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Options for pro-actively identifying emerging risk in the fish production chain

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Summary

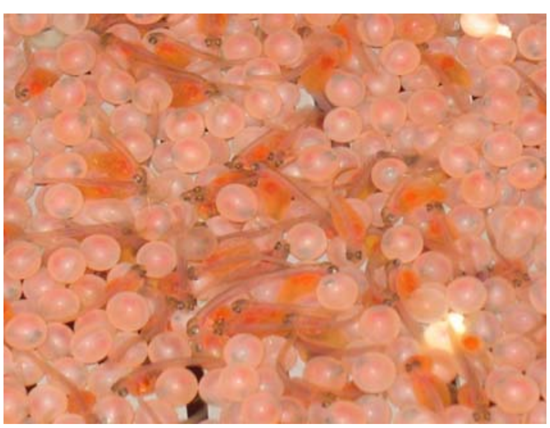
Introduction

Present early warning systems for food safety hazards / risks have shown their limitation with regard to their potential to identify the development of a food safety risk/ hazard in an early stage of its development. To improve this situation the 4-years project “Emerging risks in Dutch food chain”, was initiated in 2005, funded by the Ministry of Agriculture, Nature and Food Quality (LNV) in the Netherlands. The main objective of this project is to develop a method / procedure allowing the identification of emerging food safety problems in an early stage making pro-active measures by regulatory institutions possible.
The first year of the project was used to collect information on existing early warning systems and to study several recent food safety incidents revealing factors of importance in the development of the food safety problem. Special attention was given to analysis of the host environment of the agricultural sector, in particularly to the “holistic approach” i.e. influences from outside the food production chain that may directly or indirectly be related to the development of a food safety hazard / risk (so called indicator).
It was decided to develop the concept of the “holistic approach” further by focussing on the fish production chain, in particularly salmon production.
This report presents the results of an extensive inventory of the farmed salmon production chain. The objective of this study is to formulate indicators including their respective data sources within the salmon production chain and a wide area of disciplines around it (host environment), to enable the development of a pro-active emerging risk identification.

Salmon production chain analysis

The farmed salmon production chain is an example of a complex and global seafood chain. The focus of the project is aimed at the Dutch marketing and consumption of salmon. The Norwegian salmon production chain was included into the analysis, because no production of salmon and aqua feed takes place in The Netherlands. Because of its high content of omega-3-fatty acids which is claimed to protect against cardiac diseases, salmon is becoming more important in the diets of many people.

The notifications in the Rapid Alert System for Food and Feed (EU) with regard to salmon (both wild and farmed) and derived products during the period from 2003 to 2006 totalled 98. Most of the notifications are related to microbiological hazards, in particular the presence of *Listeria monocytogenes* in smoked salmon. The second major hazard category is chemicals, particularly.



Hatching salmon eggs

residues of veterinary drugs (malachite green) in unprocessed salmon from Chile.
Potential hazards in the processing stage of farmed salmon are mainly focused on pathogenic bacteria, biotoxins and chemical contaminants, which are all included in HACCP plans

Indicators

Within the whole salmon production chain (inclusive feed production) and in its host environment, interviews with key stakeholders have been organised. The indicators were derived by analysing the interviews (and the literature). The indicators are divided into on the one hand indicators that concern the food chain itself and on the other hand indicators that can be found in the host environment.
The salmon feed production is focussed upon and is being dealt with separately. Indeed one of the important indicators, from a total of 55, is the use of vegetable oils as aqua feed in stead of fish oil. As the production of fish oil is declining and the demand for fish is ever increasing, a shortage of fish oil occurs. This shortage and subsequent high prices of fish oil have stimulated the use of vegetable oils as a feed ingredient. However, new unexpected contaminations in vegetable oils such as pesticides or heavy metals may cause new emerging risks.
Another indicator is the (future) use of krill as a serious alternative as feed ingredient for aquaculture. The amounts available are gigantic (hundreds of million tonnes) and it contains the natural red pigment astaxanthin. However large scale exploitation may prove costly in many aspects, as the krill is the sole food source for many sea animals and the survival of krill is very delicate in relation to any changes in the ecosystem.

Data sources

Data sources support the validity and reliability of indicators of emerging risks. Categorized data sources for the farmed salmon production chain have been identified by expert networks (highly innovative participants), stakeholders (commercial companies like Nutreco, Marine Harvest, Skretting and Ewos), scientific panels (research organisations like ICES, Norwegian Research Council), NGO's (Greenpeace, Bellona, WWF) and governmental sources (FCA, FVO, VWA)
These data sources are not confined to only websites and statistical data or scientific reports. It appears that results of meetings, conferences and symposia of organisations in the host environment play an important role in the support of indicators.
The key issue dealing with data sources of any kind is to establish the reliability of the source. In the course of this project the indicators of the salmon production chain have been established and relevant data sources have been found. However the ranking needs to be executed by experts in the follow up project. Also the link with the yet to be developed model will be established at the same time.

Conclusion

This research was challenging by virtue of investigating the changes and possible threats in the farmed fish production and marketing. The introduction of the host environment analysis with regard to for example economics, legislation and human behaviour has given rise to interesting results with respect to indirect (pro-active) signals which could lead to the emergence of risks.

Recommendation

Government officials within the Agricultural ministry will now be able to develop policy measures taking into account the host environment and its effect on the fish production chain. Further development of an emerging risk detection support system will be recommended in order to take in consideration the pro-active emergence of food safety risks.

Contents

1 Introduction

1.1 Background

National and international food safety authorities have a need for robust and reliable methods to identify emerging risks related to food safety and animal health. Following the results of the "EMRISK" project on forming a global system for identifying food-related emerging risks (Noteborn, 2006) and the analysis of recent crises and definition of indicators in the "emerging risks in the Dutch food chain" project (Hagenaars, 2006 and Kleter, 2006) more specific research is needed.

In this project the options for pro-actively identifying indicators for emerging risks in a specific food production chain, are investigated. For this purpose the fish production chain has been selected as food safety is one of the major concerns facing the fishing industry today. Fish and fishery products are in the forefront of food safety improvement because they are among the most internationally traded food commodities.

Besides these general notions, the main reasons for the project team to focus on the fish production chain are as follows:

- In the EU Rapid Alert System for Food and Feed (RASFF) fish cases are most frequently present, preceded by mycotoxins in nuts.
- Identified as one of the high risk industries in The Netherlands (meat, egg, fishery products and ready to eat meals).
- Many potential hazards and indicators are present.
- EU has launched an intensification of disease monitoring and prevention.
- New and harmonized legislation is being developed on EU level.
- Developments in legislation for antibiotics on Codex Alimentarius level.

This project named as "Options for pro-actively identifying emerging risk in the fish production chain"
is part of the Dutch research program "Emerging risks in the Dutch food chain", which is funded by the Ministry of Agriculture, Nature and Food Quality (LNV) in The Netherlands and coordinated by Dr. H.J.P. Marvin of RIKILT – Institute of Food Safety, Wageningen University and Research Centre.

1.2 Objectives

The main objective of the Dutch research program is to develop a system for pro-actively approaching the identification of emerging risks in the Dutch food chain. In this project the emphasis is on the options for pro-actively identifying emerging risks extending the outcome of the parallel synthesis project and the mini symposium, both of which were also part of this year's research program.

The synthesis project aims at deriving a functionality of emerging risks based on the retrospective case studies and inventory of emerging hazards (performed in 2005) in order to develop a certain methodology ("what are the possibilities").

The mini-symposium's goal is to discuss the possibilities of pro-active identification of emerging risks by the exchange of information on present emerging risk and early warning systems/approaches in order to create new insights and/or new concepts for the future.

Therefore the objective of this project is to formulate indicators including their respective data sources within the host environment of the salmon production chain, to be selected for their use in the development of a pro-active emerging risk identification.

1.3 Methods

For the development of a risk profile in the fish production chain an analysis is performed. Within the fish production chain the farmed salmon production chain has been investigated. The main reason for choosing this specific chain is to keep the study within certain boundaries and focus on a fish sector with important environmental, economical and health aspects.
The inventory research has been performed by reviewing literature. Key items addressed in this literature search were product production and consumption figures, food safety issues and the effects of quality systems for food safety (HACCP). The inventory study has resulted in a listing of possible risks in salmon production chain. For the purpose of a preliminary proof of principle to formulate indicators, a possible emerging risk was identified within the salmon production chain. The example chosen is: substituting fish oil and meal in fish feed with vegetable materials (oils and proteins). Following this, a questionnaire has been set up and used in interviews with experts within the salmon production chain. The questionnaire has been focused on the chain and its host environment. The results of the experts' opinions are used to formulate the indicators. Furthermore the relevant data sources for the indicators are provided.

1.4 Results of parallel projects (2006)

The synthesis project dealing with the results of the studies on emerging risk identification has shown that the current structure for hazard identification in the Netherlands and EU have proven useful. However incidences have occurred in which the system was incapable to flag food safety hazards as they emerged.
So far the results of the first year of the project in general point to three areas within the host environment for food safety risks: perception, operations and behaviour. The perception of emerging risks appears to vary and needs to focus on building of confidence in the food safety system. Operations are identified within the processes involved in risk analysis, but for effective emerging risk identification it should include collecting information from the host environment. The behaviour aspect related to consumer risk demands a commitment of stakeholders to not only to food safety standards, but also to cooperate and trust each other to share information.

The workshop "Emerging risks and early warning systems" held on 19th October 2006 in Wageningen was organised to learn from the experience and knowledge of the participants to enable a definition of the contours of a future Early Warning System. During the one day workshop ten presentations were held, interchanged with five discussions blocks.
The main findings concluded that with an emerging risk system, two approaches are feasible. On the one hand shows the system how risks arise from a scientific point of view and on the other hand it signifies that a risk assessment can be used to decide how to act on the identified risk. The human experts interpret data, but their usage is ambiguous, since their own history and point of view may influence their interpretation. So the objectivity is at stake and can be overcome by inviting experts with a multidisciplinary background.

Furthermore the usefulness of emerging risk systems were summarised in features like:

- The dynamic/self-learning character of used models
- The quality of models/data
- The distinction between searching for known and unknown risks
- The interaction with users to develop an emerging risk system.

Commitment and collaboration of the stakeholders (like governments and industries) is very important to create a useful emerging risk system.

2 Farmed salmon production chain analysis

2.1 Introduction

Food safety nowadays gets a lot of attention. Even though food is much safer then in the past, consumers are becoming less confident in the safety of food (Frewer et al, 1998). Reasons for this lack of trust can be found in the increased complexity of food production due to lack of transparency as result of globalisation, increased technology and enlargement of food supply chains. Quality and safety are therefore difficult to determine. This lack of trust is harmful for the food industry, because of the simple fact that consumers with a lack of trust in food consume less (Poortinga et al., 2002). An example of such a complex and global food chain is the farmed salmon production chain. In this chapter we describe this salmon production and trade chain in order to detect possible risks concerning food safety. The focus is aimed at the Dutch consumption of salmon.

2.2 Natural lifecycle of salmon

The production cycle in modern salmon farming is closely based on the natural life cycle of the fish.

2.2.1 Salmon eggs

In the wild the cycle begins in fresh water as eggs which are deposited in the riverbed, fertilised and covered with gravel. The number of eggs produced by a female salmon can range from 2.000 to over 17.000. Up to 85% of the eggs can be lost before hatching. Low oxygen levels, freezing, water pollution, and predation by fish, insects and birds are all threats at this stage. Excess sediment in water is also extremely detrimental as it can smother eggs or cover the redd trapping fish inside.

2.2.2 Alevin stage

A newly hatched salmon is called an alevin. At this stage, it looks like a thread with eyes and a huge yolk sack which provides all nutrition for the fish in the first weeks of its life. Alevins remain in the redd (gravel nest) until the yolk sac is absorbed. At this point, they work their way up through the gravel and become free-swimming, feeding fry. Alevin require cold, clear, oxygen-rich water. Excessive sediment in the water is one of the greatest dangers to salmon at this stage. It can reduce oxygen levels and cover the top of the redd, trapping the tiny fish inside. Aquatic insects and other fish are an alevin's primary predators.

2.2.3 Fry stage

Salmon fry stay in fresh water for a year in nature. The young fish initially live in quiet pools. Their parr marks (bars and spots along their side) help them hide among the cover provided by rocks, stumps, undercut banks and overhanging vegetation. As salmon fry grow larger, they move out into more open, faster moving water. During their fresh water residence, salmon fry feed chiefly on terrestrial insects, small crustaceans, or anything available to them, although they do not appear to eat other fish at this time.

2.2.4 Smolt stage

Many physical changes occur in a young salmon to help it make the transition from a freshwater to saltwater existence. This process is called smolting. As the time for migration to the sea approaches, the salmon fry replaces its parr marks, a pattern of vertical bars and spots useful for camouflaging the fish in fresh water, with the dark back and light belly coloration useful to fish living in open water. They seek deeper water, avoid light, and their gills and kidneys begin to change so that they can process salt water. The young fish remain in estuaries and tidal creeks for several months feeding on small fish, insects, crustaceans and molluscs. They gradually move into deeper, saltier water, but remain near shore.

2.2.5 Ocean Adult stage

Salmon can stay at sea for 1 to 5 years. During their ocean existence, salmon primarily eat fish along with amphipods, molluscs, crab larvae and squid. Some salmon remain close to shore during their ocean residence, but most undertake extensive migrations.

2.2.6 Spawning stage

Salmon reach sexual maturity between 3 and 7 years of age. Salmon begin entering the rivers in early June. The fish select spawning sites with high water flow through the gravel which will provide plenty of oxygen for their eggs. Once a female salmon selects a spawning site, she rapidly pumps her tail to wash out a depression in the stream gravels. As she deposits her eggs, they are fertilized by the male. The female salmon then uses the same tail movements to completely cover the eggs with gravel. Over several days, she will lay several more pockets of eggs like this in a line upstream.
After spawning, most of the adult fish die. Their carcasses decompose and provide nutrients to the river systems so algae, crustaceans etc. can grow and these are then utilised by the fry as they emerge from the gravel.

2.3 Farming methods

2.3.1 Broodstock

The salmon farming cycle mimics the wild lifecycle. Eggs (roe) and sperm (milt) are gathered from adult salmons, known as broodstock and selected for their desirable character traits. They are mixed together and the fertilised eggs are kept in incubation systems at a steady temperature. The breeding of fish is comparable to the conventional breeding of other animals. Farmers continually select those animals that have the qualities they want to see in the following generations.

2.3.2 Hatching

After the eggs hatch, the alevins stay in the incubator until their yolk sacs are empty. As they become fry, they are placed in a freshwater feeding tank. Because the salmon fry are relatively large (compared with many other marine fish species), they adapt easily to manufactured feeds, without any requirement for live feeds.

2.3.3 *Smoltification*

When the salmon fry are about six grams they are moved to a lake or larger freshwater tanks where they pass through the parr stage (green brown in colour with distinctive fingerprint markings) and become smolts (silver colour). This is the stage at which they are moved on to the sea, with the salinity of their water gradually being increased as the transfer takes place. After just over a year in the sea the fish will have reached market weight of about 4 kg.

2.3.4 *Grow out*

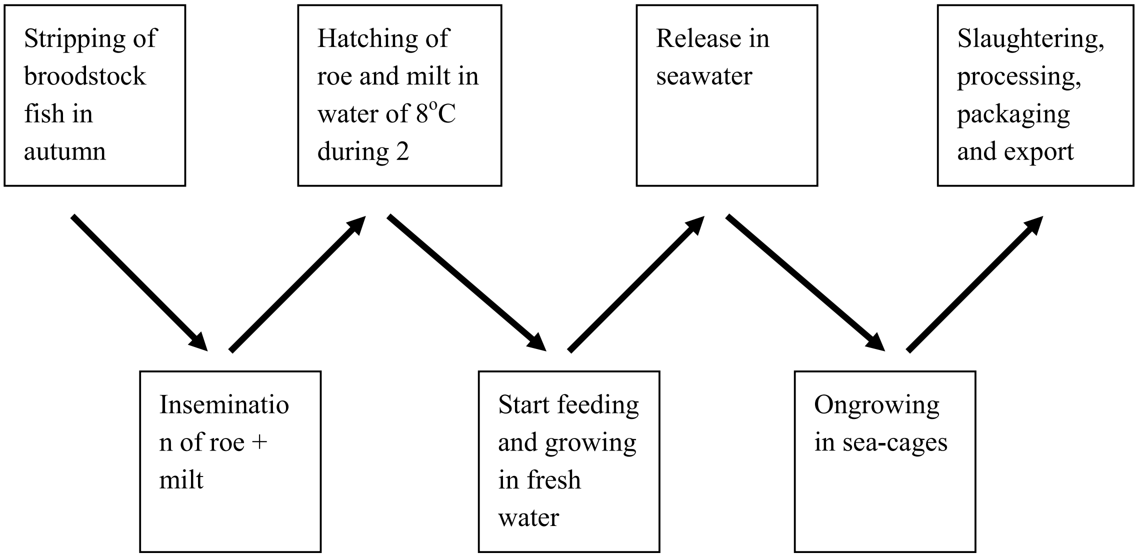
The best farmers can grow a 4-kg salmon after about eight months in freshwater and a further 12 months in sea cages. This 4-kg salmon usually requires just over 4 kg of feed. These figures indicate that the best salmon farming only gains some four months over the fastest rates of growth in the wild.

2.3.5 *Slaughtering*

When the fish have reached slaughter weight, they are usually transported to a harvesting station by well boat, which carries them in seawater that is filtered and regulated to provide an optimum environment. The slaughter method varies between countries. In Scotland and Chile the standard practice is by a blow to the head. In Norway the regular practice is to chill the water to calm the fish, which is a cold-blooded species, then CO2 is used as an anaesthetic. However this will change in 2007 due to new EU regulation regarding animal welfare. After slaughtering the salmon are gutted. Approximately 80% of the salmon is packed in Styrofoam boxes filled with ice.

2.3.6 Summary

From roe to plate, the farming (activities) of the salmon is summarized in figure 1.



Timescale: (in months)		2	3-4	11-12	20-30	→	4 kg fish
Name of fish:		yolk-sac fry	fingerling	smolt	salmon		
Number of producers in Norway: (2004)	15-20	170			150		80/120*
Value in M€:	12	144			1.008		300/60**

*) 80 = number of slaughtering and processing plants; 120 = number of exporters and domestic outlets (16 of these companies sell 80% of the total production)

**) 300 = value of slaughtering / processing; 60 = value of sales and marketing

Figure 1: From roe to plate (source: Aquaculture in Norway, 2005)

Note: For the number of producers and value in M€ in figure 1, the figures are for salmon and sea trout together, all though salmon represents 90% of these values.

2.4 Salmon feed

2.4.1 Introduction

Worldwide salmon is one of the most important and popular fish species on the growing market farm-raised fish. Because of its high content of omega-3-fatty acids which is supposed to protect against cardiac diseases, salmon is becoming more important in the diets of many people. Fish oil is a traditional feed ingredient and important ingredient to maintain salmon quality and high levels of the essential fatty acids. However worldwide, fish oil is in short supply and many efforts have been put into substitution by plant based oils. Both in fish or plant based ingredients contaminants are of concern, in particular PCB’s, dioxins, pesticides and heavy metals. Changing dietary composition of feed may cause risks for the health, quality and food safety aspects in salmon.

Considerable research efforts have been put on the potential replacement of fish oil with vegetable oils. Vegetable oils, in particular linseed and rapeseed oil constitute a considerable part in current salmon feed (up to about 30%).

2.4.2 Global production of aqua feed

The amount of raw materials to produce aqua feed reached a total of 33 Mt worldwide in 2002, of which 27,4 Mt whole fish were caught and 5,6 Mt trimmings were used. The annual production from about 400 aqua feed plants is around 6,3 Mt fishmeal and 1 Mt fish oil. The main producing countries in 2004 were Peru, Chile, China, Thailand, USA, Japan and Denmark.

Almost all fishmeal is used as a high protein (60-72%) ingredient in feed for farmed land animals and farmed fish. Fish oil is used mainly in the feed of farmed fish. A typical farmed salmon diet contains 35-40% fishmeal and 25% fish oil.

Aquaculture is expanded worldwide by more than 9% per annum for the 10 years to 2002. However, to date, the expansion of aquaculture has not resulted in any increase in fishmeal and fish oil supplies. Already progress is being made in substituting fish oil and meal in fish feed with vegetable materials (FIN, 2006)

2.4.3 Salmon feed production

Salmon feed, like fishmeal and fish oil is produced from stocks of fish for which there is currently little or no demand for human consumption. Another source for aqua feed is recycling the trimmings from food fish processing. In EU fishmeal and fish oil are produced in approved manufacturing plants, where no production of meat or bone meal takes place.

The bulk of salmon feeds are produced by three or four large companies, who operate worldwide. Fish meal and fish oil are the main constituent in salmon feed and are derived largely from the huge industrial fisheries in South America and still form the basis of salmon diets. Recently however, increasing pressure on these sources has led to intensive research into the substitution of fish products with vegetable protein and oils. The production and supply chains of salmon feed are short and transparent. Food safety therefore can be managed quite well. Other parts of the feed production market (especially in SE Asia) are less clear. The increasing shortage in food ingredients and increasing prices in combination with dietary changes in feed composition may lead to emerging new or re-emerging known risks.

2.4.4 Changes in salmon feed composition from fish based to plant based

Traditionally farm raised fish is fed to a large extend with fish meal and fish oil. The high content of omega-3- fatty acids in fish like salmon can be mainly ascribed to this dietary component. As the health promoting effects of salmon is essential for its healthy image, the components remain essential to produce high quality fish. However, resources are limited and supply has reached its sustainable limits. Where fish oil contains about 30% of the required fatty acids, plant based oils also may contain about 10%. The reduction of unsaturated fatty acids when fish oil is replaced by vegetable oils is can be offset by a generally lower content of contaminants in plant based material if the quality of the vegetable oils is good. In general marine fish oils often contain relatively higher levels of contaminants such as PCB's and dioxins, but detailed information on levels and variation of contaminants in currently used vegetable oils is limited.

Internationally the availability of fish meal and fish oil is quiet stable but market demand for salmon and other fish is still growing rapidly. Also, it is not allowed to re-use salmon remains in salmon production (intra-species).

The transition to plant based feed ingredients will be of increasing importance. Presently the major sources are soy, rapeseed, maize, palm-oil, linseed and flax. They are used both as a resource for proteins and fatty acids. Linseed oils and flax-oil are currently highly preferred because of their contents in omega-3-fatty acids and their availability on the world market.

Soy oil is less suitable as it is often of GMO origin or GMO contaminated. Aquaculture, just like baby foods and organic production claim to be GMO free. Soybean and rapeseed production generally require high pesticide inputs, even under integrated production. Therefore the risk for pesticide residues may be relevant there. Rapeseed oil in general is of high quality but has become less attractive due to market prices which have increased since the demand for bio fuel increased and is subsidized. Only the low-end market of rapeseed oil may be attractive but has a higher risk of inferior quality and contaminants.

As fish feed if often treated at 150o C the risk for undesired micro organisms is low, compared to the occurrence of PCB's, pesticides (Endosulfan), or heavy metals (both of terrestrial and marine origin). As far is known the ratio of plant based oil and of fish based oil does not affect the health conditions of the salmon directly.

2.4.5 Environmental contaminants

Fish meal and fish oil are rather sensitive for environmental contaminants. Many marine environments are contaminated e.g. with PCB's and dioxines which are accumulated in Salmon as this fish species is a top predator in the aquatic food chain.

Vast quantities of industrial and agricultural chemicals have been deposited into the oceans for the last 50 years. The contamination of marine environment varies much over the World, where southern regions tend to be cleaner. The northern Atlantic, the Baltic Sea and the Mediterranean are generally more risky in this respect. Even contaminants no longer in use can be found in sediments on the ocean floor. Already banned PCBs were used as flame retardant insulators and continue to enter the oceans from leaking equipment, illegal dumping, and disposal of PCB containing equipment in hazardous waste sites. Dioxins are deposited into the ocean from the air and are emitted during waste incineration, chemical manufacturing, paper bleaching, and a variety of other processes. Since fishmeal is produced from pelagic fish and fish oils (which are high in fat), high levels of these contaminants end up in salmon feed.

The salmon feed industry profits from clear legislation and strict guidelines concerning contaminants.

As vegetable oils generally have lower levels of contaminants the replacement of fish oil by vegetable oil is considered to be positive. However, when the quality of plant based materials is not controlled and sources are unclear risk for pest residues and heavy metals may be considerable.
The quality of salmon feed may vary due to availability of ingredients and this effects the growing on conditions at fish farms (water temperature, feeding regimes etc.) At present there are no indications that this is relevant in the current practice of the big fish industries.
New developments such as intensive use of “krill” may pose new unexpected problems.

2.5 General overview of farmed salmon supply chain

Atlantic salmon culture began in the 19th century in the UK in freshwater as a means of stocking waters with parr in order to enhance wild returns for anglers. Sea cage culture was first used in the 1960s in Norway to raise Atlantic salmon to marketable size. The early successes in Norway prompted the development of salmon culture in Scotland, and latterly Ireland, the Faeroe Islands, Canada, the North Eastern seaboard of the USA, Chile and Australia (Tasmania). Minor production also occurs in New Zealand, France and Spain. All of the major production areas lie within latitudes 40-70º in the Northern Hemisphere, and 40-50º in the Southern Hemisphere. Japan, Russian Federation, Canada and Alaska historically have been major suppliers of wild-caught salmon (see Figure 2 and Table 1).
The early Norwegian success reflected the excellent deep sheltered sites available, favourable hydrographic conditions (stable temperatures and salinities), natural salmon strains that mature late, and heavy governmental support and investment. Scottish strains of salmon tend to mature early, reducing the value of fish as they reach marketable size, so Norwegian strains were introduced to reduce this problem. Generations of cross breeding have resulted in hybrid strains which are now the norm in most production areas (FAO, 2006)
Irish production has been limited by shallow sheltered water and local opposition. The economic value of salmon farming in the Faeroes has now overtaken that of fishing. North American salmon culture mainly features Atlantic salmon on both coasts. Chile has become a major producer since Atlantic salmon were introduced from Norway and Scotland in the early 1980s. Chile benefits from low production costs and easy access to fish meal for salmon feed production, which allows it to compete with Northern hemisphere producers for lucrative markets (FAO, 2006).
Rapid increases in production have led to falling prices, which in turn have put increasing pressures on producers to limit costs. Significant future expansion of the industry may rely on the development of offshore sites, since most of the available suitable inshore sites are already in use, and because of increasing antagonism towards, and regulation over, further expansion in sheltered areas.
The vast majority of Atlantic salmon currently in production is hybrid stock, derived originally from native crossed with Norwegian stock. Some family breeding programmes are now in place, in order to attempt to identify family lines with increased production potential and/or disease resistance. The use of sex or genetic manipulation in Atlantic salmon is not widely used in cultured fish (FAO, 2006).

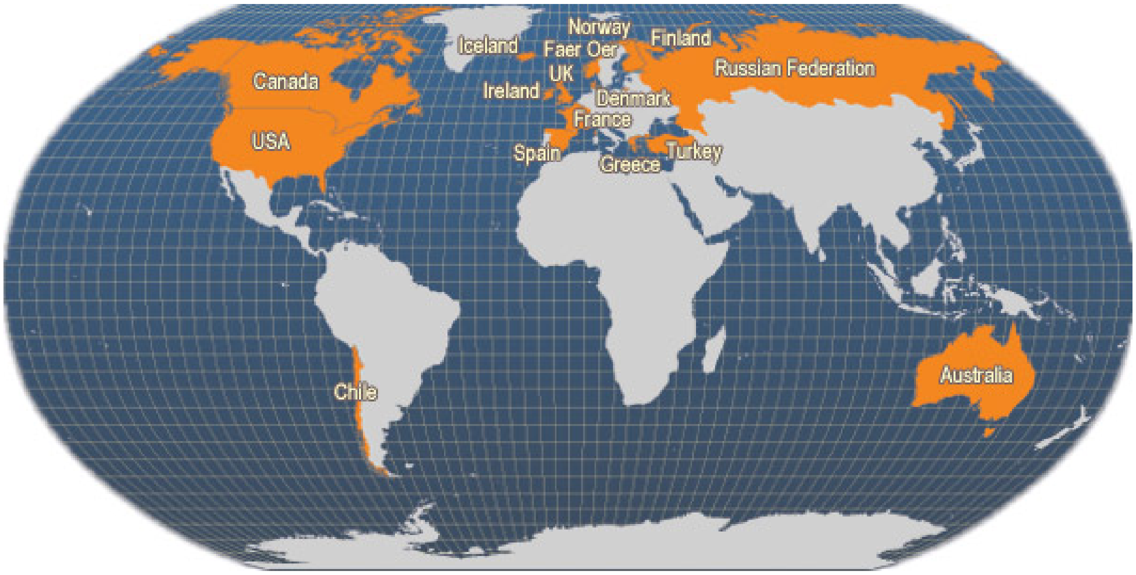


Figure 2: Main producer countries of Salmo salar (FAO fishery statistics, 2002)

Table 1: Main salmon species for human consumption. Source: www.goedevis.nl

Main salmon species for consumption	Scientific name	Habitat	Region	Wildcatch/culture
Pink, chum and sockeye salmon	Oncorhynchus spp	Pacific	Alaska, Canada, Russian Federation, Japan	wild
Atlantic and coho salmon	Salmo salar and Oncorhynchus kisutch	Atlantic Ocean and Pacific	Norway, UK, Chile	culture

The global salmon culture has experiences tremendous growth since the early 1980s. From an annual production of 13,000 tonnes in 1980 (see Figure 3), it was estimated at 1.3 million tonnes in 2003 (FAO, 2006, Engle et al., 2006). In comparison, the wild quantities increased from 561,000 tonnes in 1980 to 895.000 tonnes (FAO, 2006) down from 975,000 tonnes in 1995. From 1997, the farmed quantities have been higher than the wild-caught. The joint global supply of farmed and wild salmon thereby quadrupled from 574,000 tonnes in 1980 to 2.2 million tonnes.

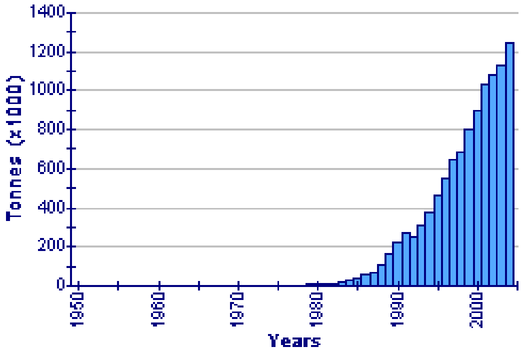


Figure 3: Global aquaculture production of salmon. Source: FAO, 2006

As mentioned before, the salmon farming industry primarily takes place in Norway, Chile, the UK (mostly Scotland), and Canada. Norway has continued to lead the world in production of farm-raised salmon and mainly supplying the EU Chilean production has replaced Norwegian product in the US market. Canada and the UK have also demonstrated growth over the last decade. Table 2 shows an overview of the salmon producing countries.

Table 2: Salmon producing countries. Source: FAO, 2006

Country	Farm location	Culture type	2003 (tonnes)	2004 (tonnes
Australia	Oceania - Inland waters	Freshwater culture		
Australia	Pacific, Southwest	Brackish water culture	13,972	14,828
Canada	Atlantic, Northwest	Mariculture	34,550	35,000
Canada	Pacific, Northeast	Mariculture	55,600	47,374
Chile	America, South - Inland waters	Freshwater culture	395	2,373
Chile	Pacific, Southeast	Mariculture	280,086	346,956
Cyprus	Asia - Inland waters	Freshwater culture		
Denmark	Atlantic, Northeast	Mariculture		
Denmark	Europe - Inland waters	Freshwater culture	16	16
Faeroe Islands	Atlantic, Northeast	Mariculture	56,318	37,296
Finland	Atlantic, Northeast	Brackishwater culture		
Finland	Europe - Inland waters	Freshwater culture		
France	Atlantic, Northeast	Mariculture	544	735
France	Europe - Inland waters	Freshwater culture		
Greece	Europe - Inland waters	Freshwater culture	19	7
Iceland	Atlantic, Northeast	Brackishwater culture	1,833	2,538
Iceland	Atlantic, Northeast	Mariculture	1,875	4,082
Iceland	Europe – Inland waters	Freshwater culture		4
Ireland	Atlantic, Northeast	Mariculture	16,347	14,067

Country	Farm location	Culture type	2003 (tonnes)	2004 (tonnes
Norway	Atlantic, Northeast	Mariculture	507,412	565,902
Portugal	Europe - Inland waters	Brackishwater culture		
Russian Federation	Atlantic, Northeast	Mariculture	300	203
Spain	Atlantic, Northeast	Mariculture	50	30
Sweden	Atlantic, Northeast	Mariculture		
Turkey	Mediterranean and Black Sea	Mariculture		
United Kingdom	Atlantic, Northeast	Mariculture	145,609	158,099
United Kingdom	Europe - Inland waters	Freshwater culture		
United States of America	Atlantic, Northwest	Mariculture	16,315	15,127
Total			1,131,241	1,244,637

The earliest sales of salmon were as a canned product prepared from wild-caught fresh salmon. In recent years however, the major salmon products sold have been fresh and frozen fillets. New packaging technologies, such as leak-proof Styrofoam packaging was, was developed in the 1980s for farmed salmon (Anderson, 2003 as cited in Engle et al., 2006). The new packaging provided a means to increase air shipment of fresh salmon. The farmed salmon industry has tended to be dominated by large, integrated, agribusiness firms. A re-structuring process began in the salmon industry in Norway in the 1990s as firms merged and larger firms were formed (Anderson, 2003 as cited in Engle et al., 2006). The four largest firms controlled 28% of Norway's production capacity. Ownership structures have become more international (see Table 3). Salmon farms have recently integrated vertically into processing facilities with sales offices in several countries. In Chile, the four largest firms accounted for 35% of the exports in 2001, and the largest accounted for 60% of the exports (Anderson, 2003 as cited in Engle et al., 2006).

Table 3: Main salmon producing companies in the world. Source: Tveterås and Kvaløy, 2004, as cited in Engle et al., 2006).

Company	Headquarter	Total production 2003 (tonnes)	Norway	UK	Chile	Canada	US	Other countries
Nutreco[1]	Netherlands	178,500	70,000	32,000	59,000	12,500		5,000
Pan Fish	Norway	86,100	31,100	20,500		9,800	12,000	12,700
Fjord Seafood	Norway	72,500	35,000	7,000	28,000		2,500	
Stolt Sea Farm	Norway	70,500	15,000	6,000	24,000	25,000	500	
Cermaq	Norway	48,500		8,000	32,500	8,000		

1 Pan Fish ASA has acquired all the outstanding shares in Marine Harvest for EUR 1,325 million (enterprise value) from Nutreco in 2006. The combined Pan Fish-Marine Harvest company will become the world's undisputed leader in the fish farming business, with an annual salmon production of 346,000 tonnes (wfe) in 2006. In addition, Pan Fish has bought 25.7 per cent of the shares in Fjord Seafood from Geveran Trading.

Company	Headquarter	Total production 2003 (tonnes)	Norway	UK	Chile	Canada	US	Other countries
Aquachile	Chile	48,000			48,000			
Pesquera Camanchaca	Chile	37,000			37,000			
Cultivos Marinos Chiloe	Chile	34,500			34,500			
Salmones Multiexport	Chile	34,000			34,000			
Pesquera Los Fiordos	Chile	33,000			33,000			

The increased consolidation provided a means to achieve economic efficiency and supply salmon at lower prices, putting smaller firms at an economic disadvantage. For example, smaller Scottish farmers had an economic disadvantage and therefore oriented towards a higher-quality, lower volume product produced under stringent health controls.

The largest markets for salmon globally are the US, Japan and the EU. However new markets are developing in Central and Eastern Europe, S.E. Asia, China and South America.
In Europe, most of the salmon consumed is farmed, and this is also the fastest growing market. Per capita consumption has risen as prices have declined until 2004. In 1984, the price per kilo Atlantic salmon was 5.7 US $ (Engle, et. al., 2006). In 2003, this price was only 2.8 US $. Since 2004, salmon prices apparently have been recovering (see figure 4). However in October 2006 a sharp salmon price drop occurred partly as a result of market speculations (personal comment of Rabobank). Partly as a result of this decline, culture was mainly focused on efficiency.

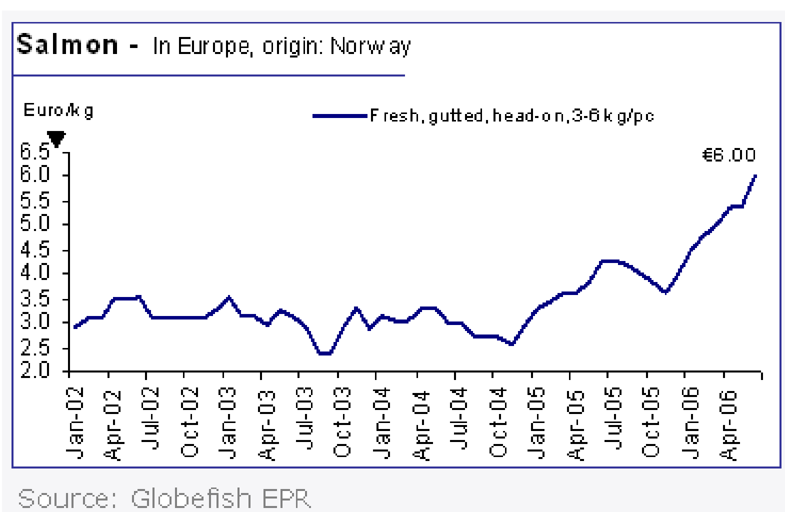


Figure 4: Price development of salmon. Source: FAO, 2006

As prices have decreased (before 2002 in figure 4) with the growing supply from aquaculture, the salmon industry has turned to development of a wide range of value-added products that range from gourmet smoked products to salmon jerky and salmon bits for salad toppings.

To summarize, an overview is given of the main supply chain features of the main salmon producing countries in the world: Norway, Chile and Scotland (see table 4).

Table 4: Main feature overview of salmon supply chain of main salmon producing countries in the world (source: Johnson, 2005 and Fjord Seafood, 2004)

	Norway	Chile	UK (Scotland)
Main export market	Focus on EU	Focus on US	Focus on EU
Chain parties	Several intermediates	Few intermediates	Several intermediates
Salmon product	Fresh chilled	Frozen	Fresh chilled
Historical development	Longest experience	Capital based development	Medium long experience
Governmental involvement	Financial support from government	Little involvement	-
Know how	Skilled workforce	Buy of know how	Skilled workforce
Control/standards	High	Low	High

2.6 Salmon supply chain in The Netherlands

Salmon is not produced in The Netherlands itself, however imported mainly from Belgium, Germany, Sweden, Chile, China and the USA (see table 5). Note that in table 5 both wild and farmed salmon is included, as the statistics do not differentiate between these two types of salmon. Most salmon is mainly originating from Norway, Scotland and Chile and shipped via other countries into the Netherlands. For instance China is a growing re-exporter of fish products. This can be an example of salmon becoming a more global commodity. If these global shipments increase and the salmon supply chain is becoming more international and more complex, we need to take this into consideration when we discuss food safety issues and possible risks. Besides this, because of the EU Schengen agreement, intra EU transports of salmon products are difficult to trace. Most salmon is shipped fresh chilled via truck to The Netherlands with maximum transport duration of 4 days. Approximately 20% of the imported salmon is frozen. Most imported salmon is gutted, and a small amount is imported as fillet. Furthermore it is not clear from this data sources (see table 5 and 6) how much of the imports into The Netherlands is actually consumed here and what part is re-exported. These data are not available in any public statistical data source and have to be obtained from salmon importing, exporting, processing plants and retail outlets, so require additional research. However a report, very recently published by LEI (Smit, 2006), mentions that 50% of the production of smoked fish (salmon and eel) is consumed in The Netherlands, the other 50% is (re-)exported.

Table 5: Import volumes (in tonnes) of salmon of The Netherlands. Source: Eurostat, 2006

Import volumes in tonnes	2000	2001	2002	2003	2004	2005
France	101	40	29	138	357	175
Belgium & Luxemburg	1,330	952	1,220	1,626	1,847	2,265
Germany	2,533	2,926	3,128	2,811	3,839	4,196
Italy				2		
UK	360	546	2,021	393	431	341
Ireland	28	40	237	44	165	29
Denmark	1,663	2,076	1,649	1,866	938	677
Portugal				2		
Spain	27	1		1	51	35
Iceland	35	8		356	586	405
Norway	577	1,887	697	65	8	45
Sweden	1,526	1,599	1,550	1,136	1,706	1,553
Finland	1					
Faeroes	245	19	22			
Turkey				8		
Latvia					2	9
Poland	247	23	32	29	34	9
Russia	606	431	507	219	15	
Morocco		1	1			
Egypt					15	
Ghana		5	16	11	9	
Kenia		19				
Uganda		19				
Seychelles						14
USA	2,171	2,931	2,989	3,094	2,829	2,534
Canada	2,644	585	1,398	421	387	273
Chile	960	684	1,916	419	184	1,885
Thailand	150	72	323	112	285	280
Vietnam					40	
Indonesia	23	3	176	14	14	22
Malaysia	14	32	15		7	
China	3,042	2,647	2,245	2,453	4,638	4,872
South-Korea	92	63	209	57	14	
Other	3		66	41	153	
Total world	18,378	17,609	20,444	15,318	18,364	19,619

Table 6, gives an overview of the salmon species and product import into The Netherlands. Also in this case, figures can be different from actual import volumes, because of the difficult traceability of salmon shipments within the EU.

Table 6: Import volumes (in tonnes) per salmon species and per type product in the Netherlands. Source: Eurostat, 2006

Import volumes in tonnes	2000	2001	2002	2003	2004	2005
Salmon	18,377	17,604	20,443	15,311	18,365	19,618
Pacific salmon "Oncorhynchus nerka, Oncorhynchus gorbuscha, and other Oncorhynchus sp.	6,738	8,464	5,622	4,317	5,489	4,778
Atlantic salmon "Salmo salar" and Donausalmon "Hucho hucho", frozen	328	43	226	189	230	87
Filets of Pacific salmon "Oncorhynchus nerka, Oncorhynchus gorbuscha, Onc	621	758	682	724	853	1,280
Filets of Pacific salmon "Oncorhynchus nerka, Oncorhynchus gorbuscha, Onc	5,731	4,752	7,005	5,636	7,370	9,837
Pacific salmon "Oncorhynchus nerka, Oncorhynchus gorbuscha, and other Oncorhynchus sp.	6,352	5,510	7,687	6,360	8,723	11,117
Prepared and conserved salmon, whole or in pieces	4,959	3,587	6,471	4,445	4,423	3,636

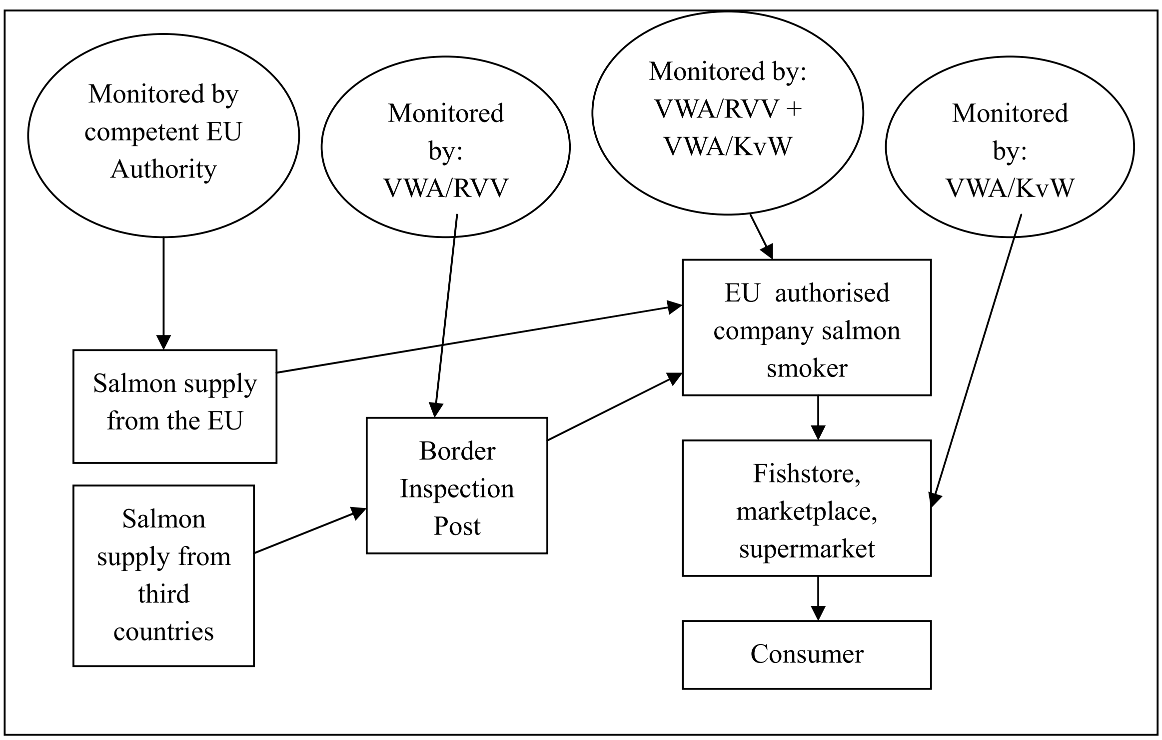


Figure 5: Salmon supply chain in The Netherlands. Source: VWA, 2005 (translated).

Note: Since 2006 the VWA/RVV and VWA/KvW are merged into the VWA

2.6.1 Border Inspection Post (BIP)

All salmon imports from third countries (non EU countries) have to be inspected by the BIP. Norway is not an EU country, however member of the EEA (European Economic Area). The EEA came into being on 1 January 1994 following an agreement between the European Free Trade Association (EFTA) and the European Union (EU). It was designed to allow EFTA countries to participate in the European Single Market without having to join the EU. This means that e.g. Norway has agreed to enact legislation similar to that passed in the EU in the areas of Social Policy, Consumer Protection, Environment, Company Law and Statisticslegislation. Imports from EU and EEA member states do not have to pass the BIP and can go immediately to fish processors. However imports from EEA or third countries have to be reported at the border control and need a health certificate. Inspections are done by a veterinarian (see further information about border inspections in VWA, 2005).

2.6.2 Salmon processing companies

Salmon processing companies have to be authorized by the VWA . In the Netherlands there are more or less 20 small smoking companies. Nearly all salmon which is processed (smoked, fresh) in The Netherlands is re-exported. Main export countries are: Germany, Belgium, France and the US (VWA, 2005).

2.7 Identified problems

2.7.1 Introduction

The farmed salmon industry has been at the centre of numerous accusations from environmentalist non-governmental organizations (NGOs). Salmon production has been labelled as unsustainable and environmentally unsound for the following alleged reasons (Engle, et al., 2006):

- Use of Atlantic salmon in Pacific waters has potential to weaken the genetic pool in the Pacific Ocean;
- Discharge of waste products from the net pens where salmon are raised pollutes surrounding waters;
- Mercury and PCB (polychlorinated biphenyl) concentrations are higher in farm-raised than in wild-caught salmon;
- The use of astaxanthin in salmon feeds is unnatural and should be labelled as an additive;
- The use of fish meal and fish oil in salmon will lead to over fishing of pelagic species upon which other species and fisheries depend. Many of these claims haven been exaggerated according to Engle, et al. (2006), and information has often been used incorrectly out of context. Nevertheless, the very active opposition of some environmental NGOs to farm-raised salmon production has constrained sales and dampened market growth to some degree.

These problems and several others are illustrated in figure 6. The question is however, whether or not these accusations are in fact true. In the following paragraphs hazards in the farmed salmon industry are identified from a scientific perspective.

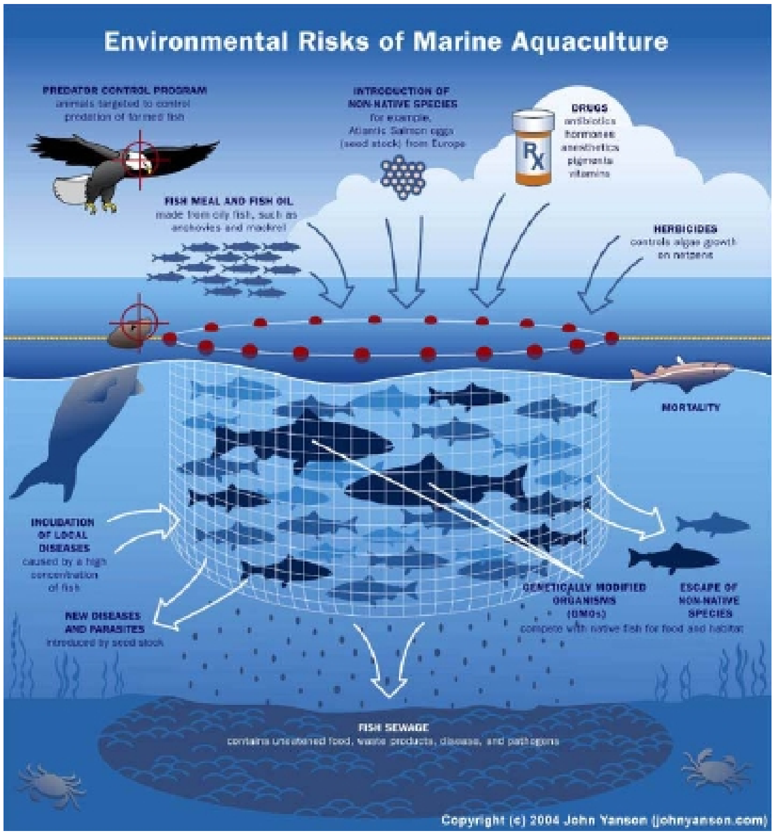


Figure 6: Overview of environmental effects of marine fish culture. Source: Wolowicz, 2005.

2.7.2 *Identification and characterisation of hazards in farmed salmon industry*

A hazard is described a biological, chemical or physical agent in, or condition of, food with a potential to cause an adverse health effect (CAC, 2001). Hazards in food make it unsafe and can result in illnesses and even death of people. These food borne illnesses can occur as isolated cases, but also as an outbreak of food poisoning from ingestion of a common contaminated food. A single outbreak can affect hundreds or even thousand of people.

Food borne illness outbreaks are primarily investigated by governmental health departments. The reporting of these outbreaks is often linked with the pathogen, but may include outbreaks with unknown etiology (originally infecting micro organism) and foods. Outbreaks should be linked to specific foods in order to alert consumers to food safety hazards and provide policymakers and public health official's better information to design risk based hazard control plans.

2.7.2.1 Microbiological hazards

Fresh or frozen salmon is considered to be a possible source of microbiological hazards. These include spores and vegetative cells of bacterial pathogens, especially *Clostridium botulinum*, and various parasitic pathogens. Water, including untreated sea water, and ice used on the vessels and in the processing facilities may also be sources of pathogenic bacteria and parasites. Due to the nature of the product, containers and processes, *C. botulinum* is the primary biological hazard associated with canned salmon. Contamination of salmon products is almost always due to poor hygiene (poor personal hygiene, poor processing hygiene or poor water quality).

The microbiological hazards for salmon may be divided in several groups like: pathogenic bacteria, histamine and parasites.

Pathogenic bacteria

The pathogenic bacteria most likely to be found in salmon are the above mentioned *Clostridium* species. Besides these bacteria from aquatic origin, pathogenic bacteria are also found in the animal/human reservoir. These bacteria, like *Salmonella, Shigella, Campylobacter* and *Escherichia* coli are normally not found in fish but in outer and inner surfaces of diseased or asymptomatic carriers. However an exception is *Salmonella* which although rarely detected in temperate waters, may occur in tropical waters and on fish from such waters. Contamination of salmon (products) is therefore almost always due to poor hygiene (poor personal hygiene, poor processing hygiene or poor water quality). The main preventative measure to avoid contamination in this case is to applying good hygienic practices in the processing stages.

The presence of pathogens from the animal/human reservoir is a serious safety concern for products to be eaten without (further) cooking or ready to eat (RTE) products. Growth of these pathogens is only possible at elevated temperatures (>5°C), and at this condition spoilage will proceed very rapidly and the fish will probably be rejected due to off-odours and off-flavours long before being either toxic or infective organisms reach high numbers. Cooking the raw fish on the other hand will destroy these pathogens. Although these levels are low or absence in raw fish, *Listeria monocytogenes* can easily be isolated from processes fish products. Especially in smoke houses (e.g. salmon) the level of *L. monocytogenes* can be quite high in RTE sea food. Heat treatment is the best Listericidal processing step, but some heat resistance in salmon is known due to a high lipid content. Control of *L. monocytogenes* growth in salmon products where a heat treatment process is not used, can be done by freezing of products which will eliminate growth, and sufficient levels of acid and NaCl which will also prevent growth. These processing steps are included in the HACCP and GHP programs, to eliminate the pathogen. In some cases a special *Listeria* surveillance program may be installed. However some pathogens are heat resistant like toxin producing types of *Clostridium botulinum*. Refrigeration is often regarded as the primary method of preservation of fresh sea food. For example at temperatures below 10°C there is no risk of toxin production by *C. botulinum* types A and B.

Histamine

Histamine food poisoning (HFP) is a food borne chemical intoxication caused by the consumption of spoiled or bacterially contaminated fish. Histamine production in fish is related to histidine content in the fin muscle of the fish, the presence of bacterial histidine decarboxylase (HD) and environmental conditions. The main bacteria responsible for histidine decarboxylation are members of the Enterobacteriaceae family. Although HFP is mainly caused by scombroid fish (certain fin fish like tuna and mackerel causing fish poisoning) other non-scombroid species like salmon have also been implicated. Various processing steps have little effect on the histamine levels. Heat processing can destroy bacterial contaminants and even HD activity, but has no effect on the histamine level. Refrigeration will cease bacterial growth and will slow down residual enzyme activity, but histamine levels will continue to increase. Also smoking and canning (with heat) will not destroy histamine. The introduction of HACCP principles, including improvements in handling and processing together with constant monitoring have reduced the incidence of HFP considerably (Lehane and Olley, 2000)

Parasites

The presence of parasites in fish is very common, but in most cases the effect on economics or public health is generally little. In most cases, infections of man are acquired by eating intermediate hosts that are raw or incompletely cooked, partially pickled or smoked or poorly preserved. The Anisakis species is known worldwide and can cause human disease when seafood is eaten raw or improperly cooked. Anisakiasis is common in Europe (the Netherlands), Japan and the US. Anisakis spp. are widely distributed geographically as well as within numerous fish hosts (cod, herring, squid, salmon a.o.). It should also be noted, that the parasite has never been detected in a large number of aquaculture salmon examined (ICMSF, 2003).

To kill or inactivate nematodes in fish, low or high temperatures or high salt concentrations may be used. In the EU, conditions concerning control of parasites are laid down in Council Directive no. 91/493/EEC (EC, 1991). All fish and fish products must be subject to a visual inspection during processing for the purpose of detecting and removing any visible parasite. Further, all fish that are to be consumed raw or almost raw must be subjected to a freezing process (-20oC for at least 24 hours in all parts of the fish). This also applies to fish products that are heated (e.g. hot smoked) to a temperature of less than 60°C. As far as salted fish is concerned, the process must be sufficient to destroy the larvae of nematodes. The US regulations stipulate that the freezing process to destroy parasites should be -20°C for 7 days or -35°C for 15 hours (FDA, 2001).

The infections are preventable if the food is prepared sufficiently to destroy the infective stages of the parasite. However, it is extremely difficult to change cultural and eating habits, and therefore these parasites will continue to prevail. Thus, the best prevention and control of anisakiasis is eating well-cooked or well-frozen fish only. A short period of freezing - either of the raw material or the final product - must be included in the processing as a mean to control parasites.

2.7.2.2 Chemical hazards

There are no toxic chemicals, but there are toxic concentrations of all chemicals. Very few chemicals are present in high enough concentrations to pose a threat to human health. The chemical contaminants with some potential for toxicity are (Ahmed, 1991):

- Inorganic chemicals: arsenic, cadmium, lead, mercury, selenium, sulphites (used in shrimp processing)
- Organic compounds: polychlorinated biphenyls, dioxins, insecticides (chlorinated hydrocarbons). This is a very diverse group with a wide range of industrial and agricultural users. Unfortunately the chemical stability allow them to accumulate and persist in the environment
- Processing related compounds: nitrosamines and contaminants related to aquaculture (antibiotics, hormones).

Environmental chemical contaminants

Problems related to chemical contamination of the environment are nearly all man-made. Discharge into the ocean of waste material from industrial processing and sludge from sewage treatment plants, as well as draining into the sea of chemicals used in agriculture and raw untreated sewage from large urban populations all participate in contaminating the coastal marine environments. From here the chemicals find their way into fish and other aquatic organisms. Increasing amounts of chemicals may be found in predatory species as a result of biomagnification, which is the concentration of the chemicals in the higher levels of the food chain. Or they may be there as a result of bioaccumulation, when increasing concentrations of chemicals in the body tissues accumulated over the life span of the individual. In this case, a large (i.e. an older) fish will have a higher content of the chemical concerned than a small (younger) fish of the same species. The presence of chemical contaminants in seafood is therefore highly dependent on geographic location, species and fish size, feeding patterns, solubility of chemicals and their persistence in the environment.

Most countries have regulation in place concerning maximum levels of a number of compounds of environmental chemical contaminants for fish (see table 7)

Table 7: Environmental chemical contaminants. Tolerances and critical limits in fish and fish products (EC, 2001; FDA, 1998).

Substance	Maximum levels		Fish commodity
	US (PPM)	EU (mg/kg wet weight)	
Arsenic	76-86		Molluscs
Cadmium	3-4	0.05 – 1.0	Fish, molluscs
Lead	1.5 – 1.7	0.3 – 1.5	Fish, molluscs
Methyl mercury	1.0	1.0	All fish
PCB	2.0		All fish
DDT, TDE	5.0		All fish
Dieldrin	0.0		All fish
Dioxin		0.000004	All fish

Results from a large number of surveys have shown, that residues of chemical contamination normally are lower than the limits shown in table 7 and do not give rise to any concerns regarding health of the consumer.

Veterinary drugs

The development of aquaculture has, in the very beginning led to an increase use of veterinary drugs and vaccines to combat diseases in farmed fish companies. However, in Norway the use of antibiotics has dramatically dropped since 1994 (see figure 7), due to EU legislation. The salmon in Norway are now vaccinated before entering the sea cages. Antibiotics were commonly used in aquaculture worldwide to treat infections caused by a variety of bacterial pathogens of fish including *Aeromonas hydrophila, Aeromonas salmonicida, Edwardsiella tarda, Pasteurella piscidida, Vibrio anguillarum, Vibrio salmonicida* and *Yersinia ruckeri*. They were commonly used as in-feed medications or surface coated onto feed pellets and dispersed in water. In Canada and Chile, where antibiotics are approved and still in use, specific doses and withdrawal periods are specified by manufactures. Some of the antibiotics in common use for farmed salmon are shown in table 8.

The use of antibiotics in fish farming is associated with new hazards in fishery products that are not encountered in wild captured species. The main hazards are antibiotic residues and the development of antimicrobial resistance in bacteria that may be transferred to consumers of farmed fish.

With the increased use of veterinary drugs in food production, there is global concern about the consumption of low levels of antimicrobial residues in aquatic foods and the effects of these residues on human health.

Table 8: Examples of antibiotics used in salmon aquaculture (source: Huss, 2003)

Group	Compound	Remarks
Sulphonamides	Sulphamerazine Sulphadimidine Sulfadimethoxine[1]	Bacteriostatic agents with broad spectrum activity against furunculosis in salmonids
Potentiated Sulphonamide	Co-trimazine/Sulfatrim[1,2,3]	Used for treating diseases like furunculosis, vibriosis and enteric red mouth in salmon
Tetracyclines	Chlortetracycline Oxytetracycline[1,2,3,4]	Wide use in aquaculture a.o. in salmon
Penicillins (Betalactams)	Ampicillin[4] Amoxycillin[2,4]	Used to treat furunculosis in salmon
Other antibiotics	Florfenicol[1,3,4]	Used to treat rainbow trout fry syndrome and furunculosis in salmon

1. Use permitted in Canada (http://www.syndel.com/msds/canada_approved.htm)
2. Licensed for use in the UK (Alderman and Hastings 1998)
3. Use permitted in Norway (Alderman and Hastings 1998)
4. Use permitted in Japan (Okamoto 1992)

Norwegian salmon farming industry has decreased the use of antibiotics (see figure 7) to a minimum in the last decade. (www.fhl.no), due to fish health programs (vaccination) to prevent fish becoming ill.

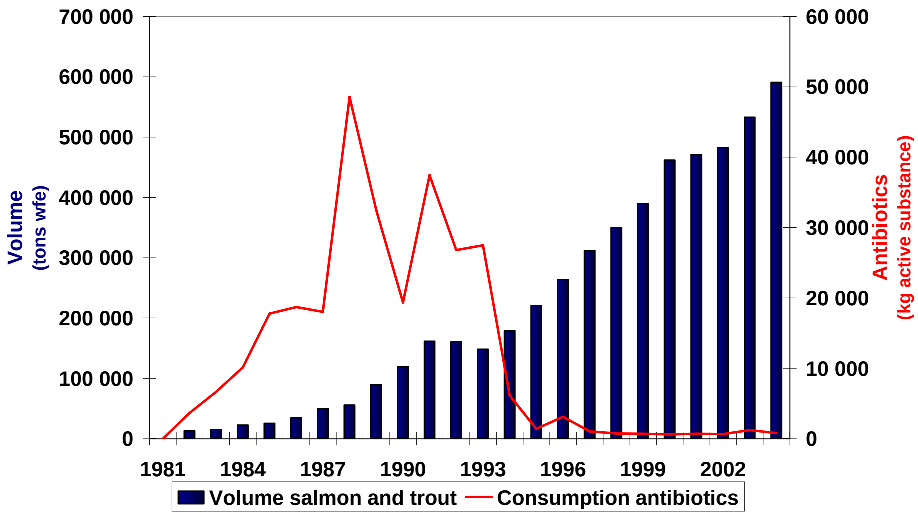


Figure 7: Use of antibiotics in Norway set off against the volume of farmed salmon and trout.

2.7.2.3 Physical hazards

Physical hazards include any potentially harmful extraneous matter not normally found in food. The extraneous matter found in fish products can be divided or classified as:

- non-food safety hazards (e.g. filth)
- food safety hazards (e.g. glass, metal, wood, bones, stones, hard plastic).

Control measures during processing for physical hazards can include:
for metal inclusions:

- periodically checking all equipment for damage or missing parts
- passing the product through metal detection or separation equipment

for non-metallic objects:

- passing the product through an X-ray detector.

However, since injuries from physical hazards associated with salmon or salmon products are not likely to occur, these physical hazards present a low risk and are addressed using normal Good Manufacturing Practices.

2.7.3 Examples of effort to tackle problems in the salmon industry

2.7.3.1 Fish health

In the past, antibiotics were simply cast into the net pens to prevent diseases. Excessive use of antibiotics results however in an ever-ascending spiral of treatment simple to maintain the same level of fish health (Barton, 1997). Besides this, antibiotics residues were found in salmon products and the surrounding aquatic ecosystem was harmed. Salmon farmers have taken however a preventive approach to disease control instead of a reactive treatment approach by using vaccines to immunize fish against some of the most dangerous diseases. Vaccination has been very effective and has caused dramatic reductions in the use of antibiotics. In recent years the use of antibiotics has fallen dramatically in the farmed salmon industry in Norway from about 50 tonnes to less than one tonne annually. This is largely as a result of the successful development and use of vaccines against the principle fish pathogens (Alderman and Hastings, 1998). For example, in 1987, Norwegian salmon farmers used 1.065 grams of antibiotics per kg of fish, but by 1996 they used to less than 0.003 grams per kg. Nowadays the use of antibiotics is prohibited without prescription of a veterinarian. This makes salmon flesh from Norway, the farmed meat with the lowest antibiotic use (Asgard et al. as cited in Lindbergh, 1999).
Antibiotics should never be used as an easy alternative to good fish farming practices. National governments need to put in place control programmes for residues of antimicrobials in aquaculture production. Such control programmes should control the approval or licensing of antimicrobials and should control their sale and use in fish farming. What is required at national level is up-to-date legislation and standards that are based on sound science, a monitoring programme and adequate resources for enforcement of the legislation.

Another threat to salmon farming is Sea lice (*Caligus* spp.). Sea lice are ecto-parasites that harm the salmon. One way of reducing the parasite problem is “fallowing”. This means, cleaning the nets and keeping the net empty for a period of time. Another method used is antifouling. This is a special coating which reduces growth of organisms to the net pens itself. A third method is the use of cleaner fish (wrasse). These fish eat the sea lice from the skin of the salmon. Two drawbacks using this method however are, (1) salmon hunt the cleaner fish and therefore the net pen has to be stocked with cleaner fish repeatedly; (2) to prevent the smaller cleaner fish from escaping the net pen, mesh size need to be smaller than 12 cm. This however, reduces the flow of "clean" water through the net pen. In Table 9 an overview is given of salmon viruses, bacteria, parasites and fungi.

Table 9: Salmon pathogens (source: FAO, 2006)

DISEASE	AGENT	TYPE	SYNDROME	MEASURES
ISA (Infectious salmon anaemia)	Orthomyxovirus	Virus	Lethargy; appetite loss; gasping at water surface; pale gills & heart; fluid in body cavity; dark liver; haemorrhages in internal organs	No treatment; statutory controls; biosecurity; bloodwater treatment
VHS (Viral Haemorrhagic Septicaemia)	Rhabdovirus	Virus	Bulging eyes and, in some cases, bleeding eyes; pale gills; swollen abdomen; lethargy	No treatment; statutory controls; vaccines being developed
IPN (Infectious Pancreatic necrosis)	Birnavirus	Virus	Erratic swimming, eventually to bottom of tank where death occurs	No treatment; statutory controls; biosecurity; broodstock screening; vaccines being developed
SPDV (Salmon Pancreas Disease virus)	Togavirus	Virus	Weight loss; emaciation; mortalities	No treatment; withholding feed; vaccination
Furunculosis	Aeromonas salmonicida	Bacterium	Inflammation of intestine; reddening of fins; boils on body; pectoral fins infected; tissues die back	Antibiotics; vaccination
BKD (Bacterial Kidney Disease)	Renibacterium salmoninarum	Bacterium	Whitish lesions in the kidney; bleeding from kidneys and liver; some fish may lose appetite and swim close to surface; appear dark in colour	Statutory controls; biosecurity; broodstock screening

Winter sores	Moritella viscose (multifactorial)	Bacterium	Ulcers	Antibiotics; vaccination
ERM (Enteric Redmouth)	Yersinia ruckeri	Bacterium	Black, lethargic fish 'hanging' in areas of low flow; bilateral exophthalmia; abdominal distension as result of fluid accumulation; haemorrhages of mouth and gills	Antibiotics; vaccination in freshwater
SRS (Salmon Rickettsial Disease)	Piscirickettsia salmonis	Bacterium (rickettsia)	Increased mortality; anorexia; pale gills and lowered haematocrits; swollen abdomens; affected fish appear dark and lethargic, swimming at the sides of enclosures	Antibiotics
Saprolegniasis	Saprolegnia	Fungus	White or grey patches of filamentous threads on surface; cotton-like appearance radiating in circular, crescent-shaped or whorled pattern; usually begins on head or fins	Bronopol/formalin bath
Sea lice	Lepeophtheirus salmonis; Caligus elongatus	Ecto-parasites	Reduced growth; loss of scales; haemorrhaging of eyes and fins	Paraciticides (bath e.g. Azamethiphos, Cypermethrin, Hydrogen peroxide); in feed (e.g. Emamectin, teflubenzuron) Cleaner fish
Gill amoeba	Paramoeba pemaquidensis	Ecto-parasite	Gill infestation	Freshwater baths

Tapeworms	Eubothrium spp.; Diphillobothrium spp.	Endo-parasites	Reduced growth; reduced condition factor; aesthetically unacceptable to consumers	Fenbendazole/praziquantel in feed for Eubothrium; avoidance of early hosts
Freshwater protozoa	Ichthyobodo; Trichodina; Ichthyophthirius	Ecto-parasites	Irritation response; heavy and laboured operculum movements; flashing and rubbing; skin cloudiness caused by excess mucus; focal redness; lethargy	Formalin baths
Algal/Jellyfish blooms	Various	Various	Various	Avoidance; airlift systems; skirts
Production diseases	Various (congenital, nutritional, environmental)	Various	Various	Improved management

2.7.3.2 Sediment build up under or near net pens

Intensive use of space and growth of the salmon pollutes the net pen surroundings. To minimize this pollution threat, intensive research is done (Naylor, 2000). Sediment gathering, innovations are however costly and therefore integrated systems as for instance poly culture look more promising (Troell, et al., 1997, 1998, 1999; Chopin, et al., 1999; Neori, 2000). Integrated systems, for instance fish (tilapia) poly culture with chicken; duck or rice farming are common practice (Yan, et al., 1998). Open marine poly culture with salmon is however difficult because of the water current. However, some integrated systems are economic and ecological interesting. Integration of seaweed and salmon seems profitable. The effective intake of nutrient by commercially attractive algae and seaweed culture near salmon net pens can reduce farming costs or even increase revenue. There is a high *Gracilaria chilensis* demand. This algae species is used for agar production (Troell, 1997). The seaweed species *Porphyrai* is used for sushi (Chopin, 1999).

2.7.3.3 Traceability

In recent years, producers, wholesalers, distributors and retailers invest more and more in the transparency of the salmon supply chain. Besides the commonly used HACCP, COOL (Country Of Origin Labelling) and techniques like Electronic Data Interchange (EDI), Efficient Consumer Response (ECR), Efficient Foodservice Response (EFR), new certificates are initiated to guarantee food safety within the supply chain. Label rouge aims, besides animal welfare and good farming practises, at controlled fat content and maximum quality of salmon products by doing intensive tests. Another aquaculture supply chain initiative is EurepGAP (Euro Retail Produce Working Group) where a number of fish farming companies and retailers are aiming at a international standard for good agricultural practice.

2.7.3.4 Modern biotechnology: growth-enhanced transgenic salmon

Through genetic modification, salmon have been created that contain an added gene for production of growth hormone. This gene was originally obtained from Chinook salmon and its activity is controlled by another DNA segment called "promoter" from another fish, the ocean pout. This combination of promoter and gene leads to the continuous, rather than seasonal, expression of growth hormone. Nevertheless, growth hormone levels are reported to be still within the ordinary ranges that are observed in conventional fish.

The genetically modified (GM) salmon shows enhanced growth, with young GM salmon growing 4-6 times as much as fast as conventional ones of the same age. The final sizes of the GM and conventional salmon are the same, though. It is therefore expected that aquaculture of GM salmon will reduce the time before the fish reaches marketable sizes, approximately one-and-a-half year for GM salmon and two till three years for conventional salmon. In addition, the GM salmon is reported to convert feed to body mass more efficiently, by 10-30% (Aqua Bounty, 2006).

The company that has developed this salmon has filed a petition for its commercial cultivation and marketing in the USA. The characteristic of enhanced growth by production of growth hormone is considered a veterinary medicine, similar to growth hormone applied to animals by other means. The application is therefore currently being assessed by the US Food and Drug Administration's Center for Veterinary Medicine in cooperation with other government institutions. In addition to issues of medicinal importance, the company also has to address questions related to food safety for consumers and environmental safety (Van Eenennaam and Olin, 2006).
Voices of concern have been raised particularly with regard to the chance that fish may escape into the environmental and compete or interbreed with wild populations. The company has proposed to produce and sell all-female triploid salmon, which are sterile, as a means for containment and prevention of uncontrolled dissemination into the environment (Van Eenennaam and Olin, 2006).

The petition for product approval is currently in its final stages. If approved, it may enter the market by 2008, according to a quote of the company's chief executive in Business Week (2006).

2.8 Analysis RASFF reports

2.8.1 Introduction

The European Commission is operating a Rapid Alert System for Food and Feed (RASFF). The legal basis for the system is Regulation EC/178/2002 laying down the general principles and requirements of food law. The purpose of the RASFF is to provide the control authorities with an effective tool for exchange of information on measures taken to ensure food (and feed) safety. Member States notify the Commission when a foodstuff poses a serious risk to the health and safety of consumers, and the probability that the foodstuff is on the market in another Member State.
An ongoing study, Ababouch and Gandini (unpublished) analyses the EU Rapid Alert System data of interest to Third Countries, i.e. non EU countries exporting fish and fishery products to the EU member states. The analysis encompassed the period from January 1999 to June 2002 (see table 10).

These data indicate that the number of alerts has increased steadily during the period January 1999 - December 2001 and basically exploded in 2002. The initial steady increase and the explosion of alerts in 2002 are due to several concurrent facts:

- The alert system has become generalized and fully operational only during the last 12 or 18 months, indicating some underreporting in the initial phase;
- Several safety concerns have emerged during the period 2001-2002 which triggered several additional controls at the entry point to the EU, e.g. analysis of Vibrio, analysis of antibiotic residues and other chemical pollutants (polycyclic aromatic hydrocarbons), following the enacting of recent EU regulations to monitor these residues in fish and fishery products marketed in the EU (FDA 2003).

2.8.2 Seafood retention and rejection in EU

The analysis in table 10 has been amended with data from the weekly overviews and annual reports of RASFF for the years 2003 -2006. These data originate from the alert and information notifications which are issued weekly by the EU.
Alert notifications are sent when the food or feed presenting the risk is on the market and when immediate action is required. Alerts are triggered by the Member State that detects the problem and has initiated the relevant measures, such as withdrawal/recall. The notification aims at giving all the members of the network the information to verify whether the concerned product is on their market, so that they also can take the necessary measures.
Information notifications concern a food or feed for which a risk has been identified, but for which the other members of the network do not have to take immediate action, because the product has not reached their market. These notifications mostly concern food and feed consignments that have been tested and rejected at the external borders of the EU.
In both the case of an alert and an information notification the consumers can be reassured that product have been respectively either withdrawn (alert) from or have not reached (information) the market.

The total of alerts and information indicate a steady level for the years 2003 to 2005, considering the fact that the data of 2003 represent the week numbers 21 to 53 (so 34 weeks of the year). For 2006 a decrease in alerts and information is foreseen, if the present trend continues. This is in relation to a total figure of 262 cases for the first six months. The alerts and information for microbiological hazards have seen a steady increase of the years up to 2005. For 2006 a dramatic fall is noticed. On the other hand the increase of alerts and information for chemical hazards and residues remains steady, with a little decrease in 2004. Parasites, as a cause of alerts, remain also rather steady, with a peak in 2004.

Comparing the data from the period 1999 to 2002 with the data from June 2003 to July 2006 a considerable increase in both the alerts for microbiological and chemical hazards is noticed. But the main reason for this is due to the fact that the data after 2003 also include alerts from within EU countries themselves. So a realistic comparison between these two periods can not be done.

On the other hand it would be interesting to see whether the ever increasing introduction of quality systems has had any effect on the number of alerts and information. In theory the number of alerts should decrease in line with an intensifying of quality systems, but this may be counteracted by an increase of monitoring activities by the EU Member States. However these data are too broad to be able to conclude anything specific in relation to quality systems.

Table 10: Cause and number of detention / rejection of seafood imported into the EU during the period January 1999 - June 2002 (Ababouch and Gandini, unpublished), and cause and number of alerts / information notifications within RASFF during the period July 2003 – June 2006 (data collected by authors of this report from RASFF website)

Cause of detention / rejection	**Number of detentions / rejects**				**Number of alerts /information**			
	1999	2000	2001	2002*	2003*	2004	2005	2006*
Microbiological	59	53	49	47	88	181	173	24
Micro organisms (not specified)					26	20	18	3
Bacillus					2			
V. parahaemoliticus	13	10	19	14	19	38	12	
V. vulnificus		2	1	3	1			
V. cholerae	9	8	9	5	3	11	13	1
Other vibrios		1				1	1	
Enterobacteria	6	2	4	6	5		13	
S. aureus	7				1	1	1	
Listeria					12	41	51	3
Salmonella	20	18	10	12	15	26	29	2
Hepatitis	1	1						
Total plate count	1	8	4	7				
Moulds		1	1			1	2	
Clostridium		2	1		3			
coliforms						19	12	
E. coli					1	22	21	10
Virus						1		5
Chemicals / residues	13	15	34	158	216	325	394	206
Chemicals (not specified)						1		
Food additive					5	18	4	3
Allergen (not specified)						4	2	
Carbon monoxide					3	13	57	20
Dye						1	5	10
Food contact substance					2			
Irradiation					1	3	2	
Pollutant					3	6	8	23
Nitrate/nitrite							3	4
Biotoxins		1		1	4	10	17	16
Pesticides	2							1
Mercury	4	4	9	8	26	45	47	23
Cadmium	5	2	3	4	51	43	43	25
Lead				2	9	1	1	1
Nitrofurans				39	24	21	25	21

Cause of detention / rejection	Number of detentions / rejects				Number of alerts /information			
Histamine	1	4	1	1	15	39	21	11
Chloramphenicol	1		16	86	10	12	2	2
Furazalidone (AOZ)					35	16	11	9
Polycyclic Aromatic Hydrocarbons		4	3	7				
Veterinary drug residues				4	15	29	53	13
Sulphites			2	2	5	52	65	23
Benzopyran				1				
Malachite green				1	8	11	28	1
Antimicrobial agents				2				
Insects		2	2	1	1		1	
Parasites	1	13	11	7	4	53	20	6
Physical hazards						1		1
Quality hazards					5	6	3	9
Others	6	13	18	5				
Labelling	3	7	8	2	3	7	5	2
Sanitary certificate	1	1	3					
Shelf life	1	1	2					
Interrupted cold chain	1			1		9	7	3
Fraud hazards (not specified)					4	3	2	1
Import prohibited				1				3
Mixing of fish species		1						
Packaging hazards			2			6	4	1
Not specified		1	1			4	1	5
Total	79	94	112	217	303**	537**	558**	240**

**) data only available of six months*

***) number of notifications; please note that multiple hazards may be reported by a single notification*

2.8.3 Analysis of notifications 2003-2006

The data from the Rapid Alert System for Food and Feed (RASFF) have been analyzed for notifications concerning salmon and derived products. Through RASFF, authorities of EU Member States and the EFTA nations (Norway, Iceland) have to report their findings of hazards in consignments of food and feed products immediately. Notification can be either of the alert or information categories, with alerts being of relevance to other Member States as well, while information pertains to products that can be contained at a national level by the reporting Member State. The hazards reported in these notifications include, among others:

i) microbiological hazards like pathogenic micro organisms;

ii) chemical and biochemical hazards like mycotoxins, unauthorized drug residues, heavy metals, allergens, pesticide residues, environmental contaminant residues, food contact substances, unauthorized dyes and additives;

iii) physical hazards, like glass or metal particles, and risk of choking due to product dimensions;

iv) hygienic hazards, defective packaging, and interruption of temperature control;

v) incomplete or false labelling;

vi) lack of certification of facilities and fraudulent activities. Notifications contain data on the reason for notifying, the identity of the product and the hazard, the notifying Member States, and the country of provenance. Notifications can pertain to feed products as well, which are specifically highlighted.

For this study, RASFF notifications have been used that are published in weekly reports on the European Commission's RASFF website. In total 8416 notifications have been made during the period July 2003 – June 2006, which the current study considers. Of these notifications, 1638 pertained to fish and other aquatic animal species. Product and hazardous agent codes were assigned to each notification, the product codes according to the Euro code methodology.

2.8.4 Salmon notifications

In total 98 notifications pertained to salmon and derived products during the period considered. Most of the notifications pertained to microbiological hazards, in particular the presence of *Listeria monocytogenes* in smoked salmon (see table 11). The second major hazard category is chemicals, particularly residues of veterinary drugs (see table 11). The main product categories are salmon (fresh, frozen, chilled etc.) and smoked salmon (see table 12). Of the chemical hazards, residues of substances used for veterinary purposes, such as malachite green, are associated with the product category of unprocessed salmon from Chile, while nitrite is associated with smoked salmon. The incidences involving chemical residues showed a temporary high at the start of the period (see figure 8). In addition, *Listeria monocytogenes* is also associated with smoked salmon, mainly from EU countries, which showed a peak in number of reports in the last quarter of 2005. More than half of the EU-products came from Denmark (see table 13). More than half of the notifications were made by Italy, all but two of them pertaining to *Listeria monocytogenes* (see table 14).

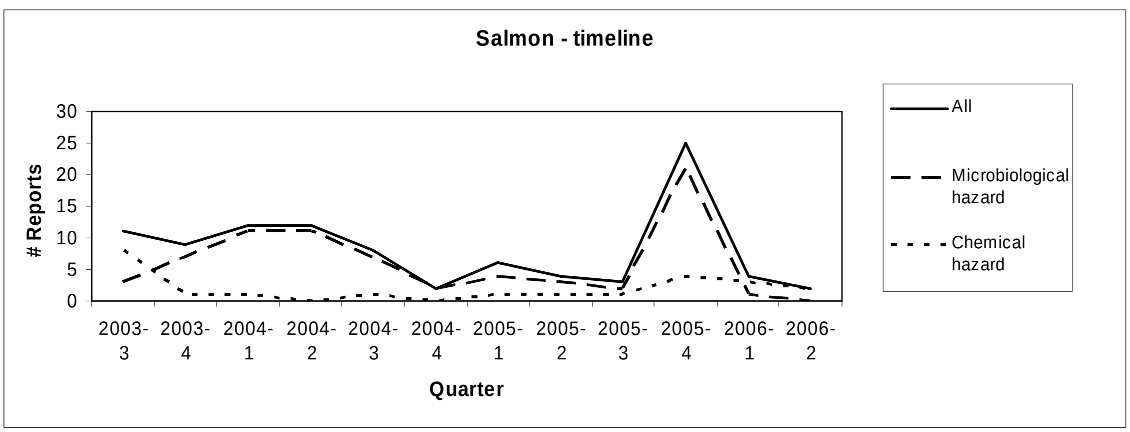


Figure 8: Incidences involving microbiological and chemical hazards

Table 11: Reports for the various hazards in salmon

Hazards		Reports
Chemical		98
Allergen	Sulphite	2
Drug residue	leucomalachite green	1
	malachite green	11
	nitrofurazone (SEM)	1
Food additive	Ethoxyquin	1
Nitrate / nitrite	Nitrite	7
Microbiological		72
Listeria monocytogenes		71
salt content		1
Hygiene		1
Temperature		1
Quality		1
Organoleptic characteristics (not specified)		1
Labelling		1
undeclared sulphites		1
Packaging		1
damaged packaging		1

Table 12: Product categories of salmon and derived products (Eurocode)

Eurocode	Reports	Category
E 4.10.35	16	Salmon and trout
E 4.40.39	1	Hard roe from other fish
E 4.50.00	1	Dried and salted fish (general)
E 4.52.22	79	Smoked salmon and trout
E 4.60.00	1	Fish products

Table 13: Provenance of salmon and derived products

Nation		Reports
EU	Cyprus	2
	Denmark	45
	France	2
	Germany	12
	Ireland	1
	Lithuania	1
	Netherlands	3
	Norway	8
	Poland	2
	Spain	1

	United Kingdom	3
non-EU	Chile	11
	Russian Federation	1
	Thailand	1
	USA	2
	Vietnam	1
	Unclear	2

Table 14: Nations reporting notifications concerning salmon and derived products

Nation	Reports
Austria	2
Belgium	2
Cyprus	2
Finland	1
France	4
Germany	3
Greece	2
Italy	56
Latvia	2
Netherlands	8
Norway	7
Slovakia	1
Slovenia	1
Spain	1
United Kingdom	6

Whereas a limited number of clinical infections have been reported to occur with *L. monocytogenes*, the impacts may be severe, particularly in sensitive populations like elderly, children, pregnant women, and immunocompromised patients, with frequently fatal or teratogenic effects. In an expert choice session on risks in aquacultured salmon organized by the Dutch National Food and Consumer Product Safety Authority (VWA) in 2005, invited experts ranked the risk of *L. monocytogenes* as second highest after the occurrence of organochlorine contaminants (VWA, 2005). This indicates that in spite of the hygiene measures set forth in national legislation, i.e. the absence of *L. monocytogenes* in samples, and those undertaken by the industry and retail sectors, this still is considered an important issue.

The particular association of *L. monocytogenes* with smoked salmon, which is usually cold-smoked, indicates a critical factor for this type of hazard. Although the process of cold smoking reduces any *L. monocytogenes* that may be already present, removal of other micro flora and prolonged cold storage conditions after processing may stimulate its growth, given that it can grow at lower temperatures (e.g. FAO, 1999). Also inadequate temperature control, allowing for faster growth at higher temperatures, might even aggravate this problem. In addition, a number of studies employing bacterial strain detection techniques have shown that the main source of *L. monocytogenes* in cold-smoked salmon is through re-contamination by *L. monocytogenes* resident in the salmon processing facilities (e.g. Vogel et al., 2001). These studies also show that it is difficult to eliminate *L. monocytogenes* from such facilities. For example, *L. monocytogenes* has been shown to sustain on contact surfaces at low temperatures in the absence of nutrients (Hsu et al., 2005). In addition, after disinfection, re-entry of *L. monocytogenes* from areas that are less reachable for disinfection agents and that therefore may act as depots, such as floors and drains, has been observed (e.g. Gudmundsdottir et al., 2005). A critical factor therefore is the prolonged cold storage of the salmon after processing without further heat treatment prior to consumption. This may also pertain to other seafood products besides salmon with similar production chain characteristics (FAO, 1999). In addition, the increasing popularity of raw-fish-based products, such as sushi, may provide for an additional factor contributing to increased exposure to this type of microbiological hazards.

The contaminations with residues of the dye malachite green and its colourless metabolite leucomalachite green, derive from the unauthorized medicinal use of these compounds in aquaculture. The metabolite leucomalachite green has a longer half-life in fish tissues than malachite green itself. Malachite green has also been used as an industrial dye and may therefore have been readily available. In spite of the fact that these compounds are not regulated medicines, their use has previously been allowed in the EU and other regions, because no other medicine was available at that time. For example, malachite green can provide protection against mould growth on fish eggs in hatcheries. It also provides protection against other affections, such as furunculosis in salmon.

After concerns had been raised about the possible genotoxicity of malachite green, use of the compound was reduced and finally prohibited as soon as alternative medicines had become available in 2002 (e.g. DEFRA, 2002). In addition, the EU established a Minimally Required Performance Level of 2 micrograms per kilogram of meat of aquaculture products (EU, 2004). Reports indicate that in European countries, most of the producers adhered to this prohibition (e.g. VRC, 2004). The VWA report on the salmon chain mentions that invited experts considered that at that time, the Chilean methods of aquaculture and control were not as much developed as those in Europe (VWA, 2005). However, another report indicates that the incidents concerning malachite green in Chilean salmon instigated initiatives by industry associations for environmental certification of salmon production (Izuka, 2003).
Re-evaluation of the toxicology data concluded that the evidence for genotoxicity and carcinogenicity of malachite green and leucomalachite green is still inconclusive, for which considering it a genotoxic agent may be a prudent approach (COTCOMCOC, 2004). In addition, regulatory agencies, such as those in Canada and Australia-New Zealand, have re-considered the contamination data and concluded that with regard to the low level of contamination, serious adverse effects of consumption of malachite green-contaminated fish appear remote (CFIA, 2006; FSANZ, 2005).

Recently the British Food Standards Agency reported that a source of malachite green contamination in fish may come from packaging of fresh fish by retailers using green-colored towels containing this dye, although not permitted (FSA, 2006). This also shows that analytical methods currently applied to the detection of malachite green are sensitive enough to detect these contaminations as well.

The case of malachite green is therefore similar to that of chloramphenicol in cultured shrimp considered as a case study in the previous year of this project. Critical factors that contribute to the abuse of unauthorized substances include increased disease pressure after rapid growth of the aquaculture industry, good availability of the substance, unawareness among producers, lack of pertinent regulations or their enforcement, no internationally harmonized regulations between exporting and importing nations, differences in chemical-analytical capacities of the exporting and importing parties, and increased sensitivity of the analytical methods.

2.9 Quality systems

2.9.1 Introduction

To ensure the quality and safety of food the introduction of quality programmes is widely accepted. Every stage from initial production to processing, storage, marketing and consumption must be included in quality systems. Preceding each quality system a transparent risk assessment must be performed. In this chapter some essential data for a risk assessment are discussed. Furthermore the most widely used quality system for food safety (Hazard Analysis and Critical Control Points or HACCP) is outlined in detail as an example of risk management. Where possible examples from the salmon supply chain are introduced, as focusing on the whole fish supply chain is too broad.

2.9.2 Scope of quality systems

The traditional quality control program was based on establishing effective hygiene control. Confirmation of safety and identification of potential problems was obtained by end-product testing. Control of hygiene was ensured by inspection of facilities to ensure adherence to established and generally accepted Codes of Good Hygiene Practices (GHP) and of Good Manufacturing Practices (GMP), which are still the basis of food hygiene today (FDA, 2003). These codes, although essential, only provide general requirements relating to food safety and product quality. Added to this is the reliance on end-product testing by companies and indeed inspection services, which in fact may result in a false sense of safety assurance. What is really needed is a system with a preventative approach, where safety hazards are anticipated and food safety is more or less already built into the product from the start of production or processing. The HACCP plan has been proven to enhance both quality and food safety of food products. This plan could go hand-in-hand from production, through processing to retail (and even on small scale up to consumer level). It basically serves as a reminder and record of commitments to produce safe foods. HACCP is an actual documented plan of action which specifies various critical points with monitoring and record keeping procedures to prevent food safety hazards. HACCP is legislated in many countries, including the European Union and the USA.

Also worth mentioning is the EurepGAP Integrated Farm Assurance Standard. Within EurepGAP the documents have been expanded with Integrated Aquaculture Assurance (IAA). This normative document started as an initiative by a simple supply chain in 2003. The EurepGAP normative documents consist of:

- Control Points and Compliance Criteria (CPCC), including a base module for all farmed fish and a species module (Salmonids) as well as documents for feed manufacturers
- Checklist for each module
- General regulations (process of certification and specific auditor requirements

Thus, EurepGAP has made a species-specific standard for salmon which focuses on the subjects like: food safety, occupational health and safety, and environmental safety. The standard covers the value chain for salmon with smolt production in freshwater, on-growing in seawater, harvesting and transport.

An approved (applicant) scheme for IAA is issued to the Scottish Salmon Producers Organisation Ltd for farmed salmon (www.eurepgap.org).

To summarize the scope of quality systems, they cover both generic requirements in GHP and GMP as well as specific requirements in a food safety assurance (or HACCP) plan. Therefore this term embodies organizational structure, responsibilities, procedures, processes and the resources needed to implement comprehensive quality management (Jouve et al. 1998). Within the framework of a quality system, the GHP and GMP program and HACCP plan provides the approach to food safety.

2.9.3 Implications of HACCP principles in salmon production chain

The safety of 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 preparations before consumption. However, the safety of seafood products and -processing cannot be studied in isolation. A large number of hazards are related to the pre-harvest situation or the raw material handling and must be under control, when the raw material is received at the processing factory.

Most fish are still extracted from a wild population, but aquaculture is a very fast growing food production system. While there are specific safety aspects associated with wild fish caught in the high sea, the intensive husbandry in aquaculture poses new and increased risks. It is imperative that the HACCP principles are extended beyond the factory-gate and applied throughout the total food production chain from harvest to the consumers' plate.

2.9.3.1 Pre-harvest conditions

In a general hazard analysis of the pre-harvest conditions for salmon and the procedures for handling the raw material before being received at the processing plant a number of significant hazards can be identified, as discussed in paragraph 2.7 (identified problems)

Pathogenic bacteria

Pathogenic bacteria from the aquatic or general environment may be present in low numbers in all fish and shellfish at the time of harvest. This is not a significant hazard as it is unlikely that these pathogens will be there in sufficient numbers to cause disease - even if the fish are eaten raw. However, if growth and toxin production of these organisms is taking place as a result of time/temperature abuse, it is reasonably likely that these pathogens and their toxins could reach unsafe levels. For fish to be eaten raw or used as raw material in products that are not heat-treated, this situation is a significant hazard that must be controlled. Pathogenic bacteria from animal/human reservoir may be present in fish and shellfish harvested in contaminated waters. This is a significant hazard for fish and shellfish to be eaten raw due to the low MID (Minimum Infective Dose) for some of these organisms.

The preventive measures for these hazards are control and monitoring of harvest areas for faecal pollution and placing a limit on the time between harvest and refrigeration to prevent growth and toxin production.

Viruses

The presence of viruses in the harvest area is of particular concern in molluscan shellfish because:

- environments where molluscan shellfish grow are often subject to contamination from sewage which may contain pathogens (bacteria, viruses)
- molluscan shellfish filter and concentrate pathogens that may be present in the water
- molluscan shellfish are often consumed raw or only partially cooked.

Thus, the presence of virus is a significant hazard in molluscan shellfish and fish to be eaten raw. The preventive measure is control and monitoring of harvesting areas for faecal pollution.

Biotoxins
Contamination of fish and shellfish with natural toxins from the harvest area can cause serious consumer illness. The toxins accumulate in fish when they feed on marine algae, where the toxins are produced.
The preventive measures for the presence of toxins in shellfish are control and classification of shellfish harvesting areas. As a result, shellfish harvesting is only allowed from "safe" waters. Significant elements in this system is the requirement, that all shellfish containers bear a tag that identifies the type and quantity of shellfish, the harvester, harvest location and date of harvest.

Biogenic amines
These amines are produced as a result of time/temperature abuse of certain fish species and they can cause illness in consumers. It is therefore a post-harvest hazard, but very often a pre-receiving hazard introduced during handling on board the fishing vessel or during transportation to the plant after landing.
The preventive measure is rapid chilling of fish immediately after capture. Generally, fish should be packed in ice or chilled sea water in less than 12 h after catch.

Parasites
It is reasonably likely that parasites will be present in significant numbers of wild caught fish species - and certain aquaculture fish if they are fed on an unheated processing waste or by-catch fish. Thus, parasites should be considered a significant hazard and a preventive measure to eliminate parasites must be identified during processing of any particular fish products.

Chemicals
Concern for this hazard primarily focuses on fish harvested from fresh water, estuaries and near shore coastal waters and on fish from aquaculture. Without proper control it would be reasonably likely to expect that unsafe levels of chemicals could be present in the fish, thus representing a significant hazard. Apart from a few acutely toxic chemicals such as mercury, most chemicals have non-acute mechanisms of toxicity from a health perspective.
The preventive measure is the presence of a government controlled monitoring programme. For aquaculture fish the preventive measures are full controls of chemical contamination of the environment (soil/water) surrounding the aquaculture site, control of water quality and of the feed supply. Only approved agrochemicals and veterinary drugs should be used and only according to manufacturers' instructions. Correct withdrawal times must be observed.
One of the great problems in ensuring the safety of seafood products is that processors often have no control and no information about the history of the raw material. This is a serious weakness and every effort to overcome this problem must be carried out. The significant hazards associated with the raw material must be identified and controlled before the raw material is received at the factory. The receiving step is the first CCP in any seafood processing, and the monitoring procedures will mainly be to check documents (certificates of origin, harvester, date and location of harvesting, copies and results of government monitoring programs, etc.).

The hazard analysis of pre-harvest / pre-receiving situation is shown is summarized in table 15.

Table 15: Summary of hazard analysis of pre-harvest/pre-receiving situation of fish and shellfish. Source: Huss, 2003

Organism	Potential hazard		Analysis of hazard			Control		
	Contami-nation	Growth	Seve-rity	Chance	Signifi-cant	Gov.1 mon.	PP1	Incl. HACCP plan
Pathogenic bacteria - indigenous - non-indigenous	- +	+ +	high high	high high	+ +	- +	- +	+ +
Viruses	+	-	high	high/low2	+	+	+	+
Biotoxins	+	-	high	high/low2	+/-	+	-	+
Biogenic amines	-	+	low	high/low2	+/-	-	-	+
Parasites	+	-	low	high	+	-	-	+
Chemicals	+	-	high	high/low2	+/-	+	-	+

1. Abbreviations: gov. mon. = government monitoring; PP = Prerequisite Programme
2. Depending on fish/bivalve shellfish species, geographical position and season, the likely occurrence may be high or low

2.9.3.2 Processing conditions for lighty preserved fish (smoked salmon)

This group includes fish products with low salt content (Water Phase Salt (WPS) <6%) and low acid content (pH >5.0) with added preservative of smoke. The products are prepared from raw or cooked raw material, but are normally consumed without any prior heating. These products have a limited shelf life and are typically stored at temperature 5°C. The presence in these products of low numbers of pathogenic bacteria normally found in the aquatic and the general environment (*Clostridiums botulinum*, pathogenic *Vibrio* sp., *Listeria monocytogenes*) is a potential hazard. Due to their low numbers, the mere presence is not a significant hazard. However, if these organisms are allowed to grow to high numbers, they are very likely to cause a serious disease, and are therefore representing a significant hazard. It should be remembered, that growth and toxin production can take place in the raw material as well as in the final product.

Contaminations of products during processing with viruses and non-indigenous pathogenic bacteria as well as possible growth of the latter are also potential hazards. However, these hazards are prevented by the prerequisite programme and therefore not likely to occur.

Production of biogenic amines is a significant hazard in fish containing large amounts of free histidine in the flesh, like salmon. The production requires growth of histidine-decarboxylating bacteria. A number of different bacteria are able to produce histamine at various conditions. It should be remembered that biogenic amines may be produced in the raw material as well as in final products.

Parasites are common in many fish species in all parts of the world, and the processing conditions and preservative parameters for lightly preserved fish products are not sufficient to kill the parasites. Thus, a "processing for safety" step must be included in the process of this type of products to control this significant hazard.

Chemical contamination of raw material is a potential hazard if it originates in aquaculture or certain coastal fisheries. Only if this is the case, should chemical contamination be regarded as a significant hazard.

The hazard analysis of processing smoked salmon is summarized in table 16.

Table 16: Summary of hazard analysis of processing lightly preserved fish products like smoked salmon. Source: Huss, 2003

Organism	Potential hazard		Analysis of hazard			Control		
	Contami-nation	Growth	Seve-rity	Chance	Signifi-cant	Gov.1 mon.	PP1	Incl. HACCP plan
Pathogenic bacteria - indigenous - non-indigenous	- +	+ +	high high	high high	+ +	- -	- +	+ -
Viruses	+	-	high	high/low2	+	-	+	-
Biotoxins	+	-	high	high/low2	+/-	+	-	+
Biogenic amines	-	+	low	high/low2	+/-	-	-	+
Parasites	+	-	low	high	+	-	-	+
Chemicals	+	-	high	high/low2	+/-	+	-	+

1. Abbreviations: gov. mon. = government monitoring; PP = Prerequisite Programme
2. depending on fish species, geographical position and season, the likely occurrence may be high or low

In summary, the significant hazards are the result of:
a. Growth of pathogenic bacteria from the aquatic or the general environment
b. Production of biogenic amines
c. Presence of parasites
d. Chemical contamination (depending on geographical area).

The following preventive measures can be applied:
a. Growth of pathogenic bacteria:
- Growth of *C. botulinum* can be prevented by WPS 3.5% and a storage temperature < 5°C
- Growth of *L. monocytogenes* cannot with certainty be prevented by the parameters used in the preservation of this category of products

b. Production of biogenic amines:
- Storage at low temperature (<5°C) will prevent the growth of a number but not all of histamine producing bacteria. There are no experimental data to demonstrate complete control of this hazard

c. Presence of parasites:
- Introduction of a freezing step (-20°C for at least 24 hours)

d. Chemical contamination
- Securing raw material from areas with no chemical contamination.

Based on the considerations above, the following CCPs can be identified:
- Receiving step
- Salting step
- Freezing step.

2.9.4 Smoked salmon slices processing method in the Netherlands

Salmon in EU authorised companies is processed in the following ways:

2.9.4.1 Delivery/storage

Salmon is stored in ice before processing. Storage life of striped salmon after slaughtering is maximum 16 days, except the salmon are stored at 0^oC in ice. Shelf life of fillets is maximum 7 days. Fresh salmon is sometimes frozen in such a way that fillets are surrounded by a thin ice layer (glazing). Processing of salmon starts by removal of the head.

Potential hazards in this stage

Table 17: Potential hazards in delivery/storage phase. Source: VWA, 2005

Chemical	Microbiological	Physical
Residues of animal drugs	Viruses	Glass
Malachite green	Aeromonas spp.	Wood
Pesticide residues	Listeria monocytogenes	Metal
Dioxines	Bacillus cereus	
Radionuclides	Vibrio parahaemolyticus	
Cadmium, lead	Clostridium botulinum type E	
Dieldrin/Aldrin	Parasites	
Organic mercury		
Inorganic arsenic		
PAH's (polyaromatic hydrocarbons)		
Colorants: astaxanthin and canthaxanthin		
Toxaphene		
Biogenic amines (Histamine, Cadaverine)		

2.9.4.2 Rinsing

Rinsing is done with Glyroxyl. This is a solution of glycerol and water peroxide, which is permitted for fresh fish. Rinsing is done by spraying via flow production.

Potential hazards in this stage

Table 18: Potential hazards in rinsing phase. Source: VWA, 2005

Chemical	Microbiological	Physical
High concentration of glyroxyl	Contamination with:	Glass
	Listeria monocytogenes	Wood
	Staphylococcus aureus	Metal

2.9.4.3 Filleting

In this part the fish is separated at the spine in a left and right piece by using a specially designed machine. After filleting, the spines are collected and sold to fishmeal and fish oil producers.

Potential hazards in this stage

Table 19: Potential hazards in filtering phase. Source: VWA, 2005

Chemical	Micro biological	Physical
-	-	Metal

2.9.4.4 Pickling and absorbing

The salmon fillets are treated with salt, called pickling. The aim of pickling is to give flavour to the salmon before the smoking process can start. The original goal of the use of salt is to extract water from the salmon, however is this unfavourable for trade because of weight lose. Wet pickling is possible by using a water solution with salt and sodium lactate as a pH stabiliser is injected in salmon filets. 3% water is added. For products that need an extra heavy smoke flavour, smoke condensate is added. Another method is dry pickling in which sugar is added to the salt. In addition, salt needs to be absorbed. For injected salmon this takes 4 to 7 hours and with dry salted salmon 14 to 18 hours.

Potential hazards in this stage

Table 20: Potential hazards in pickling and absorbing phase. Source: VWA, 2005

Chemical	Microbiological	Physical
High concentration of:	Contamination with:	-
Sodium lactate	Listeria monocytogenes	
Smoking condensate	Staphylococcus aureus	
Nitrite	Faecal streptococcus	
Water binding additives	Salmonella	
Non fish protein	Shigella	
	Escherichia coli	
	Outgrowth of above mentioned bacteria	

2.9.4.5 Cold smoking and drying

The salmon are smoked cold and dried in the smoke house. The goal of this phase is to give the salmon flesh flavour and consistency. The temperature does not exceed 30^{o}C. The smoking time is dependent of the intended product and takes about 6 to 18 hours.

Potential hazards in this stage

Table 21: Potential hazards in cold smoking and drying phase. Source: VWA, 2005

Chemical	Microbiological	Physical
PAH’s	Listeria monocytogenes	Metal
Chloride phenols	Clostridium botulinum	
Fat oxidation products		

2.9.4.6 Lowering the temperature

After smoking the temperature is lowered to 6°C, to prevent bacterial growth and guarantee a longer shelf life.

2.9.4.7 Trimming

In this phase the fins and edges of the belly are removed if the end product needs to be bone free.

Potential hazard in this stage

Table 22: Potential hazards in trimming phase. Source: VWA, 2005

Chemical	Microbiological	Physical
-	-	Metal

2.9.4.8 Tempering

In the tempering phase the salmon is prepared to be cut. Before cutting and packing, the temperature is lowered to 0°C. Another method is quickly freezing to -12°C (immediately further processing) or -20°C (storing).

2.9.4.9 Cutting in slices for consumers

At 0°C, the salmon is cut automatically into slices. Via flow production the slices are transported to the packaging station where the slices are weighed carefully.

Potential hazard in this stage

Table 23: Potential hazards in cutting slices for consumers phase. Source: VWA, 2005

Chemical	Microbiological	Physical
-	-	Metal

2.9.4.10 Packaging

The salmon slices are packed by hand on cardboard and into the packages, and then vacuum-sealed.

Potential hazards in this stage

Table 24: Potential hazards in packaging phase. Source: VWA, 2005

Chemical	Microbiological	Physical
Softeners in packaging material	Clostridium botulinum	-
	Listeria monocytogenes	
	Staphylococcus aureus	
	Salmonella	
	Escherichia coli	
	Enterobacteriaceae	
	Outgrowth of above mentioned bacteria	

2.9.4.11 Storing

The packages are put in cardboard boxes and via shock freezing stored in a freezer at -20^{o}C. Salmon that is cut at a temperature of 0^{o}C is not stored in this way and is stored also at 0^{o}C.

Potential hazard in this stage

Table 25: Potential hazards in storing phase. Source: VWA, 2005

Chemical	Microbiological	Physical
-	With Clostridium botulinum, anaerobe grow-out contamination	-

2.9.4.12 Labelling

This phase can be done immediately after packaging or later in the freezer depending on what is demanded and offered in the market. The labels must contain information where the salmon was produced or caught in the wild. Besides this all additives must be shown. Frozen packages are defrosted during transportation just until they arrive at the retailer. Salmon that is cut at -12^{o}C contains 63-67% moisture and has a shelf life of 14 days just after defrosting. Salmon that is cut at 0^{o}C contains 59-63% moisture and has a shelf life of 21 days.

2.9.4.13 Retail

Monitoring in this phase of the salmon supply chain is done by inspector of the VWA/KvW. They visit every retailer that sells salmon once per year minimal by using a checklist with hygiene codes. When an abnormality is detected, inspection is intensified. In retail smoked salmon is found on marketplaces, fish speciality stores and supermarket chains. Unpacked salmon is mainly found at fish speciality stores. For retail shelf life is very important. Salmon is mainly bought during the second half of the week. It is important that salmon which is not sold during the end of the week can be sold in the beginning of the next week or even longer. Retailers are permitted to sell salmon when they follow the hygiene codes which contain HACCP codes (see further information VWA, 2005). A research carried out by VWA (VWA, 2005) in 2003 and 2004, concluded that shelf life is a bottleneck in the retail phase. Besides this, VWA (2005) found out that Glyroxyl is used in retail to disinfect equipment and possibly used on salmon itself. This development could stimulate retailers for not following hygiene measurements because they use Glyroxyl instead.

2.9.4.14 Consumer

It is expected that consumers do not follow shelf life period instructions strictly. It is known that consumers in most cases do not transport salmon in a cooler. Besides this, consumers often do not eat the salmon in one time. There are few reports of complaints about salmon products. The most popular salmon product is smoked salmon, which can be bought in nearly every supermarket and fish speciality store. Salmon steaks and salmon salad are also popular. In spite of the fact that salmon can be seen as one of the cheaper fish products, Dutch consumption did not increase considerably (VWA, 2005), except for in increase in the demand for fresh salmon, because of the popularity of sushi dishes.

2.10 Conclusions

The study of the farmed salmon supply chain has resulted in following conclusions:

- The farming of salmon is relatively young as an industry (15 years) and has experienced a surge in production figures, a 100 fold increase from 1980 to 2005. Although still a delicacy, salmon has become available for a broader audience partly thanks to the introduction of the (lower priced) farmed salmon.

- Actual import, export and consumption data of salmon are limited. This could suggest that on a national level it is unclear what is the actual size of the Dutch salmon market.

- At the same time the farmed salmon industry has been faced with accusations of non-governmental organisations regarding non-sustainability and non-environmental friendly. The sector has taken these accusations seriously and has improved farming methods, decreased contaminants in salmon feed and introduced GMP, EurepGap and HACCP quality systems.

- The salmon feed industry is facing a radical change from fish based oil to plant based oil, as production of fish oil remains more or less stable, but increased demands for fish oil (Asia) and future applications of fish oil in e.g. nutritional foods (omega-3-fatty acids), are edging towards a competitive market with possible shortages.

- Research has shown that some plant based oils can partly replace fish oil as salmon feed, but oils like rapeseed, linseed and flax are also in demand by other industries (bio fuel). Besides, the quality of the plant based oils is not always controlled and it is unclear to what extend pest residues and heavy metals may pose a risk.

- Incidents mentioned in the Rapid Alert System of Food and Feed, like malachite green and Listeria monocytogenes, make it clear that salmon is not without certain hazards and that the industry should be vigilant at all times.

- Potential hazards in the processing stage of farmed salmon are mainly focused on pathogenic bacteria, biotoxins and chemical contaminants, which are all included in HACCP plans.

3 Indicators for emerging risks, results from interviews

3.1 Introduction

Based on the results of the parallel projects (Achterbosch, 2007) the conclusion was drawn that three areas play an essential role concerning food quality and food safety in the food chain. These are: perception, operations and behaviour. How do companies perceive food safety risks, what do they actually do about it (e.g. quality systems), what can we say about their behaviour (what are their drives) including how do companies communicate and interact with their business partners? These are questions that need to be raised when we want to detect actual and potential food risks. However, if we want to design an emerging risk identification system we not only need to focus on the food chain itself, but also on the so-called influential sectors. This is the host environment of the food supply chain regarding emerging risks (see figure 9). Changes in this host environment can cause risks for the food chain.

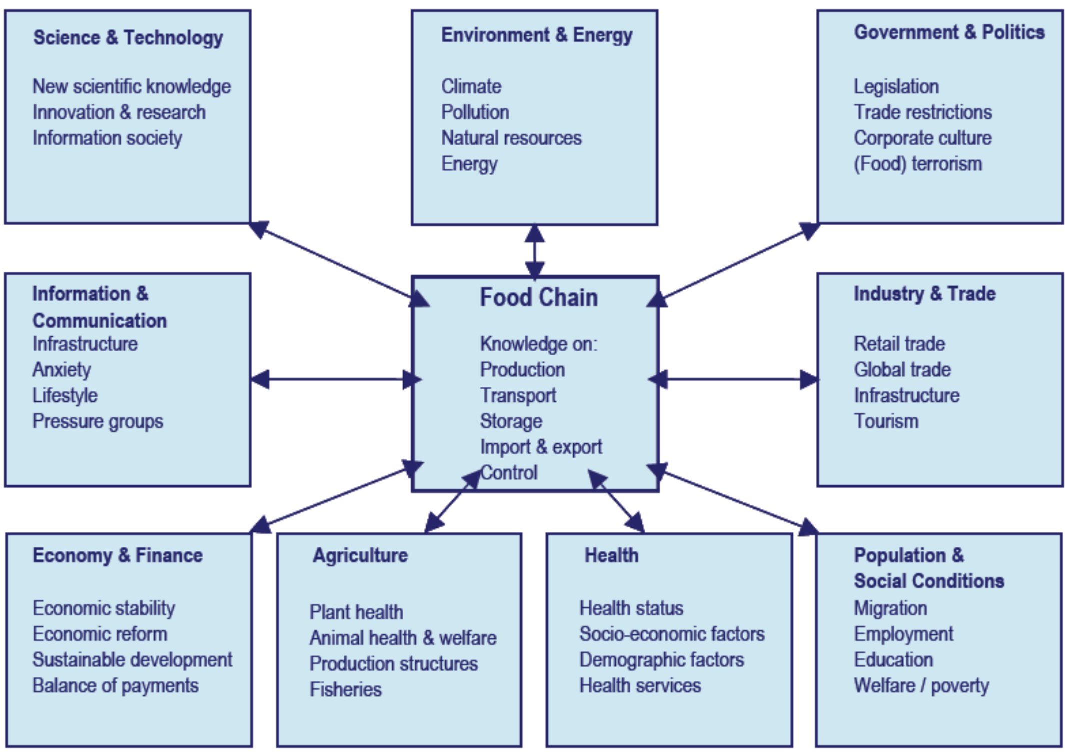


Figure 9: The new arrangement of influential sectors in the host environment of the food supply chain regarding emerging risks (Source: Noteborn, 2006)

In this chapter we will address (emerging) food safety issues in both the food chain and its host environment (the influential sectors). In order to narrow down the scope of the research, we focus on one specific food chain: the farmed salmon supply chain and more specifically the salmon feed chain (see for a broad description chapter two). We focus on the Netherlands, but since the salmon supply chain is global, we cannot ignore international aspects. Besides, food safety is an issue that concerns the whole food chain and not only the final stages of the production process. In order to obtain information about the salmon supply chain and its host environment we studied relevant literature (see chapter two) and we conducted interviews with 18 experts. These experts are people working for companies within the salmon supply chain (both in the Netherlands and in Norway) and experts that are closely related to the salmon supply chain, such as a bank, the Netherlands Nutrition Centre and a scientist (see annex 2 for the entire list of interviewees). In this chapter we discuss the results of the interviews. We first deal with the four defined areas. Then we make some general remarks about the interviews and show which indicators could be distilled from the interviews. Finally we draw some conclusions.

3.2 Three important areas within the salmon supply and salmon feed chain

3.2.1 Perception

Controlling food safety and food quality is important for companies. Not every company has the same quality standard. This also depends on the customers they focus on (and the other way around; you get the customers you deserve). Lower quality can lead to a lower price. From the interviews we learned that food safety (quality) is an issue that had the focus of companies for many years, especially after a couple of incidents had happened. Today's focus has however slightly changed towards sustainability and ethical issues (animal welfare, ecological footprints, GMO etc.). This can have an impact on safety aspects as well. When more sustainable raw materials are being sought, e.g. slaughter methods change, animals are being fed differently, GMO is used etc., the whole process changes. Perceptions play an important role in when it comes to food safety and the actual behaviour towards it. When situations are not perceived as risky, people are not likely to respond to it. Perceptions are not necessarily based on facts, thus highly subjective and difficult to influence.

Consumers tend to perceive the information conveyed by companies being highly subjective. A negative image is build up easily when the salmon industry does not communicate well with its customers. This can result in a situation where minor incidents can have a severe impact on the salmon industry. Companies are not pleased with this development. An example is the use of antibiotics. In Norway, the use of antibiotics in salmon has decreased dramatically (by 95%) in the last decade as a result of the development of vaccines (Nifes, 2003). However, the majority of the consumers is not aware of this and still believes antibiotics are heavily used by the industry. The same accounts for the level of dioxin in fish feed. The maximum level in the EU is 2.25 ng, while in Norway feed is produced that does not exceed the level of 0.5 ng. It is very unfortunate that the public at large still believed that fish contains high levels of dioxin.
Furthermore, eating fish has a healthy image; this possibly can outweigh these incidents. A lot of risk-benefit research is done at the moment.

3.2.2 Operations

As mentioned before, the companies we visited have implemented a food quality/food risk controlling system. They often claim to be more rigorously than they ought to be with respect to EU regulations. "Just to be on the safe side" it is claimed, for now and for the future when norms are possibly revised. The salmon sector is becoming more and more a global market, with respect to production, obtaining raw materials, processing stages, transport and consumption. However regulations vary between countries due to various systems in different parts of the world, but also within for example EU countries. The role of local habitats, perceptions towards health risks and food safety (GMO, vegetable proteins) cultural variations, control and inspection, different languages, corruption and political forces don't need to be underestimated. A problem which was already identified in the VWA report is that inspections in Dutch harbours or airports are perceived as more strict and therefore are more time consuming than in other countries. This has resulted in the situation that other locations are being sought (e.g. in Antwerp). To overcome this, Dutch companies can try to improve efficiency for instance by using electronic measurement devices (smart boxes) and computerised forms. Furthermore, some countries, which have a high consumption of salmon, can use their position to either reject or tolerate certain (raw) materials or whole fish from abroad. This can jeopardize human or environmental health.

3.2.3 Behaviour

Larger companies appear to be more in control and often have the power to enforce specific demands on food quality and safety. A strategy can be to integrate (for instance buying up) with (production) companies in order to increase power and control over the process. Or large companies can demand high quality of inputs by using their market power.

The companies we talked to, all have their own quality systems. However the question is, how the quality/food safety system is functioning in a daily routine. For instance, do companies sometimes need to make a decision which is not according to regulations? Costs often can be an important factor in the decision process. Another factor is trust: companies work with other companies they perceive to be trustworthy. Relationships between business partners last long and mistakes are easily forgiven for the sake of the relationship. Furthermore, within the company employees have different goals. Some are concerned with prices; quality etc. and others are more concerned with keeping relationships with business partners and for example sustainability issues.

A dilemma companies can face is the fact some salmon species are not yet farmed or caught under sustainable circumstances. Also food safety for some species is less clear than for others (e.g. tropical species like shrimps). However, when companies decide to quite selling these products they can risk losing clients when other companies still offer the products. Besides this, these species can be a cheap alternative for other more expensive and sustainable produced species.

The internal communication (within the salmon supply and salmon feed chain) is rather clear in the companies we spoke with. Partnerships last for a long time (sometimes more than 20 years) and the food chain is rather short (companies import directly from farms in Norway and Scotland). Due to an increase in the use of vegetable oils for the salmon diet, the traditional market has changed. Peru, Denmark, Chile, Iceland and Norway used to be the main countries which provided the ingredients for the salmon feed (anchovy and blue whiting). Furthermore, due to the shortage of marine oils and the higher prizes, other (vegetable) raw materials are being sought in other countries. This can lead to different international communication patterns.

The external communication is perceived to be difficult, as the message send out by NGO's has a stronger influence on the information that reaches the public than the communication from companies.

3.3 Indicators

In this paragraph we describe the indicators we derived by analysing the interviews (and the literature). Indicators can be defined as an entity that indicates (or is actually, direct or indirect, related to) the possibility of the occurrence of an emerging risk (Noteborn, 2006). In the tables of this paragraph the indicators are divided into on the one hand indicators that concern the food chain itself and on the other hand indicators that can be found in the influential sectors. The salmon feed case study (the so-called preliminary proof of principle) is being dealt with separately. In the column with the heading “background” some explanations and examples are given to explain and describe what the holistic effects can be. Of course, other (side or indirect) effects can occur which are not mentioned. This however, illustrates the difficulty of the use of an effective holistic and pro-active food safety system.

Indicators related to the food chain

Indicator	Background
Quality of the management and other personnel Background Education Transparency	The quality of the management can be an important indicator for the way the company handles food safety issues. This can mean that employees can have different cultures (e.g. cultural difference about hygiene). Educational level can be different. Clear communication between employees.
Number of people within the company responsible for food quality and food safety (related to the size of the company)	Sometimes companies have one or more persons responsible for food safety. If they have sufficient time they can perform regular checks/audits. Sometimes they have also other tasks within the company, which can affect their time availability and objectivity with regard to food safety.
Quality system within the company	A company that does not have the quality food safety electronic controlling system or a food quality/safety protocol on paper, can have less control on the production process and can cause risks. Besides this any risk occurring further along the chain can not be fully tracked and traced.
Registered or unregistered company	If unregistered companies still exist, products from these companies are maybe difficult to control according to food safety regulations.
Size of the company	The size of companies can affect power/control over the production processes and thus lower health risks. They can do this by hiring educated personnel that focus solely food safety and quality. Also larger companies can demand higher quality of inputs because by using its market power.
Processing techniques	For example, cold smoked salmon appears to be more sensitive for Listeria contamination than hot smoked salmon.

Product care with disinfectants	Increased use of disinfectants for example peroxides, sulphite and glyroxil, etc. can increase food safety hazards. Furthermore, increase focus on disinfecting food can decrease the focus on basic hygiene protocols and management.
Fresh or frozen fish	It appears that fresh fish is easier to trace than frozen fish (in supermarkets). A reason for this is, frozen products are less perishable and therefore the supply chain can be longer.
Safe and riskier species, countries, production methods	Some species seem to have a higher food safety risk (for instance butter fish). Besides this a producing country can be risk for instance because of certain production methods (Pangasius), processing techniques, transport, insufficient regulations (for instance Africa).
Recirculation systems or open sea farming	Closed recirculation systems can be better monitored than farms at open sea
Number of regular inspections (and sanctions!) from the Food and Consumer Product Safety Authority (VWA)	Companies, who receive inspections more frequently and structural, are probably more aware of food safety hazards. Compliance increases when violations are sanctioned right away.
Number of suppliers raw materials vegetable oils	With the change to vegetable based oils, more suppliers worldwide are needed compared with well known fish oil suppliers, more attention to possible hazards and audits
Number of customer complains concerning food safety	Companies can monitor complaints concerning food safety issues of the products sold to customers
Wild catch or farmed fish	Farmed fish can be traced more easily when the total production process and related inputs are fully transparent and traceable.
Shelf life of the product	The longer the product can be stored, the more transformations the product has experienced
Years of experience with farming the particular fish	With the farming of some species, there is a broad range of experience. Some species are rather new and effects are less known.
Value adding to products by processing, etc	For instance by adding supplements to products This can increase handling of the product during processing. Besides this, the supplement itself needs to be monitored and the effects of supplements to the salmon need to be monitored. Product type as a result of processing. For instance fresh salmon in sushi can increase the risk of food safety hazards.

Indicators related to the influential sectors:

Environment and Energy

Indicator	Background
Origin of the caught or farmed species (area)	Some seas/areas have higher contamination scores than others, e.g. the Baltic Sea
Fish farms can influence the environment negatively (over fertilisation, nitrogen's and minerals)	Due to food and manure residues. Companies can reduce this effect by better production management, equipment and innovation.
Number of escapes from farmed fish out of the cages	Fish escaped from farms can influence wild species. Due to the diet and the faster growth, DNA or brain structure can change. Effects on human health are not known
Frequency of fish diseases	Condition of fish is important. If fish have a bad condition they can be more easily susceptible to pathogens
Flame retardants, PCBs	The level of these contaminants can be a result of feed management and the surrounding environment of the production site. These contaminants accumulate in fatty tissue
Radio-activity	Russian nuclear weapons on the bottom of the ocean can effect the level of radio activity in that area
Oil market	The demand for bio diesel fuels for other purposes than salmon production can drive up the price of vegetable oil. Which means use of vegetable oils become to expensive for salmon production

Economy and Finance

Indicator	Background
Price increases of the stock	Due to a shortage and high demand for marine oils and proteins, prices have increased. Fish feed companies can look for alternatives such as vegetable originated inputs.
Speculating on the market	Speculating on the salmon market can increase price fluctuations. Low margins on prices can have an effect on quality and food safety
Organization of the supply chain	The amount or size of salmon price mark-ups in the supply chain (e.g. a lot of chain parties or a few dominant chain parties) can put pressure on quality and food safety levels. When profit margins in salmon decrease this can have a bad effect on food safety. Due to fixed supermarket prices and higher costs/lower margins in production or processing stages some companies increase volumes by adding water and protein. The added product can be unknown and cause a risk.
Consolidation of companies	Companies in the salmon supply chain or salmon feed chain are merging. In this way they are more in control themselves, but also have a more internal focus: Less learning and criticism from other companies (although attention from NGO's will increase)
Market stability	Big price fluctuations can have a bad effect on food safety due to uncertainty of investments. For instance investment in a food safety monitoring system.
Higher demand for salmon and higher production costs	Producers can focus on bulk production and efficiency and less on quality and food safety.
Higher transportation costs	This can increase feed prices and increase demand for vegetable oils.

Science and Technology

Indicator	Background
Level of innovation within the company	Amount of research done within the company/supply chain. Some companies have their own R&D division or work closely with research institutes. Risks can be detected sooner and new innovations can be used.
Amount of scientific or other research done on the subject of emerging risks within a specific country	If not much research is done related to food safety, hazards are detected less quickly
Regulations on new innovations	For instance: new innovations like new medicines or use of GMOs can have an effect on food safety.

Information and Communication

Indicator	Background
Increased demand for new species or new product combinations	New species can be a higher risk, because of the less developed awareness and experience about these species. New product trends such as sushi, filet americain, carpaccio, tapas can have a higher food safety risk
Consumer perceptions regarding food safety in fish	The way of communicating to consumers can have an effect on food safety. Focussing on dioxin hazards in salmon, can increase consumption of other "less" controlled alternatives.
Consumer knowledge of food preparation, storage and hygiene (fish)	The level of knowledge about food preparation and storing (cooling) has an effect on food safety. Consumers can make basic mistakes in storing (too long) or preparing fish (dirty equipment). Companies can prevent this by putting this type of information on their labels
Increased demand for fish products	High demand can attract new companies to the market as a result of higher profit. The increase of trade can decrease transparency. Increase of demand can drive up salmon prices and maybe gives a chance for new and cheaper substitutes which have a higher food safety risk. For example Pangasius and tilapia could be a substitute for cod
Increased demand for convenience food	Consumers want products that are easy to prepare and are less time consuming. A trend is to eat more processed fish (pieces) instead of the entire fish. Fish can also be bought at other than the traditional selling points: supermarkets. Easy to prepare food often needs more processing. This can mean a higher possible risk

Increased demand for sustainable fish and animal friendly farmed/caught fish	Sustainability and food safety/quality do not necessarily go together. Focus on animal welfare (e.g. ecological salmon production) can affect focus on food safety.
Increased demand for nutritional/functional foods	If demand for fish oil increases as a result of higher demand as an ingredient for baby milk powder, fish oil prices can rise and effect salmon food safety
Availability of data	Insufficient, difficult availability, fragmented or expensive production, import and export data makes the market less transparent and in turn it is difficult to detect food safety hazards.

Agriculture

Indicator	Background
Contaminants in vegetable salmon feed ingredients	The use of vegetable ingredient can increase the risk of contaminants such as nitrite, pesticides that effect salmon.
Use of agricultural ingredient for fish production is relatively new	This means companies have less experience if a food hazard would occur, as a result of agricultural products.
Increased demand for bio diesel fuels	As mentioned before, this can effect salmon production. However, by-products from vegetable oil production can become interesting for salmon feed production.

Industry and Trade

Indicator	Background
Labour costs and availability of raw materials. Transportation costs	This development leads to globalisation of the industry. Search for cheaper labour e.g. salmon processing in China for the Dutch consumer market. Possibly different perceptions towards food safety and health risks. The duration of the transport of fish from egg to shelve can take longer which also can cause risks
The use of technology during transports	The temperature during transport can show variations. By using smart boxes the temperature can be measured during every stage
Harbour or main port that is used to distribute the fish	Strict rules can increase import via other, less strict harbours. Intensifying regulation can therefore have an adverse effect. For example, Schiphol can have strict regulation on fish imports in relation to inspections in other import/export harbours. Therefore other supply channels are being sought.

Upcoming markets	Some countries have upcoming markets, for example Asia (e.g. China) as a rising fish production, processing and trading economy. These new supply trade routes require monitoring and regulating to control and minimize food safety hazards.

Health

Indicator	Background
New species or new product combinations	Less experience with new species or products can increase food safety risks.
Quality of research concerning "healthy" fish products	Omega 3 fatty acids seem to be healthy. Research on the effects has only just started.

Government and Politics

Indicator	Background
Differences in perceptions regarding food safety risks	Differences in perception regarding food safety risks cause variations in regulations and variations in implementation of these regulations between countries within EU and between EU and third countries (Chile seems to have a open and transparent economy however appears to have less strict rules on antibiotics use). This can lead to risks for other countries were the development is perceived as a risk.
Power and inequalities	Some countries with high consumption/import of salmon or export raw materials for fish feed have power to either reject or trust imports

Population and Social Conditions

Indicator	Background
Welfare of producing country	A less developed producing country can have less strict regulations and controls in relation to more developed importing countries
Consumer profile	For instance consumers can be old which means higher health risks. Consumers can be less educated or can have less buying power, which means they can have a different perception towards food preparations, storage or hygiene

3.4 Emerging risks in the aqua feed chain

Farmed fish is dependent on a healthy diet to develop correctly, and it needs variation depending on its size. In general fish feed consists of fishmeal, fish oil, minerals, fibres and vitamins. To grow one kg, a farmed salmon needs approximately one kg of feed. Chicken and pig have an unfavourable conversion rate and need respectively approximately two and three kg feed (Aquaculture in Norway, 2005). In this paragraph the implications of the present situation of the fish oil market and the change to vegetable based oil as well as other alternatives are discussed.

3.4.1 Present situation of fish oils

Fish oils originate from Peru, Denmark, Chile, Iceland and Norway (see table 26). From 2000 - 2004, fish oil production declined in all main producing countries with the exception of Iceland. The 2005 production estimate is about 570,000 tonnes in the five main exporting countries, a 12% decline from the 650,000 tonnes produced in 2004. Peru continues to be the main fish oil producer worldwide, with about a quarter of total fish oil production.

Table 26: Fish oil production (x 1000 tonnes) in 5 main exporting countries (source: Globefish, 2006)

Fish oil production in 5 main exporting countries

	2000	2001	2002	2003	2004	2005
Peru	593	304	193	208	352	290
Denmark	137	146	105	109	67	72
Chile	171	143	146	130	142	122
Iceland	95	108	80	92	49	55
Norway	83	66	62	51	37	31
Total (5)	**1079**	**767**	**586**	**590**	**647**	**570**

Fish oil prices showed strength, especially when compared with soy oil prices (see figure 10). In the opening months of 2006, fish oil prices were US$ 750/tonne, exceeding those of the competing vegetable oil by US$ 200/tonne or 40%. This differential seems to be bound to even widen further in the near future. Fish oil experiences strong demand by the aquaculture industry, where it is essential in the diet of carnivorous species. The present high prices have scared away traditional users of fish oil, especially in the European margarine industry.

Fish oil production is likely to decline even further in 2006. Peruvian catches will be low in the opening months of 2006. In the first 6 weeks of 2006, some 310,000 tonnes of fish for reduction were caught, 60,000 tonnes more than in the same period of 2005. However the full opening of the catch season is postponed until late March 2006 due to the progression of spawning. Catches are much lower in Iceland, after the 2005 capelin boom. In the first six weeks of 2006, some 36,000 tonnes were landed, down from 320,000 tonnes during the same period 2005. Norway reported higher blue whiting landings than in 2005. However, the overall prospects are for reduced fish oil production in 2006, and exporters are expecting further price increases (Globefish Helga Josupeit, 2006).

One of the characteristics of salmon is the red colour, which is caused by a substance, called astaxanthin that the fish absorbs when it eats small crustaceans in the ocean (Aquaculture in Norway, 2005). Astaxanthin is also synthetically produced and is the most widely used colorant in the salmon industry. No negative effects have been described in clinical trials on dietary astaxanthin (Nifes, 2003). Colorant however, is also expensive, it accounts for 25% of the total feed costs.

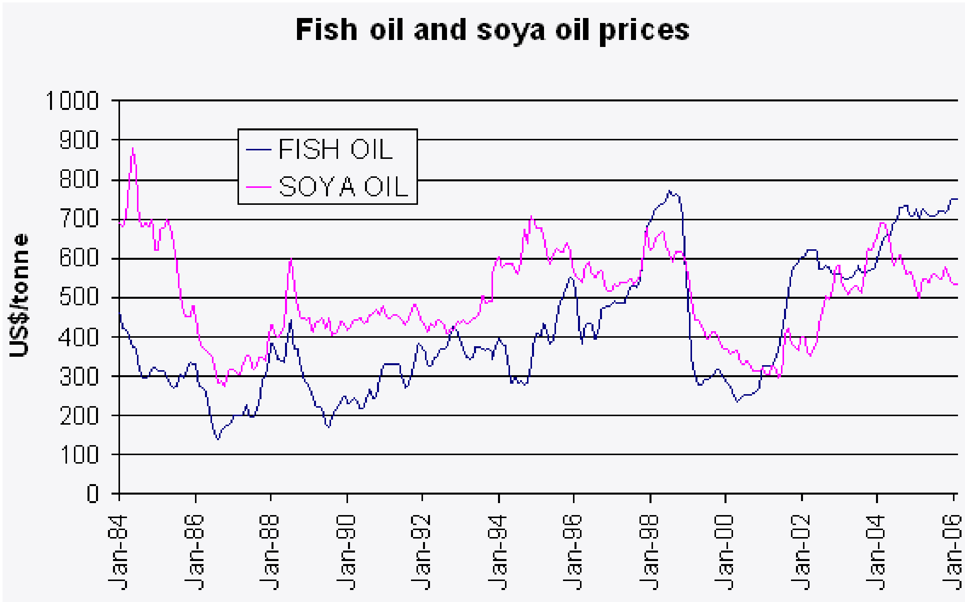


Figure 10: Fish oil and soya oil prices (source: Globefish, 2006)

3.4.2 *Risk benefit of aqua feed*

Risk benefit research looks for balance of positive and negative effects of feed. One of the results of this research is for example that the fatty acids DHA in farmed salmon have a stronger effect than dioxin. On the website of National Institute of Nutrition and Seafood Research (NIFES) in Bergen Norway, a search can be carried out to find undesirable contaminants and their respective data sources. Monitoring at NIFES includes effects on trends. A new EU 6th Framework Project (FP 6) called Aquamax, has the objective of aiming for sustainable aqua feed to maximise the health benefits of farmed fish for consumers. Besides being very beneficial for consumers' health, seafood also can contain undesirable substances.

Mayor challenges of production of safe and healthy seafood in the years ahead are:
- Shortage of marine resources
- Balance of nutrients and contaminants
- Sustainability of feed resources
- Scientific documentation in the whole fish production chain

So the expansion of fish farming requires the development of sustainable feed, which is the main objective of the Aquamax project.

The objectives of Aquamax are:
- To develop feeds based on sustainable alternatives to fish meal and fish oil to produce healthy and minimally contaminated fish that are highly nutritious and acceptable to consumers.
- To assess health benefits of fish produced on new feeds.
- To assess the safety of fish farmed on the new feeds. (effects of contaminants on gene expression in farmed fish)
- To assess consumer perception of farmed fish fed with new diets.

Also the question of "why do positive aspects seen to outweigh the risks in balanced risk assessment?" will be assessed in as much as investigate how the positives interact with the negatives sides.

3.4.3 *Change to vegetable oils*

The shortage and subsequently higher prices of marine oils have stimulated the use of other oils in the fish feed, such as vegetable oils. In recent years, more and more vegetable raw materials from agriculture are used, such as rape-seed oils (Aquaculture in Norway, 2005).
The feed accounts for almost halve of the fish-farmer's operating expenses. So, farmers are searching for ways to use the feed as efficiently as possible.
Replacement of fish oil by vegetable oil has got much attention both on its effects on fish quality and human health as well as the effects on contamination with persistent organic pollutants. Traditionally fish diseases and related factors have been extensively studied though the particular role of vegetable replacements is not studied in particular.
The impact of replacement from fish to vegetable oils on the environment is partly known. At least the decreasing demand of sea-born feed ingredients is considered to be more sustainable.

The transition from fish oil based production to more plant oil based production is absolutely necessary and will continue. However, there are potential risks that new unexpected contaminations such as pesticides or heavy metals may cause new risks. The transparency and traceability of new food ingredients will become more important. Currently some eastern European and Asian countries are considered as potential risk areas.
The role of omega 3 fatty acids and health aspects of salmon will limit the replacements in salmon feed. All quality aspects will be of primary importance in maintaining market shares.
Rape-seed oils are a good substitute for marine oils, better than soya oil. This is due to the higher level of omega 3. However, the market for vegetable oils like rape-seed oil is a highly competitive one. Other industries like the bio diesel industry have shown their interest as well. So possibly in the future the salmon industry has to look out for other (inferior) oils.
With regard to GMO in aqua feed of vegetable based oil, there are no negative effects on the fish health and quality of the fillets. Research at NIFES has shown that GMOs do not have any effect on the oil content and no transgenic changes in the muscle are observed.
More plant based feed (carbon hydrates) may have impact on fish health but there is no indication that this is occurring in present systems.
Management and monitoring systems are available and improved continuously in the fish farm industry. Also the origin of plant based feeding ingredients will be registered under the new regulations. It is expected that integrated control of pests and diseases will be the standard for future agriculture worldwide. Nowadays, however, pesticide input varies greatly all over the world. Therefore strict regulations and monitoring are needed.

3.4.4 *Krill an alternative aqua feed*

A lot of research is done on fish feed and its content in Norway, and in recent years this has opened the way to use of alternative raw materials without a reduction in quality and health effects of the farmed fish. It is obvious that due to the increase in salmon production and the declining marine oil production alternatives are being sought. But, the search for cheap alternative raw materials other then the traditional marine oils can pose a risk on the industry. The use of raw materials from agriculture changes the fish feed market and can have negative side effects in relation to food safety issues. This possibly depends on the country where it is grown, levels of environmental pollution in the area, presence of contaminants in the resource and the difficulty of finding non-GMO vegetable raw materials.

Besides vegetable oils, the use of other animal oils, such as offal (blood products from pigs) are another option and already used outside the European Union.
In the meantime, Norway is looking for cheaper alternatives to fishmeal from small pelagic, and is investing a lot in developing its fishmeal industry from krill. Norway is set to substantially increase production of krill for farming feed. Krill are shrimp-like marine invertebrate animals, near the bottom of the food chain in the worlds' oceans.
In the Antarctic it is estimated some hundreds of million tonnes is present. About half of this amount is consumed by sea mammals etc. A mere 100,000 tonnes is being caught each year for among others aquaculture. Krill also contains red pigment. Krill meal is already on the market, but at a high price. The negative side of krill is the presence of a high amount of fluorides in their exoskeleton, which can be toxic to humans and animals. In the pharmacy world krill tablets are available, but for mass-consumption and commercially prepared products, krill must be peeled. The survival of krill is very delicate, as disturbances of the ecosystem can result in a sharp decline of the krill population. During a coccolithophore bloom in the Bering Sea in 1998 (Weier, 1999), for instance, the diatom concentration dropped in the affected area. However, krill cannot feed on the smaller coccolithophore, and consequently, the krill population in that region declined sharply. This in turn affected other species: the shearwater population dropped, and the incident was even thought to have been a reason for salmon not returning to the rivers of western Alaska in that season (Brodeur, 1998).

According to Nicol and Foster (2003) there is continuing commercial interest in products derived from krill. An examination of patent databases indicates that the development of products for human consumption has been overtaken by the development for aquaculture, pharmaceutical and medical products. The development of products for aquaculture is most likely to be the factor that will drive growth in the krill fishing industry. The great scope of expansion of a krill fishery in the Antarctic has been anticipated by the imposition of precautionary catch regimes to ensure that ecological effects are minimized and the overcapitalization in the industry is prevented. Management of the Antarctic krill fishery has proceeded in advance of expansion and precautionary catch limits for Antarctic krill currently targeted at a total of 4,89 million tonnes (50 times the existing harvesting level). The growing demand for marine oils and for aquaculture feed will mean that the Antarctic krill will continue to be in the picture.

Vanuatu (an island group off the East coast of Australia) made clear its intention to enter into krill fishery at the 24th Annual Meeting of the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) which ended in Tasmania on 3rd November 2005. Vanuatu intends to make a formal application to CCAMLR at its next annual meeting for permission to operate five fishing vessels, including an 8.000-tonne vessel, in the Convention area. Its overall catch could exceed 300,000 tonnes. The five vessels will be managed by Norway, meaning that the country will increase to more than double the catch of krill from its current quota of 200,000 tonnes. The rising fishmeal price on a global scale is in the background of the Norwegian move to increase production of krill. Japan's catch, as applied to CCAMLR for next year, will be 30,000 tonnes, and that of the Republic of Korea, 45,000 tonnes. The CCAMLR has adopted precautionary levels for krill fishing, expecting a rapid expansion (Globefish, 2006).

3.5 Conclusions

The search for indicators for emerging risks within the farmed salmon production and feed chain has resulted in some concluding remarks:

- In order to focus on the environment of the interviews four areas are of great importance. These areas are: perception, behaviour, implementation and communication.
  The perception of the companies regarding food safety and quality has changed more towards sustainability and ethical issues, which may have a certain impact on emerging risks.
  The behaviour of the companies depends partly on their strategy. Other important factors that influence their drives are costs, trust, quality and possible dilemmas they encounter.
  The implementation of control systems much be viewed within the perspectives of the global market of salmon food and feed.
  The communication of the companies is based on long lasting partnerships between them. External communication with NGOs and consumers is perceived to be difficult at times, as the information from the companies is often interpreted as being subjective.

- The indicators related to the salmon production chain highlight the close ties between companies within the sector and the standard of quality and safety they pursue. The indicators related to the influential sectors show the interdependence of the companies to the host environment. The environment and sustainability as well as ethical aspects play an important role in its effects on the companies' performance. Increased demands for fish and its health claims have profound effects on aquaculture and how the consumers are informed.

- The production of one of the mayor feed items, fish oil, is declining and the demand for fish is ever increasing. This shortage and subsequent high prices of fish oil have stimulated the use of vegetable oils as a feed ingredient. However, new unexpected contaminations in vegetable oils such as pesticides or heavy metals may cause new emerging risks. Also the role of omega 3 fatty acids and health aspects of salmon may limit the replacements in salmon feed.

- Krill has been under investigation, and is indeed already used, as a serious alternative as a feed ingredient for aquaculture. The amounts available are gigantic (hundreds of million tonnes) and it contains the natural red pigment astaxanthin. However large scale exploitation may prove costly in many aspects, as the krill is the sole food source for many sea animals and the survival of krill is very delicate in relation to any changes in the ecosystem. So again in view of sustainability a hard nut to crack.

4 Data sources

4.1 Introduction

The study of VWA on emerging risks defines two different systems with regard to risks: primary (known risks) and secondary (unknown risks).
This project/case study on salmon is performed with focus on the secondary system with the following definition: ‘use a combination of information derived from indicators that are situated in the host environment of the food supply chain, but all having a direct or indirect influence on the safety of the chain. These secondary systems use the indicators from different influential sectors of the host environment to understand how, when and where the likelihood of a risk may emerge. In the end it is expected that the proximity of their influence on the food chain will determine how strong or weak the link with the safety of the food or feed chain is. This so called holistic view of the risk assessment allows recognition of the presence of an emerging hazard and should help to enable timely assessment of its risk to human or animal health (Noteborn, 2006).
Within this chapter (see table 27) a list of indicators, cause and effects and data sources relevant for the salmon case is presented, to show the relationship between the factors. Including in this table a column is added for an expert (qualitative) classification (ranking) of each data source on reliability (to be executed in the follow up project in 2007).

4.2 Inventory of data sources

In Annex 3 a list of indicators is given as mentioned in report of VWA EMRISK project in Annex 5 (Noteborn, 2006). The table in annex 3 shows the possible links with the farmed salmon production, including examples of relevant data sources. In the follow up project the indicator and data source listing will be extended.
Identified data sources can be classified into categories. This makes it possible to qualify the reliability of the data source. Data sources will provide identified indicators to be used to determine the value and trends (i.e. behaviour of these indicators in time) of the indicators and to translate the value and trends towards a signal.

Categorized data sources (not extensive examples of) for the farmed salmon chain are:

Expert networks (selection of highly innovative participants):

EFARO European fisheries and Aquaculture Research Organization. Directors of the main European Research Institute involved in the Fisheries and Aquaculture research and the Directorate General "Fish" of the European Union.
“rondetafel groep” in Netherlands including commercial companies and other organizations.

Stakeholders (Commercial companies involved in seafood and feed production):

Nutreco, world leader in R&D of farmed fish and fish feed production.
Marine Harvest, innovative salmon production company in Norway.
Skretting and EWOS, two leading fish feed production companies in Norway

Scientific panels (research organisations):

West European Fish Technology Organisation (WEFTA),

Norwegian Research council. The Research Council of Norway is a national strategic body and funding agency for research and innovation activities. It covers all fields of research and innovation and works together with research institutions as well as the private and public sectors to reach the national financial goals and quality targets set in this area.

ICES (international council for exploration of the sea, the organisation that coordinates and promotes marine research in the North Atlantic.)

Public information (news, interviews, magazines):

Applied journals,
Food science and technology abstracts,

Consumer concerns (consumer behaviour, trends):

USA Consumer Sentinel,
UK office Fair Trade Statistics,
GFK statistics,
LEI socio economic data.

Conferences and symposia (combining expert networks and scientific panels):

Aquaculture Europe,
Brussel Seafood Exhibition,
Aquanor Trondheim,
World aquaculture.

NGO organizations:

Greenpeace,
Stichting Noordzee,
WWF
The Bellona Foundation (multi-disciplinary international environmental NGO based in Oslo, Norway.)

Governmental sources: food safety and control:

FDA,
EU Food and Veterinary Office,
EU Rapid Alert System for Food and Feed,
VWA

Other organisations:

Production boards (PVis),
FAO (The Food and Agriculture Organization of the United Nations leads international efforts to defeat hunger.)
WHO (The World Health Organization is the United Nations specialized agency for health.),
Marine Stewardship Council

These data sources provide either regular (yearly reports, statistics), once (news items) or irregular (workshops) information (data).

4.2.1 Indicators in relation to data source

In table 27 a selection of indicators, as mentioned in chapter 3, is listed. The indicators represent a set of possibilities in terms of what can be measured. For those indicators where this is useful specific data sources are added in order to further characterise these indicators. So the information from the data sources will determine the value and trend of the indicator. In the EMRISK project (Noteborn, 2006) a list of criteria was drawn up to be used for the ranking system of the indicators. The ranking system will be part of the follow up project planned for 2007.

Once the indicators are ranked and have a qualitative or quantitative value they can be translated towards a signal. The signal can imply food risks in several ways (cause and effect or risk pathway). In order to get insight in which chains are involved and where the risks take place geographically, the risk pathways need to be projected on production chain knowledge. This will also be done in a separate project in the year 2007 in an emerging risk detection support system.

*Table 27: Identification of some indicators for salmon production chain including specific data sources. * Ranking of indicators will be executed in follow up project in 2007*

Indicator	Cause and effect	Specific data source for indicator	Ranking of indicators*
Increase in production	Increase in production → increasing disease pressure → antibiotic use → health risk	FAO (world salmon production) Eurostat (European salmon production)	
Decreasing wild fish stocks	Decrease wild stocks for fish feed production → more expensive fish feed → replacement of fish oil and fish meal by cheaper vegetable protein and oil	ICES, FAO	
Replacement of fish protein and oil with vegetable sources	Replacement of fish oil and fish meal by cheaper vegetable protein and oil → production in other countries with other regulations and control systems. → increased use of antibiotics, genetically modified vegetables → unknown effects on fish growth, fish health, fish composition.	World trade organisation	
Fatty acid composition of fish	Fatty acid composition of final product (reduced omega 3 levels) → reduced health benefits for consumer	Research organizations like WEFTA and Norwegian research council	

New developed chemicals for modern technology	Flame retardant production → used in modern technology → disposed → environmental contamination → accumulation in fish → health risk.	Research organizations (UVA)	
Consumer trends towards natural and fresh seafood products	Natural and fresh seafood products → long shelf life demanded → development of mild conservation techniques → unknown resistant micro organisms → health risk.	Consumer organizations, World trade organisation	

4.3 Qualitative remarks on data sources

The reliability of a data source needs to be ranked as well as the importance of the data source (this is not the same as importance of the data itself!). With this ranking it must be taken into account that a low reliability (data from commercial companies) can be of high importance (highly innovative new trends). Highly reliable data (research organisations) is less aggressive but even though of high importance.

In next phase of the project it is foreseen that a ranking of the data sources can be reached, based on classification norms set by a 'holistic' expert working group with knowledge of different influential sectors. Supported by the model with risk pathway and reliability ranking the food safety expert will be eased in making decisions on what measures should take place and where to prevent the emerging of food safety risks.

4.4 Conclusions

The search for data sources has resulted in some conclusions:

- Data sources will provide identified indicators to be used and to determine the value and trends of these indicators. These data sources are not confined to only websites and statistical data or scientific reports. It appears that results of meetings, conferences and symposia of organisations in the host environment as well as governmental organisations play an important role in the support of indicators.
- The key issue dealing with data sources of any kind is to establish the reliability of the source as indicators for emerging risks are numerous and high in variability. Therefore it is imperative that a group of experts, representing all influential sectors, screen these data sources and rank them for reliability. In turn this information will be input for a model structuring the risk pathway.
- In the course of this project the indicators of the salmon production chain have been established and relevant data sources have been found. However the ranking needs to be executed by experts in the follow up project. Also the link with the yet to be developed model will be established at the same time.

5 Discussion and recommendations

5.1 Indicators as input for identifying emerging risk

One of main challenges of identifying emerging risk is to define and substantiate proper indicators. In the synthesis project of the emerging risk study Achterbosch et al (2007) point at both the technical and behavioural aspects of indicators and their possible undesirable human or societal impact on risks. In order to ensure that stakeholder perception with respect to emerging risks are recognized, Achterbosch et al (2007) propose to consider broadening the working definition of emerging risks to the following:

"An emerging risk is a potential food or feed borne or diet-related hazard that may become a societal risk in the (near) future."

The indicators that relate to the technical aspects both within the aquaculture production chain and its host environment are described in underlying report. The volume growth in the aquaculture in general and in the farmed salmon sector in particular, is apparent. With new emerging markets and pressure on the existing companies to keep up with rising demands on quality and safety, increased investments and ingenuity are needed.

Beside this, the recent challenge which companies in the salmon sector face is the investment to improve on sustainability and ethics. In the interviews it seemed that discussions on sustainability and to lesser extent ethics prevailed over food safety issues.

In particular, the position of fish oil as main ingredient of aqua feed is under pressure. A substitute for fish oil is found in vegetable based oil. As long as all technical indicators of risk are known and contained, and the omega 3 fatty acids are still present, this substitute appears to be in order. However, some other questions are raised, as yet more vegetative material is used for animal feed and some oils are in direct competition with other destinations like bio fuel. Furthermore the origin of raw materials for vegetable oil is uncertain. Also the healthy aspects of fish, in particular omega 3 fatty acids contents, could unleash wild claims in future as fish oil and vegetable oil are facing ever increasing prices on the world market.

Concluding, it is the perception of what is safe or desirable which is important in the change of feed ingredient to vegetable oil.

The issue of using krill as an alternative feed for farmed salmon on a large scale is also wide open for debate on a global level. Precautionary catch limits have set to ensure that ecological effects are minimised. However the growing demand for marine oils and for aquaculture feed will mean that these limits will be under continuous pressure. The societal impact of encroaching on this vulnerable ecosystem is a point for discussion here.

The ethical discussion in the salmon industry focuses on fish welfare at slaughter level. In Norway the stunning of salmon to anaesthetize before being bled to death, is still done with CO2 and chilling water (0,1^{o}C). However not all fish are anaesthetized properly and some are still conscious whilst being slaughtered. The present system is efficient as it handles many fish at any given time.

In Scotland, Chile and Canada another method of anaesthetic is used in the form of a blow to the head of the fish, which renders the fish unconscious immediately. In 2007 the carbon dioxide method will

be prohibited in Norway. Two alternative methods to anaesthetize salmon before slaughter are being examined. The electrical anaesthetic is still being tested, because too high voltage results in severe muscle contraction and blood in fillets. Using al too low voltage is not sufficient to anaesthetize the salmon completely and defeats the object of merciful killing, besides which the quality of the fish is negatively affected.
Concluding, the ethics of slaughtering is an important factor with regard to the salmon industry.

Another point of discussion in defining indicators is the aspect of legislation. Legislation, laws and quality control are generally considered to be positive for the large fish companies as it allows them to manage salmon production chains with well defined limits. Norms should be preferably scientifically based. The fact that legislation is not the same all over the world can be a major drawback in optimizing safety and free trade.
We believe that most of the scientific research is following regulation instead of being concerned with new developments and thus emerging risks. Research regarding possible risks is expensive and the outcome is not always perceived.
New problem concerning legislation is the difference in dealing with environmental issues in relation to legislation that deals with food safety matters. Food safety legislation is often falling behind legislation regarding environmental issues, because the former requires an extensive (human) risk assessment of the contaminants. Take the issue of flame retardants as an example. In the environment, as well as human exposure (breast milk) the contamination of flame retardants increases. Use of some flame retardants has been banished; no international legislation on e.g. PBDE (flame retardant group) exists yet. Continuing, but generally declining issues are persistent pesticides, dioxins, PCBs which accumulate in the environment is a worrying issue. A new environmental problem is perflourinated alkylated substances, used among several other applications as Teflon and flame retardants. This substance is relatively new in research, as analytical procedures are developing and research on environmental presence, human burden, and toxicity data is emerging. Environmental and food safety legislation is still lacking.

And finally………..Why not extend the emerging risk to food security and health aspects of food, beside food safety. It is a known fact that more people die of lack of food and bad eating habits (too much and too fat) than of unsafe food (citation of an interviewee).

5.2 Recommendations

This study investigating the salmon production chain and its possible indicators for emerging risks will be finalised with some recommendations for further research:

- Government officials within the Agricultural ministry will now be able to develop policy measures taking into account the host environment and its effect on the fish production chain. Further development of an emerging risk detection support system will be recommended in order to take in consideration the pro-active emergence of food safety risks.

- The information gathered in this study can be useful as input for the development of a demonstration model for emerging risk detection in an IT environment. Both the identified indicators and criteria set for reliable data sources will be supportive in quantifying the signaling procedures.

- Further research is recommended in the seafood sector, with the objective to further investigate the indicators of emerging risk and set up a workshop with experts from within the seafood sector, as well as research, NGOs' and government. Also verification of the reliability of data sources will be an important aspect of this expert workshop.

- Following discussions in the interviews, held as part of this study, it is recommended that communication with consumers is intensified, not only about emerging risks, but also concerning improvements made by the seafood sector. Actions by the industry to alleviate allegations once made by NGOs' concerning antibiotics, hardly ever reach the consumer. Few consumers know that salmon is vaccinated and that the use of antibiotics in Norway has virtually stopped since 1994!

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Annex 1 Questionnaire food safety and emerging risks

Introduction:
The Dutch Ministry of Agriculture, Nature and Food Quality and the Dutch Food and Consumer Product Safety Authority want to detect potential food safety risks pro-actively. In order to do this all future food safety risks and developments need to be included in the detection system. These developments can be within the sector itself, but also in the influential sectors, such as climate changes, consumer health, consumer trends, economic situation etc. In order to develop such a system we first focus on a specific food sector; the salmon supply chain (aquaculture) and aqua feed chain. By conducting interviews within the sector itself and its influential sectors we try to distillate out indicators that we can put in our model/system. Your answers will be dealt with anonymously.

In general

1. Could you tell something about the company?
   mission
   number of employees, etc
2. Could you describe your job?
3. What is your background?
4. Is food safety an issue for your company? Please explain in what way.

Fish farming in general

5. What kind of developments do you see in the aquaculture sector in general?
6. And more specific in the salmon supply chain and the aqua feed chain?
7. Could you describe the salmon supply chain in ten years, how will it look like?
8. What about aqua feed?
9. Are there any obstacles to accomplish this?
10. What type innovation (or other changes are) is needed to overcome this?
11. Is food safety a big issue in the salmon supply chain (why yes or no)?
12. And in the aqua feed chain?

Information and communication

13. Which trends do you see in consumer behaviour concerning fish/aqua feed?
14. And food safety?
15. In what way do they effect your organisation?
16. How does your company obtain information about trends?

Economy and finance

17. How would you describe the economic situation in the salmon farming/aqua feed sectors?
18. Is it a stable one?
19. Why is that?
20. Are there many differences between companies (small/large, countries, chain, species)
21. Do you consider the salmon supply chain as innovative?
22. Why?
23. And the aqua feed chain?

Government and policy

24. What developments do you distinguish in the regulation concerning food safety?

25. In what way do they influence your company?
26. Do you consider the regulations as sufficient?

Environment and Energy (climate changes, pollutions etc.)

27. How does the environment effect the salmon growth or aqua feed chain?
28. In what way does it influence your company?
29. What can you do about it?

Food safety in the food chain

30. What potential food safety risks do you see in the aquaculture/salmon farming/aqua feed sectors?
31. Is the salmon supply chain transparent? (and aqua feed?)
32. Who is mainly responsible for food safety (within the food chain)?
33. Where within the chain are the risks the highest? (type of company, country, species)
34. Who can do something about it?
35. What can you do?
36. Do you consider the current risk detection system sufficient?

- In what way?
- What can be done to change this?
- Do you see a role for yourself?
- Could you give an example of risks that occurred in the past concerning food safety (that concerned you company)?
- What were the causes and consequences?
- Are these issues being dealt with properly?
- How?
- Did this concern imported goods or local ones?
- What lessons can be learned from this?

37. What type of food safety risk detection system do you have in you company?
38. Is it time consuming or costly?

Communication within the food chain

39. Could you tell something about the contents of the salmon diet?
40. From where do you get the ingredients?
41. Are there differences in quality?
42. Are the products traceable?
43. How many suppliers do you have?
44. How often do you see them?
45. What behaviour do you aspect from your partners within the food chain (what are their main characteristics)?
46. What happens when fish oil will not be available anymore within the next 5 years?
47. Where to do you transport the fish feed?
48. Where to do you transport the salmon?
49. Is it true that (trading) companies avoid Rotterdam/Schiphol because they follow the rules to strictly?
50. Are there statistics which confirm this trend?

Annex 2 List of persons interviewed

Food chain	
Name	Company
Peter Franken	Smit Trading BV, Rotterdam
Maurice Langezaal/Ronald Buis	Schmidt seafood Rotterdam
John Oosterhuis	Albert Heijn, Zaandam
Reinder Sijtsma	Nutreco, Boxmeer
Tim Verhoeff	Malenstein air, Schiphol
Hans Abrahamsen	Skretting, Stavanger
Nanne Jørum	Skretting, Stavanger
Nina Flem	Skretting, Stavanger
Øyvind Oaland	Marine Harvest, Hjelmeland
Trine Danielsen	CAC, Langavik
Lars Andre Fronsdal	Fister smolt, Hjelmeland
Karl Tore Maeland	EWOS, Bergen (N)
Influential sector	
Name	Company
Joop Luten	IMARES, IJmuiden / Fiskeriforskning, Tromsø
Gorjan Nikolik	Rabobank International, Utrecht
Louis van Nieuwland	Netherlands Nutrition Centre, Den Haag
Johan Verreth	Wageningen University, Wageningen
Gro-Ingunn Hemre	NIFES, Bergen (N)
Marc Berntssen	NIFES, Bergen (N)

Annex 3 List of Indicators and link with farmed salmon and aquafeed case (source EMRISK report annex 5)

http://www.efsa.eu.int/etc/medialib/efsa/science/sc_commitee/sc_opinions/sc_op_ej375_emrisk.Par.0006.File.dat/sc_annex5_emriskvwa_en.pdf

Remark: the numbers of indicators correspond with those mentioned in EMRISK report annex 5.
Also in this Annex 5 the main features of the indicator is explained as well as a reference to key sources.
(Italic marking = important to salmon production project)

Influential sector	Class	Indicator	Sources
Economy & Finance	Economic stability	2 (New business starts by sector)	
	Economic reform	2 (Number of market admission permits issued), 4 (Control intensity by sector), 5 (Illegal behaviour by sector), 6 (Sanctions charged by sector)	
	Balance of payment	1 (Value of goods exported internationally by sector)	
Industry & Trade	Retail trade	1 (World trade flows), 5 (International trade balance), 6 (Retail sales of selected goods per capita), 7 (Market share of more sustainable produced goods and services)	
	Services	1 (Number of food services, products and technologies exported)	
	Business infrastructure	5 (Chemical management by sector)	
Environment & Energy	Climate	2 (Estimates of temperature)	

	Pollution	1 (Number of days air pollutants exceed healthful levels)	
	Energy	3 (Sector energy consumption by type of use)	
	Production pattern	1 (Agricultural population per hectare of arable and permanent crop land)	
	Consumption behaviour	4 (Generation of (hazardous) waste by sector), 5 (Waste water recycling rates by sector)	
	Natural resources	4 (Land/water contamination), 6 (Expert assessments of the health status of wild stocks of fish, crustaceans and molluscs), 7 (Number of toxic materials released into the environment by sector), 8 (Number of commercial crop varieties)	EEA indicators on contamination (http://themes.eea.europa.eu/IMS/CSI): - Progress in management of contaminated sites (CSI 015) - Emissions of primary particles and secondary particulate precursors (CSI 003) - Hazardous substances in blue mussels in the north-east Atlantic. - Input of hazardous substances in the north-east Atlantic - ICES - UVA - Greenpeace
Government & Policy	Corporate culture	1 (Corruption index by sector), 2 (Costs of internal/industrial self regulation), 3 (Index of compliance with rules and regulations by businesses per sector)	

	Global trade restrictions	1 (Index of WTO trade agreements by sector), 2 (Index of trade partners and trade volumes per sector), 3 (Number of ethical trading issues by sector), 4 (Number of products passing through national borders without inspection)	
	Legislation	1 (Percent of food safety development compatible legislation per sector)	
Science & Technology	Innovation and research	4 (Changes in food/feed process technology)	IFT annual meetings: award winners, exhibitors and scientific program; same for Fi (Food ingredients) and (Hi) Health Ingredients: http://www.am-fe.ift.org/cms/ http://www.fi-events.com/ http://www.hi-events.com/content/default.aspx Applied journals Food Science and Technology Abstracts (bibliography, available through Agralin) WEFTA Norwegian Research Council
	Information society	1 (Estimates of preliminary research findings), 3 (Survey on innovation in enterprises), 4 (Patent index)	1. Food Science and Technology Abstracts (bibliography, available through Agralin) 3. UK Department of Trade and Industry on-line database of R&D investment in each sector (UK and international): http://www.innovation.gov.uk/rd_scoreboard/search.asp 4. Financial Times Innovation Indicator (patents per country): http://www.scientific.thomson.com/news/innovation-insights/newsletter/2006-01/spot1.html
	Knowledge based services	1 (Patent index), 2 (Number of conferences by sector)	

Health	Health status	7 (Deaths from heart disease), 8 (Deaths from all cancers)	
	Demographic and socio-economic factors	4 (Age dependency ratio)	
Population & Social Conditions	Poverty and social exclusions	3 (Food insecurity conditions), 4 (Healthy Eating Index)	
	Eating habits	2 (Retail sales of selected foods per capita), 3 (Market share of more sustainably produced goods and services), 4 (Food consumption intensities and patterns), 6 (Demand for processed foods), 8 (Demand for local food)	National food consumption surveys DAPHNE (EU) FAOSTAT
	Living conditions and welfare	4 (Effective buying income per capita), 5 (Cost of living index by country)	
Information & Communication	Pressure groups	1 (Number of new activist groups), 2 (Demands by consumer/civil NGO organisations), 3 (Changes in expert opinions)	2 Check websites of expert NGOs, e.g.: Center for Science in the Public Interest (USA) www.cspinet.org/ Center for Food Safety (USA) www.centerforfoodsafety.org International Slow Food Movement www.slowfood.com
	Life style choice	1 (Consumer opinions on the general economic situation), 2 (Buying intentions concerning consumer durable goods), 4 (Index of expectations for the future), 7 (Household/family structure)	

	Anxiety	1 (Number of customer complaints), 2 (Level of consumer confidence), 3 (Fear factors)	1. UK Office of Fair Trade Statistics - Consumer Complaints: http://www.oft.gov.uk/News/Statistics/default.htm USA Consumer Sentinel: http://www.consumer.gov/sentinel/trends.htm
Food Supply Chain	Coordination	4 (Customer orientation)	
	Safety and quality orientation	1 (HACCP systems), 2 (Traceability systems), 3 (Social responsibility), 4 (Environmental management)	1. FDA (USA): National Seafood HACCP Compliance Database System http://www.cfsan.fda.gov/~comm/seaeval3.html 2. Exporting nations with EU HACCP QMP audits, such as Canada and USA: http://www.hc-sc.gc.ca/fn-an/securit/eval/reports-rapports/fsa_qmp_report-esa_epg_rappport_e.html http://seafood.nmfs.noaa.gov/HACCPProgReq.pdf
	Processing and packaging	2 (P&P quality), 3 (Labelling flexibility)	
	Storage and transport	2 (Transport quality referring to duration and distance)	
	Systematic hygiene and veterinary control	1 (Controlled units/total units by type of sector), 2 (Number of violations/controlled units by sector), 3 (Number of administrative sanctions), 4 (Penal sanctions)	EUROSTAT food safety statistics (in progress): http://www.unece.org/stats/documents/ces/ac.61/2005/wp.17.e.pdf Food and Veterinary Office, country reports: http://ec.europa.eu/food/fvo/ir_search_en.cfm
	Quality controls	1 (Samples taken for each product/national production), 2 (Non-regular samples/total samples), 3 (Quantity of sequestered products/total production)	EUROSTAT food safety statistics (in progress): http://www.unece.org/stats/documents/ces/ac.61/2005/wp.17.e.pdf Food and Veterinary Office, country reports: http://ec.europa.eu/food/fvo/ir_search_en.cfm

	Import controls	1 (Controlled units/total units by type of product/country)	EUROSTAT food safety statistics (in progress): http://www.unece.org/stats/documents/ces/ac.61/2005/wp.17.e.pdf Food and Veterinary Office, country reports: http://ec.europa.eu/food/fvo/ir_search_en.cfm
Agriculture	Structure and environment	2 (Hectares under integrated pest management)	
	Plant health and biocides	1 (Toxic chemicals released or used by sector), 2 (Rate of outbreaks by sector/product)	
	Fisheries	1 (Total catch of fish by product/country), 2 (Fish species with consumption restricted)	Examples of EEA indicators (http://themes.eea.europa.eu/Sectors_and_activities/fishery/indicators): - Marine fish stock size (CSI 032) - Aquaculture production (CSI 033) - Fishing fleet size (CSI 034) - Catches, major species and areas (FISH 11) - Fish stocks outside Safe Biological Limits (FISH 1a)
	Contamination	1 (Pattern of residues in animal origin products), 2 (Profile of radioactivity in animal products), 3 (Illegal products intended for animal nutrition)	- Rapid Alert System for Food and Feed: ec.europa.eu/food/food/rapidalert/index_en.htm
	Animal health and welfare (incl. fishery)	1 (Estimates of pathogens presence in (non-food chain related) farmed en wildlife reservoir), 2 (Veterinary services), 11 (HACCP systems), 12 (Use of antimicrobials)	