SECTOR ENVIRONMENTAL GUIDELINES

FISHERIES AND AQUACULTURE

Partial Update 2015 | Last Full Update: Prior to 2003

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Cover Photo: USAID/Bangladesh's Women Fish Pond Project. 2007. Jeannie Harvey

About this document and the *Sector Environmental Guidelines*

This document presents one sector of the *Sector Environmental Guidelines* prepared for USAID under the Agency's Global Environmental Management Support Project (GEMS). All sectors are accessible at www.usaidgems.org/bestPractice.htm.

Purpose. The purpose of this document and the *Sector Environmental Guidelines* overall is to support environmentally sound design and management (ESDM) of common USAID sectoral development activities by providing concise, plain-language information regarding:

- the typical, potential adverse impacts of activities in these sectors;
- how to prevent or otherwise mitigate these impacts, both in the form of general activity design guidance and specific design, construction and operating measures;
- how to minimize vulnerability of activities to climate change; and
- more detailed resources for further exploration of these issues.

Environmental Compliance Applications. USAID's mandatory life-of-project environmental procedures require that the potential adverse impacts of USAID-funded and managed activities be assessed prior to implementation via the Environmental Impact Assessment (EIA) process defined by 22 CFR 216 (Reg. 216). They also require that the environmental management/mitigation measures ("conditions") identified by this process be written into award documents, implemented over life of project, and monitored for compliance and sufficiency.

The procedures are USAID's principal mechanism to assure ESDM of USAID-funded Activities—and thus to protect environmental resources, ecosystems, and the health and livelihoods of beneficiaries and other groups. They strengthen development outcomes and help safeguard the good name and reputation of USAID.

The Sector Environmental Guidelines directly support environmental compliance by providing: information essential to assessing the potential impacts of activities, and to the identification and detailed design of appropriate mitigation and monitoring measures.

However, the Sector Environmental Guidelines *are **not** specific to USAID's environmental procedures. They are generally written, and are intended to support ESDM of these activities by all actors, regardless of the specific environmental requirements, regulations, or processes that apply, if any.*

Region-Specific Guidelines Superseded. The *Sector Environmental Guidelines* replace the following region-specific guidance: (1) *Environmental Guidelines for Small Scale Activities in Africa* ; (2) *Environmental Guidelines for Development Activities in Latin America and the Caribbean*; and (3) Asia/Middle East: *Sectoral Environmental Guidelines.* With the exception of some more recent Africa sectors, all were developed over 1999–2004.

Development Process & Limitations. In developing this document, regional-specific content in these predecessor guidelines has been retained. Statistics have been updated, and references verified and some new references added. However, this document is not the result of a comprehensive technical update.

Further, *The Guidelines* are not a substitute for detailed sources of technical information or design manuals. Users are expected to refer to the accompanying list of references for additional information.

Comments and corrections. Each sector of these guidelines is a work in progress. Comments, corrections, and suggested additions are welcome. Email: gems@cadmusgroup.com.

Advisory. *The Guidelines are advisory only. They are not official USAID regulatory guidance or policy. Following the practices and approaches outlined in the Guidelines does not necessarily assure compliance with USAID Environmental Procedures or host country environmental requirements.*

CONTENTS

FISHERIES

For decades fish have made up approximately 16 percent of animal-based proteins and 6 percent of total proteins (including plants) consumed worldwide. Over 30 percent of fish protein come from freshwater and diadromous fish (i.e., fish that migrate between saltwater and freshwater). (World Health Organization)

Philippines: Fisherman Showing His Catch of Sardines. Harry Edwards. USAID.

BRIEF DESCRIPTION OF THE SECTOR

Fisheries are an important source of food and revenue worldwide, and employ over 155 million people, 98 percent of whom are in developing countries. Capture fisheries and aquaculture supplied the world with about 148 million tonnes of fish in 2010 (with a total value of US$217.5 billion), of which about 128 million tonnes was utilized as food for people.[1] For decades fish have made up between 16 percent of animal-based proteins and 6 percent of total proteins (including plants) consumed worldwide. Over 30 percent of these fish proteins come from freshwater and diadromous fish (i.e., fish that migrate between saltwater and freshwater). Of all the animal protein consumed in Africa in 2007, 18 percent was from fish—rates are as high as 58 and 65 percent in Ghana and Sierra Leone. In Asia, approximately 23 percent of animal protein comes from fish. In countries such as Cambodia, Bangladesh, Indonesia, and Myanmar, fish comprises between 50 to 68 percent of dietary protein intake. While the average for Latin America and the Caribbean is less than 10 percent, many of the island nations in the Caribbean get at least 20 percent or up to 50 percent of animal protein from fish.[2]

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.

[1] The State of World Fisheries and Aquaculture. FAO. 2012. http://www.fao.org/docrep/016/i2727e/i2727e.pdf.

[2] World Health Organization. (accessed May 2015).

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.

SMALL-SCALE FISH FARMING IS A SOURCE OF PROTEINS AND INCOME FOR FARMERS

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.

VIETNAM

In northern Vietnam, aquaculture systems have centered on grass carp since its introduction from China 40 years ago. This species is reared in both ponds and cages and fed with grasses, maize residues and cassava leaves. In the south of Vietnam, an equivalent "poor person's system" based on giant gourami also feeds on vegetable matter (although growth rate is a constraint). In southern Vietnam, a second low-cost system is the culture of pangasius catfish (*Pangasius hypophthalmus*), reared in overhung latrine ponds. These grow quickly without purchased inputs and can be the basis for a more diversified system.

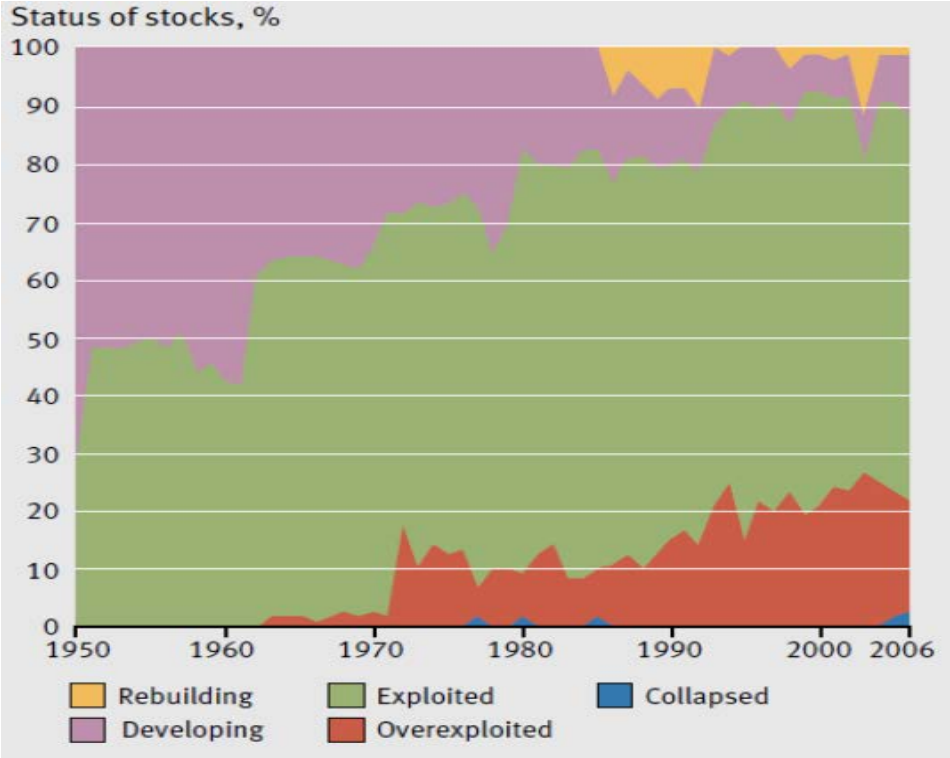
Source IIRR, IDRC, FAO, NACA and ICLARM, 2001.

Global production of fish from aquaculture has grown substantially in the past decade and continues to be the fastest-growing animal food producing sector. It currently accounts for approximately half of the world's food fish consumption, compared with 33 percent in 2000. With global capture fishery production stagnating and increasing demand from growing populations, aquaculture is receiving more and more attention. Most global aquaculture production occurs in developing countries (approximately 90 percent) and Low-Income Food Deficit Countries (LIFDCs, approximately 80 percent). About 80 percent of aquaculture farmers are small farmers and there are few large production sectors, such as shrimp and salmon. The aquaculture industry in LIFDCs

over the last three decades has grown at double the pace of developed countries, primarily on small, family-managed fish farms. [3]

While marine capture fisheries more than quadrupled their catch from the early 1950s to the mid-1990s, over the last two decades catches have stabilized or diminished, despite increased fishing effort. As shown in the figure on page 3, the proportion of marine fish stocks that are overexploited, depleted or recovering from depletion rose from 10 per cent in early 1970s to over 20 percent in 2006. Of the 133 local, regional and global extinctions of marine species documented worldwide over the last 200 years, 55 per cent were caused by overexploitation, while the remainder was driven by habitat loss and other threats. Technology can enhance the intensity and range of human impacts on marine biodiversity although it can also play a significant role in making fishing practices less destructive.

Overfishing is also a problem in freshwater wetlands, although in many cases adequate data are not available to quantify the extent of the loss. Recreational fishery practices such as stocking and selective take can also have important evolutionary impacts on freshwater fish



Trends in the State of Global Fishery Stocks 1950-2006
From UNEP 2012 reproduction of Kleisner, K. and Pauly, D. (2011). Stock-catch status plots of fisheries for Regional Seas. In The State of Biodiversity and Fisheries in Regional Seas (eds. Christensen, V., Lai, S., Palomares, M.L.D., Zeller, D. and Pauly, D.). pp.37–40. Fisheries Centre Research Reports 19(3)

[3] Adapted from State of World Aquaculture. FAO. 2010. http://www.fao.org/fishery/regional-aquaculture-reviews/reviews-2010/en/ and Aquaculture: Not Just an Export Industry. FAO. 2003. http://www.fao.org/english/newsroom/focus/2003/aquaculture.htm

stocks. Invasive species and by-catch from fisheries can be a major threat to groups such as sharks, turtles and albatrosses.[4]

There are two basic modes of practicing aquaculture: intensive and extensive. **Intensive aquaculture** uses technology to raise fish, and it involves a larger degree of human control and more inputs such as feeds, fertilizers and fuel. Stocking densities are also higher in intensive versus extensive aquaculture. In salmon aquaculture, for example, the fish are hatched, reared and fed in controlled ponds until they are big enough to harvest. Open-ocean aquaculture, or offshore aquaculture, is a form of intensive aquaculture that has become a method of employment and area of experimental research in some developing countries in recent years and is a method of farming fish in cages located 3 to 200 miles off the coast.

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. 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. Aquaponics – systems that combine aquaculture with hydroponics – are also becoming popular due, in part, to water scarcity. However, as described in the next sections, negative environmental impacts may results from more intensive or larger-scale efforts. These impacts can be mitigated in appropriately planned projects.

CLIMATE CHANGE

Climate change is impacting coral reefs, mangroves, salt marshes and other ecosystems that provide important nursery and breeding grounds for many freshwater and marine species. Coral reef systems, for example are impacted due to ocean acidification, and their sensitivity to sea surface temperatures, which can lead to coral bleaching and death of fish species. Risk analysis indicates that 30 percent of coral reefs in Asia are likely to be lost within the next 30 years (Cruz et al. 2007). Sea level rise, salt water intrusion, increased frequency and intensity of storms and changes in hydrologic flows are also having impacts, often on already stressed ecosystems.

Climate change is making it more difficult to predict future climate based on historical baseline conditions or trends. This uncertainty is increasing project design risks and community vulnerabilities. In response, project designers should now include a focus on climate change adaptation — defined as adjustment to natural or human systems in response to actual or expected climate change effects. Successful fisheries and aquaculture projects need to include efforts to moderate climate-related risks and vulnerabilities and to take advantage of potential benefits to improve the likelihood of long-term project success

These Guidelines provide information on the relationship between climate change and fisheries activities. Taken individually, impacts of small activities may appear minimal, but collectively,

[4] Adapted from Global Environmental Outlook (GEO) 5: Biodiversity. UNEP. http://www.unep.org/geo/pdfs/geo5/GEO5_report_C5.pdf

their scale and magnitude can have far reaching effects on human health and life-sustaining natural systems.

When making use of climate change scenarios, those involved in fisheries projects need use adequate climate change scenarios based on the life expectancy of the project. Risk management frameworks can be used to understand the implications of climate change uncertainties and impacts when informing planning, investment and operation decisions.

POTENTIAL ENVIRONMENTAL IMPACTS OF FISHING SECTOR AND THEIR CAUSES

ADVERSE IMPACTS FROM CAPTURE FISHERIES

OVER-HARVESTING

Widespread, unsustainable fishing practices have left capture fisheries with a shrinking resource base. About one third of stocks are overexploited. Parts of Asia and low-income and small island nations have been significantly impacted by the effects of overfishing, and Africa lost 9 – 49% of catches by mass in 2000. The World Bank and the FAO have estimated that overfishing may cost $50 million in net economic losses worldwide, though this phenomenon also causes loss of employment and reliable protein sources.[5] Fish populations are generally reproducing less than their biological and ecological potential because of habitat loss and pollution pressure. With climate change, waters temperatures may fluctuate outside of the ranges suitable for reproduction, or alter behavior, and further stress reproduction. There is a need of strict management plans to restore their full and sustainable productivity[6], and in some cases, countries have gone as far as to ban all fishing in their waters, as Palau did in 2014.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 and an overall loss in biodiversity of the region. As climate change increases the stress on these systems, productivity is likely to decline in addition to decreased response to practices considered “sustainable” today.

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.

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[5] Srinivasan, U.T., Cheung, W.W.L., Watson, R. and Sumaila, U.R. (2010). Food security implications of global marine catch losses due to overfishing. Journal of Bioeconomics 12, 183200 http://www.ecomarres.com/downloads/Thara2.pdf

[6] The State of World Fisheries and Aquaculture. FAO. 2012. http://www.fao.org/docrep/016/i2727e/i2727e.pdf.

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 Southeast Asia, Africa, and the Aegean Sea, also damages coral reefs and has caused nearby fisheries to decline. With stressors such as climate change, habitat change, and overfishing, non-target organisms may be especially sensitive to fishing practices that introduce toxic substances because they may be experiencing changes in metabolism, which may increase absorption of toxins, increased stress to natural occurring toxins such as algal blooms, and pressure from species expanding their range or population due to warmer waters.

SPECIES INTRODUCTION

Introduction of fish species is often a means of augmenting fish populations in regions with challenges meeting subsistence and commercial protein demand as well as promoting recreational fishing. While the economic benefits may be positive, the ecological impacts are almost overwhelming negative. Introduced species compete with native fish populations for both food and habitat, and often outcompete native species weakened by overfishing, habitat destruction, and climate change (e.g., warming water, change in stream flow, increased algal production, etc.). In addition to direct competition for food and habitat resources, the introduced species may also hybridize with native fish, directly prey on them, destroy critical habitat, or introduce a disease to the native stocks. While total aquatic biomass may be maintained, the result is a cascading loss of biodiversity in fish, benthic invertebrate, and aquatic plants species.

POSSIBLE IMPACT OF CAPTURE FISHERIES LISTED BY TYPE[7]

NEGATIVE IMPACTS ASSOCIATED WITH CAPTURE FISHING	ENVIRONMENTAL CONSEQUENCE
Bottom structure damage from dredging, trawling	Damage to important habitat for lower level aquatic food web (e.g., eelgrass habitat and benthic communities) that supports the rest of the food chain.
Lost gear and nets	Ghost fishing leading to additional depletion of resources and damage to non-target species such as turtles, marine mammals, and birds; loss of biodiversity and abundance; threat to endangered species.
Introduction of exotics	Competition for resources with native fish populations, leading to decline in traditional fisheries; loss of biodiversity; changes in food web structure; degradation in water quality.
Overfishing and bycatches	Leads to take of non-target species, including birds caught by long-lines, and immature fish; focus on large species changing the dynamics of population structure; reduces economic sustainability of fishing industry; threat to endangered species; discarding on bycatches and process wastes results in increased food for scavengers potentially leading to anoxia of the local seabed

[7] Adapted from Garcia, S.M., Zerbi, A., Aliaume, C., Do Chi, T., Lasserre, G. (2003). The ecosystem approach to fisheries. Issues, terminology, principles, institutional foundations, implementation and outlook. FAO Fisheries Technical Paper. No. 443. 71 p.

NEGATIVE IMPACTS ASSOCIATED WITH CAPTURE FISHING	ENVIRONMENTAL CONSEQUENCE
Changes in population structure	Modified genetic diversity; modifies age distribution of the population by targeting individuals of reproductive age and inducing high juvenile mortality; changes growth and maturation dynamics by removing predators; lack of high level predators can cause a cascade effect that results in overpopulation followed by population crashes due to resources partitioning.
Chemical alteration and pollution	Addition of highly toxic compounds to system (cyanide fishing); organic wastes from processing facilities damage water quality and can contaminate other non-target species; reduction in water quality and increase in organic content leading to eutrophication, algal blooms, and increased biochemical oxygen availability
Large scale ecosystem stress	Change to immature and stressed ecosystem by targeting and reducing abundance of high value predators, changing the trophic chains and flow of biomass; threatens endangered species.
Increased fishing capacity by community	Influences potential for overfishing; decreases market value of catches over short-term due to availability in the market; maladaption for economic growth based on increased physical access

FOR AQUACULTURE

POLLUTION

Aquaculture systems cause pollution in a variety of ways:

- Pond water discharged into coastal areas or streams can raise sedimentation rates, accelerate the nutrient cycle and lower dissolved oxygen (do) levels. These changes can lead to eutrophication, a state in which a water body is polluted with excess nutrients that remove dissolved oxygen from the water and cause rapid plant growth, including toxic algal blooms. the toxins from these algal blooms 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 processed fish 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 have the potential to cause algal blooms, harming surrounding habitats and depleting dissolved oxygen concentrations near the facility.

- Anti-fouling agents are often used to prevent organism growth on cages and netting. some anti-fouling agents, such as tbt (tributyltin), 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.

HABITAT DESTRUCTION

Because they are located in inter-tidal zones, mangrove forests are sometimes cleared for replacement by aquaculture ponds. Mangrove forests support a diverse population of grasses, birds, and other land-based and aquatic animals and provide important services such as stabilizing coastlines, reducing storm erosion, and acting as spawning and nursery areas for many fish and crustaceans all of which have implications for climate change adaptation. 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 and can cause fish and crustacean populations to collapse.

Installing open ocean aquaculture pens may include dredging, drilling, and other bottom disturbances with the potential to displace wild fish, bottom dwellers, and impact the ecology of the surrounding ocean.

IMPACTS ON FRESHWATER SOURCES

Intensive aquaculture requires large quantities of freshwater, usually obtained from groundwater or surface freshwater bodies. Freshwater is globally in high demand, and with climate change, additional water stress may lead to localized conflict. Aquaculture in these areas with physical or access issues to freshwater may then compete with downstream users, These issues may be exacerbated by climate change in areas where hotter conditions and changes in precipitation patterns results in decreased or less predictable water availability. Pumping groundwater near coastal areas may cause saltwater to enter the aquifer and contaminate the underground reservoir. Again, climate change may make this more likely due to sea level rise. Groundwater extraction may also cause land subsidence (i.e., land surface slump or collapse). If aquaculture ponds are not designed properly, saltwater can seep into surface reservoirs, canals and rice paddies, damaging drinking water reserves and crops. As noted above, pond water is sometimes discharged into freshwater bodies, adding excess nutrients and pollutants and increasing salinity. Salts can also seep into drinking water sources from poorly designed sediment disposal sites.

DISEASE

Intensive aquaculture uses a dense stocking rate in an attempt to maximize use of inputs. 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.

Climate change must also be considered for its potential to contribute to disease as evidence suggests that parasites and pathogens may expand their range and will become more virulent with increase global temperatures. 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. The overapplication of antibiotics has been shown to lead to the creation and spread of antibiotic-resistant bacteria.[8]

ADVERSE EFFECTS ON OTHER ORGANISMS

The site of a proposed fishpond near Kibwaya, Tanzania. Six families grow rice on this land. Can the water resources here support fish ponds? Will ponds increase household income for these farmers? Do they have the ability to sustainable manage the ponds?

Although the use of genetically engineered fish in aquaculture was approved only very recently, 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, in the future, 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 or non-native to the area or water body into which they escape, they may become invasive, interfering with the established ecosystem that native species are a part of, impacting the food sources, spawning areas, and surrounding habitat. Non-native species may also introduce new diseases.

Nearly all marine and brackish water aquaculture requires inputs from natural fisheries. Wild organisms or larvae are sometimes used as seed stock for aquaculture operations. In some species, collecting larvae or young animals, if not done carefully, may depress the local population of the species to dangerously low levels.[9]

Aquaculture based on carnivorous organisms (such as salmon and shrimp) requires large quantities of fishmeal. Fishmeal is manufactured from harvests of smaller prey fish, or fish not otherwise consumed by people. Growing one unit of salmon may require several units of wild fish. In 2006, the aquaculture sector consumed 4.9 tonnes of small forage fish for every tonne of

[8] FAO. (2015).

[9] Tacon, A.G.J, and M. Metian. Global overview on the use of fish meal and fish oil in industrially compounded aquafeeds: Trends and future prospects. 2008. Aquaculture 285:146-158. http://www.cnr.uidaho.edu/fish510/PDF/fishmeal.pdf.

salmon produced, and 3.4 tonnes of small prey fish for every tonne of trout produced.[10]Expanding aquaculture by harvesting more small forage fish may lead to their populations to shrink, not only making the aquaculture unsustainable but endangering other aquatic animals that feed on these small wild 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 UPSTREAM AND DOWNSTREAM USERS

As mentioned previously, intensive and semi-intensive aquaculture systems require large volumes of fresh water, often drawn from surface waters. In rural areas, this results in less water available to irrigate crops and forces people (mainly women) to travel further to collect water for household use for both downstream users and upstream users who may be required to enter into water sharing agreements in order for ponds to have enough water for operation. 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.

POSSIBLE ENVIRONMENTAL IMPACTS OF AQUACULTURE LISTED BY PRODUCTION TYPE[11]

In addition to the impact on native fisheries and water quality described in detail above, specific culture systems have additional environmental impacts as summarized in FAO ADCP/REP/89/43 - Aquaculture Systems and Practices: A Selected Review (Baluyut,1989).

CULTURE SYSTEM	ENVIRONMENTAL IMPACT
EXTENSIVE: RELIES ON NATURAL FOOD	
Seaweed culture	May occupy formerly pristine reefs; rough weather losses; market competition; conflicts/failures, social disruption. Impacts on local fishing communities by occupying large surface areas of coast, loss of biodiversity from changes in seawater flow, shading, and removal of bottom substructures.[12]
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.
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.

[10] Ibid.

[11] Pullin, Third World Aquaculture and the Environment (1989), as cited by Baluyut (1989).

[12] Phillips, M.J. Environmental Aspects of seaweed culture. FAO Technical Resource Paper. Available at: http://www.fao.org/docrep/field/003/AB728E/AB728E05.htm.

CULTURE SYSTEM	ENVIRONMENTAL IMPACT
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	
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.
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.
Sewage-fish culture (waste treatment ponds; latrine and septic waste used as pond inputs; fish cages in wastewater channels)	Possible health risks to farm workers, fish processors and consumers; consumer resistance to produce.
Cage and pen culture, especially in eutrophic waters or on rich benthos (carp, catfish, milkfish, tilapias)	As with extensive cage and pen systems above.
INTENSIVE: HATCHERY-CONTROLLED CONDITIONS FOR MOST OF THE LIFE CYCLE	
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.
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.
Other—raceways, silos, tanks, etc.	Effluents/drainage high in BOD and suspended solids; many location-specific problems.

CLIMATE CHANGE

PLANNING FOR A CHANGING CLIMATE

Sea level rise, changing ocean salinity, shifting temperatures, and precipitation pattern shifts are climatic changes affecting fisheries and aquaculture—and especially the people that rely on them for food and employment. Climate change will change the frequency, intensity, and duration of extreme events, including droughts, floods, high winds, and tropical storms. Project design, construction and operation must take into account these changes which may result in damage to habitat, declining fish populations, or put coastal fishing infrastructure or aquaculture operations at high risk. Particularly on the coasts of Africa and Asia, changes in climatic conditions combined with the natural rate of erosion may cause flooding of low lying areas, saltwater intrusion into fresh water areas, and loss of coral reef habitat.[13] Additionally, fish and aquaculture resources need to be protected from overfishing, habitat degradation, and stresses from climate change. Therefore, projects need to be designed to withstand exposure to an altered climate and be resilient to deviations from historical conditions. Specifically the aspects of fisheries project design sensitive to weather need greater attention to risk analysis and climate change probabilities than in the past, to help ensure that appropriate materials and designs are selected and the long-term success of projects is achieved. USAID has developed guidance to assist with mainstreaming climate change into development activities called Adapting to Coastal Climate Change – A Guidebook for Development Planners[14].

A particular fishing community's vulnerability to climate change is the degree to which it may be unable to cope with a changed climate. Vulnerability is a function of exposure, sensitivity, and adaptive capacity. While exposure and sensitivity, discussed above, refer to physical attributes, adaptive capacity has to do with the "human element." Adaptive capacity refers to the capacity or potential to:

- Adjust to, rebound from, or cope with the consequences of climate variability and changes
- Moderate potential damages
- Take advantage of opportunities

Elements of adaptive capacity include:

- Access to information
- Access to financial, technical, human resources
- Social capital and cohesion
- Redundancy of transportation and information systems
- Economic diversification

Planning for climate change requires an understanding of how climate affects habitat, hydrologic cycles, the economy of the fisheries sector, and policies that govern the sector. Planning also requires considering the unique climate sensitivities of fish species; for example, some species require very narrow water temperature ranges for reproduction while others can tolerate higher or lower temperatures. Metabolism of fish can also change with water temperatures. Some fish may be more resilient than others when facing a changing climate, and some locations may be at lower risk of impacts like sea level rise, salt water intrusion, or increased storm intensity, rainfall, and drought. Climate change impacts may be more severe if other non-climate

[13] Providing Options to Respond to Climate Change in West African Coastal Areas. UNESCO. 2012. http://www.unesco.org/new/en/natural-sciences/ioc-oceans/single-view-oceans/news/providing_options_to_respond_to_climate_change_in_coastal_areas/

[14] USAID. 2013. Adapting to Coastal Climate Change- A Guidebook for Development Planners. http://www.crc.uri.edu/download/CoastalAdaptationGuide.pdf

stressors—like overfishing, increased water withdrawal, and erosion—make marine and aquaculture environments more sensitive. Some species may no longer be economically viable as they are increasingly affected by climate changes, diseases, or invasive species. In order to build capacity, projects might consider:

- Researching and storing data and information on the geographic and spatial scale of the fishery; climate change predictions in the region; and the dynamics of the ecosystem over time and in response to temperature, salinity, and current changes. This process will establish an historic baseline from which to measure future changes.
- Incorporating climate change issues into fisheries planning efforts. The planners need to take into account the life expectancy of the project and use appropriate climate change scenarios to identify potential risks to the fishery.
- Employing management approaches that seek to avoid overfishing, and promote ecosystem health.
- Researching the feasibility of marketing and selling new species as they may take the place of traditional species that will migrate elsewhere as ocean temperature and pH shift.
- Considering policies and regulatory processes that promote sustainable fishing including strengthening the rule of law (fisheries enforcement and aquaculture regulation) and improving civil society engagement (co-management approaches).

ADAPTING TO CLIMATE CHANGE BY MINIMIZING VULNERABILITY THROUGH PROJECT DESIGN

Adapting planning, design, and project execution to climate change involves ensuring that existing fishing communities, new aquaculture operations, and associated facilities are able to withstand variations in climatic conditions and especially extreme weather events. Designers and project managers should focus on incorporating information on climate from historical records, recent trends, and future projections. For example, Large scale investments in off-shore seaweed or bivalve aquaculture facilities may require longer term planning to protect the investment from global climate change (i.e., sea-level rise and temperature increase), whereas tilapia ponds are generally small investments that are threatened more by near term water available issues and land use conflicts rather than longer term climatic fluctuations. Future projections should also take into consideration environmental thresholds that, if surpassed, could cause rapid ecosystem change. Note that near-term projections are more reliable and less uncertain than long-term emissions and climate predictions. In many cases managing for greater uncertainty rather than specific trends may be most appropriate. It is also important to ensure that workers in the industry have access to these resources. In many cases managing for greater uncertainty and risk associated with potential extreme conditions rather than past historical trends emphasizes the **precautionary principle** over "**business as usual**." This type of focus on risk analysis and management is commonly applied by the financial and insurance industries and can also be used in assessing potential development activities.

For example, design and siting for fisheries projects in coastal communities should take into account projected sea level rises, and storm surges. Construction should also be avoided in or near flood plains, rivers, and wetlands whenever possible. In locations where drought conditions are becoming more frequent, inland aquaculture project designers should ensure that a reliable

source of water can be sustained to supply the operation. Ultimately, more robust fisheries infrastructure will ensure resilience to climate change.

From a **risk management** perspective, it is less costly to design for the potential direct and indirect impacts of climate change on fisheries, than to have fishermen and the fishing industry risk major losses or for communities to face food shortages.

Direct Impacts	Indirect Impacts	Possible Adaptation Responses
• Changes in fish stock abundance, species composition, and location of commercially important species	• Reduced nutrition • Reduced incomes • Food insecurity • Migration • Reduced access to markets	• Fisheries restoration through no-take zones, tradable fishing rights • Fisher managed natural regeneration of fish stocks, mangroves • Insurance

MINIMIZING GREENHOUSE GAS EMISSIONS (GHG) AND MAXIMIZING SEQUESTRATION

When the entirety of the fisheries and aquaculture industries are taken a whole, the GHG emissions are significant,[15] mainly due to fuel use by fishing vessels, and fuel for the transportation, processing, and storage of fish. Decreasing dependence on fossil fuels and improving fuel efficiency in the fisheries sector may include opting for alternative fuels (e.g.,natural gas, biofuels, wind, or solar); shifting to low or no-fuel techniques such as seining; reducing vessel speed; or installing more efficient engines. The provision of relevant climate change mitigation information and technical assistance to stakeholders can decrease agriculture's contribution to climate change.

At the same time, fishing and aquaculture can impact ecosystems that serve to store carbon. Mangroves and other coastal/freshwater ecosystems (such as wetlands and seagrasses) store carbon in their soils and plant matter. Disturbing those ecosystems releases carbon into the atmosphere. The release of greenhouse gases from soils can be a slow process and restoration efforts can help to slow or reverse that process. Additionally, large fish species themselves serve as large oceanic carbon sinks and the appropriate management of fisheries has the potential to store carbon[16]. Certain practices can help prevent the carbon already stored in these environments from escaping into the atmosphere. These practices include minimizing use of trawl nets and other destructive fishing practices, and avoiding land clearing for aquaculture ponds.[17]

[15] FAO. 2009. World Review of Fisheries and Aquaculture. ftp://ftp.fao.org/docrep/fao/011/i0250e/i0250e01.pdf

[16] Pershing, A.J., Christensen, L.B., Record, N.R., Sherwood, G.D., Stetson, P.B. (2010). The impact of whaling on the ocean carbon cycle: Why bigger was better. PLOS One, Available at: http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0012444

[17] FAO. 2009. Final Report: Expert Consultation on GHG emissions and mitigation potentials in the agriculture, forestry and fisheries sectors. http://www.fao.org/climatechange/59239/en/

SECTOR PROGRAM DESIGN – SOME SPECIFIC ENVIRONMENTAL 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. USAID has published a guide on Sustainable Fisheries and Responsible Aquaculture (2013), which provides detailed guidance for staff and partners on how to design capture fisheries and aquaculture projects. Some specific design best management practices to consider in design which help mitigate negative environmental impacts are:

BEST MANAGEMENT PRACTICES EXAMPLES 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 section on "solid waste management" in these guidelines).
- Do not discharge bilge and ballast water with oil and grease concentration above 10 mg/liter—some local environmental laws may consider oily water hazardous waste and it may require separate handling and treatment.
- 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.

GUIDELINES FOR POLICY WORK FOR CAPTURE FISHERIES

- Provide incentives for preventing illegal, unreported, and unregulated (IUU) fishing by creating systems that are easy to comply with and are thoughtful of habits and processes used by fishers.
- Coordinate with local and national authorities to identify needs in the sector that considers multiple dimensions of resource governance, including the enabling policies and laws, integrated coastal and water resources management, incentives to promote resource stewardship, spatial land and marine planning, land and sea tenure or access rights, and sound management at the seascape/landscape scale.
- Build and leverage champions and constituencies strategies that encourage stewardship, fair trade, and long-term productivity.

- Reform fisheries by the using co-management, community-based management, rights-based approaches, voluntary certification and codes of conduct, and proper economic incentives, including secure tenure and property rights to address the governance of common property resources.
- Ensure that a framework is in place to establish and adopt management plans that are based on sound science, considers all stakeholders (including women and indigenous rights), and are based on a "systems approach" that maintains the integrity and health of ecosystems.
- Consider large-scale landscape and seascape planning and zoning for specific uses and user groups.

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.
- Choose sites that are near wild stock populations. avoid introducing non-native or 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 (i.e., the species is not well adapted to the local environment).
- 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.

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

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.
- Areas with slight (one meter or less) or no tidal fluctuations, as are common in Latin America and Asia, cannot be properly drained or filled through reliance on tidal fluctuations, and will often need to have a pump system installed instead. For saline brackish ponds with moderate (between two and three meters) tidal fluctuation, as occurs in many parts of Africa, choose land with average elevation to enable ordinary high tides and ordinary low tides to filter, renew, and drain water. Sites with tidal fluctuations above four meters require very large, expensive dikes to prevent flooding during high tide.
- 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. Consider how climate change may impact the availability of water over the time period for which the pond is expected to function. Water supply should be pollution-free and with a pH of 7.8 to 8.5.

Designing Ponds

- Design to prevent storm and flood damage that could cause overflow discharges. Take into account future changes in the size and frequency of storms due to climate change.
- 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; and
- 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, biological oxygen demand (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.

INVASIVE SPECIES: NILE PERCH

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

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 downstream 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; and
- 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. 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 upstream of recreational areas, marine parks, fishing grounds, shellfish beds used for commercial or recreational harvest, or other sensitive areas.

MITIGATION AND MONITORING ISSUES

FACTORS AFFECTING AQUACULTURE PROJECT SUCCESS

Field studies of small-scale fishponds in Zimbabwe and Zambia have shown a large number of project failures and pond abandonments. Many of the management and design factors that caused these operations to fail also add to environmental and climatic challenges to the project. These lessons can be applied across other parts of the world.

PRIORITIES

Many farmers choose to dig fishponds with encouragement from development agencies as a solution to protein needs and livelihood investment, but they have misconceptions that the project will bring immediate benefits. 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 weigh 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, or stocks may die if oxygen exchange rates are low and the water becomes anoxic.

BIOLOGICAL FACTORS

Farmers may experience problems maintaining adequate stocking and survival rates due to predation, slow development, or inadequate food supplies. .

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—which may be necessary for securing supplies or selling produced fish. Unrest as well may lead to periods where ponds on not maintained, and therefore, there is a financial and labor barrier to reentering the market once stability returns (i.e., pond cleaning, fixing berms, restocking, water supply). 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:

NON-NATIVE OR EXOTIC SPECIES

Tightening controls on importation of animals and plants will help prevent introduction of non-native or exotic species that may compete with natural fish populations or food sources for extensive aquaculture projects. 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. Methods of control of alien plants include physical removal by hand, use of machinery, or biological control. The latter technique can contain alien populations with fewer environmental impacts but is a more lengthy and risky process because control organisms must themselves be rigorously tested for adverse impacts before their release into the environment.

Removal by chemicals, particularly use of herbicides, is a widely used management method that can also be effective in controlling invasive species. This method is fast-acting and relatively inexpensive, but must be implemented with caution, as over-use or improper use of herbicides can cause herbicide resistance, impacts on native species, pollution, and human health problems.[18]

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

The relative success of capture fishing and conducting extensive aquaculture projects is dependent on sustaining high-quality ecosystems. This is because these ecosystems provide hatcheries, food sources, and water purification services important to fish. 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 erosion causes excess sedimentation in fish habitats.

Controlling damaging activities such as pollution, sedimentation, and over-fishing can help mitigate habitat destruction. Certain aquatic habitats such as mangrove swamps and coral reefs are ecologically and economically important and are particularly threatened by development, destructive fishing practices such as dynamite and chemical fishing, and sediment runoff from deforestation, anchor damage, dredging, and manipulation of natural river, lake, and flood plain characteristics.

Replanting denuded areas can often restore mangrove habitats, however coral reefs are more difficult to restore and are highly sensitive to environmental stress. Thus, it is crucial to monitor these ecosystems for changes in temperature, sedimentation, nutrient loading, storm damage and toxins.

[18] Adapted from Managing Invasive Plants: Concepts, Principles, and Practices. U.S. Fish and Wildlife Service. 2009. http://www.fws.gov/invasives/staffTrainingModule/methods/chemical/introduction.html

MITIGATION AND MONITORING ISSUES

ACTIVITY	PROBLEM	APPLICABILITY	MITIGATION TECHNIQUES
All Fisheries			
	Pollution (bioaccumulation or as waste from project activities)	Mollusk, capture fisheries, aquaculture	Aquatic organisms are particularly vulnerable to biocides, leachates, pesticides. Larger fish species are also prone to bioaccumulate heavy metals in their tissue, • Monitor water conditions closely for contaminants. • Survey location surrounding project sites for sources of pollution (e.g., upstream tanneries, agricultural fields, etc). • Reduce sources of pollution, and where reduction is not sufficient, set up physical barriers to pollution. • Promote regulations and community oversight to limit and monitor discharge into the environment • Bivalves themselves, can be used as bioremediation for heavy metal contamination (not for consumptive use) and act as carbon sinks.
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.

ACTIVITY	PROBLEM	APPLICABILITY	MITIGATION TECHNIQUES
			• (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			
Site Selection	Loss of mangrove habitat	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.
Site Selection (continued)	Loss of mangrove habitat (continued)	General (continued)	
	Lack of 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. • Depending on the direction of prevailing winds and currents, orient the cages to prevent debris from collecting between them.
Design	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.
	Impacts to pond floor	Mollusk Culture	Use off-bottom systems such as rafts and lines.

ACTIVITY	PROBLEM	APPLICABILITY	MITIGATION TECHNIQUES
	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.
	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).
Construction	Erosion	General	Minimize disturbance of soil and vegetation.
	Seepage into ground and surface waters	General	Build ponds on soils with adequate clay content.
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.
	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.

ACTIVITY	PROBLEM	APPLICABILITY	MITIGATION TECHNIQUES
		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.
Operations (continued)	Excess of organic nutrients	General	• Treat aquaculture and human wastes according to sanitation guidelines. • Use polyculture (e.g., raising 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	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.
Operations (continued)	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.
		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.
		Birds	• Eliminate safe roosting and perching places; • Place the containment units deeper below the surface of the water to reduce the attraction of surface-feeding birds such as gulls; • Move young/small stock to an area where they are less accessible to predatory birds;

ACTIVITY	PROBLEM	APPLICABILITY	MITIGATION TECHNIQUES
			• Place nets above cages to keep birds off; • Adjust top nets so they do not sag under the weight of preying birds, enabling them to more easily reach the fish; • Use brightly colored nets to reduce the likelihood of birds accidentally swimming into nets.

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  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.

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  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.

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- FAO Newsroom Focus (August 2003). Aquaculture: not just an export industry. http://www.fao.org/english/newsroom/focus/2003/aquaculture.htm
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  Topics include:

  - Aquaculture development. 6 - Use of wild fishery resources for capture-based aquaculture (2011)
  - Aquaculture development. 5- Use of wild fish as feed in aquaculture (2011)
  - Fisheries management. 4- Marine protected areas and fisheries (2011)
  - Aquaculture development. 4- Ecosystem approach to aquaculture (2010)
  - Fisheries management. 2- The ecosystem approach to fisheries. 2.2 The human dimensions of the ecosystem approach to fisheries. (2009)
  - Fishing operations. 2- Best practices to reduce incidental catch of seabirds in capture fisheries. (2009)
  - Information and knowledge sharing. (2009)
  - Responsible fish trade. (2009)
  - Aquaculture development. 3- Genetic resource management. (2008)
  - Fisheries management. 2- The ecosystem approach to fisheries. 2.1 Best practices in ecosystem modelling for informing an ecosystem approach to fisheries. (2008)
  - Fisheries management. 3- Managing fishing capacity. (2008)
  - Inland Fisheries. 1- Rehabilitation of inland waters for fisheries. (2008)

- Aquaculture development. 2- Health management for responsible movement of live aquatic animals. (2007)
- Increasing the contribution of small-scale fisheries to poverty alleviation and food security. (2005)
- Fisheries management. 2- The ecosystem approach to fisheries2003Implementation of the International Plan of Action to deter, prevent and eliminate, illegal, unreported and unregulated fishing. (2002)
- Food and Water Watch. Offshore Fish Farming – Top 10 Problems. http://www.foodandwaterwatch.org/fish/fish-farming/offshore/problems/

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  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://books.google.com/books?hl=en&id=jR6hTsiGVOoC&dq=Fisheries+and+Aquaculture+Research+Planning+Needs+for+Africa+and+West+Asia&printsec=frontcover&source=web&ots=rDik6g7Ada&sig=K_MoqTe-wdGfQWvtvZ6Q7mGlCFg&ei=US-TSaqfG83dtgekscjWCw&sa=X&oi=book_result&resnum=1&ct=result

  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.

- 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.uneca.org/awich/FORGOTTEN%20WATERS-FRESHWATER%20AND.pdf

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.

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  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.

- Srinivasan, U.T., Cheung, W.W.L., Watson, R. and Sumaila, U.R. (2010). Food security implications of global marine catch losses due to overfishing. Journal of Bioeconomics 12, 183-200 http://www.ecomarres.com/downloads/Thara2.pdf

- Sustainable Aquaculture: Seizing Opportunities to Meet Global Demand (1998). Rural Development Department, The World Bank. Agriculture Technology Notes No. 22, December. Available at: http://www-wds.worldbank.org/external/default/main?pagePK=64193027&piPK=64187937&theSitePK=523679&menuPK=64187510&searchMenuPK=64187283&siteName=WDS&entityID=000094946_00102805334371

  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 Ninth International Symposium on Tilapia in Aquaculture. (2011). Conference program, papers, and presentations. http://ag.arizona.edu/azaqua/ista/ISTA9/ISTA9.htm

  The ninth of a series of symposia that have brought together tilapia biologists who review the latest discoveries in tilapia nutrition, physiology, reproductive biology, genetics, ecology, improvements in production systems, and other fields related to tilapia and their use in aquaculture. The symposium had a special emphasis on best management practices, quality control, new product forms, international trade, and opening new markets for farmed tilapia products. The symposium included a trade/exhibit show, which provided a forum for industry suppliers, seafood marketers, and the aquaculture press to meet directly with researchers and producers.

- The Review of the Status, Trends, and Issues in Global Fisheries and Aquaculture with Recommendations for USAID Investments. The USAID SPARE Fisheries & Aquaculture Panel. http://pdacrsp.oregonstate.edu/miscellaneous/F%26A_Subsector_Final_Rpt

- Tucker, C.S. and J.A. Hargreaves (eds). 2008. Environmental best management practices for aquaculture. Wiley-Blackwell. Ames, Iowa. 592 pp.

- UN Educational, Scientific, and Cultural Organization, Intergovernmental Oceanographic Commission (2012). Providing options to respond to climate change in West African coastal areas. http://www.unesco.org/new/en/natural-sciences/ioc-oceans/single-view-oceans/news/providing_options_to_respond_to_climate_change_in_coastal_areas/

- USAID. (2003). Review of the Status, Trends and Issues in Global Fisheries and Aquaculture, with Recommendations for USAID Investments. http://pdacrsp.oregonstate.edu/miscellaneous/F%26A_Subsector_Final_Rpt.pdf

- USAID. (2006). Fisheries Opportunity Assessment. http://www.crc.uri.edu/download/Fish_Opp_Assess_Final_012607_508.pdf.

- USAID. 2013. Sustainable fisheries and responsible aquaculture: a guide for USAID staff and partners.

- Van Houtte, A. 2001. Establishing legal, institutional and regulatory framework for aquaculture development and management. In R.P. Subasinghe, et al., eds. Aquaculture in the Third Millennium. Technical Proceedings of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand, 20-25 February 2000.

CLIMATE CHANGE RESOURCES

Note: USAID's Global Climate Change (GCC) Office can provide support on the climate change aspects of this Guideline. To contact the GCC office, please email: climatechange@usaid.gov

- USAID. 2007. Adapting to Climate Variability and Change: A Guidance Manual for Development Planning. http://pdf.usaid.gov/pdf_docs/PNADJ990.pdf
- USAID. 2009. Adapting to Coastal Climate Change: A Guidebook for Development Planners. http://pdf.usaid.gov/pdf_docs/PNADO614.pdf

  The guidance provides information to assist planners and stakeholders as they cope with a changing climate throughout the project cycle.
- IPCC. 2007. Observations: Oceanic Climate Change and Seal Level in: Climate Change 2007: The Physical Science Basis. Contributions of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter5.pdf
- Pew Ocean Science Series. 2009. Redistribution of Fish Catch by Climate Change. A Summary of a New Scientific Analysis. http://www.seaaroundus.org/ClimateChange/images/Pew%20OSS%20Final%20climate%20change%20and%20fisheries.pdf
- FAO. 2009. Fisheries and Aquaculture in a Changing Climate. http://www.fao.org/climatechange/17792-0d5738fda3c03582617e6008210ab1e3a.pdf
- FAO. 2009. World Review of Fisheries and Aquaculture. ftp://ftp.fao.org/docrep/fao/011/i0250e/i0250e01.pdf
- Seafish. 2009. Research & Development Factsheet: Fishing Vessel Fuel Emissions. http://www.seafish.org/media/Publications/FS27_04.09__Fuel_emissions.pdf
- FAO. 2009. Final Report: Expert Consultation on GHG emissions and mitigation potentials in the agriculture, forestry and fisheries sectors. http://www.fao.org/climatechange/59239/en/
- National Communications are submitted by countries to the UNFCCC and include information on country context, broad priority development and climate objectives, overviews of key sectors, historic climate conditions, projected changes in the climate and impacts on key sectors, potential priority adaptation measures, limitations, challenges and needs. http://unfccc.int/national_reports/non-annex_i_natcom/items/2979.php

- The World Bank's Climate Change Knowledge Portal is intended to provide quick and readily accessible climate and climate-related data to policy makers and development practitioners. The site also includes a mapping visualization tool (webGIS) that displays key climate variables and climate-related data. http://sdwebx.worldbank.org/climateportal/

- **National climate change policies and plans**. Many countries have policies and plans for addressing climate change adaptation.

DOCUMENTS DISPONIBLES EN FRANÇAIS

- Manuel en environnement- Ressources complémentaires — Pisciculture

- Outils pour l'identification des effets environnementaux de secteurs d'activités spécifiques, des mesures d'atténuation appropriées et lignes directrices http://www.acdi-cida.gc.ca/acdi-cida/acdi-cida.nsf/fra/EMA-218123621-NNZ

- FAO Directives Techniques pour une Pêche Responsable ftp://ftp.fao.org/docrep/fao/003/w3591f/w3591f00.pdf

- Directives environnementales, sanitaires et sécuritaires pour l'aquaculture. société financière internationale Avril 2007 http://www1.ifc.org/wps/wcm/connect/8b273f804886581ab426f66a6515bb18/057_Aquaculture.pdf?MOD=AJPERES

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- Code de conduite canadien sur les pratiques de pêche responsable http://www.dfo-mpo.gc.ca/fm-gp/policies-politiques/cccrfo-cccppr-fra.htm#directrices

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