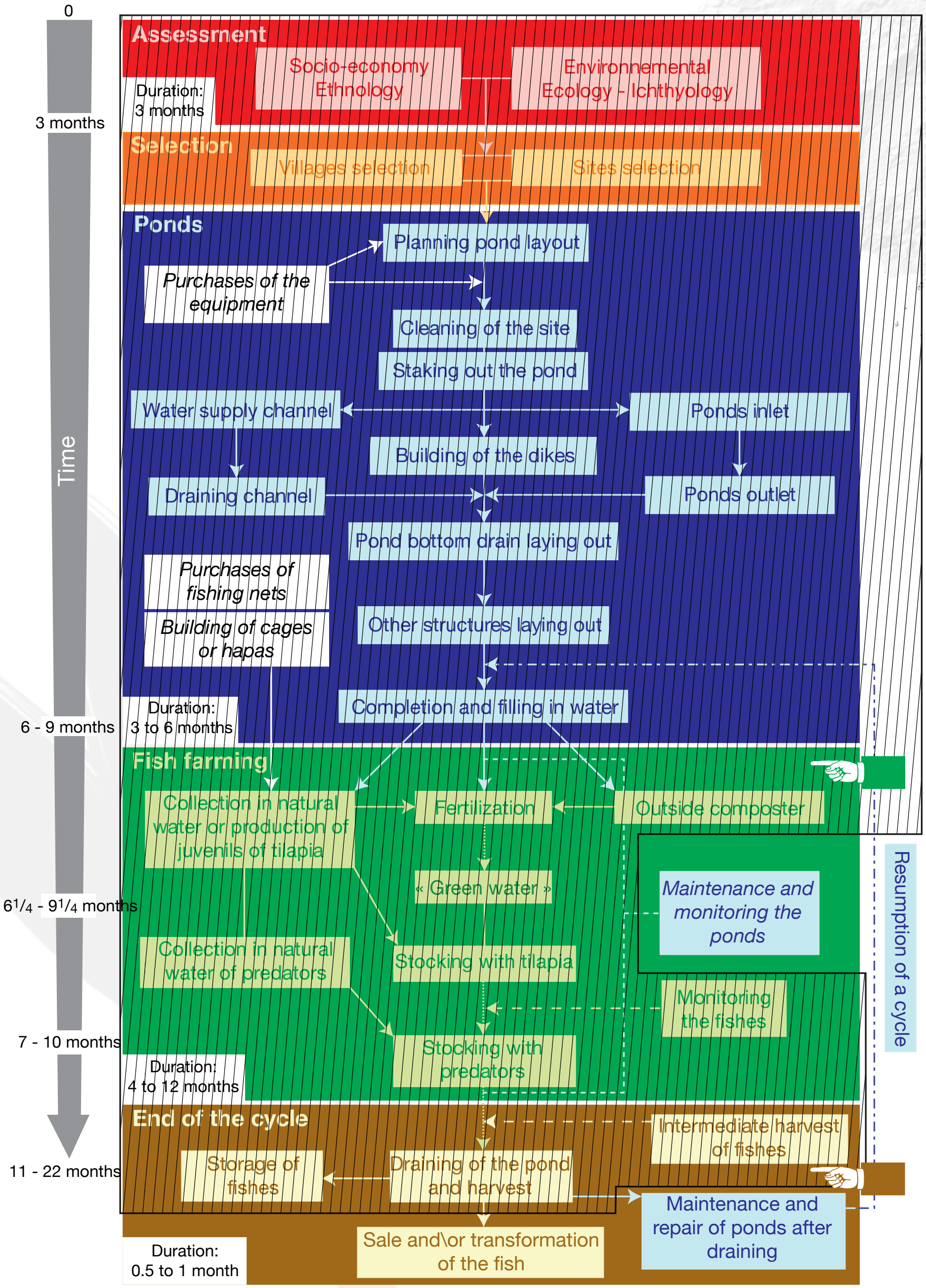


Figure 140. Setting up fish ponds: 5. End of cycle and starting again…

⇨ An attack by **pathogenic organisms**, which will either attack externally on the skin, gills or fins, or internally in the blood, digestive tract, nervous system, etc.

The risk of disease is even greater when fish undergo combined stressors, such as being handled when the water temperature is below normal or being overcrowded in an environment where the dissolved oxygen is low.

Other factors that may encourage the propagation of disease, and make it much more difficult to control, include:

✓ The presence of diseased wild fish;

✓ The presence of intermediate hosts such as snails and fish-eating birds, which may provide a necessary link in the disease organism's life cycle;

✓ The introduction of disease organisms through contaminated inputs such as food, trash fish or processing wastes, including imported eggs, juveniles, or broodstock, or water from an upstream pond or farm.

Disease can be prevented through good management practices:

⇨ **Ensure that water quality is good. There should be a sufficient supply of water, adequate concentrations of dissolved oxygen, and no pollution.**

⇨ **Keep the pond environment healthy**. Control silt, control plants, maintain a healthy balance of phytoplankton and zooplankton, and change the water if necessary.

⇨ **Keep the fish in good condition by controlling stocking density**. If necessary, keep different sizes or sexes separate to control fighting. Care for your fish during storage and transport.

⇨ **Prevent the introduction of disease organisms** from outside your farm.

⇨ **Prevent the spread of disease organisms** within your farm. If a disease breaks out, remove dead or dying fish from the ponds as quickly as possible (at least once a day), and do not disturb or stress the remaining fish more than necessary.

Apart from obvious signs such as dead or dying fish, there are many other signs that fish are not healthy (Figure 141, p. 156):

The behavior of your fish becomes unusual:

- Swimming is weak, lazy, erratic,
- Fish are floating in the water with their heads up,
- Fish rub against hard objects,
- Fish are flashing and twisting,
- Fish are darting repeatedly,
- Fish are crowding and gathering in shallow water or where the water flows into the pond,
- Individual fish are isolated from the main group.

✓ Physical signs are present on the fish:

- Gaping mouth,
- Open sores, lesions, bloody areas, loss of scales, bloated belly, or abnormal coloration on the body,
- Gills are pale, eroded, swollen, bloody or brownish,
- Eyes are cloudy or distended,
- Fins are folded or eroded,
- Disease organisms are visible on the skull, gills, or fins.

It is not always easy to determine why fish in a fish pond are showing signs of bad health. However, there are two common situations that you should be able to recognize immediately:

⇨ If many (or all) of the fish show distress or die suddenly, showing only some of the above symptoms of disease such as gasping at the surface or gaping mouths, the cause is prior stress (such as rough or poor handling or transport) and/or bad water quality (often low concentrations of dissolved oxygen) or the presence of toxic materials such as pesticides or other pollutants.

⇨ Only a few fish are dead while others show distress. Usually a few fish die over a period of several weeks and some of the above symptoms are present. The cause is improper feeding and/or development of a disease organism.

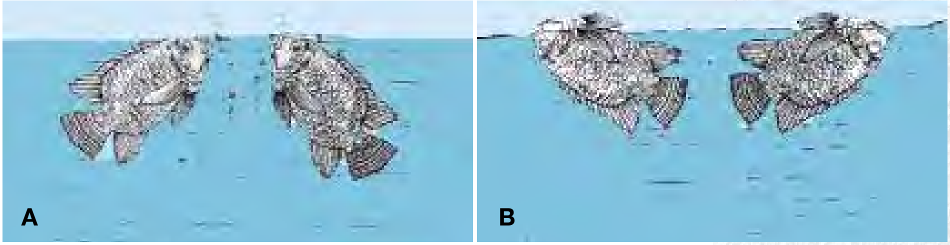


Figure 141. A: Fish gulping at the surface; B: Dead fish floating at the surface.

Most treatments require chemicals that are not easy to obtain, can be difficult to handle, and may be toxic. You should avoid using these treatments, and you may have to sacrifice sick fish. However, it helps to know if you are dealing with a disease caused by pathogenic organisms.

If it is necessary to know the identity of the disease or pathogen in a particular case, you can carry out an autopsy to:

1. Search for external parasites;
2. Search for internal parasites;
3. Note the color and aspect of the liver.

There are three major groups of living organisms that can cause fish diseases (Figure 142 below and Figure 143, p. 157):

✓ **Viruses**. Their detection and identification requires highly specialized laboratory techniques. Control of viral diseases is difficult and requires specialized advice.

✓ **Bacteria**. These are minute single-cell organisms (l to 12 µm), which usually live in colonies. Their detection and identification generally also requires special laboratory techniques. The treatment of bacterial diseases such as tail or fin rot, or skin ulcers, requires experienced, specialized advice.

✓ **Parasites**. Parasites are very small organisms comprised of one or several cells. They develop either inside or outside the body.

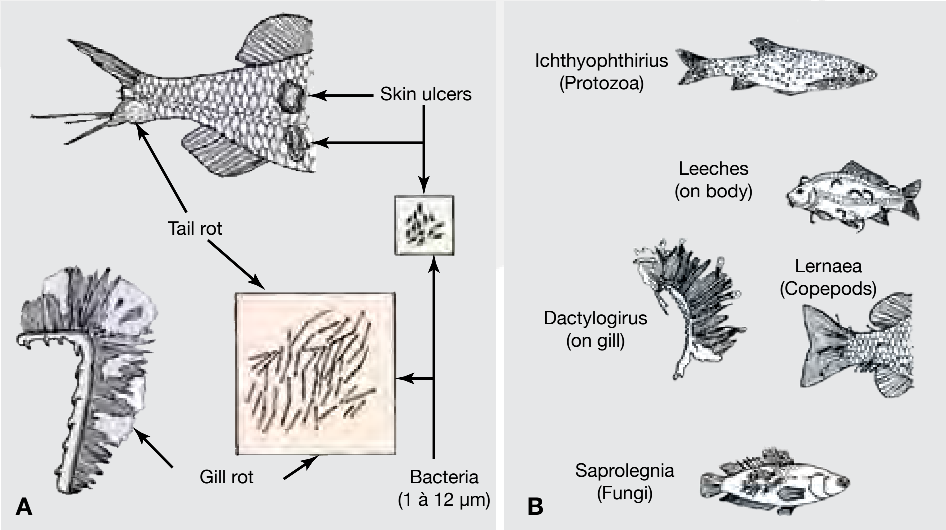
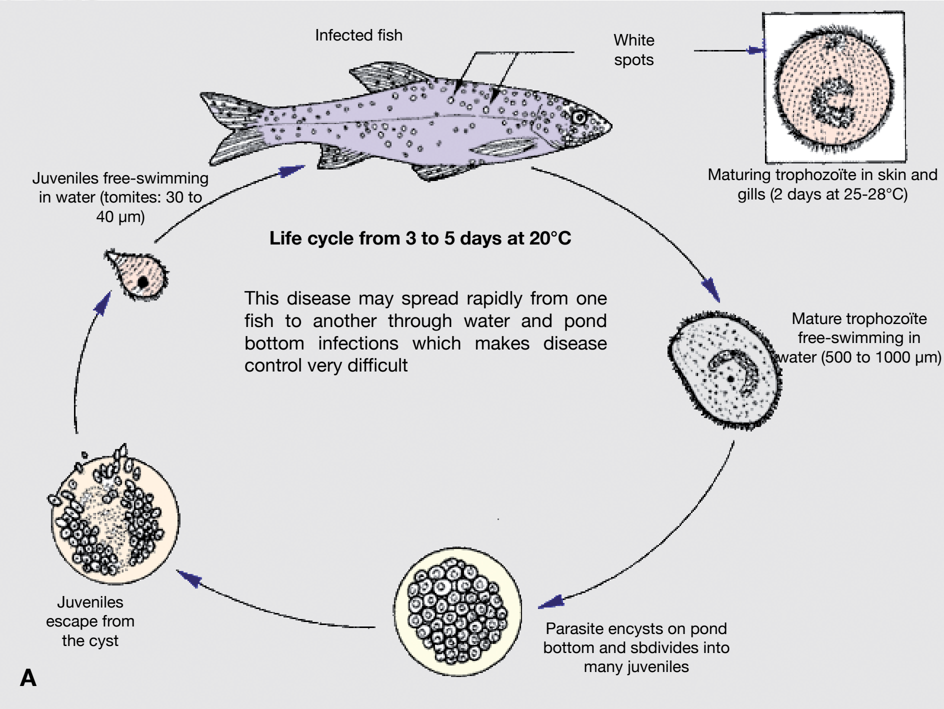


Figure 142. Diseases of fish. A: Bacterial diseases; B: External parasites.



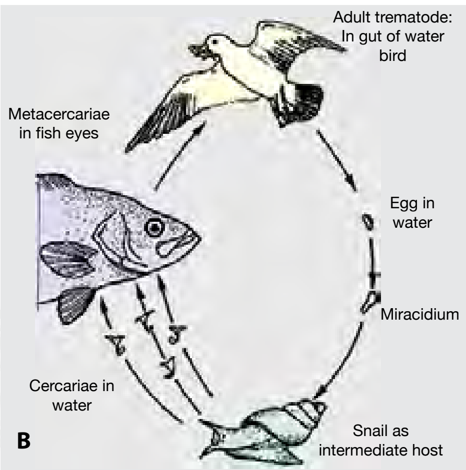


Figure 143. Examples of life cycles of fish diseases.
A: *Ichthyophthirius multifilis* – White-spot disease;
B: *Diplostomum spathaceum* - Diplostomosis.

• Internal fish parasites are very difficult to control. Although sometimes their effects can be easily identified, detection and identification of the parasites themselves usually requires special skills.

• External fish parasites are much easier to detect and identify, and it is usually possible to eliminate them.

- Protozoa are very small, single-cell parasites,
- Flukes (*Monogenea*) are very small worms that attach themselves to the fish by hooks (0.3 to 1 mm),
- *Leeches* are rather large, segmented worms that attach themselves to fish with sucker on each end (3 to 5 cm),
- *Copepods* (crustaceans), which attach themselves to the fish's body and often have two elongated egg sacs attached,
- *Fish lice* (Crustacea) have a flat, disc-like body covered by a rounded dorsal carapace (6 to 10 mm),
- *Water fungi* (water molds) are made of filaments that usually grow into a cotton-like mass or mat. They can also develop in the gills.

I.2. FEEDING FISH

Most of the time, fish will eat mostly small animals and plants that grow in green water (Chapter 08 p. 118).

However, it may be necessary to provide additional food if primary production in the pond is not good and the fish grow slowly.

Nutritionally, organic matter includes proteins, lipids (fats), and carbohydrates, as well as substances present in relatively low proportions (micronutrients), such as vitamins and minerals.

Nutritional requirements vary by species (Table XXIX, below).

Diets vary by species as well (Appendix 03 p. 207).

Many kinds of materials may provide supplementary food for fish, including:

- ✓ Terrestrial plants: grasses, legumes, leaves and seeds of leguminous shrubs and trees, fruits, vegetables;
- ✓ Aquatic plants: water hyacinth, water lettuce, duckweed;
- ✓ Small terrestrial animals: earthworms, termites, snails;
- ✓ Aquatic animals: worms, tadpoles, frogs, fish;
- ✓ Rice: broken, polishings, bran, hulls;
- ✓ Wheat: middlings, bran;
- ✓ Maize: gluten feed, gluten meal;
- ✓ Oil/cakes left after oil is extracted from mustard, coconut, groundnut, African palm, cotton, sunflower, soybean seeds;
- ✓ Sugar cane: molasses, filter-press cake, bagasses;
- ✓ Coffee pulp;
- ✓ Cottonseeds;
- ✓ Brewery wastes and yeast;
- ✓ Kitchen wastes;
- ✓ Slaughterhouse wastes: offals, blood, rumen contents;
- ✓ Silkworm pupae;
- ✓ Manure: chicken droppings, pig manure.

Table XXIX. Levels of nutrients required by different species of fish.

	Percentage per size class of fish				
Nutrients	**< 0.5 g**	**0.5 to 10 g**	**10 to 35 g**	**> 35 g**	**Breeders**
Tilapia					
Crude proteins	50	35 - 40	30 - 35	25 - 30	30
Crude lipids	10	10	6 - 10	6	8
Digestible glucids	25	25	25	25	25
Fibers	8	8	8 - 10	8 - 10	8 - 10
Catfish					
Digestible proteins	> 27	27	29	22 - 24	
Common carp					
Digestible proteins		27	31		

If you choose to provide supplementary food, products with the following characteristics are preferable (Table XXX, below):

- Adequate nutritional value: high percentage of proteins and carbohydrates and low fiber content;
- Acceptability to the fish it is intended for;
- Economic considerations: for a given quality, choose the lowest-cost food;
- Food is available during most of the fish's growth period;
- Minimal additional costs for transport, handling and treatment;
- Handling and storage will be easy.

Table XXX. Relative value of major foodstuffs as supplementary food for fish.

Foodstuff		Water	Content: Crude proteins	Content: Carbohydrates	Content: Fiber
Cereals					
Rice	broken	11.3	L	VH	VL
	polishings	10.0	L	VH	L
	bran	10.0	L	VH	H
	hulls/husk	9.4	VL	H	VH
Wheat	bran	12.1	H	VH	L
	middlings/pollard	10.5	H	VH	L
Oilcakes					
Coconut/copra		8.5	H	VH	H
Cotton seed	without hulls	7.8	VH	H	H
	complete	7.9	H	H	VH
Groundnut/peanuts without hulls		10.0	VH	H	VH
Mustard		9.5	VH	H	L
Palm		10.5	H	VH	H
Sesame		8.0	VH	H	L
Soybean with hulls		11.0	VH	H	L
Sunflower with hulls		7.3	VH	H	VH
Other terrestrial vegetables					
Coffee pulp fresh		11.4	L	VH	VH
Alfalfa, leaves		76.0	VL	L	L
Sweet potato, leaves		89.2	VL	VL	VL
Sugar cane	fresh bagasse	45.0	VL	H	VH
	molasses	25.0	VL	VH	nil
Aquatic plants					
Water hyacinth (*Eichornia crassipes*)		91.5	VL	VL	VL
Kangkong (*Ipomea aquatica*)		92.5	VL	VL	VL
Water lettuce (*Pistia* spp.)		93.6	VL	VL	VL
Animal by-products					
Cattle blood, fresh		79.6	H	nil	nil
Rumen contents, fresh		57.5	VL	H	H
Intervalle de valeurs en pourcentage du poids	Very high = VH		30 - 42	40 - 55	20 - 30
	High - H		16 - 21	20 - 30	12 - 15
	Low = L		7 - 13	7 - 10	5 - 10
	Very low = VL		< 5	< 5	< 2

Table XXXI. Examples of food formulas for tilapia and catfish farming.

Foodstuffs	Tilapia / Catfish in fertilized pond	Tilapia / Catfish in non fertilized pond	Catfish fingerlings (< 5 g)
Fish flour	5	20	55
Soy flour	15	10	7
Cotton oilcake	25	10	7
Brewery wastes	15	10	7
Bran rice	20	15	5
Wheat	10	10	-
Cocoa or coffee	10	10	-
Maize flour	-	10	5
Flour from charred bones	-	5	4
Palm oil			5
Composition (%)			
Crude proteins	28.5	29.5	43.3
Crude lipids	8.0	9.0	11.0

For best results, use simple mixtures of various foodstuffs to provide the fish with the additional proteins and carbohydrates required. As far as possible, avoid using food with a high fiber content. (Table XXXI, above). The mix should include the foodstuffs that are the most readily available at the lowest cost.

It is hard to decide exactly how much food to feed the fish. The farmer should observe the fish to get an idea of their needs.

The following factors will also help determine how much food will be necessary:

- Small fish need more food, relative to their size, than large fish do.
- If natural food is abundant, less additional food is necessary.
- If food is of high quality, less additional food will be necessary.
- Fish in warmer water need more food than fish in cooler water.

The total daily amount of supplementary food provided to fish in a particular pond is usually expressed as a percentage of the total weight or biomass (B) of the fish in the pond. This percentage is called the daily

Table XXXII. Examples of adequate food quantities as a function of time per m² of pond.

Time	Weight / m²
1	360
2	480
3	720
4	960
5	1200
6	1440

Table XXXIII. Feeding rate for tilapia in a pond as a function of size (table from Marek).

Size class	Rate in monoculture	Rate in polyculture
5 to 10 g	6.67	5.33
10 to 20 g	5.33	4.00
20 to 50 g	4.60	3.71
50 to 70 g	3.33	2.67
70 to 100 g	2.82	2.24
100 to 150 g	2.16	1.76
150 to 200 g	1.71	1.43
200 to 300 g	1.48	1.20
300 to 400 g	1.29	1.03
400 to 500 g	1.15	0.93
500 to 600 g	1.09	0.87

feeding rate (DFR). For example, if DFR = 2.5 % of fish biomass B = 80 kg, 80 x (2.5 / 100) = 2.0 kg of supplementary food should be provided each day. This quantity will change as the fish grow and total biomass in the pond increases (Table XXXII and Table XXXIII, p. 160).

If the fish do not eat all the food provided, quanitities should be decreased a little the next day. Conversely, if the fish quickly eat all the food provided, quanitites should be increased a little the next day.

It is easiest to observe the fish well if they are fed them at the same time each day, preferably early in the morning and late in the afternoon, when the weather is cooler. They should also be fed from the same location every day.

It is better to feed the fish in the shallowest part of the pond so that it is easier to observe them while they eat. If they are given too much food, part of it will settle at the bottom of the pond and pollute the water.

A square or circle frame made of bamboo or light wood and attach to a stake inserted into the ground will facilitate feeding and observation. If food is put into the frame (Figure 144 below), it will be easier to see how much of it settles on the bottom. The farmer may even to touch the bottom with his hand to see whether food has settled there.

In the following situations, it would be better or even necessary to stop feeding the fish:

- ✓ When the water temperature is too low or too high (Table XXXIV below);
- ✓ When there is a limited concentration of dissolved oxygen;
- ✓ On the day when manure is applied to the pond;
- ✓ If there is a disease epidemic in the pond;
- ✓ When work must be done on the pond.

Some thought should also be given to food storage. Food must be stored with special care to prevent excessive loss or deterioration of quality. The most important factors to control include:

✓ Both the air and the food should be kept as dry as possible.

✓ Air and food temperature should also be as low as possible. At temperatures above 25ºC, the rate of deterioration and loss may rapidly increase.

✓ High temperature and moisture levels also create favorable environments for mold (fungi) and insects (beetles, moths, weevils, etc.), which may cause considerable loss and contaminate food with metabolic waste.

✓ Rodents (mice, rats, etc.) and birds can consume large quanitities of food while also contaminating the food with their waste.

✓ Human theft and indirect damage to food stores may also increase control problems.

Table XXXIV. Water temperatures at which feeding should be stopped, by species.

Species	Range of stop temperature
Mosambic tilapia	< 19 and > 35°C
Nile tilapia	< 18 and 34°C
Catfish	< 18 and 36°C

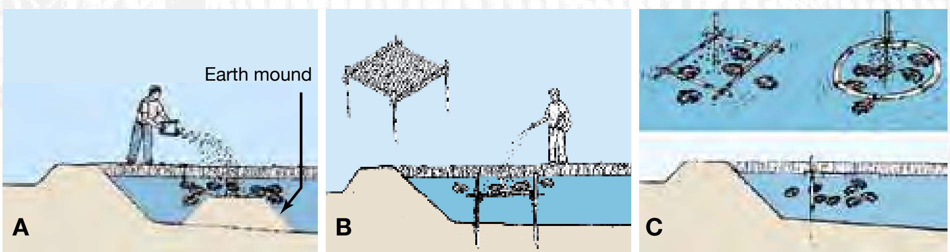


Figure 144. Structures that facilitate feeding. A: Raised pond area; B: Fixed submerged tray; C: Fixed floating frames.

I.3. DAILY FOLLOW-UP ACTIVITIES

Certain follow-up activities should be carried out each day to ensure that fish production remains high (Table XXXV, below). These activities may be reduced in a pond holding fish for production only:

At least once each day, the fish farmer should visit the ponds and check that:

- Each pond is getting an adequate water supply;
- Dikes are in good repair;
- Water quality is satisfactory, as shown by the behavior of fish and the presence of plankton.

These visits should be done early in the morning, when the concentration of dissolved oxygen is most likely to be insufficient, so the owner can improve it to preserve the fish's health. If possible, a second visit can be made in late afternoon, particularly during critical periods, to ensure that conditions remain good throughout the night.

Once each week, the following components should be subjected to more detailed inspections:

- The ponds' canals and dikes, to check for major maintenance or repair needs,
- Filters,
- Compost piles, to check if they need to be filled.

In all circumstances, the development of terrestrial vegetation should be kept under control, and used for composting.

As discussed above (Chapter 07 p. 107), farmers should also ensure that ponds remain well-protected.

Table XXXV. Monitoring. x: inspection; xx: detailed examination or major repair; V: In drained pond only.

Items	Monitoring and possible action	Daily	Weekly	Periodically
Water supply				
Main water intake	Clean/repair/adjust	x	-	-
Water supply canal	Clean/repair/adjust	x	xx	-
Pond inlet	Clean/repair/adjust	x	-	xx V
Filters	Check/clean	x	-	x
Pond				
Water level	Check/adjust	x	-	-
Water quality	Color check	x	-	-
Dikes	Check/repair/protect	x	xx	xx V
Bottom mud	Check thickness/quality	-	-	x V
Aquatic plants	Check/remove	-	x	xx V
Terrestrial plants	Check/remove	-	x	xx
Pests	Check/remove	x	-	xx
Fish				
Fish behavior	Check	x	-	-
Compost piles	Check/refill	-	x	-
Theft	Protect	x	-	-

I.4. MAINTENANCE DONE AFTER DRAINING

I.4.1. DRYING OF THE POND

A pond must dry out during the period between draining and the next time it is filled with water, when it remains empty. It can be totally or partially dried, and this period can last for a short or long period.

The dry period facilitates some favorable processes, due to certain physicochemical and biological phenomena:

- Mobilization of nutrients in the soil,
- Rapid mineralization of organic debris,
- Destruction of aquatic plants, disease germs, parasites and fish predators.

The dry period can be reduced to a few days. A short period is also preferable to avoid the possibility that cracks will form in the dikes and at the bottom of the pond, when the clay shrinks. Superficial work on the surface of the pond bottom can help ventilate the ground and facilitate the three processes mentioned above. However, plowing too deeply could cause an increase in unproductive land surface, and could bury the nutrient-rich layer. Leguminous plants or a food crop may also be cultivated on the bottom of the pond during a prolonged dry period. Any plants that are not harvested can then be plowed under before the pond is filled with water again. However, this cultivation period should be as short as possible.

I.4.2. CLEARING THE BOTTOM

Generally, mud tends to accumulate in the deepest part of the pond (in front of the monk). This mud should be removed so that, during harvest, the water will be as clean as possible for the fish. This accumulated mud is comprised of sediments from the bottom of the pond as well as organic remains. It is thus very rich in nutrients and can be used as fertilizer for gardens located beside the pond. To avoid losing these nutrients, the mud may also be distributed over other parts of the bottom, but it is important not to leave too much of it on the bottom.

I.4.3. REPAIRING THE DRAINS

Drains tend to get filled during fish production. Digging a fast passage that follows the trail of the initial network should take care of the problem, but mud will have to be thrown far and not deposited at the edges of the drains.

I.4.4. REPAIRING THE DIKES

When the ponds were constructed, there was a slope inside the pond. During production, the slope degrades because the tilapia dig at the banks to build their nests, it collapses from compression while work is being completed, or it is eroded by waves in large ponds. It is then necessary to bank the dikes up with new dirt (clay) and to rebuild the original slope. You may have to re-fill burrows that small animals have dug into the dikes.

I.4.5. REPAIRING THE WATER INLET

Sometimes the water inlet has been badly planned (it is too short) and part of the dike gets washed out upstream, just above the pipe. A flat rock or a pile of stones should be deposited at the bottom of the pond at the point where the water falls, to break the jet and reduce degradation. If this is not done, the dike should be repaired with a stone facing that will limit water erosion.

1.4.6. MAINTAINING THE MONK

For monks made of brick or masonry, the external rough coat should be checked. If there is a slight deterioration, the rough coat should be remade. If the joints of the cement have already been attacked, it is necessary to rejoin the stones or bricks and replaster the unit. Defective small boards should be replaced.

I.5. FIGHTING PREDATORS

Farmed fish have many enemies and competitors, such as wild fish, frogs, insects and birds, and they must be protected from them (Figure 145, opposite). Protection is particularly important while the fish are small. Pest control in drained ponds, also called pond disinfection, has several objectives, including:

- ⇨ To kill aquatic animal predators, such as carnivorous fish, juvenile frogs and insects left in water puddles and in the mud, that can survive and feed on young fish;
- ⇨ To eliminate all fish that have not been harvested, which later would compete with the new stock for space and food, especially if their reproduction is not controlled;
- ⇨ To control disease by destroying fish parasites and their intermediate hosts, such as snails.

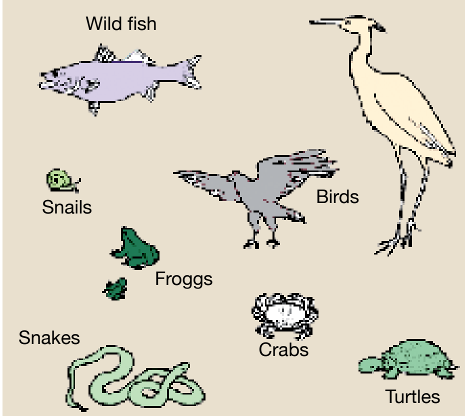


Figure 145. Some predators of fish.

As an additional benefit, disinfection treatments improve the quality of water and bottom soil, so that the pond's fertility improves.

Earthen ponds are most easily disinfected after their water has been drained as thoroughly as possible, using gravity for drainable ponds.

If the pond is kept dry (preferably in warm, sunny weather), many undesirable things will be eliminated. The sun's ultraviolet rays have a powerful sterilizing effect. The amount of time necessary to keep the pond fully dry depends on air temperature, but it ranges from a minimum of 24 hours up to one month.

If they are locally available, some agricultural by-products can also be used to disinfect drained ponds cheaply. These include rice bran (400 to 1000 kg/ha), crude sugar molasses (400 to 500 kg/ha) and tobacco dust or tobacco shavings (300 kg/ha). The required amount of by-product can simply be spread over the bottom of the pond. Then, the pond should be flooded with 5 to 10 cm of water for 10 to 15 days. It is best not to drain the pond but to fill it up, so that the fertilizing effect of the organic disinfectant is not lost. Before tobacco dust or tobacco shavings are applied, the sacks should be soaked in water overnight to prevent the dust from being blown away when it is spread along the bottom of the pond. Chemicals like lime should be avoided.

I.6. SUMMARY

- ⇨ **This section focused on:**
  - ⇨ **Daily maintenance visits;**
  - ⇨ **Controlling fish behavior and recommended procedures (ventilation, autopsy, etc.);**
  - ⇨ **Supplementary nutrition if necessary;**
  - ⇨ **Maintaining ponds by cleaning and by fighting predators.**

Once this work is finished, the pond can be re-filled and fertilized with animal or vegetable compost, animal manure, or vegetable matter, like before. Once the water becomes green again, the pond can be re-stocked.

II. CONSERVATION AND PROCESSING TECHNIQUES

Depending on how many fish are harvested and how they will be used (for sale or direct consumption), fish can be stored alive, fresh, preserved or processed, for later consumption or for sale.

Fish that are to be kept alive can be stored in either small basins/ fish ponds built for this purpose, or in cages or hapas (Chapter 09, paragraph III.3, p. 142). They can be taken out when the farmer wants fresh fish for consumption or direct sale.

Local sale of fresh farmed fish is the simplest and cheapest way of marketing it. Usually people prefer fresh to processed fish. But the fish should be handled properly to ensure that they maintain their high quality and can be sold at a good price.

The fish should not be fed for at least one day before they are harvested.

During harvest, live fish should be handled carefully and, if necessary, transferred quickly to a storage facility, for example, to remove any muddy flavor or to simplify or improve conditions for sale.

After they are harvested, fish should be rinsed well in clean water. It is best to kill them quickly with a minimum of stress. As soon as a fish dies, it starts to decompose, mainly because of increased bacterial activity; they multiply rapidly in fish if food, temperature and humidity conditions are favorable. Bacteria are especially numerous on fish's gills and in their digestive tracts. Decomposition will quickly spread from these areas to the whole body when the fish dies.

It is best to gut the fish and remove all internal organs and blood, and to remove the gills or cut the head off, as soon as the fish is harvested or killed. Cleanliness of the fish can be preserved by washing them with clean water. Fish should not be put directly on the ground, and it will be easier to protect them if they are in cases or bags of plastic to protect them from mud, dust, insects, etc.

if the fish are to be sold fresh, this should be done as quickly as possible. In this case, the farmer should either collect only as much fish as he can sell in one day, or should keep them cool, in the shade or covered with banana leaves, grass, or other material. The best option is to obtain ice, but that is rarely possible. On the other hand, dead fish should never be left in water because they will rot quickly.

If the fish must be transported, it is best to avoid the hottest hours of the day and travel early in the morning or even at night.

Although it is best to sell fish fresh, in some cases, processed fish may be preferable. They can either be cooked, or dried, salted, or smoked to remove water (Figure 146, Figure 147 and Figure 148, p. 166).

- ✓ **Drying** removes water from the surface and flesh of prepared fish.
- ✓ **Salting** removes most of the water in the flesh of the fish and replaces it with salt.
- ✓ **Smoking** removes most of the water in the flesh of the fish by exposing it to wood smoke.

The type of fish is an important consideration in the selection of a processing method. Lean fish such as tilapia are much easier to process than oily/greasy fish such as catfish. Large, full-bodied fish are more difficult to process than small, slender fish.

There are several methods of drying or smoking fish, which require more or less investment and material. We will not go into detail here. Various techniques can be found in technical handbooks published by FAO.

After processing, the dried or smoked fish should be stored properly:

- ⇨ It should be kept cool and dry;
- ⇨ It should be packed tightly to protect it from moisture in the air (which can facilitate the development of mold) and to delay the process by which fish fat becomes rancid;
- ⇨ It should be protected from insect infestation. One way to do this would be to place the fish in woven baskets lined with plastic or durable paper. If plastic bags are used, they should be kept away from direct sunlight so that moisture does not build up inside.

It is important to check regularly on the quality of stored fish and reprocess it as necessary.

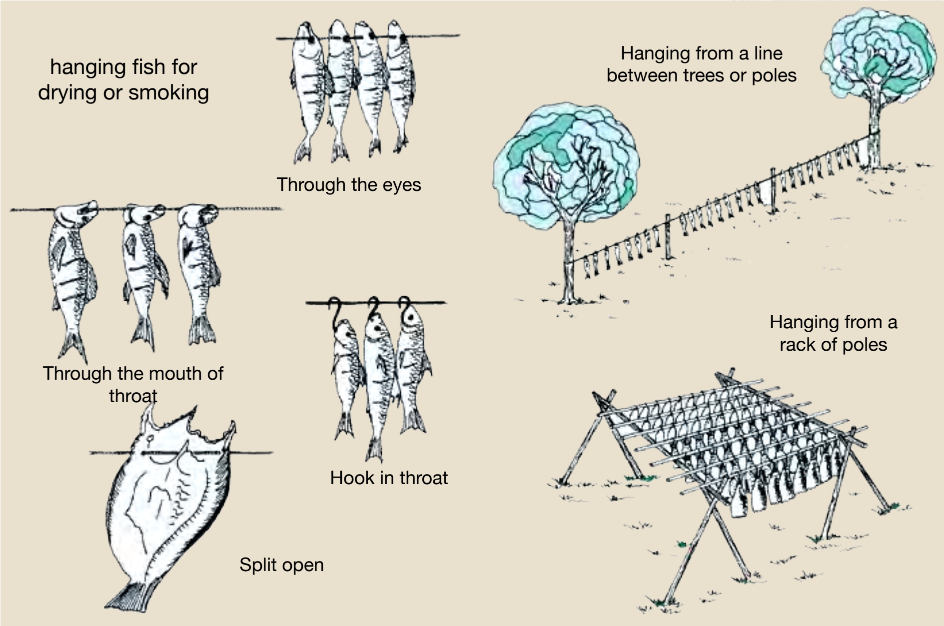


Figure 146. Methods of naturally drying fish.

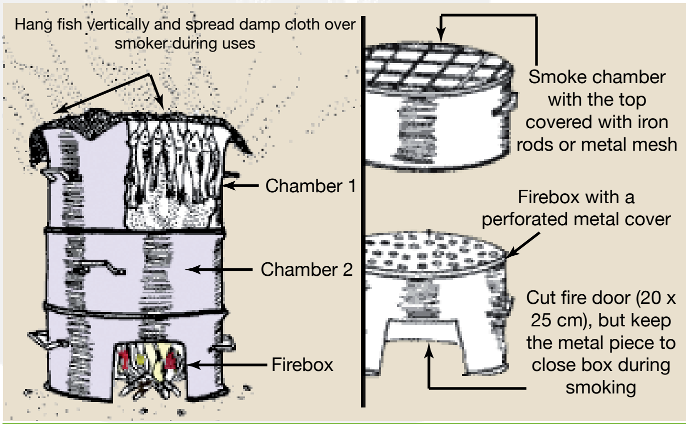


Figure 147. Examples of smoking methods.

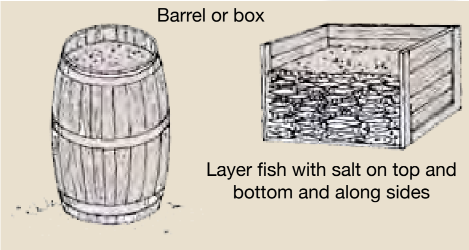


Figure 148. Example of a salting system.

- **Keep in mind that:**
  - **Fish must be prepared for sale;**
  - **Fish can be kept alive, or**
  - **They can be smoked, salted or dried.**

III. MANAGING PONDS

Proper management of fish ponds requires regular monitoring, good recordkeeping, and planning ahead for farm operations. Proper planning will help farmers decide when to fertilize the ponds.

III.1. FISH STOCKS AND USEFUL MONITORING INDICES

It is important to monitor fish stocks closely. There are a variety of indices or parameters, such as growth, production and survival, that are commonly used to measure and compare the performances of different fish stocks.

The following terms are used to describe the size of a fish stock:

✓ **Initial fish stock** is the number and weight of fish stocked in the pond at the beginning of the production cycle. Two related parameters are:

- **Stocking rate,** which is the average number or weight of fish per unit area, such as 2 fish/m^2, 2 kg fish/m^2, or 200 kg/ha;
- **Initial biomass,** which is the total weight of fish stocked in a specified pond, such as 100 kg in Pond X.

✓ **Fish stock present during the production cycle** is the number and weight of fish present in the pond. They are growing, although some of them may disappear, either escaping from the pond or dying. An important related parameter is:

- **Biomass present,** which is the total weight of fish present in a pond on a given day.

✓ **Final fish stock** is the number or weight of fish at the end of the production cycle; similarly:

- **Final biomass** is the total weight of fish present at final harvest.

Concerning the changes in fish stock at harvest or over a period of time:

⇨ **Output** or crop weight is the total weight of fish harvested from the pond.

⇨ **Production** is the increase in total weight that has taken place during a specified period. It is the difference between the biomass at the beginning and the biomass at the end of the period. For example, if a fish stock weighs 55 kg at the beginning, and weight measured after 30 days is 75 kg, 75 - 55 = 20 kg.

⇨ **Yield** is the production expressed per unit area. For example, if 20 kg were produced in a 500 m^2 pond, the yield during the period was 20 / 500 = 0.040 kg/m^2 = 4 kg/100 m^2 or 400 kg/ha.

⇨ **Production rate** is the production expressed per unit of time (day, month, year, etc.). For example, if 20 kg were produced in 30 days, the daily production rate would be 20 / 30 = 0.66 kg/day.

⇨ **Equivalent production rate** is the yield expressed per unit of time, usually per day or per year (365 days). It allows a comparison of productions obtained during various periods. For example, 400 kg/ha produced in 30 days is equivalent to (400 x 365) / 30 = 4,866.7 kg/ha/year. It may be also useful to indicate the average daily production rate, which in this case is 4,866.7 / 365 = 13.3 kg/ha/day or 1.33 g/m^2/day.

⇨ **Survival rate** is the percentage of fish still living in the pond at the end of a period of time. It should be as close as possible to 100 percent. For example, if there were 1200 fish at the beginning of the period and 1,175 fish at the end, the survival rate during that period was [(1,175 x 100) / 1,200] = 97.9%; mortality rate was 100 - 97.9 = 2.1%.

A stock of fish is comprised of individuals. Below are measurements that should be taken on individuals in order to monitor the status of the pond (Chapter 09 paragraph V, p. 149).

⇨ The **average weight** (g) obtained by dividing the biomass (g) by the total number of fish present.

⇨ **Average growth** (g), which is the increase in the average weight during a given period of time. It is the difference between the average weight at the beginning and at the end of the period.

⇨ **Average growth rate**, which is growth (g) expressed per unit of time, generally one day. Farmers can also calculate the daily growth rate, obtained by dividing growth during a given period by the duration of this period in days. This rate is calculated either for one period determined during the operating cycle, or for the entire cycle.

Example: A pond (312 m²) has been stocked with 680 fish of an initial biomass of 5.6 kg. At the end of the production cycle (149 days), 450 fish were harvested, weighing 43.8 kg. So:

Pond production = 43.8 - 5.6 = 38.2 kg

Yield = 38.2 / 312 = 12.24 kg/100 m^2

Production rate = 38.2 / 149 = 0.26 kg/day

Equivalent production rate = (12.24 x 365) / 149 = 30 kg/100 m^2/year

Survival rate = [(450 x 100) / 680] = 66%

Mortality rate = 100 – 66 = 34%

Initial average weight of the fish was 5600 / 680 = 8.2 g,

and final average weight was 43800 / 450 = 97.3 g.

So:

Average growth during the production cycle = 97.3 – 8.2 = 89.1 g

Daily growth rate = 89.1 / 149 = 0.6 g/day.

III.2. EXPECTED YIELDS

The size of the yield differs with the species being farmed. For each species, it is possible to estimate the expected weight per pond.

Consider a 400 m^2 pond containing Nile tilapia, polycultured with the African catfish *Clarias gariepinus*, with weight ranging from 5 to 10 g for the two species. At the end of 7 months of extensive farming (fish are left to themselves and not given additional food or other contributions), production of approximately 30 kg (or 750 kg/ha/year) can be expected. For the same amount of time, in a slightly less extensive operation (the pond is fertilized either a little or a lot), annual production will vary from 50 to 100 kg, or 1.2 to 2.5 tons/ha/year. This will increase to 10 tons/ha/year if a predator is added to the pond, or 150 kg per pond or 400 m^2 over 6 months.

In a polyculture system that combines *Heterotis niloticus* and *Heterobranchus isopterus*, *H. isopterus* juveniles are introduced at a maximum density of 20 individuals per 100 m^2 into tilapia production ponds. These systems produce yields of about 4 to 15 t/ha/year, depending on the amount of fertilizer that is added.

Thus, a pond of 100 $m^{2,}$ can produce 150 kg of fish per year, or approximately 12 kg per month for 100 m^2 of pond. Thus, a small pond of 200 m^2, which is the minimum recommended size, can produce approximately 24 kg of fish per month, or 0.8 kg per day.

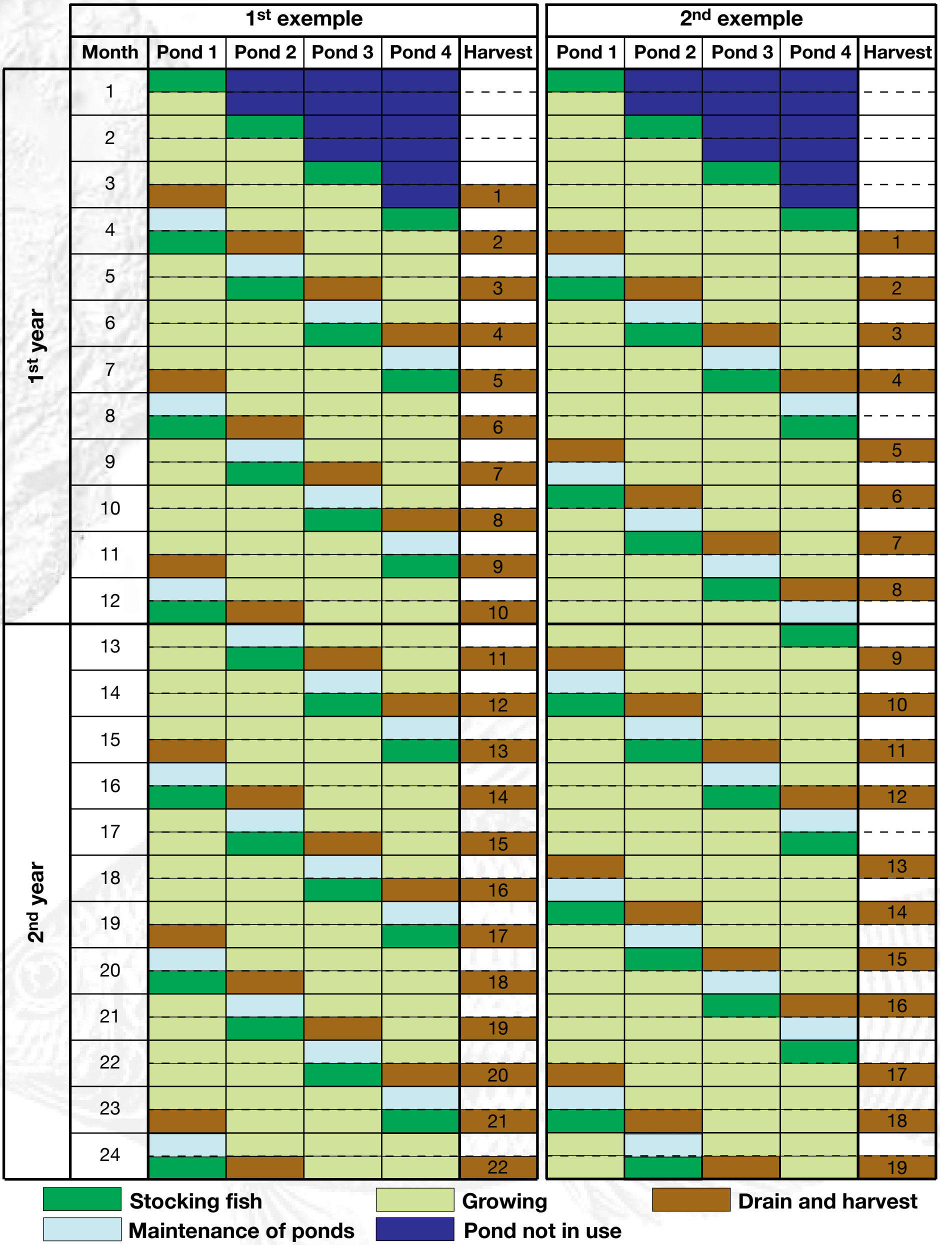
III.3. MANAGING HARVESTS

The method of managing harvests will depend on the mode of approach. But in most cases, benficiaries will have to manage this aspect by themselves. Management needs will vary depending on the number of ponds, but maintenance of at least 3 ponds will ensure a quasi-monthly harvest of fish large enough to eat.

If time of addition of juveniles to different ponds is staggered throughout the year, they can also be harvested throughout the year. In this way, the farmer will not have too many fish at any one time, and will be able to fish throughout the year.

If there are 4 ponds and a good supply of fingerlings, each pond can be stocked at a different month of the year and harvested every 3 to 6 months later, depending on the size at which the fish will be consumable (Table XXXVI, p. 169). Indeed, depending on the location, fish of 60 to 80 g can be consumed, and a tilapia can reach this size in 3 months. The duration and the time of growth will also depend on follow-up.

Table XXXVI. Examples of management techniques for 4 ponds. Harvest after 3 months (on left), and after 4 months (on right). Colors show the different steps described in the general framework for setting up ponds.



As an estimate, 4 ponds of 400 m^2, which can produce up to 50 kg per month per pond, will produce up to 500 kg per year. In a country where fish is sold for US $5/kg, groups can earn the equivalent of US $2500 per year, or approximately US $200 per month.

The distribution of harvesting proceeds among beneficiaries will depend on the type of association and grouping that they have adopted. These can vary by country, and by the ethnic groups and social structures where specific projects are being implemented.

III.4. TYPES OF PRODUCTION COSTS

The owner of a pond must first pay for the **fixed factors of production** (capital equipment with a lifespan longer than one production cycle, such as dirt, water, ponds, nets, etc.) and **variables** (articles of operation, including consumables and labor). Any expenditure devoted for the fish farm is included under these costs, and is generally called costs of operation. They include:

✓ **Fixed operating costs** remain the same, however many fish are produced on a given farm. They are related to the fixed factors of production. The most important of these are depreciation and interest costs associated with investment and costs of annual water rights, land leases, licences, and other fixed payments such as interest on loans.

✓ **Variable operating costs,** or **running costs,** are those that are directly related to farm production.

Apart from the fixed costs of pond construction (which often include the farmer's own labor), costs are very low and almost negligible for subsistence farmers. However, it is important to identify costs as realistically as possible, to avoid wasting time, money or other resources on inefficient or unprofitable operations.

As time goes on, long-lasting factors of production such as ponds, buildings, equipment and vehicles wear out.

Table XXXVII. Useful life of fish farm structures and equipment (in years, assuming appropriate use).

Structure / equipment		Years
Pond, earthen		30
Channels, earthen		20
Pond structures	Hard wood, treated	10
	Masonry	20
	Concrete	20
	PVC pipes	10
	Reinforced, concrete pipes	20
Buildings	Wood / thatch roof	4
	Sundried clay bricks	6
	Fired bricks or concrete blocks	20
Boat wooden		8
Fence, wire / treated wooden posts		10
Fishing net		5
Hapas		2
Cast nets, dip nets		2
Wheelbarrow		3
Workshop tools (saw, hammer…)		5
Pick, shovel, axe		2
Buckets, barrel		1

In the short term, they are kept in serviceable condition through maintenance, including the purchase of materials and spare parts as well as labor required for repairs.

After a certain number of years they will have to be replaced or renovated. This period is called their useful life. Useful life varies, as shown in Table XXXVII, p. 170. Some structures, such as buildings and ponds, have a very long useful life, while some eqiupment, such as wheelbarrows or nets, may wear out after a few years.

III.5.RECORD KEEPING AND ACCOUNTING

Fish farmers need to keep only simple records, which should show them, month by month:

- ✓ The **total amount of money spent** on fish farming, and per each pond;
- ✓ The **total number** (and weight) **of fish stocked** initially;
- ✓ The **total number** (and weight) **of fish harvested**;
- ✓ **Number of fish either given** to family for consumption or provided in exchange for casual labour;
- ✓ The **total number** (and weight) **of dead fish**;
- ✓ The **total number** (and, if possible, weight) **of any fish sold for cash** (cash income) and/or bartered for other commodities (equivalent value as income).

At the end of the year, the above records will provide information on:

- ⇨ The total value of fish given away;
- ⇨ The total value of all fish harvested;
- ⇨ The amount gained (net profit) or lost (net loss) through fish farming.

A simple form can be used each day to record all the activities related to fish farming that are completed over one month, as well as all money spent and all details of fish production (Appendix 01, p. 189). This is called the daily record form. You may prepare a form similar to the example below in a small school copybook, using two facing pages per form.

Any activity, such as work done on the fish farm or items of equipment purchased for it, should be immediately noted, together with such relevant data as money spent, number of fish harvested, and number of fish given away or sold. It is important to note these details as soon as they are available. At the end of the month, the numbers in each column should be added to get monthly totals.

In the same way, at the end of the year totals from each month can be used to get an annual statement of accounts.

III.6.TRAINING

In order to promote and ensure the continuity of the project, beneficiaries and future operators of the ponds must be trained. Topics will include:

⇨ **Importance of fish as food:**

Animal proteins are essential for the proper growth of children as well as the health of their parents.

⇨ **Importance of rivers: water and health**

Water provides an environment where human diseases can develop. Several parasites and diseases are spread by water and depend on a lack of hygiene; these include malaria, cholera, and schistosomiasis, to name just a few. We will return to this subject in the next section on health and ponds. We will not provide details on these two topics here, since that information is available in several books.

⇨ **How to build ponds**

This training will go through the stages listed in this handbook.

IV. PONDS AND HEALTH

Water provides an environment that parasites and vectors of serious diseases either pass through or come from. Since ponds are water points, certain rules should be followed that will limit disease and health risks.

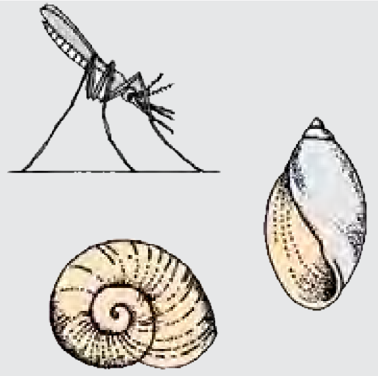


Figure 149. Mosquito and snail.

Figure 151. Cleaning dikes.

One species of mosquito and several species of freshwater mollusks transmit diseases that can be fatal, including malaria (mosquito) and schistosomiasis (snail). If plants or grasses are too dense either at the edges of ponds or in them and in the enclosures, snails and mosquitoes can live and proliferate very easily. Therefore, plants should be periodically cleared and dikes should be mowed. The edges of grasses should not hang into the water so that fish can effectively eliminate insects or other animals (Figure 149 and Figure 151, above).

Ponds or enclosures should never be used as toilets (Figure 150, below). It is to better use a latrine, if there is one, or to build one at least 10 m from the edge of the pond or enclosure and from the source of the water supply. If one has a pressing need while working near the ponds or enclosures, or the river that feeds them, or the supply canal or the inlet, one should move at least 10 m away to satisfy this need. Similarly, people should not relieve themselves on a compost heap or in the vicinity. Pond water is not for domestic use, such as drinking or washing. These minimal rules of hygiene should be taught to all people with access to the infrastructure.

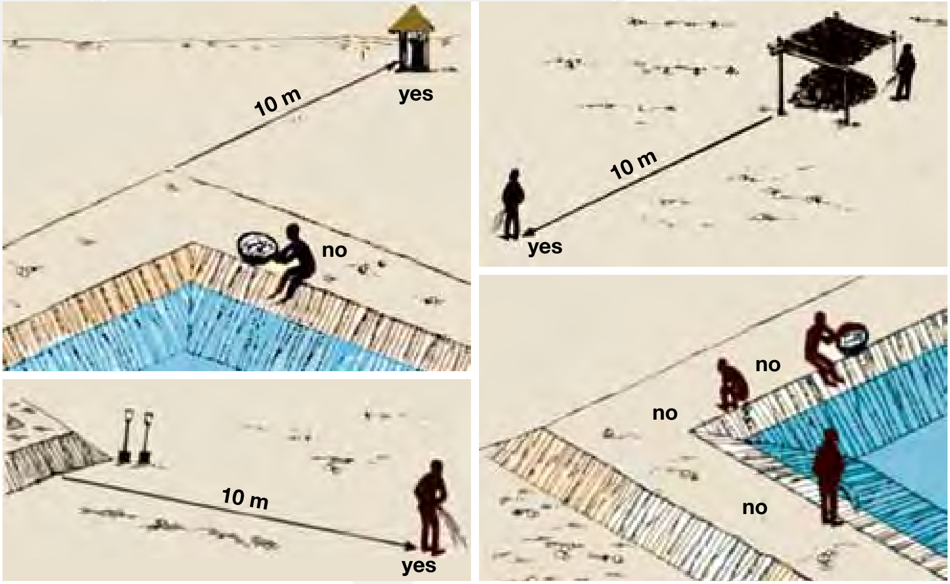


Figure 150. Human behaviors that should be avoided near ponds.

General summary

Each step in subsistence fish farming is shown in the diagram on the next page.

Semi-intensive *production was the fish farming system chosen for discussion. This system produces fish for self-consumption or artisanal production*, using *polyculture* rather than monoculture (which would require provision of external food and more intensive follow-up in order to achieve a high level of production).

It is very important to evaluate all the components of an ecosystem, including human beings, in order to identify actions that will ensure the "wellbeing" of the ponds, mainly for food safety but also for health and water and sanitation. Preferably, this phase should involve two specialists whose priority will be the biological aspects of the ecosystem.

All of the collected information will allow a determination of:

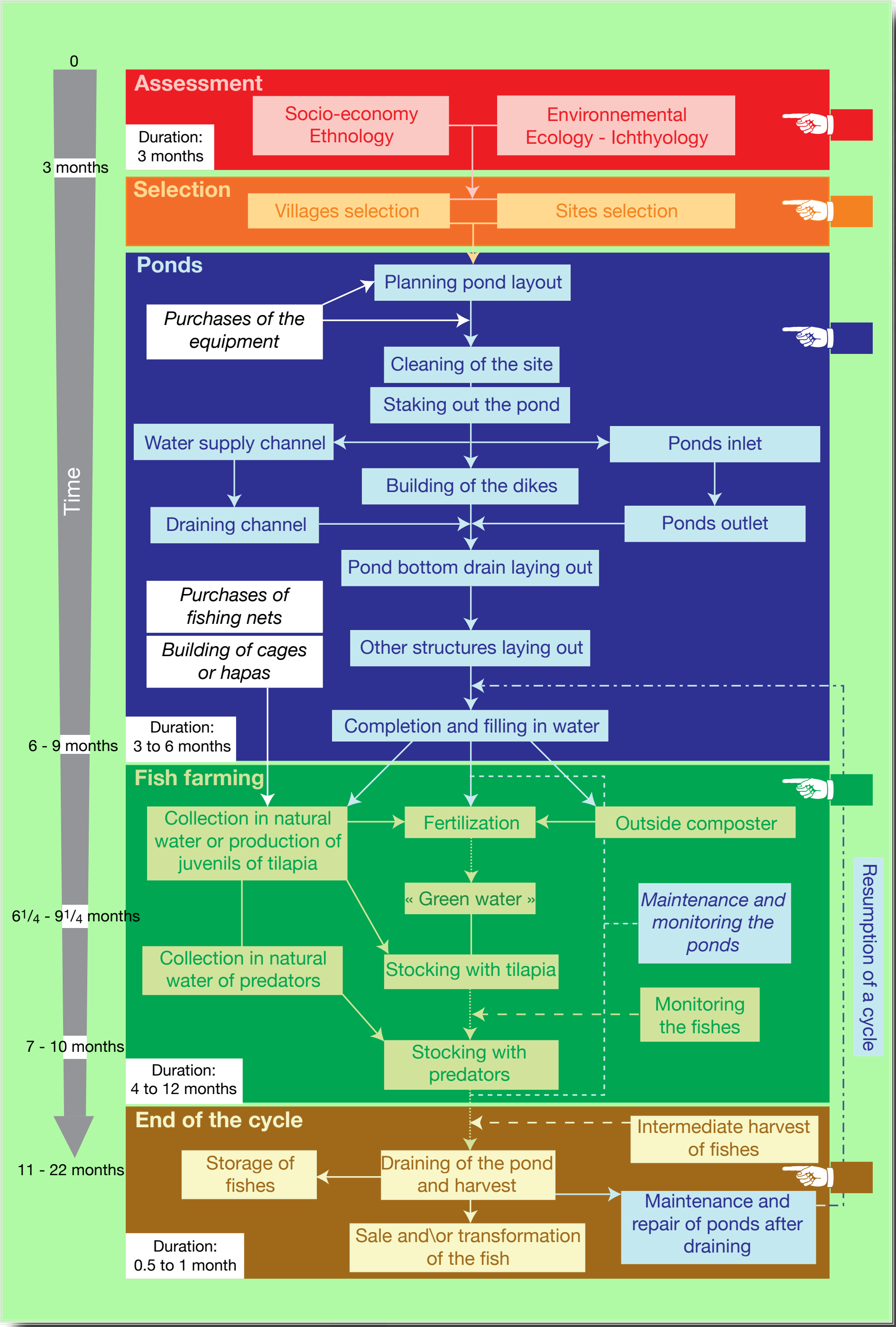
- **The area where the intervention will take place;**
- ***The available resources* that can be used and their current role in the ecosystem;**
- ***Communities and social structures*.**

The goal is to collect the data necessary to propose a solution that the beneficiary population will be willing and able to take over, if the data confirms that fish farming is a solution for the area under consideration. .

The source of fish to be used and the *drainage basin* where the action is undertaken are of highest importance, since there are risks incurred by the introduction of fish, and there is national and international legislation concerning biodiversity to consider. Even if a species has already been introduced into the zone of intervention, it should necessarily be used again.

The choice of village must take into consideration:

- ***Vulnerability* of the population;**
- ***Logistics*;**
- ***Water resources*;**
- ***Villagers' motivation*.**



0
3 months
Time
6 - 9 months
6¹/4 - 9¹/4 months
7 - 10 months
11 - 22 months
Assessment
Duration:
3 months
Socio-economy
Ethnology
Environmental
Ecology - Ichthyology
Selection
Villages selection
Sites selection
Ponds
Planning pond layout
Purchases of the equipment
Cleaning of the site
Staking out the pond
Water supply channel
Ponds inlet
Building of the dikes
Draining channel
Ponds outlet
Pond bottom drain laying out
Purchases of fishing nets
Building of cages or hapas
Other structures laying out
Duration:
3 to 6 months
Completion and filling in water
Fish farming
Collection in natural water or production of juvenils of tilapia
Fertilization
Outside composter
« Green water »
Maintenance and monitoring the ponds
Collection in natural water of predators
Stocking with tilapia
Monitoring the fishes
Stocking with predators
Duration:
4 to 12 months
Resumption of a cycle
End of the cycle
Intermediate harvest of fishes
Storage of fishes
Draining of the pond and harvest
Maintenance and repair of ponds after draining
Sale and\or transformation of the fish
Duration:
0.5 to 1 month

Site selection is the most important step in the development of a fish pond. The following factors should be considered:

- **Water: quantity and quality;**
- **Soil: impermeable;**
- **Topography: weak slope and water supply.**

Diversion ponds supplied with water by gravity should be the first choice. Ponds should be rectangular, arranged in parallel, and 100 to 400 m^2.

The manual focused on the following considerations:

- **The site must be cleaned well;**
- **Staking must be precise along the slopes;**
- **Water is controlled and managed by canals;**
- **The importance of dikes, their strength and their size, and whether the dirt is compacted;**
- **The choice of a monk for draining ponds;**
- **Total isolation of the ponds from external water bodies for better control;**
- **Conservation of soil upstream.**

- ***Fertilization*: the preparation of aerobic and anaerobic compost is important.**
- **The presence of « green water » indicates that the pond is ready to be stocked.**

After fertilization, steps include:

- ***Collection* of specimens in the wild or production of tilapia juveniles;**
- ***Stocking* of ponds with tilapia;**
- **Monitoring of *growth*;**
- ***Collection of predators* in the wild;**
- ***Stocking* with predators;**
- ***Monitoring* and *partial harvesting* of fish;**
- **After several weeks, *draining* and *complete harvesting* of fish.**

African freshwater fish species are numerous and there are many different species that can be used in fish farming. The choice of species will depend on the *geographic location* of the ponds (ichthyoregions). However, for subsistence farms, it is best to use:

⇨ *Tilapia* for main production. Tilapia is a strong fish, highly plastic and adaptable to environmental conditions. The parents provide elaborate care, and the fish is opportunistic about feeding. Tilapia should be combined with:

⇨ A *fish-eating species that* will be a *predator* and control tilapia reproduction;

⇨ Other, omnivorous and/or herbivorous species can also be used in the pond.

Predators must comprise approximately 13% of the weight of stocked tilapia. Globally, ten fish of approximately 7/8 cm for a hundred tilapia that have reached 6/7 cm are enough. Predators should be stocked approximately one month after tilapia are stocked.

The density of tilapia should be *0.5 individuals/m²*

As a main principle, gear that is not destuctive to the local wildlife should be used exclusively.

Laws related to fishing must be respected. Where appropriate, permits should be requested from the local authorities.

The manual focused on:

⇨ *Fishing methods* and precautions for keeping fish in good condition and avoiding problems; respecting local legislation;

⇨ The *biology of each species* and how specific biological characteristics facilitate high rates of production, including good breeding, feeding, and behavior, which encourage optimal growth and help to determine stocking density;

⇨ *Transport* of fish and care that will prevent loss of either some or all fish.

To insure a high rate of production, focus on:

⇨ *Daily maintenance visits*;

⇨ Monitoring the fish;

⇨ Controlling fish behavior and taking appropriate action for specific situations (ventilation, autopsy, etc.);

⇨ Providing supplemental *nutrition* if necessary;

⇨ *Maintaining ponds,* including cleaning and fighting predators.

⇨ Fish can be kept alive.

⇨ Fish must be prepared for sale. If it is not sold fresh, it can be smoked, salted or dried.

This summary provides a master plan for a system that will facilitate the production of consumable fish in the shortest possible time and at a low cost, in order to compensate for a lack of animal protein.

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Useful web sites:

www.fao.org

www.fishbase.org

www.ird.fr/poissons-afrique/faunafri/

Glossary

A

Abiotic: **Not associated with or derived from living organisms. Abiotic** factors such as sunlight and temperature influence the development and / or survival of organisms.

Abundance: Quantitative parameter used to describe a population. It is generally impossible to count all members of a plant or animal population, so indicators are used. By extension, abundance refers to the number of individuals, reported as a unit of time or area, within a given category: population, recruitment, stock, reported as a unit of time or area.

Amino acid: Class of organic compounds containing carbon, hydrogen and oxygen, which, linked together in large numbers, form proteins. Some play an essential role in fish development.

Aerobic: Condition or process for which gaseous oxygen is present or necessary. Aerobic organisms obtain their energy for growth from aerobic respiration.

Anaerobic: Condition or process for which gaseous oxygen is not present or necessary.

Anoxic: Characterized by the absence of oxygen. In an anoxic environment, aerobic respiration is impossible, so only organisms whose metabolism is ensured by other mechanisms (such as fermentation, anaerobic breathing like sulfato-reduction, bacterial photosynthesis. etc.) can live.

Aquaculture: The common term is 'fish farming' but 'aquaculture' refers broadly to the commercial cultivation of marine or freshwater animals and plants in water. Farming of aquatic organisms, including fish, mollusks and aquatic plants, requires some form of intervention in the rearing process, such as stocking, feeding, protection from predators, fertilizing of water, etc. 'Farming' implies individual or corporate ownership of the farmed organisms.

Aufwuchs: German term for the layer of algae that adheres to rocks.

B

Bacteria: Very small unicellular organisms that grow in colonies that are often large and unable to produce components of carbon through photosynthesis; mainly responsible for the rotting of vegetable matter and dead animals.

Benchmark: see Point, reference

Benthos: Groups of vegetable and animal organisms in or on the bottom of a pond. Associated term: **benthic**. Opposite: **pelagic**.

Bicarbonates: Acid salts of carbonic acid (see carbonate) solution in water; they contain the ion HCO_3 as calcium bicarbonate $Ca(HCO_3)_2$ for example.

Bioaccumulation: Accumulation of substances - such as heavy metals or chlorinated hydrocarbons - that results in high concentrations of these substances in aquatic organisms.

Biocoenose: Group of plants and animals that form a natural community, determined by the environment or the local ecosystem.

Biodiversity: Variation among living organisms from all sources, including terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are a part. The term includes diversity within species, between species and within an ecosystem.

Bioethics: Branch of morality concerning research on life and its uses.

Biomass: (a) Total live weight of a group (or stock) of living organisms (such as fish or plankton) or of a definite part of this group (such as breeders) present in water at a given time. [Syn.: **stock present**]. (b) Quantitative estimate of the mass of the organisms that constitute all or part of a population, or another given unit, or contained in a given area for a given period. Expressed in terms of volume, mass (live weight, dead weight, dry weight or ashes-off weight), or of energy (joules, calories). [Syn.: **charge**].

Biotic: Relating to life and living matter.

Biotope: Area or habitat of a particular type, defined by the organisms (plants, animals, micro-organisms) that typically live there, such as a meadow, wood, etc; or, on a smaller scale, a microhabitat.

Breeders or brood fish: Adult animal used to breed and rear juveniles.

Broodstock: Stock of fish intended for reproduction, which should receive special management in distinct ponds.

C

Calcium carbonate limestone or Limestone: Natural rock comprised mainly of carbonate calcium $CaCO_3$.

Carbohydrate: Organic compound, such as sugar, starch and cellulose, that is constituted of carbon, hydrogen, and oxygen. Carbohydrates are generally the least expensive source of food energy, particularly for omnivorous and herbivorous fish.

Carbonate: Carbon salt of dioxide, a compound formed from carbonic gas (CO_2) combined with water; for example calcium carbonate, $CaCO_3$.

Cellulose: The essential organic component in plants' solid structure; also present in animal bodies.

Charge: Level at which water is kept or may be high, at which it can, for example, flow to lower levels or browse pipes.

Colloid: Very small particle (from 0.5 to 1 micron), either mineral (such as colloidal clay), or organic (such as humus).

Conductivity: Measures the concentration of ions or salts in water by measuring the facility at which it conducts electricity. Generally water with high conductivity has a good buffering capacity. This varies with temperature and is expressed in Siemens (S) per centimeter at 25°C.

Conflict of use: Emerging conflict between different users of the same environment, who may have the same or competitive interests.

Contour line: (a) Imaginary line connecting all points at the same level of altitude. (b) Line that joins all the points in the same dimension on a map or chart; representing the course of the contour line as it exists on the ground.

Cyst: (a) Very resistant, immobile, dehydrated, inactive phase for free or parasitic organisms, forms in response to unfavorable environmental conditions. (b) Non-living membrane that surrounds a cell or group of cells.

D

Demersal: Animal living near the bottom of a lake or sea.

Dimension or **elevation**: Vertical distance or height above a given "horizontal" reference plane; see Elevation/level and Level/Reference plane.

Digestibility: Relative speed and degree to which a food is digested and absorbed.

E

Ecology: Branch of science concerned with the relationship between organisms and their environment(s).

Ecosystem: Set (or system) possessing natural structures and distinct relationships among biotic communities (of plants and animals), and their abiotic environments. The study of an ecosystem provides a methodological basis for a synthesis of the complex relationships between organisms and their environment.

Elevation or level: General terms indicating the vertical distance or height above a reference point, such as the mean sea level (see Altitude) or an arbitrarily selected horizontal point (see Dimension); calculated according to topographic data.

Embankment: (a) Area where it is necessary to raise the level of the ground to a required height by adding dirt. (b) The ground itself that is built up in this way.

Endemic: Specific or indigenous to an area. Can describe disease-causing agents and diseases which, at all times, are present or generally prevalent in a population or geographical area.

Energy: In aquaculture, usually refers to the food needs of aquatic organisms, expressed as the amount of joules/calories per day necessary to ensure the essential processes of life, that is, growth and reproduction.

Equidistance of the level lines: Difference in elevation between two neighboring level lines.

Ethology: Science of animal behavior.

Eutrophic: Rich in nutrients, photosynthetically productive and often oxygen-deficient in warm temperature conditions.

Eutrophication: Natural or artificial enrichment of a body of water with nutrients, characterized by wide plankton blooms and subsequent decrease in dissolved oxygen concentrations.

Extrusion: Process of transforming food material by subjecting it to high temperatures (100 to 200°C) at high pressures (50 to 150 bars) for a very short time (20 to 60 seconds), with very intense shear stress.

F

Fatty acid: Lipid formed of a more or less long hydrocarbon chain, comprised of a carboxyl group (-COOH) at one end and a methyl group (-CH_3) at the other.

Fecundity: In general, potential reproductive capacity of an organism or population, expressed by the number of eggs (or offspring) produced during each reproductive cycle.

Relative fecundity: Number of eggs per unit of fresh weight.

Absolute fecundity: Total number of eggs in a female.

Foodstuff, supplementary: Food provided in addition to the food that is naturally available.

Foodstuff, composed: Food with several ingredients, including vegetable and animal matter in its natural, fresh or preserved state, or products derived from their industrial transformation, or of organic or inorganic substances, possibly containing additives, intended as a complete food.

Fermentation: Anaerobic degradation of organic substances under enzymatic control.

Fingerling: Term without a strict definition; used for a young fish beginning with advanced fry up to one year of age, or beginning from hatching (independent of size). [Syn.: **juvenile**].

Food chain: Simplistic concept that refers to the sequential series of organisms, at successive trophic levels of a community, through which energy is transferred through food. Energy enters the food chain through primary producers (mostly green plants). It then passes to herbivores (primary consumers), then to carnivores (secondary and tertiary consumers). Nutrients are then recycled to primary production by detritivores (detritus feeders).

Fry: A young fish at the post-larval stage. May include all stages from hatchling to fingerling. An advanced fry is any young fish from the beginning of exogenous feeding after the yolk is absorbed while a sac fry is from hatchling to yolk sac absorption.

G

Gauge: Wooden model used as a guide for a desired form. Used, for example, for a canal or dike.

Gamete: Reproductive cell of a living male or female organism.

Gene: Basic element of the genetic inheritance contained in chromosomes.

Genetics: Science of studying the transmission of traits from parents to offspring in living beings.

Genotype: Genetic structure of an organism at the locus or loci controlling a given phenotype. An organism is a homozygote or a heterozygote at each of the loci.

Gonado-somatic ratio: Ratio of the weight of the gonads to total live weight (or of the total live weight to the weight of the gonads), usually expressed as a percentage.

H

Halieutic: Science of the exploitation of live aquatic resources.

Herbivore: Animal that feeds mainly on plants.

Hormone: Chemical substance produced in one part of an organism and conveyed through the bloodstream to another part of the organism, where it has a specific effect.

Humus: Decomposed organic matter, present in organic manure, compost or soil, in which the majority of nutrients are available for fertilization.

Hybridization: Fertilization of a female of a species by the male of a different species.

Hydraulics: The action or utilization of energy related to the movement of water.

I

Ichthyology: The study of fish.

Ichthyophagous: Animal that feeds mainly on fish. [Syn.: **piscivorous**].

Indigenous: Native to a country or a place. [Syn.: **native**].

Irrigation sluice: Device placed on a supply canal to divert its flow into two (T-shape) or three (X-shape) parts, to increase the level of water in a section of the canal, or to control the water supply through the water level in a pond.

J

Juvenile: Growth stage of the young organism before the adult stage. [Syn.: **fingerling**].

K

L

Larva, larvae: Specific stage that a variety of animals pass through after they hatch and before they change from juvenile to adult form by metamorphosis.

Level: see **Elevation.**

Level or **reference point**: Level or point used several times during a topographical survey and the connection at which the raised lines or points are defined.

Levelling: Measurement of differences in levels at various points on the ground during a topographical survey.

Life cycle: The sequence of development stages for an individual, from the egg stage up to death.

Line of saturation: Upper limit of the wet zone in a partially-submerged earthen dike.

Line of sight: Imaginary line from the eye of the observer to a fixed point. This is always a straight line, and is also called «axis of sight.»

Limnology: The study of lakes, ponds and other stagnant fresh water points, and their biotic associations.

Lipid: One of the main categories of organic compounds (fats and similar substances) present in living organisms. Lipids have two principal functions: they are a source of energy and a source of certain food components (fatty-acids) essential to growth and survival.

M

Macrophagous: Refers to a living organism that feeds on prey that is larger than its mouth. Opposite: microphagous.

Macrophyte: Vascular plant, large in comparison to microscopic phytoplankton and filamentous algae. The basic structure of an aquatic macrophyte is visible to the naked eye.

Maturation: Process by which gonads evolve toward maturity.

Metamorphosis: In some animals, changes that characterize the passage from the larval state to the juvenile or adult state. These changes affect both form and physiology and are often accompanied by a change in the type of habitat.

Mesocosme: Ecosystem isolated in an enclosure, that can be either small or large, from a volume of water measuring from one to 10,000 m^3. Mainly used for the production of live prey in jars, basins, plastic pockets, ponds and enclosures.

Metabolism: Physical and chemical processes by which food is transformed from complex matter; complex substances are decomposed into simple substances, making energy available to the organism.

Milt: Seminal fluid of fish, which contains fish sperm.

Monoculture: Farming or cultivation of only one species of organism at any time.

Mulch: Non-dense cover comprised of organic residue (such as cut grass, straw, leaves) that is spread on the surface of the ground, mainly to preserve moisture and stop weeds from growing.

Mulching: Placement of a layer of vegetable matter on top of the soil, in order to protect young plants (see Mulch).

N

Nekton: Animal that swims actively in a pond and is capable of constant and directed mobility, such as an insect or a fish.

Niche: Ecological role of a species in a community; conceptualized as the multidimensional space whose coordinates are the various parameters representing the condition of existence of the species and to which it is limited by the presence of competitor species. Used sometimes improperly as the equivalent of microhabitat, which refers to the physical space occupied by a species.

Food niche: A fish's role in a farming system regarding food consumption.

Ecological niche: The space occupied by a species, including physical space as well as functional role. A given species can occupy various niches at different stages in its development.

Nitrate: Final product of the aerobic stabilization of organic nitrogen. Nitrate's presence in water indicates that the water has received organic enrichment from agriculture or industry. Nitrates are often used as a fertilizer in pond cultivation.

Nitrite: First stage in the oxidation of the ammonium excreted by aquatic organisms as a final product of metabolic degradation. Nitrite stops oxygen from fixing to hemoglobin, and thus is toxic for fish. Shellfish are less affected because haemocyanin is only partially inhibited. A given concentration of nitrites are however more toxic in fresh water than in salty or brackish water.

Nitrogen: Odorless gas element that constitutes 78% of the terrestrial atmosphere; present in all living tissue. In gas form, it is almost inert.

Nitrogen, ammonia (Ammonia nitrogen): Special term referring to the total weight of nitrogen in ionized form, $NH4^+$.

Nursery: Protected place where young can be reared after they hatch but before they pass into the external environment.

Nycthemeral: 24-hour succession from day to night that regulates the periodic variation of the physiology of plants and animals.

Nutrition: All processes by which an animal (or a plant) absorbs and uses food or nutrients; the act or process by which an organism is fed.

O

Oligotrophic: Refers to an environment where the nutrient concentration is low.

Omnivore: Animal that feeds on both vegetable and animal matter.

Ontogeny: The early life history of an organism, that is, the stages it passes through from zygote to mature adult. Associated term: **ontogenetic**.

Oxidation: Chemical reaction by which, for example, there is an oxygen contribution.

P

Parthenogenesis: Reproduction from a female gamete, without fertilization by a male gamete (for example, by rotifers).

Pelagos: All the aquatic organisms present in a "water column". The term includes nekton and plankton. Associated term: **pelagic**. Opposite: **benthos**.

Perennial: Refers to terrestrial vegetation which grows and survives more than one year and usually has leaves throughout the year.

Periphyton: Associated microlagues and micro-organisms living attached to any immersed surface.

pH: Coefficient used to denote the activity of hydrogen ions in a solution or in soil. The pH of pure water is equal to 7 and denotes a neutral solution. A solution with a pH lower than 7 is considered an acid solution, while a solution with a pH higher than 7 is considered alkaline.

Phenotype: Physical or external appearance of an organism in contrast to its genetic constitution. Characteristics of an individual that can be measured and observed.

Photoperiod: Period during which something is lit, naturally or artificially; refers to biological phenomena associated with light.

Photosynthesis: (a) Process by which green plants containing chlorophyll transform solar energy into chemical energy, by producing organic matter from minerals. (b) Mainly production of carbon, beginning with carbon gas CO_2 and water, which releases oxygen.

Phylogeny: Refers to the evolutionary history of groups of living organisms, in contrast to ontogeny, which refers to the developmental history of an individual. Associated term: **phylogenetic**.

Phytobenthos: Benthic flora.

Phytoplankton: Unicellular algae, which live suspended in water. Vegetable component of plankton.

Piscivorous: Animal that feeds mainly on fish. [Syn.: **ichthyophagous**].

Plan: Imaginary plane surface; any straight line connecting two unspecified points of a plan is located entirely in this plan.

Plankton: All very small organisms, either plants (phytoplankton), or animals (zooplankton), that live suspended in water.

Planktivorous: Animal that feeds on phyto- and/or zooplankton.

Plasticity: (a) The capacity of soil to be molded without breaking and to hold a shape even when force is no longer applied. (b) Ability of an organism to adapt its traits to a given environment.

Point, lost: Temporary topographic point of reference for carrying out a survey between two definite points; this point is not used after the necessary statements have been made.

Point, reference: Fixed point usually identified on the ground with a reference mark placed at the end of a line of sight. (see Benchmark).

Polyculture: Cultivation of at least two noncompetitive species in the same farming area.

Porosity: Free space between particles or lumps of soil.

Post-larva: Stage that immediately follows the larval stage, in which the organism still has some characteristics of the juvenile stage.

Pressure loss: Occurs, for example, due to friction or the shifting of speed that occurs when water moves through a pipe or other hydraulic work.

Probiotic: Bacteria, yeast or algae added to some food products, which aid the digestion of fibers, stimulate the immune system, and prevent or treat gastro-enteritis.

Protein: Organic compound with a large, complex molecule, comprised of one or more chains of amino-acids; essential to the functioning of all living organisms. Food proteins are essential for all animals, and have a role in reconstituting tissues or as a source of energy.

Protozoa: Very small unicellular animals, which sometimes live in colonies.

Q

R

Raceway: Basin in the form of a circuit used for enclosure farming.

Ration: Total quantity of food provided to an animal during one 24-hour period.

Recruitment: Process of integrating a new generation into the global population. By extension, the new class of juveniles itself.

Repopulation: Process of releasing a large number of organisms produced in enclosures into the natural environment, with the aim of reconstituting diminishing stocks.

Resilience: Refers to the ability of an ecological system or subsistence system to be restored after tensions and shocks.

Respiration: Process by which a living organism, plant or animal, combines oxygen and organic matter, releasing energy, carbon gas (CO_2) and other products. [Syn.: **breathing**].

Rhizome: Thick, horizontal stem, generally underground, which grows upward and sends its roots downward.

S

Scrubbing: In-depth migration of soluble substances or colloids in the interstices of the soil.

Sedentary: Refers to an organism that does not move much and remains in its own habitat.

Selection (genetic): Process by which individuals that possess interesting properties are chosen for use as breeders.

Size, commercial: Minimal size that an organism must reach before it can be sold.

Size, portion: Size at which a fish can be consumed by one person.

Slaked lime: Lime paste obtained by adding water to quicklime.

Spawning: General term to indicate ovules, fertilized or before being fertilized; also used for fertilized eggs, as well as very young, usually numerous, fish from the same recruitment class.

Swim bladder: Organ filled with a gas mixture rich in oxygen, which allows osseous fish to stabilize themselves in water. This organ is connected to the esophagus. Cartilaginous fish (a group of selacians such as rays and sharks) do not have this organ.

T

Taxonomy: Classification of fossils and live organisms according to their evolutionary relationships.

Tenure: Socially defined agreements, often described in terms of “groups of rights” held by individuals or groups (recognized either legally, or customarily), concerning rights of access and rules of use of grounds or resources, such as individual trees, plant species, water or animals.

Thermocline: Water levels stratified by temperature (such as a sea, a lake, reserve of water) located under the surface, where temperature variation increases abruptly (that is, where temperature decreases quickly as depth increases). A thermocline usually constitutes an ecological barrier and its oscillations are a considerable influence on the distribution and productivity of fish stocks.

Trace element: Metal or metalloid, present in small quantities (a trace state) in living tissue, necessary for the metabolism of these tissues.

Traceability: Ability to trace a product or organism’s entire course from farming to sale.

Trophic: Refers to the nutrition of organs and tissues.

Turbidity: Disturbance or reduction of light penetration into water that results from the presence of suspended matter, colloidal or dissolved, or of planktonic organisms.

U

V

Vitamin: Substance necessary in very small amounts for development of the body and its vital functions.

Vitelline: Nutritive cells, substances or stuctures used as endogenous food for eggs or larvae.

Vitellus: Total of the nutritive reserves built into the cytoplasm of an egg.

W

X

Y

Z

Zoobenthos: Benthic fauna.

Zooplankton: Microscopic animals living in suspension in water. Animal component of plankton.

Zoosanitary: Refers to animal health.

Zootechnical: Technological knowledge that ensures the success of animal farming.

Appendix

Contents

CONTENTS - APPENDIX

Cover photo:
⇨ Cichlidae, *Hemichromis fasciatus* in the wild, Liberia, ASUR, 2006 - © Yves Fermon, Claire Gsegner

Appendix 01
FORMS EXAMPLES

Below are models for:

1. Forms for overall monitoring of ponds. They can be used for all ponds at the same time, or separately for each pond. Individual record files can then be sythesized.
2. Forms for following up on the fish. Again, this can be done by species, by individual pond, for all the ponds at once, etc.

These are examples and should be changed depending on needs. Specific information is, however, necessary for proper management of ponds and fish stocks.

I. FORMS FOR MONITORING PONDS

Daily fish per pond

Pond n° **Month** **Year**

Date	Activities and remarks	Money spent	Dead fish	Fish given		Fish sold	
				Workers	Family	Quantity	Income
Total of the month							

Annual balance per pond

Pond n° **Years**

Month	Money spent	Dead fish	Fish given			Fish sold	
			To workers	To family	Total	Quantity	Income
January							
February							
March							
April							
May							
June							
July							
August							
September							
October							
November							
December							
Total							

- ✓ Date: Date of observation;
- ✓ Activities and remarks: Activities accomplished (feeding, cleaning the dikes, etc.) and remarks (water color, flow, etc.);
- ✓ Money spent: Money spent on one activity (manpower, etc.)
- ✓ Dead fish: Number, weight, species of dead and removed fish;
- ✓ Distributed Fish: Fish given to workers or for consumption by family;
- ✓ Sales of fish: Fish sold at the market or outside the farm to obtain money.

At the end of the year or at the end of the cycle, a general assessment of activities, income and general consumption can be made, where appropriate, to improve the operating system for subsequent cycles.

II. FORMS FOR FOLLOWING UP ON FISH

Below are two types of forms for following up on fish:

1. The first two follow up on quantitative aspects of production. They allow the farmer to keep track of fish production by pond and for all ponds together.
2. The third form is organized by species and fish or by batch of fish to estimate growth and evolution of the ratio of weight / size of fish.

All this information will help improve production for the next cycle (density by species, additional food, cycle time, etc.).

Fish stock

Date Pond n° Surface or volume (V)

Species					
Introduction date	Di				
End date	Df				
Duration (days)	Df - Di				
Initial number	Ni				
Initial biomass (g)	Bi				
Initial mean weight (g)	Pmi				
Initial density	Ni / V				
Initial mean size (cm)	Tmi				
Dead fish					
Final number	Nf				
Final biomass (g)	Bf				
Final mean weight (g)	Pmf				
Final mean size (cm)	Tmf				
Total ration (g)	RT				
Total production (g)	Bf - Bi				
Conversion rate	RT / (Bf - Bi)				
Day growth (g)	(Pmf - Pmi) / days				
Day growth (cm)	(Tmf - Tmi) / days				
Survival (%)	(Nf - Ni) x 100				

Evaluation sheet for growth and production

Date

Pond					
Surface or volume					
Controle n°					
Beginning date	Di				
End date	Df				
Duration (days)	Df - Di				
Initial numbers	Ni				
Initial biomass (g)	Bi				
Initial mean weight (g)	Pmi				
Dead fish					
Final number	Nf				
Final biomass (g)	Bf				
Final mean weight (g)	Pmf				
Total ration (g)	RT				
Total production (g)	Bf - Bi				
Conversion rate	RT / (Bf - Bi)				
Day growth (g)	(Pmf - Pmi) / jours				
Survival (%)	(Nf - Ni) x 100				

Monitoring of fish - Size / Weight - individual or mean

Pond n° Date

Species	Nomber	Sex	Standard length (cm)	Weight (g)	Remarks

Appendix 02

DATA TABLES

The tables presented here provide information on:

Table XXXVIII.	**Tonnage of halieutic products per African country.**
Table XXXIX.	**Checklist of freshwater species that have been introduced in Africa.**
Table XL.	**List of introduced freshwater species, by African country.**
Table XLI.	**List of freshwater species used for aquaculture in Africa.**

TABLE XXXVIII. Tonnage of halieutic products per African country, 2005 (FAO, 2006).

F = FAO estimate from available sources of information.

Country	Fish, crustaceans, molluscs			Aquatic plants		
	Capture	Aquaculture	Total	Capture	Aquaculture	Total
South Africa	817608	3142	820750	6619	3000	9619
Algeria	126259	368 F	126627 F	-	-	-
Angola	240000 F	-	240000 F	-	-	-
Benin	38035	372	38407	-	-	-
Botswana	132	-	132	-	-	-
Burkina Faso	9000	6 F	9006 F	-	-	-
Burundi	14000 F	200 F	14200 F	-	-	-
Cameroon	142345	337	142682	-	-	-
Central African Republic	15000 F	0	15000 F	-	-	-
Congo	58368	80	58448	-	-	-
Congo DR / Zaïre	220000 F	2965 F	222965 F	-	-	-
Côte d'Ivoire	55000 F	866 F	55866 F	-	-	-
Djibouti	260 F	-	260 F	-	-	-
Egypt	349553	539748	889301	-	-	-
Eritrea	4027	-	4027	-	-	-
Ethiopia	9450	0	9450	-	-	-
Gabon	43863	78	43941	-	-	-
Gambia	32000 F	0	32000 F	-	-	-
Ghana	392274	1154	393428	-	-	-
Guinea	96571 F	0	96571 F	-	-	-
Equatorial Guinea	3500 F	-	4027	-	-	-
Guinea-Bissau	6200 F	-	6200 F	-	-	-
Kenya	148124	1047	149171	-	-	-
Lesotho	45	1	46	-	-	-
Liberia	10000 F	0	10000 F	-	-	-
Libya	46073 F	266 F	46339 F	-	-	-
Madagascar	136400	8500 F	144900 F	-	-	-
Malawi	58783	812	59595	-	-	-
Mali	100000 F	1008 F	101008 F	-	90 F	90 F
Morocco	932704	2257	934961	12813	-	12813
Mauritania	247577	-	247577	-	-	-
Mozambique	42473	1222	43695	-	56	56
Namibia	552695	50 F	552745 F	0	67 F	67 F
Niger	50018	40	50058	-	-	-
Nigeria	523182	56355	579537	-	-	-
Uganda	416758	10817	427575	-	-	-
Rwanda	7800 F	386 F	8186 F	-	-	-
Senegal	405070	193 F	405263 F	0	1	1
Sierra Leone	145993	0	145993	-	-	-
Somalia	30000 F	-	30000 F	-	-	-
Sudan	62000	1600 F	63600 F	0	-	0
Swaziland	70 F	0	70 F	-	-	-
Tanzania	347800 F	11 F	347811 F	240 F	6000 F	6240 F
Chad	70000 F	-	70000 F	-	-	-
Togo	27732	1535	29267	-	-	-
Tunisia	109117	2665	111782	-	-	-
Zambia	65000 F	5125 F	70125 F	-	-	-
Zimbabwe	13000 F	2452	15452 F	-	-	-
Total	**93253346**	**48149792**	**141403138**	**1305803**	**14789972**	**16095775**

TABLE XXXIX. Checklist of freshwater species that have been introduced in Africa (FAO, 2006; Fishbase, 2006).

Environment (E): Found in: m = marine, s = brackish
Maximal size (T): SL = Standard Length - FL = Fork Length - TL = Total Length;
m = male; f = female; ns = non sex
Aquaculture (A): 1 = used for consumption

Order	Family	Species	Author	E	T	A
Osteoglossiformes (Bony tongues)	Arapaimidae	*Heterotis niloticus*	(Cuvier, 1829)		100 SL m	1
Anguilliformes (Eels)	Anguillidae	*Anguilla anguilla*	(Linnaeus, 1758)	m-s	200 TL ns	1
Clupeiformes (Herrings, sardines)	Clupeidae	*Limnothrissa miodon*	(Boulenger, 1906)		17.5 TL ns	
Cypriniformes (Carps, minnows)	Cyprinidae	*Aristichthys nobilis*	(Richardson, 1845)		146 SL ns	
		Barbus anoplus	Weber, 1897	s	10.1 FL f	
		Barbus barbus	(Linnaeus, 1758)		90 SL ns	
		Carassius auratus auratus	(Linnaeus, 1758)		41 TL ns	1
		Carassius carassius	(Linnaeus, 1758)		64 TL ns	1
		Catla catla	(Hamilton, 1822)		120 TL ns	
		Ctenopharyngodon idella	(Valenciennes, 1844)		150 TL ns	1
		Cyprinus carpio carpio	Linnaeus, 1758		120 SL ns	1
		Gobio gobio gobio	(Linnaeus, 1758)	s	13 SL ns	
		Hypophthalmichthys molitrix	(Valenciennes, 1844)		100 TL ns	1
		Labeo rohita	(Hamilton, 1822)		96 TL ns	
		Labeobarbus aeneus	(Burchell, 1822)		50 FL m	
		Labeobarbus natalensis	(Castelnau, 1861)		68.3 TL m	
		Mylopharyngodon piceus	(Richardson, 1846)		180 SL ns	
		Rutilus rubilio	(Bonaparte, 1837)		25.8 FL f	
		Rutilus rutilus	(Linnaeus, 1758)		45 SL ns	
		Scardinius erythrophthalmus	(Linnaeus, 1758)	s	35 SL ns	1
		Tanichthys albonubes	Lin, 1932		2.2 SL ns	
		Tinca tinca	(Linnaeus, 1758)	s	64 TL ns	
Characiformes (Tétra)	Citharinidae	*Distichodus niloticus*	(Hasselquist, 1762)	s	83 TL m	
	Characidae	*Astyanax orthodus*	Eigenmann, 1907		10 TL m	
Siluriformes (Catfish)	Bagridae	*Bagrus meridionalis*	Günther, 1894		97 TL f	
	Schilbeidae	*Schilbe mystus*	(Linnaeus, 1758)	s	34 SL ns	
	Clariidae	*Clarias gariepinus*	(Burchell, 1822)		150 SL ns	1
	Ictaluridae	*Ictalurus punctatus*	(Rafinesque, 1818)		100 SL ns	
	Siluridae	*Silurus glanis*	Linnaeus, 1758		500 TL ns	1
Salmoniformes (Salmons)	Salmonidae	*Hucho hucho*	(Linnaeus, 1758)		165 SL ns	
		Oncorhynchus mykiss	(Walbaum, 1792)	m-s	100 SL ns	1
		Salvelinus fontinalis	(Mitchill, 1814)		85 SL ns	
		Salmo trutta fario	Linnaeus, 1758		60 TL ns	
		Salmo trutta trutta	Linnaeus, 1758		140 TL ns	1
Esociformes (Pikes)	Esocidae	*Esox lucius*	Linnaeus, 1758	s	150 TL ns	1
Cyprinodontiformes (Killis, mosquito fish)	Aplocheilidae	*Pachypanchax playfairii*	(Günther, 1866)	s	10 SL m	
	Cyprinodontidae	*Aphanius fasciatus*	(Valenciennes, 1821)	m-s	6 SL ns	
	Poeciliidae	*Gambusia affinis*	(Baird & Girard, 1853)	s	4.2 SL ns	
		Gambusia holbrooki	Girard, 1859	s	6 SL f	
		Phalloceros caudimaculatus	(Hensel, 1868)		5.2 TL ns	
		Poecilia latipinna	(Lesueur, 1821)		12 SL ns	
		Poecilia reticulata	Peters, 1859	s	5 SL f	
		Xiphophorus hellerii	Heckel, 1848	s	14 TL m 16 TL f	
		Xiphophorus maculatus	(Günther, 1866)		4 SL m	

TABLE XXXIX (cont). Checklist of freshwater species introduced in Africa (FAO, 2006; Fishbase, 2006).

Environment (E): Found in: m = marine, s = brackish
Maximal size (T): SL = Standard Length - FL = Fork Length - TL = Total Length;
m = male; f = female; ns = non sex
Aquaculture (A): 1 = used for consumption

Order	Family	Species	Author	E	T	A
Perciformes (Perch, gobies)	Moronidae	*Morone saxatilis*	(Walbaum, 1792)		200 TL m	
	Terapontidae	*Terapon puta*	Cuvier, 1829	m-s	30 TL ns	1
	Latidae	*Lates niloticus*	(Linnaeus, 1758)	s	200 TL m	1
	Centrarchidae	*Lepomis cyanellus*	Rafinesque, 1819		31 TL m	
		Lepomis gibbosus	(Linnaeus, 1758)		32 SL ns	
		Lepomis macrochirus	Rafinesque, 1819		41 TL m	
		Lepomis microlophus	(Günther, 1859)		43.2 TL m	
		Micropterus dolomieu	Lacepède, 1802		69 TL m	
		Micropterus punctulatus	(Rafinesque, 1819)		63.5 TL m	
		Micropterus salmoides	(Lacepède, 1802)		65 SL ns	1
	Percidae	*Perca fluviatilis*	Linnaeus, 1758	s	60 SL ns	
		Sander lucioperca	(Linnaeus, 1758)	s	130 TL ns	1
	Cichlidae	*Amatitiana nigrofasciata*	(Günther, 1867)		10 SL	
		Astatoreochromis alluaudi	Pellegrin, 1904		19 SL ns	
		Astronotus ocellatus	(Agassiz, 1831)		45.7 TL m	
		Oreochromis andersonii	(Castelnau, 1861)	s	61 TL m	1
		Oreochromis aureus	(Steindachner, 1864)	s	45.7 TL m	1
		Oreochromis esculentus	(Graham, 1928)		50 SL m	
		Oreochromis karongae	(Trewavas, 1941)		38 SL ns	1
		Oreochromis leucostictus	(Trewavas, 1933)		32 TL ns	
		Oreochromis macrochir	(Boulenger, 1912)		40.2 TL m	1
		Oreochromis mortimeri	(Trewavas, 1966)		48 TL ns	
		Oreochromis mossambicus	(Peters, 1852)	s	39 TLns	1
		Oreochromis niloticus eduardianus	(Boulenger, 1912)		49 TL ns	
		Oreochromis niloticus niloticus	(Linnaeus, 1758)	s	64 TL ns	1
		Oreochromis shiranus shiranus	Boulenger, 1897	s	39 SL ns	1
		Oreochromis spilurus niger	Günther, 1894		32 SL m 29 SL f	
		Oreochromis spilurus spilurus	(Günther, 1894)	s	19.2 SL m 16.3 SL f	
		Oreochromis urolepis hornorum	(Trewavas, 1966)	s	24 SL m	
		Serranochromis robustus jallae	(Boulenger, 1896)		39.6 SL m	
		Serranochromis robustus robustus	(Günther, 1864)		56 TL m	1
		Tilapia guinasana	Trewavas, 1936		14 TL m	
		Tilapia rendalli	(Boulenger, 1897)	s	45 TL ns	1
		Tilapia sparrmanii	Smith, 1840		23.5 TL m	
		Tilapia zillii	(Gervais, 1848)	s	27 SL ns	1
	Eleotridae	*Butis koilomatodon*	(Bleeker, 1849)	m-s	10.7 TL m	
	Anabantidae	*Microctenopoma ansorgii*	(Boulenger, 1912)		8 TL m	
	Osphronemidae	*Macropodus opercularis*	(Linnaeus, 1758)		5.3 SL ns	
		Osphronemus goramy	Lacepède, 1801		70 SL m	
		Trichogaster trichopterus	(Pallas, 1770)		15 SL m	
	Channidae	*Channa striata*	(Bloch, 1793)		91.5 ns	
		Channa maculata	(Lacepède, 1801)		25 SL ns	
Lepidosireniformes (Lung fish)	Protopteridae	*Protopterus aethiopicus aethiopicus*	Heckel, 1851		200 TL ns	

TABLE XL. List of introduced species, by African country.

N = native (if the number is null, the species comes from another continent)
I = introduced - E = endemic
o = introduced but not established - q = to be verified

Family	Species \ Country	South Africa	Algeria	Angola	Benin	Botswana	Burkina Faso	Burundi	Cameroon	Cape Verde	Central Africa	Comoros	Congo	Congo DR	Côte d'Ivoire	Djibouti	Egypt	Eritrea	Ethiopia
Arapaimidae	*Heterotis niloticus*				N		N		N		I		I	I					N
Anguillidae	*Anguilla anguilla*																N	o	
Clupeidae	*Limnothrissa miodon*							N						NI					
Cyprinidae	*Aristichthys nobilis*		I														o		
	Barbus anoplus	N																	
	Barbus barbus																		
	Carassius auratus auratus	I																	I
	Carassius carassius																		I
	Catla catla																		
	Ctenopharyngodon idella	I	I												I		I		I
	Cyprinus carpio carpio	I	o			I			I		I				I		I		I
	Gobio gobio gobio																		
	Hypophthalmichthys molitrix	I	I														o		I
	Labeo rohita																		
	Labeobarbus aeneus	N																	
	Labeobarbus natalensis	N																	
	Mylopharyngodon piceus																		
	Rutilus rubilio																		
	Rutilus rutilus																		
	Scardinius erythrophthalmus																		
	Tanichthys albonubes																		
	Tinca tinca	I																	
Citharinidae	*Distichodus niloticus*								N				I				N		N
Characidae	*Astyanax orthodus*																		
Bagridae	*Bagrus meridionalis*																		
Schilbeidae	*Schilbe mystus*			N	N	N			N				I		N		N		N
Clariidae	*Clarias gariepinus*		N	N	N	N	N	N					N		I	N	N	N	N
Ictaluridae	*Ictalurus punctatus*																		
Siluridae	*Silurus glanis*		I																
Salmonidae	*Hucho hucho*																		
	Oncorhynchus mykiss	I																I	I
	Salmo trutta fario	I																	
	Salmo trutta trutta	I																	I
	Salvelinus fontinalis	o																	
Esocidae	*Esox lucius*		I																I
Aplocheilidae	*Pachypanchax playfairii*																		
Cyprinodontidae	*Aphanius fasciatus*		N														N		
Poeciliidae	*Gambusia affinis*	I									I	I			I		I		
	Gambusia holbrooki																		I
	Phalloceros caudimaculatus																		
	Poecilia latipinna																		
	Poecilia reticulata	I										I							
	Xiphophorus hellerii	I																	
	Xiphophorus maculatus																		

TABLE XL (cont.). List of introduced species, by African country.

N = native (if the number is null, the species comes from another continent)
I = introduced - E = endemic
o = introduced but not established - q = to be verified

Family	Species \ Country	South Africa	Algeria	Angola	Benin	Botswana	Burkina Faso	Burundi	Cameroon	Cape Verde	Central Africa	Comoros	Congo	Congo DR	Côte d'Ivoire	Djibouti	Egypt	Eritrea	Ethiopia
Moronidae	*Morone saxatilis*	I																	
Terapontidae	*Terapon puta*																I		
Latidae	*Lates niloticus*				N				N				I		N		N		N
Centrarchidae	*Lepomis cyanellus*	I											I						
	Lepomis gibbosus												I						
	Lepomis macrochirus	I											I						
	Lepomis microlophus																		
	Micropterus dolomieu	I																	
	Micropterus punctulatus	I																	
	Micropterus salmoides	I	I			I			o				o				o		
Percidae	*Perca fluviatilis*	I																	
	Sander lucioperca		I																
Cichlidae	*Amatitiana nigrofasciata*																		
	Astatoreochromis alluaudi								I		I		I	I					
	Astronotus ocellatus														I				
	Oreochromis andersonii	I		N		N								I					
	Oreochromis aureus	I							N								N		
	Oreochromis esculentus																		
	Oreochromis karongae																		
	Oreochromis leucostictus							I						N					
	Oreochromis macrochir	o	I	N	o	N	I	I	I		I		o	N	I		I		
	Oreochromis mortimeri													I					
	Oreochromis mossambicus		I	I	I	N							I	I	o		I		
	Oreochromis niloticus eduardianus							N						N					
	Oreochromis niloticus niloticus	I				I		I			I	I	I	I				I	
	Oreochromis shiranus shiranus																		
	Oreochromis spilurus niger																		N
	Oreochromis spilurus spilurus													I					N
	Oreochromis urolepis hornorum														I				
	Serranochromis robustus jallae	I		N		N								N					
	Serranochromis robustus robustus																		
	Tilapia guinasana					I													
	Tilapia rendalli	N		N		N		I	N				N	N					I
	Tilapia sparrmanii	N		N		N													
	Tilapia zillii				N				N		N			N	N		N	I	I
Eleotridae	*Butis koilomatodon*																		
Anabantidae	*Microctenopoma ansorgii*												N	N					
Osphronemidae	*Macropodus opercularis*																		
	Osphronemus goramy		o												o				
	Trichogaster trichopterus																		
Channidae	*Channa maculata*																		
	Channa striata																		
Protopteridae	*Protopterus aethiopicus aethiopicus*							N						N			N		N
Number of introductions		24	11	1	2	4	1	4	4	0	6	3	12	8	9	0	9	4	11

TABLE XL (cont.). List of introduced species, by African country.

N = native (if the number is null, the species comes from another continent)
I = introduced - E = endemic
o = introduced but not established - q = to be verified

Family	Species \ Country	Gabon	Gambia	Ghana	Guinea	Guinea Equatorial	Guinée-Bissau	Kenya	Lesotho	Liberia	Libya	Madagascar	Malawi	Mali	Morocco	Mauritius	Mauritania	Mozambique	Namibia
Arapaimidae	*Heterotis niloticus*	I					N	N				I							
Anguillidae	*Anguilla anguilla*							I			N						N		
Clupeidae	*Limnothrissa miodon*																	I	
Cyprinidae	*Aristichthys nobilis*														I			o	
	Barbus anoplus								N										I
	Barbus barbus														I				
	Carassius auratus auratus											I				I			I
	Carassius carassius							I											
	Catla catla															I			
	Ctenopharyngodon idella							I							I	I		o	
	Cyprinus carpio carpio			I				I	I			I	o		I	I		I	I
	Gobio gobio gobio														I				
	Hypophthalmichthys molitrix											o	o		I	I		o	
	Labeo rohita											I				I			
	Labeobarbus aeneus								N										N
	Labeobarbus natalensis																		
	Mylopharyngodon piceus														I				
	Rutilus rubilio																		
	Rutilus rutilus											o			I				
	Scardinius erythrophthalmus											o			I				
	Tanichthys albonubes											I							
	Tinca tinca											o			I				
Citharinidae	*Distichodus niloticus*							N											
Characidae	*Astyanax orthodus*																		I
Bagridae	*Bagrus meridionalis*												N					N	
Schilbeidae	*Schilbe mystus*			N	N		N	N		N							N		N
Clariidae	*Clarias gariepinus*	I	N			N	N			N	N						N	N	
Ictaluridae	*Ictalurus punctatus*																		
Siluridae	*Silurus glanis*																		
Salmonidae	*Hucho hucho*														I				
	Oncorhynchus mykiss							I	I			I	I		I	o			
	Salmo trutta fario							I				I							
	Salmo trutta trutta							I	I			I	I		o				
	Salvelinus fontinalis							I							o				
Esocidae	*Esox lucius*											o			I				
Aplocheilidae	*Pachypanchax playfairii*											q							
Cyprinodontidae	*Aphanius fasciatus*										N				I				
Poeciliidae	*Gambusia affinis*			I				I				I			I	I			
	Gambusia holbrooki							I				I				I			
	Phalloceros caudimaculatus												I						
	Poecilia latipinna							I											
	Poecilia reticulata							I				I				I			I
	Xiphophorus hellerii											I				I			I
	Xiphophorus maculatus											I				I			

TABLE XL (cont.). List of introduced species, by African country.

N = native (if the number is null, the species comes from another continent)
I = introduced - E = endemic
o = introduced but not established - q = to be verified

Family	Species \ Country	Gabon	Gambia	Ghana	Guinea	Guinea Equatorial	Guinée-Bissau	Kenya	Lesotho	Liberia	Libya	Madagascar	Malawi	Mali	Morocco	Mauritius	Mauritania	Mozambique	Namibia
Moronidae	*Morone saxatilis*																		
Terapontidae	*Terapon puta*																	N	
Latidae	*Lates niloticus*				N		N	NI		N				N	o		N		
Centrarchidae	*Lepomis cyanellus*							q				o			I	I			
	Lepomis gibbosus														I				
	Lepomis macrochirus							q				I	I		I	I			
	Lepomis microlophus														I	I			
	Micropterus dolomieu															I			
	Micropterus punctulatus																		
	Micropterus salmoides							I	I			I	I		I	I	o	I	I
Percidae	*Perca fluviatilis*														I				
	Sander lucioperca														I				
Cichlidae	*Amatitiana nigrofasciata*																		
	Astatoreochromis alluaudi							N											
	Astronotus ocellatus																		
	Oreochromis andersonii							I										N	
	Oreochromis aureus							o			o	I		N					
	Oreochromis esculentus							N											
	Oreochromis karongae												NI					N	
	Oreochromis leucostictus							I											
	Oreochromis macrochir	I		I				I		I		I				I		N	
	Oreochromis mortimeri							q											
	Oreochromis mossambicus							I	N			I							I
	Oreochromis niloticus eduardianus							I											
	Oreochromis niloticus niloticus	I	N					I				I				I			
	Oreochromis shiranus shiranus											o						N	
	Oreochromis spilurus niger							N				I						I	
	Oreochromis spilurus spilurus							N											
	Oreochromis urolepis hornorum																		
	Serranochromis robustus jallae												N						N
	Serranochromis robustus robustus												N						N
	Tilapia guinasana																		E
	Tilapia rendalli	N						I				I				I		N	
	Tilapia sparrmanii											I	N					N	N
	Tilapia zillii		N	N	N		N	N				I		N	N	I	N		
Eleotridae	*Butis koilomatodon*											N						N	
Anabantidae	*Microctenopoma ansorgii*											I							
Osphronemidae	*Macropodus opercularis*											I							
	Osphronemus goramy											I				I			
	Trichogaster trichopterus																		I
Channidae	*Channa maculata*											I							
	Channa striata											I				I			
Protopteridae	*Protopterus aethiopicus aethiopicus*							N											
Number of introductions		4	0	3	0	0	0	22	4	1	1	35	8	0	25	23	1	7	9

TABLE XL (cont.). List of introduced species, by African country.

N = native (if the number is null, the species comes from another continent)
I = introduced - E = endemic
o = introduced but not established - q = to be verified

Family	Species \ Country	Niger	Nigeria	Uganda	Reunion La	Rwanda	Sao Tome & Principe	Senegal	Seychelles	Sierra Leone	Somalia	Sudan	Swaziland	Tanzania	Chad	Togo	Tunisia	Zambia	Zimbabwe	Number of introduced	Number of native
Arapaimidae	*Heterotis niloticus*	N						N				N			N	I				6	10
Anguillidae	*Anguilla anguilla*																			2	3
Clupeidae	*Limnothrissa miodon*					I								N				NI	I	5	2
Cyprinidae	*Aristichthys nobilis*																			4	0
	Barbus anoplus												N							1	3
	Barbus barbus																			1	0
	Carassius auratus auratus								I										I	7	0
	Carassius carassius																			2	0
	Catla catla																		I	2	0
	Ctenopharyngodon idella		I		I	I						I		I			I			15	0
	Cyprinus carpio carpio		I	I	I	I						o	I	I		I	I	o	I	28	0
	Gobio gobio gobio																			1	0
	Hypophthalmichthys molitrix					I														10	0
	Labeo rohita		o																I	4	0
	Labeobarbus aeneus																		I	1	3
	Labeobarbus natalensis																		I	1	1
	Mylopharyngodon piceus																			1	0
	Rutilus rubilio																I			1	0
	Rutilus rutilus																			2	0
	Scardinius erythrophthalmus																I			3	0
	Tanichthys albonubes																			1	0
	Tinca tinca																o	o	I	6	0
Citharinidae	*Distichodus niloticus*											N			N					1	6
Characidae	*Astyanax orthodus*																			1	0
Bagridae	*Bagrus meridionalis*													N					I	1	3
Schilbeidae	*Schilbe mystus*							N		N		N	N	N	N	N		N	N	1	23
Clariidae	*Clarias gariepinus*	N		N				N		N	N	N			N	N				2	26
Ictaluridae	*Ictalurus punctatus*		I																	1	0
Siluridae	*Silurus glanis*																I			2	0
Salmonidae	*Hucho hucho*																			1	0
	Oncorhynchus mykiss				I							I	I	I			o	o	I	16	0
	Salmo trutta fario																			3	0
	Salmo trutta trutta												I	I					I	10	0
	Salvelinus fontinalis																		I	4	0
Esocidae	*Esox lucius*			I													I			6	0
Aplocheilidae	*Pachypanchax playfairii*								E					I						1	0
Cyprinodontidae	*Aphanius fasciatus*																N			1	4
Poeciliidae	*Gambusia affinis*											I						o	I	13	0
	Gambusia holbrooki				I															5	0
	Phalloceros caudimaculatus																			1	0
	Poecilia latipinna																			1	0
	Poecilia reticulata		I	I	I				I									I		11	0
	Xiphophorus hellerii				I													o		6	0
	Xiphophorus maculatus		I		I															4	0

TABLE XL (cont.). List of introduced species, by African country.

N = native (if the number is null, the species comes from another continent)
I = introduced - E = endemic
o = introduced but not established - q = to be verified

Family	Species / Country	Niger	Nigeria	Uganda	Reunion La	Rwanda	Sao Tome & Principe	Senegal	Seychelles	Sierra Leone	Somalia	Sudan	Swaziland	Tanzania	Chad	Togo	Tunisia	Zambia	Zimbabwe	Number of introduced	Number of native
Moronidae	*Morone saxatilis*																			1	0
Terapontidae	*Terapon puta*										N			N						1	3
Latidae	*Lates niloticus*	N		NI				N		N				I	N					5	14
Centrarchidae	*Lepomis cyanellus*												I					I	o	8	0
	Lepomis gibbosus																			2	0
	Lepomis macrochirus												I					o	I	9	0
	Lepomis microlophus																			2	0
	Micropterus dolomieu												o	I				o	o	6	0
	Micropterus punctulatus												I						I	3	0
	Micropterus salmoides		o										I	I			I	I	I	21	0
Percidae	*Perca fluviatilis*																			2	0
	Sander lucioperca																I			3	0
Cichlidae	*Amatitiana nigrofasciata*				I															1	0
	Astatoreochromis alluaudi			N		N								N						4	4
	Astronotus ocellatus																			1	0
	Oreochromis andersonii													I					o	5	3
	Oreochromis aureus	N	N	o				N							N			I	o	7	7
	Oreochromis esculentus			N		I								NI						2	2
	Oreochromis karongae													N						1	2
	Oreochromis leucostictus			N		I								I						4	2
	Oreochromis macrochir					I						I		I		I			N	20	5
	Oreochromis mortimeri																	N	N	1	2
	Oreochromis mossambicus			I	I				I					I			I			15	2
	Oreochromis niloticus eduardianus			N		N								I				N		2	5
	Oreochromis niloticus niloticus				I	I								I	N		I	I	I	18	2
	Oreochromis shiranus shiranus													N						1	2
	Oreochromis spilurus niger																	I		3	2
	Oreochromis spilurus spilurus			I							N			N						2	4
	Oreochromis urolepis hornorum			N										N						1	2
	Serranochromis robustus jallae												I					N	N	2	7
	Serranochromis robustus robustus												I	N				N		1	4
	Tilapia guinasana																			1	0
	Tilapia rendalli	N		I		I		N							N				N	7	12
	Tilapia sparrmanii												N	N				N	N	1	10
	Tilapia zillii	N	N					N		N		N		I	N	N	N			5	22
Eleotridae	*Butis koilomatodon*		I						N					N						1	4
Anabantidae	*Microctenopoma ansorgii*																			1	2
Osphronemidae	*Macropodus opercularis*																			1	0
	Osphronemus goramy			o					I											6	0
	Trichogaster trichopterus					I			I											3	0
Channidae	*Channa maculata*																			1	0
	Channa striata																			2	0
Protopteridae	*Protopterus aethiopicus aethiopicus*			N		I						N		N				N		1	9
Number of introductions		0	8	9	10	11	0	0	5	0	0	5	10	16	0	3	12	14	21	381	217

TABLE XLI. List of freshwater fish used in aquaculture, by country (FAO, 2006; Fishbase, 2008).

N = native (if the number is null, the species comes from another continent)
I = introduced - E = endemic - o = introduced but not established - q = to be verified
A = Commercial production - X = Experimental

Family	Species \ Country	South Africa	Algeria	Angola	Benin	Botswana	Burkina Faso	Burundi	Cameroon	Cape Verde	Central Africa	Comoros	Congo	Congo DR	Côte d'Ivoire	Djibouti	Egypt	Eritrea	Ethiopia	Gabon	Gambia
Arapaimidae	*Heterotis niloticus*				N		N		N		IA		IA	IA	A				N	IA	A
Anguillidae	*Anguilla anguilla*		A														N	o			
Cyprinidae	*Carassius auratus auratus*	IA																	I		
	Carassius carassius																		IA		
	Cirrhinus cirrhosus																				
	Ctenopharyngodon idella	I	IA												I		IA		I		
	Cyprinus carpio carpio	IA	oA			I			IA		I				I		IA		I		
	Hypophthalmichthys molitrix	I	I														oA		I		
	Scardinius erythrophthalmus																				
Alestidae	*Brycinus lateralis*	N		N		N								N							
Bagridae	*Bagrus bajad*				N		N		N								N		N		
Claroteidae	*Chrysichthys nigrodigitatus*			N	N				N						A					N	N
Schilbeidae	*Schilbe intermedius*	N			N	N									N				N		
Clariidae	*Clarias anguillaris*		N		N		A		N						N		A		N		N
	Clarias gariepinus	A	N	N	N	N	N	N	A		A		N	A	I	N	N	N	N	IA	N
	Clarias ngamensis	N		N		N															
	Heterobranchus bidorsalis						N		N								N		N		N
	Heterobranchus longifilis			N	N		N	N	N		N			N	NX		N		N		N
Siluridae	*Silurus glanis*		I																		
Mochokidae	*Synodontis nigromaculata*	N		N		N		N						N							
Salmonidae	*Oncorhynchus mykiss*	IA																I	I		
	Salmo trutta trutta	I																	I		
Esocidae	*Esox lucius*		I																I		
Mugilidae	*Liza ramado*		N														N				
	Mugil cephalus	N	N	N					N	N		N			N		A			N	N
Moronidae	*Dicentrarchus labrax*		A														A				
Terapontidae	*Terapon puta*																IA				
Latidae	*Lates niloticus*				N				N				I		N		N		N		
Centrarchidae	*Micropterus salmoides*	IA	I			I			o				o				o				
Percidae	*Sander lucioperca*		IA																		
Cichlidae	*Oreochromis andersonii*	I		N		N								I							
	Oreochromis aureus	I							N						A		N				
	Oreochromis karongae																				
	Oreochromis macrochir	o	I	N	o	N	I	I	I		I		o	N	I		I			I	
	Oreochromis mossambicus	A	I	I	I	N							I	I	o		I				
	Oreochromis niloticus niloticus	IA				I	A	IA	A		IA	I	IA	IA	A		A	I		IA	N
	Oreochromis shiranus shiranus																				
	Sargochromis carlottae			N		N															
	Sargochromis giardi			N		N															
	Sarotherodo galileus galileus				N				N				N	N	N		N		N		N
	Sarotherodon melanotheron melanotheron				N				N					N	X						N
	Serranochromis robustus robustus																				
	Tilapia cameronensis								EA												
	Tilapia rendalli	N		N		N		I	N				N	N					I	N	
	Tilapia zillii				N				N		N			N	N		N	I	I		N
Number of species used in aquaculture		7	5	0	0	0	2	1	4	0	3	0	2	3	6	0	8	0	1	3	1
Number of species introduced for aquaculture		5	3	0	0	0	0	1	1	0	2	0	2	2	0	0	4	0	1	3	0
Number of species introduced		11	8	1	2	3	1	3	3	0	4	1	6	4	5	0	7	4	10	4	0
Number of species natives		6	4	12	11	11	5	3	14	1	2	1	3	8	6	1	10	1	9	3	10

TABLE XLI (cont). List of freshwater fish used in aquaculture, by country (FAO, 2006; Fishbase, 2008).

N = native (if the number is null, the species comes from another continent)
I = introduced - E = endemic - o = introduced but not established - q = to be verified
A = Commercial production - X = Experimental

Family	Species \ Country	Ghana	Guinea	Guinea Equatorial	Guinea-Bissau	Kenya	Lesotho	Liberia	Libya	Madagascar	Malawi	Mali	Morocco	Mauritius	Mauritania	Mozambique	Namibia	Niger	Nigeria	Uganda	Reunion La
Arapaimidae	*Heterotis niloticus*	A	A		N	N				IA		A						N	A		
Anguillidae	*Anguilla anguilla*					I			N				A		N						
Cyprinidae	*Carassius auratus auratus*									I				I			I				
	Carassius carassius					I															
	Cirrhinus cirrhosus													A							
	Ctenopharyngodon idella					I							IA	I		oA			I		IA
	Cyprinus carpio carpio	I				IA	IA			IA	oA		IA	I		IA	I		I	IA	IA
	Hypophthalmichthys molitrix									o	o		IA	I		o					
	Scardinius erythrophthalmus									o			I								
Alestidae	*Brycinus lateralis*															N	A				
Bagridae	*Bagrus bajad*	N				N												N	N	N	
Claroteidae	*Chrysichthys nigrodigitatus*	A	N	N				N							A				A		
Schilbeidae	*Schilbe intermedius*	N			N	N										N	A		N		
Clariidae	*Clarias anguillaris*	A			N							N			N			N	N		
	Clarias gariepinus	A	A	N	N	A	A	N	N		A	A			N	N	A	N	A	N	
	Clarias ngamensis										N					N	A				
	Heterobranchus bidorsalis	A	N					A				N						N	N		
	Heterobranchus longifilis	A	N			N		A			N					N		N	N		
Siluridae	*Silurus glanis*																				
Mochokidae	*Synodontis nigromaculata*															N	A				
Salmonidae	*Oncorhynchus mykiss*					IA	IA			IA	IA		IA	o							IA
	Salmo trutta trutta					IA	I			I	I		o								
Esocidae	*Esox lucius*									o			IA							IA	
Mugilidae	*Liza ramado*				q				N				N								
	Mugil cephalus	N	N		N	N			N	N			N	N	N	N	N				
Moronidae	*Dicentrarchus labrax*								A				A		N						
Terapontidae	*Terapon puta*															N					
Latidae	*Lates niloticus*	A	N		N	NI		N				N	o		N			N	A	NI	
Centrarchidae	*Micropterus salmoides*					I	I			I	I		IA	I	o	IA	I		o		
Percidae	*Sander lucioperca*												I								
Cichlidae	*Oreochromis andersonii*					I										N	A				
	Oreochromis aureus					o			o	I		N						N	N	o	
	Oreochromis karongae										NIA					N					
	Oreochromis macrochir	IA				I		IA		I				I		N	A				
	Oreochromis mossambicus					I	N			I	A					A	IA			I	IA
	Oreochromis niloticus niloticus	A	A			IA		A		I		A		I		A		A	A	A	IA
	Oreochromis shiranus shiranus									o	A					N					
	Sargochromis carlottae																A				
	Sargochromis giardi																A				
	Sarotherodo galileus galileus	N	N		N	N		A				N	N		N			N	N	N	
	Sarotherodon melanotheron melanotheron	A	N		N			N							N				N		
	Serranochromis robustus robustus										N						N				
	Tilapia cameronensis																				
	Tilapia rendalli					I				IA	A			I		N	A	N	A	I	
	Tilapia zillii	N	N		N	N		A		I		N	N	I	N			N	N	A	
Number of species used in aquaculture		10	3	0	0	5	3	6	1	4	7	3	8	1	1	5	11	1	6	4	5
Number of species introduced for aquaculture		1	0	0	0	4	2	1	0	4	3	0	6	0	0	3	1	0	0	2	5
Number of species introduced		2	0	0	0	13	4	1	1	16	5	0	10	10	1	4	4	0	3	5	5
Number of species natives		5	8	2	9	8	1	4	4	1	4	6	4	1	9	13	2	11	9	4	0

TABLE XLI (cont). List of freshwater fish used in aquaculture by country (FAO, 2006; Fishbase, 2008).

N = native (if the number is null, the species comes from another continent)
I = introduced - E = endemic - o = introduced but not established - q = to be verified
A = Commercial production - X = Experimental

Family	Species \ Country	Rwanda	Sao Tome & Principe	Senegal	Seychelles	Sierra Leone	Somalia	Sudan	Swaziland	Tanzania	Chad	Togo	Tunisia	Zambia	Zimbabwe	Number of times used in aquaculture	Number of introduced for aquaculture	Number of times introduced	Number of times native
Arapaimidae	*Heterotis niloticus*			N				N			N	I				11	5	6	10
Anguillidae	*Anguilla anguilla*												A			3	0	2	3
Cyprinidae	*Carassius auratus auratus*				I										I	1	1	7	0
	Carassius carassius															1	1	2	0
	Cirrhinus cirrhosus															1	0	0	0
	Ctenopharyngodon idella	I						I		I			I			5	5	15	0
	Cyprinus carpio carpio	IA						o	IA	I		I	IA	oA	I	16	16	27	0
	Hypophthalmichthys molitrix	I														2	2	10	0
	Scardinius erythrophthalmus												IA			1	1	3	0
Alestidae	*Brycinus lateralis*													N	N	1	0	0	7
Bagridae	*Bagrus bajad*			N				A			N					1	0	0	12
Claroteidae	*Chrysichthys nigrodigitatus*			N		N						N				4	0	0	11
Schilbeidae	*Schilbe intermedius*	N				N		N		N	N	N		N	N	1	0	0	18
Clariidae	*Clarias anguillaris*			N		N		N			N	N				3	0	0	16
	Clarias gariepinus	A		N		N	N	N	A	A	N	N		A	A	18	1	2	26
	Clarias ngamensis									N				N	N	1	0	0	8
	Heterobranchus bidorsalis			N				N			N	N				2	0	0	13
	Heterobranchus longifilis			N		N		N		N	N	N		N	N	3	0	0	24
Siluridae	*Silurus glanis*												IA			1	1	2	0
Mochokidae	*Synodontis nigromaculata*									N				N	N	1	0	0	9
Salmonidae	*Oncorhynchus mykiss*							I	I	IA			o	o	IA	9	9	16	0
	Salmo trutta trutta								I	I					I	1	1	10	0
Esocidae	*Esox lucius*												I			2	2	6	0
Mugilidae	*Liza ramado*												A			1	0	0	4
	Mugil cephalus		N	N	N	N	N			N			A			2	0	0	26
Moronidae	*Dicentrarchus labrax*			N									A			5	0	0	2
Terapontidae	*Terapon puta*						N			N						1	1	1	3
Latidae	*Lates niloticus*			N		N		A		I	N	A				4	0	3	16
Centrarchidae	*Micropterus salmoides*								I	I			I	I	I	3	3	21	0
Percidae	*Sander lucioperca*												IA			2	2	3	0
Cichlidae	*Oreochromis andersonii*									IA				A	oA	4	2	5	3
	Oreochromis aureus			N							N			I	o	1	0	7	7
	Oreochromis karongae									N						1	1	0	3
	Oreochromis macrochir	I						I		IA		I		A	N	5	3	20	5
	Oreochromis mossambicus				I				A	I			I		A	7	2	15	2
	Oreochromis niloticus niloticus	IA		A		A		A		IA	N	A	I	IA	I	27	11	18	2
	Oreochromis shiranus shiranus									N						1	0	1	2
	Sargochromis carlottae													N	N	1	0	0	4
	Sargochromis giardi													N	N	1	0	0	4
	Sarotherodo galileus galileus			N				N			N	N				1	0	0	22
	Sarotherodon melanotheron melanotheron			A		N						N				3	0	0	11
	Serranochromis robustus robustus								IA	N				N		1	1	1	4
	Tilapia cameronensis															1	0	0	1
	Tilapia rendalli	I		N					A	A	N			A	N	7	1	7	12
	Tilapia zillii			N		N		N		I	N	N	N			2	0	5	22
Number of species used in aquaculture		0	3	2	0	1	0	3	5	6	0	2	8	6	4	170			
Number of species introduced for aquaculture		0	2	0	0	0	0	0	2	4	0	0	4	2	2		72		
Number of species introduced		0	6	0	2	0	0	4	5	11	0	3	10	5	8			215	
Number of native species		1	1	14	1	9	3	8	0	9	13	9	1	8	9				317

Appendix 03
SOME ELEMENTS OF SPECIES BIOLOGY

Some general information on the biology of some of the species used in aquaculture is presented here. Biogeographic elements were presented in chapter III, p. 21.

I. MORPHOLOGY AND SYSTEMS

Fish can be characterized by their morphology. It is very variable and is connected to how they live, including their behaviors and habits. The main anatomical terms for the external parts of a fish can be found in Figure 152 below. The morphological characteristics by which we can distinguish specific species will be provided here. The drawings and part of the text are taken from «Fauna of freshwater and brackish fish of West Africa» (Paugy *et al.*, 2003).

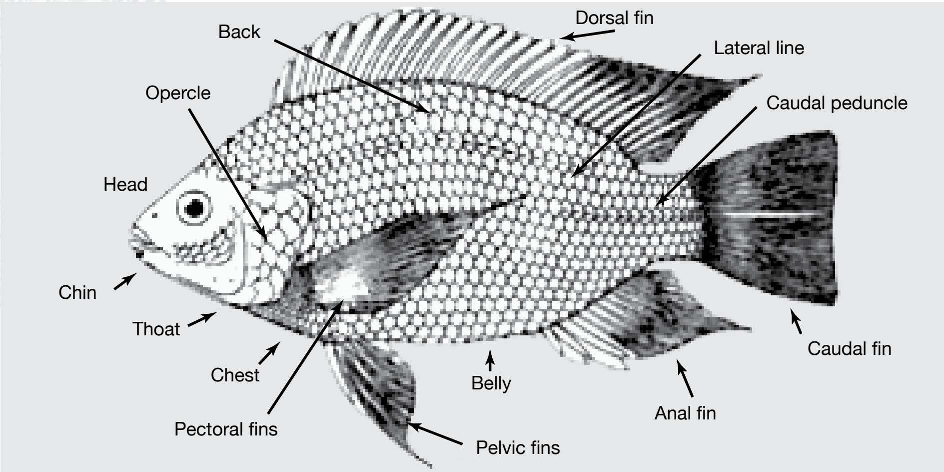

Figure 152. Principal terms for the external morphology of fish.

- ✓ *Ratio body length/body depth ((L/H)* (Figure 153 below)

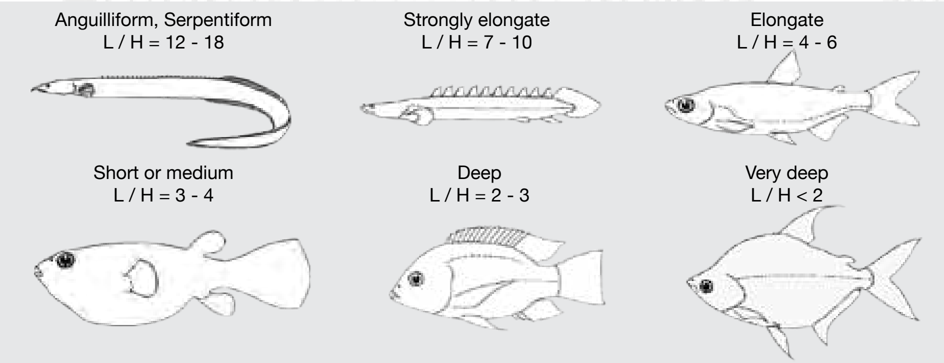

Figure 153. Different body shapes.

✓ *Body shape in cross-section* (Figure 154 below)

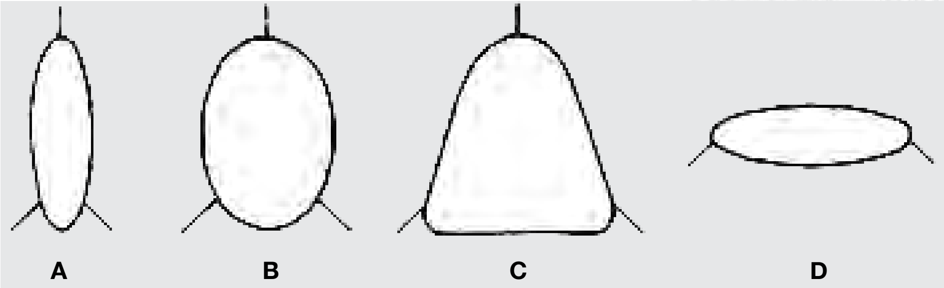

Figure 154. Cross-section of body types. A: Laterally compressed; B: More or less rounded; C: Dorso-ventrally depressed; D: Strongly depressed or dorso-ventrally flattened.

✓ *The head*

➢ The jaws (Figure 155 below)

The premaxilla(e), the maxilla(e) and, in certain families, the supramaxilla(e) of the upper jaw are normally distinguished from the mandible(s) of the lower jaw (A). Depending on species or family, the jaws may be equally long and normally developed (Alestidae, certain Cyprinidae) (B) or quite elongated, forming a beak (rostrum) (Belonidae) (C); in both cases, the mouth is called «terminal». The jaws may also be unequal, in which case the mouth is either superior (Cyprinodontidae, Centropomidae) (D), subinferior (certain Mormyridae) (E) or inferior (Mochokidae (F). Finally, some species have a protrusible mouth (Serranidae, Gerreidae) (G). In certain genera, such as *Labeo*, *Garra* and *Chiloglanis*, the mouth has well-developed lips, which sometimes form (for example, in *Chiloglanis*) a sucking disk (H) that allows the fish to cling to rocks and live in rather turbulent waters.

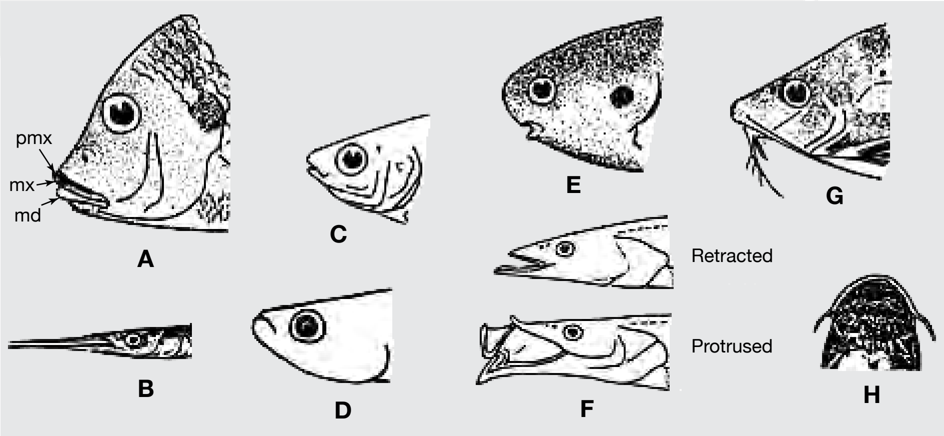

Figure 155. Jaws. A: Premaxilla (pmx), maxilla (mx), mandible (md); B: Jaws equal, prolonged into a beak; C: Jaws equal, normally developed; D: Mouth superior; E: Mouth subinferior; F: Mouth protrusible; G: Mouth inferior; H: Mouth inferior, forming a sucking disk.

➢ Teeth (Figure 156 below)

These are inserted on the rim of the jaws, by, premaxilla, maxilla, and dentary (mandibular bone), on the longitudinal axis of the roof of the mouth (vomer and parasphaenoid(s)), on both sides of the roof of the mouth (palatines and ectopterygoids), and on the upper and lower pharyngeal bones. Finally, some species have lingual teeth. Evidently, not all of these types of teeth are always present. The different kinds of teeth are distinguished here by the number of cusps they bear.

Thus, there are: monocuspid teeth that may be straight (certain *Marcusenius* species) (A), conical or caniniform (certain Alestidae and Cichlidae; B and C), cutting (*Hydrocynus* species, Sphyraenidae; D) or curved (*Synodontis* species; E); bicuspid teeth (most Mormyridae , *Distichodus*; F and G); polycuspid teeth, which have cusps set in a single plane (certain Alestidae and Cichlidae; H), and molariform polycuspid teeth, which have cusps that form a crown (certain Alestidae; I). There are also other, less common kinds of teeth.

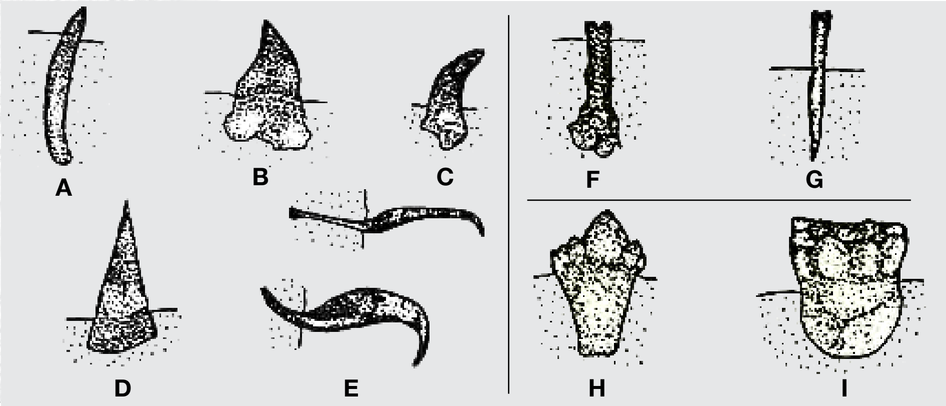

Figure 156. Tooth shapes.
Monocuspid straight (A: *Marcusenius* sp.), conical (B: *Brycinus* sp. and C: *Chromidotilapia* sp.), cutting (D: *Hydrocynus* sp.) and recurved (E: *Synodontis* sp.).
Bicuspid (F: *Petrocephalus* sp. and G: *Distichodus* sp.).
Polycuspid in one plan (H: *Micralestes* sp.) and molariform (I: *Brycinus* sp.).

➢ Eyes

Depending on the family, the eyes may be located in different positions. They are usually lateral, but may be placed dorsally, particularly in Batoidea and Pleuronectiformes (where they are, moreover, both located on the same side of the head). Finally, they may protrude, as in *Periophthalmus*. In some species, the eyes are partially covered by an adipose eyelid, a nictitating fold or a nictitating membrane.

➢ Fontanellae (Figure 157 opposite)

The cranial fontanellae are sometimes used to identify genus or species; for example the fronto-parietal fontanellae is used to identify some Alestidae (A), and the frontal and occipital fontanellae are used to identify some Clariidae (B).

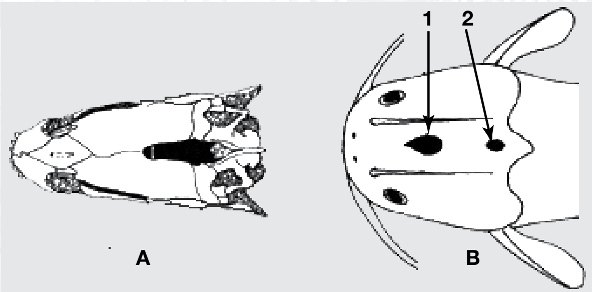

Figure 157. Fontanellae. A: *Alestes* sp.; B: *Clarias* sp.: frontal (1) and occipital (2).

- Barbels (Figure 158 below)

There may be three types of barbels, including a pair of nasal barbels just behind the posterior nostrils (Bagridae, Clariidae; A); a pair of maxillary barbels, which may have a basal membrane (some Mochokidae; B), or not (some Cyprinidae and Mochokidae); and one (some Cyprinidae) or two (Siluriformes) pairs of mandibular barbels. In certain groups, the maxillary (some *Synodontis*) and mandibular (all *Synodontis*) may be branched (C). Finally, the mandibular barbels may sometimes be enclosed in the lips, as in *Chiloglanis* (D).

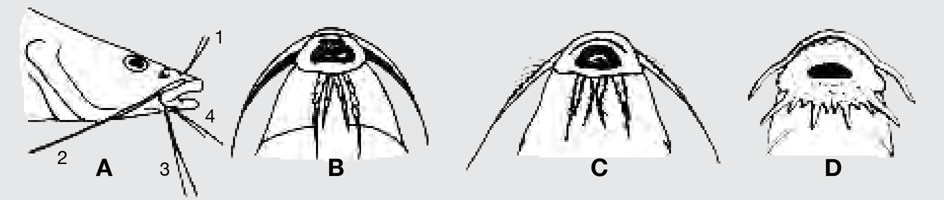

Figure 158. Barbels.
A: Types: Nasal (1), maxillary (2), outer mandibular (3) and inner (4).
B: Membranous maxillary barbels (*Synodontis* sp.);
C: Branched maxillary barbels (*Synodontis* sp.);
D: Mandibular barbels enclosed in the lips (*Chiloglanis* sp.).

- The gill cover

In Osteichthyes, there is a bony lid that covers the gill slits. Depending on the group, the branchiostegal membrane that covers the opercular bone may or may not be fused to the isthmus of the throat. This trait is used to identify certain Siluriformes. In most cases it is open wide, but in some others, the aperture may be rather small, or considerably reduced. In Chondrichthyes, the gill slits do not have a gill cover.

- The gill arch (Figure 159 opposite)

The gill arch is formed by three bones supporting, externally, the gill filaments and, internally, the gill rakers. The upper bone is the epibranchial, the lower ones are the ceratobranchial and the hypobranchial (E). In some species (Polypteridae), juveniles have a pair of external gills (F) which are later reabsorbed. This is also the case for embryos of *Protopterus*, which have three or four pairs of external gills.

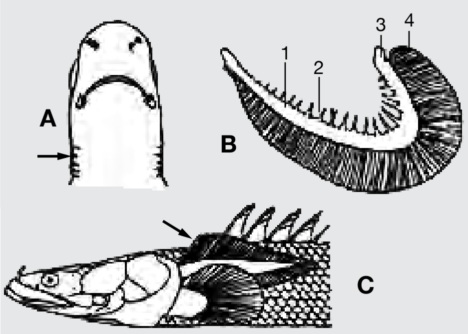

Figure 159. Gill slits without opercule (A: Sharks); gill arch formed by: ceratobranchial (1), gill rakers (2), hypobranchial and epibranchial (3), gill filaments (4) (B); external gill of a young *Polypterus* sp. (C).

- Accessory aerial breathing organs (Figure 160, p. 211)

Some fish have specialized organs that allow them to survive for some time outside the water without suffering major damage. There are several types of these organs, including the branched organ of the Clariidae (A), the lungs of

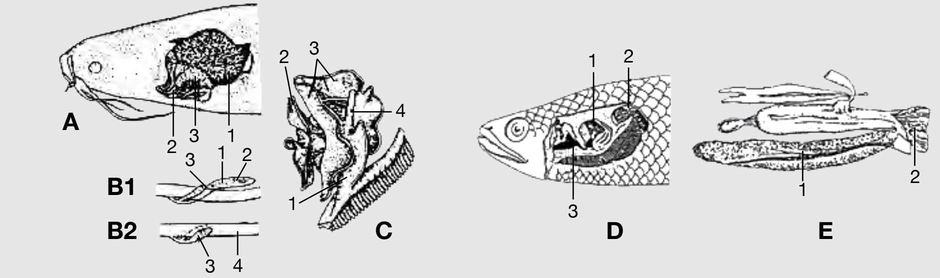

Figure 160. Accessory aerial breathing organs. Branched breathing organs (A: *Clarias* sp.), branches (1), gills (2), branchial valves (3); position of the swim bladder (1) and the lungs (2 and 3; plates of the labyrinth in an Anabantidae (C), principal plates (1-3), stylet (4); pharyngeal diverticula (D: *Parachanna* sp.), anterior chamber (1), posterior chamber (2), communication with pharynx (3); digestive tract and swim bladder (E: *Gymnarchus* sp.), swim bladder (1), opening of pneumatic duct (2).

the Protopteridae and Polypteridae (B), the labyrinthiform organ of the Anabantidae (C), the pharyngeal diverticulum of the Channidae (D), the swim bladder of *Gymnarchus* (E) and *Heterotis*.

✓ *The body*

The form and constitution of fins, the types of scales, and other features may be used to differentiate species.

➢ Fins

Two types of fins can be distinguished: paired (pelvic or ventral and pectoral) that are equivalent to Tetrapods, or unpaired (dorsal, caudal and anal):

Paired fins are **pelvic** (ventral) and **pectoral** (Figure 161 below).

In Gobiidae, pelvic fins are either fused into a ventral disk (A), or united by a transverse membrane. In *Periophthalmus*, they are also united, while pectoral fins allow these fish to move rather quickly on dry land. In Siluriformes, the first pectoral-fin ray is often ossified, forming a spine that may be denticulated on one or both margins (B). In Polypteridae, the pectoral fins are real paddles, attached to the trunk by a peduncle (C) that allows the fish to affect a wide range of movements.

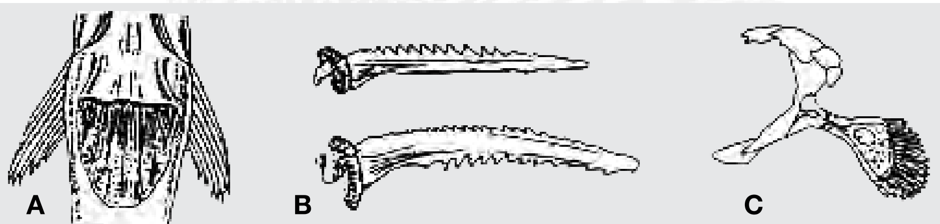

Figure 161. Pair fins. Coalesced pair of pelvic fins in a Gobiid species (A); first pectoral-fin ray denticulated on one margin (1) or on both margins (2) (B: *Clarias* sp.); paddle-shaped pectoral fin (C: *Polypterus* sp.).

Unpaired fins include the dorsal, caudal and anal fins.

There are three types of **dorsal** fin (Figure 162, p. 212): one is supported by simple spiny rays, another with soft, usually branched, rays, and the third is the so-called adipose dorsal fin. The latter is usually placed behind the soft-rayed dorsal (A). Many fish have two dorsal fins, the first spiny (anterior) and the second soft; or a single dorsal fin with anterior spiny rays with soft rays (B) behind them. In some species (the majority of Siluriformes), the first ray is represented by a strong, more or

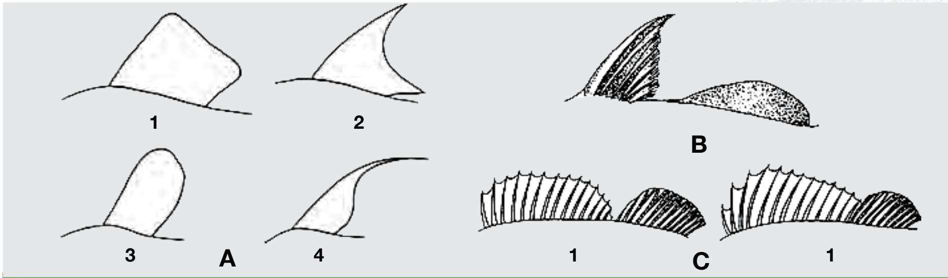

Figure 162. Dorsal fin. Soft dorsal (2) preceded by a strong spinous ray (1) and followed by an adipose dorsal (3) (A). Two dorsal fins: spiny rays (1), and simple or branched rays (2), separate (B1) and contiguous (B2). Fin margin straight (1), concave (2), rounded (3) and filamentous (4) (C).

less denticulated, spine. Depending on the species, the dorsal fin may have different shapes; that is, the outer margin may be straight, concave or rounded, or thread-like (C). Finally, some species lack dorsal fins (certain Schilbeidae).

Depending on the relative length of its upper and lower lobes, the **caudal** fin is termed (Figure 163, below) homocercal, when the lobes are symmetrical (A); heterocercal, when the lobes are externally and internally asymmetrical, with either the upper (Carcharhinidae; B1), or the lower lobe (some Amphiliidae; B2) better developed. The shape of the caudal fin may vary, depending on the species, from rounded to forked, notched, or filamentous. (C): In Cyprinodontidae, there are many different forms of caudal fin.

The morphological diversity of the **anal** fin may also be used to identify certain species, especially within Cyprinodontidae. In some adult Alestidae, its shape differs between males and females. In Perciformes, the first simple rays are modified into real spines. In some Siluriformes (Schilbeidae, Clariidae), this fin is very well developed while in other families (Gymnarchidae), it is absent.

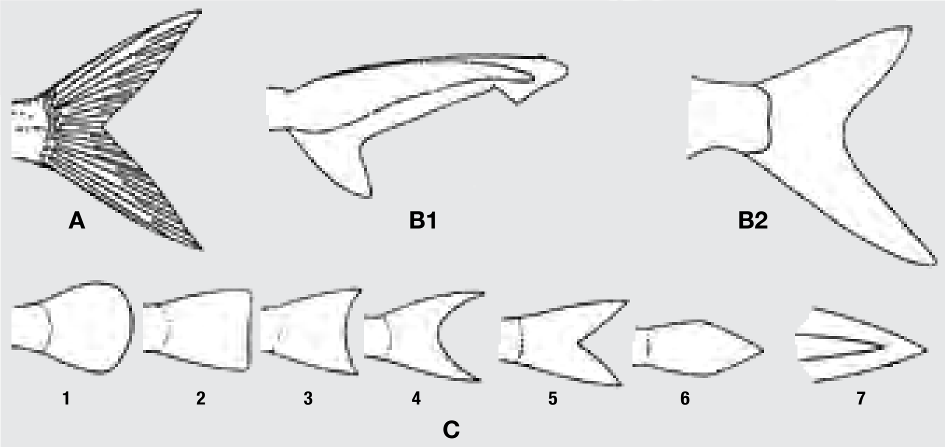

**Figure 163. Caudal fin.
Homocercal (A: *Citharinus* sp.). Heterocercal (B1: *Carcharhinus* sp.) and (B2: Amphiliidae). Caudal shapes (C): rounded (1), truncated or emarginated (2), concave (3), lunate (4), forked (5), pointed and separated from dorsal and anal fins (6), absent or coalesced with dorsal and anal fins (7).**

➢ Scales

Two principal types of scales can be distinguished by their structure (Figure 1644, p. 213). The first is ganoid scales, characteristic of Polypteridae, which are thick and rhombic and covered by a shiny outer layer of ganoine (A). The second group includes two different kinds: there are cycloids, which are thin and smooth (Clupeidae, Alestidae; B); and ctenoid, which have small spines on their posterior margin (Distichodontidae, Lutjanidae; C). In Tetraodontidae, the scales are modified into spicules (D), and in Syngnathidae they are modified into bony plates separated by areas of naked skin (sutures). Siluriformes lack scales altogether, except for certain Amphiliidae which have bony plates covering the body. Finally, Chondrichthyes have so-called placoid scales, which can be considered small teeth, also called dermal denticles, which give the skin of these fish a particularly rough surface (E). Some families have a midventral crest, which is formed by hardened scales that appear as shields (scutes), such as in Clupeidae (F).

Figure 164. Different types of scales. A: Ganoid; B: Cycloid; C: Ctenoid; D: Dermic sclerification in Tetraodontidae; E: Placoid (denticules).

➢ The lateral line (Figure 165 below)

Fish with scales have a longitudinal series of pores that frequently open at the level of the scales pentrating the lateral line. There are four types of lateral lines: complete, which have perforations on all lateral-line scales (Mormyridae and some Alestidae; A); interrupted, which have pored scales on two levels (Cichlidae, Anabantidae; B); incomplete, which only have anterior perforated scales (some Alestidae and Mugilidae; C), and absent (some Mugilidae and Nandidae).

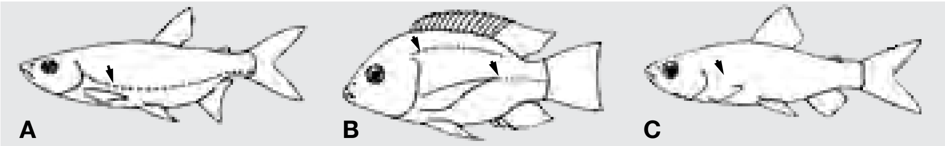

Figure 165. Lateral line. A: Complete; B: Interrupted on two levels; C: Incomplete.

➢ Electric organs (Figure 166, below)

Some families have electric organs, which vary in shape, power and function and are located in different parts of the body. The electric organs of the *Gymnarchus* species, as well as those of the Mormyridae family, produce rather weak charges; their main purpose is the detection of objects (electrolocation) and to allow individuals to recognize the species identity and sex of others (A and B). *Malapterurus* species are capable of much stronger charges, which are used for defense and attack (C).

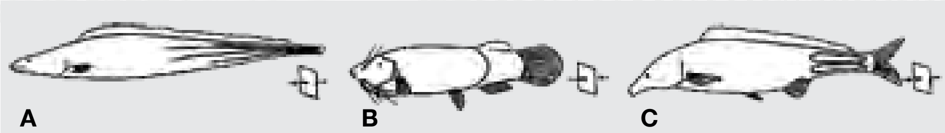

Figure 166. Location of electric organs. *Gymnarchus* (A); Mormyridae (B); *Malapterurus* (C).
The arrows indicate the direction and sense of the electric current inside the organs.
The plane is that of the electric plates.

✓ *Principal measurements and counts*

The following measurements are important for determining species and for monitoring fish in a pond. The measurements are presented in Figure 167, p. 215. The numbers in parentheses correspond to those indicated in the figures.

- **Total length, TL** (1): horizontal distance from the tip of the snout to the (hind) tip of the caudal fin.
- **Standard length, SL** (2): horizontal distance from the tip of the snout (front) to the base (or articulation) of the caudal fin.
- **Body height** (3): maximum vertical height of the fish, excluding fins.
- **Head length** (4): depending on the family, either the horizontal distance from the tip of the snout to the hind margin of the gill cover, or the horizontal distance from the tip of the snout to the hind tip of the occiput or to the bony rim of the notch formed by the scapular girdle behind the head.
- **Snout length** (5): horizontal distance from the front tip of the upper jaw to the anterior margin of the eye.
- **Eye diameter** (6): horizontal diameter of the eye.
- **Interorbital width**: minimum width between the eye sockets.
- **Predorsal length** (7): horizontal distance from the front tip of the snout to the articulation of the first dorsal-fin ray.
- **Preanal length** (8): horizontal distance from the front tip of the snout to the articulation of the first anal-fin ray.
- **Prepectoral length** (9): horizontal distance from the front tip of the snout to the articulation of the first pectoral-fin ray.
- **Prepelvic (preventral) length** (10): horizontal distance from the front tip of the snout to the articulation of the first pelvic (ventral) - fin ray.
- **Length of dorsal-fin base** (11): maximum horizontal distance measured between both ends.
- **Length of anal-fin base** (12): see dorsal-fin base.
- **Pectoral-fin length** (13): length from articulation of the first ray to the tip of the longest ray.
- **Pelvic (ventral)-fin length** (14): see pectoral-fin length.
- **Caudal-peduncle length** (15): horizontal distance from the hind margin of the anal fin (or from that of the dorsal fin if it extends further back than the anal fin) to the base of the caudal fin.
- **Depth of the caudal peduncle** (16): minimum vertical depth of the caudal peduncle (narrow part of the body where the tail is attached).

Another way to proceed is to count the following:

Fin formula: the number of spines or simple rays in Roman numerals and that of soft bifurcate (branched) rays, in Arabic numerals (example: III-7).

- **Number of scales in lateral line and/or in a longitudinal series.**
- **Number of scales in a transverse series.**
- **Number of predorsal scales.**
- **Number of scales around the caudal peduncle.**
- **Number of gill rakers on the first gill arch.**
- **Number of teeth in the outer and inner rows of the upper and lower jaws.**

⇨ **All these standard measurements help to determine which family, genus, and species farmed fish belong to.**

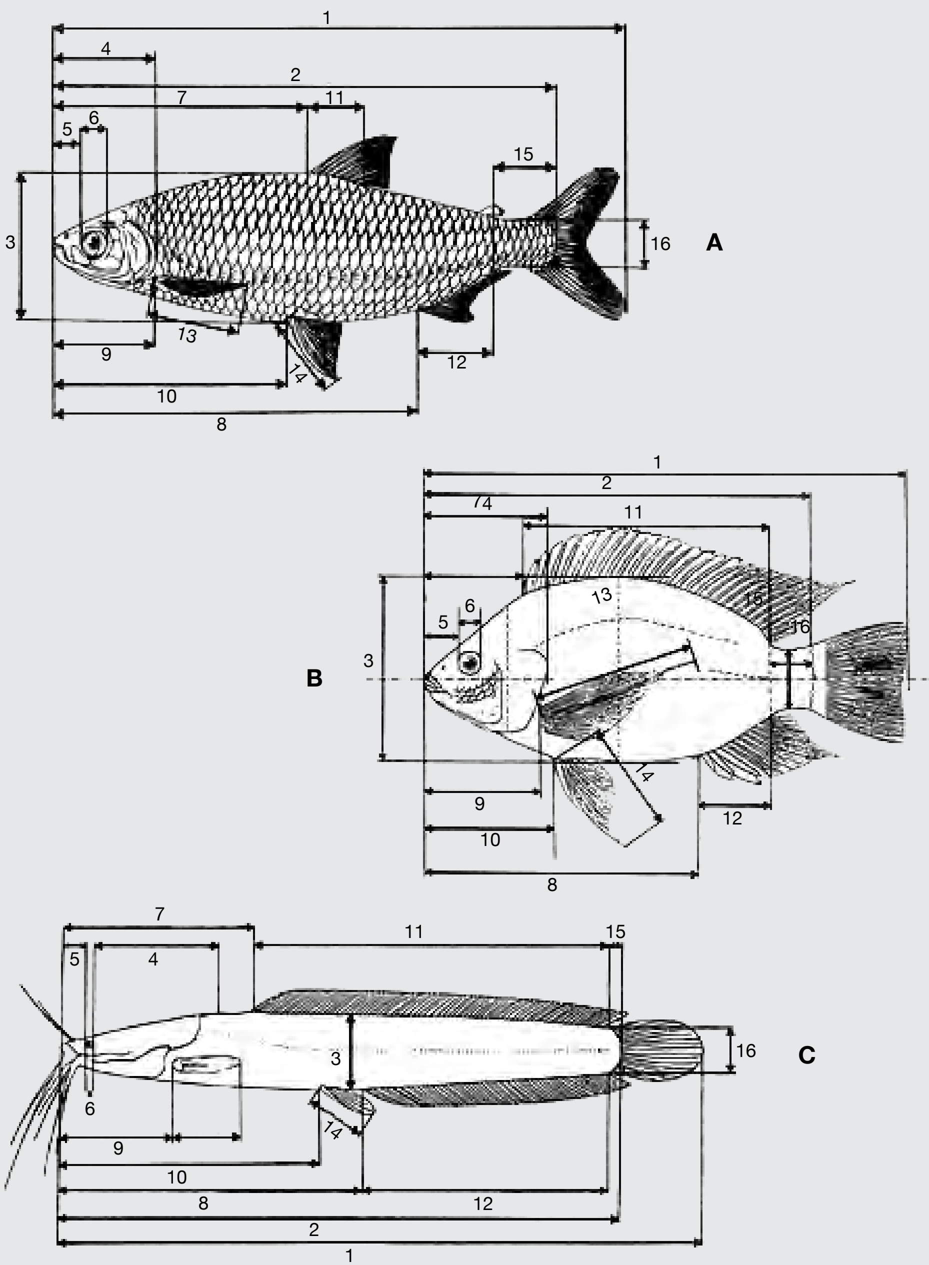

Figure 167. Principal measurements that may be taken on a fish. A: Characiform; B: Perciform; C: Siluriform. For an explanation of the numbers, please refer to the text.

II. CICHLIDAE BIOLOGY

This perciform freshwater family fish, which can also occasionally live in brackish water, is distributed predominantly across tropical areas of America and Africa, but also in Asia minor, tropical Asia, Madagascar and Sri Lanka. Cichlidae have a single nostril on either side of the head (Figure 168 below). Body shape is variable, but never very elongated. The fish is more or less compressed and covered with cycloid or ctenoid scales. It has all types of fins. The lower pharyngeal bones are fused together, forming a toothed triangle. The reader may find several files on Cichlidae species in Appendix 05, starting on p. 255.

The family is very widely distributed in Africa, where some species are very good for fish cultivation. Over a hundred genera have been described for that continent. As mentioned before (Chapter 03, paragraph II, p. 21), the main species used in African aquaculture come from three genera. Other predator species are used to control reproduction.

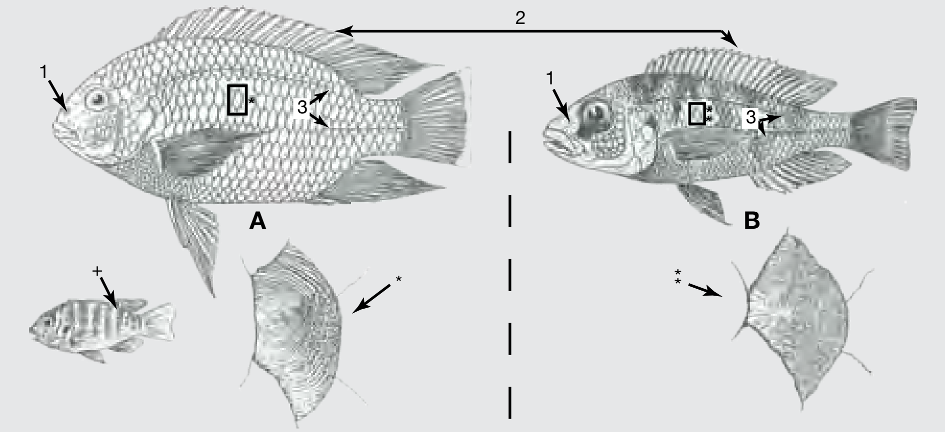

Figure 168. Cichlidae external features. A: *Tilapia zillii*; B: *Haplochromis* spp. Family characteristics: 1: A single pair of nostrils; 2: Dorsal fin in two continuous parts, spinous and soft rays; 3: Interrupted lateral line. Intra-family characteristics: + = Tilapiine mark well visible in juveniles; * = Cycloid scales; ** = Ctenoid scales.

II.1. TAXONOMY

We can generally separate Tilapiines from other African Cichlidae by the presence of the tilapiine mark on the dorsal fin, which is quite visible in juveniles, and by their cycloid scales (Figure 168 above).

Trewavas (1983) has subdivided *Tilapia sensu lato* into three main genera: *Sarotherodon*, *Oreochromis,* and *Tilapia sensu stricto*. Criteria of differentiation include the mode of reproduction. Other criteria may be used in conjuction with this.

✓ The genus *Tilapia* is comprised exclusively of species that attach their eggs to the substrate, unlike all others, which are mouth-breeders. Apart from this ethological characteristic, *Tilapia* species are differentiated from those of the other two genera by the following features: the lower pharyngeal bone is as long as it is broad, and has an anterior part that is shorter than the toothed part; its posterior pharyngeal teeth are bicuspid or tricuspid (sometimes quadricuspid) and the lower limb of its first gill arch has at most 17 gill rakers (as opposed to 28 for the other genera).

✓ Most species of *Oreochromis* have been described under the genus *Tilapia*. On the basis of ethological characteristics, Trewavas (1983) has included all species that practice mouthbreeding exclusively by females in this genus. Other features of the genus *Oreochromis* include the small size of the scales on its belly compared to those on its sides; the genital papilla, which is well-developed in both sexes, the shape of the lower pharyngeal bone (longer than it is broad or as long as it is broad, with its toothed part as long as, or somewhat longer, than its anterior part); and the posterior pharyngeal teeth, which are either bicuspid, have reduced lower cusps, or lack distinct cusps altogether.

✓ As in the genus *Oreochromis*, the majority of species now categorized under the genus *Sarotherodon* were originally categorized under the genus *Tilapia*. Based on ethological features, Trewavas (1983) has transferred to the genus *Sarotherodon* those species in which both males and females practice mouth breeding. Apart from this ethogical characteristic, the genus *Sarotherodon* has the following features: the scales on its belly are almost as large as those on its sides; its genital papilla are smaller in males than in females; its lower pharyngeal bone is longer than it is broad, its toothed part is shorter than its anterior part; its posterior pharyngeal teeth are either bicuspid, have a reduced lower cusp, or do not have distinct cusps.

II.2. FEEDING HABITS

Among the many examples of diets and their associated trophic adaptations, those observed for the Cichlidae of the African Great Lakes are the most remarkable. All types of food existing in these lakes have been consumed by these fish, which often exhibit morphological adaptations and specialized behaviors. For example, among fish that eat mollusks, some species are extractors and others are crushers. In the same way, fish that eat epilithic algae have different strategies; some graze the algae from rocks, while others cut it very short. Certain particular adaptations may also be noted, such as the existence of scale eaters and fish cleaners, which eat parasites off other fish.

Tilapia are, in general, microphagous and/or herbivorous (Table XLII, p. 217 below). However, the large majority of Cichlidae are opportunistic; that is, they can feed on a large variety of items. For example, *Oreochromis niloticus* is phytoplanktonophagous (it mainly eats phytoplankton), and it can also eat blue algae, zooplankton, and sediments rich in bacteria and diatoms, as well as artificial food.

Tilapia guineensis has an inferior mouth (located below the head). It is not a specialized herbivore, but will eat everything, especially grasses. *Sarotherodon melanotheron* is microphagous, planktivorous and benthophagous; that is, it eats mainly plankton and organisms that live at the bottom (benthos) of the lake.

Table XLII. Diets of several species of tilapia in natural waters.

Species	Phyto-plankton	Zooplan-kton	Algae	Macro-phytes	Periphy-ton	Detritus	Inverte-brates	Eggs and lavae of fish
O. aureus	X	X						
O. esculentus	X							
O. jipe					X			
O. leucostictus	X					X		
O mossambicus	X	X	X	X	X	X		X
O. niloticus	X							
O. pangani					X			
O. shiranus		X	X	X				
O. variabilis			X					
S. galileus	X							
S. melanotheron			X			X	X	
T. guineensis			X			X	X	
T. kottae	X					X	X	
T. mariae	X						X	
T. rendalli		X	X	X				
T. sparrmanii					X			
T. zillii				X			X	

II.3. REPRODUCTION AND PARENTAL CARE

Cichlidae have elaborate courtship rituals, which are connected to their parental care behaviors. The mode of care of juveniles is one of the criteria that differentiates the different tilapia genera. There are two principle breeding strategies for Cichlidae, which are enumerated below.

II.3.1. SUBSTRATE SPAWNING

Tilapia that practice this method of reproduction are categorized under the genus ***Tilapia***. Many of them are monogamous. Adhesive eggs are deposited on a hard surface. Depending on the species, this can be a hidden substrate (rock crevices, snail shells), or an open substrate (cups generally arranged on muddy sand or on loose muddy soil; Photo W, p. 219), then fertilized. The eggs are fertilized and hatch after a few days, during which both parents keep vigilant guard. When the larvae can swim freely, they remain in a group close to the substrate, monitored by their parents.

The yellowish eggs are attached to a support, a stone or piece of wood inside the nest of *Tilapia zillii*, as shown in Figure 169 below. The more cavities there are, the more fish are spawning. One of the parents stays constantly above the nest, to supervise the egg laying, and the alevins leave the nest when they reach 8 mm in length.

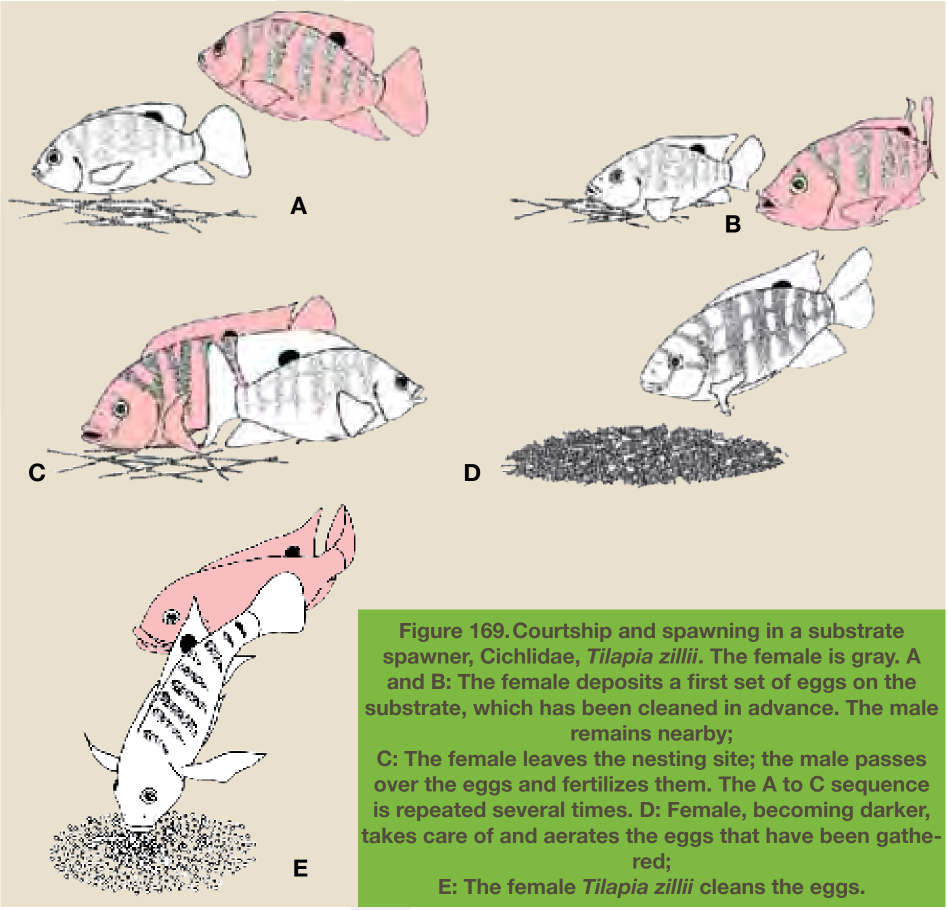

Figure 169. Courtship and spawning in a substrate spawner, Cichlidae, *Tilapia zillii*. The female is gray. A and B: The female deposits a first set of eggs on the substrate, which has been cleaned in advance. The male remains nearby;
C: The female leaves the nesting site; the male passes over the eggs and fertilizes them. The A to C sequence is repeated several times. D: Female, becoming darker, takes care of and aerates the eggs that have been gathered;
E: The female *Tilapia zillii* cleans the eggs.

II.3.2. MOUTHBROODING

Fish who use this method have larger, but less numerous, eggs than substrate spawners. Most of the time, the spawning is carried out over a substrate, often prepared by the male. However, some pelagic species can spawn in full water. In general, they are polygamous species. The males form a territory which the females visit. There are three main categories of oral incubation:

✓ **Maternal incubation** is the system used most frequently. Spawning takes place on the substrate, and the female takes the non-adhesive eggs, laid singly or in small groups, quickly into her mouth. The male deposits his sperm as the female is collecting the eggs or then fertilizes them in her mouth. Mouthbrooding continues until the juveniles are entirely independent. In certain cases, the female releases them periodically to feed and then takes them back into her mouth. This is done by all Haplochromines and the genus *Oreochromis*. Females can incubate eggs fertilized by several partners at the same time.

✓ **Paternal incubation** is only practiced by some species, such as *Sarotherodon melanotheron*.

✓ **Biparental incubation** is also rare among Cichlidae. Among the majority of chromidotilapines, both parents share care of the juveniles. There are also species where the female begins incubation and then the male takes over, such as Cichlidae gobies of Lake Tanganyika.

Among oral incubators, males often remain in the nesting area, at a shallow depth and on a movable substrate (gravel, sand, clay). Each male that shows a characteristic color pattern defines and defends a territory and arranges a nest, where it tries to attract and retain a fertile female. The size and shape of the nest vary depending on the species and even among populations within the same species (Figure 170 below). The arena of reproduction is a function of the social organization. Females, which live in bands near the reproduction area, only come to the area for brief stays. Going from one territory to another, they are courted by successive males until the moment when, stopping above the bowl of a nest, they form a transitory couple. After a synchronized sexual display (Figure 171, p. 220), the female deposits a batch of eggs. The male immediately fertilizes them by injecting its sperm on the eggs suspended in the water, and then the female returns and takes them into her mouth to incubate them. This very short operation can begin again, either with the same male, or with another male in a nearby territory. Haplochromines' anal fins have a spot that mimics an egg, which lures females. This is a system of successive polygyny and polyandry. Finally, the female moves away from the area where the males remain confined, carrying the fertilized eggs in her mouth, which she will incubate in sheltered zones.

Photo W. Nests of *Tilapia zillii* (Liberia) [© Y. Fermon].

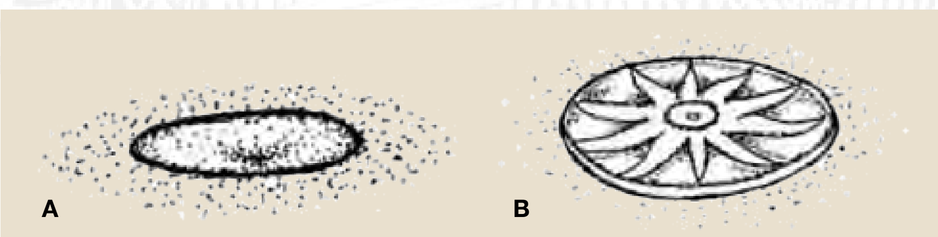

Figure 170. Nests of A: *Oreochromis niloticus*; B: *Oreochromis macrochir*.

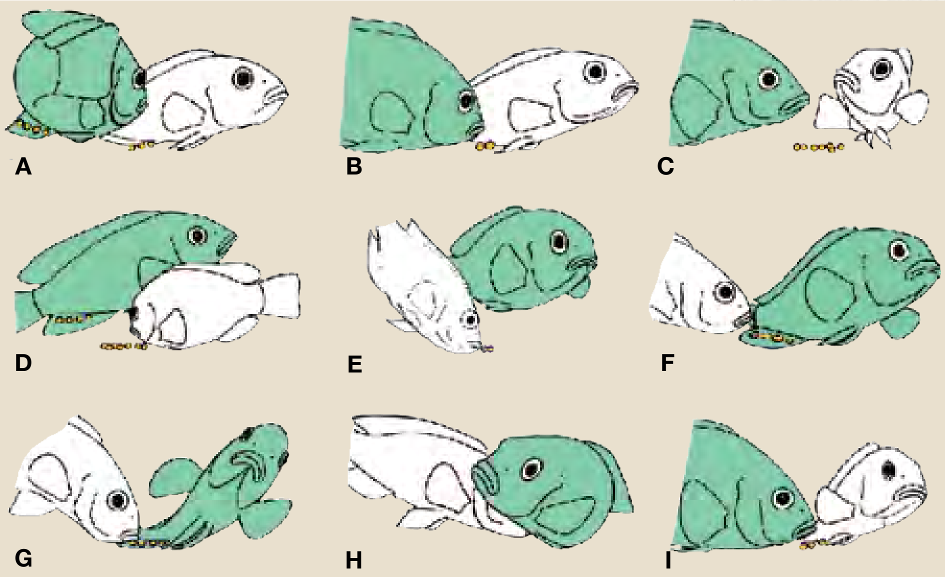

Figure 171. Courtship and spawning in the mouthbrooder Cichlidae, *Haplochromis burtoni* from Lake Tanganyika. The male is gray. A and B: The female lays eggs while the male remains close; C: After laying a few eggs, the female quickly turns; D: The female is preparing to collect the eggs before the male has had time to fertilize; E: Collection of eggs by female, F: The male spreads his anal fin to the female, showing the ocelli; G and H: The female has eggs in her mouth, trying to collect these ocelli and closer to the orifice of the male genital ejaculates at the time; I: The female begins to lay a new string of eggs. This entire sequence is repeated several times.

Hatching occurs in the female's mouth, 4 to 5 days after fertilization. The vitelline vesicle is completely resolved at 11 to 12 days of age (Figure 174, p. 222). The length of this phase depends mainly on the temperature. As soon as the vitelline vesicle is resolved and the alevins are able to take exogenic food, the female lets a cloud of juveniles escape from her mouth. They orient themselves around the mother, taking refuge in her mouth at the least sign of danger, taking cues from her movements (Figure 172, p. 220).

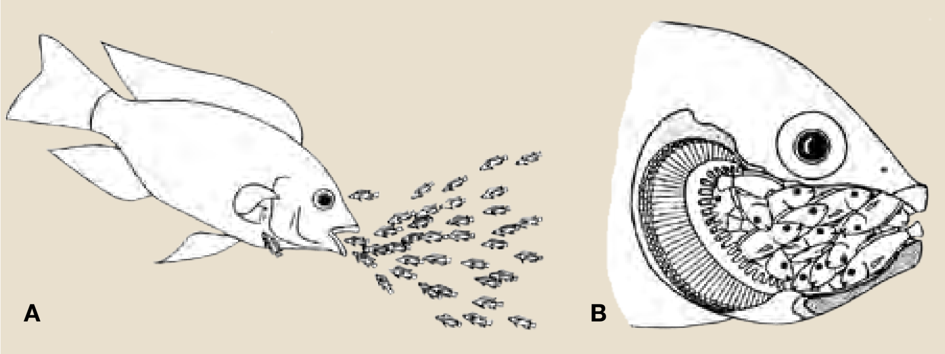

Figure 172. Mouthbrooding. A: Juveniles return to their mother's mouth when there is any danger. B: Juveniles in their mother's mouth.

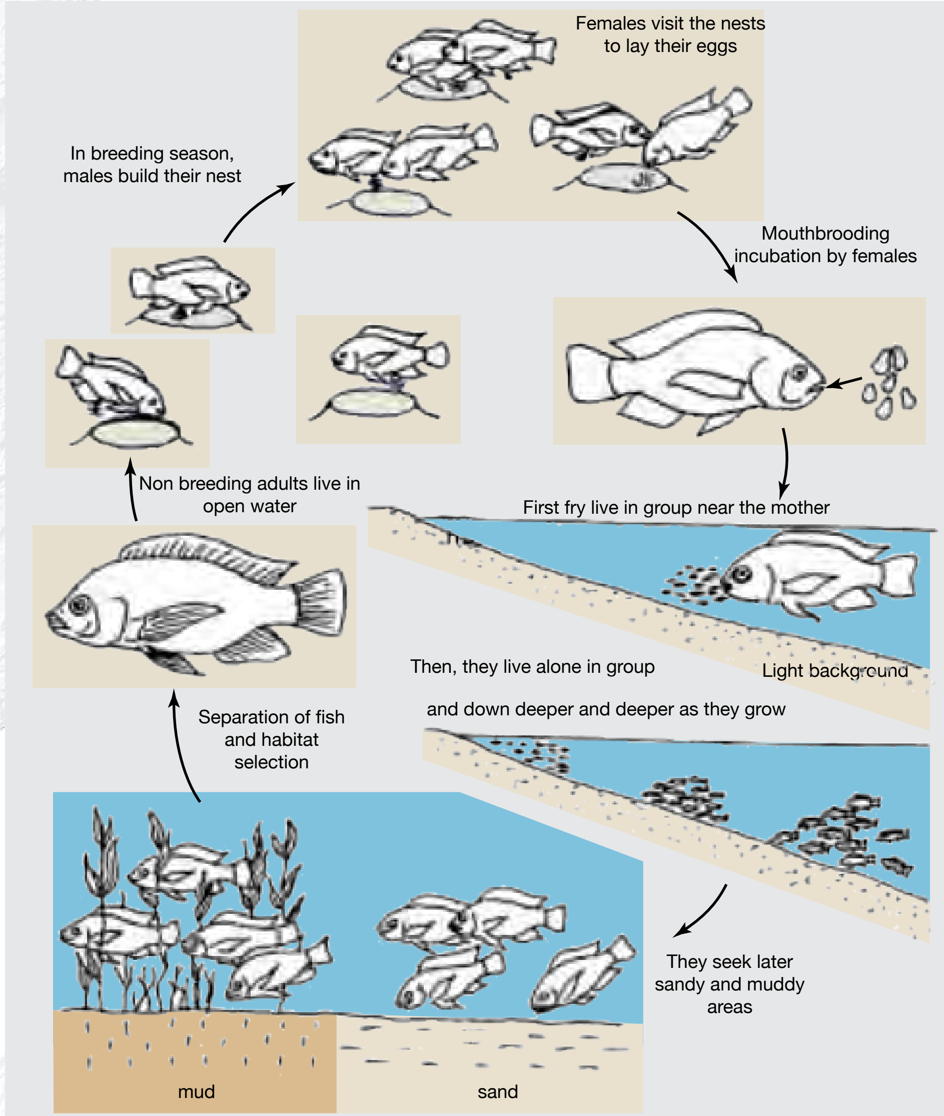

Figure 173. Example of the life cycle of a maternal mouthbrooding tilapia.

When the alevins reach a size of 9–10 mm, they are completely freed from their mother. She releases them in water that is not very deep, at the water's edge, where they organize into a group and continue to grow. The entire cycle is summarized in Figure 173, above.

A female in good condition can reproduce at intervals from 30 to 40 days at a temperature of 25 to 28°C. The same female can produce 7 to 8 spawn per year, but most females in a group rarely reproduce so frequently.

The number of eggs and alevins that a female can hold in its mouth varies depending on the size and species. The record is undoubtedly held by *Oreochromis mossambicus,* which has reached the size of 35 cm and can hold 4,000 eggs.

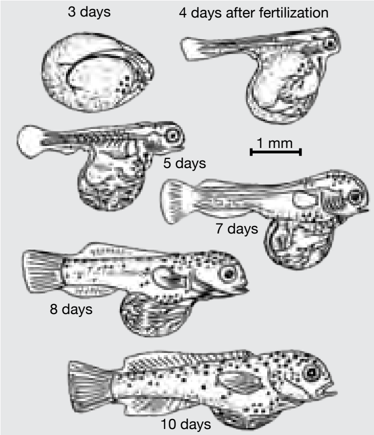

Figure 174. Stages of mouthbrooders.

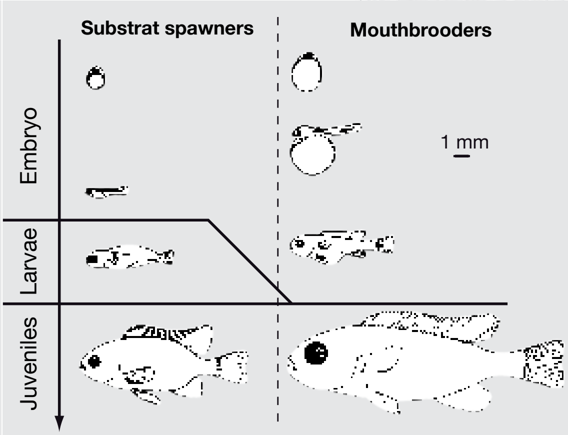

Figure 175. Comparison between juveniles of substrate spawners and mouthbrooders.

For *Sarotherodon melanotheron*, the eggs, which are an ocher yellow color and slightly pear shaped, reach 3 mm in diameter. They are incubated by the male. When they hatch, the alevins are 5 mm long, and they are 9 mm long when the vitelline vesicle is reabsorbed.

II.3.3.GROWTH

The mode of reproduction and parental care has an influence on embryos' size and development. In general, because of physical constraints, mouthbrooders'oral cavities can accommodate only a limited number of eggs (Figure 175 above).

Maximum size and size at sexual maturation vary, depending on the species. Fish in the Great Lakes reach a longer length before they mature and grow to a larger size than those in lagoons, ponds or rivers (Table XLIII, p. 223, Figure 176 and Figure 177, p. 224). In lakes, size at maturation and maximum length for males and females are the same. On the other hand, in small overpopulated areas or stretches of water, males grow more quickly than females, which are smaller at maturation than are males. This sexual dimorphism in growth is connected to the mode of parental care. As soon as individuals reach the age of maturity (1 to 3 years, depending on sex and area), male individuals grow noticeably faster than females and reach a distinctly larger size. This makes sense, since the males must establish a territory of reproduction and defend it. For substrate spawners, this difference is less important. For mouthbrooders, the male generally becomes more dominant as it gets bigger. Each time a new male is introduced into the area, all the males establish a hierarchy and preserve it until a new intruder arrives. What makes one dominant over the others? The dominant male claims the best-placed territory and guards it fiercely, attacking any male passing near the vicinity and courting the females. Thus, it will invest energy in the defense of its territory at the expense of its growth, compared to other males. However, all males will grow larger than the females.

Fish in poor environmental conditions mature at a smaller size than those that are in good conditions. If individuals are in a reproductive state all year, they still experience peaks of reproduction that coincide with the two rainy seasons in equatorial regions or with the single rainy season at other latitudes. Moreover, the growth of *Oreochromis niloticus* is extremely variable from one area to another, which suggests that the **maximum size is more dependent on environmental conditions than on possible genetic differences**. For example, in Lake Chad in Uganda, *O. niloticus* reaches 30 cm after 3 years, whereas in Lake Mariout in Egypt, it needs 5 years to reach the same size. Note that, in the same area, *O. niloticus* generally grows larger than other species of tilapia over a long time (Figure 178 and Figure 179, p. 225). **It reaches 300 to 500 g in 8 months, while *O. leucostictus* reaches 300 g and *Tilapia zillii* reaches 250 to 400 g. It grows a maximum of 3 g/day under optimal conditions.**

Table XLIII. Size at sexual maturation, maximum size and longevity of different species of tilapia.

Species	Location	Typical / Dwarf	Size at maturation (mm)	Maximum size (mm)	Longevity (years)
Alcolapia grahami	Lake Magadi	D	25	100	
Oreochromis aureus	Lake Kinneret	T	190	315	5
Oreochromis esculentus	Lake Victoria	T	230	375	10
	Lake Victoria, Kavirondo Gulf	T	230	330	7
	Lake Victoria, Jinja	T	225	340	7
	Lake Victoria, Mwanza	T	240	325	7
	Aquarium	D	105		
	Pond	D	164		
Oreochromis leucostictus	Lake Naivasha	T	180	250	
	Lake Edward	T	210	240	
	Lake George	T	140	280	
	Lake Albert	T	260	280	
	Lagon, Lake Albert	D	100		
	Pond in Uganda	D	120		
	Pond in Kenya	D	70		
Oreochromis lidole	Lake Malawi	T	285	390	5
Oreochromis mortimeri	Lake Kariba	T	300	390	8
	Lower Malolo	T	180		
	Upper Malolo	D	90		
Oreochromis mossambicus	Egypt	T		300	7
	Lake Sibaya	D	100		
	South Africa	T		390	11
	Aquarium	D	45		
Oreochromis niloticus	Egypt	T	200	330	9
	Lake George	T		400	
	Lake Rudolf	T	390	640	
	Crater, Lake Rudolf	D	250		
	Lake Edward	T	170		
	Lake Baringo	T	260	360	
	Lake Albert	T	280	500	
	Lagon, Lake Albert	D	100		
Oreochromis rukwaensis	Lake Rukwa	D	280		
Oreochromis saka	Lake Malawi	T	275	340	5
Oreochromis shiranus shiranus	Lake Malawi	T	220	290	5
Oreochromis shiranus chilwae	Lake Chilwa	T	200	290	5
Oreochromis squamipinnis	Lake Malawi	T	240	330	5
Oreochromis variabilis	Lake Victoria	T	220	300	7
Sarotherodon galileus	Lake Kinneret	T	220	345	7
	River Sokoto	D	110		
Tilapia mariae	Nigeria, River Osse	T	165	300	
	River Jamieson	D	100		
	Lake Kariba	T		450	5
Tilapia zillii	Lake Kinneret	T	135	270	7
	Pond in Egypt	T	130	250	
	Lake Naivasha	D	90		
	Aquarium	D	70		

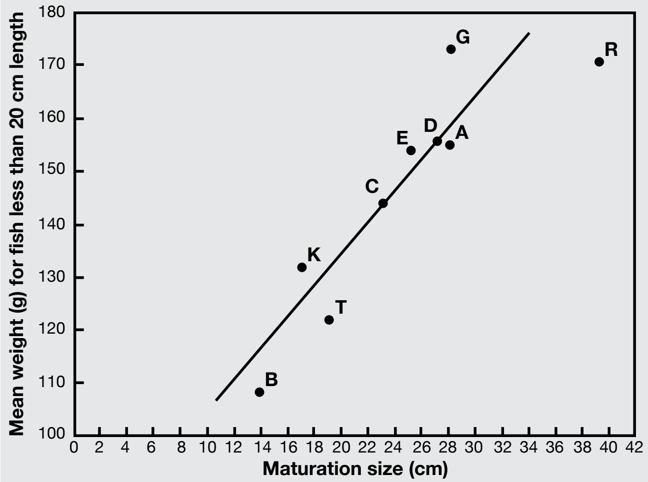

Figure 176. Relationship between the weight of a fish at 20 cm and the size at which it matures for *Oreochromis niloticus* in several geographic locations. R: Lake Turkana; A: Lake Albert; G: Lake George; E: Lake Edward; D: Lake Katinda; C: Lake Chanagwora; K: Lake Kijanebalola; T: Lagoon Tonya of lake Albert; B: Lagoon Buhuku of Lake Albert.

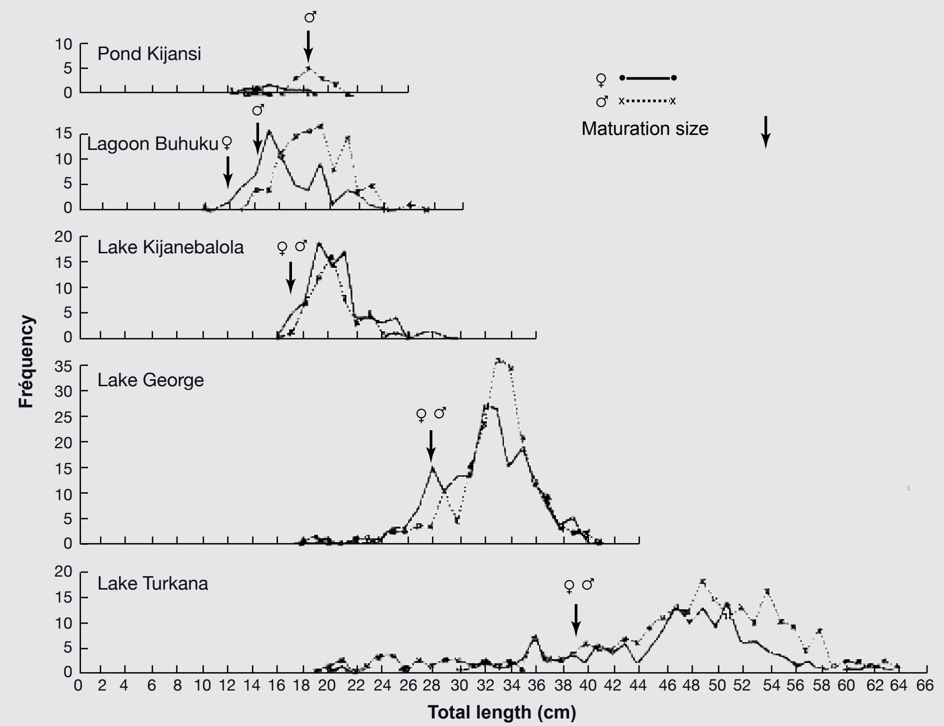

Figure 177. Size class of *Oreochromis niloticus* in several geographic locations.

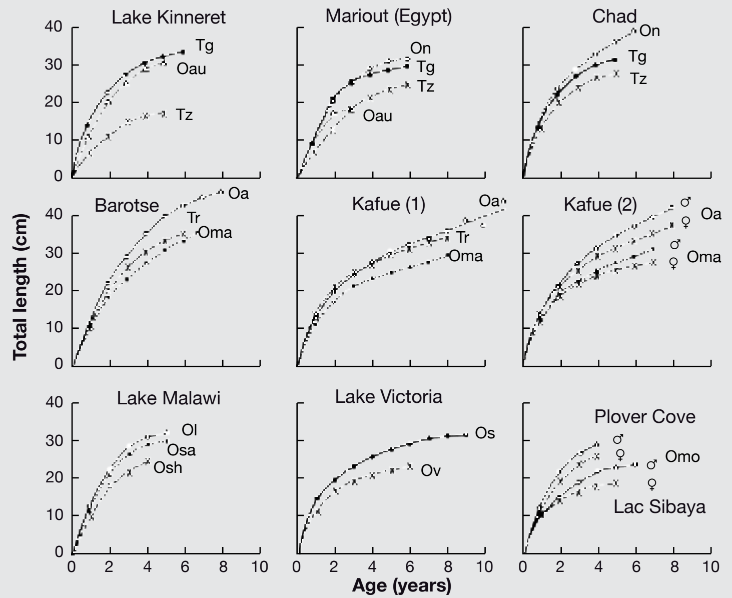

Figure 178. Comparison of growth rates for different species in natural fields by locality. Oa: *Oreochromis andersonii*; Oau: *O. aureus*; Oe: *O. esculentus*; Ol: *O. lidole*; Oma: *O. macrochir*; Omo: *O. mossambicus*; On: *O. niloticus*; Osa: *O. saka*; Osh: *O. shiranus*; Ov: *O. variabilis*; Sg: *Sarotherodon galileus*; Tr: *Tilapia rendalli*; Tz: *T. zillii.*

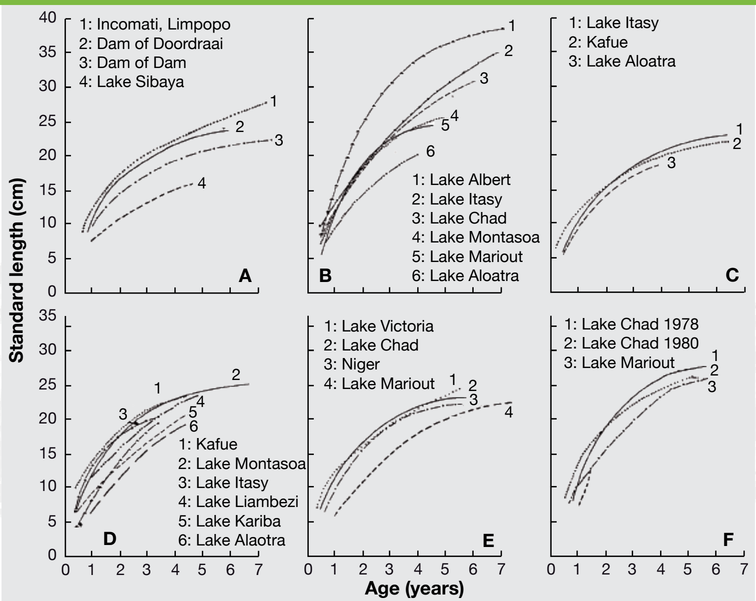

Figure 179. Comparison of growth rates for different species in natural fields by species. A: *Oreochromis mossambicus*; B: *O. niloticus*; C: *O. macrochir*; D: *Tilapia rendalli*; E: *T. zillii*; F: *Sarotherodon galileus*.

There are other fish-eating species of Cichlidae, which are used in polyculture to control the tilapia population.

⇨ The group of “green” *Hemichromis* is a complex of species with two major species: *H. elongatus* and *H. fasciatus*. The other species of the genus belongs to the group of *Hemichromis* “red”, which were also tested, unsuccessfully, since they are omnivorous rather than piscivorous.

⇨ Fish of the genus *Serranochromis,* which are the large predatory fish of Southern and Eastern Africa.

- **Tilapia are:**
  - **Robust fish,**
  - **Highly plastic and adaptive to environmental conditions,**
  - **Practitioners of elaborate parental care,**
  - **Opportunistic in terms of diet.**

III. SILURIFORM OR CATFISH BIOLOGY

Better known as catfish, Siluriformes (or, more precisely, Siluroidei) are important to fish farming. Their worldwide production capacity (more than 300,000 tons/year) is currently ranked fourth among freshwater cultivated species, after carp and other Cyprinidae, Salmonidae and Tilapia. With their great diversity of forms and biological characteristics, Siluriformes, which include more than 2500 identified species, can contribute to the development of aquatic resources through diversified systems of production. If the farming production of some species of Siluriformes is already at an economically significant level today, the aquaculture potential offered by the biological diversity of this group is still largely untapped and requires further research. In Africa, only a few species have been used, mainly from the family of Clariidae. However, knowledge of the biology of the majority of these species remains limited. But, several can serve as supplemental species, and/or can control fish populations while increasing the total weight of fish produced in ponds.

III.1. CLARIIDAE

The biology of Clariidae African, which is used in fish farming, has not been studied extensively, and the data remain scarce.

III.1.1.TAXONOMY

Clariidae are distinguished from other Siluriformes by the absence of a dorsal-fin spine, and by a very long dorsal and anal fins, an eel-shaped body, four pairs of barbels, and a suprabranchial organ, which is formed by outgrowths of the second and fourth gill arches and allows these fish to practice **aerial respiration**.

Several species, particularly those in the genera *Clarias* and *Heterobranchus*, play an important role in fisheries and fish farming. Information on two species is presented in Appendix 05, p. 272.

The genus *Clarias* is characterized by **a single, long dorsal fin** that extends to the base of the caudal fin. It has no adipose fin (except for one species, which has a reduced adipose fin). its vertical fins are not confluent, and its body is more or less elongated. Its head is flattened. The lateral cephalic bones are contiguous. The fish’s eyes, placed laterally, are small. More than 35 species of *Clarias* have been identified in Africa.

The genus *Heterobranchus* has **a large adipose fin,** supported by elongated neural spines, located between the rayed dorsal and caudal fins. The fish’s head is flattened, its lateral cephalic bones are contiguous, and its eyes, which are also laterally positioned, are small. There are only 5 known species.

III.1.2. FEEDING HABITS

Few studies have focused on the nutritional needs of Clariidae, particularly for *Clarias gariepinus* and, to a lesser extent, *Heterobranchus longifilis*, in its natural environment. The few studies that have been carried out show that the two species' general needs are similar.

Clarias gariepinus are omnivorous bottom feeders. They eat insects, crabs, plankton, snails and fish as well as young birds, dead bodies, plants and fruits. This diet varies depending on the size of the fish.

According to current knowledge, other Clariidae are all, omnivores. However, several species tend to feed mainly on fish.

For *Heterobranchus longifilis*, alevins' first meal occurs at 2 days of age, even though the vitelline vesicle has not yet been entirely reabsorbed. At this stage, the width of the alevins' mouth has grown to approximately 1 mm, and they are already able to eat large planktonique prey. The diet is primarily zooplanktonophagous until the alevins are 5-6 days old, after which it tends to diversify gradually, incorporating increasingly large insects, mainly larvae of chironomids. Stomach contents for alevins at this stage have also included shells of gastropods, organic detritus, plant remains, and seeds, showing that the diet is evolving into that of the adult omnivore with carnivorous tendencies. Alevins eat continuously day and night, and their is no specific rhythm to their feeding habits.

Clariidae are primarily nocturnal (night-active) fish.

III.1.3. REPRODUCTION

When they first mature, *Clarias gariepinus* females are from 40 to 45 cm long and males are between 35 and 40 cm. The eggs are greenish. Incubation lasts approximately 33 hours at 25°C.

Among oviparous animals, reproduction occurs during the rainy season (Figure 180 below). Fish migrate laterally to flooded plains to reproduce, then return to lakes or major riverbeds.

In the majority of African countries, the catfish's reproduction cycle starts at the beginning of the rainy season. The final stimulus for spawning seems to be associated with rising water and flooding in marginal zones. During spawning, large groups of male and female adult catfish congregate in the

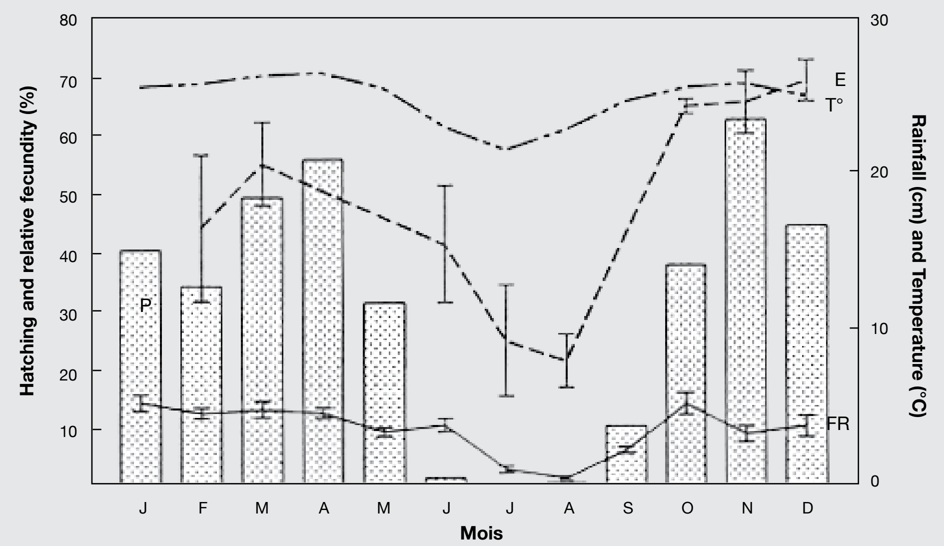

Figure 180. Relative fertility (% of total weight), % of *Clarias gariepinus* eggs that hatch at *specific* monthly average rainfalls and average temperatures. Brazzaville.

same place at the edges of lakes or in calm water, often at a depth of more than 10 cm. In captivity, the African catfish spawns on a large variety of substrates, including sisal fibers, palm leaves, and stones.

During courtship, which can last several hours, the female catfish deposits its eggs in small groups. Before courtship, the males fight. Couples are isolated. The male wraps itself in a U-shape around the female's head. When the eggs and sperm are released the female scatters the eggs over a large surface by moving its tail. The couple rests for several minutes after spawning (Figure 181, below). The partner fertilizes each group of eggs at the same time by releasing a cloud of milt above them. The eggs adhere finally to submerged vegetation. In captivity, many eggs are destroyed by violent blows of the tail. After spawning, the catfishes return to deeper water. The parents do not protect the eggs. After a few weeks, catfish produce another group of eggs and prepare to spawn again.

This second spawning is triggered by rains or a new flood. Thus, several successive spawnings can occur in the same year. The eggs hatch after 24 to 36 hours, depending on the water temperature. The larvae, known at this stage as vesicled larvae, hide in nearby vegetation. The fry and

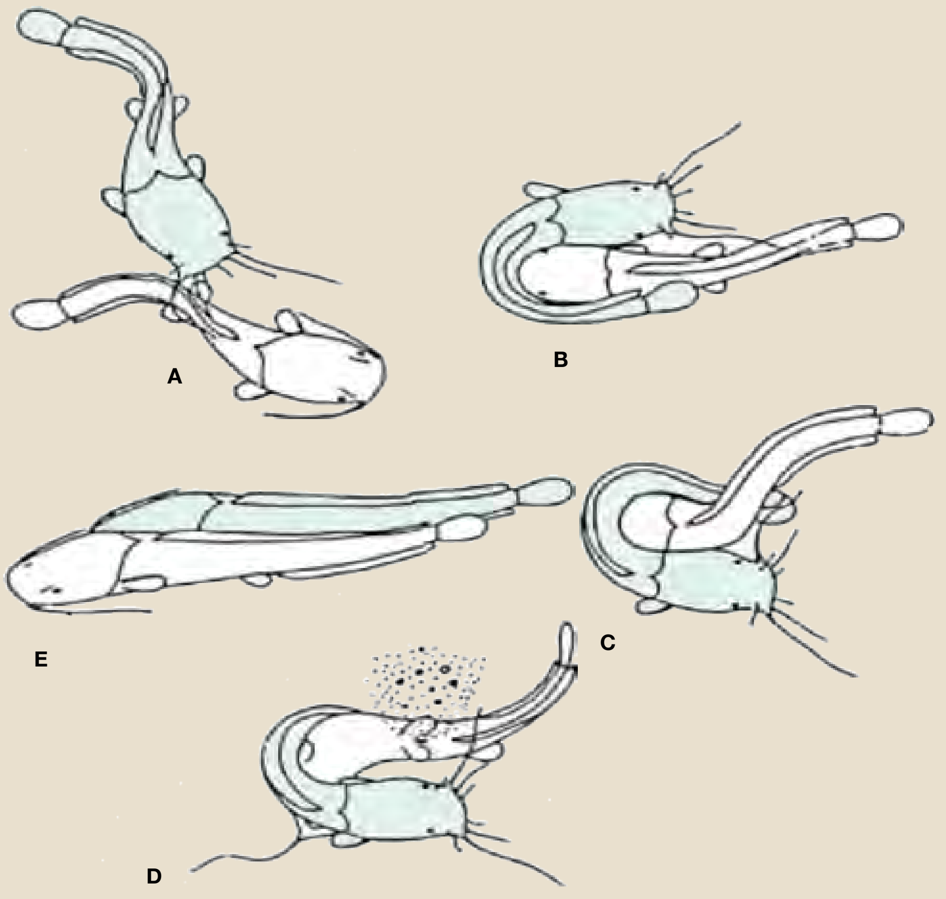

Figure 181. Courtship in *Clarias gariepinus*. A: The male (in gray) approaches the female; B and C: The male wraps itself around the head of the female and holds it firmly; D: Sperm and egg cells are released into the environment and the female scatters them by moving her tail; E: The couple rests.

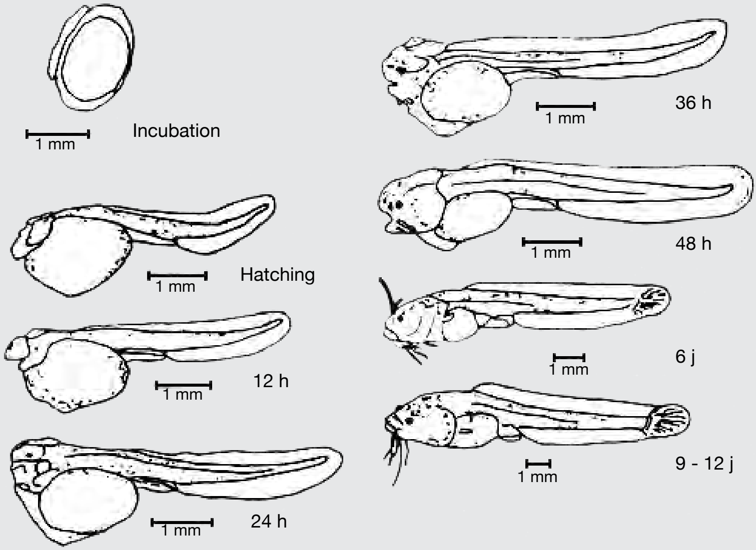

Figure 182. First stages of development for *Clarias gariepinus*.

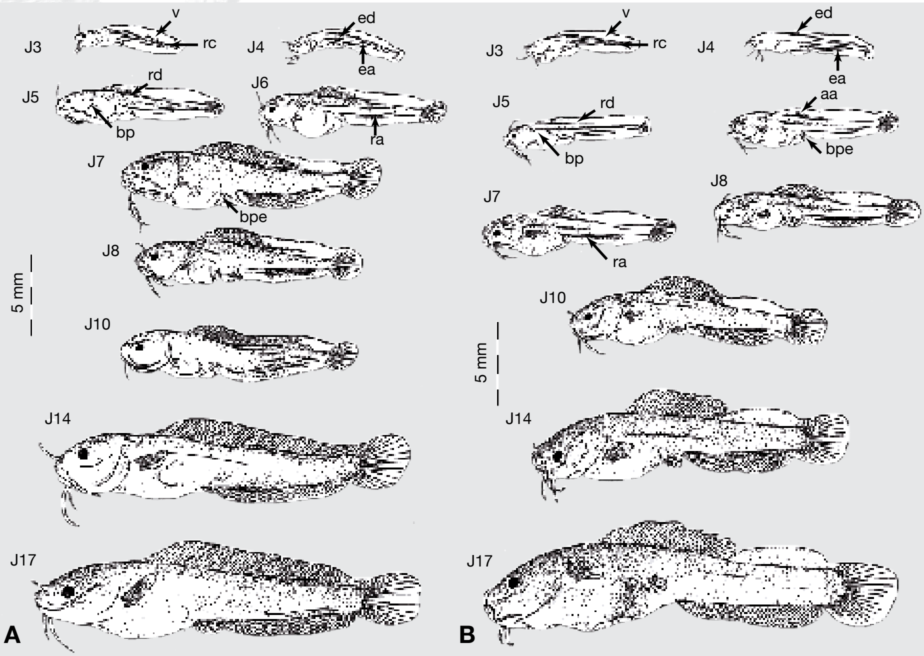

Figure 183. Stages of larval development, up to 17 days.
A: *Clarias gariepinus*; B: *Heterobranchus longifilis*.
aa: adipose fin begins; bp: burgeoning of the pectoral; bpe: burgeoning of the pelvic; ea: beginning of the anal rays; ed: beginning of the dorsal rays; ra: anal rays; rc: caudal rays; rd: dorsal rays; v: vesicles.

fingerlings of African catfish are difficult to find in nature, probably because eggs and larvae suffer such high mortality.

Parents do not provide care, except for the choice of spawning site. Eggs and larvae develop quickly, and the fingerlings are free 48 to 72 hours after fertilization (Figure 182 and Figure 183, p. 229). Fingerlings remain in flooded zones and migrate after they grow to a length of 1.5 to 2.5 cm.

The eggs of *Heterobranchus longifilis* have a broad adhesive disc. They incubate in dark, stagnant water, at a temperature range between 27 and 29°. Hatching occurs 24 to 28 hours after fertilization.

III.1.4. GROWTH

Growth rates in studies on large *Clarias* and *Heterobranchus* have been very promising, showing almost linear growth after the age of one year (Figure 184 below).

In tests in freshwater ponds, *Heterobranchus longifilis* reached, on average, 900 g in 6 months, starting from an average weight of 25 g. When they were between 100 and 500 g, the rate of growth exceeded 5 g/day.

***Clarias gariepinus* reached 500 to 1000 g in 8 months.**

III.2. CLAROTEIDAE AND AUCHENOGLANIDIDAE

These catfish are characterized by the presence of two to four pairs of barbels, well developed pectoral spines, a moderately or well-developed adipose fin, and a medium-sized anal fin. The mouth is supported dorsally by the premaxilla and part of the maxilla.

Other species of catfish can be used in fish farming, including those of the genus *Chrysichthys* and the species *Auchenoglanis occidentalis* (Photo X, p. 232). These genera were once categorized in the same family, but they have now been split into two distinct families.

III.2.1. GENUS CHRYSICHTHYS

The *Chrysichthys genus, in* the Claroteidae family, is characterized by the presence of four barbels; 6 (or, sometimes, 5 or 7) branched dorsal-fin rays preceded by a very short first spine and a well developed second spine, with slight denticulatation along the posterior margin; a small or medium-sized, non-ossified, adipose fin (with a base shorter than the width of its head); pectoral fins with 8 to

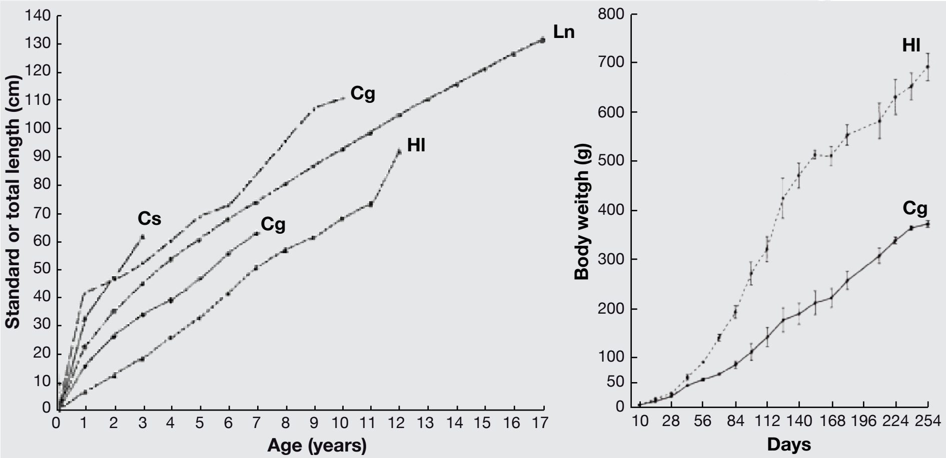

Figure 184. Comparison of growth rates for several African fish species.
A: According to size; B: According to weight.
Cs: *Clarias senegalensis*; Cg: *Clarias gariepinus*; Hl: *Heterobranchus longifilis*;
Ln: *Lates niloticus*.

11 branched rays preceded by a strong spine with distinct denticulation along the posterior margin; pelvic fins inserted at about the mid-length of the body, with 1 spine and 5 soft rays; a medium-sized anal fin with 3 to 6 spinous and 6 to 12 branched rays; and a deeply forked caudal fin. Its eyes are large and positioned laterally. The body is moderately elongate, 4 to 6 times longer than it is deep.

Chrysichthys, which is better known in francophone countries as the "mâchoiron," is generally well appreciated in Côte d'Ivoire and West Africa. The many traditional receipes for "mâchoiron" in local restaurants (maquis) illustrate local attachment to the festive character of this fish. Moreover, the biggest sales take place the day before the great festivals. The term "mâchoiron" is actually used for three species in the *Chrysichthys genus*: *C. maurus*, *C. nigrodigitatus* and *C. auratus*. It is not always easy to distinguish between *Chrysichthys maurus* and *C. auratus;* interspecific morphological differences can be tiny among individuals of comparable size, while intraspecific variability can be very large, particularlly during different seasons. On the other hand, it is easy to distinguish between these two species and *C. nigrodigitatus. C. nigrodigitatus is* larger and has a silver gray coloring, whereas *C. maurus* and *C. auratus are yellowish*.

At the adult stage, "mâchoirons," which are benthic fish, feed mainly on organic detritus and invertebrates: insect larvae (chironomids, dipters), planktonic crustaceans, and mollusks. On the other hand, fingerlings seem to feed primarily on zooplankton until they grow to 15 cm. *Chrysichthys* are a robust species, resilient to handling and able to temporarily tolerate low oxygen levels.

■ CHRYSICHTHYS MAURUS

In the wild, *C. maurus* grows relatively slowly, to approximately 12 cm (25 g, more or less) in one year. When it is bred in a pond at a density of 3 fish per m2 and fed with artificial food comprised of 33% proteins, *C. maurus* can grow from 11 g to 200 g in 12 months.

C. maurus can begin reproducing at 10 months of age. In the rivers of Côte d'Ivoire, mature individuals measure from 9 to 11 cm.

In the wild, *C. maurus* reproduces seasonally. Small diameter ovocytes (100 - 150 µm) can be observed when the great rainy season begins (around April or May). The arrival of continental freshwater and falling water temperatures (to 26 - 29°C) seem to influence the timing of the beginning of this species' reproductive process. Spawning activity begins in June and lasts until November or December. During the dry season, which begins in January, reproducing couples are rare. This species seeks crevices (rocks, deadwood, bamboo, etc.) in which to mate and deposit eggs. Parents generally remain in the nest with alevins until the vitelline vesicle is reabsorbed. Sexual dimorphism is very marked: the mature male has a broader head and the female has a plump abdomen and bulging urogenital papilla. Relative fertility is about 15 to 20 ovocytes per gram of a female's weight. Each female produces one clutch each year.

■ CHRYSICHTHYS AURATUS

The biology of *C. auratus* seems very similar to that of *C. maurus,* except it does not grow as large. Thus, this species is suitable for fish farming.

■ CHRYSICHTHYS NIGRODIGITATUS

In the wild, *C. nigrodigitatus* can grow to 18 cm (fork length) in one year, 24 cm in two years and 30 cm in three years. In studies where this fish was raised in a pond, it took eleven months to grow from 15 g (11 cm) to 250 g (26 cm). In the wild, *C. nigrodigitatus* generally can begin reproducing when it reaches 33 cm (3 years old), and its behavior is similar to that of *C. maurus* (the reproducing pair searches for a receptacle where they can spawn). The relative fertility of this species is similar to that of *C. maurus*. its mean value is 15 ovocytes per gram of a female's weight, with extreme values of 6 and 24.

Hatching occurs 4 to 5 days after spawning, when the water temperature is 29–30°C. Larvae are from 25 to 30 mg, and equipped with a large vitelline bag that is gradually reabsorbed over ten days. The fish reach 350–400 g in 8 to 10 months.

Adult females experience progressive and synchronous development of the gonads, and the reproductive season is well defined. Spawning begins at the end of August, with a maximum frequency (more than 50%) between September and October. Frequency decreases around the end of November and spawning is completed in December. However, it should be noted that although the majority of spawning occurs regularly between September and November, the annual maximum shifts appreciably from year to year.

III.2.2. GENUS AUCHENOGLANIS

The genus *Auchenoglanis*, which is in the family Auchenoglanididae, is characterized by a slightly elongated body, three pairs of barbels (one maxillary and two mandibular) and an anterior nostril on the upper lip. A dorsal fin with 7 branched rays is preceded by 2 spines, the first small, the second strong and denticulated. The adipose fin begins just behind the dorsal fin, pectoral fins with 9 branched rays are preceded by a strong spine. Pelvic fins are well developed, with 6 rays, 5 of them branched. The anal fin is medium-sized, with 6 to 8 branched rays. The caudal fin is emarginated, meaning that it has a shallow notch at the tip).

This species has been tested in Côte d'Ivoire at Bouaké. Growth rates were quite low and the test was not renewed.

III.3.SCHILBEIDAE

The Schilbeidae (a catfish family found in Africa and Asia), sometimes spelled «Schilbeidae»

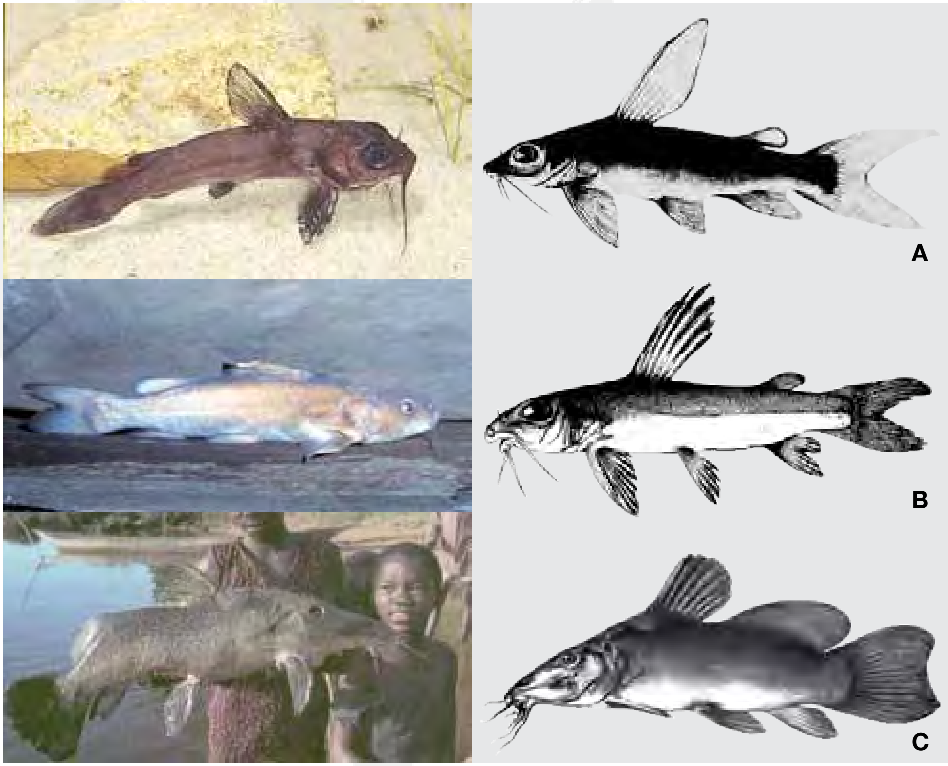

Photo X. Claroteidae. A: *Chrysichthys nigrodigitatus* [© Planet Catfish];
B: *C. maurus* [© Teigler - Fishbase];
Auchenoglanididae. C: *Auchenoglanis occidentalis* [© Planet Catfish].

have a dorsoventrally flattened head, a rather short abdomen, a laterally compressed caudal region, and an elongated anal fin (Photo Y, below). The dorsal fin is short, and sometimes absent. Pectoral fins have a spine (like the dorsal fin of most species). Three or four (depending on the species) pairs of barbels are found around the mouth. Schilbeidae are moderately good swimmers with laterally compressed bodies, as opposed to the majority of bottom-living siluriform fishes which are anguilliform or dorso-ventrally flattened. Five genera have been identified in Africa so far: *Parailia, Siluranodon, Irvineia, Schilbe* and *Pareutropius*. The first three genera are small and have little economic value. However, some species of the *Irvineia* and *Schilbe genera* may grow very large (50 cm or more), and are very popular table fish.

For *Schilbe mandibularis*, size at first sexual maturity varies for both sexes, depending on where they are in the river (upstream, downstream, or in a lake). Males are slightly smaller than females (12.3 cm compared with 14.8 upstream and 14.8 compared with 18.1 cm downstream). Relative data for the evolution of sexual maturity and the gonado-somatic ratio reveal a distinctly seasonal reproductive cycle. The species reproduces during the rainy season, from April to June, then from August to October. Reproductive activity peaks from April to June, corresponding to the peak of pluviometry. Sexual rest occurs during the dry season, from December to March. Average relative fertility reaches 163,600 ovocytes per kg of body weight, with a minimum of 15,308 ovocytes and a maximum of 584,593. The diameter of the ovocyte at spawning is approximately 1 mm. The lake environment has a negative effect on some biological reproductive indicators (including size at first sexual maturity, sex ratio, average body weight and fertility). This could be due to the strong pressures on fish in that environment.

Fish in the *Schilbe genus* become piscivorous (start eating other fish) when they reach around 13 to 14 cm TL. They can be used to control tilapia populations.

III.4. MOCHOKIDAE

All representatives of this family have a scaleless body and three pairs of barbels, one maxillary and two mandibular pairs, except in some rheophilic forms in which the lips are modified into a sucking disk. Nasal barbels are absent. The first dorsal fin has an anterior spinous ray; the adipose fin is large and sometimes rayed. The first pectoral fin ray is spinous and denticulated. The head-nape region is well ossified Eleven genera and nearly 180 species are known (Photo Z, p. 234).

Several species of the genus *Synodontis* can grow large (to more than 72 cm) and have commercial potential. Some could be used as complementary species in a polycultural system.

IV. OTHER FAMILIES

Other fish have been tested and merit fish farming trials.

IV.1. CYPRINIDAE

Fish from the carp family are often used in fish farming.

The bodies of fish from the Cyprinidae family are covered with cycloid scales and have a naked head. All rayed fins are well developed, but there is no adipose fin. The mouth protrudes, but lacks teeth. Sometimes one or two pairs of more or less well-developed barbels are present. The lower pharyngeal bones are very well developed, and bear a few teeth which are aligned in 1 to 3 rows.

Although large fish have been observed in Africa, including the *Labeo*, *Varicorhinus* and *Barbus genera*, few have been used in fish farming. *Labeo victorianus* in East Africa and *Labeo coubie* in

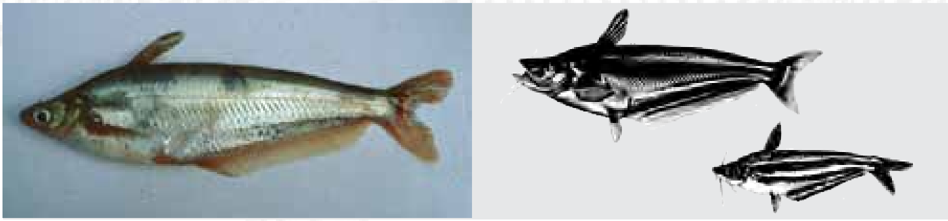

Photo Y. Schilbeidae. *Schilbe intermedius* [© Luc De Vos].

Photo Z. Mochokidae. A: *Synodontis batensoda* [© Mody - Fishbase]
B: *Synodontis schall* [© Payne - Fishbase].

Côte d'Ivoire have been used. However, the majority of large species require running water (Photo AA, p. 235).

IV.2. CITHARINIDAE

Citharinidae are large, deep bodied and compressed fishes, covered with cycloid (*Citharinops* and *Citharinus*) or ctenoid (*Citharidium*) scales. The mouth has a range of small monocuspid teeth on the edge of the lips. However, the very tiny maxillary is toothless. All species have two dorsal fins. The first has 16 to 24 branched rays. The second adipose is quite large. The dorsal fin has 19 to 24 branched rays. The fish's lateral line is straight, median and complete (with 47-92 scales). Finally, like all African Characoids, this fish has a scaly appendage at the base of its pelvic fins. All species, highly specialised microphages, have numerous thin and dense gill rakers. The most remarkable characteristic is a complex suprabranchial organ that acts like a suction-force pump to concentrate and spin foods before they are swallowed. Citharinidae are not very abundant but they have considerable economic value. All species are large. In the Chad basin, the maximum reported size for *Citharinops distichodoides* is 840 mm SL and 18 kg weight. Farming of *Citharinus citharus, an herbivore,* was tested but not continued. (Photo AB, p. 235).

IV.3. DISTICHODONTIDAE

Distichodontidae belong to the order of Characiformes. This family, which is endemic to Africa, can be identified by the following characteristics: elongated body (deeper in *Distichodus*), ctenoid scales, adipose fin generally present, lateral line in mid-lateral position, and well developed teeth.

Fish from the genus *Distichodus* can grow large (to 80 cm SL). *D. rostratus* (76 cm TL, weight of 6 kg) have been tested for fish farming (Photo AC, p. 236). They are mainly herbivorous.

IV.4. CHANNIDAE

Channidae (formerly Ophicephalidae) is a freshwater fish family that is found in Africa and Asia.

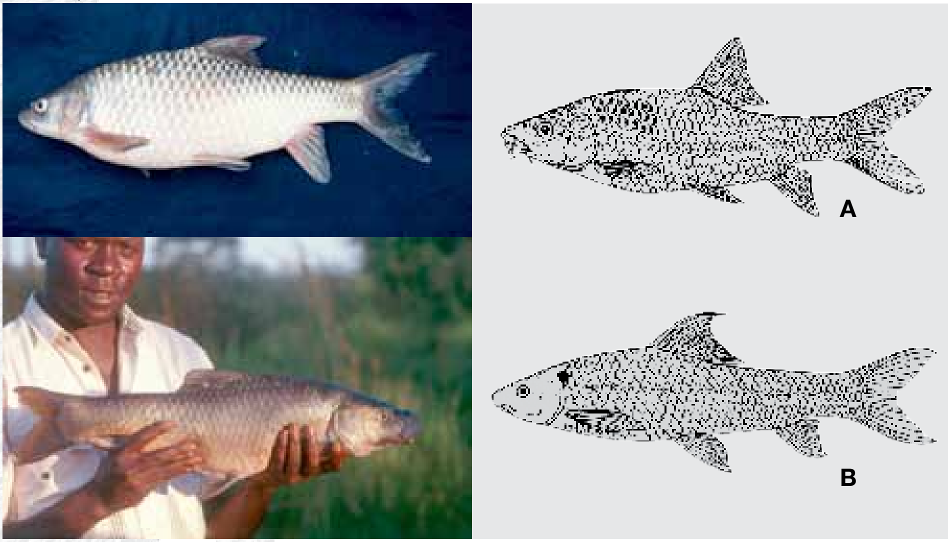

Photo AA. Cyprinidae. A: *Barbus altianalis*; B: *Labeo victorianus* [© Luc De Vos, © FAO (drawings)].

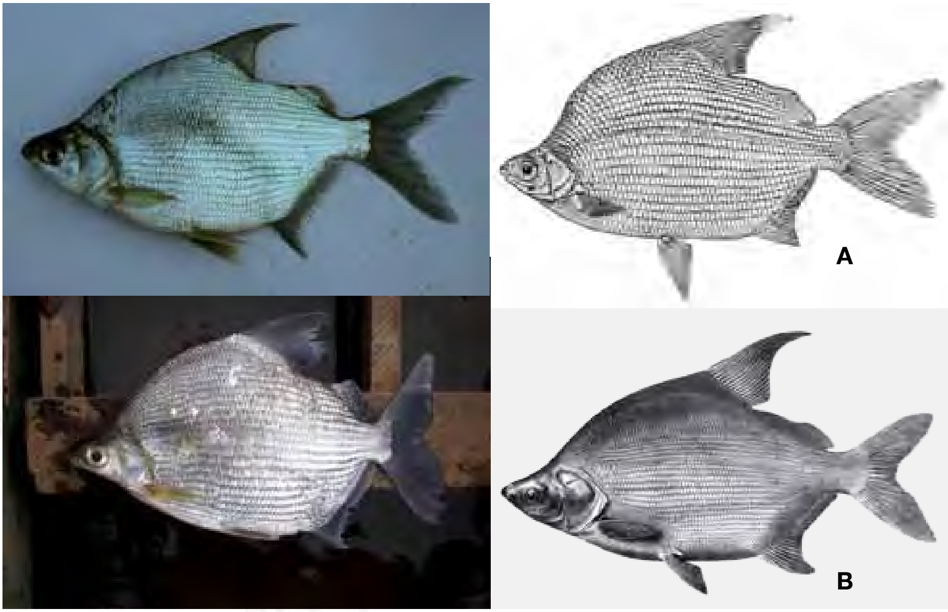

Photo AB. Citharinidae. A: *Citharinus gibbosus*; B: *C. citharus* [© Luc De Vos].

Photo AC. Distichodontidae. A: *Distichodus rostratus*; B: *D. sexfasciatus* [© Fishbase].

The body is elongated and cylindrical in cross-section, covered with cycloid scales. Unpaired fins are long, with soft rays but no spines. The fish has two suprabranchial pharyngeal cavities that provide an accessory breathing organ that allows it to breathe atmospheric air and survive outside the water for long periods.

A single genus, *Parachanna*, occurs in Africa. It is comprised of three species, two of which are found in the area considered here. *Parachanna obscura* may reach 34 cm SL and is piscivorous, and thus perfectly appropriate for the control of tilapia populations in ponds (Photo AD, below).

IV.5. LATIDAE

The Latidae family has a scaly protrusion at the base of the pelvic fins. The shape of the second suborbital bone, which is not fused to the preopercle, bears a subocular blade that extends backward into a point. A large notch separates the two dorsal fins.

This family includes the famous Nile Perch, *Lates niloticus* (also called «capitaine» in West Africa), which was tested in fish ponds (Photo AE, p. 237). This species was introduced into lake Victoria in the 1960s. Problems occurred because the fish is cannibalistic and can tolerate low oxygen levels.

This species can grow to 200 cm and a weight of 200 kg. Its growth is quite linear (Figure 184, p. 230 and Figure 185, p. 238).

This species is piscivorous and can be used to control tilapia populations in ponds.

Photo AD. Channidae. *Parachanna obscura* (DRC) [© Y. Fermon].

IV.6. ARAPAIMIDAE

The Arapaimidae, a very ancient family, is characterized by ovaries that lack oviducts. Today it is represented by only four genera: one from Australia, Sumatra and Borneo (*Scleropages*), one from Guyana and Brazil, the famous *Arapaima gigas,* which can reach 200 cm and a weight of 200 kg, and one, *Heterotis*, from Africa.

The fish's body is laterally compressed and covered with large bony scales that have a rough surface. The lateral line is complete. The fins are spineless. Maxillary and premaxillary teeth are present but pharyngeal teeth are absent.

Only one species occurs in Africa, *Heterotis niloticus*. Appendix 05, p. 274 provides more information.

Its main characteristics are:

- ✓ Rapid growth: 3 g /fish/day or more. This fish can grow to more than 100 cm in length (Figure 185, p. 238).
- ✓ Captive reproduction difficult, requiring deep water and herbaceous vegetation. This fish likes space.

Heterotis niloticus nests are built in herbaceous vegetation. They are comparable to small basins, measuring approximately 1.2 m in diameter, with a slightly excavated center at a depth of approximately 30 cm. The bottom is bare and generally flattened. The compact edges are 20 cm thick at the top and are slightly above the water. The nest is built with the plant stems removed from its center. The parents remain near the nest when the eggs are laid.

The eggs are rather small (2.5 mms diameter) and orange. They hatch approximately two days after spawning. The larvae have long, dark red, branchial filaments, which are longer outside the opercle. They quickly form a swarm, approximately 30 cm in diameter, in the center of the nest. On the 5th or 6th day, the alevins leave the nest, always in a dense swarm, and under the protection of their parents.

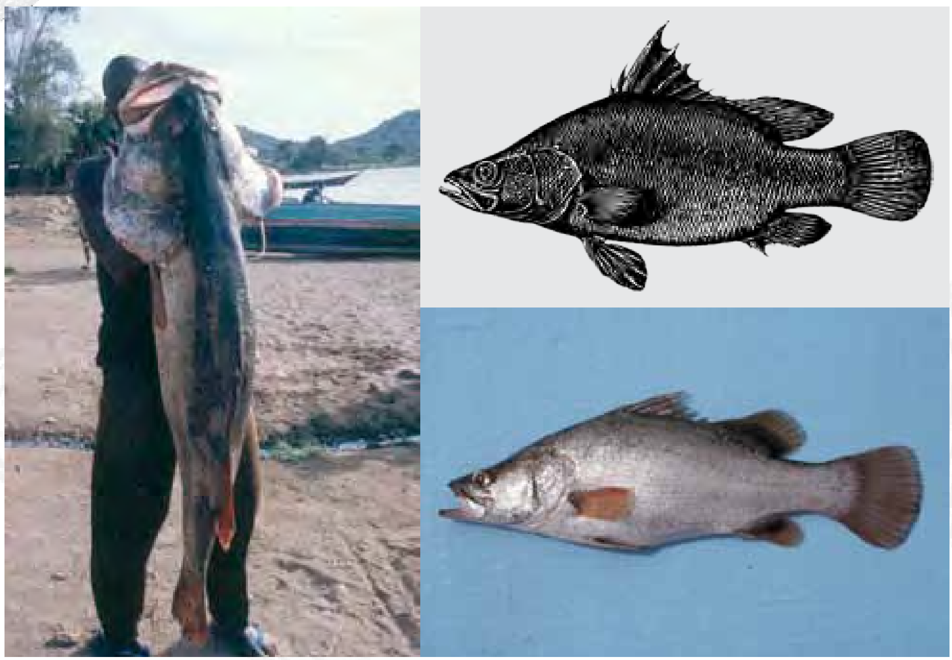

Photo AE. Latidae. *Lates niloticus* [© Luc De Vos].

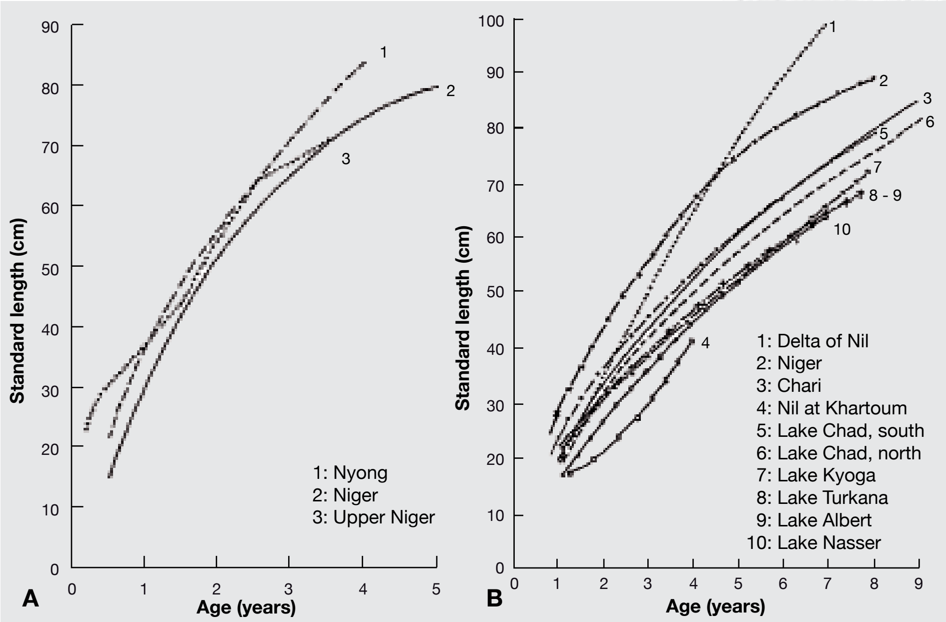

Figure 185. Growth of *Heterotis niloticus* (A) and of *Lates niloticus* (B).

Heterotis niloticus juveniles live in a swarm, then in groups whose numbers decrease progressively as the individual fish grow.

✓ The fish is microphagous- planktivorous, but has an omnivorous tendency.

- ⇨ **There are many African species of fish and many can be used in fish farming. However, in the context of livelihoods, it is best to choose:**
  - ⇨ **Tilapia for main production; with**
  - ⇨ **A piscivorous species.**
- ⇨ **Other species, such as omnivores or herbivores, may also be used in the pond.**
- ⇨ **The choice of species will depend on the pond's geographic location (ichthyoregion).**

Appendix 04
BIOGEOGRAPHIC DATA

As a complement to chapter 03 p. 21, this appendix provides information on:

Table XLIV. Characteristics of African countries;

Table XLV. Characteristics of ichthyoregions and lakes in Africa;

Figure 186. Reprinted map of ichthyoregions and countries;

Table XLVI. Ichthyoregions and their distribution by country in Africa;

Table XLVII. Genera and species of tilapia, listed by country.

These allow one to identify the ichthyoregion and which species of tilapia are present in the intervention area.

TABLE XLIV. Some characteristics of African countries.

Region: Region where the country is located
Population in inhabitants - Surface area in km² - Density of inhabitants / km²
H = Possible Habitats for fisheries in km²
HS = % of possible habitats / surface area of the country
PM = Mean production between 2000 and 2004 in tons
Prod = Productivity
Icht = Number of ichthyoregions in the country
Family, Genera, Species: Number of family, genera and species of fish known to be in the country

Country	Region	Population	Surface	Density	H	HS
South Africa	Austral	44187637	1219090	36.2	13386	1.1
Algeria	North	33333216	2381741	14.0		
Angola	Austral	13115606	1246700	10.5	22976	1.8
Benin	Sub-Sahara	7862944	112622	69.8	2958	2.6
Botswana	Austral	1639833	581730	2.8	36390	6.3
Burkina Faso	Sub-Sahara	13902972	274200	50.7	1901	0.7
Burundi	Sub-Sahara	8691005	27834	312.2	2559	9.2
Cameroon	Sub-Sahara	17340702	475442	36.5	19638	4.1
Cape Verde	Sub-Sahara	455294	4033	112.9		
Central Africa	Sub-Sahara	4303356	622984	6.9	11771	1.9
Comoros	Oriental	690948	1862	371.1		
Congo	Sub-Sahara	3702314	341999	10.8	59212	17.3
Congo (DR) / Zaïre	Sub-Sahara	62660551	2344798	26.7	113724	4.9
Côte d’Ivoire	Sub-Sahara	17654843	322461	54.8	4928	1.5
Djibouti	Oriental	768900	23200	33.1		
Egypt	North	78887007	995450	79.2	20989	2.1
Eritrea	Oriental	4786994	121320	39.5		
Ethiopia	Oriental	74777981	1127127	66.3	22048	2.0
Gabon	Sub-Sahara	1424906	267667	5.3	8524	3.2
Gambia	Sub-Sahara	1641564	11295	145.3	2290	20.3
Ghana	Sub-Sahara	22409572	238538	93.9	13871	5.8
Guinea	Sub-Sahara	9690222	245857	39.4	5090	2.1
Equatorial Guinea	Sub-Sahara	540109	28051	19.3	222	0.8
Guinea-Bissau	Sub-Sahara	1442029	36125	39.9	3756	10.4
Kenya	Oriental	34707817	581787	59.7	30576	5.3
Lesotho	Austral	2022331	30355	66.6	6	0.0
Liberia	Sub-Sahara	3631318	111370	32.6	342	0.3
Libya	North	5900754	1759540	3.4		

TABLE XLIV (cont). Some characteristics of African countries.

Region: Region where the country is located
Population in inhabitants - Surface area in km² - Density in inhabitants / km²
H = Possible Habitats for fisheries in km²
HS = % of possible habitats / surface area of the country
PM = Mean production between 2000 and 2004 in tons
Prod = Productivity
Icht = Number of ichthyoregions in the country
Family, Genera, Species: Number of family, genera and species of fish known to be in the country

Country	PM	Prod	Icht	Families	Genera	Species
South Africa	900	0.7	3	47	113	224
Algeria			3	10	16	23
Angola	8800	3.8	3	42	112	294
Benin	28919	97.8	1	46	108	182
Botswana	141	0.0	2	13	37	96
Burkina Faso	8700	45.8	2	29	67	140
Burundi	13081	51.1	2	15	30	57
Cameroon	56500	28.8	3	55	163	498
Cape Verde				1	1	1
Central Afric	15000	12.7	2	31	98	320
Comoros				12	23	28
Congo	25765	4.4	2	50	160	409
Congo (DR) / Zaïre	212000	18.6	6	65	265	1104
Côte d'Ivoire	14366	29.2	2	49	113	241
Djibouti			1	5	5	5
Egypt	287387	136.9	4	46	146	230
Eritrea			2	8	9	10
Ethiopia	12518	5.7	3	3	3	3
Gabon	9493	11.1	1	43	106	249
Gambia	2500	10.9	1	36	57	86
Ghana	74700	53.9	2	56	137	262
Guinea	4000	7.9	3	35	91	266
Equatorial Guinea	1015	45.8	2	22	30	38
Guinea-Bissau	150	0.4	1	27	47	78
Kenya	147442	48.2	6	34	75	193
Lesotho	37	63.4	1	5	11	15
Liberia	4000	116.8	2	37	75	178
Libya			3	4	5	8

TABLE XLIV (cont). Some characteristics of African countries.

Region: Region where the country is located
Population in inhabitants - Surface area in km² - Density in inhabitants / km²
H = Possible Habitats for fisheries in km²
HS = % of possible habitats / surface area of the country
PM = Mean production between 2000 and 2004 in tons
Prod = Productivity
Icht = Number of ichthyoregions in the country
Family, Genera, Species: Number of family, genera and species of fish known to be in the country

Country	Region	Population	Surface	Density	H	HS
Madagascar	Oriental	18,595,469	587,041	31.7	10,555	1.8
Malawi	Austral	13,013,926	118,484	109.8	27526	23.2
Mali	Sub-Sahara	11,956,788	1,240,198	9.6	54,034	4.4
Morocco	North	33,757,175	458,730	73.6	4,777	1.0
Mauritius	Oriental	1,248,592	2,040	612.1		
Mauritania	Sub-Sahara	3,177,388	1,030,700	3.1	21,284	2.1
Mayotte (France)	Oriental	201,234	375	536.6		
Mozambique	Austral	19,686,505	799,380	24.6	46,763	5.8
Namibia	Austral	2,044,147	825,112	2.5	16,353	2.0
Niger	Sub-Sahara	12,525,094	1,186,408	10.6	44,249	3.7
Nigeria	Sub-Sahara	131,859,731	923,768	142.7	58,480	6.3
Uganda	Oriental	30,262,610	241,548	125.3	50,078	20.7
Reunion (France)	Oriental	787,584	2,504	314.5		
Rwanda	Sub-Sahara	8,648,248	26,338	328.4	2,416	9.2
Western Sahara	North	300,905	266,000	1.1		
Saint-Helena	Austral	7,502	410	18.3		
Sao Tome & Principe	Sub-Sahara	193,413	1,001	193.2		
Senegal	Sub-Sahara	11,987,121	196,722	60.9	13,965	7.1
Seychelles	Oriental	83,688	455	183.9		
Sierra Leone	Sub-Sahara	6,005,250	71,740	83.7	4,771	6.7
Somalia	Oriental	8,863,338	637,657	13.9	12,903	2.0
Sudan	Oriental	41,236,378	2,505,810	16.5	71,237	2.8
Swaziland	Austral	1,136,334	17,365	65.4	33	0.2
Tanzania	Oriental	37,979,417	945,088	40.2	101,015	10.7
Chad	Sub-Sahara	10,542,141	1,284,200	8.2	152,252	11.9
Togo	Sub-Sahara	5,681,519	56,785	100.1	1,401	2.5
Tunisia	North	10,175,014	163,610	62.2	10,366	6.3
Zambia	Austral	11,502,010	752,612	15.3	73,065	9.7
Zimbabwe	Austral	12,382,920	390,757	31.7	3,927	1.0

TABLE XLIV (cont). Some characteristics of African countries.

Region: Region where the country is located
Population in inhabitants - Surface area in km² - Density in inhabitants / km²
H = Possible Habitats for fisheries in km²
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Icht = Number of ichthyoregions in the country
Family, Genera, Species: Number of family, genera and species of fish known to be in the country

Country	PM	Prod	Icht	Families	Genera	Species
Madagascar	30,000	28.4	1	24	39	52
Malawi	48,391	17.6	5	17	99	402
Mali	101,974	18.9	3	31	76	172
Morocco	1,577	3.3	2	14	17	23
Mauritius				20	41	59
Mauritania	5,000	2.3	3	35	68	109
Mayotte (France)				7	12	13
Mozambique	11,792	2.5	5	38	117	229
Namibia	1,500	0.9	5	14	38	82
Niger	33,587	7.6	2	24	52	91
Nigeria	166,193	28.4	1	57	147	362
Uganda	255,116	50.9	5	20	54	226
Reunion (France)				19	34	50
Rwanda	7,071	29.3	3	10	24	68
Western Sahara			1	6	7	7
Saint-Helena				0	0	0
Sao Tome & Principe				5	6	6
Senegal	50,431	36.1	2	49	98	175
Seychelles				18	26	33
Sierra Leone	14,000	29.3	1	34	81	185
Somalia	200	0.2	2	12	20	33
Sudan	52,200	7.3	3	27	60	116
Swaziland	70	21.4	1	10	18	35
Tanzania	287,443	28.5	6	30	129	449
Chad	75,640	5.0	2	31	67	139
Togo	5,000	35.7	1	40	79	150
Tunisia	894	0.9	2	10	14	18
Zambia	65,334	8.9	4	23	117	352
Zimbabwe	13,023	33.2	1	18	42	91

TABLE XLV. Characteristics of ichthyoregions and lakes in Africa.

N°: Letters corresponding to figure 186 on the next page
Drainage basins: Number of drainage basins in the ichthyoregion
Families, Genera, Species: Number of families, genera and species of fish known to be in the ichthyoregion

N°	Ichtyoregion	Surface area (km²)	Drainage basins	Families	Genera	Species
A	Angolese	520,000	131	34	78	184
B	Lower Guinea	622,000	116	56	176	511
C	Cap	232,000	158	27	49	78
D	Congolese	3,453,000	3	66	228	983
E	Upper Guinea	261,000	116	43	105	286
F	Karroid	1,087,000	77	32	64	107
G	Maghreb	1,588,000	438	22	40	60
H	Madagascar	596,000	364	24	39	52
I	Nilo-soudanian	9,668,000	74	70	218	653
J	Nilo-soudanian (Eburneo-ghanean)	425,000	108	57	148	320
K	Oriental	1,905,000	249	41	88	214
L	Sherbro Island	1,900	24	7	7	9
M	Zambezis	2,949,000	115	46	27	303
N	Zanzibar Island	23,000	1	4	6	12
O	Non defined 1 (Red sea)	61,000	48	15	34	46
P	Non defined 2 (Abyssinia)	956,000	425	31	72	99
Q	Non defined 3 (Namibia 1)	176,000	33	1	1	1
R	Non defined 4 (Namibia 2)	71,000	23	0	0	0
S	Non defined 5 (Sahara)	4,462,000	58	8	10	13
a	Lake Amaramba	3,100	1	7	10	17
b	Lake Chilwa / Lago Chiuta	9,800	1	10	23	39
c	Lake Edward / Édouard	24,000	1	12	24	62
d	Lake Georges	25,000	1	10	20	50
e	Lake Kivu	7,300	1	7	12	38
f	Lake Malombe	2,000	1	8	31	48
g	Lake Naivasha	3,500	1	3	3	3
h	Lake Natron	22,000	1	2	3	9
i	Lake Nyasa / Malawi	128,000	1	13	88	375
j	Lake Ruhondo	1,700	2	4	5	8
k	Lake Rukwa	75,000	1	14	27	60
l	Lake Tanganyika	233,000	1	25	112	371
m	Lake Victoria	309,000	2	16	45	205

Figure 186. Ichthyoregions (yellow-green borders) and countries (red borders) (Faunafri).

TABLE XLVI. Ichthyoregions and their distribution by country in Africa.

Ichthyoregions / Country	Number ichthyoregions	Angolese	Lower Guinea	Cap	Congolese	Upper Guinea	Karroid	Maghreb	Madagascar	Nilo-Soudanian	Nilo-soudanian (Eburneo-ghanean)	Oriental	Sherbro Island	Zambesis	Zanzibar Island
South Africa	**3**			1			1							1	
Algeria	**3**							1		1					
Angola	**3**	1			1									1	
Benin	**1**									1					
Botswana	**2**						1							1	
Burkina Faso	**2**									1	1				
Burundi	**2**														
Cameroon	**3**		1		1					1					
Central Africa	**2**				1					1					
Congo	**2**		1		1										
Congo DR / Zaïre	**6**		1		1					1					
Côte d'Ivoire	**2**									1	1				
Djibouti	**1**														
Egypt	**4**							1							
Eritrea	**2**											1			
Ethiopia	**3**									1		1			
Gabon	**1**		1												
Gambia	**1**									1					
Ghana	**2**									1	1				
Guinea	**3**					1				1	1				
Equatorial Guinea	**2**		1										1		
Guinea-Bissau	**1**					1									
Kenya	**6**									1		1			1
Lesotho	**1**						1								
Liberia	**2**					1					1				
Libya	**3**							1		1					
Madagascar	**1**								1						
Malawi	**5**													1	
Mali	**3**									1	1				
Morocco	**2**									1					
Mauritania	**3**							1		1					
Mozambique	**5**											1		1	
Namibia	**5**	1					1							1	
Niger	**2**									1					
Nigeria	**1**									1					
Uganda	**5**									1					
Rwanda	**3**														
Western Sahara	**1**							1							
Senegal	**2**					1				1					
Sierra Leone	**1**					1									
Somalia	**2**											1			
Sudan	**3**									1					
Swaziland	**1**													1	
Tanzania	**6**												1		
Chad	**2**									1					
Togo	**1**									1					
Tunisia	**2**							1							
Zambia	**4**				1									1	
Zimbabwe	**1**													1	
Number of countries	**48**	**2**	**5**	**1**	**6**	**5**	**4**	**6**	**2**	**23**	**6**	**5**	**1**	**9**	**1**

TABLE XLVI (cont). Ichthyoregions and their distribution by country in Africa.

Country \ Ichthyoregions	Non defined 1 (Red Sea)	Non defined 2 (Abyssinia)	Non defined 3 (Namibia 1)	Non defined 4 (Namibia 2)	Non defined 5 (Sahara)	Lake Amaramba	Lake Chilwa/Lago Chiuta	Lake Edward/Édouard	Lake Georges	Lake Kivu	Lake Malombe	Lake Naivasha	Lake Natron	Lake Malawi/Nyasa	Lake Ruhondo	Lake Rukwa	Lake Tanganyika	Lake Victoria
South Africa																		
Algeria					1													
Angola																		
Benin																		
Botswana																		
Burkina Faso																		
Burundi																	1	1
Cameroon																		
Central Africa																		
Congo																		
Congo DR / Zaïre								1		1							1	
Côte d'Ivoire																		
Djibouti		1																
Egypt	1	1			1													
Eritrea		1																
Ethiopia		1																
Gabon																		
Gambia																		
Ghana																		
Guinea																		
Equatorial Guinea																		
Guinea-Bissau																		
Kenya												1	1					1
Lesotho																		
Liberia																		
Libya					1													
Madagascar																		
Malawi						1	1				1			1				
Mali					1													
Morocco					1													
Mauritania					1													
Mozambique						1	1							1				
Namibia			1	1														
Niger					1													
Nigeria																		
Uganda								1	1						1			1
Rwanda										1					1			1
Western Sahara																		
Senegal																		
Sierra Leone																		
Somalia		1																
Sudan		1			1													
Swaziland																		
Tanzania													1	1		1	1	1
Chad					1													
Togo																		
Tunisia					1													
Zambia																1	1	
Zimbabwe																		
Number of countries	1	6	1	1	10	2	2	2	1	2	1	1	2	3	2	2	4	5

TABLE XLVII. Genus and species of tilapia listed by country.

N: Native; E: Endemic; I: Introduced; ?: Not verified

Species \ Country	Total Length	Number of countries	South Africa	Algeria	Angola	Benin	Botswana	Burkina Faso	Burundi	Cameroon	Central Africa	Congo	Congo DR / Zaïre	Côte d'Ivoire	Djibouti	Egypt	Eritrea	Ethiopia	Gabon	Gambia	Ghana	Guinea	Equatorial Guinea	Guinea-Bissau	Kenya	Lesotho
Number of species	106	48	7	2	13	7	8	3	6	30	3	11	27	18	0	8	2	10	10	7	11	12	3	10	22	1
Oreochromis amphimelas	31	1																								
Oreochromis andersonii	61	10	N		N		N						I												I	
Oreochromis angolensis	23	1			E																					
Oreochromis aureus	46	11	I							N				I		N										
Oreochromis chungruruensis	23	1																								
Oreochromis esculentus	50	4																							N	
Oreochromis hunteri	34	2																							N	
Oreochromis ismailiaensis	-	1														E										
Oreochromis jipe	54	2																							N	
Oreochromis karomo	30	2																								
Oreochromis karongae	34	3																								
Oreochromis korogwe	31	2																							N	
Oreochromis lepidurus	19	2			N								N													
Oreochromis leucostictus	32	6							I				N												I	
Oreochromis lidole	38	3																								
Oreochromis macrochir	40	25		I	N	I	N	I	I	I	I	I	?	I		I			I		I				I	
Oreochromis malagarasi	30	1																								
Oreochromis mortimeri	48	4											I												?	
Oreochromis mossambicus	39	21	N	I	I	I	N					I	I	I		I									I	N
Oreochromis mweruensis	27	3											N													
Oreochromis niloticus baringoensis	36	1																							E	
Oreochromis niloticus cancellatus	28	1																E								
Oreochromis niloticus eduardianus	49	7							N				N												I	
Oreochromis niloticus filoa	15	1																E								
Oreochromis niloticus niloticus	64	34	I				I	N	I	N	I	I	I	N		N	I	?	I	N	N	N			I	
Oreochromis niloticus sugutae	20	1																							E	
Oreochromis niloticus tana	35	1																E								
Oreochromis niloticus vulcani	28	2																N							N	
Oreochromis pangani girigan	33	1																							E	
Oreochromis pangani pangani	34	1																								
Oreochromis placidus placidus	36	4	N																							
Oreochromis placidus ruvumae	27	2																								
Oreochromis rukwaensis	36	1																								
Oreochromis saka	40	3																								
Oreochromis salinicola	10	1											E													
Oreochromis schwebischi	33	4			N							N	N						N							
Oreochromis shiranus chilwae	20	2																								
Oreochromis shiranus shiranus	42	4																								
Oreochromis spilurus niger	35	4																N							N	
Oreochromis spilurus percevali	16	1																							E	
Oreochromis spilurus spilurus	19	6											I					N							N	
Oreochromis squamipinnis	33	3																								
Oreochromis tanganicae	45	4							N				N													
Oreochromis upembae	23	2											N													
Oreochromis urolepis hornorum	27	3												I												
Oreochromis urolepis urolepis	48	1																								
Oreochromis variabilis	33	3																							N	

TABLE XLVII (cont). Genus and species of tilapia listed by country.

N: Native; E: Endemic; I: Introduced; ?: Not verified

Species \ Country	Total Length	Number of countries	Liberia	Libya	Madagascar	Malawi	Mali	Morocco	Mauritania	Mozambique	Namibia	Niger	Nigeria	Uganda	Rwanda	Senegal	Sierra Leone	Somalia	Sudan	Swaziland	Tanzania	Chad	Togo	Tunisia	Zambia	Zimbabwe
Number of species	**106**	**48**	17	0	8	10	5	2	7	14	7	6	8	10	7	12	11	1	4	3	31	7	7	3	14	9
Oreochromis amphimelas	**31**	**1**																			E					
Oreochromis andersonii	**61**	**10**								N	N										I				N	N
Oreochromis angolensis	**23**	**1**																								
Oreochromis aureus	**46**	**11**			I		N					N	N			N						N			I	
Oreochromis chungruruensis	**23**	**1**																			E					
Oreochromis esculentus	**50**	**4**												N	I						N					
Oreochromis hunteri	**34**	**2**																			N					
Oreochromis ismailiaensis	**-**	**1**																								
Oreochromis jipe	**54**	**2**																			N					
Oreochromis karomo	**30**	**2**																			N				N	
Oreochromis karongae	**34**	**3**				N				N											N					
Oreochromis korogwe	**31**	**2**																			N					
Oreochromis lepidurus	**19**	**2**																								
Oreochromis leucostictus	**32**	**6**												N	I						I					
Oreochromis lidole	**38**	**3**				N				N											N					
Oreochromis macrochir	**40**	**25**	I		I					?	N				I				I		I		I		N	N
Oreochromis malagarasi	**30**	**1**																			E					
Oreochromis mortimeri	**48**	**4**																							N	N
Oreochromis mossambicus	**39**	**21**			I	N				N	I			I		?				N	I			I		N
Oreochromis mweruensis	**27**	**3**													N										N	
Oreochromis niloticus baringoensis	**36**	**1**																								
Oreochromis niloticus cancellatus	**28**	**1**																								
Oreochromis niloticus eduardianus	**49**	**7**												N	N						I				N	
Oreochromis niloticus filoa	**15**	**1**																								
Oreochromis niloticus niloticus	**64**	**34**	N		I		N		?			N	N	N	I	N	N		N		I	N	N	I	I	I
Oreochromis niloticus sugutae	**20**	**1**																								
Oreochromis niloticus tana	**35**	**1**																								
Oreochromis niloticus vulcani	**28**	**2**																								
Oreochromis pangani girigan	**33**	**1**																								
Oreochromis pangani pangani	**34**	**1**																			E					
Oreochromis placidus placidus	**36**	**4**				N				N																N
Oreochromis placidus ruvumae	**27**	**2**								N											N					
Oreochromis rukwaensis	**36**	**1**																			E					
Oreochromis saka	**40**	**3**				N				N											N					
Oreochromis salinicola	**10**	**1**																								
Oreochromis schwebischi	**33**	**4**																								
Oreochromis shiranus chilwae	**20**	**2**				N				N																
Oreochromis shiranus shiranus	**42**	**4**			I	N				N											N					
Oreochromis spilurus niger	**35**	**4**								I															I	
Oreochromis spilurus percevali	**16**	**1**																								
Oreochromis spilurus spilurus	**19**	**6**												I				N			N					
Oreochromis squamipinnis	**33**	**3**				N				N											N					
Oreochromis tanganicae	**45**	**4**																			N				N	
Oreochromis upembae	**23**	**2**																			N					
Oreochromis urolepis hornorum	**27**	**3**												N							N					
Oreochromis urolepis urolepis	**48**	**1**																			E					
Oreochromis variabilis	**33**	**3**												N							N					

TABLE XLVII (cont). Genus and species of tilapia listed by country.

N: Native
E: Endemic
I: Introduced
?: Not verified

Species \ Country	Total Length	Number of countries	South Africa	Algeria	Angola	Benin	Botswana	Burkina Faso	Burundi	Cameroon	Central Africa	Congo	Congo DR / Zaïre	Côte d'Ivoire	Djibouti	Egypt	Eritrea	Ethiopia	Gabon	Gambia	Ghana	Guinea	Equatorial Guinea	Guinea-Bissau	Kenya	Lesotho
Number of species	**106**	**48**	7	2	13	7	8	3	6	30	3	11	27	18	0	8	2	10	10	7	11	12	3	10	22	1
Tilapia bakossiorum	**9**	**1**								E																
Tilapia baloni	**18**	**2**											N													
Tilapia bemini	**9**	**1**								E																
Tilapia bilineata	**18**	**1**											E													
Tilapia brevimanus	**27**	**6**												N						N		N		N		
Tilapia busumana	**21**	**2**												N							N					
Tilapia buttikoferi	**41**	**4**																				N		N		
Tilapia bythobates	**16**	**1**								E																
Tilapia cabrae	**37**	**4**			N								N						N				N			
Tilapia cameronensis	**14**	**1**								E																
Tilapia cessiana	**24**	**2**												N												
Tilapia coffea	**19**	**1**																								
Tilapia congica	**25**	**1**											E													
Tilapia dageti	**40**	**10**						N		N				N							N					
Tilapia deckerti	**20**	**1**								E																
Tilapia discolor	**23**	**2**												N							N					
Tilapia flava	**12**	**1**								E																
Tilapia guinasana	**14**	**2**					I																			
Tilapia guineensis	**35**	**17**			N	N				N		N		N					N	N	N	N	N	N		
Tilapia gutturosa	**9**	**1**								E																
Tilapia imbriferna	**15**	**1**								E																
Tilapia ismailiaensis	**?**	**1**														E										
Tilapia jallae	**8**	**1**																								
Tilapia joka	**11**	**2**																								
Tilapia kottae	**15**	**1**								E																
Tilapia louka	**25**	**4**																				N		N		
Tilapia margaritacea	**18**	**1**								E																
Tilapia mariae	**40**	**5**				N				N				N							N					
Tilapia nyongana	**21**	**2**								N									N							
Tilapia rendalli	**45**	**24**	N		N		N		I	N		N	N					I	N						I	
Tilapia rheophila	**10**	**1**																				E				
Tilapia ruweti	**11**	**6**			N		N						N													
Tilapia snyderae	**5**	**1**								E																
Tilapia sparrmanii	**24**	**10**	N		N		N																			
Tilapia spongotroktis	**15**	**1**								E																
Tilapia tholloni	**22**	**4**			N							N	N						N							
Tilapia thysi	**9**	**1**								E																
Tilapia walteri	**27**	**2**												N												
Tilapia zillii	**27**	**28**				N				N	N		N	N		N	I	I		N	N	N		N	N	

TABLE XLVII (next). Genus and species of tilapia listed by country.

N: Native
E: Endemic
I: Introduced
?: Not verified

Species \ Country	Total Length	Number of countries	Liberia	Libya	Madagascar	Malawi	Mali	Morocco	Mauritania	Mozambique	Namibia	Niger	Nigeria	Uganda	Rwanda	Senegal	Sierra Leone	Somalia	Sudan	Swaziland	Tanzania	Chad	Togo	Tunisia	Zambia	Zimbabwe
Number of species	**106**	**24**	17	0	8	10	5	2	7	14	7	6	8	10	7	12	11	1	4	3	31	7	7	3	14	9
Tilapia bakossiorum	**9**	**0**																								
Tilapia baloni	**18**	**1**																							N	
Tilapia bemini	**9**	**0**																								
Tilapia bilineata	**18**	**0**																								
Tilapia brevimanus	**27**	**2**	N														N									
Tilapia busumana	**21**	**0**																								
Tilapia buttikoferi	**41**	**2**	N														N									
Tilapia bythobates	**16**	**0**																								
Tilapia cabrae	**37**	**0**																								
Tilapia cameronensis	**14**	**0**																								
Tilapia cessiana	**24**	**1**	N																							
Tilapia coffea	**19**	**1**	E																							
Tilapia congica	**25**	**0**																								
Tilapia dageti	**40**	**6**					N					N	N			N						N	N			
Tilapia deckerti	**20**	**0**																								
Tilapia discolor	**23**	**0**																								
Tilapia flava	**12**	**0**																								
Tilapia guinasana	**14**	**1**									N															
Tilapia guineensis	**35**	**6**	N						?				N			N	N						N			
Tilapia gutturosa	**9**	**0**																								
Tilapia imbriferna	**15**	**0**																								
Tilapia ismailiaensis	**?**	**0**																								
Tilapia jallae	**8**	**1**																								E
Tilapia joka	**11**	**2**	N														N									
Tilapia kottae	**15**	**0**																								
Tilapia louka	**25**	**2**	N														N									
Tilapia margaritacea	**18**	**0**																								
Tilapia mariae	**40**	**1**											N													
Tilapia nyongana	**21**	**0**																								
Tilapia rendalli	**45**	**14**			I	N			?	N	N	N		I	I	N				N	N	N			N	N
Tilapia rheophila	**10**	**0**																								
Tilapia ruweti	**11**	**3**									N														N	N
Tilapia snyderae	**5**	**0**																								
Tilapia sparrmanii	**24**	**7**			I	N				N	N									N	N				N	
Tilapia spongotroktis	**15**	**0**																								
Tilapia tholloni	**22**	**0**																								
Tilapia thysi	**9**	**0**																								
Tilapia walteri	**27**	**1**	N																							
Tilapia zillii	**27**	**15**	N		I		N	N	N			N	N	N		N	N		N		I	N	N	N		

TABLE XLVII (cont). Genus and species of tilapia listed by country.

N: Native
E: Endemic
I: Introduced
?: Not verified

Species \ Country	Total Length	Number of countries	South Africa	Algeria	Angola	Benin	Botswana	Burkina Faso	Burundi	Cameroon	Central Africa	Congo	Congo DR / Zaïre	Côte d'Ivoire	Djibouti	Egypt	Eritrea	Ethiopia	Gabon	Gambia	Ghana	Guinea	Equatorial Guinea	Guinea-Bissau	Kenya	Lesotho
Number of species	106	48	7	2	13	7	8	3	6	30	3	11	27	18	0	8	2	10	10	7	11	12	3	10	22	1
Sarotherodon caroli	22	1								E																
Sarotherodon caudomarginatus	20	4																				N		N		
Sarotherodon galilaeus galilaeus	41	20								N		N	N	N		N		N		N	N	N		N	N	
Sarotherodon galilaeus multifasciatus	17	2												N							N					
Sarotherodon galileus borkuanus	16	1																								
Sarotherodon galileus boulengeri	20	1											E													
Sarotherodon galileus sanagaensis	16	2				N				E																
Sarotherodon linnellii	21	1								E																
Sarotherodon lohbergeri	14	1								E																
Sarotherodon melanotheron heudelotii	26	5																		N		N		N		
Sarotherodon melanotheron leonensis	20	2																								
Sarotherodon melanotheron melanotheron	26	14								N		N	N	N						N	N	N		N		
Sarotherodon melanotheron paludinosus	15	1																								
Sarotherodon mvogoi	24	3								N		N							N							
Sarotherodon nigripinnis dolloi	22	3			N							N	N													
Sarotherodon nigripinnis nigripinnis	20	4				N							N						N				N			
Sarotherodon occidentalis	31	5																				N		N		
Sarotherodon steinbachi	15	1								E																
Sarotherodon tournieri liberiensis	20	1																								
Sarotherodon tournieri tournieri	13	2												N												
Alcolapia alcalicus	10	2																							N	
Alcolapia grahami	20	2																							N	
Alcolapia latilabris	9	1																								
Alcolapia ndalalani	8	1																								
Danakilia franchettii	10	1																E								
Konia dikume	14	1								E																
Konia eisentrauti	10	1								E																
Myaka myaka	9	1								E																
Pungu maclareni	14	1								E																
Stomatepia mariae	15	1								E																
Stomatepia mongo	14	1								E																
Stomatepia pindu	13	1								E																
Genus																										
Oreochromis		43	5	2	6	2	4	2	5	3	2	4	14	5		5	1	7	3	1	2	1			19	1
Tilapia		43	2		6	3	4	1	1	19	1	3	8	9		2	1	2	5	3	6	6	2	5	2	
Sarotherodon		26			1	2				8		4	5	4		1		1	2	3	3	5	1	5	1	
Alcolapia		2																							2	
Danakilia		1																1								
Konia		1								2																
Myaka		1								1																
Pungu		1								1																
Stomatepia		1								3																

TABLE XLVII (next). Genus and species of tilapia listed by country.

N: Native
E: Endemic
I: Introduced
?: Not verified

Species \ Country	Total Length	Number of country	Liberia	Libya	Madagascar	Malawi	Mali	Morocco	Mauritania	Mozambique	Namibia	Niger	Nigeria	Uganda	Rwanda	Senegal	Sierra Leone	Somalia	Sudan	Swaziland	Tanzania	Chad	Togo	Tunisia	Zambia	Zimbabwe
Number of species	**106**	**24**	17	0	8	10	5	2	7	14	7	6	8	10	7	12	11	1	4	3	31	7	7	3	14	9
Sarotherodon caroli	**22**	**0**																								
Sarotherodon caudomarginatus	**20**	**2**	N														N									
Sarotherodon galilaeus galilaeus	**41**	**9**					N	N	N			N	N			N			N			N	N			
Sarotherodon galilaeus multifasciatus	**17**	**0**																								
Sarotherodon galileus borkuanus	**16**	**1**																				E				
Sarotherodon galileus boulengeri	**20**	**0**																								
Sarotherodon galileus sanagaensis	**16**	**0**																								
Sarotherodon linnellii	**21**	**0**																								
Sarotherodon lohbergeri	**14**	**0**																								
Sarotherodon melanotheron heudelotii	**26**	**2**							N							N										
Sarotherodon melanotheron leonensis	**20**	**2**	N														N									
Sarotherodon melanotheron melanotheron	**26**	**6**	N						N				N			N	N						N			
Sarotherodon melanotheron paludinosus	**15**	**1**														E										
Sarotherodon mvogoi	**24**	**0**																								
Sarotherodon nigripinnis dolloi	**22**	**0**																								
Sarotherodon nigripinnis nigripinnis	**20**	**0**																								
Sarotherodon occidentalis	**31**	**3**	N													N	N									
Sarotherodon steinbachi	**15**	**0**																								
Sarotherodon tournieri liberiensis	**20**	**1**	E																							
Sarotherodon tournieri tournieri	**13**	**1**	N																							
Alcolapia alcalicus	**10**	**1**																			N					
Alcolapia grahami	**20**	**1**																			N					
Alcolapia latilabris	**9**	**1**																			E					
Alcolapia ndalalani	**8**	**1**																			E					
Danakilia franchettii	**10**	**0**																								
Konia dikume	**14**	**0**																								
Konia eisentrauti	**10**	**0**																								
Myaka myaka	**9**	**0**																								
Pungu maclareni	**14**	**0**																								
Stomatepia mariae	**15**	**0**																								
Stomatepia mongo	**14**	**0**																								
Stomatepia pindu	**13**	**0**																								
Genera																										
Oreochromis		**43**	9		3	2	2	1	3	2	4	3	4	2	1	4	6		1	2	3	3	3	1	4	3
Tilapia		**43**	6				1	1	3			1	2			5	4		1			2	2			
Sarotherodon		**26**																			4					
Alcolapia		**2**																								
Danakilia		**1**																								
Konia		**1**																								
Myaka		**1**																								
Pungu		**1**																								
Stomatepia		**1**																								

Appendix 05
SPECIES FILES

Presented below are summaries for different species that are common in aquaculture. Each contains scientific synonyms, common names in French and English, size and maximum weight known in the literature, as well as distribution maps and biological characteristics of each species.

Oreochromis andersoni (Castelnau, 1861)

Synonyms: *Chromys andersoni* Castelnau, 1861 - *Oreochromis anulerson* (Castelnau, 1861) - *Sarotherodon andersoni* (Castelnau, 1861) - *Tilapia andersoni* (Castelnau, 1861) - *Tilapia kafuensis* Boulenger, 1912 - *Tilapia natalensis* (non Weber)

English name: Three spotted tilapia

French name:

Aquaculture: commercial

Fishery: commercial - sport

Aquarium:

Max. size: 61 cm TL

Max. weight: 4.7 kg

Biology: Benthopelagic. May be found in brackish water. Occurs in both river and swamp habitats and can adapt to fairly fast-flowing rivers, but prefers slow-flowing or standing water. Juveniles remain inshore among vegetation. Forms schools. Mainly diurnal; a detritivore that feeds on fine particulate matter, including algae, diatoms, detritus and zooplankton. Larger individuals also eat insects and other invertebrates. Female mouthbrooder. Several countries report adverse ecological impact after introduction.

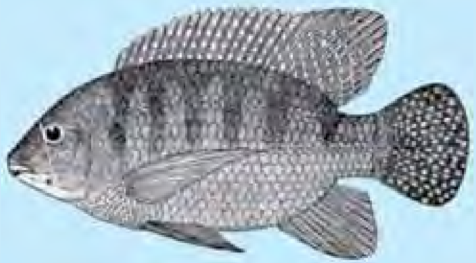
Distribution: Known from Ngami Basin, Okavango River; Cunene River and Mossamedes, Angola; upper Zambezi, Kafue River; middle Zambezi, Lake Kariba.

Oreochromis aureus (Steindachner, 1864)

Synonyms: *Chromis aureus* Steindachner, 1864 - *Tilapia aurea* (Steindachner, 1864): Trewavas, 1966 - *Sarotherodon aureus* (Steindachner, 1864): Trewavas, 1973 – *Tilapia monodi* Daget, 1954 - *Tilapia lemassoni* Blache & Miton, 1960

English name: Blue tilapia

French name: Tilapia bleu

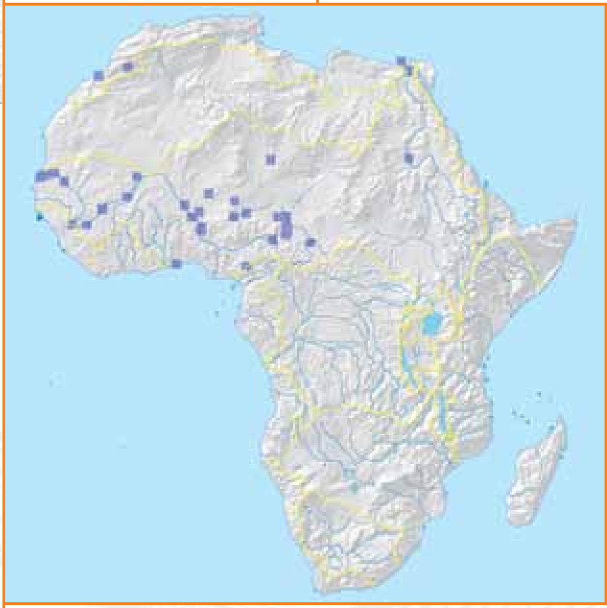


© Fishbase

Aquaculture: commercial

Fishery: commercial - bait

Aquarium: commercial



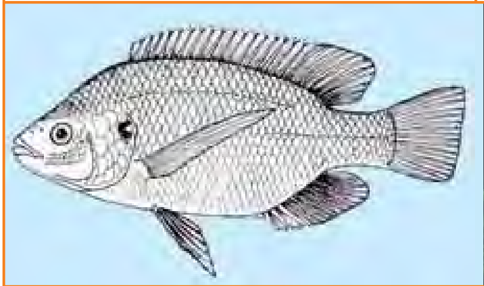
Max. size: 50.8 cm TL – 37 SL

Max. weight: 2.0 kg

Biology: Benthopelagic. May be found in brackish water. Occurs at temperatures ranging from 8° to 30°C. Considered a pest. Forms schools; is sometimes territorial; found in all types of habitats. Feeds on phytoplankton and small quantities of zooplankton. Juveniles have a more varied diet. Maternal mouthbrooder.

Distribution: The natural distribution of this species includes the Jordan Valley, Lower Nile, Chad Basin, Benue, middle and upper Niger, Senegal River.

Oreochromis esculentus (Graham, 1928)		
Synonyms: *Tilapia esculenta* Graham, 1928 - *Sarotherodon esculentus* (Graham, 1928) - *Tilapia eduardiana* (non Boulenger, 1912) - *Tilapia galilaea* (non Linnaeus, 1758) - *Tilapia variabilis* (non Boulenger, 1906)		
English name: Singida tilapia	**French name:**	



Aquaculture: commercial	**Fishery:** commercial - experimental	**Aquarium:**

Max. size: 50 cm LS

Max. weight: 2.5 kg

Biology: Benthopelagic. Occurs at temperatures ranging from 23.0 to 28.0°C. Tolerates low oxygen concentrations. Filter feeder. Food consists almost entirely of phytoplankton but also includes small animals such as insects and their larvae, and crustaceans. Maternal moutbrooder.

Distribution: Includes Lake Victoria, Lake Nabugabo, Lakes Kyoga and Kwania, and the Victoria Nile above Murchison Falls; the Malawa River (Uganda) and Lake Gangu, west of Lake Victoria. This species, which was originally endemic to Lake Victoria, is widely distributed in dams.

Oreochromis macrochir (Boulenger, 1912)

Synonyms: *Tilapia galilaea* (non Linnaeus) - *Tilapia nilotica* (non Linnaeus, 1758) - *Chromys chapmani* Castelnau, 1861 - *Tilapia andersonii* (non Castelnau, 1861) - *Chromys chapmannii* Castelnau, 1861 - *Chromys sparmanni* Castelnau, 1861 - *Tilapia squamipinnis* (non Günther, 1864) - *Tilapia natalensis* (non Weber, 1897) - *Tilapia macrochir* Boulenger, 1912 - *Loruwiala macrochir* (Boulenger, 1912) - *Sarotherodon macrochirus* (Boulenger, 1912) - *Oreochromis microchir* (Boulenger, 1912) - *Tilapia macrochir* Boulenger, 1912 - *Sarotherodon macrochir* (Boulenger, 1912) - *Tilapia kafuensis* (non Boulenger, 1912) - *Tilapia intermedia* Gilchrist & Thompson, 1917 - *Tilapia sheshekensis* Gilchrist & Thompson, 1917 - *Tilapia alleni* Fowler, 1931

English name: Longfin, Greenhead tilapia

French name: Tilapia noir

© Luc De Vos

Aquaculture: commercial

Fishery: commercial - sport

Aquarium:

Max. size: 43.0 cm SL

Max. weight:

Biology: Benthopelagic. Mates around a central volcano-shaped mound. Prefers quiet, deep water containing aquatic vegetation. Occasionally forms schools, is mainly diurnal. Feeds mostly on detritus, (blue-green) algae and diatoms. Maternal mouthbrooder.

Distribution: Known from Kafue, upper Zambezi, and Congo River systems; introduced elsewhere in Africa and in Hawaiian Islands. Also in the Okavango and Ngami region, Cunene Basin, Chambezi and Bangweulu regions.

Oreochromis mossambicus (Peters, 1852)

Synonyms: *Chromis mossambicus,* Peters, 1852 - *Tilapia arnoldi* Gilchrist & Thompson, 1917 - *Tilapia kafuensis* (non Boulenger, 1912) - *Chromis niloticus* (non Linneaus, 1758) - *Tilapia mossambica* (Peters, 1852) - *Sarotherodon mossambicus* (Peters, 1852) - *Chromis niloticus mossambicus* Peters, 1855 - *Chromis dumerilii* Steindachner, 1864 - *Tilapia dumerilii* (Steindachner, 1864) - *Chromis vorax* Pfeffer, 1893 - *Tilapia vorax* (Pfeffer, 1893) - *Chromis natalensis* Weber, 1897 - *Tilapia natalensis* (Weber, 1897) - *Sarotherodon mossambicus natalensis* (Weber, 1897)

English name: Mozambican tilapia

French name: Tilapia du Mozambique

© A. Lamboj

Aquaculture: commercial

Fishery: commercial - sport

Aquarium: commercial

Max. size: 39 cm SL

Max. weight: 1.1 kg

Biology: Benthopelagic. Highly euryhaline (able to adapt to a wide range of salinities). Grows and reproduces in fresh, brackish, and sea water. Tolerates low levels of dissolved oxygen. Considered a pest. Can be found in all kinds of habitats. Forms schools. Omnivorous; feeds mainly on algae and phytoplankton but also eats some zooplankton, small insects and their larvae. Juveniles are carnivorous/omnivorous, adults tend to be herbivorous or detritus feeders. Large specimens have been reported to prey on small fish. Maternal mouthbrooder.

Distribution: Naturally distributed in Lower Zambezi, Lower Shire and the coastal plains from Zambezi Delta to Algoa Bay. Occurs southward to the Brak River in the Eastern Cape and in the Transvaal in the Limpopo system. Widely introduced for aquaculture.

FILE VI. CICHLIDAE.

Oreochromis niloticus (Linneaus, 1758)

Synonyms: *Labrus niloticus* Linnaeus, 1758 - *Chromis niloticus* Günther, 1862 - *Tilapia nilotica* (Linnaeus, 1758) - *Sarotherodon niloticus* (Linnaeus, 1758)

English name: Nile tilapia	**French name:** Tilapia du Nil

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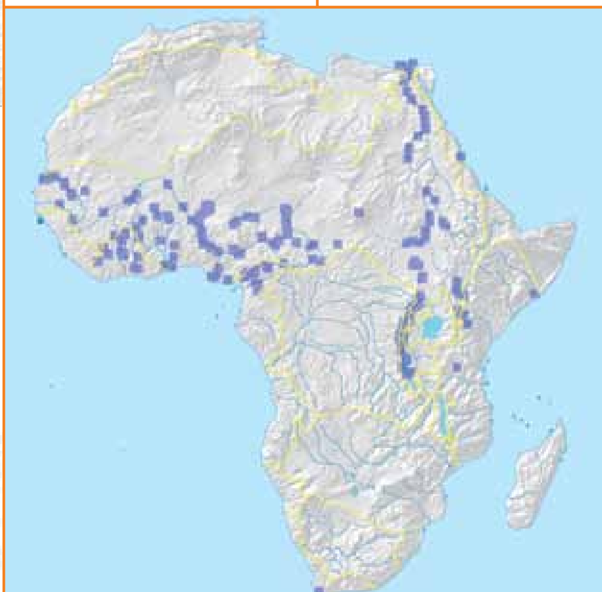
Aquaculture: commercial	**Fishery:** commercial	**Aquarium:** commercial



Max. size: 74 cm TL – 39.5 SL

Max. weight: 4.3 kg

Biology: Benthopelagic. Considered to be a pest. Found in all kinds of habitats. Diurnal. Feeds on phytoplankton and algae. Maternal mouthbrooder.

8 sub-species of *Oreochromis niloticus* are recorded:
O. n. baringoensis, O. n. cancellatus, O. n. eduardianus, O. n. filoa, O. n. niloticus, O. n. sugutae, O. n. tana, O. n. vulcani.

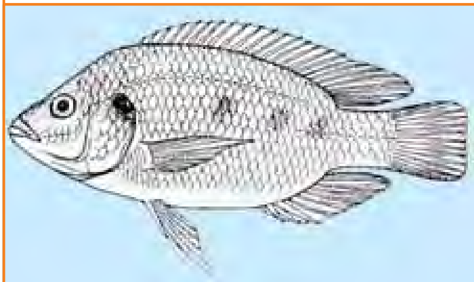
Distribution: *O. n. niloticus*: coastal rivers of Israel; Nile from below Albert Nile to the delta; Jebel Marra; basins of the Niger, Benue, Volta, Gambia, Senegal and Chad. - *O. n. baringoensis*: endemic to Lake Baringo, Kenya. *O. n. cancellatus*: Ethiopian Rift Valley, Lake Beseka and the Awash system. *O. n. edouardianus:* Albert Nile; Lakes Albert, Edward, George, Kivu; River Ruzizi and Lake Tanganyika. Introduced in Lake Victoria. *O. n. filoa:* Awash system. *O. n. sugutae*: Suguta River in Kenya. *O. n. tana*: Lake Tana. *O. n. vulcani*: Lake Turkana (Rudolf) and the surrounding area.

Oreochromis shiranus Boulenger, 1897

Synonyms: *Sarotherodon shiranus* (Boulenger, 1897) - *Sarotherodon shiranus subsp. shiranus* (Boulenger, 1897) - *Tilapia placida* (non Trewavas, 1941) - *Tilapia shirana* (Boulenger, 1897) - *Tilapia shirana subsp. chilwae* Trewavas, 1966 - *Tilapia shirana subsp. shirana* (Boulenger, 1897)

English name:

French name:



© Fishbase

Aquaculture: commercial

Fishery: commercial

Aquarium: commercial

Max. size: 39 cm SL

Max. weight:

Biology: Benthopelagic. Found mainly in densely vegetated shallow waters around Lake Malawi. Mainly diurnal; feeds on detritus and phytoplankton. Maternal mouthbrooder.

2 sub-species of *Oreochromis shiranus* have been identified: *O. s. shiranus, O. s. chilwae*

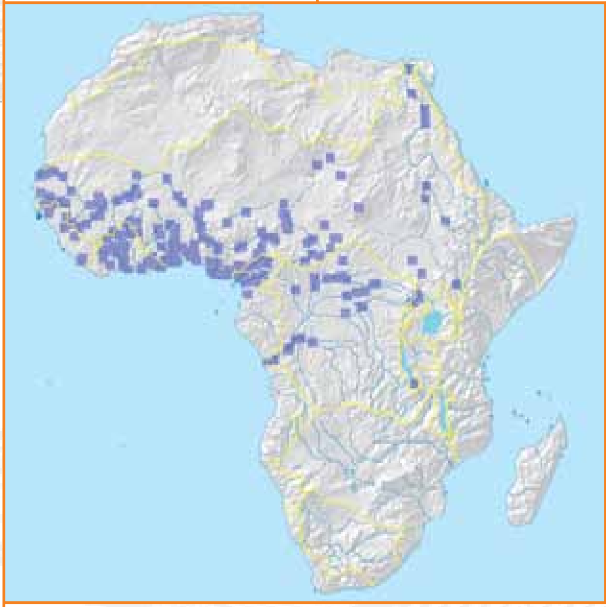
Distribution: *O. s. shiranus:* Shire River above the Murchison Rapids and its tributaries; Lake Malawi and its tributary rivers, streams and lagoons; upper Shire.
O. s. chilwae: Lake Chilwa and its basin in Malawi and Mozambique.

Sarotherodon galileus (Linneaus, 1758)

Synonyms: *Sparus galilaeus* Linnaeus, 1758 - *Tilapia galilaea* (Linnaeus, 1758) - *Tilapia galilaea galilaea* (Linnaeus, 1758) - *Tilapia pleuromelas* Duméril, 1859 - *Tilapia lateralis* Duméril, 1859 - *Tilapia macrocentra* Duméril, 1859 - *Chromis multifasciatus* Günther, 1903 - *Tilapia multifasciata* (Günther, 1903) - *Tilapia galilaea multifasciata* (Günther, 1903)

English name: Mango tilapia	**French name:**

Aquaculture: commercial	**Fishery:** commercial	**Aquarium:**



Max. size: 41 cm TL – 34 SL

Max. weight: 1.6 kg

Biology: Demersal. Occasionally forms schools; territorial. Prefers open waters but juveniles and breeding adults are found inshore. Feeds on algae and fine organic debris. Bi-parental mouthbrooder.

5 sub-species of *Sarotherodon galileus* have been identified: *S. g. borkuanus, S. g. boulengeri, S. g. galileus, S. g. multifasciatus, S. g. sanagaensis.*

Distribution: *S. g. borkuanus*: Saharan oases, Borku, Ennedi and Tibesti in northern Chad. *S. g. boulengeri*: Lower Congo from Malebo (Stanley) Pool to Matadi. *S. g. galileus*: Jordan system, especially in lakes; coastal rivers of Israel; Nile system, including the delta lakes and Lake Albert and Turkana; central Congo basin, Ubanghi and Uele Rivers; in West Africa in Senegal, Gambia, Casamance, Géba, Konkouré, Niger, Volta, Mono, Ouémé, Ogun, Cross, Benue, Logone, Shari and Lake Chad. *S. g. multifasciatus*: Côte d'Ivoire (Sassandra, Bandama, and Comoé Rivers) to western Ghana (Tano River and Lake Bosumtwi). *S. g. sanagaensis*: known to live only in the Sanaga River system, Cameroon.

Sarotherodon melanotheron Rüppel, 1852

Synonyms: *Tilapia heudelotii* Duméril, 1859 - *Tilapia heudelotii heudelotii* Duméril, 1859 - *Tilapia rangii* Duméril, 1859 - *Tilapia multifasciata macrostoma* Pellegrin, 1941 - *Sarotherodon melanotheron paludinosus* Trewavas, 1983 - *Tilapia melanotheron* (Rüppell, 1852) - *Chromis microcephalus* Günther, 1862 - *Tilapia microcephala* (Günther, 1862) - *Melanogenes macrocephalus* Bleeker, 1862 - *Tilapia macrocephala* (Bleeker, 1862) - *Tilapia leonensis* Thys van den Audenaerde, 1971

English name: Blackchin tilapia

French name: Tilapia à gorge noire

© Y. Fermon

Aquaculture: commercial

Fishery: commercial

Aquarium: commercial

Max. size: 31 cm TL

Max. weight:

Biology: Demersal. Primarily in estuaries and lagoons. Abundant in mangrove areas. Potential pest. Forms schools; is mainly nocturnal with intermittent daytime feeding. Feeds on aufwuchs (small animals and plants encrusted on hard substrates, such as rocks) and detritus.

3 sub-species of *Sarotherodon melanotheron* have been identified:
S. m. heudelotii, S. m. melanotheron, S. m. leonensis.

Distribution: *S. m. heudelotii*: lagoons and estuaries from Mauritania to Sierra Leone.
S. m. melanotheron: lagoons and estuaries from Côte d'Ivoire to Cameroon.
S. m. leonensis: brackish areas and freshwater near the coast of Sierra Leone and western Liberia. Sometimes found in the sea.

Tilapia guineensis (Bleeker *in* Günther, 1862)

Synonyms: *Chromis guineensis* Bleeker in Günther, 1862 - *Haligenes guineensis* Bleeker, 1863 - *?Tilapia affinis* Duméril,1858 - *?Chromis latus* Günther, 1862 - *?Tilapia lata* (Günther, 1862) - *?Tilapia polycentra* Duméril, 1858

English name: Guinea tilapia

French name: Tilapia de Guinée, Carpe

Aquaculture: commercial

Fishery: commercial

Aquarium:

Max. size: 35 cm TL - 28.2 SL

Max. weight:

Biology: Found also in brackish waters. Benthopelagic. Feeds on shrimp, bivalves, plankton and detritus. Oviparous. Substrate spawner.

Distribution: Known from coastal waters from mouth of the Senegal River to mouth of the Cuanza River (Angola), sometimes ascending far up-river.

Tilapia mariae Boulenger, 1899

Synonyms: *Tilapia dubia* Lönnberg, 1904 - *Tilapia heudeloti* (non Duméril, 1861) - *Tilapia mariae dubia* Lönnberg, 1904 - *Tilapia meeki* Pellegrin, 1911 - *Tilapia melanopleura* (non Duméril, 1861) - *Tilapia microcephala* (non Günther, 1862)

English name: Spotted tilapia	**French name:** Tilapia à 5 bandes

© Fishbase

Aquaculture:	**Fishery:**	**Aquarium:** commercial

Max. size: 39.4 cm TL - 23 SL

Max. weight: 1.4 kg

Biology: Demersal. May be found in brackish water. Considered a pest. Lives in still or flowing water, in rocky or mud-bottom areas. Consumes plant matter. Reaches sexual maturity at a length of 10-15 centimeters. Parents prepare nest sites on logs, leaves and other debris. Eggs (600-3300 per female) are guarded by the parents and hatch in 1-3 days. Parental care of the brood continues until the fish are about 2.5 to 3.0 centimeters. Substrate spawner.

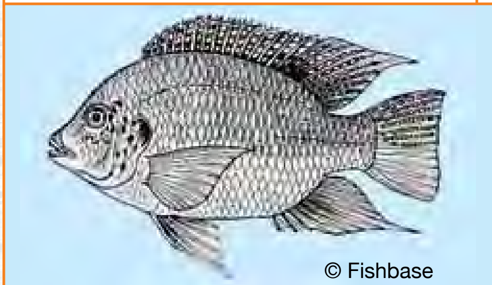
Distribution: Known from coastal lagoons and lower river courses from the Tabou River (Côte d'Ivoire) to the Kribi River (Cameroon), but absent from the area between the Pra River (Ghana) and Benin.

Tilapia rendalli (Boulenger, 1897)

Synonyms: *Chromis rendallii* Boulenger, 1896 – *Tilapia sexfasciata* Pellegrin, 1900 – *Tilapia latifrons* Boulenger, 1906 –*Tilapia christyi* Boulenger, 1915 – *Tilapia druryi* Gilchrist & Thompson, 1917 – *Tilapia kirkhami* Gilchrist & Thompson, 1917 – *Tilapia mackeani* Gilchrist & Thompson, 1917 – *Tilapia sykesii* Gilchrist & Thompson, 1917 – *Tilapia swierstrae* Gilchrist & Thompson, 1917 – *Tilapia gefuensis* Thys van den Audenaerde, 1964 –*Tilapia zillii* (non Gervais, 1848) - *Tilapia melanopleura rendalli* (Boulenger, 1897) - *Tilapia melanopleura* (non Duméril, 1861) - *Tilapia lata* (non Günther, 1862) - *Tilapia melanopleura swierstrae* Gilchrist & Thompson, 1917

English name: Redbreasted tilapia

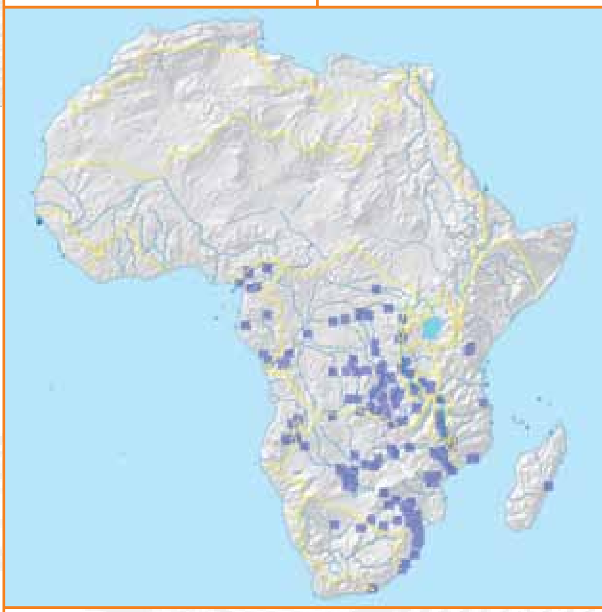
French name: Tilapia à poitrine rouge, carpe



Aquaculture: commercial

Fishery: commercial - sport

Aquarium: commercial



Max. size: 45 cm TL

Max. weight: 2.5 kg

Biology: Demersal. Considered to be a pest. Prefers quiet, well-vegetated water along river littorals (close to the shore) or backwaters, floodplains and swamps. Forms schools; is mainly diurnal. Juveniles feed on plankton. Adults feed mainly on higher plants as well as algae, insects and crustaceans. Tolerates a wide range of temperatures and salinities.

Distribution: Known from Senegal and Niger River, Congo River system, Zambezi River system, Lake Tanganyika and Malagarazi. Also known from Shaba, upper Kasaï, Lualaba system, Lake Malawi, Natal, Okavango and Cunene. Introduced elsewhere.

Tilapia zillii (Gervais, 1848)

Synonyms: *Acerina zillii* Gervais, 1848 - *Haligenes tristrami* Günther, 1859 - *Tilapia melanopleura* Duméril, 1859 - *Chromis andreae* Günther, 1864 - *Chromis caeruleomaculatus* de Rochebrune, 1880 - *Chromis faidherbii* de Rochebrune, 1880 - *Chromis menzalensis* Mitchell, 1895 - *Tilapia sparrmani multiradiata* Holly, 1928 - *Tilapia shariensis* Fowler, 1949

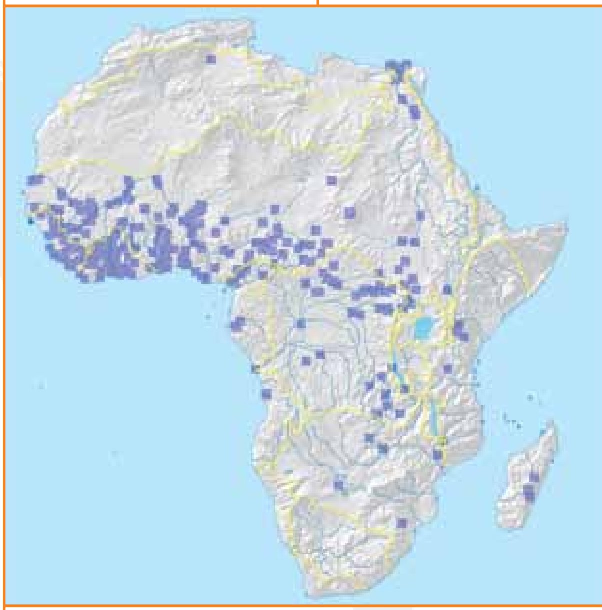
English name: Redbelly tilapia

French name: Tilapia à ventre rouge

Aquaculture: commercial

Fishery: commercial

Aquarium: commercial



Max. size: 49 cm TL - 21 SL

Max. weight:

Biology: Demersal. Occasionally forms schools; mainly diurnal. Prefers shallow, vegetated areas. Alevins are common in marginal vegetation and juveniles are found in seasonal floodplains. Herbivorous. Substrate spawner.

Distribution: Found in South Morocco, Sahara, Niger-Benue system, Senegal, Sassandra, Bandama, Boubo, Mé, Comoé, Bia, Ogun and Oshun Rivers, Volta system, Chad-Shari system, Ubangi-Uele-Ituri Rivers (Democratic Republic of the Congo), Lakes Mobutu and Turkana, Nile system and Jordan system. Introduced in several countries.

Hemichromis « vert »: *H. fasciatus* Peters, 1852 - *H. elongatus* (Guichenot, 1861)

This group includes several species but neds more taxonomic investigation. Two main species that are regularly confused are *H. fasciatus* and *H. elongatus*.

Synonyms: *H. fasciatus: H. leiguardii* Capello, 1872 - *?Hemichromis desguezii* de Rochebrune, 1880 - *Hemichromis frempongi* Loiselle, 1979. *H. elongatus*: *Hemichromis auritus* Gill, 1962

English name: Banded jewelfish	**French name:** Hemichromis rayé

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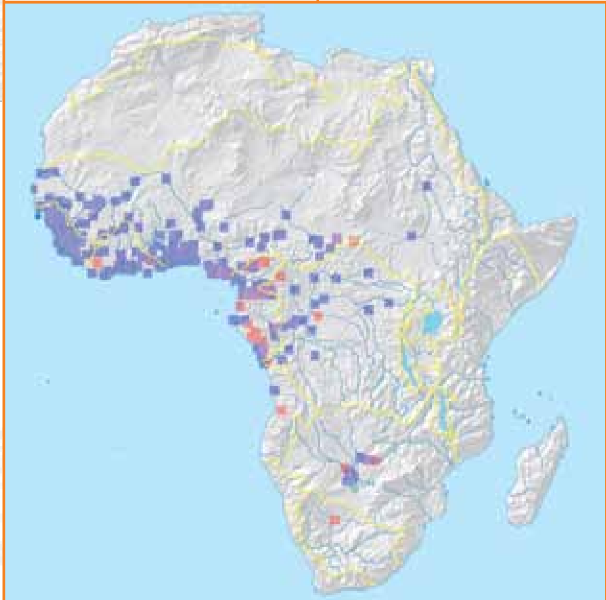
Aquaculture: commercial	**Fishery:** subsistence	**Aquarium:** commercial



Max. size: 25 cm TL - 20.4 SL

Max. weight: 0.3 kg

Biology: Benthopelagic. Potamodromous (migrates in fresh water only). Found in savannahs and forests. Feeds on fish, shrimp and aquatic insects; very aggressive and territorial. Substrate spawner.

Distribution: *H. fasciatus* (in blue on the map): Found from the Nile basin to the East and in Central regions such as Lake Chad. Widely distributed from Senegal to Congo.

H. elongatus (in red on the map). Found from Sierra Leone to Okavango and Zambezi basins.

Serranochromis angusticeps (Boulenger, 1907)		
Synonyms: *Chromys levaillantii* Castelnau, 1861- *Serranochromis levaillantii* (Castelnau, 1861) - *Tilapia levaillantii* (Castelnau, 1861) - *Paratilapia robusta* (non Günther, 1864) - *Paratilapia angusticeps* Boulenger, 1907 - *Paratilapia kafuensis* Boulenger, 1908 - *Serranochromis kafuensis* (Boulenger, 1908)		
English name: Thinface largemouth	**French name:**	
Aquaculture: commercial	**Fishery:** commercial - sport	**Ornement:** commercial

Max. size: 41 SL

Max. weight: 2.5 kg

Biology: Demersal. Lives in well-vegetated swamps and along the edges of rivers. Also lives in fast-flowing reaches over sand and rocks. Feeds on small fish, shrimp and insects. A mouthbrooding species.

Distribution: Cunene River system, Okavango River, upper Zambezi, and Kafue Rivers, and Luapula-Moeru.

Serranochromis robustus (Günther, 1864)

Synonyms: *Chromys levaillantii* Castelnau, 1861- *Serranochromis levaillantii* (Castelnau, 1861) - *Tilapia levaillantii* (Castelnau, 1861) - *Paratilapia robusta* (non Günther, 1864) - *Paratilapia angusticeps* Boulenger, 1907 - *Paratilapia kafuensis* Boulenger, 1908 - *Serranochromis kafuensis* (Boulenger, 1908)

English name: Yellow-belly bream

French name:

© K. Winnemiller

Aquaculture:

Fishery: commercial - sport

Aquarium:

Max. size: 56 TL

Max. weight: 6.1 kg

Biology: Demersal. Found in sandy and vegetated areas as well as over rocky substrates. Feeds on fish and sand-dwelling invertebrates (Ref. 5595). Larger specimens prefer deep main channels and permanent lagoons, whereas smaller fish occur mainly in lagoons and secondary channels. Oviparous. Breeds in summer, nesting along vegetated stream banks. Mouthbrooder.

2 sub-species of *Serranochromis robustus* have been identified:
S. r. robustus, S. r. jallae.

Distribution: *S. r. robustus:* Found in Lake Malawi and the upper Shire River. Reported from Luongo River, Congo system, Zambia. Translocated to the upper Ruo River in Malawi and also to Swaziland.
S. r. jallae: Found in Cunene River, Okovango River, upper Zambezi River, Kafue River, middle Zambezi River including the Luangwa River; Luapula-Moero, Lualaba and Kasai (Congo River system). Translocated to areas in Zimbabwe, to the Limpopo River and to Natal, South Africa.

Clarias (Clarias) gariepinus (Burchell, 1822)

Synonyms: *Silurus (Heterobranchus) gariepinus* Burchell, 1822 - *Clarias syriacus* Valenciennes, 1840 - *Clarias capensis* Valenciennes, 1840 - *Clarias lazera* Valenciennes, 1840 - *Clarias mossambicus* Peters, 1852 - *Clarias xenodon* Günther, 1864 - *Clarias macracanthus* Günther, 1864 - *Clarias orontis* Günther, 1864 - *Clarias robecchii* Vinciguerra, 1893 - *Clarias microphthalmus* Pfeffer, 1896 - *Clarias smithii* Günther, 1896 - *Clarias guentheri* Pfeffer, 1896 - *Clarias micropthalmus* Pfeffer, 1896 - *Clarias longiceps* Boulenger, 1899 - *Clarias moorii* Boulenger, 1901 - *Clarias vinciguerrae* Boulenger, 1902 - *Clarias tsanensis* Boulenger, 1902 - *Clarias malaris* Nichols & Griscom, 1917 - *Clarias notozygurus* Lönnberg & Rendahl, 1922 - *Clarias depressus* Myers, 1925 - *Clarias muelleri* Pietschmann, 1939

English name: North African catfish

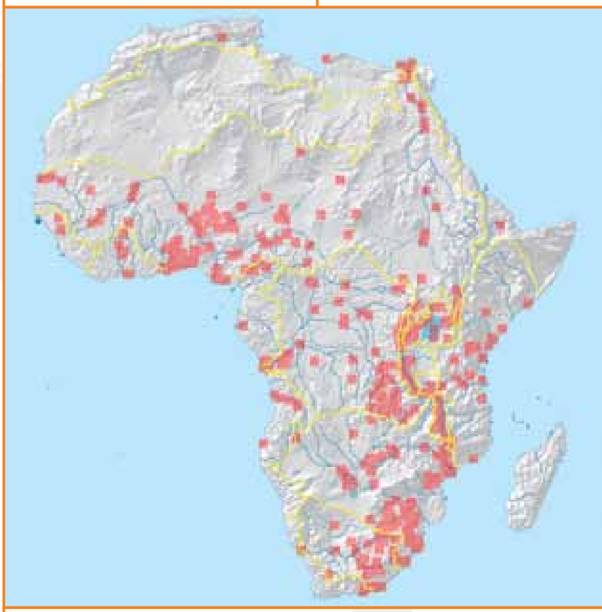
French name: Silure, poisson-chat nord africain

© Y. Fermon

Aquaculture: commercial

Fishery: minor commercial

Aquarium:



Max. size: 170 TL

Max. weight: 60 kg

Biology: Benthopelagic. Occurs mainly in quiet water, but can be found everywhere. Widely tolerant of extreme environmental conditions. Has an accessory breathing organ that enables this species to breathe air, so it can move from place to place on its pectoral fins. Forages at night on a wide variety of prey. Feeds on insects, plankton, invertebrates and fish but also eats young birds, rotting flesh and plants. Migrates to rivers and temporary streams to spawn. It has been noted that it generates weak electric discharges.

Distribution: Almost Pan-Africa, absent from Maghreb, the upper and lower Guinea and the Cape Province and probably also Nogal Province. Asia: Jordan, Israel, Lebanon, Syria and southern Turkey. Widely introduced to other parts of Africa, Europe and Asia. Several countries report adverse ecological impact after introduction.

Heterobranchus longifilis Valenciennes, 1840

Synonyms: *Heterobranchus laticeps* Peters, 1852 - *Clarias loangwensis* Worthington, 1933 - *Heterobranchus platycephalus* Nichols & LaMonte, 1934

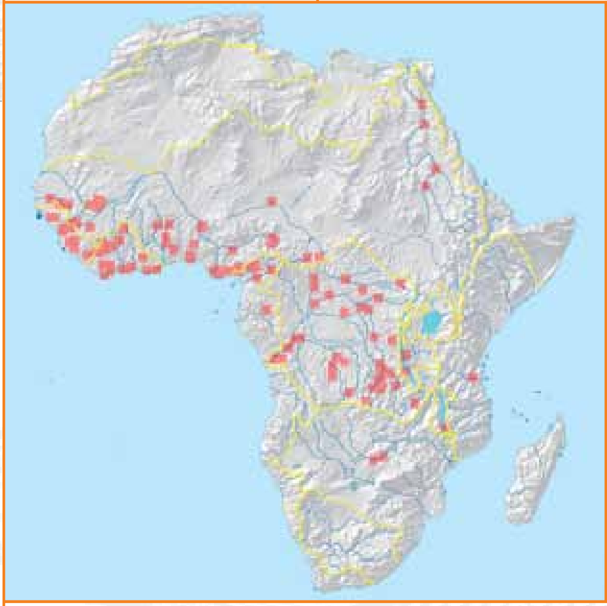
English name: Vundu

French name: Silure, Vundu

Aquaculture: commercial

Fishery: minor commercial

Aquarium: commercial



Max. size: 150 cm SL

Max. weight: 55 kg

Biology: Demersal. Occurs in large rivers or in deep pools and lakes. Most active at night, feeding on any available food, including invertebrates and insects when small, fish and other small vertebrates when large.

Distribution: Found in Nile, Niger, Senegal, Congo system, upper and middle Zambezi. Also in Lakes Tanganyika and Edward, Gambia and Benue River, Chad and Volta basins, and coastal basins from Guinea to Nigeria.

Heterotis niloticus (Cuvier, 1829)

Synonyms: *Clupisudis niloticus* (Cuvier, 1829) - *Sudis niloticus* Cuvier, 1829 - *Sudis nilotica* Cuvier, 1829 - *Sudis adansonii* Cuvier, 1829 - *Heterotis nilotica* (Cuvier, 1829) - *Heterotis adansonii* (Cuvier, 1829) - *Heterotis ehrenbergii* Valenciennes, 1847 - *Heterotis adansoni* Valenciennes, 1847

English name: African bonytongue, Heterotis	**French name:** Poissons sans nom, Heterotis

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Aquaculture: commercial	**Fishery:** commercial	**Ornement:** commercial

Max. size: 100 cm SL

Max. weight: 10.2 kg

Biology: Pelagic. Has auxiliary branchial air breathing organs that enable it to survive in deoxygenated water. Feeds mostly on plankton. During breeding, creates a circular nest in swamps. Young leave the nest after a few days and are guarded by the male.

Distribution: For this species, we must distinguish between the present area of occurrence, resulting from man-made introductions, and its original, natural geographical distribution area. It is generally accepted that the first introductions were made in the early 1950s. Original (natural) distribution: all water-basins of the Nilo-Sudanese region: Corubal, Senegal, Gambia, Volta, Niger (as well as Benue), Chad, Nile, Omo Rivers and Lake Turkana. Areas of successful introduction: artificial reservoirs in Côte d'Ivoire (Bandama and Bia basins), Cross, Sanaga, Nyong, Ogowe, Lower and Middle Congo Rivers (the species was apparently unable to overcome the Kisangani Falls), as well as Ubangui and Kasaï Rivers. Attempts to introduce the species to Madagascar have generally failed, although it may occur in certain river basins along the eastern coast of the island.

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