Environmental, Health, and Safety Guidelines for Aquaculture

Introduction

The Environmental, Health, and Safety (EHS) Guidelines are technical reference documents with general and industry-specific examples of Good International Industry Practice (GIIP)[1]. When one or more members of the World Bank Group are involved in a project, these EHS Guidelines are applied as required by their respective policies and standards. These industry sector EHS guidelines are designed to be used together with the **General EHS Guidelines** document, which provides guidance to users on common EHS issues potentially applicable to all industry sectors. For complex projects, use of multiple industry-sector guidelines may be necessary. A complete list of industry-sector guidelines can be found at: www.ifc.org/ifcext/enviro.nsf/Content/EnvironmentalGuidelines

The EHS Guidelines contain the performance levels and measures that are generally considered to be achievable in new facilities by existing technology at reasonable costs. Application of the EHS Guidelines to existing facilities may involve the establishment of site-specific targets, with an appropriate timetable for achieving them.

The applicability of the EHS Guidelines should be tailored to the hazards and risks established for each project on the basis of the results of an environmental assessment in which site-specific variables, such as host country context, assimilative capacity of the environment, and other project factors, are taken into account. The applicability of specific technical recommendations should be based on the professional opinion of qualified and experienced persons.

When host country regulations differ from the levels and measures presented in the EHS Guidelines, projects are expected to achieve whichever is more stringent. If less stringent levels or measures than those provided in these EHS Guidelines are appropriate, in view of specific project circumstances, a full and detailed justification for any proposed alternatives is needed as part of the site-specific environmental assessment. This justification should demonstrate that the choice for any alternate performance levels is protective of human health and the environment.

Applicability

The EHS Guidelines for Aquaculture provide information relevant to semi-intensive and intensive/super-intensive, commercial aquaculture production of the main aquatic species, including crustaceans, mollusks, seaweeds and finfish, located in developing countries in temperate and tropical regions. Annex A contains a full description of industry activities for this sector.

This document is organized according to the following sections:

[1] Defined as the exercise of professional skill, diligence, prudence and foresight that would be reasonably expected from skilled and experienced professionals engaged in the same type of undertaking under the same or similar circumstances globally. The circumstances that skilled and experienced professionals may find when evaluating the range of pollution prevention and control techniques available to a project may include, but are not limited to, varying levels of environmental degradation and environmental assimilative capacity as well as varying levels of financial and technical feasibility.

1.0 Industry-Specific Impacts and Management

The following section provides a summary of EHS issues associated with aquaculture, along with recommendations for their management. Recommendations for the management of EHS issues common to most projects during the construction and decommissioning phases are provided in the **General EHS Guidelines**.

1.1 Environment

Environmental issues associated with the aquaculture sector primarily include the following:

- Threats to biodiversity
- Contamination of aquatic systems
- Hazardous Materials

Threats to Biodiversity

Threats to biodiversity are mainly associated with conversion of natural habitats during construction; potential release of alien species into the natural environment during operations; potential loss of genetic resources due to collection of larvae, fry, or juveniles for aquaculture production; potential release of artificially propagated seed into the wild (e.g. there are more farmed than wild Atlantic salmon in existence); sustainability of fish meal and fish oil ingredients for fish and crustacean feeds; and development of antibiotic resistance in pathogenic bacteria that can then spread from farms to wild stock.

Conversion of Natural Habitats

The construction and operational phases of the project cycle of an aquaculture facility may require conversion of the natural environment including, for example, the removal of mangroves for excavation of ponds, or alteration of the natural hydrology of lagoons, bays, rivers, or wetlands.[2] Operational phase issues may also include alteration of aquatic habitats and substrates (e.g. under sea cages or shellfish farms).

A range of management measures can be taken to prevent and reduce the environmental impacts caused by the construction of aquaculture facilities, as presented below. Further potential impacts are related to changes to stream hydrology caused by the construction of barriers to flow (e.g. dams may cause disruption of wetland areas and changes in stream morphology, potentially affecting migratory species, including birds, and nursery areas for juvenile fish). Measures should include all of the following:

- Survey the project area before land and water conversion to aquaculture production is undertaken to identify, categorize, and delineate natural and modified habitats and ascertain their biodiversity importance at the national or regional level;
- Ensure that the area to be converted to aquaculture use does not represent a habitat that is unique or protected (such as mangrove areas), or includes high biodiversity value, such as known sites of critically endangered or endangered species, or important wildlife breeding, feeding, and staging areas;
- Be aware of the presence of critically endangered or endangered species in the areas already used for aquaculture production, and implement management processes that take them into account;
- Design facilities so that as much as possible of the natural vegetation habitat is left intact (e.g. through the use of vegetated buffer zones and habitat corridors) and that

[2] Hydrological changes may also contribute to changes in the natural geochemistry such as the release of pyrite from formerly submerged soils of cleared mangrove areas. When pyrite comes into contact with oxygen, it creates acid sulfate soil, which in turn has potentially serious impacts on the health of the aquaculture organisms for many years to come.

conversion and degradation of the natural habitat is minimized;

- Design and implement mitigation measures to achieve no net loss of biodiversity where feasible, for instance through post-operation restoration of habitats; offset of losses through the creation of ecologically comparable area(s) managed for biodiversity; and compensation to direct users of biodiversity;
- Avoid the need to frequently abandon and replace improperly designed and built aquaculture ponds:
    - Assess soil properties prior to pond construction to ensure that the bottom-sealing layer of the soil with percolation rates/porosity low enough to satisfactorily hold pond water. If there is not enough clay, then the ponds may demonstrate high seepage rates and require additional expenditure (e.g. pumping in water, or relining with clay-rich or possibly bentonite-rich topsoil from other sites) or eventual abandonment. High seepage rates can also pollute groundwater required for other purposes in the vicinity with use for drinking water a major concern.
    - Assess the soil pH and the presence of pesticide and pollutant residues (especially on land that was previously used for intensive agriculture), as well as the natural occurrence of pyrite, prior to construction as the presence of anthropogenic or natural pollutants may hinder the viability of the pond.

Conversion of Agricultural Land - Salinization

If new land areas are not available for aquaculture, an alternative is to convert former agricultural land. If the selected production is based on brackish water, this may pose a risk of salinization of surrounding agricultural land. The following measures can be taken to avoid salinization of agricultural land:

- Ensure that the embankments around brackish water pond systems are high enough to form a physical division between agriculture and aquaculture;
- Ensure that the saline / brackish water discharges are appropriately treated and disposed of (e.g. through use of discharge canals) for the receiving waters;
- Ensure that appropriate discussions are held at the community level to avoid conflicts of interest when agricultural land is transferred to aquaculture production.

Introduction of Alien, Selectively Bred, or Genetically Engineered Species

Introductions can result in interactions with the wild, including escapes from farms, or open systems (such as mussel rafts). As such, introductions can disturb the existing ecological balance; cause loss of species biodiversity; cause loss of genetic diversity of the wild populations; reduce fitness of wild population through breeding with genetically altered escapees; and result in the transmission or spread of fish diseases. The widespread seeding of an alien genotype is of considerable concern both as regards species biodiversity and genetic biodiversity.

Management measures to reduce the risks from introductions of alien, selectively bred, or genetically modified species include the following:

- Application of codes and guidelines (see Section 3.0);
- Farming of sterile fish;
- Preventing the escape of species from pond-based aquaculture systems. Examples of common escape prevention measures include:
    - Installation and maintenance of screens with a mesh that is small enough to prevent the entry and potential escape of aquatic species in the drainage channels connecting production ponds to sedimentation ponds,

as well as those connecting sedimentation ponds to the receiving water
  - Installation of fish-proof strainer dams
  - Installation and maintenance of gravel filtration on pond discharge structures
  - When necessary, consider chemical treatment of water released from hatcheries(e.g. with chlorine at acceptable concentrations for the receiving waters) to destroy escaping larvae or juveniles
  - Consider the hydrology of the region in the design of the pond system and ensure that the pond embankments are high enough to contain the pond water and prevent escape of the species during periods of heavy rainfall and potential flooding
  - Establish a contingency plan if there is an escape of the species being cultivated into the wild
- Preventing the escape of species from open water aquaculture systems. Examples of common escape prevention measures include:
  - Regularly inspect the cage and pen netting for holes(e.g. before crowding of the harvest and at intervals during the operation)
  - Design and construct cage and pen units, including choice of nets, to deal with the worst weather and environmental conditions likely to occur on the site
  - Provide for containment during periods of storm surges and excessively high tides
  - For cage culture in open waters, use submersible cages that can be submerged during storms below damaging wave action
  - Provide adequate marking of the fish farm system to warn navigators of the potential obstruction and reduce the risk of collision[3]
  - Establish a contingency plan for harvest of escapees of the species being cultivated into the wild.

[3] Shetland Aquaculture (2006).

Impacts of Harvesting on Ecosystem Functions

The practice of capturing females, eggs, fry, juveniles, or even fingerlings from the wild for the purpose of stocking aquaculture systems may threaten ecosystem biodiversity. Fry and larvae may be gathered from fresh or brackish water using very fine meshed nets resulting in considerable by-catch, as well as the removal of large number of larvae, fry, and juveniles from the food chain.[4] The recommended prevention of this type of ecosystem pressure is the breeding of stock material in captivity. However, for some species, careful harvesting of hatchlings/ and or fry (less than 3 cm) that are still at a stage of expected high mortality can result in relatively little impact on the overall population as compared to collecting larger fingerlings from a smaller population for grow-out.

Fish meal and fish oil

Fish meal and oil are derived from the capture and processing of wild pelagic fish stocks (e.g. anchovy, pilchard, herring, sardine, sand eel, sprat, and capelin). Although the production of fish meal and oil is not covered by these Guidelines, processed fishmeal and oil are the primary sources of protein and dietary lipids in fish feed for farmed fish in aquaculture operations. The aquaculture sector is an important consumer of fish meal and fish oil, and there are concerns regarding the sustainability of the pelagic fish stocks from which fish meal and fish oil are derived. Aquaculture operations should consider incorporating the use of alternatives to supplies of fish feed produced from fish meal and fish oil. Alternatives for fish feed ingredients may include use of plant material substitutes [e.g.

[4] Some jurisdictions have outlawed the larvae and fry collection or export although the practice still represents a source of income for the poor in some developing countries.

soya for bulk protein and single-cell protein (yeast for lysine and other amino acids)] and biotechnology options (e.g. bio-fermentation products).[5]

Source Water Quality

The quality of source water can also have a major effect on the viability of an aquaculture operation whether it is water used for hatchery and ponds systems or the water in which cages and pens are established. The water itself can affect the health of the organism as well as contribute to the accumulation of substances or pathogens toxic to consumers. Quality guidelines have been developed for aquaculture and vary depending upon the organism cultured.[6]

Contamination of Aquatic Systems

Aquaculture activities, particularly pond-based systems, may affect aquatic systems due to construction and operation activities, primarily the mobilization of soils and sediments during construction and through the release of effluents during operation. Fish cage culture can also be a major contributor to marine pollution in areas of high density use.

Soil Erosion and Sedimentation

Earth excavation and moving activities conducted during construction of some types of aquaculture projects may result in soil erosion and the subsequent sedimentation of nearby water bodies. Sedimentation of aquatic resources may contribute to eutrophication and overall degradation of water quality. Recommended management strategies include the following:

- Construct pond and canal levees with a 2:1 or 3:1 slope (based on soil type) as this adds stability to the pond banks, reduces erosion, and deters weeds. Avoid pond construction in areas that have a slope of more than 2 percent, as this will require energy-intensive construction and maintenance;
- Stabilize the embankments to prevent erosion;
- Reduce excavation and disturbance of acid sulfate soils during construction;
- Carry out construction work during the 'dry' season to reduce sediment runoff that may pollute adjacent waters;
- Install temporary silt fences during construction to slow down and catch any suspended sediments. Silt fences can be made of woven plastic or fabric, or hay bales.

Wastewater Discharges

Industrial Process Wastewater: The effluent released from aquaculture systems typically contains a high organic and nutrient load, suspended solids, and may also contain chemical residues including feed supplements and antibiotics. The possible impacts include contamination of groundwater and surface water from release of effluents or communication to receiving water from unconfined process and storage tanks (such as ponds and lagoons). Impacts on aquatic systems include creation of eutrophic zones within receiving waters, increased fluctuation of dissolved oxygen levels, creation of visible plumes, and accumulation of nutrients within the receiving waters.[7]

The high nutrient load results from efforts to artificially boost production levels by increasing the food supply for the cultured species. This is done by increasing nutrient availability either directly through supplemental feed or indirectly by fertilizing

5 Further information is available from Use of Fishmeal and Fish Oil in Aquafeeds: Further Thoughts on the Fishmeal Trap, FAO (2001) Available at http://www.fao.org/docrep/005/y3781e/y3781e07.htm#bm07.3.3 and Assessment of the Sustainability of Industrial Fisheries Producing Fish Meal and Fish Oil, Royal Society for the Protection of Birds (2004) available at http://www.rspb.org.uk/Images/fishmeal_tcm5-58613.pdf

6 Zweig, R. D., J. D. Morton and M. M Stewart.1999. Source Water Quality for Aquaculture: A Guide for Assessment. The World Bank. 62 pp.

7 Department of Primary Industries and the Queensland Finfish Aquaculture Industry (1999).

ponds to increase primary productivity. Pond ecosystems have a limited capacity to recycle organic matter and nutrients, and increasing the stocking rate removes this capacity, resulting in the build-up of organic matter, nitrogenous waste, and phosphorus both in the water mass and on the bottom of the pond or pen / cage.[8] The suspended solids are derived from particulate organic matter and erosion of pond floor, walls, and discharge channels.

The chemical residues may include the remains of veterinary drugs (e.g. antibiotics) that may have been applied to the cultivated species, and toxic substances such as formalin and malachite green, a cancer causing agent, that may have been that are used to treat finfish for parasites and their eggs for fungal growth. Malachite green is banned in most countries and must not be used. Formalin should only be used under controlled conditions (e.g. in dipping containers) and with proper care – it should not be introduced directly into production systems.[9]

A range of measures can be taken in pond systems and pen / cage systems to (i) reduce the amount of contamination of the effluent; (ii) prevent pond effluent from entering surrounding water bodies; and (iii) treat the effluent before its release into the receiving waters to reduce contaminant levels. Aquaculture operations in large water bodies, however, are open to the surrounding environment and do not have the second or third options, therefore any contamination takes effect immediately.[10] The following management measures can prevent the contamination of effluent:

[8] Center for Tropical and Subtropical Aquaculture (2001).
[9] Because the use of these highly toxic substances is primarily an occupational health and safety issue, refer to the Occupational Health and Safety section for a more detailed review of their application and for practical guidance.
[10] Aquaculture is also somewhat self-regulating in that if the water is highly eutrophic or laden with dissolved or particulate nutrients or BOD, this will adversely affect many cultured organism and thus would be counterproductive not to manage it to a high quality level. This would somewhat reduce impacts of effluents.

Feed:

- Ensure that pellet feed has a minimum amount of "fines" or feed dust. Fines are not consumed and add to the nutrient load in the water;
- Match the pellet size to the species' life-cycle stage (e.g. smaller pellets should be fed to fry or juvenile animals to reduce the unconsumed fraction);
- Regularly monitor feed uptake to determine whether it is being consumed and adjust feeding rates accordingly. Feed may be wasted due to overfeeding or not feeding at the right time of day;
- Where feasible, use floating or extruded feed pellets as they allow for observation during feeding time;
- Store feed in cool, dry facilities and ideally for no longer than 30 days to avoid reduction in vitamin contents. Moldy feed should never be used as it may cause disease;
- Spread feed as evenly as possible throughout the culture system, ensuring that as many animals as possible have access to the feed. Some species are highly territorial, and uneaten feed adds to the nutrient load;
- Feed several times a day, especially when animals are young, allowing better access to food, better feed conversion ratios and less waste;
- Halt feeding at a suitable interval before harvest to eliminate the presence of food and / or fecal material in the animal's gut;
- During harvesting, contain and disinfect blood water and effluent to reduce the risk of disease spread and to contain effluent matter.

Other organic materials:

- Perform slaughter and processing in an area where the effluent is contained;
- Prevent effluent leakage from harvest rafts and bins by using harvest bins in good condition with sealed bin liners and secure lids and bindings;

- Equip off-loading bays with a waterproof apron and surround with a bund to contain potential spills and prevent contamination with effluent.[11]

Suspended solids:

- Avoid discharging waters from ponds while they are being harvested with nets, as this will add to the suspended solids in the effluent drainage;
- If feasible, use partial draining techniques to empty ponds that have been harvested. The last 10–15 percent of pond water contains the highest quantities of dissolved nutrients, suspended solids, and organic matter. After harvest, hold the remaining water in the pond for a number of days before discharge, or transfer to a separate treatment facility.

Fertilizers:

- Plan the rate and mode of application of fertilizers to maximize utilization and prevent over-application, taking into account predicted consumption rates;
- Increase the efficiency of application and dispersion through such practices as dilution of liquid fertilizers or solution of granulated fertilizers prior to application. Other options include the use of powdered fertilizers or the placement of powdered fertilizer bags in shallow water to allow solution and dispersion;
- Consider the use of time-released fertilizer in which resin coated granules release nutrients into the pond water, with the rate of release corresponding to water temperature and movement;
- Avoid the use of fertilizers containing ammonia or ammonium in water with pH of 8 or above to avoid the formation of toxic unionized ammonia (NH_3);[12]
- Depending on the system (e.g., freshwater aquaculture), grow organic fertilizer (e.g. natural grass) in the pond basin after harvest;
- Initiate pond fertilization only in static ponds with no pond water overflow that can impact downstream waters and watersheds;
- Conduct pond fertilization to avoid or minimize consequences of potential runoff due to floods or heavy rain and avoid application to overflowing ponds.

Chemicals:

- Design the pond depth to reduce the need for chemical control of aquatic weeds and reduce thermal stratification;
- Do not use antifoulants to treat cages and pens. The chemically active substances used in antifouling agents are very poisonous and highly stable in an aquatic environment. Clean nets manually or in a net washing machine.

The following management measures can be taken in pond-based systems to prevent pond effluent from entering surrounding water bodies:

- In some fish systems, avoid automatic drainage of ponds at the end of the production cycle as the same pond water may be used to cultivate several crop rotations of certain species (e.g. catfish);[13]
- Reuse water from harvested ponds by pumping it into adjacent ponds to help complement their primary productivity, provided that the level of BOD is controlled; This process is called “bloom seeding,” and requires careful timing of harvests;
- Consider the hydrology of the region in the design of the pond system and ensure that the pond embankments are

[11] Shetland Aquaculture (2006).
[12] WRAC (2000).
[13] Not applicable to shrimp farming which requires the drying out of pond bottoms between harvests.

high enough to contain the pond water and prevent loss of effluent during periods of increased rainfall and potential flooding.

Process Wastewater Treatment: Techniques for treating industrial process wastewater in this sector include grease traps, skimmers or oil water separators for separation of floatable solids; flow and load equalization; sedimentation for suspended solids reduction using clarifiers or settling ponds; biological treatment, typically aerobic treatment, for reduction of soluble organic matter (BOD); biological nutrient removal for reduction in nitrogen and phosphorus; chlorination of effluent when disinfection is required; dewatering and disposal of residuals; in some instances composting or land application of wastewater treatment residuals of acceptable quality may be possible. Additional engineering controls may be required (i) for removal of residual feed supplements, chemicals, antibiotics, etc. which may pass through the wastewater treatment system, and (ii) to contain and neutralize nuisance odors. For sea water applications, unit operations for wastewater treatment may have to be suitably adapted to the relatively high salinity of the water.

Management of industrial wastewater and examples of treatment approaches are discussed in the **General EHS Guidelines**. Through use of these technologies and good practice techniques for wastewater management, facilities should meet the Guideline Values for wastewater discharge as indicated in the relevant table of Section 2 of this industry sector document.

Other Wastewater Streams & Water Consumption: Guidance on the management of non-contaminated wastewater from utility operations, non-contaminated stormwater, and sanitary sewage is provided in the **General EHS Guidelines**. Contaminated streams should be routed to the treatment system for industrial process wastewater. Recommendations to reduce water consumption, especially where it may be a limited natural resource, are provided in the **General EHS Guidelines**.

Hazardous Materials

The aquaculture sector may involve the handling and use of hazardous materials (e.g. oil, fertilizers, and other chemicals). Recommendations for the safe storage, handling, and use of hazardous materials, including guidance on oil spills and containment, is provided in the **General EHS Guidelines**.

1.2 Occupational Health and Safety

As a general approach, health and safety management planning should include the adoption of a systematic and structured approach for prevention and control of physical, chemical, biological, and radiological health and safety hazards described in the **General EHS Guidelines**. Occupational health and safety hazards related to the daily operations of the aquaculture sector can be grouped into two categories:

- Physical hazards
- Exposure to chemicals
- Exposure to water borne disease

Physical hazards

A number of hazards are connected with the daily working routines in aquaculture, including heavy lifts, electric shock, and drowning.

Heavy Lifts

A number of activities involving heavy lifts are carried out during daily operations (e.g. refilling automatic feeders in the ponds and grading the fish). The following management measures can be taken to reduce exposure of personnel to injuries as a result of heavy lifts:

- Use mechanical and / or automated equipment to facilitate lifts heavier than 25 kg;

- Design workstations that can be adapted to individual workers, especially if fish are processed post-harvest;
- Construct ponds that are rectangular in shape to facilitate harvesting. If ponds are of sufficient size, and the embankments are at least 2.5 meters wide, vehicles can be used on the embankments to drag harvest seines.

Electric Shock

Electrical devices typically used in aquaculture include manifold and cover water pumps, paddlewheels, and lighting installations. The risk of electrical shock is therefore present during all operations in which the workers are in contact with the water. Measures to reduce the risk of electric shock include:

- Waterproof all electrical installations;
- Ensure that fuses are used and that there is an appropriate connection to the ground;
- Ensure that all cables are intact, waterproof, and without connection;
- Provide training in the correct handling of electric equipment (e.g. pumps and) to avoid the risk of short circuits;
- Employ lock out / tag out procedures.

Drowning

The risk of drowning is present in almost all aquaculture operations and, especially, in cage aquaculture at sea. Management measures to reduce the risk of drowning among workers and site visitors include the following:

- Provide lifejackets and harnesses with safety clips (karabiners) that lock on to lines or fixed points;
- Ensure that personnel are experienced swimmers;
- Train personnel in safety at sea, including procedures for supervision of personnel;
- Require that personnel wear lifejackets at all times on exposed sites and at sea;
- Where large vessels are used to transport personnel and equipment to marine sites, ensure that the vessel can be securely berthed on the pontoons, reducing the risk of falling into the gap between the vessel and the pontoon.

Exposure to Chemicals

A variety of chemicals may be used in the operation of an aquaculture facility to treat and / or control disease organisms or to facilitate production (e.g. lime, diluted chlorine, or salt). Fertilizers are also generally caustic materials and care should be taken in their application. Recommended guidance for the management of occupational chemical exposure is discussed in the **General EHS Guidelines**.

Water-borne Disease

Workers may be directly or indirectly exposed to water-borne diseases due to frequent contact with water (ponds) and the close proximity of living quarters to surface water bodies. The potential for transmission of water-borne disease should be addressed as part of the occupational health and safety program including specific additional medical screening for the labor force and implementation of preventive measures (e.g. mosquito nets in living quarters). Additional guidance on the prevention and control of communicable diseases is provided in the **General EHS Guidelines**.

1.3 Community Health and Safety

Community health and safety hazards arising from aquaculture operations include the following:

- Salinization of neighboring agricultural land;
- Effects on water resources;
- Food safety impacts and management

- Physical hazards

Effects on Water Resources

Water resources used in aquaculture may include the sea, estuaries, rivers, lakes, and groundwater. The extraction of water from these resources may result in changes to the natural water regime, potentially affecting fish stocks and commercial / recreational activities (e.g. fisheries and recreational activities downstream of the extraction point), or the availability and quality of groundwater. Water management strategies should target the maintenance of hydrologic conditions which provide water quality and quantity consistent with community needs and uses; and, in the case of coastal facilities, prevent salt water intrusion from affecting drinking and agricultural water supplies.

Aquaculture operations may act as breeding grounds for different insects, especially the mosquito and tsetse fly, thus increasing the risk of insect-borne disease among communities in the region. Operators should plan site design and operation to prevent and control these potential impacts. Additional information is provided in the Disease Prevention section of the **General EHS Guidelines**.

Food Safety Impacts and Management

Development of Resistance to Veterinary Drugs

The main veterinary drugs used in aquaculture are antibiotics, which are employed to prevent and treat bacterial diseases. Antibiotics are generally administered in feed, having either been added during manufacture or surface-coated onto the pellets by the manufacturer or the farmer. The development of antibiotic resistance by pathogenic bacteria may arise when bacteria acquire resistance to one or more of the antibiotics to which they were formerly susceptible. That resistance eventually makes the antibiotics ineffective in treating specific microbial diseases in humans.[14] In addition, when antibiotics are unintentionally consumed as residues in food, the amount ingested cannot be quantified or monitored and may cause direct health concerns (e.g. aplastic anemia), posing a serious risk to human health. This can also occur with integrated fish farming systems where antibiotic residues, from livestock manures used for fertilizer, can be introduced to fishpond culture.

Recognition of the risks brought about by consumption of veterinary drugs has led to the banning of certain antibiotics in aquaculture production and the establishment of maximum residue limits (MRLs)[15] for those with known risks. Observance of MRLs is required by law under some national jurisdictions and is encouraged elsewhere.[16] Use of resistant strains should be encouraged and good farm practices to maintain healthy fish stocks promoted.

The following actions can be taken to limit the use of antibiotics:

- Vaccination should be adopted where possible as a way of limiting the use of antibiotics;
- Where appropriate, aquaculture facilities should fallow sites on an annual basis as part of a strategy to manage pathogens in pen production units. The minimum fallow period should be four weeks at the end of each cycle;
- Facilities involved in aquaculture production should use a veterinary service on a frequent basis to review and assess the health of the stock and employees' competence and training. With the assistance of the veterinary service,

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[14] FAO (2002b).

[15] Annex IV of Regulation 2377/90/EEC lists nine substances that may not be used in food-producing species because no safe level of residue can be determined: chloramphenicol, chloroform, chlorpromazine, colchicine, dapsone, dimetridazole, metronidazole, nitrofurans (including furazolidone), and ronidazole.

[16] The *Codex Alimentarius* contains maximum residue limits (MRLs) for veterinary drug residues in all major food products, including salmon and giant prawn. A simple MRL database is provided by FAO/WHO at the following Web site: http://www.codexalimentarius.net/mrls/vetdrugs/jsp/vetd_q-e.jsp

facilities should develop a Veterinary Health Plan to include the following aspects:[17]

- Summary of major diseases present and potentially present;
- Disease prevention strategies;
- Treatments to be administered for regularly encountered conditions;
- Recommended vaccination protocols;
- Recommended parasite controls;
- Medication recommendations for feed or water.

If antibiotics are recommended, the following measures should be considered:

- Apply approved over-the-counter antibiotics in strict accordance with the manufacturer's instructions to ensure responsible use;
- Apply approved antibiotics that are purchased and utilized by prescription under the guidance of a qualified professional;
- Develop a contingency plan covering how antibiotics should be applied following the identification of disease outbreaks;
- Store antibiotics in their original packaging, in a dedicated location that:
  - Can be locked, is properly identified with signs, and limits access to authorized persons
  - Can contain spills and avoid uncontrolled release of antibiotics into the surrounding environment
  - Provides for storage of containers on pallets or other platforms to facilitate the visual detection of leaks
- Avoid stockpiles of waste antibiotics by adopting a "first-in, first-out" principle so that they do not exceed their expiration date. Any expired antibiotics should be disposed of in compliance with national regulations.

Physical Hazards

Communities may be exposed to a number of physical hazards, including drowning, associated with the presence of pond systems or other project infrastructure in proximity or in between community areas, requiring frequent crossing and physical interaction. Community use should be taken into consideration in the design of access routes, for example by providing wide enough walking areas with fall protection along potentially hazardous locations.

2.0 Performance Indicators and Monitoring

2.1 Environment

Table 1 presents effluent guidelines for this sector. Guideline values for process emissions and effluents in this sector are indicative of good international industry practice as reflected in relevant standards of countries with recognized regulatory frameworks. These guidelines are achievable under normal operating conditions in appropriately designed and operated facilities through the application of pollution prevention and control techniques discussed in the preceding sections of this document. These levels should be achieved, without dilution, at least 95 percent of the time that the plant or unit is operating, to be calculated as a proportion of annual operating hours. Deviation from these levels in consideration of specific, local project conditions should be justified in the environmental assessment.

Emissions guidelines are applicable to process emissions. Combustion source emissions guidelines associated with steam- and power-generation activities from sources with a capacity equal to or lower than 50 MWth are addressed in the

[17] For more information, see EUREPGAP guidance on integrated aquaculture assurance at: http://www.eurepgap.org/fish/Languages/English/index_html

General EHS Guidelines with larger power source emissions addressed in the **EHS Guidelines for Thermal Power**. Guidance on ambient considerations based on the total load of emissions is provided in the **General EHS Guidelines**.

Effluent guidelines are applicable for direct discharges of treated effluents to surface waters for general use. Site-specific discharge levels may be established based on the availability and conditions in use of publicly operated sewage collection and treatment systems or, if discharged directly to surface waters, on the receiving water use classification as described in the **General EHS Guidelines**.

Table 1. Effluent levels for aquaculture

Pollutants	Units	Guideline Value
pH	pH	6 – 9
BOD_5	mg/l	50
COD	mg/l	250
Total nitrogen	mg/l	10
Total phosphorus	mg/l	2
Oil and grease	mg/l	10
Total suspended solids	mg/l	50
Temperature increase	°C	<3[b]
Total coliform bacteria	MPN[a] / 100 ml	400
Active Ingredients / Antibiotics	To be determined on a case specific basis	

Notes:
[a] MPN = Most Probable Number
[b] At the edge of a scientifically established mixing zone which takes into account ambient water quality, receiving water use, potential receptors and assimilative capacity

Environmental Monitoring

Environmental monitoring programs for this sector should be implemented to address all activities that have been identified to have potentially significant impacts on the environment, during normal operations and upset conditions. Environmental monitoring activities should be based on direct or indirect indicators of emissions, effluents, and resource use applicable to the particular project. Monitoring frequency should be sufficient to provide representative data for the parameter being monitored. Monitoring should be conducted by trained individuals following monitoring and record-keeping procedures and using properly calibrated and maintained equipment. Monitoring data should be analyzed and reviewed at regular intervals and compared with the operating standards so that any necessary corrective actions can be taken. Additional guidance on applicable sampling and analytical methods for emissions and effluents is provided in the **General EHS Guidelines**.

2.2 Occupational Health and Safety

Occupational Health and Safety Guidelines

Occupational health and safety performance should be evaluated against internationally published exposure guidelines, of which examples include the Threshold Limit Value (TLV®) occupational exposure guidelines and Biological Exposure Indices (BEIs®) published by American Conference of Governmental Industrial Hygienists (ACGIH),[18] the Pocket Guide to Chemical Hazards published by the United States National Institute for Occupational Health and Safety (NIOSH),[19] Permissible Exposure Limits (PELs) published by the Occupational Safety and Health Administration of the United States (OSHA),[20] Indicative Occupational Exposure Limit Values published by European Union member states,[21] or other similar sources.

Accident and Fatality Rates

Projects should try to reduce the number of accidents among project workers (whether directly employed or subcontracted) to

[18] Available at: http://www.acgih.org/TLV/ and http://www.acgih.org/store/
[19] Available at: http://www.cdc.gov/niosh/npg/
[20] Available at: http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9992
[21] Available at: http://europe.osha.eu.int/good_practice/risks/ds/oel/

a rate of zero, especially accidents that could result in lost work time, different levels of disability, or even fatalities. Facility rates may be benchmarked against the performance of facilities in this sector in developed countries through consultation with published sources (e.g. US Bureau of Labor Statistics and UK Health and Safety Executive)[22].

Occupational Health and Safety Monitoring

The working environment should be monitored for occupational hazards relevant to the specific project. Monitoring should be designed and implemented by accredited professionals as part of an occupational health and safety monitoring program. [23] Facilities should also maintain a record of occupational accidents, diseases, and dangerous occurrences and other kinds of accident. Additional guidance on occupational health and safety monitoring programs is provided in the **General EHS Guidelines**.

[22] Available at: http://www.bls.gov/iif/ and http://www.hse.gov.uk/statistics/index.htm
[23] Accredited professionals may include certified industrial hygienists, registered occupational hygienists, or certified safety professionals or their equivalent.

3.0 References and Additional Sources

Center for Tropical and Subtropical Aquaculture. 2001. Best Management Practices for Hawaiian Aquaculture. Publication No. 148. Waimanalo, Hawaii. Available at http://govdocs.aquake.org/cgi/reprint/2003/526/5260130.pdf

Department of Primary Industries and the Queensland Finfish Aquaculture Industry. 1999. Industry Environmental Code of Best Practice for Freshwater Finfish Aquaculture. Prepared by Dallas J Donovan, Kuruma Australia Pty Ltd. Queensland: Department of Primary Industries. Available at http://www.abfa.info/PDFS/Codeed2.pdf

Division of Applied Biosciences, Faculty of Fisheries, Graduate School of Agriculture, Kyoto University. 2004. Nitrogen and Phosphorus Budget in Coastal and Marine Cage Aquaculture and Impacts of Effluent Loading on Ecosystems?: Review and Analysis Towards Model Development (Abstract). Kyoto: Division of Applied Biosciences. Available at http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=15664033&dopt=Abstract

Euro-Retailer Produce Working Group (EUREP). EUREGAP. Available at: http://www.eurepgap.org/Languages/English/index_html

Food and Agriculture Organization of the United Nations (FAO). 1991. A Strategy for Aquaculture Development in Latin America. Rome: FAO. Available at http://www.fao.org/documents/show_cdr.asp?url_file=/docrep/008/u1780e/U1780E05.htm

FAO. 1997. Technical Guidelines for Responsible Fisheries 5. Aquaculture Development. Rome: FAO. Available at ftp://ftp.fao.org/docrep/fao/003/W4493e/W4493e00.pdf

FAO. 2001. Report of the Technical Consultation on Legal Frameworks and Economic Policy Instruments for Sustainable Commercial Aquaculture in Africa South of the Sahara. Arusha, United Republic of Tanzania, 4–7 December 2001. Rome: FAO. Available at http://www.fao.org/documents/show_cdr.asp?url_file=/DOCREP/005/Y3575B/Y3575B00.HTM

FAO. 2002a. FAO Fisheries Technical Paper 428. Farming Freshwater Prawns. A Manual for the Culture of the Giant River Prawn (Macrobrachium rosenbergii). Technical Guidelines for Responsible Fisheries 5. Rome: FAO. Available at http://www.fao.org/documents/show_cdr.asp?url_file=/docrep/005/y4100e/y4100e00.htm

FAO. 2002b. The State of the World's Fisheries and Aquaculture (SOFIA). Rome: FAO. Available at http://www.fao.org/documents/show_cdr.asp?url_file=/docrep/005/y7300e/y7300e06.htm

FAO. Code of Conduct for Responsible Fisheries. Rome: FAO. Available at http://www.fao.org/documents/show_cdr.asp?url_file=/DOCREP/005/v9878e/v9878e00.htm

FAO and World Health Organization (WHO). 1962–2005. Codex Alimentarius. Geneva: FAO and WHO. Available at http://www.codexalimentarius.net/web/index_en.jsp

Federation of European Aquaculture Producers (FEAP). 2000. Code of Conduct for European Aquaculture. Brussels: FEAP. Available at http://www.feap.info/FileLibrary/6/FEAP%20Code%20of%20Conduct.pdf

Francis-Floyd, R. 1996. Use of Formalin to Control Fish Parasites. College of Veterinary Medicine, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Gainesville, FL: College of Veterinary Medicine. Available at http://edis.ifas.ufl.edu/VM061

Green, Bartholomew W. 2000. Level of Adoption of Selected Good Management Practices on Penaeid Shrimp Farms in Honduras. 36849-5419. Department of Fisheries and Allied Aquacultures, Auburn University. Auburn: Auburn University. Available at http://www.ag.auburn.edu/fish/

United Kingdom (UK) Health and Safety Executive (HSE). 2005a. Fatal Injuries Report 2004/05. Fatal Injuries in Farming, Forestry and Horticulture. Part 3: Non-Fatal Injuries in the Agricultural Sector, 1994/95–2003/04, pp.42–46. London: HSE. Available at http://www.hse.gov.uk/agriculture/pdf/fatal0405.pdf

UK HSE. 2005b. United Kingdom, Fatal Injuries Report 2004/05. Fatal Injuries in Farming, Forestry and Horticulture. Part 2: Analysis of Reportable Fatal Injuries in the Agricultural Sector, 1994/95–2003/04. p 23. London: HSE. Available at http://www.hse.gov.uk/agriculture/pdf/fatal0405.pdf

National Committee for Research Ethics in Science and Technology (NENT). 1995. The Holmenkollen Guidelines for Sustainable Industrial Fish Farming. Oslo: NENT.

National Committee for Research Ethics in Science and Technology. 1998. The Holmenkollen Guidelines for Sustainable Aquaculture. (Supercede the Holmenkollen Guidelines for Sustainable Industrial Fish Farming). Oslo: NENT. Available at http://www.ntva.no/rapport/aqua/report.htm

Northern Central Regional Aquaculture Center (NCRAC). 1992. Pond Culture of Walleye Fingerlings. Fact Sheet Series # 102. March 1992. In cooperation with the US Department of Agriculture (USDA). East Lansing, MI: NCRAC. Available at http://aquanic.org/publicat/usda_rac/fact.htm

OSPAR Commission. 1992. Convention for the Protection of the Marine Environment of the North East Atlantic. OSPAR. Available at http://www.ospar.org/eng/html/welcome.html

Shetland Aquaculture. 2006. A Code of Good Practice for Scottish Finfish Aquaculture , January 2006. Lerwick: Shetland Aquaculture. Available at http://www.shetlandaquaculture.com/code-of-good-practice

Southern Regional Aquaculture Center (SRAC). 1998. Fertilization of Fish Fry Ponds. SRA Publication No. 469. In cooperation with the US Department of Agriculture (USDA). Stoneville, MS: SRAC. Available at http://aquanic.org/publicat/usda_rac/fact.htm

SRAC. 1999. Fertilization of Fish Ponds. SRA Publication No. 471. In cooperation with the US Department of Agriculture (USDA). Stoneville, MS: SRAC. Available at http://aquanic.org/publicat/usda_rac/fact.htm

United Nations Environment Programme (UNEP). 2001. Stockholm Convention on Persistent Organic Pollutants. Stockholm: UNEP. Available at http://www.pops.int/documents/convtext/convtext_en.pdf

United Nations Educational, Scientific and Cultural Organization (UNESCO). 1971. Convention on Wetlands of International Importance especially as Waterfowl Habitat (as amended in 1982 and 1987). Paris: UNESCO. 1994. Available at http://portal.unesco.org/en/ev.php-URL_ID=15398&URL_DO=DO_TOPIC&URL_SECTION=201.html

US Environmental Protection Agency (EPA). 2001. Office of Water, Engineering and Analysis Division. Update and Overview of the Effluent Limitations

Guidelines and Standards for the Aquaculture Industry. NCRAC Meeting. 16–18 February, 2001. Washington, DC: US EPA. Available at http://aquanic.org/jsa/effluents/EPA%20presentation%20at%20NCRAC.htm

United States (US) Bureau of Labor Statistics (BLS). 2004a. Census of Fatal Occupational Injuries Charts, 1992–2004. Table (p.10): Number and rate of fatal occupational injuries by private industry sector, 2004.) Washington, DC: BLS. Available at http://www.bls.gov/iif/oshwc/cfoi/cfch0003.pdf

US BLS. 2004b. Industry Injury and Illness Data — 2004. Supplemental News Release Tables. Table SNR05: Incident rate and number of nonfatal occupational injuries by industry, 2004. Washington, DC: BLS. Available at http://www.bls.gov/iif/home.htm

US Department of Commerce, National Oceanic and Atmospheric Administration (NOAA). 2005. National Offshore Aquaculture Act of 2005. Washington, DC: NOAA. Available at http://www.nmfs.noaa.gov/mediacenter/aquaculture/docs/03_National%20Offshore%20Aquaculture%20Act%20FINAL.pdf

US Department of Commerce, NOAA National Marine Fisheries Service (NMFS). Code of Conduct for Responsible Aquaculture Development in the US Exclusive Economic Zone. Washington, DC: NMFS. Available at http://www.nmfs.noaa.gov/trade/AQ/AQCode.pdf

US Food and Drug Administration (FDA). 2001. Center for Food Safety & Applied Nutrition. Fish and Fisheries Products Hazards and Controls Guidance: Third Edition. Washington, DC: US FDA. Available at http://www.cfsan.fda.gov/~comm/haccp4.html

United States Joint Subcommittee on Aquaculture (JSA) Working Group on Quality Assurance in Aquaculture Production. 2001. Guide to Drug, Vaccine and Pesticides in Aquaculture. Washington, DC: JSA. Available at http://aquanic.org/jsa/wgqaap/drugguide/aquaculture_drug_guide.pdf

World Bank, ISME, cenTER Aarhus. 2003. Draft Code of Conduct for the Sustainable Management of Mangrove Ecosystems. Prepared by Professor Donald J. Macintosh and Dr. Elizabeth C. Ashton. Washington, DC: World Bank. Available at http://www.mangroverestoration.com/MBC_Code_AAA_WB070803_TN.pdf

World Bank. 2005. The NEPAD Action Plan for the Development of African Fisheries and Aquaculture. Washington, DC: World Bank. Available at http://siteresources.worldbank.org/INTARD/Resources/ACTION_PLAN_endorsed.pdf

International and regional codes

FAO Code of Conduct for Responsible Fisheries: http://www.fao.org/documents/show_cdr.asp?url_file=/DOCREP/005/v9878e/v9878e00.htm

FAO Technical Guidelines for Responsible Fisheries

- Aquaculture Development, 1997 ftp://ftp.fao.org/docrep/fao/003/W4493e/W4493e00.pdf
- Aquaculture Development 1. Good Aquaculture Feed Practice, 2001 ftp://ftp.fao.org/docrep/fao/005/y1453e/y1453e00.pdf
- Integration of Fisheries into coastal area management, 1996 ftp://ftp.fao.org/docrep/fao/003/W3593e/W3593e00.pdf
- Precautionary approach to capture fisheries and species introductions, 1996http://www.fao.org/documents/show_cdr.asp?url_file=/DOCREP/003/W3592E/ W3592E00.HTM
- Responsible Fish Utilization, 1998 ftp://ftp.fao.org/docrep/fao/003/w9634e/w9634e00.pdf
- Guidelines on the collection of structural aquaculture statistics,1997

Species introductions and Biodiversity

FAO Technical Paper, International Introductions of Inland Aquatic Species 1988 http://www.fao.org/docrep/x5628E/x5628e00.htm#Contents

Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), 1973. http://www.cites.org/

Convention on Biological Diversity (CBD), 1992. http://www.biodiv.org/convention/articles.asp

ICES/EIFAC Code of Practice on the Introductions and Transfers of Marine Organisms, 2004 http://www.ices.dk/reports/general/2004/ICESCOP2004.pdf

EIFAC Code of Practice and Manual of Processes for Consideration of Introductions and Transfers of Marine and Freshwater Organisms, 1988.

European Inland Fisheries Advisory http://cdserver2.ru.ac.za/cd/011120_1/Aqua/SSA/codes.htm

Health management and best practice

CODEX Alimentarius. http://www.codexalimentarius.net/web/standard_list.do?lang=en

International Aquatic Animal Health Code, 2005. http://www.oie.int/eng/normes/fcode/a_summry.htm

FAO/NACA Asia Regional Technical Guidelines on Health Management for the Responsible Movement of Live Aquatic Animals and the Beijing Consensus and Implementation Strategy, 2000. http://www.fao.org/documents/show_cdr.asp?url_file=/DOCREP/005/X8485E/x8485e02.htm

FAO/NACA Manual of Procedures for the Implementation of the Asia Regional Technical Guidelines on Health Management for the Responsible Movement of Live Aquatic Animals. 2001. http://www.fao.org/documents/show_cdr.asp?url_file=/DOCREP/005/Y1238E/Y1238E00.HTM

FAO/NACA Asia Diagnostic Guide to Aquatic Animal Diseases, 2001 http://www.fao.org/documents/show_cdr.asp?url_file=/DOCREP/005/Y1679E/Y1679E00.HTM

Better-practice approaches for culture-based fisheries development in Asia http://www.aciar.gov.au/web.nsf/att/ACIA-6M98FT/$file/CBF_manual.pdf

Holmenkollen Guidelines for Sustainable Aquaculture, 1998. http://www.ntva.no/rapport/aqua.htm

Development of HARP Guidelines. Harmonised Quantification and Reporting Procedures for Nutrients. SFT Report 1759/2000. TA-1759/2000. ISBN 82-7655-401-6. http://www.sft.no/publikasjoner/vann/1759/ta1759.pdf

Shrimp culture

Bangkok FAO Technical Consultation on policies for sustainable shrimp culture, Bangkok, Thailand, 8-11 December 1997. http://www.fao.org/documents/show_cdr.asp?url_file=/DOCREP/006/x0570t/x0570t00.HTM

Report of the Ad-hoc Expert Meeting on Indicators and Criteria of Sustainable Shrimp Culture, Rome, Italy. 28-30 April 1998. http://www.fao.org/documents/show_cdr.asp?url_file=/DOCREP/006/x0570t/x0570t00.HTM

Code of Practice for Sustainable Use of Mangrove Ecosystems for Aquaculture in Southeast Asia, 2005 http://www.ices.dk/reports/general/2004/ICESCOP2004.pdf

The International Principles for Responsible Shrimp Farming, http://www.enaca.org/modules/mydownloads/singlefile.php?cid=19&lid=755

Codes of Practice for Responsible Shrimp Farming. http://www.gaalliance.org/code.html#CODES

Codes of Practice and Conduct for Marine Shrimp Aquaculture, 2002. http://www.fw.vt.edu/fisheries/Aquaculture_Center/Power_Point_Presentations/FIW%204514/Lecture%209.1%20-%20aquaculture%20and%20environment/shrimpCOP.pdf

National codes and best practices

Canada: National Code on Introductions and Transfers of Aquatic Animals, 2003. Department of Fisheries and Oceans, Government of Canada. http://www.dfo-mpo.gc.ca/science/aquaculture/code/Code2003_e.pdf

Chile: Code of Good Environmental Practices (CGEP) for well-managed salmonoids farms, 2003. http://library.enaca.org/certification/publications/Code_2003_ENGLISH.pdf

India: Guidelines for Sustainable Development and Management of Brackish Water Aquaculture, 1995. **http://www.mpeda.com/**

Japan: Basic Guidelines to Ensure Sustainable Aquaculture Production, 1999.

Philippines: Fisheries Code, 1998. http://www.da.gov.ph/FishCode/ra8550a.html

Scotland: Code of practice to avoid and minimise the impact of Infectious Salmon Anaemia (ISA), 2002. http://www.marlab.ac.uk/FRS.Web/Uploads/Documents/ISACodeofPractice.pdf

Sri Lanka: Best Aquaculture Practices (BAP) for Shrimp Framing Industry in Sri Lanka http://www.naqda.gov.lk/pages/BestAquaculturePracticeMethods.htm

Thailand: Thailand Code of Conduct for Shrimp Farming (in Thai) http://www.thaiqualityshrimp.com/coc/home.asp

USA: Code of Conduct for Responsible Aquaculture Development in the U.S. Exclusive Economic Zone. http://www.nmfs.noaa.gov/trade/AQ/AQCode.pdf

Guidance Relative to Development of Responsible Aquaculture Activities in Atlantic Coast States, 2002. http://www.asmfc.org/publications/specialReports/aquacultureGuidanceDocument.pdf

USDA Aquaculture BMP Index, 2004. http://efotg.nrcs.usda.gov/references/public/AL/INDEX.pdf

Guidelines for Ecological Risk Assessment. of Marine Fish Aquaculture. NOAA Technical Memorandum NMFS-NWFSC-71. http://www.nwfsc.noaa.gov/assets/25/6450_01302006_155445_NashFAOFinalTM71.pdf.

Guidelines for Environmental Management of Aquaculture in Vietnam http://imagebank.worldbank.org/servlet/WDS_IBank_Servlet?pcont=details&menuPK=64154159&searchMenuPK=64258162&theSitePK=501889&eid=000310607_20061101130138&siteName=IMAGEBANK

Industry / Organization codes

Australian Aquaculture Code of Conduct. http://www.pir.sa.gov.au/byteserve/aquaculture/farm_practice/code_of_conduct.pdf

Environmental Code of Practice for Australian Prawn Farmers, 2001. http://www.apfa.com.au/prawnfarmers.cfm?inc=environment

A Code of Conduct for European Aquaculture. http://www.feap.info/FileLibrary/6/CodeFinalD.PDF

NZ Mussel Industry Environmental Codes of Practice, 2002. Mussel Industry Council Ltd., Blenheim

Judicious Antimicrobial Use in US Aquaculture: Principles and Practices, 2003. http://www.nationalaquaculture.org/pdf/Judicious%20Antimicrobial%20Use.pdf

Draft Protocol for Sustainable Shrimp Production, in preparation. http://www.ntva.no/rapport/aqua.htm

BCSFA Code of Practice, 2005. http://www.salmonfarmers.org/pdfs/codeofpractice1.pdf

Annex A: General Description of Industry Activities

The aquaculture sector is very diverse, in terms of products and production methods, as detailed in Table A-1.

Extensive systems[24] use low stocking densities and no supplemental feeding. Extensive systems may use man-made ponds or, more often, existing natural structures (e.g. lakes or lagoons) that are typically large (>2 ha). Semi-intensive systems[25] (approximately 2 to 20 tons/ha/yr) use higher stocking densities, supplemental feeding, and additional management (such as water changes) and typically utilize man-made ponds, pens, or cages. Some semi-intensive systems, especially polycultures, utilize natural lakes (e.g. filter feeders and omnivorous fish can be cultured in cages in shrimp or prawn ponds).[26]

Intensive systems[27] use maximum stocking densities and are dependent on a mixture of natural and formulated feeds. Semi-intensive and intensive systems typically use small pond compartments of up to 1 ha for ease of management. Site selection for the aquaculture facility is often the most important issue related to environmental health and safety. Criteria for site selection include water supply and quality; soil quality; protection from natural hazards; and accessibility to inputs, including markets and labor.[28] An aquaculture facility requires a steady supply of water in adequate quantities throughout the year. Water supply should be pollution-free and have a stable and suitable pH, adequate dissolved oxygen, and low turbidity. Some producers may treat the intake water to remove unwanted substances, for example, using a filter to remove potential predators. In addition, aquaculture farms should not be located close to each other, as this could increase the risk of disease transfer and may have a detrimental effect on the water quality of the intake water.

Table A-1. Diversity of Aquaculture Production Methodologies

Resource	System	Installations
Water (fresh, brackish, or marine)	Stillwater	Ponds and lakes
	Flow-through	Ponds, raceways, tanks (land-based) Cages (lake and sea based) Large offshore units (sea based)
	Re-use or recirculation	Tanks and land-based ponds
Nutrition	Extensive (No feed)	Ponds (land-based) Substrate - shellfish (sea-based) Substrate - seaweeds (sea-based)
	Semi-intensive systems (Supplemental feeding and/or fertilizer)	Ponds (land-based) Raceways (land-based)
	Intensive systems (Feed)	Ponds (land-based) Cages (lake and sea based) Raceways (land and sea-based) Silos and tanks (land-based)
Species	Monoculture	Animals (ponds and tanks, cages/pens in lakes or sea) Plants (ponds and tanks, cages/pens in lakes or sea)
	Polyculture	Animals (fish species)

24 Production system characterized by (i) a low degree of control (e.g. of environment, nutrition, predators, competitors, disease agents); (ii) low initial costs, low-level technology, and low production efficiency (yielding no more than 500 kg/ha/yr); (iii) high dependence on local climate and water quality; use of natural water bodies (e.g. lagoons, bays, embayments) and of natural often unspecified food organisms.]

25 System of culture characterized by a production of 0.5-5 tons/ha/yr, possibly supplementary feeding with low-grade feeds, stocking with wild-caught or hatchery-reared fry, regular use of organic or inorganic fertilizers, rain or tidal water supply and/or some water exchange, simple monitoring of water quality, and normally in traditional or improved ponds; also some cage systems e.g. with zooplankton feeding for fry.

26 Center for Tropical and Subtropical Aquaculture (2001). Other polyculture systems are practiced in Asia, primarily carp in association with duckeries and piggeries and the growth of crops on pond embankments.

27 Systems of culture characterized by a production of 2 to 20 tons/ha/yr, which are dependent largely on natural food, which is augmented by fertilization or complemented by use of supplementary feed, stocking with hatchery-reared fry, regular use of fertilizers, some water exchange or aeration, often pumped or gravity supplied water, and normally in improved ponds, some enclosures, or simple cage systems.

28 Food and Agriculture Organization of the United Nations (FAO), 1989, ADCP/REP/89/43, Aquaculture Systems and Practices: A Selected Review. http://www.fao.org/docrep/T8598E/t8598e00.HTM.

The site should have soils adequate for the intended structures (e.g. clay-loam or sandy-clay soil for ponds, and firm bottom mud for pens) to allow the structure to be driven deep into substrate for better support. Aquaculture facilities should be protected from high wind, waves, and tides; excessive storm water runoff; predators; and other natural hazards. Moderate tides, however, may help to ensure adequate water exchange through ponds, pens, and cages.

Figure A-1 presents the typical production cycle for an aquaculture facility. The production period varies from species to species and from region to region, depending on the market requirements for size and on the growth rates for the species, which is dependent on temperature, feed quality, and feed allocation. Most operations have a grow-out period of 4 to 18 months.

Preparation and Stocking

Freshwater Ponds

Ponds are most commonly constructed by excavating soils and using the spoils from excavation for the embankments. Soils that are suitable for earthen pond construction have the following characteristics: adequate clay content (clay slows down or may even eliminate seepage), low organic content, proper soil texture, and preferably alkaline pH. When producing at high densities, or during the early stages of fry or juveniles, ponds can be sealed with a plastic sheet or concrete, or production can take place in sealed raceways or tanks to facilitate cleaning.

Pens and Cages

Pen and cage systems involves the rearing of fish within fixed or floating net enclosures supported by rigid frameworks and set in sheltered, shallow portions of lakes, bays, rivers, estuaries, or the seacoast. Pens and cages are largely similar. Pens are anchored to the lake or sea bottom, which serves as the floor of the pen, while cages are suspended in the water, and can be either fixed or floating. Cages can typically be located in more exposed situations and in deeper water than pens. Fry may be grown to fingerling size in special nursery compartments and then released to pens or cages for grow-out, or fingerlings for stocking may be purchased from land-based facilities. In some cases, the stocking material may be wild caught.

Open Water Culture

Seaweed and mollusks are typically farmed in open marine waters. Structures (e.g. rafts, racks, or stakes) that provide a growth surface for the intended species are placed in suitable areas. Often the species to be grown settle by themselves on the structures, and the producer will only remove unwanted species and occasionally thin the stock. The aquaculture of other species, notably oysters, requires more active management and the spat or other juvenile stages are added to the structures for on-growing.

Start-Feeding

The early stages of fish and crustaceans production often demand a special feeding regimen, and the use of artificial feeds for these early stages can be problematic. During the initial feeding phase, organic and / or inorganic fertilizers (e.g. nitrogen and phosphorus) are often added to create an algal bloom. The algal bloom boosts primary productivity levels in the pond by generating a food source for microorganisms such as zooplankton, which are eaten by the fry or larvae of the organisms being cultivated. The algal bloom also prevents the establishment of aquatic plants. Veterinary drugs may be added at this stage to reduce the risk of disease or in response to actual outbreaks. A broad spectrum antibiotic is the most frequently used medication.

On-growing

After start-feeding, a transition toward on-growing takes place. The quality of the feed used can vary widely, depending on the species grown and / or the level of sophistication of the farm setup. A simple solution involves the use of minced fish meat prepared at the farm site and offered daily throughout the grow-out period. Intensive operations may exclusively use high-quality, pelletized, formulated feed throughout the production period.

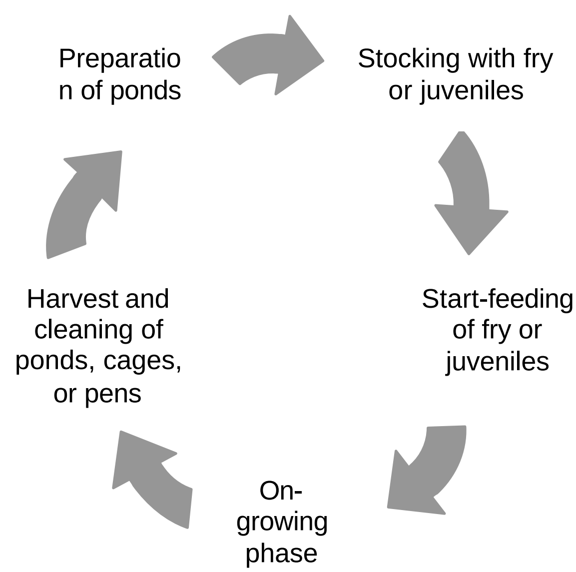
During feeding, the biomass will increase, resulting in increased oxygen consumption, and pond aerators (e.g. paddlewheels and diffusers) are often used to aerate the water. During the on-growing period, the stock are monitored regularly for disease and willingness to eat, allowing the pond manager to intervene (e.g. applying antibiotics and changing the pond water) if unsuitable conditions develop.

Harvesting and Cleaning

Once the stock has reached the desired size, they are harvested and marketed. Some species are sold live, and others are slaughtered before sale. In the latter situation, special facilities for slaughtering may be installed at the farm (e.g. to control the "blood water" resulting from harvest of the organisms). The slaughtered product is then iced and may be sent out for further processing off-site at a specialized fish processing plant, or sold fresh to local markets.[29]

After harvesting, the aquaculture effluent may be conveyed into a sedimentation basin before being discharged to the receiving water. After the pond has been emptied, the pond bottom is cleaned to remove the sediment of uneaten feed and feces. For intensive and semi-intensive systems, ponds are usually allowed to dry completely and are treated (e.g. with lime or pesticides) to control diseases, competing organisms, and predators before the next production cycle begins. In the case of cages and pens, fouling on the nets may be removed in a mechanical cleaning process, which is often followed by bathing the nets in chemicals to reduce settling on the nets in the grow-out period.

Figure A.1: Typical Production Cycle for an Aquaculture Facility



[29] Refer to the EHS Guidelines for Fish Processing for practical guidance on EHS issues in this sector.