chapter 10

FOOD SAFETY ISSUES

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Introduction

Most food safety issues are not specific to capture-based aquaculture, or even to the products of any form of aquaculture. However, this report would be incomplete without a general account of the hazards and risks associated with fish production, processing, marketing and consumption, together with an outline of some of the specific risks that may be especially prevalent in capture-based aquaculture products. Therefore, this chapter commences with a description of the risks associated with food, especially seafood consumption. A section on the hazards and risks associated with the products of capture-based aquaculture follows, and the chapter ends with a section on strategies for food safety and quality, including the application of HACCP and environmental certification to capture-based aquaculture products.

Food consumption and associated risks

Hazards that may adversely affect our health are inherent in all human activities, including activities related to food production, such as capture-based aquaculture. Knowledge of the risks associated with seafood consumption is based on epidemiological data that are not always properly understood. The identification of hazards and the determination of their relevance to health, as well as their control, are functions of risk analysis. Risk analysis is an emerging discipline in food safety, and forms the methodological basis for assessing, managing and communicating the risks associated with food-borne hazards. There is a fundamental difference between a hazard and a risk. A hazard is a biological, chemical or physical agent in food, or a condition of food, with the potential to cause harm. A risk is an estimate of probability and severity to exposed populations from the adverse health effects resulting from hazards in food. Understanding the association between the reduction in hazards associated with food and the reduction of risk to consumers is of central importance in the development of appropriate food safety controls (Figure 146).

Figure 146. Food safety controls
(Source: FAO)

All foods can transmit disease, including fish, shellfish and fish products. Food-borne outbreaks are usually defined as the occurrence of two or more cases of a similar illness resulting from the ingestion of common food (Huss *et al.* 2000). In Europe (42 countries), fish, shellfish and fish products were identified as vectors in 5.3% (6th in importance) of the human disease outbreaks investigated in the period 1993-98 (WHO 2001). In other areas problems have been linked to the high consumption of raw fish (which creates further hazards) and of certain potentially toxic species, such as puffer fish, that are highly risky (and whose consumption is forbidden in most countries). These problems can be largely prevented and controlled through appropriate food-safety measures but a number of problems remain, even after the application of Good Manufacturing Practices (GMP), Good Hygienic Practices (GHP), and HACCP principles in the processing of certain types of seafood. For example, there are insufficient controls for monitoring and regulating biotoxins in fish (e.g. ciguatera).

General hazards associated with wild and farmed seafood

The traditional habit of consuming raw (uncooked) seafood in certain countries is an area where prevention of food-borne illnesses is not well developed. The true incidence of illnesses transmitted by seafood is not completely known. Few countries have established reporting systems for seafood-borne illnesses, so data is scarce. Nevertheless, available epidemiological data is useful in demonstrating trends and identifying areas of concern.

Generally, the number of cases resulting from seafood ingestion is small compared to those caused by meat products. However, the importance of seafood as a vehicle for disease depends on a number of factors, such as the diet of the population and the traditional ways of preparing food. In Japan, for example, the proportion of outbreaks due to seafood is high, since fish are an important part of the diet and a lot of fish may be eaten raw. Moreover, in Asia, the custom of eating raw fish leads to food-borne trematode (parasite) infections derived from cultured fish.

The statistics for seafood-borne illnesses show that nearly 80% of all outbreaks related to fish consumption are caused by biotoxins such as ciguatera or scombrotoxin (Huss *et al.* 2000). While the presence of biotoxins in fish is related to certain geographical factors (warm tropical waters), the formation of scombrotoxin (biogenic amines) takes place in specific fish species *post mortem* (such as Scombroidae and Clupeidae) – particularly when these fish are kept at temperatures of >5°C (histamine may also be formed at temperatures below 5°C; it depends on the type of fish flora). Only 12% of seafood-borne outbreaks are due to bacteria (*Clostridium botulinum*, *Escherichia coli*, *Salmonella* spp., *Staphylococcus* spp., *Vibrio* spp., *Bacillus cereus*). Unfortunately, the statistics do not include information on the types of fish products, which were consumed prior to the outbreaks of illness. Knowledge of the safety principles involved in fish processing, e.g. pH, smoke, additives, packaging and preparation before eating (cooked or uncooked products), is useful to evaluate the hazards related to fish products.

The hazards associated with finfish, whether wild or farmed, can be grouped into pre-harvest contamination and harvesting and processing contamination.

Pre-harvest contamination

Pre-harvest contamination mainly involves biological hazards: bacteria, parasites, biotoxins from toxic algae and, to a lesser extent, chemical hazards.

The hazards associated with human pathogenic bacteria in finfish can be divided in two groups: those naturally present in the aquatic environment (referred to as indigenous bacteria) and those present as a result of contamination with human or animal faeces or otherwise introduced into the aquatic environment (Feldhusen 2000). At least ten genera of bacterial pathogens have been implicated in seafood-borne diseases (Figure 147):

- → bacteria which are normal components of the marine or estuarine environment (indigenous bacteria) such as *Vibrio cholerae, V. parahaemolyticus, V. vulnificus, Listeria monocytogenes, Clostridium botulinum* and *Aeromonas hydrophila*;

- enteric bacteria which are present due to faecal contamination (non-indigenous bacteria) such as *Salmonella* spp., pathogenic *Escherichia coli*, *Shigella* spp., *Campylobacter* spp. and *Yersina enterocolitica*.

Hazards are relevant or irrelevant according to the risk level at the time of consumption. Indigenous pathogenic bacteria, when present in fresh cultured products, are usually found at fairly low levels and, where these products are adequately cooked, food safety hazards are insignificant. If fish is consumed raw or is not properly cooked the risk can be significant. In Japan, for instance, there are a number of *V. parahaemolyticus* (fish normal flora) outbreaks due to consumption of raw fish.

A few bacteria associated with the faecal contamination of seafood continue to pose a large-scale health threat; these are particularly relevant when culture systems are close to centres of human population, e.g. in Hong Kong. There are also situations where the fish culture system is far from human population and contamination with *Salmonella* spp. may exist. This happens in places where there is a large population of birds (e.g. near the coast); *Salmonella* spp is part of the normal flora of birds, and transfer through their droppings on cages, ponds, etc., cannot be ruled out.

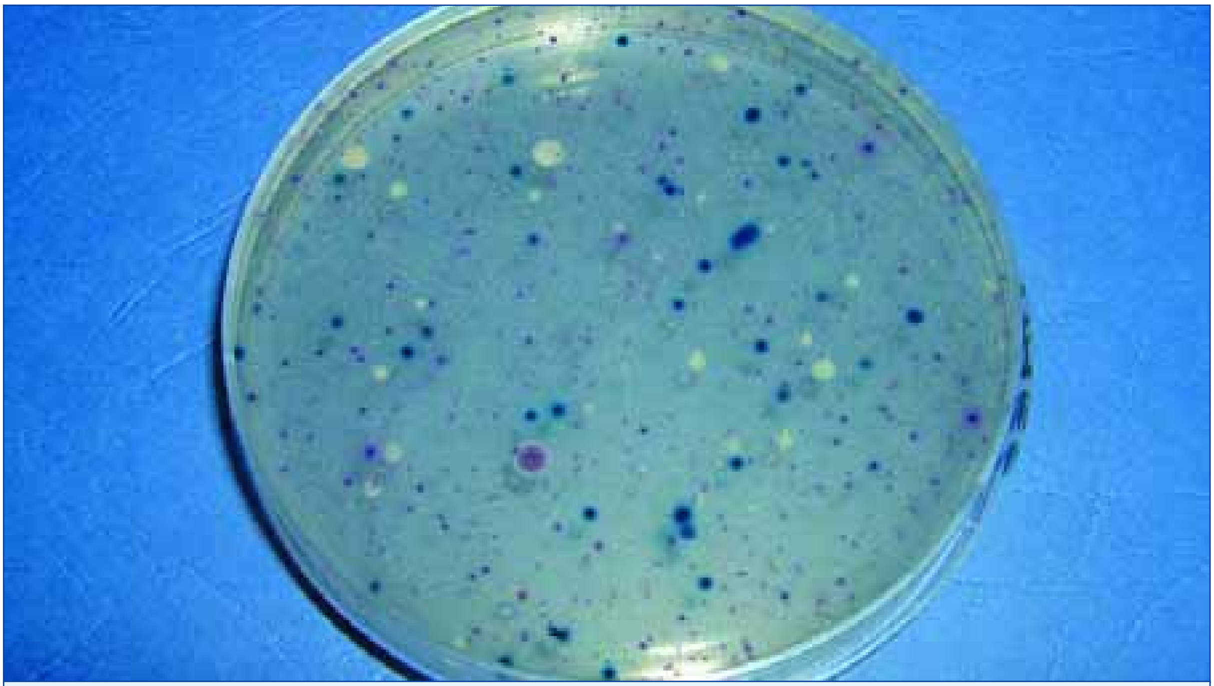

Figure 147. Bacterial seafood analysis (Photo: C. Silvestri)

Live fish may be infected with a number of pathogenic bacteria normally found in the aquatic environment, such as *C. botulinum* and various *Vibrio* spp. However, only the proliferation of these organisms can be regarded as a hazard. The severity of the diseases related to these organisms may be high (botulism, cholera) or low (*Aeromonas* infections), but the likelihood of provoking disease (risk) is very low. Most pathogenic strains require temperatures of more than 5°C for growth and they compete with the normal spoilage flora that proliferate comparatively more rapidly at low temperatures. Thus, products are likely to be spoiled before toxin production or the development of high numbers of pathogens. When products are cooked before consumption, and no further contamination takes place, the risk is largely reduced, as the bacteria and their toxins are heat sensitive (Feldhusen 2000).

In the last 15-20 years there has been an increasing concern worldwide about *Listeria monocytogenes* and its implications for food safety. It has been found in processed seafood products, such as cooked or frozen seafood, marinated fish, "*surimi*", "*sushi*", and smoked fish. The hazard for human health is listeriosis; in Germany there have been an estimated 200 cases per year in a population of 80 million (Feldhusen 2000). At present, there have been no reports of epidemic outbreaks due to this bacteria in the fish products consumed globally; *L. monocytogenes* has been identified as the causative agent in only a few cases. However, the incidence of *Listeria* in fish products is very high in Latin America; in Brazil it was found in domestic and imported seafood, whether raw or ready-to-eat, but the real incidence of *Listeria* is difficult to assess (Destro 2000). Pre-harvest contamination with pathogens from the animal/human reservoir (*Salmonella* spp., *E. coli*) can cause illness but, again, normal cooking procedures mitigate the risk that is related to the consumption of raw fish dishes such as "*sushi*".

Problems related with animal feed ingredients may exist; for example, meat and bone meal (MBM) and animal by-products have been reported to have the highest incidence of *Salmonella*. Chemical or physical pre-treatments substantially decrease initial *Salmonella* population levels in feed protein sources, and have effectively lowered population levels in poultry feed; however *Salmonella* may survive long-term storage (Ha *et al.* 1998).

The presence of parasites constitutes another biological hazard; a large number of fish species can serve as sources of parasitic infections (WHO 1995). In Japan, about five species of parasites affect humans. Among them, the most important is *Anisakis simplex*, which is uncommon in humans since it is killed by normal cooking or freezing of fish products but the consumption of uncooked seafood (e.g. "*sushi*") can cause anisakiasis (Ogawa 1996; WHO 1999). This is especially noticeable in communities where eating raw or inadequately cooked fish is a cultural trait; about 2 000-3 000 cases are reported every year in Japan. The juvenile stage of this parasite infects humans through several cultured fish species.

The most important biological hazards are biotoxins, whose occurrence is widespread. In pre-harvest contamination, ciguatera constitutes the main hazard. Ciguatera is a global problem caused by the consumption of warm-water fish infected with ciguatoxins, a family of heat-stable, lipid-soluble, highly oxygenated, cyclic polyether molecules. They have their origin in *Gymnodinium toxicum*, a benthic dinoflagellate that is at the base of tropical coastal marine food chains (Lewis and Holmes 1993). More than 400 species of fish can be involved in ciguatera poisoning. Ciguatera is mostly confined to the Pacific, Western Indian Ocean and the Caribbean seas; in fact it has a greater socio-economic impact in those regions where fish is the principle source of protein (Lewis 1992). The affects of ciguatera poisoning can last for several weeks or months; gastrointestinal symptoms, such as vomiting, diarrhoea, nausea and abdominal pain typically occur, often associated with neurological problems. Effective treatment of ciguatera requires accurate diagnosis, and intravenous mannitol is a possible treatment. Detecting ciguatoxins is difficult, mostly due to their low levels in ciguateric fish (<0.05 ppb for one common type of ciguatera molecule). Detecting ciguatera is even harder when different classes of these biotoxins coexist, as in Hong Kong where both Pacific and Indian Ocean ciguatoxins occur (Lewis 2000).

The potential hazards due to chemical contaminants in fish and fish products from aquaculture include heavy metals, dioxins, dioxin-like PCBs and similar substances, and residues and unauthorized substances. Heavy metals, such as mercury, cadmium and lead can be tolerated by humans only at extremely low levels. Fish can accumulate substantial concentrations with respect to mercury in their tissues and thus represent a major dietary source of this element. Fish are known to be the largest mercury source, with the exception of direct exposure. The use of chemicals in fish culture is regulated in the USA and in Europe; in some countries regulations may exist but most have no regulatory body to control their use.

Dioxins are mainly a man-made hazard, resulting chiefly from the incomplete combustion of urban wastes. The term “dioxins” is a generic name that encompasses two different types of compounds, the polychlorinated dibenzo-p-dioxin (PCDD) (75 congeners) and the polychlorinated dibenzofurans (PCDF) (135 congeners). Seventeen of these compounds are of recognized toxicological human concern.

Polychlorinated biphenyls (PCBs), also known as “dioxin-like”, are a family of 209 congeners, of which about thirteen are of toxicological human concern. PCBs are also a man-made hazard; they were mainly produced for industrial use in electrical equipment (transformers and capacitors). The international treaty on persistent organic pollutants (POPs), drafted by 122 nations in South Africa in December 2000, targeted PCBs as one of the dirty chemicals to be phased out globally. Some countries, in particular developed countries, banned the production of PCBs many years ago (e.g. the USA in 1976). However, due to the persistence of PCBs in the environment, they continue to be a food hazard, even in countries that banned their production a long time ago.

Dioxins are only slightly volatile, and therefore tend to show limited geographical distribution (e.g. a lake, or a portion of a river) mainly following fallout from the smoke plumes of combustion, and in water courses thereafter. By now, however, they can be found in many areas all around the world. PCBs have low water solubility (also they remain on the water surface). However, in contrast to dioxins, PCBs are highly volatile; the result is that PCB contamination can be found worldwide, including the Arctic and Antarctic regions. Both dioxins and PCBs are highly soluble in lipids and therefore tend to accumulate in animal and human lipids. Fat in milk, meat, eggs, fish and their products are the main source of dioxins and PCBs in our diet.

Dioxins and dioxin-like compounds may be accumulated in fish, either from the water with which they are in contact (freshwater or seawater) or from contaminated feeds. In practice it is impossible to avoid some contamination with dioxins and, in particular, PCBs; however, it should be possible to avoid specific geographical locations (land or water) that may be exposed to significant contamination by dioxins and PCBs. Accumulation of dioxins and PCBs by fish directly from water is possible, but this route is generally considered negligible for species at the top of the trophic chain.

Usually, high-energy feeds are the first cause of concern. Studies conducted in various countries have shown that cultured fish, particularly those reared on aquafeeds containing fishmeal and fish oil, exhibit levels of dioxins and dioxin-like substances greater than those found in wild fish (Easton, Luszniak and Von der Geest 2002; Hites *et al.* 2004). These findings could also be related to the amount of these substances in the fish feed used, particularly in the fishmeal and fish oil incorporated. Limits for dioxin and dioxin-like substances in fish and fish products exist in almost all countries (for example, in the case of the European Union, Council Regulation (EC) No. 2375/2001, 29 November 2001, applies). Despite the findings mentioned above, it is important to note that all studies to date have shown that the levels of dioxins and PCBs in both wild and farmed fish are generally well below regulatory and advisory limits; however, concerns about this type of hazard remain.

Regular surveillance, particularly in developed countries, shows that levels of dioxins and PCBs in the human diet and in body lipids (e.g. mothers’ milk and blood) have generally fallen substantially since the mid-1980s, following the enforcement of improved regulations on garbage combustion, the ban on the production of PCBs, and the development of regulations regarding the disposal and handling of PCBs. Nevertheless, the risk of these types of hazards may be significant in specific geographical areas where such measures do not apply, or only partially apply, or due to the faulty implementation of regulations.

Other possible sources of chemical contamination may include fertilizers, pesticides, drug-residues, disinfectants, chemotherapeutants, medicines for disease control in fish, antifoulants used in cage nets, etc. The number of possible hazardous substances is very large; therefore specific hazard analysis may be necessary in each specific location. In any case most countries have regulations that define the specific obligation to establish an approved residue-monitoring plan for aquaculture that includes fish, water and sometimes feeds.

The potential exists for the strains of some human pathogens, such as *Streptococcus* (Weinstein 1997), to develop high antibiotic resistance, resulting in infections that can be more difficult to treat. Resistance can spread to other types of bacteria and human pathogens, through gene transfer mechanisms special to bacteria (Dixon 2000).

Preventing pre-harvest contamination is quite difficult, since most of the pathogens occur naturally but can be controlled by Best Management Practices. If operators are to remain competitive, they will have to follow the market pressure to achieve improved Food Safety Standards and bear the high economic cost of prevention procedures.

Risks of contamination in harvesting and processing

The way in which fish are harvested may also impact quality. It follows therefore that good techniques are very important to reduce the risks of contamination. The stress due to the transportation and handling of live fish during the rearing process and during partial harvesting can also cause an immunodeficiency, decreasing their resistance to infections by pathogens, bacteria, etc. Oxidative stress research is particularly important in the health assessment of farmed fish; stressed fish are more vulnerable to disease due to an impairment of their antioxidant defence systems (Ferrante *et al.* 2003).

During the harvesting and processing of the various fish products, pathogenic agents that are present in the raw fish may survive in the final product. Further contamination may also occur, due to biological (bacteria, scombrotoxins, parasites) and physical hazards. Human pathogens that may contaminate the fish product during post-harvest handling include *Bacillus cereus*, *Listeria monocytogenes*, *Staphylococcus aureus* and *Clostridium perfringens* (Feldhusen 2000). *Clostridium botulinum* is an ubiquitous, spore-forming, anaerobic organism that produces a neurotoxin causing life-threatening food-borne illness. *C. botulinum* type E is naturally found in aquatic environments and is often isolated from fish. The mere presence of *Clostridium botulinum* in or on a fish product will not cause illness, however; viable *C. botulinum* spores must also be given the opportunity to germinate and produce toxin. If the fish are properly handled and processed, to prevent growth of the organism and production of the toxin, there should be no risk of botulism. Although the hazard of *C. botulinum* toxin is serious, the risk is low because of the implementation of strict specific regulations (e.g. LACF – Low Acid Canned Food) in many countries. Another form of toxins are the scombrotoxins, which will be described in a later section because of their particular importance in capture-based aquaculture.

The allergy producing substance histamine will develop in fish where large amounts of free histidine and bacteria are present. Histidine may be converted to histamine if the products are stored at elevated temperatures for a sufficient time. The dynamics of histamine formation depend on a number of factors, for instance the type of fish flora, the ratio between external surface and weight, high temperature/shorter time and inappropriate handling of the fish. The higher temperature allows the bacteria that decarboxylate histidine to histamine to proliferate and produce substantial amounts of the active agent, the enzyme histidine decarboxylase (Chamberlain 2000). High histamine levels indicate that the fish have been stressed during the harvest operation and stored at high temperatures for a prolonged period, giving rise to toxicity. Sedation of the fish during harvesting, and effective temperature controls during handling and processing, are practical solutions to minimize this hazard. In the past, high histamine levels in seafood products exported from the Indo-Pacific region have resulted in severe economic losses and a number of importing countries have now introduced regulations on the maximum allowable histamine content (Chamberlain 2000). For example, the United States Food and Drug Administration has established an upper histamine limit in raw and frozen tuna of 50 ppm, and has also specified a health hazard (scombrotoxic) limit of 500 ppm (USFDA 1996). Histamine is considered a toxic or deleterious substance because, if ingested at sufficiently high levels, it is known to cause scombroid poisoning. The presence of other amine decomposition products in fish may also have a synergistic effect of histamine toxicity (Lehane and Olley 2000). Histamine fish poisoning (HFP) is a mild illness, but it is important in relation to food safety and international trade. HFP occurs throughout the world (Mines, Stahmer and Shepherd 1997); however, there are no reliable statistics on its incidence. Since 1970, the countries with the highest number of reported cases are Japan, the United States and the UK. Fish containing histamine may look fresh in terms of appearance and colour; therefore such quality attributes are not adequate to assess the presence or absence of histamine. HFP is a significant public health and safety concern; it was first diagnosed in 1828, and since then it has been described in many countries, being now the most prevalent form of seafood-borne infection in the United States.

Consumers are becoming more demanding, and litigation following food poisoning incidents is more common. Producers, distributors and restaurants are increasingly held liable for the quality of the products they handle and sell. Such forms of illness, which are a consequence of improper handling or storage of fish, need to be controlled by effective testing methods to identify those fish likely to be toxic. Control and prevention are possible (Lehane and Olley 2000), and many countries have set guidelines for maximum permitted levels of histamine in fish, following the USFDA. However, histamine concentrations in a spoiled fish are extremely variable, as is the threshold toxic dose. Biotoxins usually survive in cooked fish, while parasites are killed when fish is frozen or cooked.

The main problem associated with distribution of seafood products is time-temperature and inappropriate handling (Figure 148). Most bacteria cannot proliferate at temperatures below 5°C; thus the proper cooling of seafood during transportation becomes an important consideration. Chilled products should be loaded when the core body temperature is below 4°C for fresh products, and below -18°C for frozen products.

Few pathogens are generally present in smoked products but there is still a high incidence of *Listeria*. The risk posed by the consumption of cooked (fresh or frozen) fish is also low. The principal food safety risks associated with cooked products are caused by heat stable chemicals or biotoxins (ciguatera or fish containing an excess of histamines). An indirect hazard for human health is an allergic reaction to the ingestion of dead parasites; in general this risk is considered by authorities to be very low but current regulations exist, particularly in developed countries. Processed seafood sometimes also exhibit physical hazards, such as contamination with foreign material (glass, metal) (Huss, Reilly and Ben Embarek 2000). Maintaining healthy conditions during processing can be achieved through preventative measures, such as GMP, effective hygiene and sanitation programmes, etc.

Figure 148. One of the major problems in seafood distribution is inappropriate handling (Photo: M. Nakada)

Hazards of special relevance to capture-based aquaculture

A number of biological (bacteria, viruses, parasites, and biotoxins such as ciguatoxins and scombrotoxins), chemical (heavy metals, pesticides, antibiotics) and physical (foreign bodies) hazards may be associated with capture-based farmed seafood products. Some of these may derive from naturally present environmental contaminants in which the fish are captured or farmed; others may be due to contamination introduced during processing. Most of these problems have already been described in the previous section of this chapter; the following extra comments draw attention to problems of special relevance to capture-based aquaculture.

Pre-harvest contamination

All of the problems described earlier, in the section on general hazards in wild and farmed seafood, are also applicable to some capture-based aquaculture products; a number have special relevance to this part of the aquaculture sector. For example, in the capture-based aquaculture of eels, 21% of Japanese eel culture ponds were reported to be contaminated with *Salmonella* in 1989 (Huss, Reilly and Ben Embarek 2000).

In several types of capture-based aquaculture there is a need to develop a suitable practical diet for grow-out production. Trash fish is often used as a principle source of feed in these forms of aquaculture, and can be a source of infection and some diseases involving opportunistic parasites. For instance, the trematodes, cestodes, nematodes and acanthocephalans recovered from cultured groupers were thought most probably to be transmitted through the trash fish that was fed to them (Bondad-Reantaso, Kanchanakhan and Chinabut 2001). Parasitism is an ubiquitous phenomenon in the marine environment, and in capture-based aquaculture there is the potential to develop several parasitic infections, which may be zoonotic if the fish is eaten raw. In groupers (*Epinephelus suillus*), the source of infection may be the fresh trash fish used as feed in the capture-based aquaculture practices applied. In other cases, the correlation between parasitic nematode species and their relative infections and the use of fresh trash fish cannot be ascertained, because their pathogenicity in humans has not yet been established.

Other problems occur in capture-based aquaculture due to the common practice of "seed" importation. In Japan, for example, the capture-based aquaculture of amberjack is based on the importation of fry from Hainan, China and Hong Kong. This trade developed due to the lack of juveniles available in Japanese coastal areas (Ogawa 1996). The increase of fry imports was correlated with an increase of the monogenean infection (*Neobenedenia girellae*) that suddenly appeared in these fish. It seems that the fry were infected before shipment to Japan. Since this parasite is not host-specific, infection can spread to other domestic fishes (Ogawa 1996), including grouper (Bondad-Reantaso, Kanchanakhan and Chinabut 2001).

The fish families involved in ciguatera poisoning include several capture-based farmed species, including serranids (groupers) and carangids (yellowtails). An example of this type of seafood-borne infection occurred in Haiti in 1995, and was due to the consumption of cooked greater amberjack, *Seriola dumerili* (Poli *et al.* 1997). This infection is usually limited to wild fish. There is a potential to control such contaminations in capture-based aquaculture, so there could be a possibility of guaranteeing ciguatera-free fish (Sadovy 2000), thus providing a marketing opportunity.

Tunas are recognized as predators able to concentrate large amounts of heavy metals (Voegborlo *et al.* 1999), depending on their origin. This therefore represents a potential problem for capture-based aquaculture. Eels (*Anguilla* spp.) are good candidates for the investigation of mercury bio-accumulation, due to their long life spans in freshwater systems. Studies in Australia, Europe and New Zealand have shown mercury bio-accumulation in eel tissues (Redmayne *et al.* 2000). However, in general it is wild fish that accumulate high levels of heavy metals. Capture-based aquaculture, being based on the on-growing of wild "seed" in controlled systems where water quality and diets are controlled, should be less susceptible to this problem. In the wild, the larger and older the fish, the greater potential for the accumulation of heavy metals in its tissues exists.

The risk of dioxins and PCBs in fish reared through capture-based aquaculture should be low, and comparable to the levels found in wild fish, when they are fed raw fish (fresh or thawed). In any case, the levels of accumulation in the cultured fish will depend mainly on the levels of dioxins and PCBs in the feed presented, whether it be raw fish or a compounded aquafeed. For instance it is known that the levels of dioxins and PCBs in species of small pelagics fished from the South Pacific off South America are lower than those of similar species in the North and Baltic Seas.

Japan has banned the use of organic tin coatings, the application of a chemical substance to the nets used by the farmers of yellowtails to prevent the growth of fouling organisms, for fear of its accumulation in fish tissues and consequential human health concerns (Ogawa 1996). Initial investigations of human blood and livers have shown enhanced concentration of some organo-tin derivatives (Hoch 2001).

Permitted chemotherapeutants, such as the antimicrobials used in capture-based aquaculture to prevent infectious diseases in fish, may lead to the presence of residues in fish flesh and to the development of antibiotic resistance in both humans and fish-pathogens (Schnick 2001); this practice therefore needs control.

Risks of contamination in harvesting and processing

All of the problems described in the earlier section of this report, on the general hazards in wild and farmed seafood products apply to capture-based aquaculture. However, this section mentions some problems that are particularly important for this sector.

Thunnus spp. are known to be easily stressed (Figure 149); if the tuna are over-stressed, the muscle can become “burned”. This is due to the production of lactic acid by the anaerobic glycolysis process. Stress also can create high levels of histidine to be produced, which creates the HFP problems that have been described earlier. Scombrotoxins (biogenic amines) are biotoxins that are produced mainly in scombroid fish species, such as tunas, due to inappropriate handling during harvesting and poor post-mortem conditions, particularly when these fish are kept at elevated temperatures (>5°C). It is important to highlight this hazard, since high levels of histamine in bacterially contaminated fish of these particular species can be toxic to the consumer. It is thus of importance in capture-based aquaculture, particularly to tuna farming. It has been noted that cooked fish have been involved in a higher number of cases of HFP than raw fish in Japan. Given the Japanese preference for raw fish, this may seem surprising but it is probably due to the fact that only the highest quality fish are sold in the raw fish markets there.

Other species that are reared in capture-based aquaculture are also associated with HFP. These include amberjack (*Seriola* spp.) and yellowtail amberjack (*Seriola lalandi*). The fish used as feed in some forms of capture-based aquaculture can also be associated with HFP; these include herrings (*Clupea* spp.), anchovies (*Engraulis* spp.), and sardines (*Sardina pilchardus*).

Figure 149. Capture-based farmed tuna; the harvesting time is a delicate phase because tuna are easily stressed (Photo: L. Mittiga)

Strategies for food safety and quality

Hazard analysis and critical control point (HACCP)

By the end of the 1980s, developed countries arrived at the conclusion that classic food inspections, based on the analysis of samples of the final product and on generic hygiene measures, were not enough to provide the necessary level of protection to consumers. Inspection needed to address all the relevant hazards in food production and therefore had to be incorporated into the harvesting, processing and distribution of fish products. The system that was eventually developed was called “Hazard Analysis and Critical Control Point” (HACCP). In the HACCP system, each substance, micro-organism, pest, or condition which can contaminate the food is identified and called a “hazard”. By the beginning of the 1990s, developed countries were already applying HACCP on a voluntary basis. In 1997, it was incorporated into the WHO/FAO *Codex Alimentarius* in the form of a general guideline; subsequently, the system was officially adopted, and governments started to change their regulations accordingly (FAO 2000).

The plethora of regulations, agreements and guidelines concerning the safety of aquaculture products around the world has become a rather complex matter, as there are many international and national texts. The relevant internationally agreed texts are the GATT Agreement on the Application of Sanitary and Phytosanitary Measures (GATT 1994) and the basic *Codex Alimentarius* Commission (CAC) texts on food (including fish) safety. There are also FAO and WHO texts of particular relevance to farmed fish, such as the FAO aquaculture guidelines (FAO 1997b) and the food safety issues discussed in a paper by FAO/NACA/WHO (1999). A specific section for aquaculture will be adopted in the Code of Practice for Fish and Fishery Products of the *Codex Alimentarius* (http://www.codexalimentarius.net).

At the national level, many countries have now adopted specific HACCP-based regulations regarding the safety of fish and fish products, including the products from aquaculture. Approximately 65% of the total international fish trade is now carried out under HACCP-based regulations. Regional regulations also exist. For example, there are a series of directives in the European Union that enforce the use of HACCP systems. Directive 91/493/EEC of July 1991 lays down the hygienic conditions for the production and placement of fishery products on the market; 93/43/EEC (14 June 1993) is also applicable to fishery products; and the Commission Decision 94/356/EEC (20 May 1994) sets detailed rules for the 1991 directive, with regard to hygiene checks on fishery products, to ensure that producers follow and adhere to the requirements of the EU.

Regulations are changing very quickly; further changes and new regulations are likely in the next few years. Moreover, the HACCP-based regulations of different countries are not fully equivalent from the point of view of the analysis of regulatory texts. Future regulations will tend to include either direct quantitative risk analysis of the relevant hazards associated with a given product, or some indirect measurement of those risks (Lupín 2000).

The application of the HACCP system to capture-based aquaculture

While the implementation of HACCP-based food safety assurance programmes is well advanced in the fish processing sector, their application to fish farming generally (including capture-based aquaculture) is still in an early phase. The lack of scientific data regarding the effectiveness of the on-farm control of pathogenic micro-organisms is one of the problems that cause the insufficient application of HACCP in capture-based aquaculture.

A prerequisite for implementing an HACCP system in any fish farming operation is compliance with the principles of good aquaculture practice, sometimes known as best management practices (BMP). Good aquaculture practices can be defined as those practices necessary to produce high-quality products conforming to food laws and regulations of the intended marketing country. Governments should strive to promote the use of such practices through the education of farmers and the promotion of food safety procedures.

The successful application of HACCP requires the full commitment of the owner of the fish farm, together with its workforce and expert team (Figure 150). It is necessary to examine carefully the nature and extent of any hazards associated with products from aquaculture, and their methods of production. The first step is to assemble an HACCP team that should include experts in all the activities related to fish farming. This multidisciplinary team should consist of experts in aquaculture, fish farm management, fisheries extension, public health, parasitology, and fish inspection and quality control. The second step involves a description of the product and its intended use by the purchaser. The intended use may include processing as value-added products or consumption after cooking. The third step involves designing a flow diagram. The fourth step involves the on-site confirmation of the flow diagram approach. Finally, the fifth step consists of the application of the seven principles of the HACCP system (FAO/NACA/WHO 1999), adapted to production from capture-based aquaculture.

Figure 150. Harvesting of Japanese amberjack in Japan; in future, capture-based aquaculture will apply the HACCP system (Photo: M. Nakada)

There is an excellent text available from EUROFISH, in conjunction with SIPPO (the Swiss Import Promotion Programme) called “Guide to Hygiene within the Fish Industry” (J. Dallimore, pers. comm. 2002) that details all of the requirements for HACCP accreditation, and is full of illustrations showing the requirements in action.

An effective HACCP system must control the production and delivery of products from the first day that the fish are held in captivity until they are delivered to the consumer. The documentation must allow full traceability. The systematic procedure for setting up an HACCP system is as follows:

- analyse the complete production process and estimate the probability of a hazard occurring, and the risks involved. In capture-based aquaculture there are six main areas of concern: collection, on-growing, harvesting, packing and processing, delivery, and point of sale;
- determine the Critical Control Points (CCPs) that may be present in the system. These may include the quality of the trash fish used as feed, harvesting operations, hygiene in the packing area, temperature control levels, etc.;
- specify the limits which, when adhered to, will guarantee that the CCPs are under control (e.g. fresh fish always to be kept below 5°C after harvest);
- establish protocols and documentation for monitoring the CCPs;
- develop and specify corrective actions when monitoring reveals that a CCP is no longer under control;
- establish procedures for modification that include supplementary tests and procedures to confirm that the HACCP system is working effectively;
- develop a complete documentation system that records all of the stages necessary to the system.

It must be noted that to establish and maintain an HACCP system is a complex and time consuming operation, but one that must not be ignored. It is suggested that all companies employ a consultant experienced in HACCP systems to evaluate the CCPs needed, and to provide training to management and staff to ensure that the criteria in the system are met.

Environmental certification and its application to capture-based aquaculture

Environmental certification of aquaculture is increasingly seen by many as a multipurpose instrument. It represents a means for aquaculturists to produce value-added farmed organisms and a means for environmentalists to increase the level of environmental awareness and protection in the industry. An environmentally certified product gives consumers assurance on quality and some sensitivity to the way that the product is produced. Consumers can then make informed purchases; this can constitute a method for minimizing the risk faced by retailers of being accused or found guilty of supplying products that are produced in an environmentally unsustainable way (Mallows 1999). Such considerations should be also applied to the products of capture-based aquaculture.

Currently, the driving force behind eco-label initiatives derives mainly from Agenda 21 of the UN Conference on Environment and Development held in Rio de Janeiro, Brazil in 1992 (www.un.org/esa/sustdev/agenda21.htm), which were reinforced by the fisheries agreements that were achieved during the 2002 Summit in Johannesburg (www.johannesburgsummit.org). Many NGOs have taken up this topic; some of their views are extreme; others are more balanced. For example, a report on aquaculture for a US-based NGO, the Environmental Defense Fund (EDF) presents recommendations for the private sector of aquaculture, such as "Organic certification and potentially other eco-certification programmes should be established that empower consumers to choose aquaculture products grown in an environmentally sound manner…" (www.edf.org).

The labelling of a product as "environmentally certified" is based on an assessment of its entire cycle, extrapolated both upstream and downstream, and is dependent on a systems approach, e.g. Environmental Management System (EMS) to production, distribution and marketing. There are two main standard systems specifications for implementing an EMS: the ISO (International

Organization for Standardization) 14000 series and the EU-accredited Eco-Management and Audit Scheme (EMAS). Neither is legally binding. The ISO series is still being developed, and its components include standards for Environmental Auditing (ISO 14010-14013), Environmental Site Assessments (ISO 14015), and Eco-labelling and Self-declaration Environmental Claims (ISO 14020-14024). The main certification criteria involve the development of an EMS. The required components for ISO certification are included in ISO 14001. For initial design, development and implementation, an EMS ISO 14004 can be used, as it consists of a set of guidelines rather than a full auditable certification criterion (Mallows 1999).

Eco-labelling is currently gaining acceptance in USA and EU markets. The Marine Stewardship Council (MSC), an organization supported by commercial interests that promotes the sustainable exploitation of the sea, has considered extending its eco-labelling system for capture fisheries to aquaculture (M. New, pers. comm. 2003). A certification system designed specifically for aquaculture has been developed by the Aquaculture Certification Council (ACC), but is currently confined to marine shrimp and prawns (ACC 2003); this initiative has its origins in a producers organization, the Global Aquaculture Alliance (GAA) and may therefore be subject to scepticism about its independence.

Recently, ecolabelling has become a major issue in the USA where the public is informed in restaurants and information points (such as university aquariums) under the Seafood Watch Program. Products are graded as “best choices”, “proceed with caution” and “avoid”, and in restaurants the consumer is also advised if a fish product is “environmentally sustainable”. Capture-based aquaculture will need to address these issues where products are sold in these sensitive main markets (www.intrafish.com/articlea.php?articleID=25219).

In response to growing public concerns about food quality, two of Japan’s biggest supermarkets, Aeon Co. (formerly Jusco) and Ito-Yokado Co., plan to improve the information provided on fish labels. The labels will include information on the origin of the fish, including “production histories” covering data on the farming area, the farming company and the feedstuffs used. Aeon Co. began this programme by labelling eel products in May 2002. By 2003, it planned to include other farmed fish such as yellowtails. It will also provide details of its own management of the fish farming process, and display information on whether its fish have been given anti-infective drugs (www.asahi.com/english/business/K2002032700610.html).

In 1995 the Food and Agriculture Organization of the United Nations (FAO) adopted a Code of Conduct for Responsible Fisheries (FAO 1995). The CCRF sets out principles and international standards of behaviour for responsible practices, with a view to ensuring the effective conservation, management and development of living aquatic resources, with due respect for ecosystem and biodiversity. The Code recognises the nutritional, economic, social, environmental and cultural importance of fisheries (including aquaculture practices), and the interests of all those concerned with the fisheries sector. The CCRF takes into account the biological characteristics of the resources and their environment, and the interests of consumers and other users. The Code is not legally binding, but FAO Member States and all those involved in fisheries are encouraged by FAO to apply it.

The feasibility of implementing a certification scheme in an aquaculture operation can be compared to other similar situations. Quality assurance, together with safety assurance such as HACCP, can be integrated quite simply with certification criteria; it is easier to incorporate existing quality and safety schemes into something new, such as a certification system, than to try to add a certification process to an existing assurance scheme. The inclusion of documentation on traceability is also essential for insurance purposes. The problem that must be addressed is performance monitoring (use of resources, waste discharge, etc.). By using a separate organization to verify certain aspects of aquaculture production, the farm and the certifiers must both ascertain whether performance targets are being achieved and maintained. The operator, the regulating body or the certification organization can undertake this monitoring activity, though it would be better if all parties shared the responsibility.

Conclusions

The expanding trade in capture-based farmed species of various ages and life stages for the seafood industry without appropriate health considerations may increase the risk of spreading pathogens that are associated with human illnesses. Little is known about the impact of contaminated food on human health and its epidemiology. Food safety concerns associated with capture-based aquaculture affect all levels of this activity. Illness caused by the consumption of contaminated food not only has socio-economic consequences (e.g. production losses) but also causes public health concerns. Such problems may seriously affect small-scale farmers, who represent the backbone of many rural communities in Asian aquaculture. Their livelihoods may be threatened through reduction in food availability and loss of income and employment.

The level of hygiene during the production and consumption of seafood in Europe keeps bacterial risks at a low level (Feldhusen 2000). Food-borne sicknesses associated with capture-based farmed products could be largely prevented and controlled through appropriate food-safety measures. Responsibility for food safety associated with the products from aquaculture is shared between governments, fish farmers, the processing industries, and consumers.

Reducing the number of seafood-related sickness outbreaks worldwide requires continued and coordinated efforts by many different agencies, including those involved with water quality, disease surveillance, consumer education, and seafood harvesting, processing, and marketing (Feldhusen 2000). Where appropriate, the aquaculture sector should institute farm management programmes based on the principles of the HACCP system, which should be applied at all stages from production, collection and transport, to the consumption of food. This would allow a systematic approach to the identification and assessment of the hazards and risks associated with the production, distribution and use of aquatic food. The application of HACCP-based food safety assurance programmes in fish farming is in its early phases (FAO/NACA/WHO 1999). Strategies for food safety guarantees and education must be enhanced among communities where eating raw or inadequately cooked fish is a cultural habit.

Capture-based aquaculture provides opportunities to reduce the risks associated with food safety. For example, in the culture of species where ciguatera is problematic, capture-based farmed species could be “certified” ciguatera-free, so that they would be regarded as a safe source of fish for human consumption (Cesar *et al.* 2000); this could assist profitable marketing.

The development of certification systems that assure quality and good practices should be advantageous for capture-based aquaculture operations, providing such schemes are manifestly independent and accepted as valid by consumers. Research is also necessary to reduce the risks associated with the feed consumed by capture-based farmed species.