Best Environment Practice (BEP), health, monitoring and regulations, codes of conduct.

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ABSTRACT: Guidelines for responsible aquaculture development are now becoming commonplace. Such guidelines are being packaged as principles of Codes of Conduct. The Codes of Conduct are frameworks based on international and national legislation, ethical rules and developed through a process of consultation, negotiation, and agreement within a group of stakeholders all directly involved or affected by the topic. But in most cases a Code of Conduct only over-arches a sector, leaving the industries or subindustries to generate their own detailed Codes of Best Practice (CBP). CBP is more specific and can be defined as a collection of recommended practices *at farm level*. The framework for CBP is related to the environment in many respects. The aquatic ecosystem and aquaculture include many factors such as water management, the physical and chemical environment, biotic factors, regulation and monitoring of water. The authorities propose environmental quality standards (EQS) for every industry and farmers who intend to start new aquaculture ventures are obliged to make an environmental impact assessment (EIA) of their sites before licences are granted. The monitoring of discharged water from aquaculture facilities is stipulated by authorities. The farmer is forced to apply the latest progress in feed and feeding practices, considering the feed quality both with regard to the fabrication and the composition of the feed. Feeding regimes are as necessary as the quality of the feed and it is important to apply the new development with computer programs to optimize feeding in relation to fish behaviour. Reduction in bio-wastes is possible by using various technical devices to collect feed wastes, nutrients, organic material and dead fish from production units. Diseases must be combatted by using preventive measures including approved veterinary medicines, drugs and chemicals. But traditional antibiotics have now largely been replaced by vaccines, and even these will probably be replaced by probiotic feeds.

The food quality of aquaculture products compete in an open market and must therefore be of the highest possible quality and has a taste appealing to consumers and free of any health hazards. Therefore regulations and protocols for the use of chemical and antibiotics in the production of farm animals must be strictly followed. Post-harvest treatment must comply with regulations for proper and humane treatment of animals and processing must comply with accepted hygienic and safe practices for the handling of food for human consumption.

1. INTRODUCTION

Guidelines for responsible aquaculture development are now becoming commonplace. They have been formulated by International conventions, such as the Bangkok Declaration - by producer organisations, such as the Federation of European Aquaculture Producers (FEAP) and national farming associations and by legislation and regulations, coming in the form of EU directives and national regulatory agencies. All of these have the stated aim of creating a sustainable aquaculture sector which is also environmentally responsible and publicly acceptable.

2. CODES OF CONDUCT

2.1. Background

Such guidelines promoting responsible aquaculture, no matter what their origin, are emerging as the guiding principles behind the establishment of Codes of Conduct.

It is recognised that this voluntary measure, if used responsibly by Producers' Associations, can exercise restraints which lead to a significant amount of quality control. The FAO developed the concept of responsible fisheries within a Code of Conduct, and followed this up with the Code of Conduct for Aquaculture Development (FAO 1997). The FAO Code sets out principles and international standards of behaviour for responsible fisheries and aquaculture practices with a view to ensuring the effective conservation, management and development of living aquatic resources, with due respect for the ecosystem and biodiversity. An acceptable Code of Conduct should be able to cross any frontier and remain free of local and national considerations. All Codes should involve a process of consultation, negotiation and agreement within a group of stakeholders that are either directly involved or affected by the subjects. The diversity of stakeholders is considerable, involving: i) government authorities, policy-makers, planners and regulators; ii) producers, farm operators; iii) manufacturers and suppliers to aquaculture; iv) processors and traders of aquaculture products; v) consumers; vi) banks and investors; vii) special interest groups and non-governmental organisations (NGOs); viii) researchers, social and natural scientists; ix) international organisations (regional, global) and; x) media. It is important to show that such Codes, though not legally enforceable, do carry a certain amount of moral weight and have indeed exercised a good deal of influence. Codes of Conduct such as these have been shown to generate good collaboration between legislators, regulators and the producers, based on an involvement of the Producers Associations and recognition of fish farmers activities and needs.

Faced with the increasing difficulties of regulating aquaculture activities because of the number of interests involved, the variety of institutions involved, the diversity of natural resources involved, what has been called "the tangled web of laws and regulations", as well as the series of initiatives to direct the industry towards environmentally friendly and socially sustainable practices, increasing importance has been given to Codes of Conduct and Codes of Practice built on best environmental practice (BEP) and best management practice (BMP). Such recommendations are not legally binding but constitute a Code of Practice to be consulted and used by countries to promote environmental protection when formulating national policies and legislation governing aquaculture and fisheries activities.

3. CODES OF BEST PRACTICE

3.1. Differences between Code of Conduct and Code of Practice

The Codes of Conduct are frameworks based on international and national legislation, ethical rules and developed through a process of consultation, negotiation, and agreement within a group of stakeholders all directly involved or affected by the topic. In most cases a Code of Conduct only over-arches a sector, leaving the industries or subindustries to generate their own detailed Codes of Best Practice (CBP). Codes of Practice/Codes of Conduct may constitute a type of institutional and regulatory framework that is appropriate for the special needs governing aquaculture activities and production. A Code of Practice is more specific and can be defined as a collection of recommended practices *at farm level.* (Table 1)

Table 1. Basic Principles of Codes of Practice (irrespective of species, location or culture technology)

1. Protecting human health and safety

Checklists for: Employee training (boat or equipment handling, Life-saving and First Aid, Diving,Alarm systems, Radio communication, Hazardous materials and waste, Handling chemicals and therapeutants)

2. Protecting the livestock and animal welfare

Checklists for: routine inspections of farm stocks to observe behaviour and indicators of health problems and stress, precautions to be taken during handling and harvesting

3. Operational data for efficient management

Checklists needed for:

- ✔ Number of eggs, juveniles and adults
- ✔ Origin of deliveries
- ✔ Disease-free certification
- ✔ Number of fish lost and harvested
- ✔ Diseases and treatments
- ✔ Post-mortems and health control

4. Handling artificial feed on the farm

- ✔ Maintain complete records of origin, type and quantity of feed to improve Food Conversion Rates
- ✔ Use feeds with high digestibility
- ✔ Use feeds with correct levels of Phosphorus and Nitrogen
- ✔ Minimise uneaten food and, if possible, remove sediments

5. Handling bio-wastes on the farm

- ✔ Collect mortalities daily
- ✔ Dispose of mortalities correctly by incineration or in silage
- ✔ Collect, treat and correctly dispose of kill water and blood water
- ✔ Collect and correctly dispose of waste (offals, etc)
- ✔ Recycle wastes whenever possible
- ✔ Buy and use recyclable packaging materials whenever possible

6. Handling chemicals, drugs and veterinary medicines on the farm

- ✔ Keep records of purchase, use and removal
- ✔ As far as possible use proactive prevention - vaccines, immunostimulants, etc
- ✔ Buy chemicals and medications through authorised channels
- ✔ Use only authorised chemicals and medication
- ✔ Follow manufacturers instructions - dose rate, frequency and time duration
- ✔ Neutralise unused or residues of chemicals

- ✔ Use non foaming and biodegradable detergents
- ✔ Use only authorised antifoulants on nets and boats

7. Handling general farm wastes

- ✔ Where possible try to collect faeces and sediments below the cages.
- ✔ Have screened area for storing spare or discarded equipment materials
- ✔ Collect and dispose of rubbish daily and correctly
- ✔ Separate biological matter from other matter and incinerate
- ✔ Organise regular litter collection from around onshore site and below cages
- ✔ Prevent escapees (see No.8 below)

8. Preventing genetic risks

- ✔ Prevent escapes as far as possible
- ✔ Prevent Gamete loss as far as possible
- ✔ Treat outlets of hatchery broodstock tanks to kill gametes
- ✔ Where possible harvest fish from cages before spawning season
- ✔ Use methods to delay or prevent spawning - photoperiod, triploid, etc.
- ✔ Use local strains of fish
- ✔ Minimise genetic selection for single traits

9. Integrating with the public

- ✔ Where possible and practical, integrate onshore facilities with local aesthetics (landscaping, cleaning, etc)
- ✔ Avoid possible offensive activities (post-harvest handling, incinerating mortalities, rendering, etc) in public

10. Integrating with the environment

- ✔ Make a baseline study of the environment around the site before operations begin
- ✔ Monitor the environment regularly
- ✔ Maintain all records and make available for authorities and regulators
- ✔ Use predictive models or computer programmes to highlight potential risks
- ✔ Alternate sites where possible
- ✔ Assist in site recovery
- ✔ Use single production tuns
- ✔ Use biological management rather than chemical solutions where possible
- ✔ Certify/register compliance of the site with government regulations

3.2. Framework for CBP (environment)

The framework for CBP is related to the environment in many respects. It is easy to forget that the husbandry process, especially for aquatic animals, is very complex. However, it should not be forgotten that aquaculture technology is very diversified as well as quite complex (Ackefors 1999) (Table 8). It covers: i) different technical systems such as still-water systems, flow-through water systems, closed recirculating systems; with ii) various biological systems such as extensive, semi-intensive, intensive systems and integrated systems; and with iii) herbivorous, omnivorous and carnivorous animals

Therefore producing a CBP is not a simple task, and may have to be constructed from a series of operational elements.

3.3. Diversity of aquaculture as indicated by Production Elements

Here is an overview of the many factors in the rearing process. These include:

- Biological factors such as genetics and breeding, nutrition and pathology are very important as well as the knowledge of the ecology, physiology and behaviour of the animals
- Technical-biological factors comprise mechanical engineering (water supply, water treatment, container design, feeding, aeration, temperature control), Electrical engineering (environmental controls), Electronic engineering (monitoring and control), Agricultural engineering (integration with other farming systems)
- Technically-economically feasible methods such as the cost of water, energy, feed, material, labour, land and plant investments as well as legal aspects; financial management (cost efficiencies, book-keeping)
- Socio-economic conditions and marketing include several very important factors: post-harvest technology (processing and packaging), Marketing (sales and market analysis), Public Relations (business transparency).

3.4. Legislation and regulation

3.4.1. Importance of environmental quality standards (EQS)

The aquaculture industry is dependent on the legal framework for its development. Environmental authorities propose environmental quality objectives (EQOs) and corresponding environmental quality standards (EQSs) for the industry and decide which water bodies can be used for the cultivation of aquatic organisms.

In many countries, environmental quality objectives (EQOs) are determined and established so that the environment can be managed in such a way that these objectives would be achieved. Environmental quality standards (EQSs) are then set for specific variables in order that the objectives are attained. Therefore, quality standards are now implicit within any process of regulation, enforcement and quality control. In those countries they are believed to be important to protect the consumer, the environment and also the product. Many countries now operate the EQO/EQS system in their approach to managing the environmental impacts of different activities. The uses of the aquatic environment are set, e.g. consumer protection (edible aquatic species may be safely eaten), protection of aquatic life, protection of water quality for industrial use, water sports and nature conservation. Standards or criteria are then established to protect these uses and applied by the competent authority in regulation. Quality standards may be set nationally, for example List I and List II and Red List substances (e.g. under the Dangerous Substances Directive (76/464/EEC) and its Daughter directives, for example, the Cadmium Directive (83/513/EEC)), or they may be locally derived from available data (e.g. sediment quality) to provide operational guidelines.

The authorities propose environmental quality standards (EQS) for every industry and farmers who intend to start new aquaculture ventures are obliged to make an environmental impact assessment (EIA) of their sites before licences are granted.

3.5. Environmental considerations

3.5.1. Site selection

A good site selection is the prerequisite in which quantitative and qualitative aspects must be considered. There are three fundamental issues:

- Environmental factors affecting the choice of site, technology, and husbandry, including prior constraints that require some sort of understanding or technological solutions, such as the pre-treatment of water;
- The environment within the culture system, including the possible effects of production upon health and safety of the operation, and secondary constraints that either limit the efficiency of the farm or require additional treatment to render the stresses acceptable;
- Discharges from the system that may require some measure of control to minimise their potential impact on the environment downstream or on adjacent enterprises.

3.5.2. Water management

Water supply and water management is fundamental to all aquaculture. The technology as well as other factors must be adapted to the available water resources. Pre-treatment of incoming water is essential in some cases, particularly when the farmer shares water with other stakeholders - industry, forestry, agriculture and other types of aquaculture.

In many areas the water is too acidic (PG1) for an optimal culture medium, e.g. for rearing juveniles of salmon for later stocking in the seas. In such cases liming of the water source might be necessary. In other cases the water contains too much iron, manganese or other metals. Sand filters or simple aeration might mitigate the concentration of these metals. Supersaturation of gases like carbon dioxide is another problem if water is pumped from a well. Degassing of the increased carbon dioxide concentration is necessary.

The supply of water might also be affected by other users such as industries, agriculture, forestry or by other aquaculture farmers. The pre-treatment of water is in this case more tricky. The farmer has to investigate the kind and concentration of the pollutant in order to make adequate measures to clean the water if possible. The coastal zone is utilised by many stakeholders and is of great importance for food production.

3.5.3. Physical and Chemical environment

The temperature regime has a very important bearing on the species to be reared. The temperature range as well as the optimal temperature for growth differs from species to species and sometimes also for different strains of the same species. For various species it is also important to know the temperature range for survival. Temperatures below - 0.7ºC are lethal for salmonids Sites in certain parts of the sea with salinities between 20 and 30ppt may get super-cooled water in winter time and are not suitable for rearing salmon (*Salmo salar*) and rainbow trout (*Oncorhynchus mykiss*)

Salinity is another parameter of paramount importance. Some species have a wide tolerance, such as salmonids after the smolt stage and Mediterranean sea bass (*Dicentrarchus labrax*), but others may be restricted to a certain salinity level such as Gilt head seabream (*Sparus aurata*).

Wave action and strong currents may be limiting factors. Growth rates, food conversion efficiency, and resistance to disease can be impaired by mechanical stress such as wind-generated wave action. Wind exposure areas require certain moorings and stable cages to withstand high waves and ice loads in winter time.

Depth conditions influence the site location with regard to mooring and temperature. The very deep net cages down to 20m depth may mitigate high and low temperature regimes found in extreme summer, and winter conditions.

Current and water exchange influence the conditions in the cages as well the prerequisites for mussel (*Mytilus edulis*) cultivation. For the latter, the continuous supply of phytoplankton and organic material is important. Turbidity and suspended sediments may favour the growth of filter feeders such as mussels.

3.5.4. Biotic factors

For some species, bacteria may be harmless and used as feed, but for others bacteria may cause disease and impair growth rate. Such organisms may also be harmful to the consumer and affect human health. Shellfish may accumulate and concentrate bacteria and viruses and for this reason water quality standards are in place for the culture of aquatic organisms. The bio-quality of water is usually based on the number of faecal coliform bacteria per 100ml water.

Toxic microalgae cause many problems in waters used for mussel or oyster (e.g. *Cassostrea gigas, Ostrea edulis*) cultivation. Usually the mussels remain unaffected while consumers of the products are affected. Causative organisms for diarrhetic shellfish poisoning (DSP) are the dinoflagellates of the genera *Dinophysis* and *Prorocentrum*. DSP causes nausea, vomiting and diarrhoea if consumers eat poisonous mussels. Paralytic shellfish poisoning (PSP) is another disease caused by planktonic alga such as *Alexandrium tamarense*. PSP is more serious for humans as the toxin attacks the nervous system and the respiratory organs. Amnesic shellfish poison (ASP) sometimes causes problems for the mussel industry. Associated symptoms, after mussel consumption, are nausea, vertigo and memory loss. The problems associated with toxic algae dictates that regular sampling of mussels and analyses of the amount of toxins is required.

Phtyoplankton may also be hazardous to fish. Fish farmers in many countries have experienced mass mortalities of culture stocks due to phytoplankton blooms, e.g. *Chrysochromulina* in Sweden and Norway (Rosenberg et al. 1988). Four distinct lethal mechanisms have been discovered: i) excessive oxygen demand; ii) excessive oxygen concentrations; iii) mechanical damage of the gill tissue; and iv) toxins produced by the algae (Black et al. 1991).

Predators are an additional problem for the aquaculturist. Marine salmonid farmers are troubled by seals and birds. In the 1990s, increasing cormorant (*Phalacrocorax carbo*) populations became a problem, particularly in the inland waters of Europe (EIFAC 1994). Seals are normally protected, as well as cormorants, either by conventions or national jurisdiction. The antagonism between fishermen and authorities concerning controlled hunting is similar to the situation with regard to farmers

3.5.6. Monitoring of discharged water from aquaculture facilities

Monitoring of coastal aquaculture operations is proposed by several authors (e.g. GESAMP 1996a).
It embraces:

i) Regulation - compliance with terms of licence, protection of the natural environment and safeguarding water quality;

ii) Farm management - optimising husbandry practice, control of water quality, limiting interference from other aquaculture operations; and

iii) Public health - protection of product quality.

The starting point of this section is the technology used when assessing the impact of a discharge of waste water from an aquaculture production unit. It is more difficult to treat the outgoing water and mitigate the waste products from farming in open water systems such as cages. For this reason it is necessary to consider i) the level of production; ii) the feeding technology; iii) the quality of feed; and iv) the capacity of the recipient.

3.5.7. Benthic fauna

Environmental criteria include the composition of the benthic faunal community and various standard recommendations for bottom sediment and water column quality. It is essential to calculate the anticipated discharge of nutrients and organic waste from future aquaculture operations with regard to the capacity of the recipient (Ackefors and Enell 1990; 1994). Such calculations have been done in various districts of the Norwegian west-coast with regard to the load of nitrogen in cage farming of salmon in the so called LENKA project (Pedersen et al. 1988; Ibrekk 1991. Contamination with bacterial, chemical or natural toxins is avoided by analysing water quality and being vigilant with regard to the outbreak of toxic algal blooms. EQSs are also related to good husbandry in order to prevent disease outbreaks or to provide measures against disease outbreaks through vaccination or other actions.

3.5.8. Better feed quality

The feed coefficient ration (FCR) and the content of phosphorus and nitrogen in the feed are two important factors to consider when assessing the environmental impact of aquaculture. Mass balance calculations are used to calculate the discharge of pollutants. By calculating the feed coefficient versus the content of phosphorus and nitrogen in feed minus the retained quantity of those substances in the harvest, Ackefors and Enell (1990; 1994) described the development from 1974 to 1994. In marine environments, the feed coefficient has decreased from 2.3 to less than 1.3. At the same time, the nitrogen content in the feed has decreased from 7.8% to 6.8% and the phosphorus content from 1.7% to less than 1%. This means that the discharge of phosphorus per tonne produced fish has decreased from 31kg to less than 9.5kg and the nitrogen discharge from 129kg to 53kg from 1974 to 1994. Current practice shows that it is possible to reduce the discharge of nutrients even more e.g. the largest cage farm operations in Sweden discharge only 6.4kg phosphorus and 55kg nitrogen per tonne produced fish

3.5.9. Reduction of discharged material to the environment

Various technical devices have been designed to collect feed wastes, nutrients, organic material and dead fish. The ability to collect and treat wastes are greater from land-based rearing units (such as ponds and tanks) than from open cage systems. Simple treatment units are settling ponds, swirl tanks or specially designed tanks for collecting waste and wastewater. Other methods include various kinds of sieves and filters. The constraints with the aforementioned treatment units are that the polluted water is diluted from aquaculture farms and that there is a high flow rate. In addition, dissolved substances are much more difficult to collect than particulate matter.

Recirculation technology allows a more complete control of the aquaculture operation with regard to the discharge of waste and water. This method is aimed at land-based systems and is used mainly in hatcheries and for raising "expensive" fish in the grow-out phase. It is especially used in temperate climates to rear warm water species such as eel (*Anguilla anguilla*), African catfish (*Clarias gariepinus*) and sturgeon (*Acipenser sp.*) which require a temperature above 20ºC throughout the year for optimal growth rate.

Simple recirculating systems consist of fish tank units and treatment units like gravel, trickling or other biofilters. The system is linked to a tank for suspended solid removal. More comprehensive systems have attached denitrification units as well as a special UV unit for the disinfection of bacteria. An ozonation unit can also be applied to break down organic molecules which then can be attacked by the bacteria in the biofilters. The system is rather complicated and expensive to build. The advantage with this technology is that you save water (it is recycled many times) and energy (tanks are isolated or/and the unit is indoor) and it is easy to control the waste. The system may also prevent the spread of disease from outside sources or between separate units of the system.

3.5.10. Improvement of feeding technology

Optimal feeding can be achieved by studying fish behaviour, obtaining information on the environmental conditions (such as temperature) and the size of the fish and improving the quality of the feed. Several computer programmes have been designed to optimise the amount of feed given to the fish during various parts of the day and under various lighting conditions.

The type of feed as well as the way it is fabricated is thus of utmost importance to reduce waste from aquaculture farms.

The composition of the feed is a factor of great importance. Altering the composition of the constituents in the feed such as fat, protein, carbohydrate and energy has contributed very much to reduce the output of wastes. Fat content in feed produced for salmonids has increased from 8% to 30%, protein has decreased from 58% to 40% and carbohydrate from 24 to 13%, and finally the energy content of the feed has increased from 14.8 to 19.2 MJ/kg during the period 1975-1989 (Johnsen and Wandsvik 1991; Talbot and Hole 1994).

This means that the nitrogen content in the feed has decreased from 7.8% to 7.1% (Ackefors and Enell 1994) and that the fish can utilise the fat for energy requirements instead of using protein for this purpose, hence less nitrogen components are excreted. Johnsen and Wandsvik (1991) showed that when fat levels in the feed increased from 22% to 30%, the ammonia concentration in effluent water from a land-based salmon farm in Norway decreased by 38%. With the low fat level the effluent water contained 0.234 mg N/l and with the higher fat level only 0.146 mg N/l.

At the same time the phosphorus content in the feed has decreased from 1.7% to 1.0% which means less excretion of phosphorus components (Ackefors and Enell 1994). Dietary phosphorus requirements for optimum growth of rainbow trout and Atlantic salmon range from 0.5 to 0.8% in the feed. The phosphorus content of whole fish is approximately 0.4 to 0.5% of fresh weight (Lall 1991). The bio-availability of dietary phosphorus is influenced by several factors including chemical form, digestibility of the diet, particle size, interaction with other nutrients, feed processing and water chemistry.

3.5.11. Reduction in the use of medication and chemicals

Diseases are easily spread in water and cultured fish in cages can therefore be contagious to wild fish if disease becomes prevalent in the dense school of fish inside the cage. In addition, stressed fish and a less nutritious feed might also contribute to increased sensitivity to disease.

However, disease can also be a problem in well maintained operations. The eradication of disease is necessary in order to cure the fish and limit the losses for the farmers. In the 1970s and 1980s numerous antibiotics were used. Due to current knowledge and developments, it is possible to vaccinate as a preventive measure and the use of antibiotics is currently very limited in aquaculture. In addition to vaccination, the knowledge of probiotic feed is increasing. Micro-organisms are included in the feed, or a mixture of micro-organisms are put in the water because microflora in the gut plays an important role with respect to the well being and health of fish (Trust and Sparrow 1974; Ali 2000).

3.5.12. Improvement of food safety and product quality

Aquaculture producers operate on an open market with customers and their requests. The farmers must therefore produce fish and shellfish of the highest quality - a fresh and nutritious product with the characteristic composition of protein, lipids and carbohydrate as comparable to wild fish of high quality. The product must have a good taste and not contain pollutants, bacteria or viruses that may be harmful to the consumers.

Rules and procedures for chemicals used in the production of animals must be followed. Withdrawal time after use of antibiotics should be followed according to the Directives from the Food and Hygiene Authorities. The slaughter technique should be in accordance with experienced technology. Hygienic and other rules for the processing and distribution of products must be followed.

4. CONCLUSIONS

Codes of practice must be designed around the interests of the farm animals themselves as well as the interests of the local people and consumers. The interests of farm animals must take into account their life histories, physiology and behaviour, together with the proposed culture technology and pre- and post-harvest handling.
In certain areas, general rules can be followed by all farmers but the industry is very complex when considering the large diversity of species and for these reasons special rules (almost an individual CBP) must be created for various parts of the aquaculture industry.

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