"Food for Thought: the Use of Marine Resources in Fish Feed"

Report 2/03
Written by: Taija-Riitta Tuominen and Maren Esmark

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<th>Author(s)</th>
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<tr>
<td>Taija-Riitta Tuominen, MSc Student, University of Tromsø, Norway</td>
<td>WWF-Norway</td>
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<tr>
<td>Maren Esmark, Marine Conservation Officer, WWF-Norway</td>
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<th>Section 5 is revised by:</th>
<th>Editor</th>
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<tr>
<td>Dr. Mikko Heino, Institute of Marine Research, Norway</td>
<td>Andreas Tvereraas, Head of conservation, WWF-Norway</td>
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| Section 4 and 6 is revised by | |
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| Jan Vidar Jacobsen, EWOS Innovation AS | |

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Foreword

WWF's mission is to conserve nature and ecological processes while ensuring the sustainable use of renewable resources. WWF therefore recognises the potential value to society of aquaculture in terms of providing food security, revenue and an alternative food source to wild-caught fish. However, farming of aquatic organisms can cause detrimental effects on the environment and be socially and economically unsustainable in the short-term and in the long-term. Its consequences have proven disastrous in some areas of the world.

Aquaculture in general and fish farming in particular is perceived as relieving the present fishing pressure on wild fish stocks to allow depleted stocks to recover. In this report, WWF take a closer look at this assumption in relation to the sustainability of feeding farmed salmon and trout.

Is fish farming a long-term answer to the fisheries crisis? No. The only cure for fisheries mismanagement is good management. Whether or not fish are produced by aquaculture will not reduce the pressure on wild stocks. An end to overfishing, reductions in fleet size, ending harmful subsidies and an ecosystem, rather than single stock, approach to management will contribute to ending the current fisheries crisis.

WWF-Norway has, during the writing of this report, received great interest both from industry, governments and other NGOs. WWF hopes that addressing this issue will contribute in the long quest for protecting the biodiversity in our oceans.

The report looks into the raw materials used for feed in aquaculture, specifically of salmon and trout. It examines the sustainability of the fisheries which are exploited to produce the feed, the added pressure the fish farming industry puts on those stocks, the efficiency of feeding fish to carnivorous fish, and some of the alternatives.

The report is a wake-up call for both governments, which must better manage its industrial fisheries that supply the fish farming industry, and the aquaculture industry, where WWF’s contribution can assist an industry with much potential in shifting onto more sustainable footing.

Gland, Switzerland, 14 February 2003

Dr. Simon Cripps
Director, Endangered Seas Programme
WWF International
1 Summary

Global production of aquaculture products more than doubled during the 1990s, reaching around 45 million tons in 2000, while captured fisheries had a total of 96 million tons in 2000. Aquaculture in general and fish farming in particular are thought to help relieve the present fishing pressure on ocean fish stocks and allow depleted wild stocks to recover. But, fish farming is not a solution to the current collapse and mismanagement of the world's fisheries. An end to overfishing, reductions in fleet size, ending harmful subsidies and an ecosystem rather than single stock approach to management will contribute to ending the current crisis. In this report, WWF takes a closer look at the assumption that fish farming takes the pressure off wild fish stocks, related to the sustainability of salmon and trout farming. The conclusion is that rather than taking away pressure on wild fisheries, salmon and trout farming is increasing this pressure.

Fish feed is produced from wild caught fish

Salmonids are carnivorous fish, and their feed consists of vast amounts of fishmeal and fish oil produced from fish caught mainly in the North East Atlantic and the South East Pacific.

The annual global catch of fish is about 96 million tons, of which more than 30 million tons are used to produce fishmeal and fish oil. Landings of wild-caught fish have remained on a stable level during recent years.

Currently, aquaculture consumes 70 per cent of the global production of fish oil and 34 per cent of the total fishmeal (IFFO, 2002c) produced in the world. By 2010 it is estimated that these figures will rise to approximately 80 – 100 per cent and 50 per cent respectively. The salmon and trout industry is a major consumer of fish oil, and at present this industry alone consumes 53 per cent of the world's total fish oil production.

How much wild fish is needed to produce 1 kg of farmed salmon?

1 kg of fish feed for salmon or trout consists on average of 280g of fish oil. To produce 1 kg of fish oil, around 12 kg of wild caught fish is needed, depending on species and season. The average feed factor in Norway is 1.2 kg. To produce 1 kg of salmon:

\[ 280g \times 1.2 = 330.6g \text{ of fish oil} \]
\[ 330.6g \times 12 = 3967g \text{ of wild caught fish} \]

1 kg of salmon requires 4 kg of wild caught fish

The demand for high quality seafood is increasing. Many countries are predicting big jumps in the growth of their fish farming industries. For example in Scotland and Norway it is expected that cod
farming will grow quickly. It will only take a few years before the aquaculture industry consumes all fish oil produced in the world. If fish oil supply fails, like it did in 1998 under the strong El Niño in the Pacific, the aquaculture industry will face severe shortages of fish oil.

Fish caught for fish feed
Small, bony, pelagic fish species, (often referred to as industry fish species) are fished to produce fishmeal and fish oil, being essential ingredients in the fish feed used to produce carnivorous species such as salmon and trout. Fisheries along the coast of Chile and Peru, and industrial fisheries in the North East Atlantic, supply the marine resources consumed by salmon and trout farming.

In Europe, the situation for the blue whiting, a species primarily used as “industry” fish, is depressing. A total collapse is expected if the current fishing practice continues. In 1997, FAO reported that most of the traditional fishery resources of the North-East Atlantic were fully exploited or overexploited, with several stocks in a depleted condition. The pelagic fisheries in the South East Pacific Ocean were characterised as “fully fished” in 2001, and present catch statistics show that the fisheries are not increasing. The most important commercial species is the anchoveta. The population is highly unstable. The stock has finally recovered after many years of overfishing in the 1970’s and the collapse caused by the strong El Niño in 1998.

At present, it is not possible to increase catches in any of the fisheries in the South East Pacific Ocean. There is also clearly no room to increase the percentage of the catch used to produce fish oil or fishmeal in this area as Peru and Chile have large human populations who can consume this healthy seafood directly. Partially due to issues over food-security, both governments advocate the use of fish for human consumption instead of reducing it into meal and oil.

All fish species used for fishmeal and fish oil in both the Pacific and the Atlantic are very important for the marine ecosystem, as they are prey for fish, birds and mammals. Increased exploitation of these species to meet the demands from an expanding fish farm industry could very well turn out to be an ecological time bomb under the industry.

Alternative sources for fish oil
Since no increase in global production of fishmeal and fish oil is expected, the salmon farming industry is now looking for alternative feed resources. Increased use of fish offal or even utilisation of by-catch could contribute to solving the problem; feeding farmed fish a resource that otherwise would be lost. Unfortunately, the trend seems to be that less fish is processed on land and vast amounts of fish offal is dumped in the sea every year.

Another alternative is to increase the use of vegetable proteins. There are several examples where fishmeal and fish oil in feeds for carnivorous species can be totally or substantially replaced by alternative protein and oil sources. Fish oil can be substituted by plant oil, a method that has already been developed, or the fish feed can be produced from plant or zooplankton. Other alternatives include microorganisms grown from natural gas. Also, harvest of small crustaceans like krill can be fed to farmed fish. Large scale harvesting of krill, the most important species in the food web, could have severe knock on effects on the marine ecosystems if sufficient caution is not shown.

When developing a strategy to meet the shortage in fish oil and fishmeal, it is important that governments and industry include all potential environmental effects of the proposed alternatives.
Conclusion and recommendations

Intensive fish farming is not a solution for helping depleting wild fish stocks. Only better fisheries management can help relieve the pressure on current fisheries. Today’s farming of carnivorous species such as salmon and trout is not sustainable, as it consumes four times as much wild caught fish as it produces farmed fish.

By using large amounts of wild-caught fish to feed farmed fish, the European aquaculture industry is actually increasing the pressure on ocean fish populations. The demand for wild-caught fish for fish feed puts pressure on wild fish stocks like the blue whiting, and WWF fears that the growing fish farming industry will contribute to a further pressure on already heavily exploited fish species.

- WWF calls out to governments for a better fisheries management including reductions in fleet size, ending harmful subsidies and adoption of an ecosystem based approach to management.

- The aquaculture industry must, as it is the biggest consumer of fish oil and a major consumer of fishmeal, make sure it only buys oil and meal from healthy, sustainable and well managed fish stocks. The industry should make any effort to find more sustainable alternatives, preferably fish offal and fish waste or fish feed from certified fisheries.

- WWF is not encouraging more farming of carnivorous fish species. However, species from lower down the food web like fish with herbivorous diets or filter feeders such as oysters can potentially be sustainable.

- WWF asks governments to advocate the use of fish waste and fish offal from fisheries and fish processing to be used for fishmeal and fish oil, while at the same time controlling levels of contaminants.

- WWF asks governments to ensure that when research and testing on future alternative feed resources is conducted, the precautionary principle is be implemented.
2 Introduction

Feeding has a central and essential role in fish farming, and the present use of wild caught fish as feed to farmed fish, brings in the question of sustainability. Concern arises from the marine resources reduced to fish feed, and the environmental effects of those fisheries. Annual global catch of fish is around 96 million tons (FAO Fishstats 2002, FID 2002c), and more than 30 million of this is used to produce fishmeal and fish oil (FAO 2000a). More than 70per cent of global fish oil and 35per cent of fishmeal production is used to make feed for aquaculture (IFFO 2002c). It has been predicted that already by the year 2006 the demand for fish oil will be higher than the production (Waagbø 2001), and others have indicated that Aquaculture products will consume 100per cent of the global fish oil production by 2004 (EWOS, 2001). However, this report uses the latest numbers from IFFO, The International Fishmeal and fish oil Organisation, which estimates that by 2010, the aquaculture industry will consume almost 100per cent of the global fish oil production.

High quality fishmeal and fish oil make up more than half of the content of salmon and trout feed (Waagbø 2001). About 5 kg fish is needed to produce 1 kg fishmeal (Tacon & Forster 2000), and around 10 kg of is needed to produce 1 kg of fish oil. It has been calculated that it takes 3 – 5 kg of wild fish to grow 1 kg of salmon. Therefore, fish farming, and especially that of salmonid species, sets pressure on the stocks of wild fish. In 2002, it is estimated that the salmon and trout industry alone consumed over 50 per cent of the global fish oil production, by using 532.000 of fish oil of a total world production of around 1 million tons.

Shortage of fish oil is a scenario feared by environmentalists. History shows that when the price of a fish specie increases (for example caused by shortage), over-exploitation of fish stocks can be the result. Also the aquaculture industry worries about the scenario that fish oil resources soon will be scarce, and much effort is put into the search for alternative feed resources. The use of vegetable oil as substitute to fish oil has shown to be successful, and for salmon and trout, the amount of fish oil used in the feed deceases. However, this will not take the pressure of wild caught fish, as the salmon and trout industry is still growing and new species, like cod, which also depends on marine resources in the feed, is expected to increase.

This report focuses on two main areas. First, the current fish feed situation is presented, exemplified by addressing the Norwegian salmon and trout industry. Secondly, the fish species used to produce fishmeal and fish oil is listed and then assessed looking into stock situation and trends in fishery. The last part of the report focuses on alternatives to fish oil and fishmeal, also addressing possible environmental conflicts related to the different alternatives.

There is an urgent need for more sustainable alternatives for fishmeal and oil to reduce the pressure on heavily exploited fish species. The development of alternative raw materials is in progress. In addition, there is much research on the possible use of bio-proteins produced from natural gas, growth of plankton and harvests of species in lower down the food web, such as krill to use as a fish feed resource. When the aquaculture industry is looking for alternatives, it is of great importance that any possible environmental problems are addressed from the start.
3 Background

3.1 Sustainable management of marine resources

Oceans cover 70 per cent of the earth’s surface, and more than half of the world's population lives within 60 kilometres from the sea. Coastal communities are often entirely dependent on marine resources. At the same time, an increasing number of marine ecosystems are endangered or under great pressure from human activities. Local Agenda 21 emphasises the need to protect marine environments, including oceans, high seas and adjacent coastal areas, in order to achieve sustainable use of marine resources.

Marine fisheries all over the world are under heavy use (Charles 2000) and around 70 per cent of the global, known fish species are exploited to their maximum biological limits, and in many instances overfished. Around 10 per cent of fish stocks are drastically depleted (FAO 2000a), and most fisheries are in urgent need of good management (Charles 2001). At the second UN conference on environment and development in Johannesburg in 2002, an implementation plan was developed (UNCED 2002). Article 30 of this declaration says that in order to achieve sustainable fisheries the following action is required: Maintain or restore stocks to levels that can produce the maximum sustainable yield with the aim of achieving these goals for depleted stocks on an urgent basis and where possible no later than 2015.

The Declaration of the Conference on Aquaculture in the Third Millennium, Bangkok 2000 says: The aquaculture sector should continue to be developed towards its full potential, making a net contribution to global food availability.

The European Commission presented its strategy for a sustainable development of European aquaculture in September 2002. The strategy reads: This resource (fish oil and fishmeal, red.) being limited, it is extremely important to continue the research effort to find substitute protein sources in the fish feed formulation.

Sustainable development was defined by the United Nations Conference on Environment and Development (UNCED) in 1992 as: “Progress that meets the needs of present generations without sacrificing the ability of future generations to meet theirs”.

During that conference, Agenda 21 was adopted which is a comprehensive plan of action to be taken globally, nationally and locally in every area in which humans impact on the environment, for achieving sustainable development in the 21st century.

In 1991, the UN expressed concerns regarding the clear signs of over-exploitation of important fish stocks and The Food and Agriculture Organization of the United Nations (FAO) developed a Code of Conduct to promote sustainable fisheries. The code was finished in October 1995, and has been adopted by most coastal states. The code also gives guidelines for sustainable aquaculture development.
3.2 Aquaculture – The blue revolution

In the last two decades there has been a rapid expansion of commercial and intensive aquaculture, particularly in China, some parts of Europe, Asia and South America. The increase in production is a result in particular from farming marine species like tuna, shrimp, sea bass, sea bream, salmon, molluscs and, more recently, marine white fish species such as cod. The global production of farmed fish and shellfish doubled from 1987 to 1997, while the total catch of wild fish has been more or less stable for the past 15 years.

![Figure 1: World capture fisheries and aquaculture production](image)

**Aquaculture** means the farming of aquatic organisms. Farming requires some form of human involvement in the rearing process in order to improve production. Fish farming may be defined by the degree of control over the environment in which organisms are grown. In an **extensive system** neither supplementary feeding nor a direct energy input is used to support growth of the reared species. In an **intensive system**, the reared species depends exclusively on additional manufactured feeding. In a **semi-intensive system**, the reared species feeds on both: natural and supplied feed.

The total world catch of seafood was just above 96 million tons in 2000 and total production of farmed fish was over 45 million tons (FID, 2002c) of which most are freshwater fish species (about 85 per cent.), mainly carps (cyprinids) and tilapias, which are plant eating (herbivorous) fish or a combination of plant-eater and carnivore (omnivorous). The diadromous (spawn in freshwater, live in seawater) species contribute over 2 million tons of the total production of which close to 1.3 million tons are salmonids, mainly Atlantic salmon and Rainbow trout.
The rest of farmed fish are marine species. Most global finfish farming is conducted in pond-based or open-water extensive or semi-extensive practises in the developing countries, and the products mainly goes to national markets as additional food supply. By contrast, in developed countries, high-value carnivorous finfish (salmonids) are produced by intensive farming systems, using high-cost nutrient inputs in the form of nutritionally complete formulated diets (Hasan 2001, FAO 2000a). Most fish farming takes place in Asia: China is the largest producer. Europe is the other major region in terms of production by weight: there is almost 2 million tons of farmed fish produced annually. Europe is followed by South America (around 0.7 million tons). The growth in the sector is expected to continue. However, the trend within aquaculture is the production of high value species – carnivore species – suitable for export. This trend is a response to the increase in consumer demand in developed countries for high value, exclusive fish products (FAO 2000a).

### 3.3 Fish farming in Norway

Since the mid-1970s the aquaculture industry has developed rapidly, and today Norway is Europe’s leading country in fish farming, and the world’s largest producer of salmonid fish. In 2001, the production of Atlantic salmon and trout was 479 000 tons (Glette et al. 2002). The export value of Norwegian salmon and trout was 11.1 billion NOK in 2001, which is over 30 per cent of the total value of seafood exports from Norway (FID 2002c). The Norwegian aquaculture industry is predicted to grow fivefold over the next twenty years (Røsjø & Simonsen 2000).

Fish farming is largely important for the Norwegian economy and export, and it plays a significant role in the continuity of small coastal communities. The aquaculture industry provides work and maintains a dispersed population in coastal Norway. Nearly 4 000 people are employed directly in fish and shellfish farming, and an estimated total of more than 20 000 people are working either in production or services related to aquaculture (FID 2002).

### 3.4 Farming fish

The main farmed species in Norway are Atlantic salmon (*Salmo salar*) and Rainbow trout (*Oncorhynchus mykiss*). There are natural stocks of Atlantic salmon in Norway, but Rainbow trout was introduced to Europe in the mid 19th century from the Pacific Ocean. Modern salmon farming originated in Norwegian fjords, where the small industry started in 1960’s. Atlantic salmon and
Rainbow trout farming attempts to mimic the salmonid life cycle. In the wild, these species are diadromous: they reproduce in freshwaters but feed in the sea. Spawning occurs in rivers, and the young fish (parr) spend from one to six years in river. Before migrating to river, salmonids go through the process called smoltification. During smolting there are physiological changes for adaptation to life in salt water. Those prepared for more saline habitat (smolt) migrate to the sea to feed, grow and mature. Eventually, the ones who survived the sea period return to their "home river" to spawn. Therefore, the egg, larvae and juvenile fish are reared in fresh water until smolting, then transferred to sea cages, where they quickly (12 – 16 months) reach the required size for market (3 to 5 kg).

According to the Norwegian Fish Farmers Association the ultimate goal of the aquaculture industry in Norway is for all activities to be conducted in harmony with nature. Moreover, the Norwegian Ministry of Fisheries states in its environmental action plan that the political aim for aquaculture is “to develop technologies and management practises to minimise pollution and escapes, to prevent negative impacts on the marine biodiversity and the coastal environment”. These goals are good in theory. However, there are still major environmental problems related to fish farming, and consumers are already questioning the sustainability and the environmental impacts of the aquaculture industry. Also concerns related to dioxin/PCB contamination in seafood have been raised.

### 3.5 Environmental effects of intensive fish farming

WWF’s mission is to conserve nature and ecological processes, whilst ensuring the sustainable use of renewable resources. WWF recognises the potential value to society arising from aquaculture in terms of providing food security, revenue and a healthy food source. However, farming of aquatic organisms can cause detrimental effects on the environment and be socially and economically unsustainable in the short-term and in the long-term, and consequences have proven to be disastrous in some areas of the world. For example, in some parts of Asia, commercial shrimp farming has adversely affected local livelihoods, and has devastated fragile coastal ecosystems, causing mangrove destruction, coastal erosion, pollution of surface and ground waters including salinisation of vital coastal freshwater aquifers, and in some cases, introduction of exotic species.

WWF is concerned about some of the very serious environmental problems related to intensive aquaculture. Negative effects include damage to coastal resources through destruction of habitats for both terrestrial and aquatic wildlife when fishponds and accompanying infrastructure are built. Marine and freshwater systems experience serious disturbance through the disposal of wastewater and the direct release of nutrients. Wild fish populations are affected by aquaculture in several ways: through increased pressure on species exploited to produce feed; through the introduction of exotic fish and shellfish species that escape and compete with, or feed on, native aquatic animals; through dense populations incubating diseases which then can infect wild stocks; by the pathogens that accompany the introduced exotic species; catching of juveniles and adults for further growing in farms and for breeding in nurseries. In addition, unintended capture or illegal culling of fish, mammals, birds or other animals can exert pressure on species that play no role in aquaculture.
WWF’s vision is “a sustainable aquaculture industry, where no part of the production line threatens the natural environment”. WWF has two overriding concerns related to the expansion of the aquaculture industry: the intrusion of fish farms into vulnerable marine and coastal areas, with potentially detrimental environmental effects, and the overall sustainability of an industry that is dependant on wild-caught fish used as fish feed in a conversion ratio for salmon 4:1 and for Tuna as low as 20:1 (Naylor 2000).

This report focuses entirely on the second point about feed resources. Carnivorous species such as eels, yellowtail, salmon, seabass, sea bream and cod are grown on fish feed containing large proportions of fishmeal and fish oil derived from wild caught fish. Aquaculture therefore increase pressure on fish stocks rather than relieving pressure. The largest sources of fishmeal and fish oil are anchovy, sardine, and mackerel primarily caught in the Pacific Ocean off South America. Heavy over-fishing of South American pilchard has caused a serious decline in the stock from 6.5 million tons in 1985 to around 60 000 tons in 2001. In the North Sea, blue whiting is widely used in the fish-feed industry. In 2001, North Sea coastal states caught 1 800 000 tons, which is double the recommended quota from the International Council of Exploration of the Seas (ICES). WWF calls for the producers of fish feed to ask for documentation that any fishmeal and fish oil used only originates from healthy and well managed sustainable fish stocks, preferably certified to equal Marine Stewardship Council (MSC) standards.
**WWF and sustainable aquaculture**

The following 11 criteria comprise best-practice methodology that WWF expects the industry to follow:

1. Not operate in marine protected areas and areas where the activity is likely to cause serious or irreversible effect on vulnerable species or habitats, such as the escape and interbreeding or competition of culture species with wild species or races.
2. Aquatic species that are either classified as endangered or threatened, or comes from fish stocks that are not healthy and well managed, should not be caught for further growing in farms or for breeding in nurseries, except in special circumstances as a means to restore wild stocks.
3. Fish used for fish oil and fishmeal, often small marine pelagic species, should only come from healthy, well-managed and sustainable stocks, preferably independently certified.
4. Extraction of water must not have a harmful effect on humans or natural wildlife that depend on the same water source.
5. Genetically modified fish should not be developed for aquaculture and fish feed should be guaranteed free of genetically modified plants or animals.
6. Harmful quantities of waste nutrients must not be discharged to freshwater or marine ecosystems, and best available technology should be employed to ensure resource efficient farming systems and adequate wastewater treatment.
7. Toxic chemicals, antibiotics or other substances that harm the environment must not be discharged.
8. There should be no transmission of diseases and parasites to wild species.
9. Exotic species and races should be farmed in closed systems where the potential for escapes can be largely eliminated.
10. Cease the illegal capture or culling of fish, mammals, birds and other animals that have interactions with farming systems.
11. The development and spread of the aquaculture industry must be controlled and sensitive so as to avoid physical damage to coastal ecosystems and structures and negative impacts on coastal communities.
4 Fish feed

Fish feed plays a very important role in fish farming. As with other living organisms, the growth, health, and reproduction of fish are dependent on adequate supply of nutrition and energy, and the feed has a significant impact on the quality of the produced fish (Hasan 2001). Feeding expenses are half of the total costs in salmonid farming (Tveterås 2002). Piscivory fish get their energy from lipids and protein, and do not need much carbohydrate. In addition to energy, protein provides essential amino acids and dietary lipids provide essential fatty acids, that fish cannot synthesise, but which they need to maintain the cellular functions (Hasan 2001, Refstie et al. 2002). Salmonid species are fatty fish and for this reason they require high lipid levels in their feed. At present, around 30 per cent of salmon feed is fat (Lillevik pers. comm, 2003, FAO 2002), therefore the demand for fish oil in feed industry is high.

Traditionally, intensive fish feed production depends on marine resources. Fishmeal and fish oil provide the main source of protein and dietary lipids in fish feed. Fish-based feeds are advantageous for fish because they produce optimal growth and health benefits for fish and human consumers of fish. On the other hand, heavily exploited marine resources do not provide enough raw materials for the future, and the search for sustainable alternatives is underway. Limitations and fluctuations in the supply of fish make the price of fishmeal and fish oil unstable, and during the strong El Niño in 1998, the reduction in traditional fisheries in Peru and Chile led to a price increase of 20 per cent on fishmeal and 50 per cent on fish oil (Waagbø et al. 2001). It seems that in the future, price will continue to increase. Feed alternatives are likely to provide a more a stable supply and a lower and more stable price (Tveterås 2002). Moreover, suggested alternative feed resources, such as plant oils, do not have problems with contaminants, a problem which marine oils can have.

4.1 Fish oil and fishmeal in fish feed

Fish is composed of three major fractions: solids (fat-free dry matter), oil and water. The purpose of fishmeal and oil processing is to separate these parts from each other as wholly as possible. The principal method of processing fishmeal and oil today is wet pressing. The process starts with cooking to coagulate of the protein and release the bound water and oil, which is followed by pressing to separate solids from liquids. The solid material is further dried and then milled to fishmeal, and the oil is separated from the liquids with centrifugation.

The fish used to produce fishmeal and fish oil are often small, pelagic species. They are commonly referred to as “industrial fish” since the majority of the catch is processed into meal and oil. The fishmeal and oil industry requires a regular supply of fish. A wide variety of so-called industry fish species are used for this production. The composition and quality of the raw materials are predominant factors in determining the properties and yield of the products. Fish caught for fishmeal and fish oil may be divided into three categories (FAO 1986):

- Fish caught only for fishmeal and fish oil production
- By-catches from another fishery
- Fish off-cuts and offal from fish processing industry

Fish waste (offal) is the skeletons, heads and trimmings, which are left over when the edible parts are cut off. Whole fish are preferred when producing meal and oil because fish-processing waste has high ash and phosphorus content. In Norway, discharge of by-catch from commercial fish
species is prohibited (FID 2002a), and there is continuous research on the use of off cuts and other waste from fish industry (Stiftelsen Rubin 2000). However, not all species used for fishmeal and fish oil production are classified as commercial, and the use of fish waste has decreased significantly in 2002.

4.2 Producers of fish oil and fishmeal

The world’s leading fishmeal and oil producers are Peru and Chile. European production comes after the South American, and the main producers are Denmark, Norway and Iceland. Norway produces annually around 290 000 tons of fishmeal and between 80 000 and 90 000 tons of fish oil (Sildeolje – og sildemelsindustriens Forskningsinstitutt). Norway is a net importer of fish oil and fishmeal because of the high demand and consumption in salmon farming.

The world’s largest sources for fishmeal are Anchoveta and South American pilchard from the Pacific Ocean off the South American coast. These fisheries regularly undergo dramatic fluctuations. When the natural phenomenon El Niño prevents the upwelling of nutrient rich water and the production of food for fish ceases, the stocks collapse. Norwegian fish feed companies depend strongly on the South American fisheries together with supplies from fishmeal and fish oil industry on Iceland and Denmark. Also, marine oils from the southern hemisphere can be preferred by fish farmers because there is less problems with contaminants such as dioxins and PCBs.

Dioxins are toxic substances that in very small concentrations may cause adverse environmental and health effects. Dioxins are chemically comparatively resistant and tend to accumulate in fat tissue. Fish caught in northern sea areas sometimes contain high levels of heavy metals and POPs (Persistent organochlorine pollutants). Pollution can come from local sources, but the main source is long-distance emissions from industrial areas in the South transported with ocean and air streams. New research (AMAP 2002) shows that both fish and marine mammals living in areas of literally no pollution have very high levels of for example PCB. Levels of PCB in Polar bears at Svalbard has shown over 40 000 ng/g lipid weight, and for polar cod at Jan Mayen, 150 ng/g lipid weight. Pelagic fish species with high fat content, such as herring and mackerel, also have high levels of contaminants and in 1999 (SNT, 1999) were measured at 20 ng/g wet weight (herring) and 14 ng/g wet weight (Mackerel). It has been indicated (Jacobs 2000, Easton 2001) that farmed salmon contains high levels of PCB due to the accumulation of PCB in fish species used for fish feed. The ocean outside the coast of Chile and Peru does not have the same levels of contaminants as the North Atlantic. Fish farming has the advantage that the farmer controls what the fish eats, and contamination levels can be reduced by rinsing fishmeal and fish oil, by using resources from the southern hemisphere or by using more plant oils. The EU council adopted in 2002 a Directive setting legally binding limits on the presence of dioxin and other contaminants in animal feed (EU Council Directive 2001/102/EC). For fish oil this is 6 ng WHO-PCDD/F-TEQ/kg and for fish, other aquatic animals, their products and by-products this is 1,25 ng WHO-PCDD/F-TEQ/kg. (See attachment II about TEQ)
4.3 How much wild fish is needed to produce 1kg of farmed salmon?

Every kilogram of (salmonid) fish feed contains on average 350 grams fishmeal and 280 grams fish oil (Waagbø et al. 2001, IFFO 2002b). The fat and protein content of the fish used to produce this oil and meal depends on species, season and environmental factors such as ocean temperature. Herring can reach a fat content up to 16 – 18 per cent around spawning time (Seafreeze Ltd, 2001), while anchoveta and blue whiting are species that can have as little as 2 per cent fat (Lillevik, pers. com. 2003).

<table>
<thead>
<tr>
<th>Fish species</th>
<th>Protein</th>
<th>Fat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue whiting, North Sea</td>
<td>17</td>
<td>5</td>
</tr>
<tr>
<td>Sprat, Atlantic</td>
<td>16</td>
<td>11</td>
</tr>
<tr>
<td>Norway pout</td>
<td>16</td>
<td>5,5</td>
</tr>
<tr>
<td>Anchoveta</td>
<td>18</td>
<td>6</td>
</tr>
<tr>
<td>Herring, spring</td>
<td>18</td>
<td>8</td>
</tr>
<tr>
<td>Herring, winter</td>
<td>18,2</td>
<td>11</td>
</tr>
<tr>
<td>Mackerel, spring, North Sea</td>
<td>18</td>
<td>5,5</td>
</tr>
<tr>
<td>Horse mackerel, North Sea</td>
<td>16</td>
<td>17</td>
</tr>
<tr>
<td>Capelin, Norway</td>
<td>14</td>
<td>10</td>
</tr>
</tbody>
</table>

Average 15,1 7,9

Source: FAO 1986

IFFO estimates that the average use of fish oil in feed for salmon and trout is 28 per cent and the average for fishmeal is 35 per cent for salmon and 30 per cent for trout (IFFO 2002b, see Att. II).

In commercial and intensive aquaculture it is vital to know how much feed is needed for the net production.

**Feed efficiency** is defined by fish weight gain per unit of feed consumed. This is called biological *feed conversion efficiency* (FCE). The reciprocal is the biological *feed conversion ratio* (FCR), which is the quantity of feed required to produce a given amount of fish. Feed efficiency may simply be calculated as a gain in biomass (wet weight in kg) divided by the amount of feed provided (kg, normally dry weight), called the *feed factor*.

Feeding of fish is affected by many factors, such as temperature, disease and feed quality. Therefore the feed factor may vary between fish and over time. The past years, feed factor has decreased due to better feeding techniques. The average international feed factor for salmonid species is around 1.5 (Naylor et al. 2000). According to main Norwegian fish feed producers, the average feed factor in Norway is slightly better, at approximately 1.2.
It has been calculated that between four and six kilograms fish is reduced to fish feed for growing one kilogram of salmon (Bjordal, Managing Director, EWOS Norway and CEO EWOS Europe 2001, Naylor et al 2000).

The calculations in the box gives a conversion ratio of app. 4:1, based on numbers from International Fishmeal and Fish oil Organisation (IFFO) estimating average use of fish oil in fish feed for different species (Attachment I). The rate of 12:1 for producing fish oil is taken from the FAO 1986 table and 1.2 is a fairly good feed factor for farmed salmon.

How much wild fish is needed to produce 1 kg of farmed salmon?

1 kg of fish feed for salmon or trout consists on average of 280g of fish oil. To produce 1 kg of fish oil, around 12 kg of wild caught fish is needed, depending on species and season. The average feed factor in Norway is 1.2 kg. To produce 1 kg of salmon:

\[280g \times 1.2 = 330.6g \text{ of fish oil}
\]
\[330.6g \times 12 = 3967g \text{ of wild caught fish}
\]

1 kg of salmon requires 4 kg of wild caught fish

In 2001, over 700 000 tons of fish feed was used in Norway, almost all for salmon and trout farming (Fiskeri og Havbruksnæringas Landsforening, FHL). When calculating with the average fish oil content in salmon feed from IFFO and average oil content in fish from FAO 1986 table, the Norwegian aquaculture industry consumes (700.000 \times 0.28 \times 12) = 2 352 000 tons of wild caught fish. In 2000, Norway produced 2 895 841 tons of wild caught fish (FID 2002c) and 487 920 tons of aquaculture products, mainly salmon and trout.
4.4 Global demand for fish oil

Currently, aquaculture consumes 70 per cent of the fish oil and 34 per cent of the fishmeal (IFFO, 2002c) produced in the world. By 2010, it is estimated (IFFO, 2002c) these figures will rise to approximately 80 – 100 per cent and 50 per cent respectively. The salmon and trout industry is a major consumer, and IFFO estimates that the industry consumed 532 000 tons of fish oil in 2002, which amounts to 53 per cent of the total world production. Others have estimated that by 2006, aquaculture will have consumed all the fish oil produced in the world (Waagbø 2001).

China will have a significant effect on the global demand for marine resources to feed its growing aquaculture sector. In 1999, China was estimated to have taken 16 per cent of the total fish oil (FAO, 2002).

However, according to any of the estimates, it will only take a few years before the aquaculture industry will require volumes equivalent to all fish oil produced. The annual average fishmeal production since the late 1970’s has been around 6.5 million tons, and the fish oil production has reached around 1.2 million tons, except during the El Niño year in 1998 (FAO 2000a) and the small El Niño in 2002 when production was lower.

If a new El Niño appears, like the one in 1998 where total fish oil production went below 900 000 tons, the fish farming industry will face a shortage of fish oil. Current wild fish stocks and other raw material sources such as waste and offal will not likely allow a significant or sustainable increase in the supply of fishmeal and fish oil between no and 2015 (FAO, 2002).
The world’s fisheries are already heavily exploited. The predicted increase in fish farming of carnivorous species would increase the use of already depleted marine resources. WWF fears that the European aquaculture industry will directly place further pressure on already heavy exploited fish species used to produce this fish oil and fishmeal.
5 Fish species used to produce fish feed

The species used to produce fishmeal and fish oil can be divided into those which at present are little or not at all used for human consumption (but might potentially be used), and those which are primarily used for human consumption, but the surplus is sold for the production of oil and meal. (International fishmeal and oil manufactures organisation, IFOMA). The fishmeal and oil production in Northern Europe is mainly based on the following species: capelin, European sprat, Norway pout, blue whiting, Atlantic herring, Atlantic mackerel, horse mackerel and small sandeel. In South America it is based on anchoveta and South American pilchard. Herring and mackerel are mainly caught for human consumption, while the others often are named industry fish, where most of the catch is used for fishmeal or fish oil. Some species, like capelin and sprat, are also sold for human consumption.

Herrings or sardines and anchovies are known to science as the herring-like fishes, members of the order Clupeiformes. Throughout history, this group of fish has had more importance for humans than any other as source of food, oil, fertilizer and feed for animals. Clupeoids comprise up to 40 per cent of all the available global catch records during the last century (Paxton & Eschmeyer 1995). Clupeoids are small silvery and streamlined fish that swim in large schools and as an adults feed on plankton. They are important prey for numerous other fish, birds and marine mammals. They are typically highly abundant with great yearly fluctuations in stock size.

5.1 Fisheries management

95 per cent of world marine fish landings are from waters that are under national jurisdiction. Those fishing areas include coastal waters and the exclusive economic zone (EEZ) of each nation. However, fish stocks do not respect national boundaries, and many important fish stocks are jointly managed by more than one country. Most countries have similar management objectives, and the same problems arising from the exploitation of marine resources. Fisheries management is widely considered to be ineffective, as many important fish stocks are in a poor state (FAO 2000a).

Traditionally, fisheries management has two main operational tools: first, control of the catch (output control), and second, controlling the impact of the fishing fleet (input control). The output controls are widely in use, and by far the most common management tool is setting of the total allowable catch (TAC). A stock is subject to a maximum limit of total catch, which is then further divided to quotas for the countries that have access to the fishery. The national quotas may be partitioned for the fishers, vessels or communities. The input control set the limits for the total effort of fishing in an area or on a stock. The effort is regulated by restricting the number of vessels in an area, size of vessels, type of gear, time at the fishing area and closing some areas from fishing activities. In addition, there are other means, including technical measurements (e.g. mesh size) and indirect economical instruments (taxes).

By-catch

Fishery managers face problems such as illegal fishing, dumping, by-catch and “high-grading” of catch. The latter refers to fish dumped in order to increase the value of a catch. For example, large fish give better price leading to smaller fish being thrown away to free up space in the vessel or to comply with quota.

By-catch is a world wide problem: it is estimated that the annual discard of fish may be close to 40 million tons every year (Alverson et al. 1996). In addition, fish die when they pass through webbing
or free themselves from hooks. For decades, fisheries management has been aware of the problem of by-catch, yet it still exists on a very large scale. The Southeast Pacific ranked fourth among world fishing areas in terms of discards, with 2.6 million tons annually (Alverson, 1996). Even at very low by-catch rates of 1 - 3 per cent, the large anchoveta and pilchard fisheries in the area produced several hundred thousand tons of discards (Alverson, 1996). It has been suggested that landings of by-catch should be encouraged, and that it should be used to produce fishmeal and oil. As mentioned, Norway has a regulation prohibiting dumping of commercially important fish species, including herring, capelin and mackerel. Utilising by-catch is a more sustainable use of marine resources than dumping. However, the aim should be to stop by-catch by developing better gear or by establishing new regulations to limit fishing when by-catch is expected.

5.2 Towards sustainable fisheries management

The most elementary concept underlying fishery theories and practice is that of sustainable yield. Sustainable yield is the catch that could (in principle) be harvested from a population in the long term without compromising its future yields. Traditionally, the total allowable catches (TACs) have been set with the maximum sustainable yield (MSY) as the underlying objective: MSY is the highest catch that could theoretically be caught each year. The sustainable yield focuses only on the physical output from a fishery, but a fishery system involves a total ecosystem and the human activities impacting on it. Major international initiatives, such as the FAO’s Code of Conduct for Responsible Fisheries, adopted by the United Nations in 1995 (FAO 1995), attempts to address means to achieve sustainability in fisheries management. The FAO code of conduct for responsible fisheries, article 7.5.1, reads: “States should apply the precautionary approach widely to conservation, management and exploitation of living aquatic resources in order to protect them and preserve the aquatic environment. The absence of adequate scientific information should not be used as a reason for postponing or failing to take conservation and management measures“.

Further, the FAO Reykjavik Conference on Responsible Fisheries in Ecosystems was held in Reykjavik in October 2001. The conference adopted the Reykjavik Declaration, and paragraph five reads:

While it is necessary to take immediate action to address particularly urgent problems on the basis of the precautionary approach, it is important to advance the scientific basis for incorporating ecosystem considerations, building on existing and future available scientific knowledge. Towards this end we will undertake to:

(a) advance the scientific basis for developing and implementing management strategies that incorporate ecosystem considerations and which will ensure sustainable yields while conserving stocks and maintaining the integrity of ecosystems and habitats on which they depend;

(b) identify and describe the structure, components and functioning of relevant marine ecosystems, diet composition and food webs, species interactions and predator-prey relationships, the role of habitat and the biological, physical and oceanographic factors affecting ecosystem stability and resilience;
When sustainable fisheries management is the aim, focus needs to be on the whole ecosystem. There is need for more integrated fishery management methods. This new perspective is represented by the ecosystem approach, or “ecosystem-based management” (MD 2002). This is a management approach that attempts to take into consideration all relevant factors: the ecosystem in all its complexity, the species interactions in it, and human aspects involved. (WWF-Australia 2002) An Ecosystem approach is more than a management tool: it is a framework of thinking, on which all fishery management should be based. In order to increase sustainability in exploitation of commercial fisheries, stock assessments relying on the single-species methods should also include multi-species considerations, which take into account not only one target species, but also all relevant species and their interactions. Moreover, the development and use of selective fishing gear and practices that minimise wasting target species and by-catch of non-target species have to be strongly promoted. Good fishery management is based on science. Unfortunately, there is still a lack of understanding in the biology of many important commercially exploited fish species. Therefore, the precautionary principle must be the foundation of future fisheries management.
5.3 Fisheries in the South East Pacific Ocean

The pelagic fisheries in the South East Pacific Ocean (FAO Statistical Area 87) were characterised as “fully fished” in 2001 (WRI 2001), and present catch statistics show that the fisheries are not increasing. One important commercial species, the South American pilchard, has shown a significant decrease in catch over the past fifteen years. Another species, the Chilean jack mackerel has been decreasing trend since 1997. The decrease is thought to be related to natural parameters such as temperature and to some extent overfishing. The anchoveta population is highly fluctuating, and the stock has finally recovered from the decline caused by the strong El Niño in 1998 and by many years of overfishing in the 1970’s.

At present, there seems no possibility of increase in catch in near future in any of the fisheries in the South East Pacific Ocean. There is clearly no room for increasing the percentage of the catch used to produce fish oil or fishmeal: Peru and Chile have large human populations, and due to food-security reasons, both governments advocate the use of fish for human consumption.

In addition, the species used for fishmeal and fish oil in the Pacific are very important for the marine ecosystem as they are prey for fish, birds and mammals. Heavy exploitation could lead to serious environmental disturbances.

Fisheries management in Chile and Peru

The coastal waters of Peru and Chile have one of the world’s largest fisheries. The trade winds that toward north-northwest, parallel to the coastline of Peru, draw the surface water westward away from the shore. Cold, nutrient-rich water rises from the deeper levels to replace the surface water. This is called up welling and the nutrients support high levels of algae growth that give rise to a diverse marine life including large fish populations. Every 3 to 7 years the up welling stops for a year, caused by a disruption of the ocean-atmosphere system in the tropical Pacific. This has a devastating effect on the fisheries along the coast. As this event appeared around Christmas, fishermen named it El Niño, meaning “the little boy”. When the nutrient poor warm water reaches
the coast, primary production declines dramatically and fish populations disappear as a result of the missing food.

Fisheries management along the coast of Chile and Peru is restricting access to areas and timing of fishing activities, meaning where and when fishing can take place. There is no TAC (Total Allowable Catch). When fish stocks show a tendency to decline, fishing activities are prohibited. These limitations have not stopped the dramatic decline of the large Peruvian anchoveta and South American pilchard fisheries. El Niño has a significant impact on the global fishmeal and oil production, as the fisheries from Peru and Chile provide a large part of the raw materials. During the latest, very strong El Niño year in 1997-1998 (NOAA 2002), the fish feed and fish farming industry were faced more clearly than ever with the fact that the increasing demand for fish feed cannot be met.
5.4 Commercially exploited fish species in the South East Pacific Ocean

*Sardinops sagax* – South American pilchard

**Common names:** South American pilchard, *på norsk:* Sardin, *en español:* Sardina

**Description:** South American pilchard is spindle-shaped, and has usually several large dark spots on the upper side of the body. Its colour is bluish green above and silvery below. It may grow to over 30cm long. The species occurs in many parts of the Pacific as well as on the coast of southern Africa.

**Biology:** South American pilchard feed mainly on planktonic crustaceans, such as copepods, and phytoplankton. It matures at the size of 24 cm, and breeds twice a year, mainly during summer months with a lesser spawning during winter/spring. The maximum reported age is 25 years, although its typical life span is much less. South American pilchard is an important prey for various large fish, birds and marine mammals.

**Capture and management of South American pilchard**

South American pilchard is principally utilised for the fishmeal and oil production, but a part of it goes to human consumption (Frimodt 1995). The countries with the largest catches are Chile and Peru. First catches were reported in 1961. The harvest increased from 1970’s and reached a peak of about 6.5 million tons in 1985, then decreased due to over-fishing and El Niño phenomenon. The total catch for 2001 was 60 406 tons (Ministerio de Pesqueria). This is dramatically less than in previous years.

Main Sources of information: FAO 2000b, FishBase 2002, Whitehead 1985, Illustration and distribution map from the Food and Agriculture Organization of the United Nations, Species identification and data programme site. Distribution map could be inaccurate.
Engraulis ringens - Anchoveta (Peruvian anchovy)

**Common names:** på norsk: Ansjos  
en español: Anchoveta

**Description:** Anchoveta has a slender and elongated body that is rather round in the cross-section. It has a pointed snout, a short upper jaw with bluntly rounded tip, and a lower jaw reaches in front of nostril. The colour is blue greenish above and silvery below. Young individuals have a silver stripe along the side, which disappears with age. It may grow up to about 20 cm.

**Biology:** Anchoveta feed on plankton by filter feeding; the diet consists mainly of diatoms (microscopic alga). In addition it feeds on copepods, fish eggs and dinoflagellates. Therefore, it is completely dependent on the up welling of the nutrient rich water. Anchoveta matures at the size of 10cm, around the age of 1 year, and breeds throughout the year along the coast of Peru and Chile, having a peak in winter/spring. It lives a maximum of about 3 years. The abundant guano-producing seabirds in Peru and southern Africa feed mainly on the large populations of anchovy and South American pilchard (Frimodt 1995).

**Capture and management of anchoveta**

Anchoveta is caught to produce fishmeal and oil, and is the most heavily exploited fish in world history. The stock has been greatly fluctuating. The largest catches were in the beginning of 1970’s (over 13 million tons), after which there was a dramatic decrease set off by overfishing and a strong El Niño in 1980’s. During the 1990’s, the stock recovered until the El Niño in 1997-1998. The total catch in 2001 was 6 442 693 tons (Ministerio de Pesquería). The countries with the largest catches are Peru and Chile.

Distribution of anchoveta

Main Sources of information: FAO 2000b, FishBase 2002, Whitehead 1988, Illustration and maps from the Food and Agriculture Organization of the United Nations, Species identification and data programme site. Distribution map could be inaccurate.
Trachurus murphyi – Chilean jack mackerel

Common names på norsk: Chilensk hestemakrell
en español: Jurel chileno

Description: Chilean jack mackerel has an elongate and fairly compressed body, a large head and eyelids. It may grow up to about 60 cm; usually it matures around 36 – 38 cm.

Biology: Chilean jack mackerel feeds primarily on crustaceans and shrimps, but also small fishes and squid. It has pelagic eggs and spawning generally occurs during the summer.

Capture and management of Chilean Jack Mackerel
Chilean jack mackerel is caught commercially with trawls, purse seines and traps and on line gear. The total catch reported for this species to FAO for 2000 was 1 540 494 ton. The countries with the largest catches were Chile and Peru. The species is utilized canned for human consumption and also made into fishmeal and fish oil.

Main Sources of information: FAO 2000b, FishBase 2002, Illustration and maps from the Food and Agriculture Organization of the United Nations, Species identification and data programme site. Distribution map could be inaccurate.
5.5 Fisheries in the North East Atlantic

The fisheries in the North East Atlantic (FAO Statistical Area 27) were characterised as “fully fished” in 1983, and as over-fished in 1994 (WRI 2001). Among the industrial fisheries today, the situation for the blue whiting is the most alarming. The species is harvested outside safe biological limits, and if present fishing effort continues, scientists fear a collapse of the stock.

In 1997, FAO reported that most of the traditional fish resources of the North-East Atlantic were fully exploited or overexploited, with several stocks depleted. "The root cause of this poor situation within European waters has been the inability of the member states within the European Union (EU) to control and reduce fleet capacity within the Common Fisheries Policy" (FAO, 1997). In its Quality Status Report 2000 of the North-East Atlantic, the OSPAR Commission states that many target species are now outside their "safe biological limits". Fishing is particularly intensive in the North Sea, with around 50-60 per cent (but up to 60-70 per cent in some cases) of the total biomass of the main commercial stocks removed each year. Fishing on this scale is clearly unsustainable and threatens the integrity of the marine ecosystem, resulting in, for example, the modification of predator-prey relationships (OSPAR 2000).

Stock catches of the main "industrial" fish species in the North East Atlantic 1970 - 2000

Fisheries management in Europe

In the European Union, fisheries management has been influenced by community-wide fisheries policy since the early 1970’s, and currently all the fishing activities are under the Common Fisheries Policy (CFP). In Norway, the era of modern fisheries management with regulation of catch and/or effort started in 1977. The Norwegian Government, through the Ministry of Fisheries, regulates Norwegian waters which include coastal waters and the 200 miles wide Exclusive Economic Zone (EEZ). TAC is the most common used system in the Northern Atlantic, the Norwegian Sea and the Barents Sea. The International Council for Exploration of Sea (ICES) conducts research on commercially-exploited fish stocks and gives guidelines for their management, including recommendations for the TACs. However, these recommendations are not always followed. For example, the total catch of blue whiting, a species widely used in the production of fishmeal and oil, was 1.8 million tons in 2001. This was more than double the recommended quota from ICES.
5.6 Commercially exploited fish species in the Northern Atlantic

*Clupea harengus* – Atlantic herring

Common names: på norsk: Sild, en español: Arenque del Atlántico

**Description:** Atlantic herring has an elongate and fairly slender body, and a rounded belly. It is bluish or greenish blue above and silvery below. There are slightly different forms and stocks of Atlantic herring, some of which may even be considered different species but are usually defined as subspecies or races. Atlantic herring can grow up to 40 cm, but is usually from 20 to 25 cm.

**Biology:** Herring mainly feeds on planktonic copepods (especially *Calanus finmarchicus* and *Temora longicornis*). In addition it eats amphipods, euphausids, small fishes and arrow-worms. Atlantic herring reach maturity between 3 and 9 years, depending on the growth rate. Each stock has its own spawning time and place: in any one month of the year, there is at least one population spawning. In the North Eastern Atlantic, killer whales primarily feed on the Atlantic herring and follow herring to its wintering areas in the fjords of Northern Norway.

**Capture and management of Atlantic herring**

Atlantic herring is among the world’s most numerous fish, and has always been important to the Northern Europeans. Some stocks collapsed in the mid-1960s–mid-1970s due to overexploitation, climatic factors may also have contributed to these collapses. Most of the herring stocks recovered after effective management measures were implemented to reduce the catch. The harvest of the Norwegian spring-spawning stock and North Sea autumn-spawning stock is considered to be within safe biological levels. However, the herring stocks in the Baltic (ICES Subdivision 22 – 32) have shown a decreasing trend and are thought to be exploited outside safe biological limits. The total catch of Atlantic herring in 1999 was 2 400 000 tons, and the countries with the largest catches were Norway and Iceland (FAO). Currently, Atlantic herring is mainly used for human consumption, but the surplus is used to produce fishmeal and oil. The European Union has prohibited the landings of herring for fishmeal and fish oil. The Baltic Sea fisheries are an exception. However, the Baltic herring have such high levels of dioxins that they cannot be used for fish feed unless cleaned of organic pollutants. The dioxins accumulate in the food web, and herring meal and oil from the Baltic sea exceed the present EU legal upper limits (Finnish Game and Fishery Research Institute 2002).

**Distribution of Atlantic herring**

Main Sources of information: FAO 2000b, ICES 2002b, FishBase 2002, Pethon 1998, Whitehead 1985, Illustration and distribution map from the Food and Agriculture Organization of the United Nations, Species identification and data programme site. Distribution map is not accurate and has been modified by WWF.
**Sprattus sprattus – European sprat**

Common names: på norsk: Brisling en español: Espadín;

**Description:** European sprat is a slender small fish with a lower jaw slightly longer than the upper. It is silvery coloured with a very dark back. European sprat may grow up to 16 cm, usually to 12 cm.

**Biology:** Sprat feeds mainly on planktonic crustaceans. It becomes sexually mature around the age of 2 years. Spawning takes place mostly in summer.

**Capture and management of European sprat**

European sprat is important in the North Sea, the Baltic Sea and Norwegian coastal waters. It is used in the production of fishmeal, as mink food and for human consumption (sold canned as “anchovy”). The Baltic stock supported a catch of 340 000 tons in 2001 and is considered to be within safe limits. Landings of sprat in the North Sea in 2001 were 200 000 tons, mostly by Denmark and Sweden. The state of the sprat stocks in the North Sea is not precisely known but they are believed to be in good condition. Herring is common as a by-catch in sprat fisheries and most sprat catches are taken in industrial fisheries where catches are limited by herring by-catch restrictions.

**Mallotus villosus - Capelin**

Common names: **på norsk**: Lodde *en español*: Capelán

**Description:** Capelin has a slender body that is almost even in height from snout to tailfin, and the sides are covered with small dark spots. The mouth is large and the upper jaw reaches to the back of the eye. It is olive green above and silvery below. Capelin may reach a maximum size of 23 cm.

**Biology:** Capelin feeds on small planktonic crustaceans: copepods (Calanus), euphausiid shrimps (krill), amphipods, as well as on marine worms and small fishes. Capelin becomes sexually mature between 2 and 4 years, depending on growth rate. Capelin spawn in large schools along the shoreline or in shallow water. Females produce large amounts of adhesive eggs (6000 – 12000). Capelin rarely live longer than five years. *Capelin is a key species in the food chain of the circumpolar waters, as it forms a major part of the diet of many larger fishes (especially cod and haddock), sea birds (e.g. puffin and common guillemot), and cetaceans.*

**Capture and management of capelin**

Capelin is principally used in fishmeal production. In addition, capelin is used for human consumption, in particular the roe (Frimodt 1995). Since the 1950’s there has been a large industrial fishery of capelin along the coast of Northern Norway (Finnmark) and Barents Sea. Since the 1960’s also in Iceland and since the 1970’s around the island Jan Mayen. By 1980, intensive fishing had increased to the stage of a high over exploitation that led to the collapse of the Barents Sea capelin in 1986. The fishery was closed until the early 1990’s, and was closed again in mid-1990’s. The total catch in 2001 was 568 000 tons. Today the capelin harvest is considered within the safe biological limits (ICES 2002f); however a decline in spawning stock was found in October 2002, and the recommended TAC for 2003 was reduced by over 50 per cent to 310 000 tons. Capelin in the Iceland-Jan Mayen area has been more stable than the Barents Sea capelin and supported a catch of 1 250 000 tons in 2001. The stock is considered to be within the safe biological limits. The countries with the largest catches of capelin are Iceland, Norway and Russia.

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Main Sources of information: FAO 2000b, FishBase 2002, Pethon 1998, ICES 2002c, ICES 2002f. Illustration and distribution map from the Food and Agriculture Organization of the United Nations, Species identification and data programme site. Distribution map is not accurate and has been modified by WWF.
**Trisopterus esmarkii – Norway pout**

Common names: på norsk: Øyepål en español: Faneca noruega

**Description:** Norway pout has a slender body and large eyes, and a longer lower than upper jaw. There is a dark spot at the upper edge of the pectoral-fin base, and a dark sideline make a curve over the pectoral fin. Norway pout is grey-brown above, silvery on sides, and white on the belly. It may reach 25 cm but typically it is 13 to 19 cm.

**Biology:** Norway pout feed on bottom dwelling crustaceans such as shrimps and amphipods, occasionally on juvenile fish, and on planktonic crustaceans (e.g. copepods). Norway pout reach the sexual maturity at 2 years (14 to 15 cm). Spawning takes place in the deep waters (about 100m) from January to July (mostly from March to May). The growth of Norway pout is rapid, and it may live to 5-6 years. *Norway pout is an important prey species for many larger demersal fish species.*

**Capture and management of Norway pout**

Norway pout is caught primarily for reduction to fishmeal by using bottom trawls. Norway pout is mainly trawled by Denmark and Norway and the fishery also targets blue whiting. Significant by-catch of other species such as haddock and whiting may occur. The stock is within safe biological limits and total catch in 2001 was 65,600 tons. ICES warns that there is a need to ensure that the stock remains high enough to provide food for a variety of predator species and warns that locally concentrated harvesting may cause local and temporary depletions of food for predators.

*Distribution of Norway pout*

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Main Sources of information: Cohen *et al.* 1990, FAO 2000b, ICESd, Illustration and distribution map from the Food and Agriculture Organization of the United Nations, Species identification and data programme site. Distribution map could be inaccurate.
**Micromesistius poutassou** – Blue whiting

Common names: på norsk: Kolmule en español: Bacaladilla

**Description:** Blue whiting is a slender fish without the chin barbell typical for codfish. The two first dorsal fins are short and widely apart from each other. It is blue-grey on the back, paler on the sides and shading to white on the belly. Blue whiting is normally 15 to 30 cm and can reach 50 cm. Females are usually larger than males.

**Biology:** Blue whiting feeds mostly on small crustaceans, but large individuals also prey on small fish and cephalopods (squids). Blue whiting grows rapidly, and may live up to 20 years. It matures between 2 and 7 years. Fish in the southern end of distribution mature earlier. Spawning takes place in free water masses at the depth of 300 to 400 m during spring. Blue whiting is an important prey for larger fish such as ling, cod, haddock and also marine mammals such as pilot whales and common dolphins.

**Capture and management of blue whiting**
Large part of the catch of blue whiting is processed industrially as oil and meal. Small amounts are marketed fresh and frozen for human consumption. Norway, Iceland, Russia and the Faeroe Islands have the largest catches. There is no international agreement on management of blue whiting and the scientific advice from ICES has not been followed. The total catch in 2001 was almost 1.8 million tons, which is the highest ever recorded. Most of the catches were landed for industrial purposes. Catch levels in recent years have been possible because of exceptionally good recruitment. It is expected that the stock will rapidly decline in the near future, since the recruitment, most likely, will not be high enough to maintain the stock under the present exploitation. The stock is considered to be harvested outside the safe biological limits.

Main sources for information: Cohen et al. 1990, FAO 2000b, FishBase 2002, Pethon 1998, ICES 2002c, Illustration and distribution map from the Food and Agriculture Organization of the United Nations, Species identification and data programme site. Distribution map is not accurate and has been modified by WWF.
**Ammodytes marinus & A. tobianus – Small sandeel and Lesser sandeel**

Common names: på norsk: Havsil, Småsil (tobis) en español: Aguacioso

**Description:** Small and lesser sandeel are difficult to distinguish. Both species have an elongated body, which is slightly compressed from the sides. The back is sandy brown. Small sandeel can be up to 20 cm, and lesser sandeel up to 25 cm.

**Biology:** Small sandeel feed on planktonic crustaceans, some large diatoms, fish egg and larvae. Spawning time depends on the distribution, different stocks spawn in different time, some in winter, while others in spring or autumn. Spawning takes place at the sea-bottom. *Small sand eel is an important prey for many larger fish such as cod, and many sea birds (e.g. puffin).*

**Capture and management of Small sandeel**

Small and lesser sandeel are not separated in fisheries statistics (also other species of sandeels may be included), and they are managed as “sandeels”. During the last decades, the sandeel has become increasingly important for the fishery industry due to the decline of other species such as Atlantic mackerel and herring. Sandeels are mainly caught by the United Kingdom, Denmark and Norway. The harvest of sandeels in the North Sea is within safe biological limits (ICESd). However, ICES recommends that catch should not increase, because the consequences of removing a larger fraction of the prey for other species, are unknown.

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Main sources of information: FishBase 2002, Pethon 1998, Illustration and distribution map from the Food and Agriculture Organization of the United Nations, Species identification and data programme site. Distribution map could be inaccurate.
**Trachurus trachurus – Atlantic horse mackerel**

Common names **på norsk**: Taggmakrell og Hestemarkell  
**en español**: Jurel

**Description:** Atlantic horse mackerel have an elongated and fairly compressed body, a large head and eyelids. The upper part of body and top of head are dusky to nearly black or grey to bluish green; the lower two thirds of body and head are usually paler, whitish to silvery.

**Biology:** Atlantic horse mackerel may grow up to about 60 cm; usually it is from 15 to 30 cm

**Capture and management of Atlantic horse mackerel**
Atlantic horse mackerel is caught mainly for human consumption, yet it is used for fishmeal and oil production. The European catch in 2001 was estimated to be 283 000 tons. The countries with the largest catches are Norway, Denmark, Ireland, Netherlands and Spain. The status of the North Sea component of the stock is still poorly known after its collapse in 1970s. The component has recovered but catches have been highly variable. The status of the western component is also uncertain but its abundance is believed to be declining.

**Scomber scombrus - Atlantic mackerel**

Common names Atlantic mackerel  *på norsk:* Makrell  *en español:* Caballa del Atlántico

**Description:** Atlantic mackerel have an elongated and fairly compressed body, a large head and eyelid. It has markings (stripes) on back slanting to near vertical, with relatively little undulating. Atlantic mackerel attains a maximum size of 60 cm.

**Biology:** Atlantic mackerel feeds on zooplankton and small fish. It attains sexual maturity at 2 or 3 years, and the eggs are pelagic. The recruitment is poorly understood. *Atlantic mackerel is prey for the tunas, sharks and dolphins.*

**Capture and management of Atlantic mackerel**

The Northeast Atlantic mackerel stock is considered to consist of three spawning components (North Sea, Western, and Southern), and a significant mixing of these components occurs at various times throughout the year. The harvest is conducted by a number of countries, but Norway, United Kingdom, Russia, Ireland, the Netherlands, and Spain take the main catches. The North Sea component of the North-East Atlantic mackerel stock collapsed in the early 1970s because of overfishing, and it shows no signs of proper recovery. Most of the Atlantic mackerel catches taken in the northern North Sea in recent years may have originated from the western component. The total catch in 2001 was estimated to be almost 678 000 tons. The spawning stock has increased in recent years, and this trend is expected to continue if fishing mortality is reduced. However, largely because of low abundance of the North Sea component, the Northeast Atlantic mackerel stock as whole is considered to be harvested outside the safe biological limits.

6 Alternatives for fishmeal and fish oil

No increase in global production of fishmeal and fish oil can be expected and the salmon farming industry is now looking for alternative feed resources. Increased use of fish offal or even use of bycatch could be a sustainable solution. They are resources that otherwise would be lost. Unfortunately, in Norway the trend is that less fish is processed on land, and vast amounts of fish offal is dumped in the sea every year. The major challenge is to find alternative feed resources that have all the necessary nutrients and a similar protein quality as fishmeal and to minimize anti-nutritional factors. There are several examples demonstrating that fishmeal and fish oil in feeds for carnivorous species can be totally or substantially replaced by alternative protein and oil sources. When developing a strategy to meet the shortage in fish oil and fishmeal, it is important that the industry considers potential environmental aspects of the proposed alternatives. Fish oil can be substituted by plant oil, a method that already is developed, or the fish feed can be produced from plant- or zooplankton. Other alternatives include microorganisms grown from natural gas, and harvesting small crustaceans like krill that can be fed to farmed fish.

6.1 Plants

Earlier, plant raw materials have been used only in small amounts in fish feed production. Soybean (*Glycine max*), gluten of corn (*Zea mays*) and wheat (*Triticum aestivum*) have been used as additional protein sources and vegetables with high starch content as a binding ingredients (Refstie *et al.* 2002). Lately, vegetable oils have been increasingly used, especially rape seed oil. Most studies show that the partial replacement of fishmeal or oil by vegetable or plant based raw materials does not affect the health or the growth of the salmonid fish (e.g. Rosenlund *et al.* 2001, Grisdale-Helland *et al.* 2002). The main concerns are to find the correct amino acid profile and eliminate the possible anti-nutritive agents. For example, chemicals used in the plant as an anti-growing defence can have a negative effect on the fish. However, the main problem seems to arise in the composition of fatty acids. However, the main problem seems to arise from the composition of fatty acids. The fatty acid composition of fish largely reflects what it has eaten (Refstie *et al.* 2002). Omega 3 is well know as a group of fatty acids that are very beneficial to human health and are considered to reduce the risk of heart disease Fish feed based on plant ingredients may contain lower levels of Omega 3 fatty acids. Although this might have no affect on the health of the fish, it could change the healthy fatty acid composition of the product for human consumption. However, even with high concentrations of alternative oils in the feed, farmed fish will still remain as a good source of Omega 3. Test panels indicates that consumers might prefer the taste of salmon fed mixtures of plant and fish oil to those fed only fish oil (Bolstad 2001).

According to the leading fish feed producers in Norway, vegetable-based alternatives are now widely in use, and will be increasingly used in the near future. Fish farmers have welcomed the use of plant ingredients in fish feed, hoping it can stabilise the feed costs when the expected deficiency in fish oil appears with increased prices.

**Environmental aspects**

Global production of vegetable oil is 100 times higher than that of fish oils (FAOSTAT 1990-98), and these products are obvious substitutes. World demand for edible oils is high and rising. Soy is a crop that provides both edible oil and protein (soy meal). Most of the recent growths in soy crop take place in the American subtropical and tropical regions. This expansion has direct and indirect impacts on natural habitats of high conservation value and the livelihoods of people and endangered species that depend on those habitats. When buying soy, the use of Better Management Practices should be required. For further details on this, see WWF position paper on soy (WWF 2002)
Fish feed is the source of nutrients in intensive fish farming and large amounts are released into the marine environment (Hasan 2001). Developing more efficient and environmentally friendly feed and feeding technologies may reduce this impact. An example is the fish farming industry in the Baltic Sea, which causes vast problems of eutrophication. A recent study in Finland shows that the nutrient load of vegetarian based fish feed is lower than from feed based on purely fishmeal and oil (Seppälä et al. 2001). This aspect is very interesting, and should be assessed further. However, the fish farming industry fears that consumers will show scepticism to a carnivorous species raised on vegetables.

### 6.2 Genetically modified organisms in feed

Genetically modified organisms are often presented as a solution to create the “perfect plant” to use for fish feed. GMO’s could compensate for an unfavourable fatty or amino acid profile. However, GMO’s are highly controversial, both environmentally and with regard to consumer resistance. All the Norwegian fish feed producers have a policy, rejects GMO’s in fish feed (Attachment VI) and the Scottish industry has the same approach (Scottish Ministerial Working Group for Aquaculture 2003).

**Environmental aspects**

WWF recognizes the potential value to society arising from the new opportunities provided by the developing science of genetically modified organisms (GMOs), especially for medical application. However, WWF is concerned about the potential dangers involved in releasing GMOs into nature (WWF 2000). The application of GMO technology to agricultural crops and animal breeding may bring short-term benefits but is also a threat to biodiversity. Release of GMOs into the nature takes place through genetically modified crops or release and escape of farm animals, including fish. The development of GMOs is much more than a greatly accelerated form of microbial, plant and animal breeding program, which relies on natural reproductive processes. It can create novel life forms and has the potential to do so at a rate unparalleled in Earth’s history, and in a manner not controlled by, or within the reach of, natural selection. Different species are adapted to different conditions. Some are very sensitive to minor changes in these conditions, or competition from other species. The adaptability of a species depends on genetic diversity. GM involves the artificial selection and combination of desired traits, which results in a great reduction of genetic diversity. Further, the reduced natural genetic variation leads to lower biodiversity. Most consumers, especially Europeans, are very sceptical towards GMO products and therefore labelling regulations are strict. These issues are further spelled out in “Background Paper on the need for a Biosafety Protocol as part of the Convention on Biological Diversity” (WWF International, 1995). For the present, WWF wishes to see a strong precautionary approach in the use and release (or escape) of GMO’s into the wild. The science is still very new and much ecological research must be done before this technology ever moves from the laboratory into standard practice.

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Genetic modification (GM) is a common name for technologies that alter the genetic makeup of living organisms such as bacteria, plants and animals, or plants. Combining genes from different organisms is known as recombinant DNA technology, and the resulting organism is called "genetically modified". GM products include medicines and vaccines, foods and food ingredients, feeds, and fibres.
6.3 Microalgae, plankton and micro-organisms

Microalgae, such as plant plankton, are the most important primary producers in marine ecosystems. Through the process of photosynthesis, microalgae such as plant-plankton utilise light, water, nutrients and CO$_2$ to grow. Plankton form the basic element of all food webs in the oceans. Microalgae growth occurs through vegetative cell division. Every cell divides into two daughter cells. Hence, a microalgae population may increase exponentially in optimal conditions, which gives extensive potential for growing large amounts of plankton. Microalgae culturing is also a very promising alternative for fishmeal and oil, as some microalgae have higher protein content and may be rich in omega 3 fatty acids (Källqvist & Willumsen 2002). Moreover, some species, such as *Spirulina*, *Chlorella* and *Scenedesmus* include the essential amino acids in the right proportions needed for fish. Hence, microalgae cultures are expected to have a significant role in fish feed production in 5 to 10 years (pers. comm Steien 2002).

Natural gas can be used to produce biomass usable for fish feed. In Norway, a process has been developed to produce biomass from natural gas. Single cell proteins are obtained from fermentation of a bacteria *Methylococcus capsulatus* by using methane gas as a carbon and energy source. This single cell protein is compatible as a protein ingredient in fish feed, and the use in salmon feed production of such products was approved by the European Union in 1995 (Norferm DA).

**Environmental aspects**

Utilising microalgae, such as plant plankton, to produce high value seafood like salmon would be a very sustainable way of producing human food. Unfortunately, the debate has been misled from time to time, when it has been claimed that producing microalgae for fish feed can “remove” harmful carbon dioxin (CO$_2$) emissions. It has been proposed to culture microalgae using CO$_2$-emissions from oil and gas production (Källqvist & Willumsen 2002). Simplified, this means that plant-plankton grows using the added CO$_2$ for photosynthesis and then the microalgae is used as raw material in fish feed. However, the CO$_2$ emissions do not disappear and the total level of CO$_2$ in the atmosphere will not decrease. The emission of CO$_2$ is just delayed. Some carbon will be released through the fish’ respiration, and the rest will be released when the fish is consumed or discarded. Carbon dioxin can attach to water molecules, and it has been argued that the CO$_2$ from fish respiration will be bound in the seawater. For farmed fish, this argument is not correct, especially as the fish stay close to the water surface where CO$_2$ will leak to the atmosphere. The only way to achieve long term reduction in CO$_2$ concentration in the atmosphere is to permanently store it in sediments.

6.4 By-products and fish offal

By-products and fish offal are not strictly speaking alternative raw materials to fish oil and fishmeal. However, the use of these resources as a means to reduce fishing mortality on other fish-species would significantly improve the sustainability of, for example, salmon farming. Huge amounts of fish catches are wasted; estimates give numbers as high as one third of all marine raw materials are dumped into the sea. Often, fish is filleted on board the fishing vessel and all cut offs are dumped back in the ocean. Using cut offs and other by-products from the fish industry is encouraged, and in Norway, both industry and Government advocate the use of fish offal. According to Stiftelsen Rubin (2002), the total amount of fishmeal production based on fish-offal and by-products in Norway, was 239 000 tons in 2000, 174 000 tons in 2001 and is expected to
decrease significantly in 2002. This is due to the dramatic reduction in the Norwegian fish processing industry as a result of low economic profit. Problems arising from using by-products and fish offal are related to logistics and in some areas, elevated levels of contamination in the viscera (guts, liver etc.). Ongoing research projects try to solve these problems. In addition to the offal from the wild fisheries, there are significant amounts of waste from fish farming itself. However, Norwegian regulations do not allow offal from fish farming to be used as feed for farmed fish (Norwegian Ministries of Fisheries and Agriculture 1998). This waste is used for other purposes, including feed for other husbandry and production of high value products for human consumption.

6.5 Harvest of marine resources from a lower trophic level
It has been suggested that raw materials for producing fish feed could be obtained by harvesting marine resources from a lower trophic level in the marine food web than fish. The major argument behind is that it is more energy efficient to feed the fish directly from a low trophic level. This is similar to the argument that humans should eat more vegetables and grain rather than meat, because it takes ten times more energy to “grow” the meat than if the grain is consumed directly. If plankton is fed for farmed fish the resource lost is dramatically lower than, if farmed fish eats fish.

In the ocean, oceanic zooplankton is below fish in the food webs, and is one of the most widespread and abundant forms of animal life on earth (Verify & Smetacek 1996). Of the zooplankton, krill and copepods are encountered in vast numbers, and are considered to be possible alternatives for fish feed production. Current research projects examine the possibility of harvesting krill and copepods for fish feed production. In its natural oceanic life, salmon prey on small crustaceans like krill in addition to a diet based on fish (Mills, 2000). The problems that arise from zooplankton harvesting are by catch, rapid spoilage of these species, and how to set limits for harvest (Saltnes 2002).

In Norway, the harvest of copepods has been suggested as an alternative to fish in fish feed. Krill is already harvested in the Antarctic, annual catches being around 100 000 tons (CCAMLR 2000). Further exploitation is considered, and the Committee for the Conservation of Antarctic Marine Living Resources (CCAMLR) has set a precautionary limit of 1.5 million tons for krill harvest in the Southwest Atlantic sector of the Southern Ocean. Euphausiids (commonly known as krill) are widespread in world's oceans, and there are many krill species that are enormous in numbers (Siegel 2000), such as Antarctic krill *Euphausia superba* (Nicol 2000).

Environmental aspects
The significance of krill in marine ecosystems has been known for centuries, especially as it has an obvious importance in the diet of many fish and baleen whales (Mauchline & Fisher 1969). Krill are key species in the pelagic marine food webs, as many species are either directly preying on krill or on species preying on krill. However, the life history of krill is still poorly understood, and it is only lately that new studies have provided some understanding (Mangel & Nicol 2000). There are indications from the Antarctic that krill harvesting may have serious, short term effects on local ecosystems and concern has been expressed within CCAMLR (ASOC, 1998) that krill catches in some areas may affect predators such as penguins by locally depleting their food source. Unwanted by-catch from krill harvest can be significant, as net size is very small. Moreover, global warming might significantly affect krill abundance (Loeb *et al.* 1997). It is extremely important that any plans of increasing harvest of krill from for example the Barents Sea, is conducted with a strong precautionary approach. Krill harvesting can have catastrophic effects on the ecosystem.
7 Conclusions

The trend in European fish farming is to produce high value, carnivorous fish such as salmon, trout, seabass, tuna and most recently cod. This report show that production of a single kilogram of salmon and trout typically uses four kilograms of wild-caught fish processed into fishmeal and fish oil for feed. With no improvement, this type of aquaculture is on a destructive path that might pose a threat not only to wild fish stocks but also to the industry’s own long-term potential. The demand for high quality seafood is increasing and it will only take a few years for the aquaculture industry to consume all the fish oil produced in the world. If fish oil supply fails, like it did in 1998 under the strong El Niño in the Pacific, the aquaculture industry will face a shortage of fish oil.

In Europe, the situation for the blue whiting is critical. A total collapse can be expected if the current fishing practice continues. The majority of fishery resources from the North-East Atlantic are fully exploited or overexploited. The pelagic fisheries in the South East Pacific Ocean were characterised as “fully fished” in 2001, and present catch statistics show that the fisheries are not increasing.

At present, there is no possibility of increasing the catches in any of the fisheries in the South East Pacific Ocean. There is clearly no room for increasing the percentage of the catch used to produce fish oil or fishmeal as Peru and Chile have large human populations, and due to food-security reasons, both governments advocate the use of fish for direct human consumption. All fish species used for fishmeal and fish oil in both the Pacific and the Atlantic are very important for the marine ecosystem as they are prey for fish, birds and mammals. Heavy exploitation could lead to serious environmental disturbances.

Fish species commonly used to produce fishmeal and fish oil:

<table>
<thead>
<tr>
<th>Fish specie</th>
<th>Status</th>
<th>Environmental impact</th>
<th>Maximum exploitation</th>
<th>History of overfishing</th>
</tr>
</thead>
<tbody>
<tr>
<td>South American pilchard</td>
<td>Dramatic decrease in catch</td>
<td>Important prey for various large fish, birds and marine mammals.</td>
<td>Yes</td>
<td>Yes, catch has dramatically decreased.</td>
</tr>
<tr>
<td><em>Sardinops sagax</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peruvian anchovy</td>
<td>Stock has recovered</td>
<td>Important prey for seabirds in Peru and southern Africa.</td>
<td>Yes</td>
<td>Yes, collapse in the 80s due to overfishing and El Niño</td>
</tr>
<tr>
<td><em>Engraulis ringens</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chilean Jack Mackerel</td>
<td>Decrease in stock since 1996</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Trachurus murphyi</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Atlantic Herring</td>
<td>Norwegian spring-spawning stock and autumn-spawning stock is OK. North Sea spring-spawning stock is exploited outside safe biological limits.</td>
<td>Important prey for killer whale</td>
<td>Yes</td>
<td>Yes, collapse in mid 70s</td>
</tr>
<tr>
<td><em>Clupea harengus</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>European sprat</td>
<td>State of stock not precisely known</td>
<td>High by catch of herring in fishery</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Sprattus sprattus</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stock</td>
<td>Key species in circumpolar waters as prey for cod, haddock, seabirds and cetaceans and larvae is feed for herring.</td>
<td>Yes</td>
<td>Yes, Barents Sea stock collapsed in 1986</td>
<td></td>
</tr>
<tr>
<td>-------</td>
<td>-------------------------------------------------------------------------------------------------</td>
<td>-----</td>
<td>-------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Capelin <em>Mallotus villosus</em></td>
<td>Stock within safe biological limits, however decrease in stock expected in 2003.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blue whiting <em>Micromesistius poutassou</em></td>
<td>Stock harvested outside safe biological limits</td>
<td>Important prey for larger fish such as ling, cod and haddock.</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Small sandeel <em>Ammodytes tobianus</em></td>
<td>Stock within safe biological limits</td>
<td>Important prey for many larger fish such as cod, and many sea birds (e.g. puffin).</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Atlantic Horse Mackerel <em>Trachurus trachurus</em></td>
<td>Uncertain, possible decrease in stock</td>
<td></td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Atlantic Mackerel <em>Scomber scombrus</em></td>
<td>No proper recovery and low abundance, considered to be harvested outside biological safe limits</td>
<td>Prey for the tunas, sharks and dolphins</td>
<td>Yes</td>
<td>Yes, North Sea component of the stock collapsed in the early 1970s</td>
</tr>
</tbody>
</table>

The table is based on the information in chapter five, and the conclusion is clear:

- Most species have a history of overfishing
- Most species are very important part of the marine ecosystem as prey for other fish, seabirds or marine mammals
- Some fisheries have high by-catch of other species
- Some species have a natural fluctuating stock, vulnerable to change in environmental factors such as temperature.
- All species are either fully exploited or there is not sufficient knowledge to increase catch

As no increase in global production of fishmeal and fish oil can be expected, the salmon farming industry is now looking for alternative feed resources. Increased use of fish offal or even utilisation of by-catch could be a sustainable solution because it is using a resource that otherwise would be lost. Unfortunately, the trend is that less fish is processed on land, and vast amounts of fish offal is dumped in the sea. Another alternative is to increase the use of vegetable proteins. There are several examples demonstrating that fishmeal and fish oil in feeds for carnivorous species can be totally or substantially replaced by alternative protein and oil sources.

Other solutions are the use of krill, harvested from the ocean, growing algae or using bacteria’s. Especially harvest of krill, the most important species in the food web, could have detrimental effects on marine ecosystems.
Intensive fish farming is not a solution for helping depleting wild fish stocks. Only better fisheries management can help relieve the pressure on current fisheries. Today’s farming of carnivorous species such as salmon and trout is not sustainable, as it consumes four times as much wild caught fish as it produces farmed fish. By using large amounts of wild-caught fish to feed farmed fish, the European aquaculture industry is actually increasing the pressure on ocean fish populations.

Growth in farming of carnivorous species like salmon and trout cannot continue based on present marine feed resources. WWF fears that the growing fish farming industry will cause a further pressure on already heavy exploited fish species used to produce fish oil and fishmeal. The blue whiting is a sad example and when a shortage in fish oil occurs, WWF fears that other species might meet the same destiny. Without clear recognition of its dependence on natural ecosystems, the aquaculture industry is unlikely to ever be sustainable.

**Recommendations**

- WWF calls out to Governments for a better fisheries management including reductions in fleet size, ending harmful subsidies and adoption of an ecosystem based approach to management.

- The aquaculture industry must, as it is the biggest consumer of fish oil, make sure it only buys fish oil from healthy, sustainable and well-managed fish stocks. The industry should make any effort to find more sustainable alternatives preferably fish offal’s and fishwaste or fish feed from certified fisheries.

- WWF is not encouraging more farming of carnivorous fish species. However, species from lower down the food web like fish with herbivorous diets or filter feeders such as oysters, can potentially be sustainable.

- WWF asks Governments to advocate the use of fish waste and fish offal from fisheries and fish processing to be used for fishmeal and fish oil, while at the same time controlling levels of contaminants.

- WWF asks Governments to ensure that when research and testing on future alternative feed resources is conducted, the precautionary principle must be implemented.
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Attachment I:
Use of fishmeal and fish oil in fish feed (IFFO 2002b)

<table>
<thead>
<tr>
<th>Species</th>
<th>Per cent fish oil inclusion in feed produced in 2002</th>
<th>Thousand tons of fish oil used in 2002</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carp</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Tilapia</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Shrimp</td>
<td>2</td>
<td>39</td>
</tr>
<tr>
<td>Salmon</td>
<td>28</td>
<td>364</td>
</tr>
<tr>
<td>Trout</td>
<td>28</td>
<td>168</td>
</tr>
<tr>
<td>Marine fish(^1)</td>
<td>12</td>
<td>100</td>
</tr>
<tr>
<td>Catfish</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Milkfish</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Other marine fish(^2)</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Carnivorous freshwater fish(^3)</td>
<td>6</td>
<td>16</td>
</tr>
<tr>
<td>Eel</td>
<td>5</td>
<td>17</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>732</strong></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Species</th>
<th>Per cent fishmeal inclusion in feed produced in 2002</th>
<th>Thousand tons of fishmeal used in 2002</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carp</td>
<td>4</td>
<td>337</td>
</tr>
<tr>
<td>Tilapia</td>
<td>7</td>
<td>73</td>
</tr>
<tr>
<td>Shrimp</td>
<td>25</td>
<td>487</td>
</tr>
<tr>
<td>Salmon</td>
<td>35</td>
<td>455</td>
</tr>
<tr>
<td>Trout</td>
<td>30</td>
<td>180</td>
</tr>
<tr>
<td>Marine fish(^1)</td>
<td>45</td>
<td>377</td>
</tr>
<tr>
<td>Catfish</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>Milkfish</td>
<td>12</td>
<td>42</td>
</tr>
<tr>
<td>Other marine fish(^2)</td>
<td>55</td>
<td>40</td>
</tr>
<tr>
<td>Carnivorous freshwater fish(^3)</td>
<td>15</td>
<td>40</td>
</tr>
<tr>
<td>Eel</td>
<td>50</td>
<td>174</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2217</strong></td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) Bass, bream, yellowtail, grouper, jacks, mullet
\(^2\) Flat fish, including cod, flounder, turbot, halibut and cod
\(^3\) Chinese bream, mandarin fish, yellow croaker, long-nose catfish (carnivorous/omnivourous) but excluding eel.
Attachment II: 
Dioxins and Toxic Equivalents

Dioxin
The term "dioxins" normally includes polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans, a total of 210 different compounds, 17 of which are highly persistent to degradation and highly toxic. Polychlorinated biphenyls, or PCB’s, are another group of structurally related chemical compounds. Theoretically, there may be as much as 209 different PCB-congeners. About half of these appear in the environment and only 13 exert dioxin-like biological effects.

Toxic Equivalents (TEQ)
Dioxins and PCBs usually occur as a complex mixture of congeners. To enable the relative toxicity of such a mixture of compounds to be expressed as a single number, the concept of toxic equivalents (TEQ) has been developed.

The toxicity of each congener is given a toxic equivalent factor (TEF) rating. The most toxic congener-2,3,7,8-tetrachlorodibenzo-para-dioxin (TCDD)-is rated as 1. Other congeners are rated between 0 and 1, depending on their relative toxicity. The total toxicity of a sample is calculated in two steps. Firstly, the concentration of each congener in the sample is multiplied by its TEF. Next, the total toxicity is calculated by adding together the contributing toxicity of each congener. This standardises the measurement so it can be used to compare results with other sites and international levels and goals. When measuring dioxins and PCB in biological samples, concentration is given in weight units such as picogram per gram wet weight (pg/g) or nanogram per gram wet weight (ng/g) (SNT 1997).

Tolerable Daily Intake (TDI)
Tolerable Daily Intake is the amount of a substance that a person can receive each day through its whole life without any health danger. TDI is given in pg TE/kg body weight. The current levels of exposure to dioxins in industrialized countries are in the range of 1 to 3 pg/kg body weight. The TDI recommended by the WHO consultation is internationally recognized as a reference value for ensuring that safe levels of exposure are not exceeded. In 1998, WHO reduced TDI from 10 pg/kg body weight to a range of 1 to 4 pg/kg body weight (WHO, 1998).
Attachment III:  
ICES and fish stock assessments

ICES is the organisation that coordinates and promotes marine research in the North Atlantic. This includes adjacent seas such as the Baltic Sea and North Sea. ICES acts as a meeting point for a community of more than 1600 marine scientists from 19 countries around the North Atlantic gather information about the marine ecosystem. As well as filling gaps in existing knowledge, this information is also developed into unbiased, non-political advice. ICES advice is then used by the 19 member countries, which fund and support ICES, to help them manage the North Atlantic Ocean and adjacent seas.

The Advisory Committee on Fishery Management (ACFM) is responsible, on behalf of the Council, for providing scientific information and advice on living resources and their harvesting. In formulating its advice on the management of around 135 stocks of fish and shellfish, ACFM utilizes information prepared by numerous stock assessment Working Groups. The advice for each stock usually includes: An estimate of historical trends in landings, spawning stock biomass, recruitment and fishing mortality rate, a description of the 'state of the stock' in relation to historical levels, the likely medium term development of the stock using different rates of fishing mortality and a short term forecast of spawning stock biomass and catch.

The European Environmental Agency has a number of indicators used to express the state of the European environment. An indicator of how fish stocks are doing, is the definitions given by ICES: In general terms stocks are characterised as being outside safe biological limits (or over fished) when the fishing pressure (mortality) exerted on them, exceeds sustainability i.e. when mortality exceeds recruitment and growth.

By comparing trends over time in recruitment (R) (the number of new fish produced each year by the mature part of the stock), spawning stock biomass (SSB), landings (estimate of the most likely removal from the stock, sometimes including discards) and fishing mortality (F), a reasonable reliable picture of stock development can often be derived.

More precise, with the introduction of the precautionary approach, a stock is considered to be outside safe biological limits (SBL) when the spawning stock biomass (SSB) (the mature part of a stock) is below a biomass precautionary approach reference point (Bpa), or when the fishing mortality (F) (an expression of the proportion of a stock that is removed by fishing activities in a year) exceeds a fishing mortality precautionary approach reference point (Fpa). However, a stock can be considered within safe biological limits even when the spawning stock biomass is lower than the biomass precautionary approach reference point (Bpa) but the Fishing mortality is lower than the fishing mortality precautionary approach reference point (Fpa) (SSB < Bpa but Fpa < F).
Attachment IV:  
GMO statements from Norwegian Feed Producers

Oslo, 15. November 2000

To whom it may concern

Fish feed declared as GMO-free

All members of the Norwegian Fish Feed Producers Association are producing fish feed declared as GMO-free in compliance with the following statement:
“Fish feed do not contain ingredients derived from genetically modified soybeans or maize. Level of adventitious presence of DNA or protein resulting from genetic modified soybeans and maize, which cannot be excluded, is not higher than 1 percent of the said feed ingredients.
In order to establish that the presence of this material is adventitious, we are in the position to supply evidence to satisfy the competent authorities that we have taken appropriate steps to avoid using the genetically modified organisms.”

Our members are: BioMar AS
Ewos AS
Skretting AS
NorAqua AS

These companies represented 98 per cent of total sale of fish feed in Norway in 1999.

Best regards

Agnar Moe
Director
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Address / Domicile / Destinario:
Marc Aschehoug Berner
Marine Ecosystems
W.W.F.-Norway
P.O. Box 8743, NO 0150
Oslo
FAX: 00 47 22 20 06 65

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