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Prevention and control of hazards in seafood

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Abstract

Seafood is high on the list of foods transmitting disease. However, the food safety issues are highly focussed and more than 80% of all seafood-borne outbreaks are related to biotoxins (ciguatoxin), scombrotoxin or the consumption of raw molluscan shellfish. The safety hazards in seafood production are listed and discussed. It is pointed out that there are serious safety concerns related to the consumption of raw fish and shellfish due to the presence of biological (bacteria, virus, parasites) and chemical (biotoxins) hazards. These hazards are present in the fish and shellfish pre-harvest and are difficult or impossible to control by applying presently available preventive measures. In contrast, the hazards related to contamination, recontamination or survival of biological hazards during processing are well-defined and can be controlled by applying Good Manufacturing Practice (GMP), Good Hygiene Practice (GHP) and a well designed HACCP-programme. Similarly, the means to prevent the growth of pathogenic microorganisms during distribution and storage of the final products are – with a few exceptions – available. Proper application of well-known preservative parameters including temperature is able to control growth of most pathogens. When this is not the always case, for example inhibition of *Listeria monocytogenes* in lightly preserved fish products, it is recommended to limit the stated shelf-life of these products to a period of no-growth for the pathogen of concern. There is a good agreement between the trends shown in disease statistics, the hazard analysis and the qualitative risk assessment of the various fish products. It is recommended that consumers should be informed of the risk of eating raw seafood – particularly molluscan shellfish and certain freshwater fish.

1. Introduction

Fish constitute a major part of animal protein consumption in many parts of the world. Globally around 100 million tonnes of fish are landed annually but only about 70 million tonnes are utilised as human food. Out of this about 27% (1992 data) is consumed as fresh fish while the remainder is processed, for example as frozen, salted, dried, smoked, or canned products. Most fish and shellfish are still extracted from a "wild" population, but aquaculture is currently the fastest growing food production system in the world, totalling nearly 22.8 million tonnes in 1996 (FAO, 1997). Over the past decade production increased at an average rate at about 9.2% per year. While it is unlikely that capture fisheries will increase substantially in coming years, it is expected that commercial aquaculture will continue to grow. Whilst this supplies much appreciated high quality protein, it may also lead to increased problems both of an environmental and a public health nature because the risk of contamination of products by chemical and biological agents is greater in freshwater and coastal ecosystems than in the open seas.

The present paper discusses the safety of various types of seafood. It is pointed out that number of problem areas exist even after application of Good Manufacturing Practice (GMP), Good Hygienic Practices (GHP) and HACCP-principles in the processing of certain seafoods. Thus insufficient measures are available to control the presence of heat stable biotoxins in fish (ciguatera) and shellfish. The traditional habit of raw consumption of specific seafoods is another area where prevention of food-borne disease is difficult or impossible.

2. Statistics of seafood-borne diseases

The true incidence of diseases transmitted by foods is not known. Only few countries have established

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food-borne diseases reporting systems, and for those who have, only a small fraction of cases are reported. It has been estimated by WHO and others that the reported incidence of food-borne disease is less than 1% of the true incidence. Nevertheless, available epidemiological data are useful in demonstrating trends and identifying areas of concern.

Data on food-borne disease outbreaks collected over a 10-year period (1983–1993) in the USA demonstrated that fish were the third most reported category according to vehicle of transmission, with unknown vehicles ranking first and multiple vehicles second (Lipp & Rose, 1997).

That seafood is high on the list of foods transmitting diseases is also shown in Table 1. Thus in countries having a well-established surveillance system in place up to 10% of all outbreaks are caused by seafood.

A food-borne outbreak is normally defined as the occurrence of two or more cases of a similar illness resulting from the ingestion of a common food.

The number of cases in outbreaks of food-borne diseases caused by seafood are generally small when compared to those caused by poultry, dairy and meat products. However, the importance of seafood as vehicle for food-borne diseases depends on a number of factors such as diet of the population and traditional way of preparing food. Thus it can be noted from Table 1 that the proportion of outbreaks due to seafood is significantly higher in Japan, where fish are an important part of the diet and fish may be eaten raw.

Aetiological agents associated with a number of seafood-borne disease outbreaks is shown in Table 2.

The trends seen in Table 2 are very similar to earlier reports (Huss, 1994). Nearly 80% of all outbreaks related to consumption of fish are caused by biotoxins (ciguatera) or scombrotoxin. While the presence of biotoxins in fish is related to fish from certain locations (warm tropical waters), the formation of scombrotoxin (biogenic amines) takes place in specific fish species post mortem (scombroids) – particularly when these fish are kept at elevated temperatures (>5°C).

Only about 12% of the outbreaks related to consumption of fish are caused by bacteria (*Clostridium botulinum*, *E. coli*, *Salmonella*, *Staphylococcus*, *Vibrio* spp. *Bacillus cereus*). Unfortunately the US statistics do not include information on the types of fish products which were vehicles for the disease outbreaks. Knowledge of the preservative principles involved (a_w, pH, smoke, preservatives, etc.), packaging and preparation before eating (cooked or uncooked products) would have been very useful in the evaluation of hazards related to the various types of fish products.

Although molluscan shellfish constitute less than 0.1% of the seafood consumed in the USA, they are responsible for a number of disease outbreaks caused by pathogenic bacteria, toxic marine algae or viruses. Molluscan shellfish concentrate particulate matter – including these pathogenic agents – during their filter feeding metabolic process. Available surveillance data suggests that seafood-borne diseases due to unknown etiologies, such as unspecified hepatitis and certain *Vibrio* species (*V. parahae-molyticus, V. vulnificus*, non – 01 *V. cholera*) represent the greatest risk for persons consuming raw molluscan shellfish (Ahmed, 1992). In England and Wales, 17 general outbreaks of gastroenteritis in 1996 and 1997 were associated with consumption of shellfish (Anon, 1998) where a total of 232 people became ill. Five outbreaks were associated with small round structured viruses (SRSV). Astrovirus, diarrhetic shellfish poisoning (DSP) and salmonella were each associated with one outbreak. In another five outbreaks, a viral aetiology was suspected and in four outbreaks no pathogen was identified.

Although seafood-borne parasitic diseases are not identified as a problem area in the statistical data shown in Table 2, it is well known that in some areas of the world (Asia) which are endemic for trematodiasis the

Table 1
Outbreaks of seafood-borne diseases

Country	Period	Number of outbreaks	% of total no. of outbreaks
USA	1973–87[a]	753	10.0
	1988–92[b]	180	7.4
The Netherlands	1980–81[a]	60	8.7
	1983–90[c]	23	4.0
Canada	1982–83[a]	140	7.6
Japan	1981–90[d]	–	21.7

[a] Huss (1994).
[b] Bean et al. (1996).
[c] Notermans and Van de Giessen (1993).
[d] Lee et al. (1996).

Table 2
Aetiology of seafood-borne disease outbreaks in the United States in the period 1988–1992 (after Bean et al., 1996)

Aetiology	Numbers of outbreaks (% of total) associated with	
	Shellfish[a]	Fish
Bacterial	12 (35%)	18 (12%)
Biotoxins	5 (5%)	41 (28%)
Scombrotoxin		74 (51%)
Parasitic	0	0
Viral	1 (3%)	0
Confirmed	18 (53%)	134 (92%)
Unknown	16 (47%)	12 (8%)
Total	34 (100%)	146 (100%)

[a] The term 'shellfish' in this table is assumed to include both molluscan shellfish and crustaceans.

consumption of raw freshwater fish leads to food-borne trematode infections. WHO estimates that some 40 million people suffer from such infections and that about 10% of the world population is at risk (WHO, 1995).

3. Hazards in seafood

A number of biological, chemical and physical hazards are associated with seafood as shown in Table 3. Some of these hazards are specific for fish and/or shellfish and are related to the environment where the animals are captured. Others are more general in nature since fish and shellfish – like any other proteinaceous food – may become contaminated during processing, and growth of pathogens may take place in products.

3.1. Pre-harvest contamination

Some pathogenic bacteria are naturally present in the aquatic (*C. botulinum type* E, pathogenic *Vibrio* sp., *Aeromonas*) and the general environment (*C. botulinum* type A, B, *Listeria monocytogenes*). These pathogens may therefore also be found on the live fish or fish raw material. The presence of these organisms is normally not a safety concern since they are present on the fish in numbers too low to cause disease. An exception is accumulation of high numbers of some of these organisms (*Vibrio* spp.) in filter-feeding molluscan shellfish, particularly since these animals are often eaten raw.

There is now increasing evidence that certain *Salmonella* types may also be part of the indigenous microbial flora in tropical aquaculture. It is well established that aquatic birds spread salmonellae and other human pathogens in the environment (Beveridge, 1988; Fenlon, 1983). Salmonellae have been reported in fish ponds; surveys have shown that 21% of Japanese eel culture ponds (Saheki, Kobayashi & Kawanishi, 1989), 5% of North American catfish ponds (Wyatt, Nichelson & Vanderzant, 1979), and 22% of shrimp ponds (Reilly & Twiddy, 1992) were contaminated with the organism. In separate studies in Asian countries, salmonellae have occasionally been found in shrimp ponds (Lobrerra, Bulalacao & Tan, 1990; Putro, Annggawati, Fawzya & Ariyani, 1990; Rattagool, Wongchinda & Sanghtong, 1990; Nayyarahamed & Karunasagar, 1995). Evidence exists to suggest that certain serotypes of *Salmonella* may be part of the indigenous microflora of crustacean farms in tropical producing countries (Nayyarahamed & Karunasagar, 1995), a view shared by a recent expert meeting (WHO, 1999). Species of *Salmonella* have been isolated from brackish water prawn ponds in Southeast Asia (Reilly & Twiddy, 1992), and from a similar environment in India (Iyer & Shrivastava, 1989). The principal serotype of *Salmonella* isolated from these studies was *S. weltevreden*, a serotype not commonly associated

Table 3
Seafood associated hazards and their prevention

Hazards	Safety concern		
	Presence/contamination/Elimination		Growth in raw materials or products
	Pre-harvest	During processing	
Pathogenic bacteria			
Indigenous in aquatic environment *C. botulinum type* E, *Vibrio* spp., *Aeromonas*	Consumption of raw shellfish	Heat-treated and other RTE-products[a]	RTE-products
From the general environment *C. botulinum type* A, B, *Listeria monocytogenes*	–[b]	Heat-treated and other RTE-products	RTE-products
From the animal/human reservoir *Salmonella*, *Shigella*, *E. coli O157*, *Staphylococcus*	Consumption of raw fish and shellfish	Heat-treated and other RTE-products	RTE-products
Biogenic amines	–	–	Scombroid fish
Viruses	Consumption of raw shellfish	–	–
Parasites	Consumption of raw fish	Survival in RTE-products	–
Biotoxins (poisonous fish and shellfish)	Warm water fish, shellfish		
Chemicals (heavy metal, pesticides, antibiotics)	Fish from aquaculture or polluted coastal areas		
Physical foreign materials		All products	–
Preventive measure	Monitoring of harvesting area	SSOP[c] or prerequisites	Control of preservative parameters incl. temp.

[a] RTE – Ready-to-eat products.
[b] – means that there are no safety concerns.
[c] SSOP – Sanitation Standard Operation Procedures, Prerequisites – regulatory requirements for hygiene and sanitation.

with salmonellosis in humans. While salmonellae tend to be associated with the intestinal tracts of warm blooded animals, they have also been reported from the gut of tilapias and carps grown in waste-fed and non-waste-fed aquaculture ponds (Buras, 1993; Iyer & Shrivastava, 1989). Salmonellae have also been reported in carp and tilapia raised in ponds fertilised with raw sewage in India and in Africa (Balasubramanian, Rajan & Raj, 1992; Ogbondeminu, 1993).

Pre-harvest contamination with pathogens from the animal/human reservoir (*Salmonella, Shigella, E.coli*, enteric virus) may pose a risk since in some cases a very low infective dose is required to cause illness (1–10 cells for some *Shigella* and *Salmonella* serotypes, one infections particle for Norwalk virus). Normal cooking procedures will eliminate the risk from these pathogens. The safety concerns are therefore primarily related to consumption of raw shellfish or raw fish dishes such as cewiche or sushi.

A large number of fish species, both marine and freshwater, can serve as a source of medically important parasitic infections (WHO, 1995). These infections are prevalent in only a few countries in the world and essentially among communities where eating raw or inadequately cooked fish is a cultural habit. In countries where there is also an ignorance of the problem and untreated animal and human waste is used in aquaculture ponds as fish feed, the situation is particularly serious (trematodiasis in Asia).

The presence of biotoxins is a serious health concern in many parts of the world. Ciguatera is a disease associated with tropical fish. The toxin is produced by dinoflagellates and the fish become toxic through food chain magnification. Therefore large fish carry more toxin than small fish. More than 400 species of fish have been identified as carriers of this toxin. Unfortunately there are no signs to warn the consumer when a fish is a toxin carrier. Strategies for the design and implementation of monitoring systems for the reduction of risks posed by harmful marine algae have been proposed (UNESCO, 1996). Histamine formation, on the other hand, is related primarily to the scombroid fish species and caused by abusive handling. Proper control of fish storage time and temperature are the tools to eliminate this hazard.

Accumulation of toxic marine algae (dinoflagellates) in filterfeeding shellfish has been the cause of countless outbreaks of "shellfish-poisoning" named according to the symptoms they provoke (Paralytic Shellfish Poisoning (PSP), Diarrhetic Shellfish Poisoning (DSP), Neurotoxic Shellfish Poisoning (NSP) and Amnesic Shellfish Poisoning (ASP)). Unfortunately all the toxins (saxitoxin, brevetoxin, domoic acid, okadaic acid) are heat stable. Thus, if sufficient numbers of toxic algae are accumulated in the live shellfish consumption will cause disease whether the shellfish are cooked or not.

In contrast to the naturally occurring biotoxins, the presence of chemical residues in the environment and the fish is a man made-problem. Risk from chemical contaminants (heavy metals, pesticides, drug – residues) in commercially harvested marine fish and shellfish is low. Potential risks are from fresh water fish, aquaculture products, subsistence and recreational fishing in certain coastal areas or polluted rivers (Price, 1992).

Preventing pre-harvest contamination with disease agents is either not possible or very difficult. Nature cannot be changed easily and the naturally occurring disease agents (some pathogenic bacteria, parasites, biotoxins) will always be present, while chemical and faecal pollution (some pathogenic bacteria, enteric virus) can be prevented at a cost. The immediate preventive measures include monitoring of the fishing areas for the presence of toxic algae and faecal pollution. The presence of faecal coliform bacteria or *E.coli* is used as indicator for faecal pollution but it has been shown that these organisms are poor predictors of the presence of human enteric viruses (Oliver, 1988; Richards, 1985). Unfortunately no more accurate index of the presence of viruses in shellfish or their growing waters has yet been identified.

3.2. Safety concerns during processing

During processing of the various fish products, pathogenic agents present on the raw material may survive and thus be present on the final product or they may be eliminated. Further contamination with new pathogens is also possible.

For chill-stored products that have been mildly heated in hermetically sealed packages or packed without recontamination, the safety concern is survival of psychrotrophic pathogens. A heat treatment which can provide a six-decimal reduction in the numbers of psychrotrophic *C. botulinum* spores is recommended and it is generally agreed that this can be obtained by a time–temperature combination of 90°C for 10 min (Gould, 1999). If only *Listeria monocytogenes* is of concern, a heat treatment of 70°C for 2 min will ensure destruction (Moir & Szabo, 1998). For products with a short shelf life or where any possible growth of surviving pathogens can be prevented, a milder heat treatment is acceptable.

In non-heated ready-to-eat (RTE) foods (e.g., cold smoked salmon) low numbers of pathogens are normally present. This may be as a result of contamination during processing or a carry-over from the raw material. It is reasonable to assume that these pathogens will be there at low levels only, reflecting the general level of these organisms in nature and therefore not representing a hazard. Thus, the International Commission on Microbial Specifications for Foods (ICMSF) has stated that foods containing 100 or fewer *L. monocytogenes*/g do not pose a health risk for individuals who are not particularly susceptible (Van Schothorst, 1996). However, even low levels of pathogens warrant consideration because of the potential for growth and toxin production in the final products.

Recontamination of heat treated products before packaging and further contamination of non-heated RTE-products is a serious safety concern where only a low infective dose is required to cause disease (*Salmonella*, *Shigella*, *E.coli* 0157, certain viruses) or where there is a potential for growth and toxin production in the final product.

Elimination of parasites in RTE-products is a safety concern during processing. In low salt RTE-products with less than 5% water phase salt (WPS) (cold smoked fish, gravad fish, matjes-herring), a freezing step (−20°C for 24 h) must be included to ensure safety. In high salt products (salted, marinated herring) a holding time before placing on the market is essential to ensure safety. The holding time necessary will depend on the amount of WPS, being 10–12 weeks for products with 6–7% WPS and 5–6 weeks for products with 8–9% WPS (Horst, Roepstorff, Huss & Bloemsma, 1995).

It is clear that the current regulation and production practice does not protect the consumers against allergic hazard due to ingestion of killed parasites (Audicana, Audicanna, Fernandez de Corres & Kennedy, 1997). An Opinion paper on this issue from the Scientific Committee on Veterinary Measures Relating to Public Health at the EU (1998) is pointing to this hazard and suggest that the prevention should focus on information to consumers.

Physical hazards such as contamination with foreign material (glass, metal) or leftover bones in boneless cuts are possible post-harvest hazards or defects.

The preventive measures for post-harvest contamination are GMP, effective hygiene and sanitation programmes, well constructed factories as it is outlined in the Sanitation Standard Operation Procedures (SSOP) and the "prerequisites" as required by the USA (Federal Register, Vol. 60 No. 242, 1995 part 123), European legislation (EEC, 1991a) and as specified by the Codex Alimentarius (FAO/WHO, 1997).

3.3. Growth in final products

The main strategy in most countries to reduce the safety hazards in foods has been to reduce the initial microbial contamination. Tremendous efforts at an enormous cost have been applied to ensuring that food is manufactured in the most hygienic way. Even then it is clear from what is stated above that any food – unless heat sterilised – may contain low numbers of pathogens. While this by itself is not necessarily a safety concern, the ultimate growth of these pathogens to high numbers, particularly in RTE-product, is a serious hazard. If conditions for growth of pathogens are favourable, the initial level of contamination is of relatively minor importance. An initial reduction in number of one log is off-set by just over three generations of growth! The conclusion must be that to increase the safety of foods the focus should be not only on hygienic processing, but even more on the magnitude of factors which reduce growth rate of potentially hazardous micro-organisms. Much more attention must be paid to the role of temperature, water activity, pH, other preservative compounds and the interaction between these parameters in assuring food safety. A true understanding of the ecology of the biological disease agents and their behaviour in the various food products is also needed to obtain major improvements in controlling food-borne illness.

A large amount of research has been done to identify safe preservative parameters for prevention of growth of pathogenic organisms, and in nearly all cases are these parameters now well-known and can be applied. There are exceptions such as the growth of *Listeria monocytogenes* in lightly preserved fish products (e.g., cold smoked salmon). The normal preservative parameters (smoke constituents, 3–5% WPS, storage temperature $\leqslant 5°C$) are not sufficient to inhibit growth, and other precautions are necessary (limitations of shelf life) or need to be developed.

Table 3 summarises the seafood associated hazards and the safety concerns.

4. Risk assessment and product categories

The safety of various seafood products varies considerably and is influenced by a number of factors such as origin of the fish, microbiological ecology of the product, handling and processing practices and traditional preparations before consumption. Taking most of these aspects into consideration, seafood can conveniently grouped according to risk (Huss, 1994):

1. Molluscs, including fresh and frozen mussels, clam, oysters in shell or shucked and raw fish to be eaten without any cooking.
2. Fresh/frozen fish and crustaceans – to be eaten after proper cooking.
3. Lightly preserved fish products (i.e., $NaCl < 6\%$ (w/w) in water phase, $pH > 5.0$). This group includes salted, marinated, fermented, cold smoked and gravad fish.
4. Semi-preserved fish i.e., $NaCl > 6\%$ (w/w) in water phase, or $pH < 5.0$, preservatives (sorbate, benzoate, nitrite) may be added. This group includes salted and/or marinated fish and caviar, fermented fish.
5. Mildly heat-processed (pasteurised, cooked, hot smoked) fish products and crustaceans (including pre-cooked, breaded fillets).
6. Heat-processed (sterilised, packed in sealed containers).

7. Dried, dry-salted and smoke-dried fish.

In ranking seafood in risk categories the method of NACMCF (1992) with some modifications has been applied. Hazard characteristics and various risk factors has been formulated into "statements" as shown below. Thus the risk of causing food-borne disease is high if:

I. There is epidemiological evidence that the particular type of product has been associated with food-borne disease many times – or with very serious diseases.
II. The production process does not include a Critical Control Point (CCP) for at least one identified hazard.
III. The product is subject to potentially harmful recontamination after processing and before packaging.
IV. There is substantial potential for abusive handling in distribution or in consumer handling that could render the product harmful when consumed.
V. There is potential for growth of pathogens in the product.
VI. There is no terminal heat process after packing or during preparation in the home.

The various seafood can then be assigned to a risk category in terms of health hazards by using a + (plus) to indicate a potential risk related to the hazard characteristics. The number of plusses will then determinate the risk category of the seafood concerned as shown in Table 4.

Molluscan shellfish and fish to be eaten raw are very high risk products. All the potential risk factors are present and evaluated "positive" with a plus. These products certainly have a bad safety record and there is no way to obtain complete control of the hazard of accumulating biological disease agents in the shellfish. The European requirements of relaying and depuration of live bivalves harvested in polluted areas may not be sufficient to assure consumer safety. While the numbers of *E. coli* in these shellfish can be reduced to acceptable levels (less than 230 *E. coli*/100 g, Council Directive no. 91/492/EEC, 1991) enteric viruses can persist through the depuration period and cause subsequent disease (West, 1986; Power & Collins, 1989). Heat treatment is the only sure way to eliminate viruses. Recommendations from the Ministry of Agriculture, Fisheries and Food in UK presented in 1998 stated that internal temperature of molluses must be maintained at 90°C for 1.5 min before consumption. This has a significant effect on the number of cases of viral gastroenteritis transmitted by molluses (Appleton, 1991).

The risk posed by consumption of cooked (fresh or frozen) fish is low. The principle food safety risks associated with cooked products are caused by heat stable chemicals, or biotoxins (Table 2), such as ciguatera or fish containing excess levels of histamine.

The main problems with RTE fish products (no terminal heat application) are the dangerous combination of a potential for harmful microbial contamination or recontamination, and the possibility for growth of these pathogens in the final product. Examples are the growth of *Listeria monocytogenes* in lightly preserved fish products, growth and toxin production by *C. botulinum*

Table 4
Risk categories for seafood products (modified after Huss, 1994)

Seafood product	Bad safety record	No ccp for at least one identified hazard	Potential for: Harmful contamin./recontam.	Potential for: Abusive handling	Potential for: Growth of Pathogens	No terminal heat application	Risk category
Molluscan shellfish Raw fish	+	+	+	+	+	+	High[a]
Fresh/frozen Fish and crustacean	+[b]	+[c]	–	+	–	–	Low
Lightly preserved fish[d]	(+)	–	+	+	+	+	High
Semipreserved fish[d]	–	–	–	(+)	–	+	Low
Mildly heat processed Hot smoked, cooked, pasteurised	(+)	–	+	(+)	+	+	High
Heat processed Sterilised, canned	(+)	–	(+)	–	+	+	Low
Dried, smoke-dried Heavily salted	–	–	–	–	–	+	No risk

[a] High risk products have four or more plusses. Low risk products have less than four plusses.
[b] Bad safety records for scombroid fish and in areas where ciguatera is prevalent.
[c] No CCP for biotoxins.
[d] See text.

type E in products with less than 3% salt in the water phase and growth of any pathogen in heat-treated products. Such products are categorised as high risk and have also been the cause of food-borne diseases. Fortunately, it is possible to identify CCP's to eliminate most of the hazards related to these products, but growth of *L. monocytogenes* in lightly preserved fish products remains a problem area.

Heat processed, sterilised, canned fish products have been the cause of a few, but dramatic and spectacular cases of botulism and a substantial number of histamine poisoning. However, considering the volume of canned fish produced in the world, the safety record is excellent. By application of the HACCP-concept it is possible to identify the CCP's and to eliminate the hazards. To eliminate the risk of heat stable biogenic amines being present in the final product, it is imperative that handling of the raw material on-board fishing vessels is included in the HACCP-programme.

5. Conclusions and recommendations

In evaluating the extent of the risks and currently available control practices the following conclusions and recommendations can be made.

Conclusions: Most hazards related to consumption of fish and fish products can be controlled by applying GMP, GHP and a well designed HACCP-programme. However, there are situations where problems remain and special considerations are needed:

- Consumption of raw molluscan shellfish is hazardous. Pathogenic *Vibrio* spp. and viruses may have accumulated in the live animal – even when all preventive measures have been properly applied.
- Presence of heat stable biotoxins in fish and molluscan shellfish.
- Consumption of raw fish causing transmission of parasites (e.g., trematodiasis in Asia) and/or pathogenic bacteria (e.g., cholera in Peru).
- Growth of *Listeria monocytogenes* in lightly preserved fish products.

Recommendations:

- More emphasis should be directed at control of fish and shellfish at the point of capture.
- Methods for monitoring of harvest areas for possible faecal pollution and biotoxins should be improved.
- Consumers should be informed of the risks of eating raw seafood – particularly molluscan shellfish and certain freshwater species.
- Good Aquaculture Practices should be formulated and promoted.
- Shelf life of lightly preserved fish products should be limited to a period of no-growth for *Listeria monocytogenes*.

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