Chapter 6
Fisheries

Contents

Brief Description of the Sector

Fisheries are an important source of food, employment and revenue worldwide. Of all the animal protein consumed in Africa in 1997, 17.2 percent was from fish (Taco 2001). The fisheries sector is divided into two major sub-sectors: capture fisheries and aquaculture. The term "capture fisheries" is applied to the practice of harvesting wild fish and other aquatic organisms. Both industrial and artisanal fishing practices fall under this category.

Aquaculture is the practice of raising and harvesting fish and aquatic organisms under controlled circumstances. Typically, aquaculture is used to grow finfish (salmon, milkfish, carp, tilapia), mollusks (mussels, oysters, clams), shrimp and seaweed. Aquaculture can be pursued in fresh, brackish and salt-water bodies.

Aquaculture was introduced into Africa in the 1950's. During the 1960s, however, aquaculture development sharply regressed and most ponds were abandoned for a variety of reasons: lack of secure land tenure, farmers' reluctance to adopt aquaculture technologies, shortages of labor and stocking material, drought, and political turmoil. With donor support, aquaculture is again taking root in Africa, although it is still practiced mainly by small farmers as a secondary or part-time activity in freshwater ponds in rural areas. According to FAO statistics, aquaculture (fresh, salt, and brackish) produced 2.56 percent as much fish in 1995 as inland capture fisheries (Aguilar-Manjarrez, FAO, 1998).

There are two basic modes of practicing aquaculture: intensive and extensive. **Intensive aquaculture** subjects an organism to hatchery-controlled conditions for most of the life cycle. This form is most commonly applied to finfish. In salmon aquaculture, for example, the fish are hatched, reared and fed in controlled ponds until they are big enough to harvest. **Extensive aquaculture** usually involves unsophisticated technology, relies on natural food and has a low input-to-output ratio. Typically, only part of the life cycle is controlled. Extensively operated fish ponds often rely on a supply of young fish from the wild, and use minimal feed and fertilizer inputs.

Small-Scale Fish Farming in Rwanda

Rwandan fish farmers were surveyed in 1998 to estimate the costs and returns of extensive aquaculture, sweet potato, Irish potato, cassava, taro, sorghum, maize, sweet peas, beans, soybeans, peanuts, rice and cabbage production. Fish farming—predominately Nile tilapia (*Oreochromis niloticus*), *Tilapia rendalli*, and common carp *(Cyprinus carpio)*—yielded the highest cash income per unit of land. Sweet potatoes produced the highest carbohydrate yield, while soybeans were the least expensive source of protein. Because of the high economic returns from aquaculture, farmers kept only 31 percent of their fish harvest for consumption; 61 percent was sold as a cash crop. Income from fish culture was used for a variety of purposes, including re-investment in fish farming or other agricultural activities; payment of children's school fees and taxes; purchasing household goods, medicines, lands and livestock; and savings in bank accounts.

Source: Hishamunda et al., 1998.

Small-scale fisheries provide many benefits to both farmers and the environment. For poor farmers, they are both a major cash crop and an important source of protein. For local communities, aquaculture can create employment and diversify income-generating activities. In addition, aquaculture can serve as insurance against long-term shortfalls in capture fishery yields. It can prevent over-exploitation of finite stocks and minimize competition for land use. Moreover, aquaculture can provide active benefits to water bodies, such as improving productive capacity and water quality, converting polluting waste products into fish protein, controlling the spread of diseases such as malaria and schistosomiasis, and providing sewage treatment and low-cost weed clearance in irrigation systems. Finally, wastes from aquaculture can be used as fertilizer for agricultural production.

Fish Population Collapse in Malawi's Lake Malombe

Fish stocks on the Upper Shire River, the water body connecting Lake Malawi to Lake Malombe, are seriously depleted. Catch of chambo, the primary fish stock, collapsed from 570 tons in 1983 to 96 tons in 1991. In Lake Malombe, kumbuzi, a small fish making the bulk of the catch after chambo stocks plummeted, is also in decline. The value of the total catch on the lake fell nearly 70 percent from 1983 to 1991. This has prevented thousands of fishermen from earning a living and feeding their families.

The populations of both the river and the lake collapsed due to over-fishing by artisan fisherman. Because neither water body was managed, the fishermen went from using 3-inch nets to half- and quarter-inch nets to catch smaller and smaller fish. Seine fishing, introduced to catch the smaller fish, worsened the collapse by reducing aquatic vegetation, removing nutrient-rich sediment and destroying nursery areas.

Malawi’s fisheries department instituted rules to conserve stocks, including regulating net mesh sizes, controlling night fishing and closing fishing grounds for most of the year. These regulations were widely disregarded, however, and the department lacked funds to enforce them.

A community-based management project sponsored by FAO and the United Nations Development Programme (UNDP) was more successful at sustainably managing the water bodies. The project established beach village committees who created rules and then policed them in partnership with the authorities. New fishermen were obliged by local custom to report first to the local headman, making them easier to track. "There was one fisherman … using a tiny mesh," recalled Michael Sambakunfi, the committee's secretary. "When members saw it was actually a mosquito net, they grabbed it and burned it." FAO estimates that 90 to 95 percent of area fishermen observe the committee rules.

Many families combine fishing with part- or full-time agriculture, growing mainly maize and groundnuts. Poor people who only crew the boats, however, earn too little to afford land to farm. During the 1992–1995 drought, fish stocks on Lake Malombe dropped again, and many people fenced off gardens on the lakebed to grow dry-season vegetables and maize.

Experts believe the committees will have to further limit the number of boats allowed to fish in the waters to achieve sustainability. However, jobs are difficult to find outside the fishing industry, and one of the dangers facing the project is that people will fish illegally if they cannot secure extra money. GTZ, the World Bank, and FAO/UNDP have all been actively promoting new industries and small businesses to help replace the income lost from fishing. If adequate means of supporting and feeding the community are found, the committees hope to close Lake Malombe to fishing for two years to allow fish populations to return.

Source: Alyanak, Leyla. FAO, 1996.

Potential Environmental Impacts of Development Programs in the Sector and Their Causes

Many of the impacts summarized below can be avoided through careful resource management and through sound planning and design of small-scale fisheries. Significant adverse impacts may include:

For Capture Fisheries

Over-harvesting. Widespread, unsustainable fishing practices have left capture fisheries with a shrinking resource base. FAO estimates that 11 of the world's 15 major fishing areas and 69 percent of the world's major fish species are in decline and in urgent need of management. Over-fishing by foreign fleets, particularly in West Africa, has depleted local fish stocks, forcing small-scale fishermen to fish further out to sea—a safety hazard—or in protected areas such as marine national parks. As harvests of valuable fish stocks decrease, fisherman are forced to collect lower-value fish, resulting in less return on investment and continuing the cycle of over-harvesting. (See the box on facing page.)

By-catch. Some types of fishing equipment—such as nets with small mesh sizes, trawlers, and long lines—collect both the desired species (catch) and many non-target species (by-catch). For example, driftnets entangle and drown birds, sharks, whales and dolphins. Prompted by governments and conservation groups around the world, the United Nations banned large-scale driftnetting on the high seas in 1993. Smaller driftnets, however, are still being used in coastal waters.

By-catch includes unwanted or undersized animals. These animals are culled and returned to the sea, often dead or dying; the populations of many non-target species are dropping as a result. In many cases, the discarded animals are juveniles, which increases the rate of population collapse.

Toxic Substances. Toxic substances, such as cyanide, and techniques like dynamiting and electrocution are used to more easily harvest fish. But cyanide, which anesthetizes fish for harvesting, also poisons coral reefs and non-target organisms. Dynamite fishing, practiced in the coastal zone of Eastern Africa, damages coral reefs and has caused fisheries to decline in these areas.

Endangered Species. Nearly 150 fish species are threatened in Africa, due to a combination of over-harvesting, habitat destruction and the introduction of exotic animals that compete with native species. Loss of fish populations leads to economic hardship for artisan fishermen and reduces food security for the entire population.

For Aquaculture

Pollution. Aquaculture systems cause pollution in a variety of ways:

- Pond water discharged into coastal areas or streams can adversely affect sedimentation rates, the nutrient cycle, and dissolved oxygen (DO) levels, and can raise sedimentation rates, accelerate the nutrient cycle and lower dissolved oxygen levels. These changes can lead to eutrophication, a state where a water body is polluted with excess nutrients, which remove dissolved oxygen from the water and cause rapid plant growth, including toxic algal blooms. These toxins may concentrate in shellfish, creating a serious risk to human health. Degraded organic materials from pond bottoms release toxic sulfide compounds and ammonia into the water. The net result from these combined nutrient changes may be decreased water quality and increased stress on aquatic life, with damage to capture fisheries.

- Feeding regimes for bred species often cause excess food to accumulate below aquaculture pens. This excess food is consumed by benthic (bottom-dwelling) organisms or is left to decompose. Decomposition causes degradation of water quality and decreasing oxygen levels in the water body, which can be fatal to aquatic organisms. Consumption by benthic organisms, on the other hand, disrupts the balance of the entire ecosystem.
- Fish wastes from intensive aquaculture, in combination with decomposing excess food, also cause algal blooms.
- Anti-fouling agents are often used to prevent organism growth on cages and netting. Some anti-fouling agents, such as TBT, interfere with reproductive functions of both cultured and wild shellfish.
- Human activities associated with aquaculture also generate pollution. Human wastes generated from habitation near aquaculture cages can degrade water quality and create health hazards. For ease of access, fish processing facilities are often located near fishponds or enclosures. If wastes from fish-processing activities are disposed of in fishponds, this also damages water quality.

A Tilapia fishpond in Tanzania. The pond restricts water flow on a small stream. What will happen to downstream users if more ponds like this one are constructed?

Habitat Destruction. Because they are located in inter-tidal zones, mangrove forests are often cleared for replacement by aquaculture ponds. Mangroves, however, stabilize coastlines, reduce storm erosion, act as spawning and nursery areas for many fish and crustacea, and generally support a diverse population of grasses, birds, and other land-based and aquatic animals. Mangroves also serve as a renewable resource, providing firewood, timber, pulp, and charcoal for local communities. Destroying mangroves has disastrous effects on the environment, including destruction of shorelines and loss of fish breeding grounds. These habitat changes may cause fish populations to collapse.

Wetlands are often converted to freshwater aquaculture ponds. This results in flooding and loss of animal habitats, and adversely affects downstream water quality.

Impacts on freshwater sources. Intensive aquaculture requires large quantities of freshwater, usually obtained from groundwater or surface freshwater bodies. This leaves less water available for downstream uses, such as municipal water supply and agriculture. Pumping groundwater near coastal areas may cause saltwater to enter the aquifer and contaminate the underground reservoir. Groundwater extraction may also cause land subsidence (i.e., the land surface slumps or collapses). If aquaculture ponds are not designed properly, saltwater can seep into surface reservoirs, canals and rice paddies. As noted above, pond water is often discharged into freshwater bodies, adding excess nutrients and pollutants and increasing salinity. Salt can also seep into freshwater sources from poorly designed sediment disposal sites.

Disease. Intensive aquaculture uses a dense stocking rate with intentional overcrowding. Overcrowding may induce stress in aquatic organisms and increase their susceptibility to diseases. It also contributes to poor water quality and the rapid growth and transmission of parasites and pathogens, which may spread to wild populations and local capture fisheries. To treat and prevent disease, a variety of chemicals are used, including antibiotics, parasiticides (parasite-killing drugs), pesticides, hormones, anesthetics, pigments, minerals, and vitamins. These chemicals are generally used in finfish or hatchery aquaculture, and applied along with feed. They may disperse beyond the pens and affect non-target organisms. Application of antibiotics also leads to the creation and spread of antibiotic-resistant bacteria.

Adverse effects on other organisms. Organisms escaping from aquaculture systems may have adverse impacts on wild populations. Species bred or genetically engineered for aquaculture are selected for high growth rates and/or disease resistance, usually at the expense of other survival characteristics. If these animals compete and interbreed with wild populations, the net result can be populations which are less genetically diverse and possibly less resistant to environmental changes.

If the escaping organisms are exotic to the area or water body into which they escape, where they are used, they may interfere with the food, habitat and spawning areas of native species. Non-native species are also a source of new diseases and predators.

Nearly all marine and brackish water aquaculture requires inputs from natural fisheries. Wild organisms or larvae are generally used as seed stock for aquaculture operations. Collecting larvae or young animals, if not done carefully, may depress the world population of the species to dangerously low levels.

Aquaculture based on carnivorous organisms (such as salmon and shrimp) requires large quantities of fishmeal. Fishmeal is manufactured from harvests of “trash fish,” fish not otherwise consumed by people. Growing a pound of salmon may require 3–5 pounds of wild fish, and between 1985 and 1995 the world's shrimp farmers used 36 million tons of wild fish to produce just 7.2 million tons of shrimp (Emerson 1999). Expanding aquaculture by harvesting more trash fish may lead their populations to collapse, not only making the aquaculture unsustainable but endangering other aquatic animals that feed on trash fish.

Clustering and poor siting of aquaculture facilities can obstruct access to water resources by wild populations. Predators, often drawn to aquaculture sites, may become entangled in net pens and drown.

Adverse impacts on downstream users. As mentioned previously, intensive and semi-intensive aquaculture systems require large volumes of fresh water, often drawn from surface waters. This practice leaves less water available for downstream users. In rural areas, this results in less water available to irrigate crops and forces women to travel further to collect water for household use. Also, seepage and discharges from fishponds can degrade the quality of water available to downstream users, affecting drinking water, agriculture, capture fisheries and recreational uses of water bodies.

The site of a proposed fishpond near Kibwaya, Tanzania. Six families grow rice on this land. Will they receive any compensation? What is the effect of introducing alternative uses?

Possible Environmental Impacts of Aquaculture Listed by Production Type[1]

Culture System	Environmental Impact
Extensive	
1. Seaweed culture	May occupy formerly pristine reefs; rough weather losses; market competition; conflicts/failures, social disruption.
2. Coastal bivalve culture (mussels, oysters, clams, cockles)	Public health risks and consumer resistance; microbial diseases, red tides, industrial pollution; rough weather losses; seed shortages; market competition, especially for export produce; failures, social disruption.
3. Coastal fishponds (mullet, milkfish, shrimp, tilapias)	Destruction of ecosystems, especially mangroves; increasingly non-competitive with more intensive systems; nonsustainable with high population growth; conflicts/failures, social disruption.
4. Pen and cage culture in eutrophic waters and/or rich benthos (carp, catfish, milkfish, tilapias)	Exclusion of traditional fishermen; navigational hazards; conflicts, social disruption; management difficulties; wood consumption.
Semi-intensive	
1. Fresh- and brackish water pond (shrimp and prawns, carp, catfish, milkfish, mullet, tilapias)	Freshwater: health risks to farm workers from waterborne diseases. Brackish water: salinization/acidification of soils/aquifers. Both: market competition, especially for export produce; feed and fertilizer availability/prices; conflicts/failures, social disruption.
2. Integrated agriculture-aquaculture (rice-fish; livestock/poultry-fish; vegetables-fish and all combinations of these)	As for freshwater above, plus possible consumer resistance to excreta-fed produce; competition from other users of fishmeal inputs (livestock and cereal production); toxic substances in livestock feeds (e.g., heavy metals) may accumulate in pond sediments and fish; pesticides may accumulate in fish.
3. Sewage-fish culture (waste treatment ponds; latrine wastes and septage used as pond inputs; fish cages in wastewater channels)	Possible health risks to farm workers, fish processors and consumers; consumer resistance to produce.
4. Cage and pen culture, especially in eutrophic waters or on rich benthos (carp, catfish, milkfish, tilapias)	As with extensive cage and pen systems above.

[1] Source: Pullin, *Third World Aquaculture and the Environment* (1989), as cited by Baluyut (1989).

Intensive	
1. Freshwater, brackish water and marine ponds (shrimp; fish, especially carnivores—catfish, snakeheads, grouper, sea bass, etc.)	Effluents/drainage high in Biological Oxygen Demand (BOD) and suspended solids; market competition, especially for export product; conflicts/failures, social disruption.
2. Freshwater, brackish water and marine cage and pen culture (finfish, especially carnivores—grouper, sea bass, etc.—but also some omnivores such as common carp)	Accumulation of anoxic sediments below cages due to fecal and waste feed build-up; market competition, especially for export produce; conflicts/failures, social disruption; consumption of wood and other materials.
3. Other—raceways, silos, tanks, etc.	Effluents/drainage high in BOD and suspended solids; many location-specific problems.

Sector Program Design—Some Specific Guidance

As with other program and project development activities, potentially damaging environmental impacts need to be addressed early in the design process in order to avoid costly mistakes or project failure. Listed here are good management practices and design criteria that can help prevent adverse impacts.

Best Management Practices for Capture Fisheries

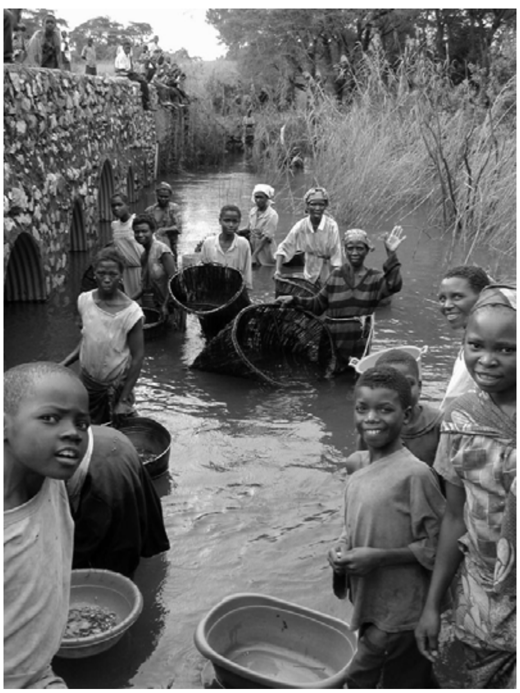
- Do not discharge toilets, washwater, non-oily bilge water, deck washwater, fish offal, or kitchen waste into coastal and sensitive waters.
- Exclude motorized vessels from areas that contain important shallow-water habitats.
- Establish no-wake zones for boats and ships to decrease erosion and turbidity.
- Use oil-absorbing materials in bilge areas of a boat's inboard engine; dispose of and replace them appropriately (see chapter on "Solid Waste Management" in these guidelines).
- Do not discharge bilge and ballast water with oil and grease concentration above 10 mg/liter.
- Clean boats in the water by hand. Use detergents and cleaning compounds that are phosphate-free and biodegradable: for example, no TSP (trisodium phosphate). Do not use detergents containing ammonia, sodium hypochlorite, chlorinated solvents, petroleum distillates or lye.

Best Management Practices for Aquaculture

General Guidelines for Site Selection for Aquaculture

Proper site selection is critical to successful aquaculture projects. A poor site will not only make an aquaculture project more difficult to manage, but it may also destroy critical natural habitats, spread disease and contaminate freshwater sources. Use the following general guidelines for selecting a suitable aquaculture site:

- Maintain adequate distance from other fish farming enterprises, natural spawning runs, restricted areas (national parks, world heritage areas, conservation areas) and sensitive ecosystems (including swamps, mangroves, mud flats, intertidal areas, bays, lakes, rivers, coral reefs, sea grass meadows, and shellfish beds).
- Choose sites with adequate wave, current, and tidal patterns. Areas of high currents will minimize waste accumulation through hydrodynamic dispersal. Lower levels of waste allow excess nutrients to be more easily assimilated into the local food web. Currents and tides also help replenish anoxic water with oxygen-rich water from surrounding areas. Rotting vegetation in a water body is an indicator of stagnant water and should be avoided. Remember to check for seasonal water variations.
- Do not use sites with incompatible users, such as riverbed sand extraction operations, harbors, sewage outfalls, oil platforms, shipping lanes, tanneries, sugar refineries and distilleries, or palm oil processing plants. Do not use sites polluted with chemicals, pesticides or heavy metals.



Women and children seining for fingerlings with traditional fishtraps, near Malambanyama, Chibombo District, Zambia.

- Choose sites that are near wild stock populations. Avoid introducing exotic fish species into a body of water. Remember to consider predator populations, existing ecosystem relationships and pathogen concentrations.

Other General Guidelines for Aquaculture

- Use hatchery stock where possible.
- Use non-native species only where escape is impossible or where survival and reproduction under local conditions is impossible.
- Use palatable feed with high utilization rates and low waste. Use feed of the appropriate size for the age of the stock. Feed often and at low levels to minimize waste. Distribute feed evenly.
- Use pathogen-free stock. If necessary, quarantine and provide treatment.
- Use drugs or pesticides only as needed during a disease outbreak, not on a routine preventive basis. Delay harvest of treated stock and delay discharge of treated water until the drug or pesticide has degraded fully.
- Apply Integrated Pest Management (IPM) to the aquaculture program. Aquaculture combined with rice production enables a farmer to grow two crops on the same land. The fish will consume algae and weeds, fertilize the water, and improve soil texture. Aquaculture in irrigation channels will control algae and weeds.

Specific Guidance for Pond Aquaculture

- *Siting Ponds*
  - Locate ponds where they do not cause a loss of habitats such as mangroves, wetlands, lagoons, rivers, inlets, bays, estuaries, swamps, marshes or high wildlife-use areas. Situate ponds away from tidal areas subject to flooding.
  - Choose sites with good soil, preferably clay-loam or sandy-clay, that will retain water and be suitable for building dikes. Soil should be alkaline (having a pH of 7 and above) to prevent problems that result from acid-sulphate soils (e.g., poor fertilizer response; low natural food production and slow growth of culture species; probable fish kills). Acidic and organic soils (e.g., high in humus or compost) are not suitable.
  - For saline brackish ponds, choose land with average elevation that can be watered by ordinary high tides and drained by ordinary low tides. Tidal fluctuation should be moderate, between two and three meters. Sites with tidal fluctuations above four meters require very large, expensive dikes to prevent flooding during high tide. Areas with slight tidal fluctuations, of one meter or less, cannot be properly drained or filled.
  - Provide a buffer zone for areas near riverbanks and coastal shores that are exposed to wave action.
  - Ensure that the area has a steady supply of water, in adequate quantities throughout the year. Water supply should be pollution-free and with a pH of 7.8–8.5.

- *Designing Ponds*
    - Design to prevent storm and flood damage that could cause overflow discharges.
    - Provide settling ponds for the effluent, and also for water intake, if the water supply has high sediment loads.
    - Ensure that pond depth is shallow enough to prevent *stratification* (potentially dangerous layering of the pond water into a warmer upper layer and a cooler, dense, oxygen-poor lower layer). If not, include a means of providing aeration or other destratifying mechanisms.
    - Include reservoirs for water storage and treatment.
    - Isolate supply and effluent canals as far as possible from each other, and from other farms.
    - Where possible, use a closed or re-circulating system with treatment; do not use more than small amounts of fresh water to top off the pond.
- *Constructing Ponds*
    - Line bottoms and sides of ponds, levees and canals with impervious material to prevent seepage into surrounding soils and groundwater.
    - Construct stormwater bypasses around the area of the ponds.
    - Dig ponds deep enough to control weed growth.
    - Minimize sediment erosion by:
        - using gradual slopes in construction;
        - planting vegetation on the surfaces of slopes;
        - compacting and lining the banks;
        - making discharge channels large enough to handle peak loads without scouring.
    - Construct wetlands to treat the settling pond water from freshwater ponds.
- *Operating Ponds*
    - Operate ponds so that they do not cause a loss of, or damage to, habitats, including mangroves, lagoons, rivers, inlets, bays, estuaries, swamps, marshes and other wetlands, high wildlife use areas, reefs, parks, ecological reserves, or fishing grounds.
    - Screen pond entrances and exits to keep fish stock in and other animals out.
    - Discharge saline ponds into deep water with high currents. Discharging saline water into intertidal zones is not acceptable.
    - Prevent erosion by leaving sediment, unless removal is absolutely necessary.
    - Keep freshwater use to a minimum in brackish or saline ponds.

- *Monitoring and Controlling Ponds*
  - Maintain water quality with aeration, sustainable stocking rates and controlled feeding rates, not with water exchange (replacing old pond water with clean water).
  - Treat effluent in settling ponds with filter feeders, and pass settling pond water from freshwater ponds through a constructed wetland before discharge.
  - Use the effluent as liquid fertilizer on crops, particularly forage crops where bare ground is minimal.
  - Monitor and control effluents before discharging to meet water quality standards for turbidity, suspended solids, BOD, pH, dissolved oxygen (DO), ammonia, nitrate, nitrite, disease organisms and pesticides. In freshwater ponds, monitor and control phosphorus.
  - Alternate freshwater ponds, where possible, and allow ponds to dry out, lie fallow, or grow a crop to reduce the need for sludge and nutrient removal.
  - Plow non-saline sludge into agricultural lands that are not susceptible to runoff and leaching.
  - Avoid discharge of saline ponds into freshwater habitats.

Specific Guidance for Net Pen Aquaculture

- *Siting Net Pens*
  - Locate all open-net pens in highly flushed, deep-water sites with no tidal reversals.
  - Site net pens at least one km from the mouths of streams or rivers when using fish that travel upstream to spawn.
  - Site net pens downcurrent of recreational areas, marine parks, fishing grounds, shellfish beds used for commercial or recreational harvest or other sensitive areas.
- *Constructing Net Pens*
  - Construct all net pens to prevent breakup of facilities and loss of stock, wastes, feed or supplies even in severe weather conditions.
  - Keep boats from discharging sewage into the water by:
    - constructing a shore facility with a proper septic system and drain field, tanks and pump-out or a small treatment plant, where conditions are suitable;
    - using holding tanks and a pump-out boat to empty the tanks at regular intervals.
- *Operating Net Pens*
  - Maintain sufficient storage capacity to handle even large, catastrophic fish kills caused by algal blooms or disease epidemics.

- Provide adequate safe storage, with secondary containment, for drugs, fuels, solvents and toxic materials. Preferably, locate this storage on shore.

- *Monitoring and Controlling Net Pens*
  - Place a bag or other container around all net pens to isolate diseased fish. The bag should be impermeable and capture all fish wastes. Arrange to treat and neutralize bag water or wastewater before discharge.
  - Collect and dispose of waste feed and feces from bagged or contained pens as compost. Collect and dispose of waste floatables, scum and oils from bagged or contained pens with other compost in a suitable facility.
  - Collect and dispose of unmarketable fish, blood and guts:
    - with other compost in a suitable facility;
    - by sending it to a rendering plant, or
    - by sending it to a properly operated landfill.
  - Avoid discharges near or upcurrent of recreational areas, marine parks, fishing grounds, shellfish beds used for commercial or recreational harvest, or other sensitive areas.

Environmental Mitigation and Monitoring Issues

Field studies of small-scale fishponds in Zimbabwe and Zambia have shown a large number of project failures and pond abandonments. Reasons why the projects failed include:

Motivation. Many farmers choose to dig fishponds in anticipation of benefits or to associate themselves with a "culture of development," rather than a belief in the technology. Such farmers may be discouraged from continuing fish farming in the face of maintenance problems and/or lack of short-term economic returns. Moreover, development organizations and agencies often structure projects around false assumptions, including:

- Assuming members of fish farming households have equal authority in making decisions;
- Assuming farmers frequently make decisions by weighing costs, benefits, and risks; and
- Assuming fish production is the farmer's primary concern.

When these assumptions are not valid, the farmers may not be able to resolve management and operational problems and will discontinue fish farming.

Environmental Factors. Projects may fail due to uncontrollable environmental disasters, such as droughts and floods. Also, if water temperatures are too low, fish may not grow to adequate size in time for harvesting.

Biological Factors. Farmers may experience problems maintaining adequate stocking and survival rates.

Financial Factors. The project may not generate adequate or rapid enough financial return, especially in systems requiring inputs of fish feed. External factors like political unrest may disrupt access to distant markets. Also, competition from capture fisheries may decrease prices and prevent a project from reaching profitability.

Social Factors. Theft of tools and stocks can jeopardize project success and reduce individual and community enthusiasm for aquaculture.

Administrative Factors. Extensive bureaucracy and poor communications between farmers and project supporters may generate distrust or apathy and result in project failure. Poor information exchange, lack of extension services and lack of contingency planning can each be fatal blows to a fishpond project.

External Environmental Conditions Affecting Project Success

Even with good management and design, fisheries projects are still at risk from external environmental conditions which can prevent project success. Types of trauma include:

Exotic and Endangered Species. Alien species introduced into African water bodies have adversely affected native populations. The Nile perch (*Lates nilotica*), introduced into Lake Victoria 30 years ago to stimulate the fisheries of Uganda, Kenya and Tanzania, is now dominant in the lake and believed to be responsible for the decline or loss of more than 200 native fish species. Water hyacinth (*Eichornia crassipes*) has spread to freshwater bodies across Africa, including Lake Victoria and Lake Kariba, blocking water channels, altering hydrological regimes and leaving surrounding areas prone to increased flooding.

Tightening controls on importation of animals and plants will help prevent introduction of exotic species. This policy, however, requires allocating resources to police borders and entry points, and to enforce fines for breach of regulations; such resources may not be available.

Alien plants can be physically removed by hand, by machinery or by chemicals. Biological control can contain alien populations with fewer environmental impacts. The latter, however, is a more lengthy process, because control organisms must themselves be rigorously tested for adverse impacts before their release into the environment.

Pollution. Fish life cycles can be adversely affected by pollution from industries (including the fish processing industry), human wastewater, nutrient loading and pesticides from agricultural runoff, water body acidification from vehicle and power station emissions, dredging, reclamation, sedimentation, dams, river channel modifications, and alteration of freshwater drainage. Pollutants, including heavy metals, pesticides and radioactive wastes, will bioaccumulate in fish and mollusk populations.

Nutrient loading of a water body can best be mitigated at the source—for example, by treating human effluent and capturing agricultural runoff. Early-warning networks can monitor for toxic algal blooms caused by excessive nutrient enrichment of water bodies. Instead of closing water bodies during periods of seasonal contamination from metals or hazardous wastes, mollusks can be grown in polluted water and then purged in clean water sources before processing or sale. Encouraging vegetative ground cover to prevent runoff, along with active techniques like flushing and dredging the water body, can help mitigate pollution from sedimentation.

Habitat destruction. UNEP estimates that 38 percent of all coastal ecosystems in Africa, such as mangrove swamps and coral reefs, are under threat from development, including the growth of coastal settlements and their associated sewage discharges. According to the FAO, "Industrialization, urbanization, deforestation, mining, and agricultural land and water use often cause degradation of aquatic environments, the greatest threat to inland fish production" (FAO 1999). Fishery resources are damaged when:

- aquatic habitats are destroyed or fragmented;
- bodies of water are impounded (dammed) or channeled;
- too much water is drawn or diverted, or
- soil becomes eroded.

Manipulation of the hydrological characteristics of rivers, lakes and flood plains may also do significant harm.

Coral reefs are adversely affected by human activities such as sediment runoff from deforestation, eutrophication, bleaching, disease, dynamite and chemical fishing, anchor damage, dredging, and groundings from ship traffic.

Controlling damaging activities such as pollution, sedimentation, over-fishing, etc., can help mitigate habitat destruction. Replanting denuded areas can often restore mangrove habitats. Coral reefs are more difficult to restore and are highly sensitive to environmental stress. Thus, it is crucial to monitor coral ecosystems for changes in temperature, sedimentation, nutrient loading, storm damage and toxins.

Activity	Problem/Impact		Applicability	Mitigation Techniques
All Fisheries				
	Pollution		Mollusk	Mollusks are particularly vulnerable to biocides, leachates, metals and pesticides. Monitor water conditions closely for contaminants.
Capture Fisheries				
Design/ Operations	Over-harvesting		Capture fisheries	Set minimum size limit for harvested fish. Use bag limits. Use appropriate fishing gear. Choose the largest possible size of mesh in fishing nets. Close seasons during critical stages in fish life cycles.
	By-catch (catching fish and other aquatic animals that are too small or of the wrong species)		Capture fisheries	Use mesh sizes that allow small and juvenile fish to escape. Use a square mesh, or a mesh with square windows, instead of a diamond-shaped mesh. (Diamond-shaped mesh constricts during towing.) Use a by-catch reduction device to allow large animals to escape from nets.
	Use of hazardous substances and techniques		Capture fisheries	Educate fishermen about the long-term environmental and economic damage from using cyanide or dynamite on ecosystems.
Aquaculture				
Design				
	Site selection	Mangrove habitats	General	Always leave the most productive mangrove stands intact. Use already cleared land whenever possible. Reuse existing ponds before creating new ones. Site ponds on the landward side of the mangroves; leave the seaward side undisturbed. Ponds should have a small surface area (footprint) relative to total mangrove area. Ponds should be spaced well apart. Mangroves should be retained and replanted in the middle, or on the banks, of ponds.
		Adequate water supply and circulation	Finfish	Avoid shallow areas and areas with aquatic vegetation. Place units in an area with a good current flowing through it. The action of the current helps water move through the cage system, removing metabolites and replenishing oxygen.

Activity	Problem/Impact	Applicability	Mitigation Techniques
			Depending on the direction of prevailing winds and currents, orient the cages to prevent debris from collecting between them.
	Control of nutrient loading	General	Filter feeders—organisms that strain their food out of the water—improve water quality by consuming plankton and preventing eutrophication. Consider growing mollusks or seaweeds in conjunction with other species, to reduce nutrient loading.
	Control of seepage into ground and surface waters	General	Build ponds on soils with adequate clay content.
	Impacts to pond floor	Mollusk Culture	Use off-bottom systems such as rafts and lines.
	Erosion of ponds	General	Plan for seasonal constraints. Use settling ponds or other control structures.
	Disease prevention	Finfish	Locate cages where disturbances from people and animals can be minimized.
Construction			
	Erosion	General	Minimize disturbance of soil and vegetation.
	Control of dissolved oxygen supply	Mollusk	Do not seed mollusks too closely together or they will generate anoxic conditions (i.e., remove all oxygen from the water).
Operations			
	Overfeeding	General	Use high-quality feed. Feed the right amounts at the right time. Use feed pellets designed to float longer in the water column. Instead of fishmeal, use meals made from terrestrial animal byproducts, plant oilseeds and grain legumes; from yeast; or from cereal byproducts.
		Finfish	Consider culturing herbivorous fish that do not require feed inputs.
	Overcrowding	General	Use lower stocking densities.

Activity	Problem/Impact	Applicability	Mitigation Techniques
	Disease prevention	General	Stock certified pathogen-free fish. Use lower stocking densities. Vaccinate fish. Isolate diseased fish in bags, rather than nets. Allow net pens to sit fallow between stockings. Apply IPM. Filter or ozonate the effluent from pond and recirculating tank systems.
		Finfish	Avoid unnecessary or excessive handling of fish; this will minimize stress and prevent disease. Avoid unnecessary disturbance of the fish by restricting activities around the cage site. Promptly remove diseased and dying fish. During disease outbreaks, retain aquaculture effluent to prevent disease from spreading to wild populations.
		Shrimp	Consider treating influent water supply (for example, with chlorine) to eliminate pathogens and carriers; this may reduce disease incidence and associated use of chemicals.
	Excess of organic nutrients	General	Treat aquaculture and human wastes according to sanitation guidelines. Use polyculture (i.e., raise several species, including at least one herbivorous species) to consume excess nutrients. Do not discharge nutrient-enriched water into freshwater bodies.
		Finfish	Move fish pens to different locations periodically to prevent buildup of fish wastes and sediments below cages. Manage fish wastes through bag systems, fallowing, vacuuming or harrowing.
		Shrimp	Avoid frequent draining of shrimp ponds in order to allow microbial processes and deposition to remove nutrients and organic matter from within. This will also conserve freshwater. Use aeration and water circulation to break down organic matter and minimize anaerobic sediment accumulation at the bottom of shrimp ponds. Aeration may also remove ammonia. Use settling ponds to treat suspended solids. Always settle effluents released at the time of harvest.
	Inadequate dissolved oxygen supply	General	Use seaweed to oxygenate the water and to improve water quality by removing ammonia and phosphorus.

Activity	Problem/Impact	Applicability	Mitigation Techniques
	Adverse impacts from use of anti-fouling chemicals	General	Use IPM or polyculture to control weeds. Construct deeper ponds. Consider use of less-toxic alternatives to hazardous products. Designate areas for storage and refueling. Apply chemicals with proper containment away from watercourses or wetlands. Prepare an Emergency Spill Response Plan. Contain spills and treat contaminated soil and water as required.
	Erosion	General	Consult extended-range weather forecasts. Predetermine shutdown criteria for bad weather conditions. Maintain vegetated buffer zones. Stabilize disturbed areas as soon as possible. Monitor sediment in water and treat as required prior to release.
	Predation (wild animals eating aquaculture fish)	General	Use properly tensioned netpen lines and thick ropes to avoid entanglement from birds or aquatic animals. Use double nets to reduce predation. Rotate deterrence techniques to give predators less opportunity to get used to a particular technique.

Activity	Problem/Impact	Applicability	Mitigation Techniques
		Finfish	Place protective netting on the sides and tops of cages to protect fish from bird and mammal predation. Place the nets as far from the cages as possible, and weight them to prevent them from being pushed together by water movement. Choose a size of net mesh that will prevent birds from becoming entangled. Bird predation can be reduced by: ▪ eliminating safe roosting and perching places; ▪ placing the containment units deeper below the surface of the water to reduce the attraction of surface-feeding birds such as gulls; ▪ moving young/small stock to an area where they are less accessible to predatory birds; ▪ placing nets above cages to keep birds off; ▪ adjusting top nets so they do not sag under the weight of preying birds, enabling them to more easily reach the fish; ▪ using brightly colored nets to reduce the likelihood of birds accidentally swimming into nets.

Resources and References

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Resources

- ***A Brief for Fisheries Policy Research in Developing Countries***. M. Ahmed, C. Delgado and S. Sverdrup-Jensen (1997). 16 p. ISBN 971-8709-59-2. Available at: http://www.cgiar.org/iclarm/pubsof/newbooks.html#towards

Outcome of the International Consultation on Fisheries Policy Research in Developing Countries, jointly organized by International Center for Living Aquatic Resources Management (ICLARM), the International Food Policy Research Institute and the Institute for Fisheries Management and Coastal Community Development, and held 3-5 June 1997 at the North Sea Centre, Hirtshals, Denmark. Forty-two scientists, academicians and policymakers from developing countries, together with representatives from donor and international organizations, contributed to the development of a set of recommendations that include: (1) policy research priorities and an agenda for international and national research initiatives; and (2) guidelines for improving the capacity of developing country institutions in fisheries' policy research, including enlargement of the scope for collaborative research.

- ***A Roadmap For the Future for Fisheries and Conservation***. M.J. Williams, Ed. (1998). ICLARM Conf. Proc. 56, 58 p. ISSN 0115-4435, ISBN 8709-94-0. Available at: http://www.cgiar.org/iclarm/pubsof/newbooks.html#towards

These proceedings report on the fisheries session of the Marine and Coastal Workshop convened by IUCN, the World Conservation Union, 17–18 October 1998. The workshop sought to present and review the state of the art in marine and coastal conservation and sustainable development issues, and to discuss and develop directions, priorities and the role of IUCN in addressing these issues. The seven papers in the book discuss views from fisheries, conservation and resource management experts. The consensus expressed is that fisheries conservation is becoming more complex: it was previously the domain of fishers, fisheries managers and scientists, but now multipolar interests are concerned, including fishers and fisheries experts, consumers, local communities, civil society and other economic sectors.

- ***Code of Conduct for Responsible Fisheries***. FAO. Available at: http://www.fao.org/fi/agreem/codecond/ficonde.asp

This code sets out principles and international standards of behavior for responsible practices, with a view to ensuring the effective conservation, management and development of living aquatic resources, with due respect for ecosystems and biodiversity. The code recognizes the nutritional, economic, social, environmental and cultural importance of fisheries, and the interests of all those concerned with the fisheries sector. The code takes into account the biological characteristics of the resources and affected environment. It also addresses the interests of consumers and other users. All those involved in fisheries are encouraged to apply the code and give effect to it.

- ***Co-management in Small-Scale Fisheries. A Synthesis of Southern and West African Experiences***. (1998) Paper presented at IASCP conference in Vancouver, Canada, 9–14 June. In: *Fisheries Co-*

management in Africa. Proceedings from a regional workshop on fisheries co-management research held 18–20 March 1997 in Mangochi, Malawi. [16]. Available at: http://www.ifm.dk/reports/16.PDF

This presentation summarizes the findings from eight African countries where case studies of co-management arrangements in artisanal fisheries were undertaken during the period 1996–97. In most of the cases, co-management represents a new approach to fisheries management. In some cases, it has only been applied within the last 3–5 years, and in a few it is merely being considered as an option. The comparison of cases at this early stage may help address critical issues in the planning and implementation of fisheries co-management in Africa. These include the provision of incentives for fishers and other stakeholders to cooperate among themselves and with government in managing fisheries. The level of cooperation is determined by key factors affecting the local politico-historical, biophysical, economic and sociocultural environments of fishing communities and associated fisheries. Incentives for cooperation are determined by the character of the decision-making arrangements in place. These include setting collective choice rules and, in particular, the operational rules for a fishery, and thus the legitimacy of the arrangements in the eyes of the fishers. The co-management approach is intended to replace ineffective conventional, centralized management systems. The differing bio-physical environments seen in the cases represent three ecological systems: lake/reservoir, lagoon/estuary and open coast. In most of the cases only a few fish species are target species. These are often subject to heavy fishing pressure or are already over-fished. In most cases the fishers and their families are totally dependent on the fishery for their livelihood since, with few exceptions, they have no alternative sources of income.

- Alyanak, Leyla. *Fisherpeople launch patrol of their own slack waters*. FAO, 1996. http://www.fao.org/news/1997/970102-e.htm

Account of community-based management of Lake Malombe.

- ***FAO Technical Guidelines for Responsible Fisheries*** (1997). No. 5: Aquaculture Development. FAO, UN, Rome. 40 pp. Available at: http://www.fao.org/
- "Farming fish the right way". R. Kapadia and M. Williams (2000). ICLARM, USAID. ICLARM Focus for research, 3(2), April, 4 p. USAID order no. PN-ACK-990.
- ***Fisheries and Aquaculture in Sub-Saharan Africa: Situation and Outlook in 1996*** (1996) FAO Fisheries Circular No. 922 FIPP/C922, ISSN 0429-9329. Rome. Available at: http://www.fao.org/fi/publ/circular/c922/c922-1.asp

The contribution of the fisheries sector to the economy of the region has been largely beneficial. Over the last decade, significant progress has taken place including strengthened artisanal fisheries development; the consolidation of a small industrial base; growing export receipts leading to a positive trade balance; and, more recently, indications of a promising takeoff for aquaculture. However, in marine capture fisheries, most bottom-dwelling stocks are thought to be fully exploited, and catches by distant-water nations are steadily decreasing. The immediate potential for increases in production and supply for local markets is primarily with lower-value small pelagics species. Inland fisheries figure importantly in food security, providing over 40 percent of domestic catches.

Freshwater production is close to its estimated potential. Since 1990, per-capita fish supply has followed an alarming downward trend. The major challenge for the fisheries sector will be to maintain production to meet current levels of demand. This will require significant efforts to improve the management of capture fisheries, to support the development of aquaculture, and to promote intra-regional trade.

- ***Fisheries and Aquaculture Research Planning Needs for Africa and West Asia***. J.H. Annala, Ed. (1997). ICLARM Conf. Proc. 50, 80 p. ISSN 0115-4435, ISBN 971-8709-67-3. Available at: http://www.cgiar.org/iclarm/icpub2.htm

Proceedings of the ICLARM workshop on 23–25 September 1995 in Cairo, Egypt. Discussion of coral reef resource systems; coastal aquatic and inland aquatic resource systems; African Great Lake and reservoir resource systems; social sciences and co-management; and the partnerships between national aquatic research systems and ICLARM in Africa and West Asia.

- ***Fisheries Policy Research in Developing Countries: Issues, Priorities and Needs***. M. Ahmed, C. Delgado, S. Sverdrup-Jensen and R.A.V. Santos, Eds. (1999). ICLARM Conf. Proc. 60, 112 p. ISSN 0115-4435, ISBN 971-802-005-5. Available at: http://www.cgiar.org/iclarm/pubsof/newbooks.html#towards

Organized into three sessions, the first session focused on policy issues related to major changes in the demand and supply of fish. The second session focused on the impact of fisheries policies on food security and the environment. The third session was a discussion of priority areas for fisheries policy research targeted to developing countries. Regional and global fisheries policy issues, recommended topics for fisheries policy research in developing countries and implementation strategies were also discussed.

- ***Forgotten Waters: Freshwater and Marine Ecosystems in Africa—Strategies for Biodiversity Conservation and Sustainable Development***. Caroly A. Shumway USAID (1999), x, 167 p. Available at: http://www.dec.org/pdf_docs/PNACF449.pdf Electronic copy cost: $2.00

This report provides a primer on Africa's threatened aquatic biodiversity, along with lessons learned from successful and failed conservation projects and options for biodiversity conservation. The report provides an overview of the value of aquatic biodiversity, identifies the biologically and socio-economically most important sites, discusses threats, and recommends activities for urgent conservation action. The report addresses both freshwater and marine biodiversity, covering the following aquatic habitats and their associated flora and fauna: lakes, rivers, and streams; wetlands, including floodplains, freshwater swamps (also known as marais), mangroves, and coastal wetlands; and coral reefs. Associated wildlife include all terrestrial and aquatic organisms whose survival depends on wet habitats. Ocean pelagic areas are addressed briefly. Key recommendations include: improve institutional capacity for aquatic resource management; encourage appropriate economic and sectoral policies; involve the community in aquatic resource conservation and management; support needed research; mimic natural disturbance regimes in order to maintain or restore natural hydrological cycles; assist in establishing critical aquatic resources that can provide both conservation and fisheries benefits; and assist in developing fisheries that are compatible with biodiversity goals. Includes bibliography.

- ***Research for the Future Development of Aquaculture in Ghana***. M. Prein, J.K. Ofori and C. Lightfoot, eds. (1996). ICLARM Conf. Proc. 42, 94 p. ISSN 0115-4435, ISBN 971-8709-43-6. Available at: http://www.cgiar.org/iclarm/icpub2.htm

Proceedings of a workshop held in Accra, Ghana, 11–13 March 1993, which presented the preliminary results of a project entitled "Research for the Future Development of Aquaculture in Ghana." The project was funded by the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), and was executed by ICLARM in collaboration with the Institute of Aquatic Biology (IAB), Accra, Ghana. The aim of the project was to determine "what makes sense" for aquaculture development in Ghana, focusing on smallholder farmers.

- ***Sustainable Aquaculture: Seizing Opportunities to Meet Global Demand*** (1998). Rural Development Department, The World Bank. Agriculture Technology Notes No. 22, December. Available at: http://wbln0018.worldbank.org/essd/essd.nsf/rural+development/aquaculture

This document reviews the continuing growth and importance of aquaculture globally. According to FAO statistics, 1995 worldwide production from aquaculture represented about 21.3 million tons (19 percent) of the total annual fish production from all sources. Aquaculture grew at an annual average rate of 10 percent during the last decade. In contrast, during the same period, the catch of wild fish from both inland and marine waters (capture fisheries) averaged an annual growth rate of less than 2 percent. Moreover, the contribution of aquaculture to human nutrition between 1990 and 1995 increased, while that from capture fisheries declined by about 10 percent. This reversal occurred because an increasing percentage of the wild catch are species of lower value that are being used to produce fishmeal for feed and fertilizer.

- ***The Third International Symposium on Tilapia in Aquaculture***. R.S.V. Pullin, J. Lazard, M. Legendre, J.B. Amon Kothias and D. Pauly, Editors (1996). ICLARM Conf. Proc. 41, 575 p. ISSN 0115-4435, ISBN 971-8709-42-8. Available at: http://www.cgiar.org/iclarm/pubsof/newbooks.html#towards

The proceedings of the Third International Symposium on Tilapia in Aquaculture held in November 1991 in Abidjan, Côte d'Ivoire. The conference reviewed the latest research and discussed recent and future developments in tilapia culture. Attended by fishery scientists from around the world, the conference was the most important meeting held in western Africa and made important contributions to the sustainable development of aquaculture in Africa and other countries. Available in English and French, with translation by Catherine Lhomme-Binudin.

- UNEP World Conservation Monitoring Centre. ***GEO3 Endangered Animals Snapshot***. http://valhalla.unep-wcmc.org/isdb/geo3.cfm

This online database lists endangered species by geographical location (region and country) and animal type. Species are further divided into critically endangered, endangered, and vulnerable categories. Information available about each species includes its native range, when it was listed as an endangered species, and links to resources about the specific animal.