

**EUROPEAN PARLIAMENT**

**Directorate-General for Research**

**WORKING PAPER**

**THE FISH MEAL AND FISH OIL INDUSTRY  
ITS ROLE IN THE COMMON  
FISHERIES POLICY**

**Fisheries Series**

**FISH 113 EN**

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## EXECUTIVE SUMMARY

### 1. Introduction

The raw materials used by the fish meal and fish oil industry are derived from directed industrial fisheries<sup>1</sup> and from the by-products of fisheries for human consumption (fish trimmings). The interaction between the CFP and the fish meal and fish oil industries is through the directed fisheries for teleost 'feed fish' from which fish meal and fish body oils are derived, and sharks from which some liver oils are extracted.

The reformed CFP (EC, 2002) is a move away from single stock management towards an ecosystem based approach to fisheries management in line with the requirements of the Rio Convention of Biological Diversity (1992) and the FAO Code of Conduct for Responsible Fisheries (1995). The Commission has advocated a long-term strategy to promote the protection of vulnerable species and habitats and suggests that this is achieved through means such as gear restrictions and closed areas and seasons. Within the context of the fish meal and fish oil industry this will affect the directed fisheries for teleost<sup>2</sup> feed fish (e.g. sandeels, Norway pout, sprats and blue whiting) which are used to produce fish meal and fish body oils, and the significantly smaller directed fishery for sharks from which some fish liver oils are derived. Fish trimmings, such as offal, which are derived from the processing of fish targeted for human consumption, are also an important source of raw material for the fish meal and fish oil industry. However, the effect of the CFP on these fisheries is considered outside of the remit of this report as the fish meal and fish oil industries use only the by-products of these fisheries.

The European Commission has asked ICES to evaluate the impact of industrial fishing on marine ecosystems (EC, 2002). This will include monitoring industrial fisheries to ensure that their impact on fish species used for human consumption and other marine species remains low. Industrial fishers use purse seines and light otter trawls to catch feed fish and long lines and tangle nets to catch sharks. Purse seines, long lines and tangle nets operate in the water column, and otter trawls operate closer to the sea floor but with only sporadic contact with it. The direct effects of these gears on the ecosystem therefore involve the accidental catching of other species and limited disturbance to the sea floor. The indirect effects of these fisheries will involve the predators and prey of species caught in directed industrial fisheries.

The fisheries for feed fish are controlled by a series of management measures including total allowable catch (TACs), by-catch limits and closed areas. Apart from TACs, the management measures have been established to prevent damage to species dependent on feed fish and the juveniles of other species. The fisheries for sharks are unregulated.

The feed fish fisheries support a substantial part of the Danish, Swedish and Finnish fishery sectors. In Denmark for example, 41% of the fishers rely in some way on the feed fish fishery. The employment dependency on the shark fisheries is reported as being no more than 200.

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<sup>1</sup> For the purposes of this report, *industrial fisheries* are defined as all fisheries which target fish not destined for human consumption and which enter an industrial process. Some fish species are used for both industrial purposes and for human consumption.

<sup>2</sup> 'Bony' fish e.g. gadoids, clupeids and sandeels.

The main demand for fish meal and fish body oils is as animal feed in agriculture and aquaculture. The European Union is one of the major consumers of feed fish products, accounting for approximately 18% and 19% of world meal and oil consumption respectively between 1997-2001. In 2002, the main consumers of fish meal within the EU were the aquaculture industry (33%), the pig industry (32%) and the poultry industry (29%). Fish liver oils provide health benefits to humans and are used in health supplements. The squalene oil in shark liver is used in cancer and AIDS inhibiting drugs.

## **2. The structure of the fish meal and fish oil industry in the European Union**

### **2.1. The industrial fisheries**

The industrial fishery for feed fish is conducted by both EU registered vessels (landing 1 524 000t annually) and non-EU vessels which land into EU ports (landing 277 000t annually). Trimmings from the fish processing industry produce 912 500t annually. The directed fishery for sharks conducted by EU countries, lands between 7 000 to 14 000t annually.

The two main target fish of the industrial feed fish fisheries are sandeels and sprats which formed 42% (642 000t) and 31% (472 000t) respectively of the EU feed fish fisheries annually between 1998-2002. Most sandeels are caught in the North Sea, whilst sprat are caught in the Baltic, North Sea and Kattegat/Skagerrak. Other important industrial feed fish include herring (186 000t landed annually), blue whiting (111 000t), and Norway pout (96 000t). Approximately 87% of the EU's industrial herring is taken in directed fisheries in the Baltic. Their small size in this region makes them unmarketable for human consumption. Herring is also caught as by-catch in the sprat fisheries in the Baltic, Kattegat/Skagerrak and North Sea and forms between 0-35%, 17% and 8% of the catch respectively. Blue whiting is taken in directed fisheries in the North Sea and east Atlantic. One of the problems associated with the Atlantic blue whiting fishery is that so little is known about the biology and ecology of this species, yet species is increasingly targeted. Norway pout is caught in the North Sea, Kattegat and Skagerrak but its use in the fish meal sector has decreased significantly because of management measures which restrict by-catch and the availability of alternative target fisheries.

Denmark is the largest of the EU industrial fishing nations and takes 69% of the total EU feed fish catch. Other EU countries catching feed fish, including the candidate countries, are Sweden (19.4%), Finland (5.0%), the UK (3.2%), Ireland (2.6%) and Poland (1.7%). Latvia and Lithuania have banned the targeting of fish for industrial purposes.

Between 9 to 15 vessels are reported to target shark in the Eastern Atlantic, and this is conducted by vessels registered in the UK, Spain and Portugal.

### **2.2. Trimmings**

Trimmings from other fisheries represent 33% of the total supply of raw material to the fish meal and fish body oil industry. It is estimated that 80% of the trimmings from fish processing enter the fish meal and fish body oil industry in Denmark, although this figure is only 10% in Spain. In the UK, Germany and France, between 33-50% of fish trimmings enter the fish meal and fish body oil industry.

## 2.3. Fish meal and fish oil processing

Table ES1 shows the number of fish meal processing plants in the EU and their dependence on the directed feed fish fisheries and trimmings.

**Table ES1. Fish meal plants in the EU and their reliance on directed industrial fisheries and trimmings from other fisheries**

	Factories	% trimmings	% feed fish
Denmark	4	10	90
France	3	100	0
Germany	1	100	0
Ireland	1	60	40
Spain	10	100	0
Sweden	1	25	75
UK	3	85	15

*Source: IFFO (2002), Digest of Selected Statistics, Annual Conference, Cancun*

The number of fish meal plants has fallen in the last 20 years. The Danish sector has seen a reduction from 20 to 4 plants, whilst the UK sector has seen a reduction from 10 to 3.

## 3. Production, import and export of fish meal and fish oil

### 3.1. Fish meal and fish oil processing

Fish meal and fish body oils are derived from directed fisheries for feed fish (providing 67% of raw material) and trimmings produced as by-products of processing fish for human consumption (providing 33% of raw material). Fish meal is produced by cooking the fish, before pressing them to remove water and body oil, and finally drying them at temperatures of between 70°C to 100°C depending upon the meal type manufactured. After extraction from the fish meal, fish body oils are purified through centrifugation. Fish oil represents around 5-6% of the total raw material body weight.

Between 1997 and 2001, the EU was the world's fourth largest producer of fish meal at 9%, and the second largest producer of fish body oil at 16%.

In the EU, Spain and Portugal are the only recorded producers of fish liver oil, producing 2 500 tonnes shark liver oil per annum.

Four different grades of fish meal are produced within the EU, which differ according to their processing treatment and their nutritional quality. These are:

- High quality - usually reserved for small scale aquaculture units (trout farms) or marine species (30% of the fish meal market).
- LT meal - is highly digestible and used in salmon and piglet production (and together with Prime forms 48% of the market).
- Prime.
- FAQ (fair average quality) - has a lower protein content and is used as a feed ingredient for pigs and poultry (22% of the market).

### **3.2. Fish meal and fish oil consumers**

The importance of fish meal as an ingredient in animal feed varies from country to country depending on the extent of its feed requirements. The UK is the largest consumer of fish meal in the EU largely due to its extensive salmon aquaculture sector. Greece, Italy and smaller Mediterranean island states such as Malta and Cyprus rely on fish meal as feed ingredients for bass and sea bream aquaculture. Other marine farmed species dependent on feed fish include halibut, turbot, sole, cod, hake, haddock, redfish, sea bass, congers and tuna.

Germany, France, Spain, the Netherlands, and the candidate countries (particularly Poland and Hungary), are more reliant on feed fish supplies to support the pig and poultry sector.

### **3.3. Fish meal and fish oil imports and exports**

The European Union is a net importer of fish meal (~442 000 tonnes) and fish body oils (~63 000 tonnes), although this is a rather simplistic interpretation as there are significant international product flows based on product specification and price. Denmark exports around 30% of its product to the southern countries within the EU (Greece and Italy) and a further 15% to Norway. The remaining 55% is exported to a number of Far Eastern countries where there is a high demand for high quality meal and oils.

Fish meal imports and consumption are known to have fallen markedly in 2002 and 2003 and are down 18% against the preceding years. This is as a result of the ban on the use of fish meal in ruminant feed.

Denmark exported 98 100 tonnes of fish oil in 2001 and 113 700 tonnes in 2000. This compares to Norway which exported between 90 126 tonnes of fish oil in 1995, but this was reduced to 44 746 tonnes in 1998.

The main European exporters of liver oils are Norway (4 000 tonnes), Spain (4 500 tonnes) and Portugal. Most of these oils are cod liver oils. Spain also exports between 900 and 2 500 tonnes of high grade 'industrial' shark oils. This is equivalent to 4 500 to 14 000 tonnes of shark (liveweight) which is exported to Japan.

## **4. The interaction between fish meal and fish oil industry and the fishing sector**

Economically the feed fish sector is very small relative to other EU fisheries. In terms of supply, targeted feed fish fisheries account for 21% of the total EU catch. In economic value terms, however, the production of feed fish accounts for only 0.5% sector employment and 2% sector value added. Table ES2 summarises the economic significance of the fish meal and oil sector within Europe.



**Table ES. The economic significance of Europe's fish meal and oil sector in 2003**

Country	Sector	Employees (FTE)	Value added
Denmark	Fish catching	507	83
	Fish processing	395	11.1
Sweden	Fish catching	93	14
	Fish processing	35	4.3
United Kingdom	Fish catching	11	1.45
	Fish processing	105	5.
Ireland	Fish catching	10	1.45
	Fish processing	46	2.5
Spain	Fish catching	0	0
	Fish processing	250	2.6
France	Fish catching	0	0
	Fish processing	270	4.4
Germany	Fish catching	0	0
	Fish processing	62	1.5
Poland	Fish catching	60	2
	Fish processing	53	(-)
Finland	Fish catching	305	3.6
Other	Fish processing	20	(-)
Total	Fish meal	2,222	136.9
Total EU fishery sector		482,374	6,416.8
% EU fishery sector		0.46%	2.13%

Source: Fishing fleet data is derived from economic studies EU figures derived from EU Fisheries Regional-Socio Economic Studies, 1998. Fish processing data has been extracted from interviews with fish meal manufacturers.

The value added from the fish meal and oil sector is M€137. Employment in the EU fish meal and oil sector (catchers and processors) is 2 222 in total: 45% in catching, 19% in feed fish processing and 35% in the processing of trimmings.

The additional multiplier effects from the production sector are quite small relative to other fishing groups because fish meal processing is not a labour intensive operation. However, by far the most significant issue is the reliance of the EU animal feed and aquaculture sector on fish meal. 4 549 people are directly employed in the aquaculture support sector including aquafeeds, whilst a further 63 189 workers are involved in EU aquaculture production. However, these workers are not entirely dependent on supplies from within the EU, 44% and 27% of meal and oil supplies are derived from other international suppliers.

## **5. Fish meal and fish oil industry, fish stocks and marine ecosystems**

### **5.1. The biology of fish targeted by the industrial fisheries**

The effects of fishing on populations of teleost<sup>3</sup> feed fish (e.g. sandeels and Norway pout) and elasmobranch<sup>4</sup> populations (e.g. sharks) are very different due to differences in their biology and life history. Industrial teleost feed fish are characterised by early maturation and high fecundity. Their populations respond quickly and strongly to changes in environmental

<sup>3</sup> 'Bony' fish e.g. gadoids, clupeids and sandeels.

<sup>4</sup> 'Cartilaginous' fish e.g. sharks, skates and rays.

conditions which increases the uncertainty of stock forecasts. The elasmobranchs tend to live longer, reproduce later and produce fewer young than the teleosts. Populations of elasmobranchs are therefore inherently less resilient to the loss of individuals than teleosts, as it takes longer to replace the harvested fish. Populations of elasmobranch are always likely to be smaller than those of teleosts.

## **5.2. The effects of industrial fishing on the ecosystem**

The removal of large numbers of industrial fish will impact their prey and predator populations, which may have consequences for species on other trophic levels. The effect of fishing on industrial feed fish may be difficult to determine as natural fish predation on these species is considered to be higher than industrial removals, especially on sandeel and Norway pout stocks. Whilst estimates of sandeel consumption in the North Sea show that other fish are important predators, there is evidence that predation on feed fish has declined as stocks of their large gadoid predators are weak. Strong stocks of industrial feed fish may also be detrimental to the juveniles and eggs of their predators, as many industrial feed fish prey on the eggs and compete with the larvae of fish caught for human consumption. The effects of removing large numbers of predatory sharks are largely unknown.

The accidental capture of juveniles of commercially important gadoid species, such as cod, haddock and whiting, is one of the most controversial aspects of industrial fishing as most undersized fish are landed and processed. The catch of most industrial fisheries are considered relatively 'clean' with few by-catch, but juveniles of some commercial species are known to shoal with feed fish: whiting and haddock are known to shoal with Norway pout, and juvenile herring are known to shoal with sprat. Overall however, the by-catch of the industrial fisheries is considered to be less than other fisheries and addressed by management measures such as closed areas.

## **5.3. Management and sustainability of the industrial fisheries**

In EU waters most of the targeted feed fish stocks, for which data are available, are considered to be within safe biological limits. Some stocks are un-assessed because they are not fished heavily, e.g. sandeel in the Shetland fishery and Norway pout in Division VIa, so data are insufficient to determine the state of these stocks. However, since the majority of stocks assessed are considered safe, management measures centred on a TAC scheme (set under the precautionary approach) seem a robust approach. Total allowable catches (TACs) have been used to regulate the fishing of Norway pout and sprats since the before the CFP. Sandeels, however, were only subject to a TAC from 1998 onwards. Blue whiting is also subject to a TAC for the North Sea and Western Waters, but up to and including 2002, catches were prohibited in international waters. This has now changed and an autonomous TAC (non specific to nationalities) of 250 000 tonnes has been set for international waters.

Control measures are also in place to limit the impact of by-catch by the industrial fisheries. For instance there is a by-catch restriction when fishing for Norway pout in the Norwegian EEZ. Other fisheries, particularly sprat, have similar restrictions. These control measures include closing areas to fishing on a seasonal or permanent basis to reduce by-catch and protect juvenile gadoids e.g. closed boxes for Norway pout, sandeels and sprat.

Given the strong link between feed fish populations and environmental parameters, consideration should be given for the inclusion of indices of environmental status in the setting of TACs. This is analogous to the formal consideration of *El Niño* events in the setting of quotas of the Peruvian anchovy.

No management measures are in place for the elasmobranchs in Western waters. Elasmobranchs are especially vulnerable to stock depletion due to their life histories, as discussed previously.

## **6. Evaluation of the economic aspects of fish meal and fish oil consumption in the EU**

The main variable influencing the price of fish meal is supply from South America and demand from the Far East. World production in aquaculture is increasing and the increased demand for fish meal and oil is likely to result in: (a) an increase in the price; (b) an increase in substitution. Whilst EU aquaculture production has stabilised in the last 2 to 3 years, it is predicted to increase again to reduce pressure on wild caught stocks. By 2010, the demand for fish meal and oils has been estimated to increase from 206 000 to 318 000 tonnes for fish meal and from 194 000 to 327 000 tonnes for fish oil. Without any corresponding change in the EU feed fish supply base and allowing for substitution, the EU's deficiency in production is predicted to rise from 44% to 68% for fish meal, and from 27% to 47% for fish oil.

### **6.1. Alternatives and substitutions of fish meal and fish oil**

Soya is the main competitor product to fish meal. The price ratio of soya to fish is presently 1:2.72. Soya is cheaper than fish meal but nutritionally not as good. Substitutions of soya for fish meal are influenced by price, but only provided that the perceived quality of the meal is not adversely affected. The world supply of fish meal relative to soya is small (fish meal accounting for 5% of the total quantity of meal available on the market).

The price of plant oils and fish oils are similar and as such, the usage of fish oils in animal feeds are more susceptible to substitution. Whilst usage of fish oil in aqua-feeds is substitutable by up to 50-80% in salmonids and up to 60% in marine fish diets, the effect that substitution may have on immunity, growth and the ability to sustain omega 3 fatty acids suggests that a high demand for fish oils will continue, with some substitution taking place as a result of price fluctuations. The continuous growth in aquaculture production will also ensure that fish oils will be fully utilised.

## **7. Analysis of the interaction between fish meal and fish oil consumption and human animal health**

### **7.1. Animal health**

Fish meal is considered an excellent source of protein for all farmed and aquacultured animals, as it is rich in essential amino acids, particularly lysine, cysteine, methionine and tryptophan which are key limiting amino acids for growth and productivity in the major farmed species. Fish oils contain high levels of omega-3 polyunsaturated fatty acids ( $\omega$ -3 PUFA or n-3 PUFA) which have been shown to improve animals' immune competency. Animal health is improved with fish meal and fish oils in their diet. Typical inclusion rates for fish meal in animal diets are around 2-10% for terrestrial animal species, but can rise to in excess of 40% for fish diets.

The inclusion of fish meal and fish oil in animal feed results in improved efficiencies of production across all the major farmed species and has potential for the dietary manipulation of tissue/product composition to produce 'healthier' foods for use in the human food chain. The waste products of animals fed fish meal and fish oil contain less nitrogen and phosphorus reducing the environmental impact of effluent disposal.

## **7.2. Human health**

In the 1970s, evidence from observational research showed that the Greenland Inuits, a population that consumes large amounts of fatty fish and marine animals, showed a low mortality rate from coronary heart disease despite their high intake of fat (about 40% of their total caloric intake). This so-called "Eskimo paradox" was later attributed to the presence of n-3 PUFA in their diet. The n-3 PUFA eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) are mostly found in fatty fish and fish oils and are scarce or absent in land animals and plants.

The fatty acid n-3 PUFA exert beneficial effects on several different cardiovascular risk factors including favourable influences on blood pressure, platelet function and coagulation. They further reduce platelet aggregation and the induction of abnormal vascular growth. Prevention intervention trials have firmly established the protective cardiovascular effect of fish consumption on sudden cardiac death although data were collected only from middle aged men.

Fish oils have been shown to possess anti-inflammatory effects beneficial to the human immune system when high levels of fish oil (more than 2.4g of EPA and DHA per day) have been consumed. The effects of n-3 PUFA are probably dose-dependent as studies providing more modest amounts of EPA and DHA have not consistently demonstrated these effects on the immune system. Although fish oils have been shown to alleviate some of the symptoms of rheumatoid arthritis, implementation of the clinical use of fish oil has been poor since they do not receive the marketing input that underpin the adoption of usual pharmacotherapies. The most valuable effects of fish oils could be to enable sufferers to reduce their use of pain-relieving drugs which sometimes have severe side effects.

Several recent studies in which human infants were fed formulas supplemented with DHA, showed that DHA may provide some advantage with respect to mental development. Declines in DHA concentration in the brain are associated with the onset of cognitive decline. The recommended intake of EPA and DHA is 500mg a day, which is equivalent to consuming fish 2.5-3 times a week. However, a 1g fish oil capsule can provide 200 - 300mg of EPA plus DHA. In many countries, especially those of northern Europe, where the consumption of fish is considerably less than that recommended, the use of fish oil capsules is an effective method of ensuring the human population receives the recommended dosage of EPA and DHA.

## **8. Synthesis and Conclusions**

### **8.1. Evaluation of the efficiency of converting fish into fish meal and fish oil as a means of obtaining human food**

The efficiency of humans obtaining their nutrients directly from fish caught for this purpose, as opposed to eating animals which have been fed on fish caught for industrial purposes, depends upon the efficiency with which the farmed fish use the feed. Naylor *et al.* (2000)

calculated a typical global feed conversion ratio of 2. This is equivalent to the conversion ratio often observed in natural systems. This would suggest that the efficiency of humans consuming fish directly, and eating animals fed on fish meal and fish oil is about equal. Similar results were presented in the SEAFEDS (2003) report. When feed conversion ratios of less than 2 are obtained, then there is an increase in ecological efficiency over wild food chains. The aquafeed supply company Nutreco, use a conversion ratio of 1.2 for salmon. This would suggest that it is more efficient to consume salmon derived from aquaculture than wild caught fish (i.e. 100 tonnes of sandeel would produce 16.7 tonnes of salmon).

The main alternative to fish meal is soya which is substantially cheaper than fish meal. The use of plant oils as a substitute for fish oils is a regular occurrence. However, nutritionally these alternatives are considered poorer compared to fish meal and oils, due to the lower energy content and lower levels of digestible amino acids which are essential for growth. Biotechnology could be used to create genetically modified plants to produce nutritionally valuable, fatty acid rich oils although these approaches may not be acceptable to society. EU legislation on additives and genetically modified (GM) ingredients constrains high levels of substitution.

## **8.2. Analysis of the compatibility of the fish meal and fish oil industry with the economic and ecological objectives of the new CFP.**

The ecological objectives of the CFP, especially regarding industrial fishing, are to ensure that their impact on human consumption fish species and other marine species remains low. The reformed CFP also calls for fishing effort to be managed in line with sustainable catching opportunities, and requires an immediate and significant reduction in effort.

Currently, most stocks of feed fish caught by the industrial fisheries are considered to be within biologically safe limits, although blue whiting in the Atlantic is of serious concern. However, feed fish populations are subject to rapid population change related to extrinsic forcing over which we have no control. A precedent has been already been set for overfishing feed fish without accounting for the huge effect of extrinsic forcing on their populations. A moratorium was declared on fishing off the coast of Peru in 1975 after anchovy stocks crashed as a direct result of the El Niño effect, which caused huge mortality to the anchovy stock as a result of raised water temperatures, and heavy overfishing which had been conducted for several decades.

The status of the EU targeted shark fisheries are more difficult to assess. The fishery is small scale but economically significant in some areas. Much of the data necessary to make an assessment of the status of the fishery and its ecosystem effects are lacking. At present this fishery is unregulated. Given the vulnerability of most shark species to fishing impacts, there would appear to be a compelling case, until data are available, for appropriate precautionary management measures to be introduced.

Industrial fishing is a significant component of some EU fishing fleets and the vessels involved may catch feed fish full or part time. In Denmark, the industrial fisheries affect 41% of total fisher employment and 61% in Sweden. Direct employment in the industrial catching and processing sector in the EU is 2 222 in Full Time Equivalents. If catches are constrained, as a result of management objectives, then aside from those employed directly in the sector, the linkage with the farming and aquaculture sector (63 189 farm workers and 4 549 aquafeeds and downstream support workers) is of significance. If the EU is 44% dependent

on aquaculture supplies, 29 800 workers can be linked directly to the EU feed fish and trimmings sector.

Overall the industrial fishing of feed fish appears to be ecologically and socio-economically sustainable. This is the result of the success of the current management regime, although TACs for most feed fish are not taken to their full extent. However, as populations of small teleost species, such as those that form the basis of these fisheries are inherently volatile there is still a need to refine our ability to make stock predictions, for example through the inclusion of environmental drivers/regime states in the setting of TACs. It should also be recognised that the current ecosystem status of the North Sea is not the desired one, and as stocks of other fish, particularly gadoids are rebuild consideration must be given to the ecological interactions between feed fish and gadoid eggs and larvae and between adult gadoids and the stocks of feed fish. There is also need for further measures to ensure full documentation and recording of by-catch.

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## LIST OF ACRONYMS

ACF	Advisory Committee on Fisheries (EC)
AGFM	Advisory Group on Fisheries Management (ICES)
ANFACO	Asociación Nacional de Fabricantes de Conservas de Pescados y Mariscos (National Association of Manufacturers of Tinned Fish and Seafood)
CFP	Common Fisheries Policy
DIFRES	Danish Institute for Fishery Research
DEFRA	Department for the Environment, Food and Rural Affairs (UK)
EC	European Commission
EEA	European Environment Agency
EP	European Parliament
FOI	Danish Research Institute of Food Economics
FEAP	Federation of European Aquaculture Producers
FEFAC	Federation Europeen des Fabricants D'Alimentaire Composés
FTE	Full time equivalent
Fiskeridirektoratet	Danish Fisheries Directorate
Fiskeriverket	Swedish Board of Fisheries
FGFRI	Finish Game & Fisheries Research Institute
EU	European Union
FAO	Food and Agriculture Organisation
FTE	Full Time Equivalent
IAWS	Irish Agricultural Wholesale Society
ICES	International Council for the Exploration of the Seas
IFFO	International fishmeal and fish oil organisation
ICES	International Council for the Exploration of the Seas
MMBM	Mammalian meat and bone meal
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic
STECF	Scientific, Technical and Economic Committee for Fisheries (of the EC)
TSEs	Transmissible Spongiform Encephalopathies
UNEW	University of Newcastle upon Tyne
UFI	United Fish Industries





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## 1. INTRODUCTION

This report examines the role of fish meal, fish body oils and industrial liver oils in the EU's Common Fisheries Policy. Occasional reference is made to non EU countries (for example Norway, Faeroes and Russia) where the resources are shared with the EU. In some cases, management issues which affect EU vessels are heavily influenced by the activities from other non EU countries. A notable example being blue whiting.

### 1.1. Fish meal and fish oil

The fish meal and fish oil industry derives its raw material from two sources:

- ◆ fish which are caught directly for the purposes of fish meal and fish body oil production<sup>5</sup>, as opposed to those caught for the purposes of human consumption;
- ◆ trimmings resulting from the processing of fish from other fisheries, such as those caught for human consumption (e.g. gadoids, pelagic fish and salmon).

Fish body oils are extracted from the same raw material as fish meal.

Fish meal and fish body oils are used extensively in farming and aquaculture as important nutritional components of animal feeds (Doreau & Chilliard, 1997; Santos *et al.*, 1998; Wood *et al.*, 1999). The demand for fish meal and fish body oils is likely to increase as the aquaculture industry expands globally to relieve pressure on wild fish stocks. Alternatives sources to fish meal are available, in theory, but many suggested alternatives e.g. Arctic krill, have failed to materialise despite some knowledge of their potential.

The fish oil industry also includes fish liver oils. This industry is considerably smaller than the fish body oil industry. Fish liver oils may be extracted from sharks (which belong to a group of fish with cartilaginous skeletons called elasmobranchs) for which there is a directed fishery. Whilst shark meat and skins are co-products of this fishery, the squalene oil extracted from the livers are the primary product (Pinero *et al.* 2001) and account for more than two thirds of vessels' income (Soto, P.<sup>6</sup>, 2003, pers. comm., September). Some fish liver oils are also extracted as a co-product of the fish sold for human consumption (e.g. cod), and cannot be described as part of the industrial fisheries.

Fish liver oils provide health benefits to humans (Abeywardena and Head, 2001; Lee and Lip, 2003; Leaf *et al.*, 2003; He *et al.*, 2003; Welch *et al.*, 2002) and are used in health supplements and medicines.

### 1.2. The fishing sector

The feed fish fisheries support a substantial part of the Danish, Swedish and Finnish fishery sectors. In Denmark for example, 41% of the fishers rely in some way on the feed fish fishery (FOI, 2002). In many EU countries, some vessels target only feed fish, whilst other vessels target feed fish as an alternative to other stocks.

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<sup>5</sup> For the purposes of this report, any directed fishery for fish not destined for human consumption but which enter an industrial process are termed 'industrial'.

<sup>6</sup> A fishing vessel agent.

The fisheries for feed fish are controlled by a series of management measures including TACs, by-catch limits and closed areas (EC 850/1998; EC 1298/2000; EC 2341/2000). Apart from TACs, the management measures have been established to prevent damage to other species dependent on feed fish, notably birds, the fish species which predate on them and juvenile fish which may be caught as by-catch. The issue of by-catch and industrial fishing is controversial as, in some areas, different species of fish shoal together, including the juveniles of commercially important gadoid species such as cod and haddock. By-catch limits have been introduced to reduce the impact of the industrial fisheries on juvenile fish (Dalskov, 2003, *DIFRES*, pers. comm., October).

Compliance with the management regime has been enforced strongly. In many respects the management regime applied to EU feed fish fisheries is more stringently controlled than human consumption fish fisheries (Banks *et al.*, 2000). Fishers are subject to licence revocation in the event of non compliance and subject to inspection level frequencies of 33% (Eliassen, 2003).

The feed fish stocks targeted by the industrial fleets are considered to be amongst the most sustainable of fisheries within the EU and almost all the main stocks are regarded as inside safe biological limits (Dalskov, 2003, pers. comm., October). The CFP roadmap (EC, 2002) considers that the stocks of small pelagic species (herring, sprat, mackerel, horse mackerel, anchovy, sardine) and species which support industrial fisheries (Norway pout, sandeels) have generally not deteriorated over the last twenty years, and especially not over the last ten years. There are some exceptions however, which include blue whiting for which the stock situation is unknown.

Shark populations are easily overfished due to their life history characteristics (slow growth, late age at maturity and few young) and uncontrolled fishing, and high price incentives, are likely to severely impact their populations. Recent evidence would suggest that there are significant problems with the directed fishery for sharks (ICES, 2003d).

### **1.3. The CFP and industrial fishing**

The CFP roadmap (EC, 2002) includes a move away from single stock management and towards an ecosystem-based approach to fisheries management. This broader approach to management will include not only the effects of fishing on the prey and predators of the exploited species, but also the effects of fishing on ecosystem components such as birds, mammals, epibenthos (such as *Lophelia* reefs) and non-target fish species. Fishing activity may be restricted if found to affect these components detrimentally. The Commission advocates a long-term strategy to promote the protection of vulnerable species and habitats by such means such as gear restrictions and closed areas and seasons. Many of the industrial fisheries are already affected by management measures that have been created to conserve biodiversity and protect juveniles of other species (closed areas, closed seasons and by-catch restrictions) and the proposed enforcement mechanisms have already been applied to the industrial fisheries of Denmark and Sweden.

The European Commission has asked ICES to specifically evaluate the impact of industrial fishing on marine ecosystems (EC, 2002). This will include monitoring industrial fisheries to ensure that their impact on human consumption fish species and other marine species remains low. Also, the roadmap calls for the improved management of fish stocks which are of interest for both industrial use and human consumption, such as blue whiting.

Other demands in the CFP roadmap include:

- A fleet which is well within the levels required to ensure sustainable production.
- A consistently high level of research applied to most species.
- Improved levels of fisheries enforcement.
- An immediate and significant reduction of fishing effort to manage fishing effort in line with sustainable catching opportunities.
- An incorporation of environmental concerns into fisheries management, in particular by contributing to biodiversity protection.
- A move towards an ecosystem based approach to fisheries.

#### **1.4. Aims of the study**

This study is defined by the terms of reference in the call for tenders No IV/ 2003 / 11 / 01.

The report is divided into the following chapters:

Chapter 2: The structure of the fish meal and fish oil industry in the European Union.

Chapter 3: Production, import and export of fish meal and fish oil.

Chapter 4: The interaction between fish meal and fish oil industry and the fishing sector.

Chapter 5: Fish meal and fish oil industry, fish stocks and marine ecosystems.

Chapter 6: Evaluation of the economic aspects of fish meal and fish oil consumption in the EU.

Chapter 7: Analysis of the interaction between fish meal and fish oil consumption and human animal health.

The report aims to provide the European Parliament with an:

- evaluation of the efficiency of converting fish into fish meal and fish oil as a means of obtaining human food;
- analysis of the compatibility of the fish meal and fish oil industry with the economic and ecological objectives of the new CFP.



## 2. THE STRUCTURE OF THE FISH MEAL AND FISH OIL INDUSTRY IN THE EUROPEAN UNION

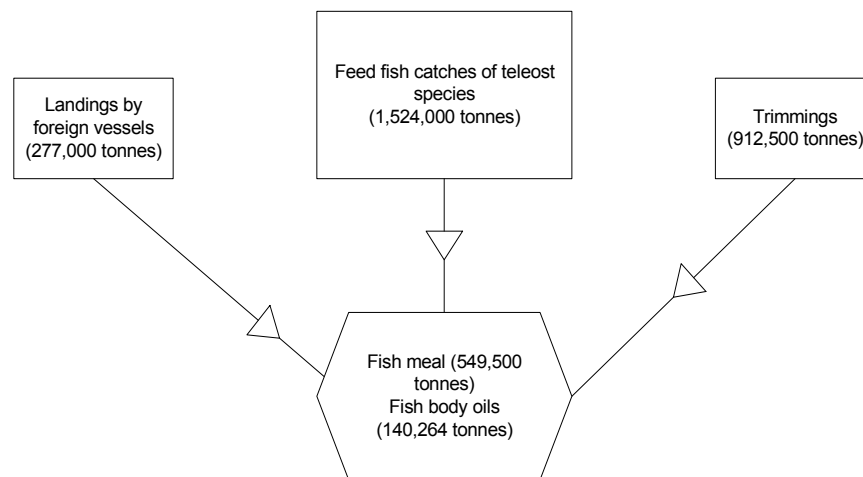
### 2.1. Sources of raw material for fish meal and fish body oil

The raw material used to produce fish meal and fish body oil in the EU is derived from:

- Feed fish caught by EU registered vessels for the sole purpose of fish meal production.
- Feed fish caught by non EU vessels but landed into EU ports.
- Trimmings, fish off-cuts and offal from the fish processing industry.

Figure 2.1. below summarises the total supply position for the feed fish sector

**Figure 2.1. The sources and quantities of raw material used to produce fish meal and fish body oils in the EU**



Note: Conversion factors fish weight (feed fish and trimmings) to meal = 1:0.2 and oil = 1:0.06

Source: Extracted from derived data (National landings statistics; interviews with fish meal manufacturers)

### 2.2. Industrial fisheries

Fish taken in the industrial fisheries can be divided into two groups. The first are fish used to produce fish meal and fish body oil as ingredients for animal food (teleost 'feed fish'). The second are fish targeted directly for liver oil or squalene (elasmobranchs, including sharks).

The industrial feed fish sector is small relative to the EU fisheries as a whole. The total EU fish catch accounted for, on average, 7.29 million tonnes in the years 1998-2000 (Eurostat, 2002). The feed fish accounted for an average of 1.5 million tonnes in this period (Table 2.1.1) which represents approximately 21% of the total tonnage landed.

Feed fish are teleost fish, which in the context of the EC, include sandeel (642,000 t landed annually between 1998-2002), sprat (472,000 t), herring (186,000 t), blue whiting (111,000 t), Norway pout (96,000 t) and horse mackerel (8,000 t) (Table 2.1.1). Herring may be used in fish meal production when fished as a feed fish, as is the case for most Baltic herring (Sweden, Finland and Poland), or when caught as a by-catch to other industrial species. There is some evidence that herring may be fed directly to domestic animals.

**Table 2.1. Average EU feed fish catches ('000 tonnes) between 1998-2002**

Country	Denmark Tonnes	%	Sweden Tonnes	%	UK tonnes	%	Ireland tonnes	%	Poland tonnes	%	Finland tonnes	%	Total tonnes	%
<b>Sandeel</b>														
North Sea	588.4	56%	28.0	10%	14.4	30%	0.0	0%	0.0	0%	0.0	0%	630.8	41%
West of Scotland	0.0	0%	0.0	0%	5.3	11%	0.0	0%	0.0	0%	0.0	0%	5.3	0%
Shetland	0.0	0%	0.0	0%	1.3	3%	0.0	0%	0.0	0%	0.0	0%	1.3	0%
<b>Sprat</b>														0%
North Sea	157.1	15%	0.8	0%	1.6	3%	0.0	0%	0.0	0%	0.0	0%	159.6	10%
Kattegat/Skagerrak	43.4	4%	6.7	2%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	50.1	3%
Baltic	63.0	6%	138.0	47%	0.0	0%	0.0	0%	22.0	85%	19.6	26%	242.6	16%
<b>Norway pout</b>														0%
North Sea	87.0	8%	4.1	1%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	91.1	6%
West of Scotland	5.3	1%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	5.3	0%
<b>Herring</b>														
Trargeted for industrial (Baltic / Skagerak/ Kattegat)	0.0	0%	104.0	35%	0.0	0%	6.0	15%	4.0	15%	56.6	74%	170.6	11%
<b>Blue whiting</b>														0%
North Sea	35.5	3%	8.2	3%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	43.7	3%
Norwegian Sea	13.6	1%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	13.6	1%
Atlantic	2.1	0%	0.0	0%	26.0	53%	26.0	65%	0.0	0%	0.0	0%	54.1	4%
<b>Other By-catches</b>														0%
Norway pout	3.4	0%	4.0	1%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	7.4	0%
Sandeel	4.3	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	4.3	0%
North Sea Sprat	12.9	1%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	12.9	1%
Skagerrak/Kattegat sprat	7.6	1%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	7.6	0%
North Sea herring	6.6	1%												
Skagerrak/Kattegat herring	15.7	2%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	15.7	1%
<b>Horse mackerel</b>	0.0	0%	0.0	0%	0.0	0%	8.0	20%	0.0	0%	0.0	0%	8.0	1%
Total Raw material	1046.0		293.8		48.7		40.0		26.0		76.2		<b>1524.1</b>	
Product weight equivalent	230.1		64.6		10.7		8.8		5.7		16.8		335.3	
Percentage national dependency	69.0%		19.4%		3.2%		2.6%		1.7%		5.0%		100.5%	

Source: National fishery departments (Dansk Fiskeridirektoratet (Dk), Fiskeriverket(Sw); Sea Fisheries Institute (PI), FGFRI (Fin), SEERAD (UK), DoM (Irl)



**Table 2.2. Summary of EU national catches ('000 tonnes) by species between 1998-2002**

Country	Denmark		Sweden		UK		Ireland		Poland		Finland		Total	
Total species breakdown	Tonnes	%	Tonnes	%	tonnes	%	tonnes	%	tonnes	%	tonnes	%	tonnes	%
Sandeel	592.7	56.8%	28.0	9.7%	21.0	43.2%	0.0	0.0%	0.0	0.0%	0.0	0.0%	641.7	42%
Sprat	284.1	27.2%	145.5	50.2%	1.6	3.4%	0.0	0.0%	22.0	84.6%	19.6	25.7%	472.9	31%
Herring	22.3	2.1%	104.0	35.9%	0.0	0.0%	6.0	15.0%	4.0	15.4%	56.6	74.3%	186.3	12%
Blue whiting	51.2	4.9%	8.2	2.8%	26.0	53.4%	26.0	65.0%	0.0	0.0%	0.0	0.0%	111.4	7%
Norway Pout	92.3	8.9%	4.1	1.4%	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%	96.4	6%
Horse mackerel	0.0	0.0%	0.0	0.0%	0.0	0.0%	8.0	20.0%	0.0	0.0%	0.0	0.0%	8.0	1%
Total species breakdown	1042.6		289.8		48.7		40.0		26.0		76.2		1516.7	

Note the information has been corroborated against ICES catch data (ICES Working Group papers, 2003). In some cases, for example average catches will not correspond with current TACs as these have fallen. This applies to Baltic herring and sprat.

Source: National fishery departments (Dansk Fiskeridirektoratet (Dk), Fiskeriverket(Sw); Sea Fisheries Institute (Pl), FGFRI (Fin), SEERAD (UK), DoM (Irl)

A further 277,000 tonnes of feed fish caught by non EU registered vessels (Norway, Iceland and the Faeroes) were processed by EU fish meal manufacturers in 2002. 76% of external supplies (211,000 tonnes) are sold to Denmark (Dansk Fiskeridirektoratet, 2002), but small quantities, usually of blue whiting, are landed by Norwegian and Faeroese vessels in Ireland and the UK for processing (Korsager, UFI, 2003, pers com, September). Estimates of Norwegian landings in Ireland and the UK are approximately 30,000 tonnes per annum into each country in 2002. Table 2.2 summarises the landings of feed fish into Denmark in 2002.

**Table 2.2. Feed fish landings into Denmark for Danish fish meal plants in 2002**

Country	Quantity (tonnes)
Sweden	113,442
UK	20,719
Finland	1,563
Germany	138
<b>Total EU</b>	<b>135,862</b>
Norway	163,632
Poland	24,829
Faeroes	33,083
Iceland	15,001
<b>Total non EU</b>	<b>236,545</b>
<b>Total</b>	<b>372,407</b>

Source: Dansk Fiskeridirektoratet, 2002

### 2.2.1. Fish Landings

Denmark is the largest of the EU industrial fishers with total landings of 1.04 million tonnes (Table 2.1.1). This represents 69% of the total EU feed fish landings. Other EU countries catching feed fish, including the candidate countries, are Sweden (19.4%), Finland (5.0%), the UK (3.2%), Ireland (2.6%) and Poland (1.7%).

Most sandeel is caught in the North Sea, whilst sprat is caught in the Baltic, North Sea and Kattegat/Skagerrak (ICES, 2002). Other target species include Norway pout and blue whiting. Blue whiting is taken as a directed fishery in the North Sea and East Atlantic. Norway pout is caught in the North Sea, Kattegat and Skagerrak (ICES, 2003). Norway pout has decreased significantly in importance as a supplier to the fish feed sector (ICES, 2002), as a direct result of strict enforcement of the by-catch regulations (Wichman, *Danish Fishermen's Association*, 2003, pers. comm., August). Herring is caught as a by-catch in the sprat fisheries in the Baltic, Kattegat / Skagerrak and North Sea<sup>7</sup>.

Very small quantities of horse mackerel are caught by Irish and UK vessels, but the bulk of these catches are reserved for human consumption fisheries (Banks / BIM, 1996; Banks *et al.*, 1999). Horse mackerel also has some significance for the Danish fleet. A small Danish feed fish fishery has traditionally taken place in the English Channel but has declined significantly in recent years (Eliassen, 2003).

Capelin has occasionally been taken by Danish / UK vessels in restricted fisheries (Eliassen, 2003; Goodlad, *Shetland Fishermen's Association*, 2003, pers. comm. August). Vessels are

<sup>7</sup> By-catch issues are referred to in section 5.15.1.

largely dissuaded from participation because of the long travelling distances to the North Atlantic, but the larger vessels are prone to undertake these activities in order to supplement their regular activities (Wichman, 2003, pers. comm.). These fisheries are therefore largely reserved for Iceland, Russia, Faeroes, Greenland and Iceland (ICES, 2003).

The percentage of herring taken as by-catch in these fisheries are 8, 17 and 0-35 in the North Sea, Skagerrak/Kattegat and Baltic fisheries respectively. Herring can also be targeted as a feed fish (Fiskeriverket, unpublished data, 2003), such as in the Baltic. In some cases, such as in Sweden and Poland, it is sold for fish meal (Fiskeriverket, 2003; Gdynia, *Sea Fisheries Institute*, 2003, pers. comm., August) whilst in Finland, whole herring (along with sprat) may be sold to mink farms (Anon, *FGFRI*, 2003, pers. comm., August). Part of the reason why herring from the Baltic does not tend to be sold for human consumption is because it tends to be small and of low market value (Eliassen, *Fiskeriderktoratet*, 2003, pers. comm., October). There are also problems with the Baltic product, most notably the higher dioxin levels found in Baltic species, although carbon filtration process can eliminate these toxins (Jensen, *TripleNine*, 2003, pers. comm., September). Small quantities of herring are also used as ingredients in fish meal in Ireland (Banks, 1996; Doyle, *Irish Fishermen's Organisation*, 2003, pers. comm., August) using the carcasses produced by the Celtic Sea herring roe fishery.

### 2.2.2. The EU share of species catches

Appendix 1 shows the history of landings for the principal teleost feed fish fisheries in the last 10 years, 1992/1993-2002 (ICES, 2002). The data have been disaggregated to show the share of the catch along with the long term catch trends. Table 2.3 below summarises the current TACs, and the historic uptake for the key species.

**Table 2.3. Summary quotas for industrial species**

Species	TAC (2003)	EU share of TAC	Average EU % uptake in preceding years (2000-2002)
Sandeel (North Sea)	823,000	94%	81%
Sandeel (Norwegian)	131,000	EU allocation	
Baltic Sprat	310,000	42%	92%
North Sea Sprat	257,000	94%	87%
Kattegat/Skagerrak Sprat	50,000	EU allocation	49%
Baltic Herring	143,349	94%	
Norway Pout (North Sea)	198,000	87%	44%
Norway Pout (Norwegian waters)	100,000	EU allocation	
Blue whiting (Western waters)	302,935	46%	98%
Blue whiting (North Sea)	67,250	41%	

\*Note: ICES catch data shows that 50% of the blue whiting TAC is destined for human consumption fisheries – Netherlands, France, Spain, Portugal, Germany. As from 2003 250,000 tonnes is set aside as a blue whiting autonomous quota for International Waters.

Source: Council Regulation (EC) No 2341 / 2002; Council Regulation (EC); Council Regulation (EC) No 1091/2003; Council Regulation 1091/2003; ICES Working Group papers, 2002

## Sandeels

Catches of sandeel (Appendix 1. Figure A.1.1) show a marginal decline. The TAC is reported to have been undershot considerably in 2003. Sandeels account for 42% of the EU's feed fish catch (Table 2.1.1). The EU, largely Denmark, is the dominant participant in this fishery representing 92% of the total catch, (ICES, 1993-2002). Sandeels represent the cornerstone of the Danish feed fish sector where it accounts for 56% of the input into Danish fish meal factories (Table 2.1.2). The UK and Sweden are minority EU fishing nations in this fishery (Figure A.1.15). Norway has a 23% share in this fishery. The most notable issue is that Norwegian catches and effort are increasing significantly, whilst the Danish catch and effort remain largely stable, although there are considerable annual peaks and troughs (ICES, 2003). The TAC for this species is largely constant and in some years is under-fished (uptake for the years 1998-2002 averaged 80% of the total). Catches are invariably above this during periods of very strong year classes (ICES, 2003).

## Sprat

Sprat accounts for 31% of the EU's feed fish catch (Table 2.1.1). Denmark and Sweden are key players in each of the fisheries: the North Sea; Baltic, and Kattegat/ Skagerrak. Sweden uses 7% of the sprat caught for human consumption (Fiskeriverket, 2003), and Denmark uses 2% (Dansk Fiskeridirektoratet, 2002). Two other Baltic States, Poland and Finland also catch sprat (Poland and Finland catching, on average, 5% and 4% of the total EU catch for sprat respectively), but this is mainly for fish meal production. Finland's catch of sprat averages 54,000 tonnes. This is sold whole to mink farms (Anon, *FGFRI*, 2003, pers. comm. August). Almost all Polish landings (22,000 tonnes) of sprat are made in Denmark as feed fish (Gdynia, *Sea Fisheries Institute*, 2003, pers. comm.; Fiskeridirektoratet, 2002). Historically, both Sweden and Poland had a high human consumption of sprats (Banks, 1996). This consumption pattern has since changed, in respect to the former, because of the perceived problems with dioxins (Jensen, *TripleNine*, 2003, pers. comm., September; Persson, *Vastkustfisk SVC Aktiebolag*, 2003, pers. comm.).

EU catches of North Sea sprat show a long term declining trend from peak landings in the early 1990s (Figure A.1.4 ). Landings from this fishery peaked again in 2000 but fell slightly in 2001 and 2002. The historic EU uptake of quota, almost exclusively by Denmark, in this fishery has been 87% (ICES, 2003). This fishery takes place in the autumn.

EU catches in the Baltic (Regions 22-32) (Figure A.13) peaked in 1996 to over 300,000 tonnes but have since fallen steadily to 150,000 tonnes in 2002 (ICES, 2003). Quota uptake in this fishery by EU vessels (Denmark, Sweden, Germany and Finland) has average 92% of the quota. EU Candidate country uptake (Poland, Estonia, Latvia and Lithuania) has increased steadily in the last 10 years (ICES, 2003).

Kattegat / Skagerrak sprat catches peaked in the early 1990s at 94,000 tonnes. Catches have since fallen to around 20,000 tonnes per annum. Quota uptake in this fishery by EU vessels (almost exclusively by Denmark) has average 47% of the quota (ICES, 2003).

Each of the above fisheries are set herring by-catch quota limits (Council Regulation 2341/2002). These quota limits have never been reached. The strict monitoring of by-catches in all fisheries is a contributory factor to the consistent decline in EU uptake (Wichman, *Danish Fishermen's Association*, 2003, pers. comm., August).

## Herring

Herring accounts for 12% of the EU's feed fish catch. Some of this, around 22,000 tonnes is taken as by-catch in the sprat fisheries (see Chapter 5, Table 5.2). Juvenile herring and sprat are difficult to distinguish from each another whilst fishing. By-catch herring tends to be higher when herring stocks are abundant and can range from 0-35% of the total catch (Dalskov, 2003, *DIFRES*, pers. comm., October). For this reason, the Danes restrict access to the sprat fisheries in the first and last quarter of the year when a by-catch of herring is known to be lower. There are also some herring fisheries in the zone that can be caught without sprat and also some sprat can be caught in deeper water without herring (ICES, 2003). The intermixing of species has led to a number of management and control measures (see Chapter 5).

There is an exemption for catching herring as feed fish in the Baltic (EC Regulation 1434 / 98). Herring is increasingly a targeted feed fish fishery in the Baltic with an average 170,000 t sold annually between 1998 and 2002 (Fiskeriverket, 2003, unpublished data; Anon, *FGFRI*, 2003, pers. comm.); Gdynia, *Sea Fisheries Institute*, 2003, pers. comm.). This derogation is partly because of the small size of the fish (Eliassen, 2003) which limits demand from the human consumption markets, but also because of the high dioxin levels in the Baltic and the ability of meal processing to extract these through carbon filtration (Jensen, *TripleNine*, 2003, pers. comm., September). Sweden shows an increasing dependence on herring destined for feed fish (2-30%) as opposed to human consumption (Fiskeriverket, 2003, unpublished data). Approximately 80% of Finland's herring catch is sold as fish meal (Anon, *FGFRI*, 2003, pers. comm.).

Landings destined for feed fish comprise catches from the Baltic (Figure A.1.8) and the Kattegat / Skagerrak. The Danish Fisheries Directorate confirmed that whilst there was a derogation for the catching of herring for industrial species in the Baltic, the Danish Government takes the view that herring should be targeted for human consumption. (Eliassen, (2003)). This view is shared by EU candidate states Latvia and Lithuania (Babcionis, *Fisheries Department under the Ministry of Agriculture*<sup>8</sup>, 2003 pers. comm., August) but not by either Finland or Sweden.

## Blue whiting

Blue whiting accounts for 7% of the EU's feed fish catch (Table 2.1.1). The blue whiting fishery is associated with a continual expansion in effort from all participants (Figures A.1.11, A.1.13, A.1.15), except for the former USSR Baltic countries (Figure A.1.21). TACs are set for the North Sea and Western Waters, but up to and including 2002, EU vessels were prevented from fishing in International Waters. Since the start of 2003 however, the EU has set an Autonomous TAC (non specific to nationalities) for international waters of 250,000 tonnes (EC Regulation 1091/2001). The change was brought about because Norwegian vessels were frequently targeting a substantial proportion of the resource in international waters.

The blue whiting quota has been subject to some controversy as it forms part of a bilateral exchange with Norway, where EU blue whiting are exchanged with Norway in order to achieve EU access to quotas (for human consumption fisheries) in Norwegian waters. This has caused considerable resentment amongst the Irish fleet (Doyle, *Irish Fishermen's Organisation*, 2003, pers comm., August). The Norwegian share of the blue whiting catch is

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<sup>8</sup> Lithuania.

increasing significantly and appears to reflect a much more conscious effort in maximising the uptake of catching opportunities (ICES, 2003).

The EU is not the most significant of participants in the blue whiting fishery, but Denmark has caught 37% of the total blue whiting catch in directed fisheries in the North Sea between 1993 and 2002. A number of nation states share these fisheries (Figure A.1.20).

The Danish blue whiting fishery is conducted by trawlers using a minimum mesh size of 40 mm in the directed fishery, although blue whiting is also taken as by-catch in the Norway pout fishery using trawls with mesh sizes of between 16 and 36 mm (the remaining third) (ICES, 2002). Almost all of the Danish catch is taken in Divisions IIa, IVa, and Vb, with small catches from Divisions VIa and VIIc. Some blue whiting by-catch is also taken in the human consumption herring fishery in the Skagerrak (ICES, 2003).

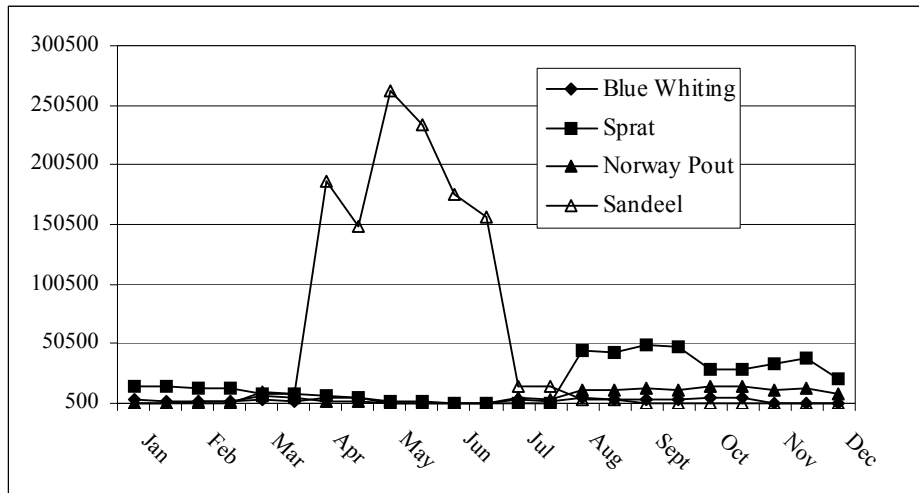
The UK, Ireland and Denmark fish for blue whiting in Western Waters. This represents a 9% share of the total catch (Figure A.21). Participation by UK and Irish pelagic trawlers represent a targeted fishery, but is only carried out by a small number of pelagic trawlers outside the mackerel (October-February) and herring seasons (July-September) (Banks and Reid, 1999). All UK, Irish and Danish catches are landed for fish meal processing (Korsager, UFI, 2003, pers. comm., September), whereas other EU participants (Netherlands, France, Germany, Spain and Portugal) target blue whiting for human consumption. Blue whiting human consumption fisheries represent around half of the total EU catch (ICES 2002).

### **Norway Pout**

Norway pout accounts for 6% of the EU's total feed fish catch (Table 2.1.1). Norway and Denmark are significant participants in the fishery (Figure A.1.19). Whilst the stock is identified as being in a reasonably healthy state, effort in the fishery has decreased significantly (Figure A.1.9). EU catches now represent around 40% of the Norway pout quota and yet the EU has an 86% share of the TAC allocation (ICES, 2003; EC Regulation 2341/2002). The fishery has traditionally been associated with by-catch problems of haddock and whiting in some years (Table 5.2) (Dansk Fiskeridirektoratet, 1998-2002, unpublished data). Close monitoring of by-catch restrictions has been the catalyst to a decline in fishing activity (Wichman, *Danish Fishermen's Association*, 2003, pers. comm., August).

### **2.2.3. Feed fish seasonal landing patterns**

Figure 2.2. shows the seasonal distribution of landing patterns for the Danish sector. It shows the sandeel fishery to be largely a summer fishery. Access to the sandeel fishery is governed largely when the fish are high in the water column. This corresponds with the lowest by-catches and when the oil content of the fish is at its highest. Equally, the sprat fishery is governed by open and closed seasons, determined by when and where the incidence of herring by-catch is likely to be lower. Blue whiting and Norway pout fisheries tend to occur at the same time with a higher degree of fishing activity in the autumn. The larger vessels tend to be more proactive in these fisheries throughout the year. Capelin may also be targeted by the larger vessels by limiting licensing in July and August.

**Figure 2.2. Seasonal distribution of catches of the Danish sector in 2002. ('000 tonnes)**

Source: Fiskeridirektoratet, 2003

### Denmark

The dedicated Danish industrial fleet is based in the ports of Esbjerg, Thyborøn, Hantsholm and Skagen. Esbjerg is base to around 50% of the fleet, Thyborøn 30% and Skagen and Hirtshals to 20% collectively. However, 58% of the Danish fleet over 15m has some dependency on feed fish fisheries. This means that industrial fishing is important to a large number of the smaller Danish ports along the East and West coast. Table 2.4 summarises the nature of the fleet and its dependency on industrial fishing relative to other fisheries, and specific importance of each industrial fishery to each group.

**Table 2.4. The composition of the Danish industrial fleet (2002)**

	Number	Average number employed	Dependency on industrial species %	FTE	Total earnings M Kr	% group dependency		
						Sandeel	Sprat	Other
Trawl 15-18m	131	2	11	29	22	17	76	7
Trawl 18-24m	110	3	16	53	35	37	53	10
Industrial	47	5	97	228	133	58	26	16
Other	87	4	25	87	45	65	18	17
Industrial	13	5	93	60	72	51	51	32
Other trawl	19	6	46	52	44	59	6	35
Total	407			509				

Source: FOI (Denmark)

The important issues are highlighted below:

- There are 407 vessels in Denmark which fish for industrial species.
- 60 vessels can be described as permanently dependent.
- There are also 347 vessels which can claim partial dependency on industrial species, including the larger demersal and pelagic vessels as well as smaller inshore trawlers.

- There are 509 FTE (Full Time Equivalent<sup>9</sup>) fishermen dependent on industrial fishing.
- The dedicated larger vessels are dependent on a range of species including blue whiting, Norway Pout and occasionally capelin. The larger industrial trawlers will fish offshore waters including the Atlantic, Greenland and the Norwegian sector. 9 of these vessels are licensed to fish for capelin in Greenland.
- The smaller vessels, in particular those operating in the Baltic, tend to be more dependent on sprat.

A number of additional factors are noted<sup>10</sup>:

- Across the range of vessels total earnings from industrial fishing accounted for M€118. This represents 23% of the fleet's income of M€510.
- The total net value added from those vessels with a dependency on industrial fishing is M€364, M€83 of which can be attributed to industrial fishing activity. This represents 30% of the value added (M€278) from the Danish catching sector

## Sweden

Seventy vessels report industrial landings in Sweden in 2001 (Anon, *Fiskeriverket*, 2003, pers comm., October). Seventy seven vessels have a partial dependency on feed fish fisheries. Fifty six of these vessels are over 24m. These vessels are 24% dependent on the feed fish fisheries. Twenty two vessels are under 24m. These vessels have an 18% dependency on the feed fish fisheries. In FTE equivalents, this represents 93 fishermen dependent on fishing. However, as is the case in Denmark, because of the integral nature of feed fish and fish destined for human consumption, 402 fishermen have some dependency on industrial fisheries. Total sector turnover is M€18, and value added, M€4.3.

These vessels have become more dependent on landing into Skagen in Denmark. Industrial landings into Skagen comprised 113,000 tonnes in 2002 (Fiskeridirektoratet, 2003, unpublished data). IFFO report Swedish fish production of 18,750 tonnes derived from feed fish. This is equivalent to a catch (with a 22% conversion factor) of 85,000 tonnes.

## United Kingdom & Ireland

Nine vessels fish for industrial species in the UK and six in Ireland. These fleets fish largely blue whiting and land into Shetland, Killybegs and the Faeroes (Goodlad, *Shetland Fishermen's Association*, 2003, pers. comm. August). UK activity on sandeels has declined considerably, largely because of the decline in the Shetland trawl fleet (under 24m) which targeted this fishery. However, the larger Shetland / NE Scotland vessels will fish for this quota as and when the opportunities arise (Goodlad, *Shetland Fishermen's Association*, 2003, pers. comm. August).

All vessels targeting blue whiting from the UK and Ireland are pelagic trawlers. Industrial fishing provides a useful additional income to the main activities of targeting herring and mackerel for human consumption (Banks and Reid, 1999). Income from industrial fishing provides around 15% of the income for these ships. Feed fish species are targeted from March to June (Banks and Reid, 1999), outside the mackerel (October-February) and herring

<sup>9</sup> Full time equivalent is calculated by taking the proportionate dependency on feed fish fishing as opposed to targeting human consumption fisheries.

<sup>10</sup> Derived from, the Fisheries Economics and Management Division, Danish Research Institute of Food Economics.



seasons (July-September). The value added generated from industrial fishing is generally small representing around M€2.9 (Banks and Reid, 1999), in the two countries combined. 7 UK vessels have also historically been given licenses to target capelin in Greenland. However, there are presently no landings of capelin into the UK.

### Other vessel activity

Fishing for feed fish in Finland provides almost the entire income for the Finnish fleet. Most of these vessels (2000+) are coastal, small scale and only a few of these 100 or more are full time (Anon, FGFRI, 2003, pers. comm).

Germany has no tradition of fishing for feed fish. However, two Danish industrial vessels have transferred to the German flag (Eliassen, 2003).

Poland's fleet has changed its fishing activity from targeting herring and sprat for human consumption to fishing for feed fish. More than 75% of Polish pelagic landings, 25,000 tonnes (Table 2.1.1.) are made into East coast Danish ports.

### 2.3. Fish trimmings

In addition to the supply of feed fish, an additional 912,500 tonnes of raw material is supplied as fish trimmings (Fish Meal Manufacturing Survey, 2003<sup>11</sup>). Trimmings represent a significant quantity of supplies to the sector, accounting for approximately 33% of raw material supplied to the fish meal and body oil sector. These trimmings are by-products of fish processed for human consumption.

The proportion of fish trimmings in each country destined for fish meal and fish body oil depends largely on the final product. It is estimated that 80% of the trimmings from fish processing enter the fish meal and fish body oil industry in Denmark (Jensen, *TripleNine*, 2003, pers. comm., September), whilst in Spain this figure is only 10% (Blanco, ANFACO, 2003, pers. comm., September). In the UK, Germany and France, between 33-50% of fish trimmings enter the fish meal and fish body oil industry.

**Table 2.5. The importance of trimmings as a source of raw material for the fish meal and fish body oil industry in 2002**

Country	Feed fish	Trimmings	% dependency
Denmark	332,000	33,200	10%
UK	7,800	42,500	84%
Spain		42,000	100%
Sweden	18,750	6,250	25%
France		25,000	100%
Ireland	8,800	13200	60%
Germany		17,000	100%
Italy		3000	100%
TOTAL	367,350	182,150	33%

Source: Survey of fish meal manufacturers; IFFO, (2003)

Table 2.5. shows the varying degrees of dependency for producers. In Spain, France and Germany in particular, trimmings account for all the raw material entering the fish meal and fish body oil industry. Fish trimmings heavily supplement the raw material throughput in the

<sup>11</sup> This survey was conducted by R. Banks by phone and personal interviews with fish meal manufacturers.

UK (pelagic, whitefish and salmon), Ireland (pelagic) and Sweden (whitefish). Around two thirds of the offal ingredients in the UK and Ireland are derived from pelagic fish (herring and mackerel). The Danish sector is heavily dependent on feed fish supplies, but trimmings can form an important source of supplies to the meal plants in Skagen and Hirtshals where the whitefish processing sector is significant. The balance between trimmings and feed fish in Denmark varies. Whilst the supply of trimmings remains broadly constant, the Danish fish meal manufacturers have been particularly successful in competing against Norwegian fish meal manufacturers for supplies (Table 2.2.) (Jensen, *TripleNine*, 2003, pers. comm., September).

The UK and German dependence on whitefish trimmings has fallen. This is in response to a decline in whitefish supplies and a reduction in 'black fish' (Korsager, *UFI*, 2003, pers. comm, September). In contrast, a greater proportion of supplies are now derived from trimmings, where the state of raw material supply is healthy. Salmon also increasingly provides an added source of supply to UK fish meal plants.

It should be noted that none of the fish meal plants rely on the landing of discards, otherwise known as trash fish. Trash fish are a common source of supply in many fish meal producing nations, with the exception of the EU, South America and the USA. Norwegian plants derive supplies from fish caught as by-catch<sup>12</sup> (140,000 tonnes, or 14% of throughput<sup>13</sup>). The EU also operates a price intervention scheme for fish. Fish withdrawn from the market is processed into fish meal. Because of the strong state of the market for food fish, withdrawals are in decline.

## 2.4 Processing capacity

Table 2.6. shows the number of fish meal plants in EU countries and their relative dependency on the source of raw material.

**Table 2.6. Fish meal plants in the EU**

	Factories	% trimmings	% industrial
Denmark	4	10	90
France	3	100	0
Germany	1	100	0
Ireland	1	60	40
Spain	10	100	0
Sweden	1	25	75
UK	3	85	15

Source: IFFO, 2002.

The number of fish meal plants has fallen significantly in the last 20 years. The Danish sector has seen a rationalisation from 20 to 4 plants (Jensen, *TripleNine*, 2003, pers. comm., September), whilst the UK sector has seen a reduction in the number of fish meal plants in the last two decades from 10 to 3 (Korsager, *UFI*, 2003, pers. comm, September).

A number of fish meal manufacturers have suggested that there is a critical mass required for fish meal processing. Fish offal manufacturers have suggested that logistically, it makes

<sup>12</sup> Norway has a no discards policy which is used in order to promote selective fishing. The rate of by-catches are monitored and the fishery is closed if by-catches are high. The no discards rule means that fish caught as a by-catch are disposed of through fish meal.

<sup>13</sup> Bjørn Myrseth, Marine Farms ASA, Norway.

practical and economic sense for a plant to be located every 800 miles as it becomes uneconomic to transport fish meal beyond distance (De Rome, *SoproPêche*, 2003, pers. comm., August; Korsager, *UFI*, 2003, pers. comm, September).

## **Denmark**

The sector has undergone a significant process of rationalisation in Denmark with as many as 20 plants in Denmark operating some 20 years ago. Currently, Denmark has four fish meal plants: one in Esbjerg and one in Thyborøn, both with a combined capacity to process 1 million tonnes a year; one in Hantsholm and one in Skagen. The Skagen plant now operates jointly with the single operating plant in Sweden (see below).

The fish meal process is highly mechanised as such there are only 395 workers (FTE) in the Danish sector.

Total sales from the sector in the years 1997-2001 have averaged M€286 of which 74% is attributed to meal and 26% to fish oils. Sector value added is estimated as M€11.1, including the premium shares to the directors.

## **Sweden**

Sweden has one fish meal plant based in Göteborg. This plant is reported as producing 25,000 tonnes of raw material (IFFO, 2002). The plant employs 35 workers (FTE). This plant is now in a joint venture agreement with the Skagen plant. Most of the Swedish fishers now land their catch into Skagen as opposed to Swedish ports.

## **The United Kingdom**

There are three dedicated meal plants in the United Kingdom, one in Aberdeen, one in Shetland and one in Grimsby. These are owned (or part owned in the case of Shetland) by one company, UFI. The Shetland plant is owned jointly with stakeholders in Shetland including the pelagic processing plant, the Harbour Trust and local fishermen. The plants collectively process around 240,000 tonnes of meal per year, most of which is derived from offal (including a significant quantity of pelagic offal). The Shetland plant processes the bulk of the feed fish product. The Grimsby plant processes whitefish offal generated from Humberside and the other English processing centres such as Fleetwood. Grimsby is also the processing centre for salmon offal generated from the west coast of Scotland<sup>14</sup>. The Aberdeen plant processes around 60% of the total UK meal product. UFI employ 105 workers: 55 in Aberdeen, 20 in Shetland and 30 in Grimsby. The value added generated from fish meal processing is M€5. This excludes the additional value added generated for the processing sector as a whole which is able to generate additional income by disposing of the offal at a commercial rate.

## **Ireland**

There is one dedicated fish meal plant in Ireland based in Killybegs, Co Donegal. This is also owned by UFI. The plant relies heavily on offal supplied by the pelagic processing sector which is largely based in Killybegs. Additional feed fish supplies of blue whiting and occasionally horse mackerel are supplied to the port by Norwegian, Faeroese and Russian

<sup>14</sup> Grimsby is focal point for processing salmon offal because of the need to separate the offal from meal dedicated to aquaculture feeds. Aberdeen specialises in the production of LT meal for the aquaculture sector.

vessels. The plant employs 46 workers and generates M€2.5 in value added. The plant produces an LT product which is largely exported to the UK salmon feed suppliers or is sold to the local aquaculture feed sector.

## France

There are no directed feed fish fisheries in France. Fish meal is produced entirely from fish offal in three plants, one based in Boulogne, one in Concarneau and one in Lorient. The combined production from these plants was 25,000 tonnes in 2003 (De Rome, *SoproPêche*, 2003, pers. comm., August). This includes 8,000 tonnes of high quality hydrolysates<sup>15</sup> (easily digested proteins). Hydrolysates have been produced by the Boulogne based fish meal manufacturers SoproPêche since 1968.

The three plants collectively employ 270 workers, 120 in Boulogne and 150 in the two Breton plants. SoproPêche is a co-operative and is wholly owned by the indigenous processing sector, thus forming an integral part of the local infrastructure. The other company, Saria owns the other two plants. Saria is a private subsidiary of German parent company. It is suggested that this company may centralise its activities to Concarneau, representing yet a further rationalisation in the EU fish meal sector.

The pig industry represents by far the most significant outlet for French meal producers. LT and FAQ meal represents around 17,000 tonnes of product. Hydrolysates (around 8,000 tonnes) are used specifically for fish fry and piglet production. It was also traditionally used to feed young calves.

## Germany

The German fish meal plant is owned by Unilever (IFFO, 2002). Raw material comprises almost entirely whitefish offal produced from the two German ports of Cuxhaven and Bremerhaven. The principal product is FAQ meal. The main outlet for the product is the German pig industry.

## Spain

Fish meal is produced in ten plants in Spain:

- 5 in Galicia,
- 2 in Cantabria,
- 1 in Pais Vasco,
- 2 in Andalucia.

The fish meal and fish body oil produced in each plant is shown in Table 2.7.

Total production of fish meal in 2001 was 42,000 t derived from 160,500 tonnes of fish offal.

**Table 2.7. Breakdown of fish meal and body oil in Spain, 2003**

Location	Meal produced	Body oil
Galicia	35,000	5,000
Cantabria	3,000	1,000
Pais Vasco	1,000	200
Andalucia	3,000	500
Total	42,000	6,700

Source: Blanco, ANFACO, 2003, pers. comm, September

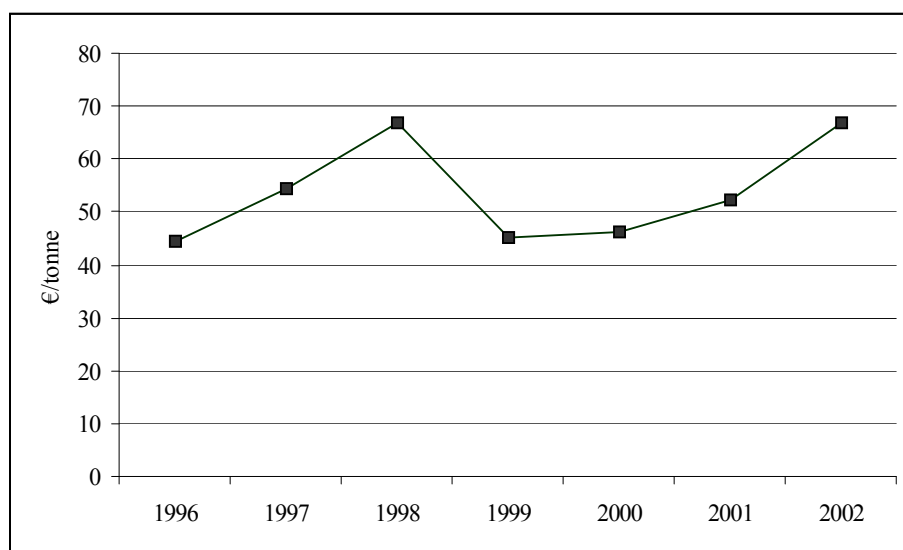
<sup>15</sup> High quality product using enzymes to separate fish from the bone and skin using enzymes.

Around 90% of the meal produced is FAQ (fair average quality). Most of the product is sold as feed to the pig and poultry sector. Approximately 15-20% is sold to aquaculture. However, Spain has probably been hit harder than most countries with the ban on sales to ruminants, which is equivalent to around 25% of its total sales. Employment in the sector amounts to 250 workers.

## 2.5. Fish prices

The average price recorded for industrial fish in Denmark is shown in Figure 2.3. and a breakdown of the average prices of the individual species is shown in Table 2.8.

**Figure 2.3. Average prices recorded for Danish industrial species (€/tonne)**



Source: Fiskeridirektoratet, 2003, unpublished data.

**Table 2.8. Average prices recorded for Danish industrial species, 2002**

Species	€/tonne
Sandeel	125
Sprat	147
Norway	137
Blue	123
Weighted	131

Source: Fiskeridirektoratet, 2003, unpublished data

## 2.6. Industrial liver oils

Small quantities of industrial liver oil are derived from directed fishing activity in Western waters. The principal fishing areas are ICES areas VIII, VIa, VIb, IXa, XII and Vb. The target species are deepwater sharks: *Deania calceus* (birdbeaked dogfish), *Centrophorus granulosus* (gulpher shark), *Centroscymnus coelolepis* (Portuguese dogfish), *Dalatias licha* (kitefin shark) (Piñeiro *et al.*, 2001) and *Centroscyllium fabricii* (Longnose velvet dogfish) (STECF, 2002). Fishing has largely been opportunistic developing from the mid to late 980s

(Soto, P.<sup>16</sup>, 2003, pers comm., August). Three distinctive groups of fishers have been identified:

- ♦ Fishing vessels operating from A Curúna, comprising indigenous vessels and foreign UK flagged vessels beneficially owned in Spain (or Piñeiro *et al.*, 2001; Soto, P., 2003, pers comm., August; Carlos, *Pescafisheries*, 2003, pers. comm., August);
- ♦ Spanish Fishing vessels operating from the coastal towns of San Vicente de la Barquera Fisterra and Avilés (Piñeiro *et al.*, 2001);
- ♦ A small fishery taking place from Viana do Castelo on the Portuguese mainland (STECF, 2002).

All fisheries saw peak landings in the 1980s / early 1990s. The UK / Spanish fishery has generated the largest of landings. In the early 1990s, there were 9 UK registered vessels (Soto, 2003) and 11 Spanish vessels (Carlos, 2003) operating in the fishery on a full time or part time basis (October to March). This fishery has evolved as a result of searching for alternative fisheries following the demise of the hake long line fishery (Piñeiro *et al.*, 2001). Fishermen are not obliged to record catches in the logbooks used to monitor species with quotas. It is also difficult to differentiate in the landing statistics between species caught in by-catch fisheries, which represent the bulk of the landings, and fish targeted in directed fisheries. Statistical information by species is also limited because few European countries differentiate between species in landings statistics and they are often collectively recorded as sharks, dogfish or skates and rays, often with confounding assessments.

Directed activity and catches are reported to be between 7,000 to 14,000 tonnes annually (Soto, P., 2003, pers. comm. September). Each vessel reports an average catch per trip of between 30 to 40 tonnes (Soto, P., 2003, pers. comm; DEFRA, 2003, unpublished data). 40% of the UK /Spanish catch is derived from VIa with other activity in areas IX a, VIb, IXa and Vb. Catches from the directed shark fishery are reported as having fallen by 60% in the last 10 years.

Fishing from the smaller Spanish ports is on a smaller scale. Landings are generally under 500 tonnes per annum (Piñeiro *et al.*, 2001). Landings from Viana do Castelo have since fallen away, partly in response to a decline in the market price (STECF, 2002).

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<sup>16</sup> Fishing vessel agent.

### 3. PRODUCTION, IMPORT AND EXPORT OF FISH MEAL AND FISH OIL

#### 3.1. Fish meal production and product outputs

World production of fish meal averaged 6.3 million tonnes between 1997 and 2001 (FAO 2001). This accounts for approximately 22 million tonnes liveweight, or 23% of the world catch<sup>17</sup>. Peru and Chile account for 55% of total supplies, followed by China with 12% (Table 3.1). The EU is the world's fourth largest producer at 9%. Other European countries (Norway, Iceland and the Faeroes) collectively produce around 8.5% of the world total.

**Table 3.1. International Production of fish meal (Average 1997-2001)**

	Average production	%
Peru	1,959	31%
Chile	803	13%
China	733	12%
<b>EU</b>	<b>597</b>	<b>9%</b>
Thailand	389	6%
Japan	357	6%
USA	305	5%
Iceland & Faeroes	285	5%
Norway	255	4%
Others	632	10%

Source: FAO (2003).

Figure 3.1. illustrates the distribution of fish meal production between the EU countries.

Denmark is by far the most significant of producer of fish meal and oil, but is significantly more reliant on feed fish<sup>18</sup> (approximately 90% of raw material) caught in directed fisheries. Sweden and Poland also rely heavily of feed fish, although significantly less than Denmark in terms of production. The UK and Ireland are partially dependent on feed fish supplies, but these quantities are less significant than their Scandinavian counterparts. Spain is the fourth largest of the producing countries. Spanish supplies are entirely dependent on by-products (trimmings) from processed fish. Other countries with total dependence on fish trimmings include France and Germany. Supplies are entirely based on whitefish by-products.

The features associated with product processing are analysed on the basis of:

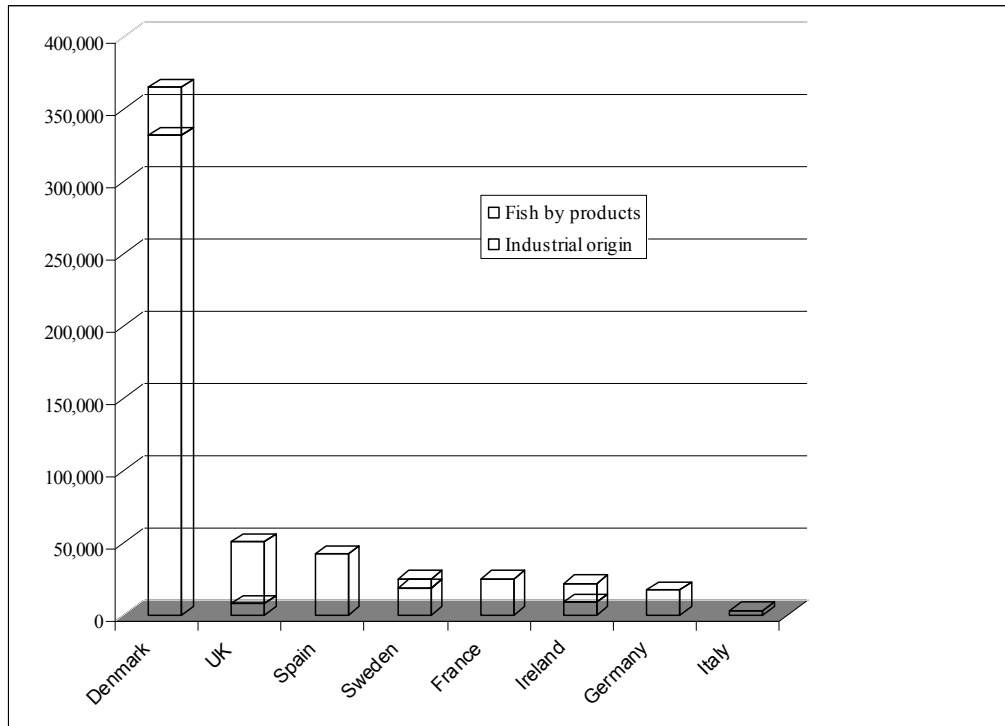
- TVN (Total Volatile Nitrogen) / ammonia (high quality fish meal contains low concentrations of ammonia)
- Fat content
- Content of dry matter
- Content of sodium chloride

<sup>17</sup> FAO fish meal production equates to 6.3 million tonnes, of which 77% is derived from directed fisheries for reduction (feed fish). The world catch is 92.4 million tonnes. Feed fish produces 22% fish meal and 6-8% fish oil. Fish offal represents one sixteenth of product weight.

<sup>18</sup> Feed fish is used to describe industrial fish species targeted for animal feeds as opposed to fish for human consumption. It was recently outlined as the appropriate terminology at the Seafeeds Workshop, University of Stirling. Industrial fishing is often used by some countries to describe large scale trawling (for gadoids) so can confuse.

Feed caught fish are pumped from the vessel, coagulated, pressed to remove the water, spun to remove the oil from the water, and the meal dried at between 70 (slow heating) to 100 °C (fast drying).

**Figure 3.1. EU production of fish meal (tonnes) in 2002**



Source: Extracted from national fishery departments and fish meal manufacturers

There are four different products sold as meal:

- ◆ High quality - usually reserved for small scale aquaculture units (trout farms) or marine species.
- ◆ LT meal - is highly digestible and used in salmon and piglet production.
- ◆ Prime
- ◆ FAQ (fair average quality) - has a lower protein content and is used as a feed ingredient for pigs and poultry

The sales of these meal types within the EU are shown in Table 3.2.

**Table 3.2. Percentage distribution of EU product sales**

Product range	%
High quality / LT meal	30
Prime	48
FAQ (Fair Average Quality)	22

Source: Interviews with fish meal manufacturers

Sandeels, sprat and herring (caught as a by-catch) tend to have higher protein qualities (70%-75%) than Norway pout and blue whiting (62%-69%). The Danish / Swedish product tends to have a higher protein content and is of a higher quality because of the preponderance of sprat used as feed fish in the product. Sandeels and sprat represent 78% and 95% of feed fish supply in Denmark and Sweden respectively. Pelagic offal are of a similar quality to higher protein feed fish and is invariably used to produce LT grade meal.



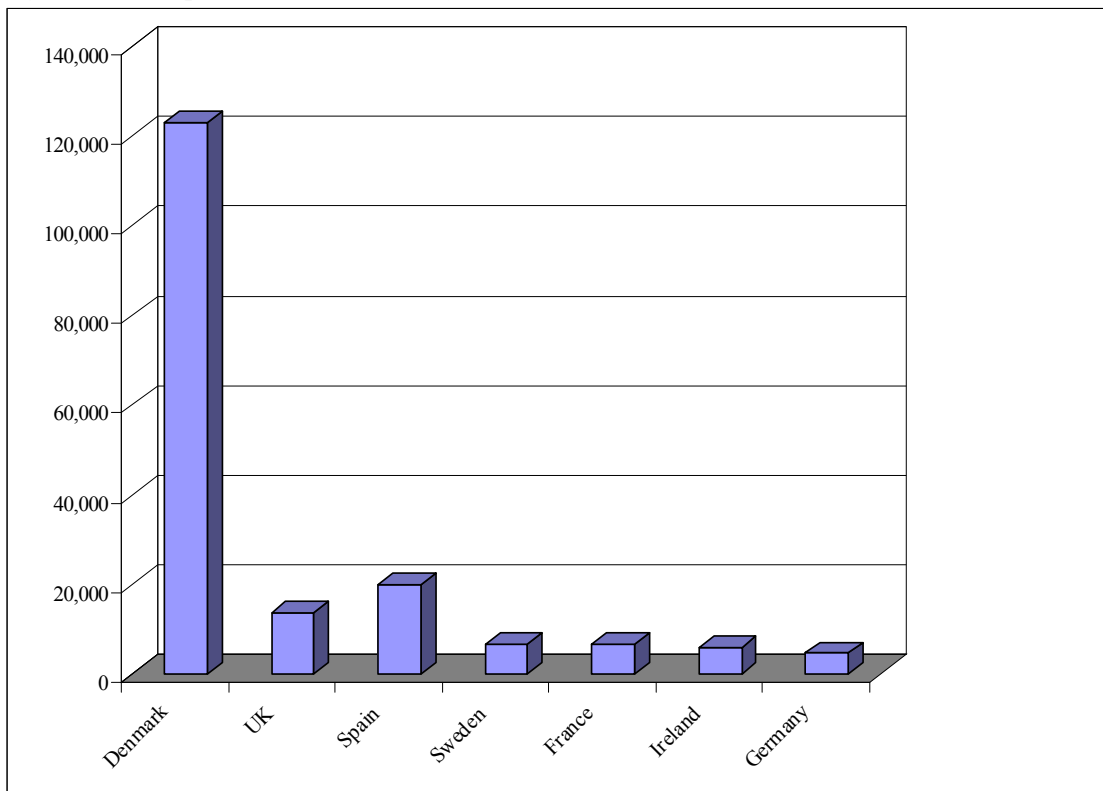
When white fish offal is added to the contents to form part of the raw material it invariably lowers the protein content (62% as opposed to the higher protein levels of 70-72%) and can reduce the overall quality of the product. As such, it is likely to be used as an ingredient in FAQ meal. Whitefish offal also produces a higher amount of ash in the product. This dilutes the protein content and as such requires a greater amount of feed needs to be added to compensate for the deficiency.

Fish offal however, can also be upgraded. Hydrolysates represent a premium product produced from off-cuts. Enzymes are added to the offal to create a higher protein meal which can be added pig meal. French fish meal manufacturers specialises in this trade.

### 3.2. Fish body oil production

Fish body oil is a co-product of fish meal. Fish oil represents around 5-6% of the total raw material body weight.. Figure 3.2 illustrates the distribution of fish oil production between the EU countries.

**Figure 3.2. EU production of fish body oils (tonnes)**



*Source: Extracted from interviews with fish meal manufactures*

#### 3.2.1. Fish body oils

World production of fish body oils averaged 1.1 million tonnes between 1997 and 2001 (Appendix 3). Peru and Chile account for 47% of total supplies, followed by the EU at 16%. Other European countries (Norway, Iceland and the Faeroes collectively produce around 17% of the world total (191,000 t). The USA is also a significant producer of fish oils.

Table 3.3. shows the mean annual production of fish body oils of the major producers between 1997-2001.

**Table 3.3. Average international production of fish body oils between 1997-2001 ('000 tonnes)**

	Average annual production('000 tonnes)	%
Peru	372	31%
<b>EU</b>	<b>186</b>	<b>16%</b>
Chile	155	13%
Iceland & Faeroes	113	10%
USA	113	10%
Norway	80	7%
Others	163	14%

Source: IFFO, 2002

Countries within the EU produce a total of 186,000 tonnes of fish body oil annually. Of this, Denmark produces 71% (132,000 tonnes) of the EU's product and Spain produces a further 20,000 tonnes (IFFO, 2002). The remaining fish meal producers collectively account for small quantities of between 4,000-10,000 tonnes each.

A broad example of the range of oil brands sold are:

- Red Tobis (sandeel)
- Tobis (sandeel)
- Standard
- Standard (salmon)

Red Tobis is the highest quality oil and is used as a colouring agent (Jensen, 2003). The red colour (astaxanthin) comes from the crustaceans which form a substantial part of the sandeel feed. Red Tobis is a product exclusive to Denmark. Most red tobis is sold to Japan as an ingredient to tuna feeds. Red Tobis accounts for approximately 1% of total EU product sales. Tobis was traditionally used as an ingredient in margarine, but is now sold almost exclusively to aquaculture. Tobis accounts for approximately 9% of total EU product sales. Standard oil is a lower grade oil but is still sold exclusively to the aquaculture sector. Standard oil accounts for 89% of the market. Salmon oils only represent around 1-2% of product sales.

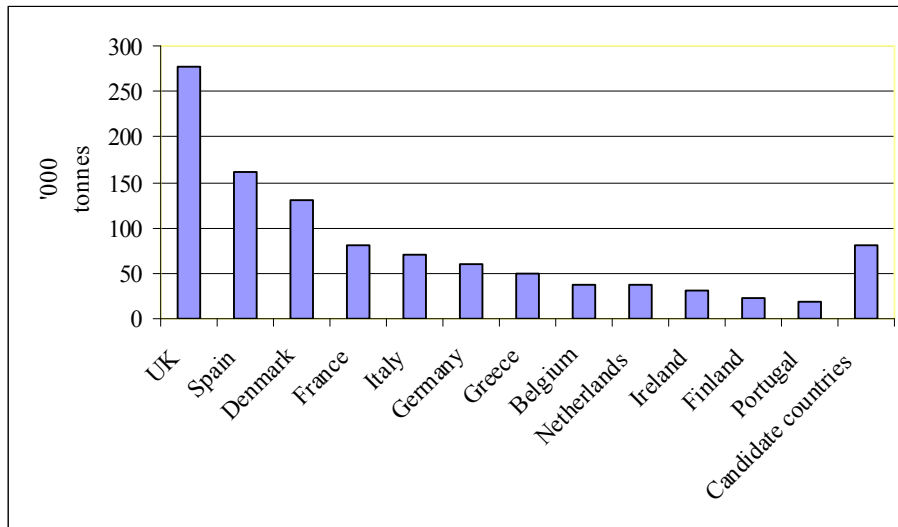
### 3.3. Imports and exports of fish meal

The European Union is one of the main consumers of fish meal and accounted for approximately 18% and 19% of world meal and oil consumption respectively between 1997 – 2001 (IFFO, 2002). The total EU consumption of fish meal, including the candidate countries, is 1.2 million tonnes per annum IFFO, 2003]. Total EU consumption of fish oil is 230,000 tonnes (IFFO, 2002).

The EU is a net importer of fish meal (~442,000 tonnes) and fish body oils (~63,000 tonnes) (IFFO, 2002). This though is a rather simplistic interpretation since there are significant international product flows based on product specification and price. For example Denmark is a significant exporter of fish meal and oil, exporting 300,000 and 100,000 tonnes respectively in the last four years. The EU countries combined export one third of their domestic fish meal product abroad and are significant importers of raw material (65% of fish meal supplies) from South America.

Figure 3.3. shows the principal fish meal consuming countries within the EU.

**Figure 3.3. Average annual EU consumption of fish meal between 1997-2001**



Source: IFFO, 2002

The principal fish meal consuming countries (Appendix 4, Table A.4.1) are:

- the UK (accounting for around 26% of EU consumption and 19% of imports),
- Spain (15% consumption and 8% imports),
- Denmark (12% consumption and 10% imports),
- France (8% consumption and 7% imports),
- Italy (7% consumption and 6% imports),
- Germany (6% consumption and 20% imports),
- Greece (5% consumption and 4% imports),
- the Benelux countries (7% consumption and 6% imports).

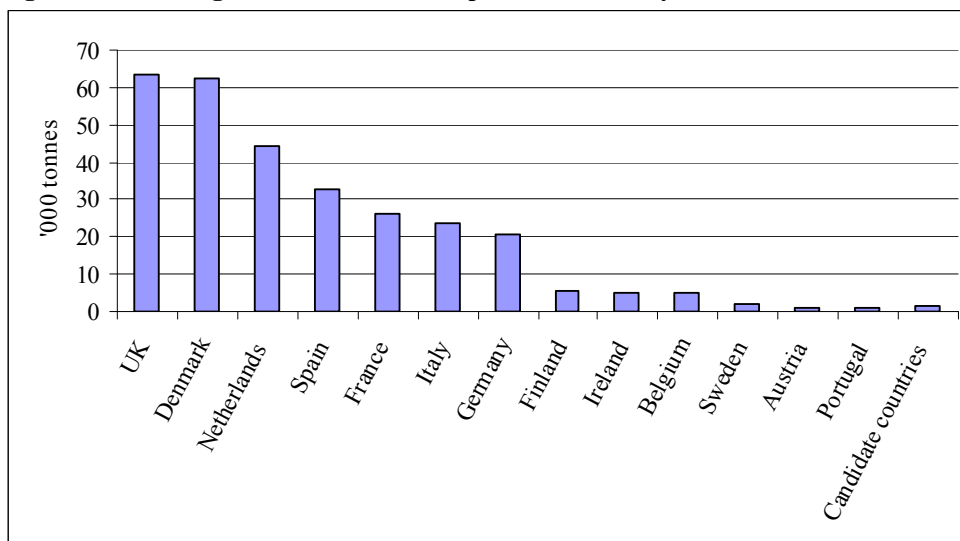
The high number of imports entering Germany is due to international meal traders. Fish meal is subsequently re-exported to other EU countries and to Norway. Throughput through these traders can account for between one third and half the product supplied to key consuming countries, such as the UK, in any one year. The candidate countries account for around 6% of total consumption, Poland and Hungary being the largest consumers, collectively importing around 50,000 tonnes.

Data on fish meal usage in Finland is inconclusive, but it is known that substantial quantities of fresh fish are used as a food for the mink industry.

Meal imports /consumption are known to have fallen markedly in 2002 and 2003, and against the preceding years, down 18%. This is as a result of the ban on the use of fish meal in ruminant feed. (Remove footnote as covered later in the text)

### 3.4. Imports and exports of fish oil

Figure 3.4. shows the principal consuming countries within the EU.

**Figure 3.4. Average annual EU consumption of fish body oils between 1997-2001**

Source: IFFO, 2002

The principal fish body oil consuming countries (Appendix 3, Table A.3.1) are:

- the UK (accounting for around 28% of EU consumption and 19% of imports),
- Denmark (27% consumption and 8% imports),
- the Benelux countries (19% consumption and 35% imports),
- Spain (14% consumption and 7% imports),
- France (11% consumption and 13% imports),
- Italy (10% consumption and 8% imports),
- Germany (9% consumption and 6% imports).

The EU candidate countries are not major consumers of fish oils.

Denmark exported 98,100 tonnes of fish oil in 2001 and 113,700 tonnes in 2000, and is currently the third main exporter of fish oils after Peru and the USA (FAO, 2003). This compares to Norway which exported between 90,126 tonnes of fish oil in 1995, but this was reduced to 44,746 tonnes in 1998 (FAO, 2002).

### 3.5. The market for fish meal and body oils

Industrial fish are used primarily to produce fish meal and fish oils for use in aquaculture and agriculture (Table 3.4.).

**Table 3.4. Average annual fish meal consumption in the EU in 1998 and 2002 ('000 tonnes)**

	1998	2002
Use in aquaculture	214 (21%)	254 (33%)
Use in pigs	310 (31%)	252 (32%)
Use in poultry	280 (28%)	225 (29%)
Use in ruminants	152 (15%)	--
Other uses incl. Pets	39 (4%)	50 (6%)
Total consumption in EU	995	781

Source: IFFO (2003)

Table 3.4. illustrates that the market share of fish meal has remained constant for the pig and poultry sector recently, with increasing demand from aquaculture. Also, it shows that the ban on feeding fish meal to ruminants has reduced the EU's consumption of fish meal by 15%.

A number of supporting comments should be noted in respect to the above points:

- The ban on feeding meal to ruminants has had a very significant effect on the sales to the UK (down 70,000 tonnes), Italy (down 35,000 tonnes), the Netherlands (down 20,000 tonnes) and Germany. The UK and Danish meal manufacturers have borne the brunt of this impact, Denmark, largely because Italy represented one of its largest export markets. Germany has also suffered particularly badly as many of its small meal manufacturers used fish meal as an integral ingredient to their feed supplies for the agricultural sector.
- The UK, being the largest market for fish meal, has seen a significant reduction in imports. Meal manufacturers that once used fish meal as a component of their product have now eliminated fish meal. The dedicated UK producer, whilst suffering from a reduction in the market, has been able to sustain product sales largely because of demand from the aquaculture sector and increased demand from pigs and poultry.

Table 3.5. shows a more detailed breakdown of the fish meal market shares with aquafeeds and feeds for young pigs and poultry having the greater significance. Fish meal in pig and poultry feed accounts for between 2-10% of the total ingredients. A lower quality meal is invariably used for chickens and growers (pigs).

**Table 3.5. Importance of EU market shares**

Ratio	Tonnage	% share of the market
Aquafeed - carnivorous	254	34%
Pig/poultry concentrate	66	9%
Pig – early weaned	41	6%
UGF in Poultry	83	11%
Pig – later weaned	33	4%
Pig – growers	157	21%
Poultry starter	66	9%
Pets	50	7%

*Source: IFFO (2003)*

Fish oils are rarely used, but have been used in the past to increase the quality of feed for ruminants (breeding ewes and cattle). Table 3.6. summarises the changes in demand for fish oils.

**Table 3.6. Fish oil consumption in aquaculture in the EU ('000 tonnes)**

Aquacultured species	1998	2002
Trout	65	62
Salmon	45	58
Bass + bream	20	30
Others	5	5
<b>Total</b>	<b>135</b>	<b>155</b>

*Source: IFFO (2003)*

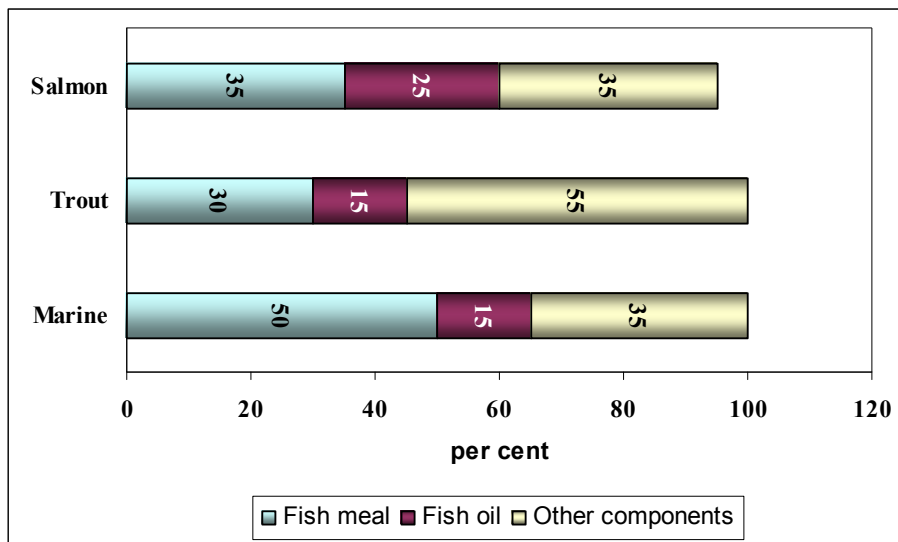
The table above illustrates the following points:

- Demand from the salmon sector has increased (up 28%) despite an increase in the price of fish oil relative to its main competitors (rape seed and soya oils).
- Demand from bass and sea bream aquaculture has increased by 50%, in line with the increasing production associated with the Mediterranean countries.
- Trout consumption has fallen, largely in line with a reduction in EU production which is presently suffering from competition from other producers.

A very small amount of fish oil is also used in the production of margarine. Salmon oil is used as an ingredient in margarine as opposed to fish feed, largely because of an ethical agreement not to re-circulate oils to species specific derivative products. Salmon oil is traded at 10-15% below the price of 'standard' fish oil. The demand is very price dependent, competing largely with palm oil.

Figure 3.5. shows the distribution of fish meal and oils in aquafeeds.

**Figure 3.5. Distribution of feed components in fish feeds**



Source: IFFO (2003) Note: Other components may include maize / wheat gluten, full fat rape or soya and vegetable oil

Salmonids need a high proportion of meal and oils in their feed. An increased content of fish ingredients improves feed conversion efficiencies (plant oils lack the long chain omega fatty acids that are contained in marine oils). The issue of feed substitutability is referred to in Chapter 6.

Trout requires a lower percentage of fish meal but a higher grade meal. Carp feeds are in significant demand in Eastern Europe but have a considerably lower fish meal / oil requirements and can be more readily substituted with alternatives.

Moreover, there is a high demand for feed fish for other carnivorous species – bass, bream and tuna, all of which represent a significant proportion of the Southern European aquaculture production – Italy, Greece, Spain, Cyprus and Malta.

The importance of fish meal as an ingredient in feed varies from country to country depending on the extent of its feed requirements. The UK is the highest consumer of fish meal partly because it has an extensive salmon aquaculture sector, but also because of the demand for fish meal ingredients into pig and poultry feeds. Greece, Italy and smaller

Mediterranean Island states such as Malta and Cyprus rely on fish meal as ingredients for bass and sea bream feed. Other marine farmed species dependent on feed fish include halibut, turbot, sole, cod, hake, haddock, redfish, sea bass, congers and tuna.

The other countries: Germany, France, Spain, the Netherlands and the candidate countries (particularly Poland and Hungary) are also reliant on feed fish supplies to support the pigs and poultry sector.

Denmark, along with Iceland and Norway, is a significant exporter of fish meal (Appendix 2). Norway's product is largely absorbed within its own country. Iceland exports significant quantities of meal into Europe, particularly the UK, and also North America. Denmark exports around 30% of its product to the southern countries within the EU (Greece and Italy) and a further 15% to Norway. The remaining 55% is exported to a number of Far Eastern countries where high quality meal and oils are much sought after (Jensen, *TripleNine*, 2003, pers. comm., September)

### 3.6. Restrictions on fish meal processing

#### 3.6.1. Statutory regulations

##### Dioxins

The European Commission has endorsed the World Health Organisation's initiative of establishing maximum dioxin levels (EC Directive 102/2001), amending an earlier Directive (EC 29 / 1999). The Directive contains the corresponding action values, setting limits for dioxins in fish oils, fish meal and fish feeds (Table 3.7). The levels established apply to both feed fish and fish destined for human consumption.

**Table 3.7. Limit and action values for dioxins in feedingstuff**

Feedingstuff	Maximum dioxin content relative to a feedingstuff with a moisture content of 12% (ng)	
	Limit value	Action value
Fish oil	6.00	4.50
Fish, their products & by-products	1.25	1.00
Compound feeds	0.75	0.40
Feeds for fish	2.25	1.50

Source: EC Directive 102/2001

The proposed legislative limits consist of two components:

#### 1. The establishment of maximum limits

The limits mean that a product such as fish oil or fish meal – with a contamination level above the corresponding maximum limit will not be allowed for use in the production of feedingstuffs (e.g. fish with a contamination level of above 6 ng/kg or fish and fish meal with a contamination level above 1.25 ng/kg whole weight).

The proposal is restricted to dioxins because on the basis of current data it seems to be inappropriate to include dioxin-like PCBs. A review of maximum limits is planned for before the end of 2004 based on new data which will set the maximum levels of PCBs. A further review is planned before the end of 2006 to significantly reduce the maximum levels.

## 2. The establishment of action values

The action values are an early warning alarm for higher than desirable levels of dioxin and trigger a proactive approach from competent actors to identify sources and pathways of contamination and to take measures to reduce the contamination. These action values have now been adopted by feed suppliers.

Dioxin levels as high as 6 had been found in European fish oils. Amongst the different food products, fish and milk tend to accumulate higher levels of dioxin than most products due to their lipid (fat) content. High dioxin levels in fish can be attributed to four factors, namely:

- location (some areas, and in particular the Baltic, register higher levels of dioxin than others),
- species (blue whiting and sprat tending to have higher levels of dioxin),
- spawning season (higher levels are recorded when the fish are closer to spawning and have a higher fat content),
- the age of the fish (mature fish tend to be higher in dioxins as they are unable to excrete dioxins fully and instead accumulate them).

The manufacturers respond to this in a number of ways:

- Carbon filtration extracts dioxins from fish oils. This requires heavy investment<sup>19</sup> and has been introduced by a number of meal manufacturers. Those without the filtration equipment subcontract those companies with it.
- The meal is extracted by applying a solvent. The technology in its infancy.
- The fish may be mixed between species, age and source prior to processing.

The practice of blending oils in order to reduce the levels of dioxin is illegal.

The UK Food Standards Agency (FSA) recorded a halving of dioxin levels in UK food from 1.8 to 0.9. In 1998, 35% of a samples tested exceeded the required maximum limits, but by 2001, this had reduced to 1%.

## TSE

According to the European Commission (2003), there is no evidence that feeding fish meal to farmed fish presents any risk to animal or human health through transmissible spongiform encephalopathies (TSEs). However, mammalian meat and bone meal (MMBM) is no longer used within aquafeeds, and a species specific meal cannot be fed to a derivative species, hence the exclusion of salmon meal as an ingredient to salmon feed. Specific exemptions have been made to allow the use of fish meal in aquaculture and for pigs and poultry.

Feed fish have also been included in the list of products, including MMBM, as unsuitable to feed to ruminants. The concern is that whilst fish meal does not contain rogue prions, it cannot be distinguished from MMBM in animal diets, and bones from fish may mask the identification of MMBM. Research has however shown that modified microscopy and ring testing can distinguish between fish meal with or without bone meal with a large degree of accuracy. These experiments have been conducted by DG SANCO, the health and consumer protection DG. The concern that applies presently is two fold: (1) ensuring that there is proper control and veterinary testing; and (2) if feeding fish meal to ruminants is exempt, it

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<sup>19</sup> TripleNine invested M€2 million on carbon filtration system (Jensen, 2002, per comm., August).



does not set a precedent for other ingredients. The EU intend to review the ban in the next 6 to 12 months<sup>20</sup>.

Use of plant protein is exempted from any control.

### **3.6.2. Voluntary measures**

A number of meal manufacturers are presently adopting the Feed Material Assurance Scheme. This is FEFAC (Federation Europeen des Fabricants D'Alimentaire Composés) endorsed certification scheme which ensures good practices and includes product traceability.

### **3.7. Fish liver oils**

Shark and cod are the two main fish whose livers are extracted for oil. Whilst sharks are specifically targeted for their livers, cod livers are taken as a by-product along with the roe. The extraction of liver oil is manual and takes place either on board vessels or in the processing plants. Shark and cod livers tend to be extracted on board vessels where the shark liver is graded for squalene content (each shark species has a different squalene content). A shark liver can account for as much as 20% of the weight of the fish. On landing into La Coruña and other Spanish and Portuguese coastal ports, the oil is stored and exported as and when the price of oil increases (Soto, P., 2003, pers. comm.).

Spain is also an exporter of shark liver oils. The export of oils is known to have decreased in the last 5 years as stock abundance has declined by 60% (FAO, 2002).

The main European exporters of shark liver oils are Spain (900-2,000 tonnes). This comprises high grade 'industrial' shark oils. This is equivalent to 14,000 tonnes of shark (liveweight). This product is exported to Japan. Squalene, a component of the oil has significant health inducing properties and is used as an ingredient to cancer and AIDS inhibiting drugs.

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<sup>20</sup> Commission of the European Communities, Working Document COM (2003) 546 final: With regard to the state of play on the prohibition to feed animal protein to farmed animals to prevent transmissible spongiform encephalopathies



## 4. THE INTERACTION BETWEEN FISH MEAL AND FISH OIL INDUSTRY AND THE FISHING SECTOR

### 4.1. Direct employment in the industrial fishing sector

The industrial fishing sector is economically very small relative to the EU fisheries as a whole. It accounts for only 0.5% of the sector's employment and 2.1% of the sector's value added (Megapesca, 1998). Table 4.1 summarises the economic significance of the fish meal and oil sector within Europe. The sector contribution to EU gross value added is M€137. Approximately 220,000 people are employed directly in the sector. More specifically, the level of economic dependency (value added) on feed fish fisheries accounts for M€136 or 87% of the total and as such is significantly greater than the economic value generated from fish offal.

**Table 4.1. The economic significance of Europe's fish meal and oil sector, 2003**

Country	Sector	Employees (FTE)	Value added
Denmark	Fish catching	507	83
	Fish processing	395	11.1
Sweden	Fish catching	93	14
	Fish processing	35	4.3
United Kingdom	Fish catching	11	1.45
	Fish processing	105	5.
Ireland	Fish catching	10	1.45
	Fish processing	46	2.5
Spain	Fish catching	0	0
	Fish processing	250	2.6
France	Fish catching	0	0
	Fish processing	270	4.4
Germany	Fish catching	0	0
	Fish processing	62	1.5
Poland	Fish catching	60	2
	Fish processing	53	(-)
Finland	Fish catching	305	3.6
Other	Fish processing	20	(-)
Total	Fish meal	2,222	136.9
Total EU fishery		482,374	6,416.8
% EU fishery sector		0.46%	2.13%

*Source: Fishing fleet data is derived from economic studies EU figures derived from EU Fisheries Regional-Socio Economic Studies, 1998. Fish processing data has been extracted from interviews with fish meal manufacturers*

Table 4.2. shows the specific dependence by group.

Sixty four per cent of the workers are dependent on feed fish supplies (fish catching and processing feed fish), and 35% on the trimmings sector. Employment in feed fish related meal tends to be less labour intensive than in offal production (Korsager, *UFI*, 2003, pers. comm. September).

**Table 4.2. Employment dependency by producing / processing group, 2003**

Sector	Total dependency	%
Fish catching	986	45
Fish feed processing	417	19
Fish trimming processing	766	35
Total	2,222	100

Source: Table 4.1; percentage dependency between trimmings and feed fish is derived from the ratios shown in Table 2.7.

## 4.2. Interdependence of the catching sector

Table 4.1. illustrates the relatively poor levels of dependency in the context of the EU fishing fleet. However, as Table 2.4 illustrates, fishers dependency extends beyond the stated FTE figures shown in table 4.1 above. Two countries, most noticeably Sweden and Denmark, have fleets which are fully or partly dependent on industrial fisheries, 407 vessels in Denmark and 77 vessels in Sweden (Section 2.1.4). For the two countries, this represents 1,585 fishers, as opposed to the 600 (507 in Denmark and 93 in Sweden) shown in Table 4.1. This represents 58% of the total number of vessels over 15 m in Denmark, and 41% of the total number of fishers in Denmark (FOI, 2003) and 61% of fishers in Sweden (Anon, Fiskeriverket, 2003, pers comm.). What this shows is that the industrial fleet rather than being a single entity, is interwoven into a substantive part of the Danish and Swedish fishery sector. Removing industrial fish from the equation would have a direct impact on a significantly greater number of vessels than those 60 vessels that are strongly dependent on the fishery.

FOI (Danish Research Institute of Food Economics)<sup>21</sup> explored further the potential impact on the Danish fishery sector in the event of (a) a ban on sandeel fishing (scenario 1) and (b) a ban on all industrial fishing (scenario 2). The assessment took account of changes in turnover and costs resulting from a loss of catch and a reduction in fishing effort. Because of the inter-linkages between human and industrial fishing activity, a ban would not only eliminate the 60 dedicated industrial vessels, it would also result in the removal 125 vessels under scenario 1 and 194 vessels under scenario 2. This would result in a loss of employment of between 479 (scenario 1) and 750 workers (scenario 2). Applying a similar rational for the Swedish fleet would probably see the loss of 88 and 136 jobs, albeit that there are different species dependencies.

## 4.3. Interdependence with the processing sector

It is difficult to measure the additional economic contribution which trimmings may have to the processing sector, but aside from the additional sales of fish by-products, the cost of disposal (silage, land fill, freezing for mink, and incineration) would add significantly to the processing production overheads. Equally, without the added supplies of trimmings some of the major meal producers (for example the UK and Ireland) would find it difficult to survive.

The alternatives fish meal disposal scenarios are shown below.

<sup>21</sup> Andersen J and Løkkegaard J: Industrifiskeriets Økonomiske Betydning for Dansk Fiskeri, DIFR Rapport 134, 2002.

**Table 4.3. Revenue generated from 1 tonne of trimmings (sales price minus operational costs)**

	€/tonne
Fish meal	84-145
Silage	14-58
Freezing for mink / pet food	50-58
Land fill	-116*
Incineration	-181*

(\* minus figures are costs)

Source: FIN (2003)

Assuming that the full range of alternative forms of disposal would be spread equally, the derived cost of disposal would be €51/tonne. Table 4.4. is based on the existing turnover / margins in the UK fish processing sector and briefly shows the extent of value added from a trimming plant. This economic data has been derived from Curtis and Bryson, 2002.

**Table 4.4. An estimate of the savings made to processing costs from the ability to sell fish trimmings**

		Demersal processing	Pelagic processing
1	Average tonnage processed per firm	1,422	2,772
2	Total turnover	5,819,273	10,350,177
3	Average price generated for meal sales	115	115
4	Additional revenue	162,823	317,369
5	%	0.028	0.031
6	Additional cost for disposal (€/t)	52	52
7	Cost of disposal (€)	5,925	5,925
8	Total saving from offal disposal (€)	168,808	323,294
9	Total saving per tonne (€/t)	119	117
10	Existing margins	3.2%	5.1%
11	Current processing margin (€)	186,217	527,859
12	Margin without fish meal (€)	17,409	204,565
13	Net % margin without disposal	0.30%	1.98%

Source: Poseidon's estimates based on costs of disposal (Table 2.6); and the costs / throughput of UK pelagic and demersal processors (Curtis and Bryson, 2002)

Table 4.4. shows that without the facility to dispose of trimmings, the margins in both the demersal and pelagic processing sectors will be severely affected by the loss of income generated from offal sales, and the additional costs to processors of disposing of the offal. This assumes a constant raw material price, when in fact these costs would either be transferred to fishers (thus lowering their raw material price), or to consumers. This of course demonstrates the logic of some processors collectively owning fish meal facilities e.g. SoproPêche.

Nevertheless the conclusions are as follows:

- A fish meal facility will generate additional income to both processors and fishers.
- Reduced margins of having to cater for offal disposal could result in fewer processors if processors were unable to pass on the costs of disposal to consumers, or pay lower prices to fishers.
- Investment in the processing sector would reduce as disposal costs would decrease the margins.

#### 4.4. Other onshore dependencies

No research has been undertaken into the multiplier effect of feed fish fishing. The fish meal processing sector is fully integrated into that of the catching sector as described above. Additional dependents will include vessel support suppliers – net manufacturers, engineers etc. These dependents are unlikely however to be as significant in number as the sector itself.

However, the significant economic dependency lies in the dependence of the aquafeed sector and fish farming on fish meal. 63,189 workers are employed in EU aquaculture production and a further 4,549 in the feed sector (MEP, 1999). Although fish meal is produced outside the EU, and the EU is deficient in its supply by 44% and 27% (Section 3.3), the EU aquafeed and other feed sectors are heavily dependent on domestic supplies. As the EU is 44% dependent on domestic aquaculture production, 29,800 downstream workers can be said to be dependent on the EU fish meal sector. Restricting the domestic supplies will both impact both price and production and employment. The interaction between the feed fish and aquafeed sector is discussed in greater detail in Chapter 6.

#### 4.5. Long term economic sustainability

The raw material (Figure 2.3.) have tends to cost between €80-€130/tonne. Higher prices can correspond to reductions in the availability of raw material but the main limiting factor is the impact on price as a result of fluctuations in international supply and demand outside (Jensen, *TripleNine*, 2003, pers. comm., September). On the basis of the analysis undertaken within the course of this study there was no evidence of windfall gains to the catching or processing sectors. No new industrial vessels have been built in Denmark in the past 8 years (Wichman, *Danish Fishermen's Association*, 2003, pers. comm., August) and the number of EU processing plants is declining. On the basis of past developments, it is expected that some form of rationalisation within the sector, processing and catching will take place irrespective of any externalities. This is on the basis that supplies are constant and remain sustainable.

## 5. FISH MEAL AND FISH OIL INDUSTRY, FISH STOCKS AND MARINE ECOSYSTEMS

### 5.1. Introduction

Within European seas, the fish harvested for fish meal and fish oil may be categorised into teleost feed fish, (such as sandeels, sprat, and blue whiting) and the elasmobranchs (mainly sharks for the purposes of this report).

The teleost feed fish fisheries may be divided further into two categories according to their use:

- i) Not used for human consumption e.g. sandeel (*Ammodytes* spp.), and Norway pout (*Trisopterus esmarkii*). The extracted products are used only for the production of fish meal and fish body oil.
- ii) May potentially be used for human consumption, but their main use is for the production of fishmeal/fish oil (e.g. blue whiting and sprat).

The liver oils from some elasmobranch shark species are extracted and used in nutritional supplements, health products, cosmetics, medicines and in industry.

The effects of fishing on these two groups are very different due to differences in their biology. The elasmobranchs tend to live longer, reproduce later in life and produce fewer young than the teleosts.

### 5.2. The biology and ecology of teleost fish species used as industrial feed fish

Teleost feed fish species caught for the production of fish meal and fish oil include sandeels (*Ammodytes* spp.), herring (*Clupea harengus*), sprat (*Sprattus sprattus*), Norway pout (*Trisopterus esmarkii*) and blue whiting (*Micromesistius poutassou*). Typically those teleosts used in the production of fish meal and fish oil, forage low in the food chain and are preyed upon by fish, marine mammals and seabirds of higher trophic levels.

Teleost feed fish are characterised by early maturation and high fecundity, and can respond quickly to productive conditions, e.g. food supply (Arnott and Ruxton, 2002). Most species respond strongly to environmental conditions (extrinsic forcing). For example, the abundance of sandeels can fluctuate massively over different temporal and spatial scales, and population collapses can occur due to the sensitivity of eggs and larvae to environmental conditions such as temperature (Arnott and Ruxton, 2000; Santos *et al.*, 2001; Sherman *et al.*, 1981). Environmental conditions have been shown to affect the recruitment of sardine and horse mackerel on the Portuguese Continental shelf (Borges *et al.*, 1997) and the abundance of herring and sardine around Devon and Cornwall (Southward *et al.*, 1988).

Some of the important species of teleost feed fish caught in European waters for the production of fish meal and fish body oils include:

#### ♦ Sandeel

There are five species of sandeel in Northern Waters, but the species *Ammodytes marinus* (Raitt's sandeel) is dominant. There is evidence of three sandeel sub-populations in the North Sea (Pedersen *et al.*, 1999; Wright *et al.*, 1998). The translocation of larvae in the water column is one of the main processes by which inter-population mixing in sandeel populations

occurs since the adults are non-migratory. Recruitment in Shetland, for example, is positively correlated with spawning in the Orkneys (Proctor, *et al.*, 1998). Recruitment to an area may be related to both the condition of the local stock, but also the conditions experienced by other stocks and influences on the transport of larvae between the areas (e.g. atmosphere-ocean conditions as indexed by the North Atlantic Oscillation (NAO)). Due to the geographic isolation of certain areas and the requirement for pre-settlement movements, it appears that sandeel populations separated by over 200km do not intermix to any significant degree (Wright *et al.*, 1998).

#### ♦ *Herring*

In the Baltic, the herring (*Clupea harengus*) is taken partly as an industrial feed fish<sup>22</sup>. The Baltic herring stock has experienced large fluctuations in growth and natural mortality during the last two decades (Rahikainen *et al.*, 2003). The variation in herring recruits (age 2) has been shown to be related to the North Atlantic Oscillation (NAO) variations, to the abundance of the young-of-the-year and to the spawning stock biomass two years earlier. A multiple regression model using these three factors explained 93% of the variation in the number of age 2 herring during 1985-2000 in the Baltic (Axenrot and Hansson, 2003). It is proposed that the strong year classes follow mild winters as early spring warming results in higher food availability in spring and early summer to the herring.

#### ♦ *Sprat*

Sprat recruitment has been shown to be significantly influenced by spring sea temperature, the area of Baltic ice coverage, and the North Atlantic Oscillation (MacKenzie and Köster, 2003). Sprat recruitment in the Baltic has also been correlated with the wind regime in the region (Karasiova, 2003).

#### ♦ *Norway pout*

The Norway pout is a short lived species (Sparholt *et al.*, 2002) and its variable recruitment is related to its life history (ICES, 2003e). ICES currently provides advice for Norway pout stock in two ICES Subareas, IV/Division IIIA and VIa, but there is some evidence that, unlike sandeel, there appears to be one stock (ICES, 2003f).

#### ♦ *Blue whiting*

Blue whiting is taken in targeted fisheries in the North Atlantic and North Sea. The blue whiting is likely to be an important species in pelagic systems in the North Atlantic but there is a great deal which is not known about the biology and ecology of the blue whiting and this is particularly worrying given the increased exploitation of this species. Information on the factors affecting recruitment in this species is comparatively poor (Bailey and Heath, 2001). Studies of the population genetics of the blue whiting have indicated that partially separated stocks exist in the extremes of the species' distribution, Mediterranean and in the eastern Barents Sea (Mork and Giæver, 1993; Giæver and Stien, 1998). Blue whiting in the northeast Atlantic system probably consists of several stocks which most likely overlap each other (Skogen *et al.*, 1999; ICES, 2003a), there appears to be gene flow between these stocks, which has been used as justification for the consideration of the North Atlantic populations as one stock for assessment purposes. However, the lag between a loss of local blue whiting stock and recruitment from another area is unknown (Skogen *et al.*, 1999).

<sup>22</sup> Sweden and Finland have directed fisheries for herring as feed fish. Denmark only allows herring to be caught as a by-catch.



### 5.3. The biology and ecology of elasmobranch species taken for industrial use

Elasmobranchs tend to be large at maturity, slow growing, have low fecundity and therefore a low intrinsic rate of population increase (Jennings *et al.*, 1998; Walker and Hislop, 1998; Jennings *et al.*, 1999; Greenstreet and Rogers, 2000; Hill *et al.*, 2001). This makes them vulnerable to even low levels of fishing mortality (Stevens *et al.*, 2000).

### 5.4. Direct and indirect effects of fishing

The direct and indirect effects of fishing on fish populations and the ecosystem are well documented in the scientific literature (Bianchi *et al.*, 2000; Dayton, 1995; Hall, 1999; Jennings and Kaiser, 1998; Kaiser and Spencer, 1996; Kaiser *et al.*, 1998). The direct effect of removing large numbers of individuals of fish from an ecosystem, will impact their prey, predators and the viability and size of target and by-catch populations directly. The physical effect of fishing activity will also affect the ecosystem directly through the death and injury of non-target species (Kaiser and Spencer, 1995) and the disturbance of habitats (Auster *et al.*, 1996; Langton and Auster, 1999). However, there are also numerous indirect effects. Changes to specific predator-prey relationships may impact the whole food chain and lead to changes in the composition of biological communities (Bianchi *et al.*, 2000; Greenstreet and Hall, 1996; Hill *et al.*, 2001; Rijnsdorp *et al.*, 1996). Removal of a species' biomass reduces the buffering capacity of the stock and makes the population more vulnerable to poor food/resource/climatic conditions. There are also genetic effects involved with removing large numbers of genetic variation from the gene pool which may adversely affect populations over time. Indirect effects may include ghost fishing, resulting from lost fishing gears, which may continue to catch and disturb biological communities and habitats unmonitored (Chopin *et al.*, 1996; Laist, 1996). However, given the different natures of the species exploited, and the catching techniques employed, these fishing effects do not apply equally to the industrial feed fish fisheries, elasmobranchs and fish targeted for human consumption.

### 5.5. The effect of fishing on teleost feed fish species

Between 1997 and 2002, an average estimated 1.5 million tonnes of industrial fish species were removed by the fleets of EU Member States each year. Close to half the fish biomass harvested and landed by the industrial fisheries in the North Sea (an average total of 630,000 tonnes per year) was composed of sandeels.

The highly variable recruitment dynamics of teleost fish used for the production of fish meal and fish oil, make predicting stock trends over time difficult. Most commercially exploited fish populations are capable of withstanding relatively large reductions in the biomass of fish of reproductive capacity (Daan *et al.*, 1990; Jennings *et al.*, 2001). However, the removal of extremely high levels of spawning stock may impair recruitment due to inadequate egg production. This has been termed 'recruitment overfishing' (Jennings *et al.*, 2001). Pelagic species are particularly vulnerable to this type of overfishing, as they are short-lived species (Lluch-Belda *et al.*, 1989; Santos *et al.*, 2001). Given the uncertainty of the biology and ecology of blue whiting in the North Atlantic, and that spawning stocks are targeted in the fishery (ICES, 2003e), this may be an issue in the industrial feed fish fishery.

Beverton (1990) reviewed the collapse of stocks of small, short-lived pelagics by examining the effect of fishing and natural extrinsic drivers. In four of the stocks studied (Icelandic spring-spawning herring, Georges Bank herring, California sardine and the Pacific mackerel),

the evidence indicated that the stocks' reproductive capability had fallen, probably due to environmental conditions, but suggested that fishing accelerated the collapse. However, he noted that given the key ecological role, as forage fish, of these species a stock collapse may result in significant alterations to ecosystem dynamics and food web functioning. Extinction of an entire industrial fish species is unlikely (Hutchings, 2000; Sadovy, 2001) but the treatment of stocks as single, panmictic populations means that the extinction (extirpation) of local populations may occur even when the whole fishery is operating within safe biological limits. At present, sandeel stocks are estimated at a broad spatial scale although there is evidence for finer-scale spatial structure in the population (Procter *et al.*, 1998; Wright *et al.*, 1998; Pedersen *et al.*, 1999). Regional stock assessments would be better suited to identify the separate stocks which are at risk of overfishing. Additionally, this may benefit areas identified as environmentally sensitive, e.g. important to species which feed on local sandeels (Furness and Tasker, 2000).

Sprat fisheries in the Baltic are considered to be inside safe biological limits (ICES, 2003e). Some sprat are taken in mixed pelagic fisheries together with herring in the region. However, the state of three of the separately managed stocks of herring is considered to be uncertain (STECF, 2003). Herring biomass in the region has declined since the 1970s (ICES, 2001d). As herring is taken in the sprat fisheries there is monitoring to ensure that the by-catch of herring is controlled. Harvey *et al.*, (2003) determined that fishing was the chief source of mortality on herring using ECOPATH/ECOSIM modelling. However, a reduction in the biomass is not solely attributed to fishing mortality, but also extrinsic drivers affecting population dynamics (Harvey *et al.*, 2003; Rahikainen, 2003).

A stock collapse may result in a species replacement, when one species proliferates as another, which occupies a similar ecological niche, declines. Observed increases in the biomass of jellyfish in the Bering Sea have been ascribed to a release from food competition with some species of feed fish (Brodeur *et al.*, 2002). This type of effect may be due to fishing in some systems (Daskalov, 2002). The inverse relationship between the biomass of feed fishes and jellyfishes in the Bering Sea can be linked with extrinsic drivers (Hunt *et al.*, 2002). However, identifying fisheries as the only driving force in species replacement is difficult and it is more likely that fishing acts synergistically with environmental factors (Hall, 1999; Jennings *et al.*, 2001). Potentially, sprats may represent a species replacement as an increase in their abundance was observed which coincided with the collapse of the herring stocks in the North Sea (Hall, 1999). Corten (1986; 1990) rejects this theory as geographical patterns in the decline and recovery of both stocks have occurred on smaller scales where there was no evidence of one species temporarily occupying the niche of the other. Other reviews report that the evidence supporting species replacement is not conclusive (Daan, 1980).

## **5.6. The effect of fishing for industrial fishing on sharks**

The targeted shark fisheries, which use long-lines, large meshed tangle nets, and line fisheries, have been developed since 1990 (STECF, 2003). The Spanish commercial fleet has been fishing in the North Atlantic and these fisheries take place in the ICES sub-area VI, VII, and XII and in Division VIIIa, b c, d and IXa. Many shark species, including Portuguese dogfish (*Centroscymnus coelolepis*) and the Leafscale gulper shark (*Centrophorus squamosus* are landed) for their liver oil (Piñeiro *et al.*, 2001). The DELASS project (Heessen, 2003) attempted to investigate various exploited populations of elasmobranchs, including the Portuguese dogfish population on the Portuguese continental slope by using a matrix population model. The model was hindered by the lack of knowledge of Portuguese

dogfish species dynamics which affected the model's outputs. The DECLASS assessment also attempted to model the leafscale gulper shark using data from the French reference fleet trawlers for ICES Subareas V, VI and VII. This model was also not considered robust due to lack of data.

Due to a lack of information within European waters, studies of exploited shark species outside of Europe can provide useful information. Smith *et al.* (1998) assessed the ability of sharks to recover from exploitation. Twenty six pacific shark species were ranked according to their intrinsic rate of population increase, which was referred to as rebound potential. Research indicated that productivity was strongly affected by age at maturity, and was little affected by maximum age. Sharks with the highest rebound potential tended to be smaller, early maturing, relatively short-lived inshore species. Those with the lowest recovery potential, and therefore the most vulnerable to exploitation, tended to be larger, slow growing, late-maturing, and long-lived species. Similarly, Sadovy (2001) considered that the species with life histories which included a late age of maturity and few young, were more likely to suffer from severe stock declines or extirpation. The gulper shark (*Centrophorus granulosus*) is caught in ICES sub-area IXa (ICES, 2002b). There has been a marked decline in landings of gulper shark, from over 995 t in 1989 to around 54 t in 2000 (ICES 2002c). It is not clear whether this is due primarily to fisheries and market forces affecting the price of liver oil, but this species is characterised by very low fecundity, with only one embryo in a pregnancy lasting about two years (Guallart and Vicent, 2001). Guallart (2002 in STECF, 2002) reports that in the Mediterranean, catch rates decline after several weeks of fishing and recovery times are from months to two years.

Determining the effects of fishing on sharks with a late age of maturity both at the population and community level is difficult due to inadequacies in data which make it difficult to estimate the stock status and population dynamics (Smith *et al.*, 1998; Heessen, 2003; ICES 2003d). The majority of deepwater fisheries have been exempt from management. Given the uncertainties in the stocks and the effects of fishing, management action is required and scientific research into European shark fisheries should be increased.

### 5.7. Genetic effects of fishing on teleost feed fish populations

Over-fished populations may exhibit the Allee effect. This is an inverse density dependence at low densities i.e. the per capita birth rate declines at low densities. The primary factors involved in generating inverse density dependence include genetic inbreeding and loss of heterozygosity and demographic stochasticity (including sex ratio fluctuations) (Courchamp *et al.*, 1999).

The genetic viability of a stock is harmed if a stock collapses and recovers, due to the reduced number of genes in the population. However, Stephenson and Kornfeld (1990) (reported in Beverton, 1990) concluded that the Georges Bank herring, which reappeared after a collapse in 1977 to 1/1000<sup>th</sup> of the 1967 peak of over 1 million tonnes ( $5 \times 10^9$  fish) have an unchanged genetic constitution. This result may be an artefact of the limited DNA technology of the time.

Teleost feed fish species are characterised by a tendency to shoal. Fishing pressure causes shoaling fish to reduce their range and maintain the same average school size (Winters and Wheeler, 1985; Ulltang, 1980). Consequently, there can be a high number of individuals in a shoal which may lead to a high level of genetic diversity within the shoal (Ryman *et al.*, 1995). The next question is what size can a genetically distinct shoal/or population be

reduced to and still recover. Beverton (1990) calculated that the smallest population that a collapsed population dropped to and subsequently recovered is in the order of a million fish but local density has to play a role.

### **5.8. The effect of fishing for fish for industrial purposes on stocks destined for human consumption ('commercial species')**

The complexity of marine systems makes it difficult to identify the effects of predator/prey removal on other communities. Marine communities often exhibit size-structured food webs, and changes in the abundance and size composition of populations, are likely to lead to changes in the quantity and type of prey consumed (e.g. Frid *et al.*, 1999). However, these changes may not be predicted by simplistic models of predator-prey interactions as they do not account of prey switching, ontogenetic shifts in diet, cannibalism or the diversity of species in marine ecosystems (Jennings and Kaiser, 1998; Jennings *et al.*, 2001).

Ecological dependence takes account of the ecological linkages in the marine systems. Ecological dependence is already considered in management advice for sandeel in the Shetland area, and sandeel in Sub-area IV, e.g. the kittiwake/sandeel interaction. ICES (2002c) identified several feed fish stocks for which ecological dependence may need to be considered further in management advice: Sandeel in Division IIIa; Norway pout in Sub-area IV and Division IIIa; Sandeel in Sub-area IV; Norway pout in Division VIa and Sandeel in Division VIa. However, assessing ecological dependence is problematic as evidence for the effects of strong ecological interactions on some stocks, e.g. the proposed kittiwake/sandeel interaction, should not be taken as evidence that they are necessarily a concern to managers of all stocks. ICES (2003c) suggested that the current approaches for assessing ecological dependence could not be widely applied and that fundamental research is needed to develop an appropriate method for assessing and ranking the strength of ecological dependence of species.

### **5.9. The direct effects of the removal of industrial teleost feed fish**





#### **5.9.1. Commercial species as predators of industrial species**

Feed fish tend to feed at or near the bottom of the food chain so fisheries interactions with the marine food web are more likely to affect their predators. Gislason (1994) reported that the sandeel and Norway pout fisheries of the North Sea took in the region of 20% of the annual production of these fish species. The consumption of sandeels in the North Sea by fish that are targeted for human consumption, seabirds, 'other fish species' and marine mammals has been estimated as; 1.9, 0.2 and 0.3 million tonnes, respectively (ICES, 1997). Bax (1991) reviewed the fish biomass flow to fish, fisheries and marine mammals, using a variety of data sets in the Benguela system, on Georges Bank, in Balsfjorden, the East Bearing Sea, the North Sea and the Barents Sea, and calculated that consumption of fish by predatory fish was 5-56t km<sup>-2</sup> compared to fisheries (of all types) which consumed 1.4-6.1t km<sup>-2</sup>, marine mammals which consumed 0-5.4 t km<sup>-2</sup> and seabirds which consumed 0-2t km<sup>-2</sup>. Fish predation on teleost feed fish is therefore considered to be higher than industrial fisheries removals, and this is especially true in the sandeel fisheries.

The ICES stomach sampling project in 1981 showed that sandeel, Norway pout and sprat provided more than 50% of the food of saithe and whiting, and between 1-30% of the food of cod, mackerel and haddock (Gislason, 1994). Greenstreet (1996) investigated the diet composition of the main predators in the North Sea. The consumption of industrial species is

shown in Table 5.1., which shows industrial fish species are a valuable food resource to predatory fish.

**Table 5.1. Diet composition (%) of the main predators in the North Sea. For each species, the food items that were found in the stomachs are highlighted**

	 >0–1%	 >1%–10%	 >10%–50%	 >50		
Predator \ Prey	Cod	Haddock	Whiting	Saithe	Mackerel	Horse mackerel
Norway Pout	7.7	6.3	8.9	32.2	7.3	
Herring	4.1	0.1	6.6	0.6	3.7	8.8
Sprat	2.1	0.3	9.4	0.4	3.2	0.4
Sandeels	7.3	7.2	27.3	9.7	16.6	0.0

Source: recalculated from Greenstreet, 1996

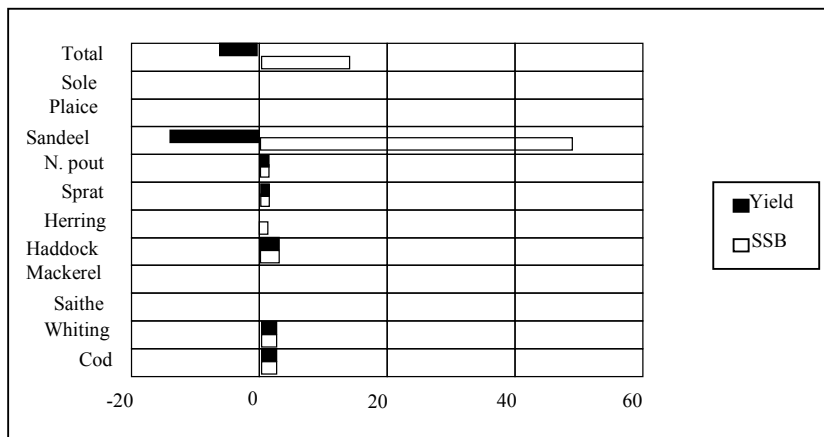
However, whilst bioenergetic estimates of sandeel consumption in the North Sea show that fish are important predators, predation on sandeels is declining (Furness 2002) as stocks of large gadoid predators are weak and their spawning stock biomass is declining (Sparholt *et al* 2002). Sparholt *et al.* (2000) tested the hypothesis that a reduction in consumption of industrial fish by gadoids, such as cod, whiting and saithe, should lead to a measurable reduction in the predation mortality of their prey (Norway pout) and found the total mortality of Norway pout for ages 1 and 2 had declined between the 1980s and 2000.

If pelagic species have become more dominant in marine systems, resulting from a decline in demersal fish predators due to fishing, then there is an argument for management to allow larger harvests of industrial species due to the reduced natural predation pressure on these stocks (Furness, 2002). However, Naylor *et al* (2000) argued that in the North Sea, exploitation of sandeel and Norway pout is implicated in the decline of cod. It has been suggested that a reduction in fishing effort on industrial fish stocks will benefit higher trophic predators (including gadoids) (Cury *et al.*, 2000; Dunn, 1998; Furness, 2002). The more recent assessments of the Norway pout stocks in ICES Subarea IV and Division IIIa (ICES, 2003e) indicates that fishing mortality is lower than natural mortality, and multispecies analyses have indicated that when F (fishing mortality) is below M (natural mortality), the fisheries are not causing problems for their predators on the scale of the stock. It further noted that locally concentrated harvesting may cause local and temporary depletions of predators and, therefore, harvesting should spread widely across large geographical areas.

The ICES Multispecies Forecast Programme (MSFOR) (reported in Gislason and Kirkegaard, 1998) predicted that if there was a 40% reduction in the industrial fishing effort in the North Sea, the harvested yield of sandeel would decrease by 19% (compared to the current situation), while the spawning stock biomass will increase by more than 50% (Figure 5.1). The model predicted that reducing the fishing mortality of industrial species, and hence increasing the sandeel stock, would only have a small effect on predatory species. Such modelling must always be interpreted with caution as models can only make predictions based on what has been programmed into them. For example, the overfishing of predatory

fish may have perturbed the marine system to such an extent that the recovery of these stocks is unlikely even if there is a reduction of the fishing effort on sandeels (Beddington, 1984). The lack of an appropriate modelling frameworks for establishing the ecosystem effects of fisheries is well recognised (Robinson & Frid 2003). But it appears that fishing mortality on sandeel and Norway pout feed fisheries is sufficiently low enough to ensure that prey items are available to predatory fish.

**Figure 5.1. MSFOR predictions of the percentage change in yield and SSB of 11 North Sea species upon a 40% reduction in sandeel fishing**



Source: Gislason and Kirkegaard, 1998

### 5.9.2. Industrial teleost feed fish as predators of commercial species

The survival of the early planktonic phases of the fish life cycle is essential for stock recruitment (Blaxter, 1974; Chambers and Trippel, 1997; Horwood *et al.*, 2000). Even small variations in the mortality rate between egg fertilization and recruitment can have a profound effect on the subsequent adult abundance (Jennings *et al.*, 2001). Many industrial fish species prey on the eggs and larvae of commercial fish. Sandeel, Norway pout and capelin consume fish eggs and larvae ([www.fishbase.org](http://www.fishbase.org)), and sprat and herring prey on cod eggs (Stokes, 1992; Köster and Möllmann, 2000). Juveniles of saithe, cod and whiting may also experience competitive interactions with Norway pout (Albert, 1994). As the abundance of the larger predatory gadoids has been reduced to low levels, the industrial feed fish which prey on their juveniles and eggs may now be exerting a higher level of mortality than previously, and may potentially affect gadoid stock recruitment and slow recovery.

### 5.10. The direct effects of the removal of sharks for industrial purposes

Most sharks are predators and are at, or near, the apex of the marine food web. The effect of removing large numbers of predatory sharks are largely unknown. The effect of their removal will depend on the structure, complexity and connectivity of the marine food web (Bax, 1998; Link 2002).

Models have been used to investigate the effect of shark removal on other fish species. Stevens *et al.* (2000) ran ECOPATH/ECOSIM models that included sharks in three systems (none of which resemble European waters but may provide useful information): (1) the NE Venezuelan shelf ecosystem that includes small sharks (mainly *Mustelus canis*); (2) the unexploited Hawaiian coral reef of the French Frigate Shoals that includes tiger sharks

(*Galeocерdo cuvier*) and reef sharks *Carcharhinus* spp. as separate components; and (3) the Alaska Gyre oceanic ecosystem that includes a group representing mainly salmon sharks (*Lamna ditropis*) and blue sharks. Initial runs were performed under three different options of the “flow control” parameter of ECOSIM: “bottom-up”(environment and prey), “top-down” (predator), and “mixed” control (the appropriate parameter set at an intermediate value between the two extremes). The models were run for 100 years. If the system was controlled by top-down effects, the removal of elasmobranchs led to widely fluctuating and unstable ecosystem responses compared to the ‘bottom-up’ control. The mixed control scenario resulted in a much more stable behaviour of biomass dynamics compared to the “top-down” and “bottom-up” scenarios. However, the mixed control ecosystem responses to the removal of sharks were still complex and unpredictable, as prey species underwent large changes in biomass, some increasing and others decreasing. In two of the models, one of the fish groups modelled (and not a prey of the sharks) decreased in abundance, probably as a result of indirect trophic interactions. Identifying the causes of the observed changes is difficult, but Stevens *et al.* (2000) concluded that the results of shark depletion may be ecologically and economically significant, and may persist over long time periods.

### 5.11. By-catch

The capture of juveniles of commercial species is one of the most controversial aspects of industrial fishing, as most undersized fish are landed and processed. Sandeel catches are considered to be relatively ‘clean’ of other species (Greenstreet, *FRS.*, 2003 pers. comm., January). Juvenile herring are known to shoal with sprat (Hopkins, 1986). Juveniles of commercial species, such as whiting and haddock are known to shoal with industrial teleost feed fish, such as Norway pout (Huse *et al.*, 2003; Eliassen, 2003).

This issue has been addressed by closures of part of the North Sea to Norway pout fishing (EC Regulation 3094/86) to reduce the by-catch of juvenile commercial species. Similarly, seasonal closures exist for the conservation of fishery resources through technical measures for the protection of juveniles of herring and sprat (EC Regulation 850/98). By-catch regulations and minimum mesh size are also in place, aimed at reducing juvenile by-catch.

The composition and volume of catches from the Norwegian industrial fisheries, which targets both blue whiting and Norway pout, was reported by ICES (2003a) using the data from Heino *et al.* (2003). Between 2000-2002, the average annual landings from the mixed fishery in the ICES statistical areas IVab and IIIa (North Sea and Norwegian Sea) were 109,000 tonnes. Catches were dominated by the target species blue whiting and Norway pout. Blue whiting formed an estimated 58% of this catch whilst Norway pout formed approximately 27%. 0-group blue whiting started to appear in the catches during the third and fourth quarters of the year in 2000-2002 (Heino *et al.*, 2003). The estimated numbers of 0-group blue whiting in the catches of industrial fishery were  $4.5 \times 10^7$ ,  $4.0 \times 10^6$  and  $1.2 \times 10^8$  individuals in 2000-2002, respectively. These numbers are not considered significant in comparison to the total recruitment in the stock (ICES 2002d). But Heino *et al.* (2003) note that some of the blue whiting in the area fished, may represent local populations, which then could be affected more strongly by the fishery. There is a need to assess the population distribution and recruitment patterns of blue whiting in EU Waters. The remaining 15% of the catch, or about 16,000 tonnes, consisted of a range of fish and invertebrates. The six most important by-catch species (in terms of landed catch) were saithe, herring, haddock, horse mackerel, whiting and mackerel, each of which represented an annual catch of at least 1000 t in this fishery. Greater numbers of saithe were caught in the third and fourth quarters, and

horse mackerel in the fourth quarter. Of the by-caught species, most individuals captured were in the length range of 25–40 cm, with herring and mackerel often slightly smaller, and saithe slightly larger. This length distribution suggests that the by-catch of these species consisted primarily of immature individuals. Heino *et al.* (2003) noted that this may be a significant source of mortality on the non-target species and recommended that additional research be carried out, increasing sample size and over a longer period of time.

In a recent study, the majority of haddock and whiting in the by-catch of the industrial fisheries of Denmark and Norway were of age 3 or less (ICES, 2003c). The mortality of haddock caught as by-catch by the industrial fisheries was small for age group 0 and 1 (less than 1% by number and weight), while the mortality percentages of older fish aged 2 and 3, were more varied. The percentages of whiting caught were generally higher. However, the mortality due to industrial fishing was considered small in comparison with the total estimated survivors for the year classes and that the natural mortality of haddock and whiting is very high.

The spatial and temporal distribution of cod by-catch in the herring and sprat fisheries of the Baltic was thought to relate to the co-occurrence of the three species on cod and sprat pre-spawning and spawning grounds. Between the years 1998–2000, the highest by-catches of cod in the herring and sprat fisheries were observed in the first and second quarters (International Baltic Sea Sampling Programme (IBSSP)). The highest by-catch and discards occurred in Baltic Assessment units SD 24–26. The estimated total by-catch of cod in combined sprat and herring fisheries in the years 1998–2000 amounted to 1340 t, 1524 t and 2091 t correspondingly. ICES (2001c) determined that the total share of by-catch in total landings of cod was within the range of 1.3% to 2.0%. The by-catch in pelagic fisheries therefore appeared to have a minor effect on the cod population. ICES (2001c) expressed concern that there was insufficient data to evaluate how accurately the data were collected and recorded.

By-catch is a problem in all fisheries. Estimates of discards (as an index of by-catch) in fisheries range from 25% of the total catch (National Marine Fisheries Service 6th Workshop, 2000) to 70% (Stratoudakis *et al.*, 2001). On a global scale, Alverson *et al.* (1994) estimated that 27 million tonnes of material are discarded in comparison to the annual landed catch of around 100 million tonnes in commercial fisheries per year, i.e., 27%. Data available for the North Sea fisheries would suggest that the proportion of fish and benthos by-caught and discarded in the main demersal fisheries can be up to four times the landed catch (Gislason, 1994).

There is evidence of declining by-catch in the sandeel fisheries and the blue whiting fishery as seen in the Danish feed fish catches (Tables 5.2 and 5.3). By-catch is an issue in the sprat fisheries (Tables 5.2), where the increase in herring by-catch is largely a result of relative increases in abundance (ICES, 2003e). The percentage of by-catches in the Norway pout fishery landings (particularly whiting) have increased (Table 5.2) but there is a reduction in effort in this fishery.



**Table 5.2. Average landings ('000 tonnes) and percentage by-catch from North Sea by different Danish Industrial fisheries, 1998-2001 and 2002**

'000 t	Sandeel		Sprat		Norway pout		Blue whiting	
	1998-01	2002	1998-01	2002	1998-01	2002	1998-01	2002
Sandeel	<b>564.3</b>	<b>622.1</b>	6.1	4.1	0.0	0.0	0.1	0.0
Sprat	6.6	1.0	<b>152.8</b>	<b>140.6</b>	0.2	0.0	0.0	0.0
Norway pout	1.6	0.0	0.4	0.2	<b>53.8</b>	<b>43.2</b>	3.5	3.7
Blue whiting	1.4	0.7	0.0	0.0	2.6	4.7	<b>31.1</b>	<b>21.1</b>
Herring	2.6	1.6	11.2	16.6	1.8	3.2	0.8	0.2
Cod	0.2	0.1	0.0	0.0	0.1	0.0	0.0	0.0
Haddock	0.7	1.2	0.1	0.0	0.9	1.5	0.2	0.1
Whiting	1.8	1.5	1.4	2.5	1.3	1.7	0.1	0.1
Mackerel	0.4	0.4	0.4	0.7	0.1	0.0	0.1	0.0
Saithe	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.1
Other species	2.2	1.4	1.8	2.7	0.9	0.4	3.3	1.6
Total	581.9	628.2	174.3	167.5	61.5	55.0	39.3	27.1
Percentage	5.8%*	3.7%*	13.1%	19.9%	4.1%	6.7%	1.3%	0.6%

Source: DIFRES Note: landings composition is estimated from monitoring samples<sup>23</sup>. \* includes herring, cod, haddock, whiting, saithe and mackerel but excludes others

In 2002, the Danish sandeel landings accounted for 622,100 t of which 3.7% were considered by-catch, which is a total of 23,018 t of by-catch herring, cod, haddock, whiting, saithe and mackerel. In the same period period, the sprat fishery took 27,972t of by-catch. In comparison, landings for the roundfish in the North Sea, in 1990, were estimated at 1,032,800t and discarding was estimated at 262,200 t (ICES, 1996), by-catch constituted approximately 25% of the catch.

<sup>23</sup> The species composition of the landing is derived in the following way: The total landings for reduction purposes by month and area is calculated using a sales-slip database. The landings are then allocated to a statistical rectangle using the relative geographical distribution from the logbook database of landings identified as having been taken in the fisheries where the landings are destined for reduction purposes. The output is the total is the total industrial landings by statistical rectangle and month. The relative species composition by statistical rectangle and month is estimated using the information in the species composition and biological database. An average composition by rectangle is estimated as the mean of all samples from the rectangle. After calculation of average composition by rectangle a new average composition is calculated taking into account the species composition in all neighbouring rectangles. This done by taking the mean species composition of the rectangles and all 8 surrounding rectangles. The total landings by species, statistical rectangle and month are calculated using the estimated species composition and total landings by month.

**Table 5.3. Average mixed species landings from the Division IIIa (Skagerrak and Kattegat), 1998-2001 and 2002**

‘000 t	All mixed fisheries	
	1998-2001	2002
Sandeel	15.2	27.7
Sprat	15.7	13.4
Norway pout	9.7	3.3
Blue whiting	4.4	6.5
Herring	8.2	14.6
Cod	0.1	0.1
Haddock	.4	.1
Whiting	1.2	1.4
Mackerel	0.1	0.1
Saithe	0.0	0.0
Other species	4.4	5.5
Total	59.6	72.6
Percentage by-catch of non target fisheries	10.0	16.2

Source: DIFRES, The composition of landings is estimated from monitoring samples

## 5.12. The effects on seabirds

The majority of research into the effects of the interaction between seabirds and industrial fishing has concentrated on the interaction with sandeel fishing.

### 5.12.1. By-catch mortality

The fish capture methods are designed to work on the behaviour of the fish. Many fish species shoal and small mesh trawls and gillnets are used to capture the shoaling fish. The industrial feed fish fisheries use trawls which are less likely to capture birds than gill nets (BirdLife International, 1999). A study in the Baltic, assessing the by-catch of common guillemot (*Uria alga*) indicated that a small degree of mortality (un-quantified) could be attributed to trawls, but the researchers did not identify the trawls as specifically targeting an industrial fish species (Österblom *et al.*, 2002).

#### *Sandeel industrial fisheries*

Seabirds consume a small proportion of the North Sea sandeel stocks in comparison with fish predators (ICES, 1997; Bax, 1991; Gislason, 1994). Sandeels are an important prey item for guillemots (Tasker and Furness, 1996). The common guillemot has been recorded as by-catch in sandeel nets in the North Sea in the vicinity of a colony feeding area (Tasker *et al.*, 2000; personal observation). However, scientific assessments of catch in the Danish fishery (Dalskov, DIFRES, 2003, pers. comm., October), dispute this observation.

#### *Norway pout industrial fisheries*

Seabirds are not thought to consume significant amounts of Norway pout (Tasker and Furness, 1996; Tasker *et al.*, 2000) and by-catch mortality is likely to be low.

***Blue whiting industrial fisheries***

No records exist of bird by-catch in mixed Norway pout/blue whiting or North Atlantic fisheries.

***Sprat industrial fisheries***

No records of bird by-catch exist for sprat fisheries in the EU.

***Herring industrial fisheries***

No specific records exist for bird by-catch in the Baltic industrial fisheries. However, by-catch of gannets (*Morus bassanus*) have been reported in herring human consumption fisheries using pelagic trawls in the North Sea: the estimated catch rate was approximately 33 gannets per 100h fishing in herring fisheries (Pierce *et al.*, 2002).

**5.12.2. Ghost fishing**

Ghost fishing occurs when lost fishing gears continues to capture organisms and is under no human control. All gear is subject to damage and loss and such nets, both intact and small fragmented pieces, capture fish for as long as the net structure is capable of entangling organisms (Jennings *et al.*, 2001). The majority of research has been carried out on lost gill nets (e.g. Erzini *et al.*, 1997; Humborstad *et al.*, 2000; Kaiser *et al.*, 1996) and pots (e.g. Bullimore *et al.*, 2001). Trawls, both otter and mid-water, are also subject to damage and loss of nets (Laist, 1996; Simpson, *University of Newcastle*, 2003, pers. comm., October). No research to quantify the effect of entanglement on birds as a result of lost gear from industrial fisheries has been conducted. This type of mortality is extremely low compared to other sources of mortality (Tasker *et al.*, 2000).

**5.12.3. Indirect effects**

The scale of the industrial fisheries had led to concerns about the impact of the fisheries on seabird populations as they compete for the same resources.

**• Competition for sandeels**

There is evidence that birds consume sandeels preferentially and this choice relates to their reproductive success (Phillips *et al.*, 1996; Rindorf *et al.*, 2000). Harris and Hislop (1978) showed that adult puffins display size selectivity when taking sprats and sandeels over whiting for their young, presumably due to the different calorific values and proportions of protein with respect to bodyweight in the different fishes. Sprats are 14.1 - 15% protein and sandeels are 17.8% protein whilst whiting have a lower proportion (Hislop *et al.*, 1991).

It is difficult to determine the effect of the sandeel fishery and sandeel biology on seabird population dynamics. The ELIFONTS (Effects of Large-Scale Industrial Fisheries on Non Target Species) research project investigated the diets and breeding success of common guillemots, European shags (*Phalacrocorax aristotelis*) and black-legged kittiwakes (*Rissa tridactyla*) in addition to the biology/population dynamics of sandeels during 1997-1998 in the Firth of Forth and Moray Firth, Scotland. The study showed that relatively small changes in the timing of peak sandeel availability in June were a major determinant of seabird breeding success on the Isle of May. The kittiwakes are especially vulnerable to changes in sandeel availability as they did not switch to prey on other species (Lewis *et al.*, 2001; Rindorf *et al.*, 2000). The timing of two events in the sandeel lifecycle appear to be critical for the success of bird populations. These are: 1) the onset of burrowing behaviour and 2) the arrival of 0-group fish on the seabirds' feeding ground. Whilst commercial fisheries do

not affect the timing of these events, fishing may interfere with the supply of 1+ fish, as if sandeel recruitment is dependent on the local stock, fishing mortality on adult fish may affect the abundance of the 0+ group fish in the following, and succeeding, years. Thus during the energetically most demanding period of the life cycle of birds, breeding and looking after the young, food availability in the immediate locality may be reduced which may affect their survival and subsequent breeding success.

The ELIFONTS study formed part of the advice which led to the EU's decision to prohibit industrial fisheries for sandeels along the East Coast of Britain. Given the many factors influencing seabird reproductive success, including climatic drivers affecting sandeel population dynamics, and fishing activities, further research has been instructed: IMPRESS (Interaction between the marine environment, predators and prey - EU fifth framework research programme). IMPRESS examines the bottom-up approach to determine the effect of climate and hydrography on temporal and spatial patterns in sandeel abundances and performance of seabirds and other predators with respect to sustainable fisheries.

Considering the importance of sandeels to seabirds during the breeding season (Monaghan, 1992) it is important to consider the spatial and temporal overlaps during the breeding season. Seabirds tend to feed close to their colonies (Furness and Tasker, 1997) as foraging further distances for resources imparts an energetic cost on seabirds (Krebs and Davies, 1993) to the possible detriment of chick and adult survival. In the EU, the main sandeel industrial fisheries are conducted off shore in the northern North Sea and the central North Sea, apart from the relatively small sandeel fishery near Shetland. The areas fished offshore are outside those generally used by breeding seabirds (ICES, 2003c).

#### • Competition for Sprat

Sprats are a popular prey item for many seabirds (Tasker and Furness, 1996). In the early 1980s, a major south and eastward shift in the wintering distribution of common guillemots (*Uria aalge*), kittiwakes (*Rissa tridactyla*) and razorbills (*Alca torda*) occurred in the North Sea. This was consistent with a decline in sprat (*Sprattus sprattus*) availability in the northern North Sea (Corten, 1990), as sprats are a major prey species of these birds in winter.

#### 5.12.4. Summary

The effects of food shortages on bird populations are difficult to detect as seabird surveys to estimate abundance, concentrate on breeding populations. Non-breeders may fill in breeding vacancies as they arise and due to the delayed maturity of seabirds the number of breeding adults can be significantly lower the total number of seabirds. This means that responses at the population level can lag behind the changes in environmental conditions and the availability of food (Klomp and Furness, 1992; Perrins and Birkhead, 1983; Gill, 1995), necessitating prolonged research programmes to determine the effects of industrial fishing on seabirds.

However, these types of data are usually the only available. Analyses of breeding population of seabirds in the North Sea shows a variety of trends (Table 5.4) which are attributable to many factors driven mainly by food availability. Guillemots (Family Alcidae) have shown an increase in abundance in contrast to the terns (Family Laridae) (Table 5.4.) over the last decade (ICES, 2001a). Guillemots are large, deep diving seabirds that are able to prolong their period of foraging whereas the foraging behaviour of terns is more energetically expensive as they feed at the surface of the water column (Cramp *et al.*, 1974). Guillemots

are more successful than terns as they are capable of hunting over larger areas for greater periods of time. Kittiwake (family Laridae) abundance and breeding success responds rapidly to increases in sandeels on local scales (Lewis *et al.*, 2001; Furness and Tasker, 2000). Despite an estimated breeding population of 400,000 pairs, which is greater than for any other seabird in the North Sea, the kittiwake population has declined over the last fifteen years. However, their ability to utilise discards at the surface of the water column means that they are more successful than other members of the family Laridae, especially the terns. Observed trends in the population figures for seabirds in the North Sea (Table 5.4.) shows that the seabirds that scavenge, e.g. gulls, fulmars and gannets, and are more likely to supplement their diet with discards and offal, and show increased abundance.

The majority of seabird populations in the North Sea region are currently at record high levels. However, this North Sea picture (c.f. Table 5.4.) can hide biologically important detail and individual sub-populations or colonies may be exhibiting trends contrary to those expressed at the regional scale. It is for this reason that the proposed Ecological Quality Objectives (Bergan Declaration) relating to seabirds tend to operate at the colony level and the recent renewal of the sandeel closure in 2002 reflects continued poor breeding in the kittiwake colonies on the east coast of the UK.

**Table 5.4. Population figures for seabirds on North Sea coasts. Wintering counts are individuals; breeding data are nesting pairs unless stated. Trends over the last ten years of breeding populations (where known or suspected) are indicated (Cramp *et al.*, 1974; ICES 2001a)**

Species	Feeding strategy	Wintering	Breeding	trend
Northern fulmar	Scavenger, opportunistic	3 744 000	307 599	↑
European storm petrel	Pelagic fish, zooplankton	0	1 000	?
Northern gannet	Scavenger, fish (target stocks)	1 578 000	60 326	↑
Great cormorant	Fish (target stocks)	14 315	2 222	↑ ~
European shag	Pelagic fish	29 115	19 804	~
Great skua	Scavenger, discards	1 000	7 303	↑
Black-headed gull	Generalist incl. rubbish	?	129 342	~
Lesser black-backed gull	Fish, discards	15 315	49 311	↑ ~
Herring gull	Opportunistic	971 700	237 114	~
Great black-backed gull	Discards	299 900	24 436	↑
Black-legged kittiwake	Pelagic fish, zooplankton, some discards	10 326 990	415 427	↓
Sandwich tern	Pelagic fish	0	30 547	=
Common tern	Pelagic fish, invertebrates	0	61 487	↓ ~
Arctic tern	Pelagic fish, invertebrates	0	74 729	=
Little tern	Crustacea, annelids	0	2 335	↑
Common guillemot	Pelagic fish, invertebrates	1 562 400	680 434 ind	↑
Razorbill	Pelagic fish, invertebrates	324 000	73 115 ind	↑
Black guillemot	Pelagic fish, invertebrates	6 595	23 741 ind	=
Atlantic puffin	Pelagic fish	2 6000	225 957 ind	↑

KEY: ↑ increasing numbers (general trend)

↓ decreasing numbers (general trend)

~ some local variation in numbers

= stable

? unknown

### 5.13. Effects on marine mammals

All cetacean species in Europe, including the harbour porpoise and the bottlenose dolphin, are listed and protected under Annex IV of the EC Habitats Directive (1992). The grey and harbour seal are listed in Annex II of the Habitats Directive which requires that EU member states consider the establishment of Special Areas of Conservation (SACs) to protect them. Other legislation including the Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS), The Bonn Convention (1979; implemented 1983) and the Bern Convention (1979; implemented 1982) also exist to protect cetaceans. Member States are required therefore, to consider the impact of all human activities on these species.

#### 5.13.1. By-catch mortality

The Ecological Quality Objective for small cetacean by-catch adopted under the Bergen Declaration requires that anthropogenic mortality to be below 1.7% per annum. No by-catch of marine mammals has been reported in the industrial fisheries (Dalskov, *DIFRES*, pers. comm, October 2003), but anecdotal evidence (reported in Huse *et al.*, 2003) exists and reports that in the sandeel fishery in the North Sea, that there are occasional by-catches of cetaceans. The opportunistic feeding behaviour of cetaceans and pinnipeds in and around trawls means they are vulnerable to becoming trapped (Fertl and Leatherwood, 1997). There is a need for further investigation of the level and spatial and temporal extent of marine mammal bycatch. Should this prove significant in areas or in certain seasons, pingers could prove an effective management measure (Larsen, 1999; Larsen *et al.*, 2002).

#### 5.13.2. Ghost fishing

No research has been conducted on the effects of ghost fishing on marine mammals explicitly relating to industrial fishing nets.

#### 5.13.3. Indirect effects

Diet composition analyses of cetaceans shows the presence of industrial feed fish species in the diet of harbour porpoise (*Phocoena phocoena*), Bottlenose dolphin (*Tursiops truncatus*), White-beaked dolphin (*Lagenorhynchus albirostris*), common dolphin (*Delphinus delphis*), Risso's dolphin (*Grampus griseus*), Atlantic white sided (*Lagenorhynchus acutus*) and Minke Whale (*Balaenoptera acutorostrata*) (Borjesson *et al.*, 2003; Couperus, 1997; Fontaine *et al.*, 1994; Kastelein *et al.*, 2002; Olson and Holst, 2001; Santos *et al.*, 1994; Santos *et al.*, 1995). In some cetaceans the proportion of feed fish reported in the diet is minimal. But in Scottish waters, sandeels constitute 58% by weight of the stomach content in harbour porpoises and 49% weight of the stomach content in the common dolphin, other feed fishes, sprat and Norway pout, were less than 1% by weight (Santos *et al.*, 1995). In Kattegat and Skagerrak, feed fish (mainly sprat and herring) constitute 13% by weight of the stomach content in juveniles and 10% by weight in adults' stomachs (Borjesson *et al.*, 2003). Sandeels contribute 86.7% to the diet by weight of Minke whale in the North Sea and further north, into the Norwegian Sea, the diet of minke whales is dominated by spring-spawning herring (Olsen and Holst, 2001). The differences in the diet composition reflect the local foraging of cetaceans. Industrial fisheries may therefore impact marine mammal populations by altering their food supply in certain areas. It is therefore important to consider the local availability of feed fish to cetaceans, and their ability to switch to other prey if the stocks are depressed, when assessing the effects of feed fish fisheries on marine mammals. This, however, has yet to be demonstrated in any cetacean population.

There is some evidence that there is a link with fisheries and grey seal population dynamics. The ELIFONTS study investigated the grey seal population on the Isle of May, in the North Sea. Grey seals (*Halichoerus grypus*) consumed mainly sandeels (*Ammodytes marinus*) but the greater sandeel (*Hyperoplus lanceolatus*) were taken also. For this study, the proportion of females of reproductive age which were not breeding, and the number of breeding failures amongst marked animals, was correlated with sandeel CPUE in the southern North Sea in the years 1990-1997. Effects were only seen when the reproductive performances of known seals was examined in relation to fishery data. It is possible that the reproductive performance of some seals may be more affected by changes in sandeel availability than other seals, reflecting either a tendency to specialise on sandeels or differences in hunting skill. Also, the body condition of female seals was positively correlated with CPUE (catch per unit effort) for the local stock area. However, the total number of pups increased steadily during the study periods so although there appears to be an interaction between sandeel abundance and seal breeding success, given the current state of the populations, it does not appear to be a major factor (Harwood, 1999).

#### **5.14. Effects on seabed habitats and benthos**

##### **5.14.1. Direct effects**

The pelagic trawls used to target many industrial feed fish and shark species, are deployed in the water column and therefore are unlikely to have any effect on benthic habitats and species. However, demersal otter trawls are also used to catch some feed fish species, such as sandeel and Norway pout. These operate closer to the sea floor, although actual contact is kept to a minimum. As they are also of lighter construction than those otter trawls used to target demersal fish they are likely to cause less damage (Greenstreet, *FRS*, 2003 pers. comm. April).

The impact of trawling is likely to depend on the substrate and the strength and frequency of natural disturbance. For instance, sandeels tend to occur in areas of sandy substrate (Wright *et al.*, 2000) which are naturally more dynamic than areas of muddy substrate. The effect of fishing gears coming into direct contact with highly dynamic sandy habitats is likely to be less than when the disturbance occurs in areas of lower energy, such as on muddy substrates and in deep water, as the level of natural disturbance is likely to be greater than that caused by fishing (Kaiser *et al.*, 1998). However, although the impact to the seabed and benthos by each individual tow may be limited due to the lighter gears, the local impact on the seabed and invertebrate communities may be quite intense as same trawl paths tend to be fished repeatedly over a period of several days by several boats operating in any particular area (Greenstreet, *FRS*, 2003 pers. comm. April). Mitigating against this, however, is the fact that these fisheries are seasonal and therefore followed by periods of recovery.

#### **5.15. Effects of fish meal in aquaculture on the ecosystem**

##### **5.15.1. Nutrients**

In 2002, 33% of fish meal produced from industrial feed fish in the EU were processed into fish feed for use in aquaculture and mariculture (IFFO, 2003). This transfer of organic matter from open water to coastal and estuarine areas may impact these more shallow areas.



On average, 10% of ingested fish feed are converted into biomass (Lindeman, 1942; Slobodkin, 1961), the rest enters adjacent systems through processes of elimination. In addition, not all pelleted food is consumed by cultivated species in cages (Cornel and Whoriskey, 1993). The impacts of this are highly site specific and range from no detectable impact in dynamic areas with strong tidal flows (Frid & Mercer, 1989) to increased algal growth and potential eutrophication with the concomitant problems of anoxia and, in some cases, growth of toxic phytoplankton species (OSPAR, 2000).

## 5.16. Sustainability

Sustainability is the “*development that meets the needs of the present without compromising the ability of future generations to meet their own needs.*” World Commission on Environment and Development, 1987.

### 5.16.1. Sustainability of target stocks (feed fish)

A short overview of the assessments of the state of exploited teleost feed fish stocks from ICES and GFCM advice are presented in Box 5.1.

#### **BOX 5.1. Summary of the feed fish stocks (ICES 2003e and STECF, 2003)**

##### **In ICES areas**

##### *Sandeel*

**Sub-area IV.** The stock is considered within safe biological limits.

**Sandeel in Division IIIa (Skagerrak – Kattegat).** Based on the available information ICES was unable to assess the state of the stock or identify safe biological limits

**Sandeel in Division VIa.** There is no current information on which to evaluate the state of the stock. The current management regime uses a multi-annual TAC of 12 000 t per year with the fishery closed from 31 July. Access is limited to vessels with a track record.

**Sandeel in the Shetland area.** Safe biological limits have not been defined for this stock. It is believed that fishing mortality is well below natural mortality. This means that natural processes largely drive stock variations.

##### *Norway Pout*

**Norway Pout in ICES subarea IV and Division IIIA.** The ACFM advice for 2001 and 2002 was that the stock was considered to be within safe biological limits and the stock could on average sustain current fishing mortality. Recruitment is highly variable and influences stock size rapidly due to the short life span of the species.

**Norway pout in Division VIa (West of Scotland).** There is no current information on which to evaluate the state of the stock. No data are available on by-catches in this fishery. Since no age compositions are available, data are insufficient for an assessment of this stock.

##### *Blue Whiting*

**Blue whiting in ICES sub-areas I-IX, XII and XIV.** The stock is assessed as one unit and is harvested outside safe biological limits. Most of the catches are taken in a directed pelagic trawl fishery in the spawning areas. (Vb, VIab, VIIbc), but catches are also taken in I, II, Va, XIVa, b. A mixed fishery with Norway pout occurs mainly in IV and IIIa.

***Sprat*****In the North Sea and in IIa**

The sprat stock is in good condition, although status cannot be evaluated relative to safe biological limits because reference points have not been set. The biomass seems to have increased in recent years, but there is a relatively low abundance of older sprat (2+) in the population.

**Sprat in Division IIIa.** The state of the stock is unknown. Sprat in this area is short-lived with large annual natural fluctuations in stock biomass.

**Sprat in the Baltic.** Based on the most recent estimate of SSB and fishing mortality ICES classifies the stock as being inside safe biological limits. SSB has decreased since 1997 to 1.2 million t in 2003, but is 30% above the long-term average. In the most recent years the fishing mortality has almost doubled compared to the early 1990s and is now close to  $F_{pa}$ . Since 1994 a number of strong year classes have entered the stock. Also the 2000 year class is predicted to be strong.

***Baltic Herring***

**Herring in Sub-div. 25-29 (excluding Gulf of Riga) and 32.** The state of the stock is uncertain and is currently thought to be harvested outside safe biological limits. The TAC in 2003 has been reduced to reflect these observations. The countries surrounding the Baltic exploit herring as part of fishery mixed with sprat in this region.

**Herring in the Gulf of Riga.** The stock is considered to be within safe biological limits.

**Herring in Sub-div. 30. Bothnian Sea.** The stock is harvested outside safe biological limits. ICES advises that fishing mortality should be reduced to or below  $F_{pa}$  (0.21) which corresponds to landing of less than 50 000 in 2003.

**Herring in Sub-div. 31, Bothnian Bay.** The state of the stock is uncertain. ICES advises that the catch should not be allowed to increase.

The main industrial feed fish species, sandeel, Norway pout and sprat are known to be short-lived species and the fisheries are based mainly on the recruiting year classes, which are sensitive to climatic drivers. Failures in stock, and fluctuations in abundance, occur in the absence of fisheries (Southward *et al.*, 1988), but fisheries are thought to increase the frequency, duration and extend of a stock collapse and depress locally important fish stocks. In EU waters most of the targeted feed fish stocks, for which data are available, are considered to be within safe biological limits. Some stocks are un-assessed because they are not fished heavily, e.g. sandeel in the Shetland fishery and Norway pout in Division VIa, so data are insufficient to determine the state of these stocks. However, since the majority of stocks assessed are considered safe, management measures centred on a TAC scheme (set under the precautionary approach) seem a robust approach. Nevertheless, given the strong link between these fish and environmental parameters, consideration should be given for the inclusion of indices of environmental status in the setting of TACs. This is analogous to the formal consideration ENSO events (a climatic phenomenon which has an oceanic component, El Niño, and an atmospheric component, Southern Oscillation, which effects anchoveta fisheries in the Pacific) in the setting of quotas of the Peruvian anchovy. These should however be supplemented by measures to restrict the ecosystem effects of these fisheries as required under the reformed CFP. These would include spatial closures i.e. the Norway Pout box, sandeel box and by-catch restrictions to protect other species. However, if the CFP moves towards a management system based on effort control (as proposed in the CFP reform roadmap) the current fleet size would appear to represent a reference level of sustainable effort. Additional measures to protect ecologically dependant species and limit incidental mortality of other species would still be required.

### 5.16.2. Sustainability of shark stocks

Elasmobranchs, including sharks, are especially vulnerable to stock depletion due to their life histories (Stevens *et al.*, 2000). The ICES Working Group on Elasmobranch Fishes (WGEF) in 2003 (ICES, 2003d) reported that the current log book returns and market sampling of skates and rays, spurdog, blue shark, shortfin mako shark, porbeagle and the sharks ((*Deania calceus* (birdbeaked dogfish), *Centroscymnus coelolepis* (Portuguese dogfish) and *Centroscyllium fabricii* (Longnosed velvet dogfish)) was insufficient to assess their stocks. Two species listed by the WGEF (ICES, 2003d) as of special concern, which are also identified as sharks whose livers are harvested for oil (Piñero *et al.*, 2001; STECF, 2002) are shown in (Table 5.5). The basking shark, which was historically targeted for its oil (FAO, 1999), is now protected by a number of policies and legislation (table 5.5). The species has been identified as been extremely vulnerable to fishing and stocks are in decline (ICES, 2003d). In 2002, there was a complete ban on landing basking sharks from within EU waters of the ICES sub-areas IV, VI and VII (annex ID of council regulation 2555/2001). Given the observations in Table 5.5 and the noted lack of information of population dynamics of other shark species, the sustainability of these fisheries under current fishing management regimes should be reviewed.

**Table 5.5. Elasmobranch species for conservation assessment**

Species	biology	trend	Policy/Legislation	IUCN Red list
Leafscale gulper shark <i>Centrophorus squamosus</i>	Extremely vulnerable to exploitation. 'Widely distributed species' may prove to be many similar to endemic or completely discrete stocks. All available CPUE and fisheries-independent data indicate steep decline.	CPUE decline in Northern Area		Not evaluated
Kitefin shark <i>Dalatias licha</i>	Highly biological vulnerability (low 'r')	Stock has shown severe decline and may be depleted		Data deficient globally. Near threatened NE Atlantic.
Basking Shark <i>Cetorhinus maximus</i>	Extremely vulnerable to fisheries (low 'r')	Significant decline in landings while value remained high	UN Fish Stock Agreement CITES, CMS, Bern, Barcelona Conventions, UK BAP species	Vulnerable, Endangered in the Northeast Atlantic.

Source: ICES, 2003d

### 5.16.3. The sustainability of fish meal and feed fish and shark oil

The supply of fishmeal and fish oil is limited and cannot be increased significantly. As aquaculture continues to expand in Europe (and world wide) demand for fish meal and fish oil is likely to exceed supply. SEAFeeds (2003) report that the fish oil supply is likely to reach critical levels before fish meal but that there is nothing inherently unsustainable about feeding fish-based feeds to fish, as long as the industrial feed fish fisheries, are managed in a sustainable way (BOX 5.2). The drive of current research in the fish meal/ fish oil industry is focussed on reducing the content of fish meal and fish oil in aquaculture feed e.g. with plant substitutes.

**BOX 5.2 Details from the SEAFeds report (2003):**

1. The global supply of fish-oil and fishmeal is relatively fixed. Aquaculture continues to expand rapidly world-wide and uses a steadily increasing proportion of this resource. Steps should therefore be taken to reduce the reliance on fishmeal and oil to supply the aquafeeds industry. The technical capabilities are already largely in place to do this. The industry, government and consumer interest groups must share the responsibility of removing the remaining constraints. Many of the constraints relate to issues of communication and legislation.

2. Where fish meal and oil are used there should be a drive to ensure that the fisheries that supply the aquafeeds industry move to more sustainable management. In the short term this should be to ensure that fishmeal and oil for aquafeeds is sourced from stocks which are within safe biological limits and subject to management regimes designed to ensure that they remain within these limits. At present many of the feed grade fisheries which supply the aquaculture industry meet these criteria. However, we currently lack the information to make broader assessments of sustainability taking account of wider socio-economic and ecosystem impacts.

3. In the long term there should be a drive toward holistic sustainability targets with the inclusion of more ecosystem based approaches to fishery management, in line with the Johannesburg commitments for all fisheries by 2015 and the new FAO guidelines on the ecosystem approach to fisheries management. The fishmeal and oil producers accept the need to play their part in collecting appropriate information and supporting this process.

4. There was no strong opposition to the overall concept of feed grade fisheries supplying the aquaculture industry, provided adequate sustainability assurances are in place. There is no strong sense that the retail market either demands or is ready to pay a premium for a shift away from fish meal and oil as the primary raw material source. In spite of this, the aquafeeds industry is both keen and technically capable of making the shift away from total reliance on fish meal and oil, when the market dictates.

**The workshop concluded as follows:****The sustainability of feeding fish to fish**

1. Some people and organisations have questioned the sustainability and efficiency of feeding large quantities of fish as food to higher value carnivorous fish.

2. The general conclusion on sustainability was that overall, there is nothing necessarily unsustainable about feeding fish-based feeds to fish, so long as the source feed grade fisheries are managed in a sustainable way.

3. Efficiency is a complex issue, with social, economic, ecological and energetic dimensions. There has been no comprehensive and objective analysis of these issues to date.

**The sustainability of feed grade fisheries**

4. By conventional criteria (related to sustained yield of the target stock) as used by organisations such as ICES, FAO, and IMARPE2, most feed grade fisheries are in a relatively healthy state (within safe biological limits, or with increasing stock bio-mass) and

subject to specific management regimes. A notable exception is the Blue Whiting (West Scotland) fishery.

5. There is a lack of agreed criteria and integrated reporting systems for the broader dimensions of sustainability relating to effects on other fisheries and wider ecosystem and socio-economic impacts. In this respect feed-grade fisheries are little different from any other human economic activity. However, “triple-bottom line” reporting is now being adopted by many companies and governments worldwide, including several major fishing companies.

#### **The fishmeal and fish-oil gap**

6. The supply of fishmeal and fish oil from conventional sources is limited and cannot be significantly increased. Given the projected increases for aquaculture in Europe, and the rapid continuing growth and increased intensity of aquaculture world-wide, demand is likely to exceed supply in the not so distant future unless dependence on fish meal and oil is significantly reduced. Fish oil supply is likely to reach critical levels before fish meal.

7. Prices will therefore rise, with implications for the market allocation of fishmeal and oil resources, the costs of high fish-meal/oil aquafeeds, and the possibility of increased pressure on the fisheries.

#### **Reductions in the fishmeal content of aquafeeds**

8. The fishmeal and fish oil content of aquafeeds can be reduced substantially. Current research suggests that at least 50% of fishmeal and 50-80% of oil in salmonid, and 30-80% of fishmeal and up to 60% of oil in marine fish diets can be replaced with vegetable substitutes.

9. Substitution of fish meal and oils will reduce the level of some undesirable substances in the final product

10. There is a range of non-technical constraints to high levels of substitution:

- a) The current modest price of fishmeal and oil, and its nutritional superiority to most alternatives provides little immediate incentive for change;
- b) Recent nutrition research and human health guidelines, as well as consumer demand, require that current high levels of Omega 3 HUFA in fish reared on high fishmeal/oil diets are not significantly diminished.
- c) EU legislation on additives and GM ingredients constrains high levels of
- d) Substitution;
- e) Reduced food conversion efficiency, increased particulate waste and organic pollution may be associated with higher vegetable protein based diets.

11. Dependence on fish meal could be further reduced if animal by-products such as meat meal, bone meal, blood meal, poultry and feather meal could be included in aquafeed formulations. This is not currently allowed under EU legislation.

#### **5.16.4. The sustainability of feeding fish meal to farmed fish**

The optimum food for cultured fish species varies in its fish meal and fish oil content. The energy/nutrient conversion ratios of aquaculture feeds depends on the species being cultured (Naylor *et al.*, 2000). Carnivorous cultured species require feed rich in wild fish protein and oil (2.5 - 5 times the biomass of wild fish as feed, as is produced). Herbivorous and lower trophic organisms which are cultured require less wild feed fish input (Table 5.6) (Naylor *et*

*al.*, 2000). Further complicating the assessment is the fact that the energy value of feed fish varies between species, and within species as a result of reproductive state and age/size class (Harris and Hislop, 1978; Iverson *et al.*, 2002).

Thus the current trend of culturing predatory species such as salmon and other marine finfish which require greater quantities of fish meal and fish oil needs to be assessed, as focussing on culturing species which require less input of feed fish derived meal and oil in their diet is likely to reduce the demand on feed fish meal and fish oil.

**Table 5.6. Global wild fish inputs used in the feed of the ten most commonly farmed fish and shellfish in 1997**

Farmed Fish	Total production (kilotonnes)	% produced with compound feeds (by weight)	Production with compound feeds (kilotonnes)	% fishmeal in feed	% fish oil in feed	Average feed conversion ratio	Wild fish used for fishmeal (kilotonnes)	Ratio of wild fish: fed farmed fish
Marine fin fish	754	50	377	50	15	2.2	1,944	5.16
Eel	233	50	117	50	10	2	546	4.69
Marine shrimp	942	77	725	30	2	2	2,040	2.81
Salmon	737	100	737	45	25	1.5	2,332	3.16
Trout	473	100	473	35	20	1.5	1,164	2.46
Tilapia	946	35	331	15	1	2	466	1.41
Milkfish	392	20	78	10	3	2	74	0.94
Catfish	428	82	351	10	3	1.8	296	0.84
Carp								
Fed	6,985	35	2,445	8	1	2	1,834	0.75
Filter-feeding	5,189	0	0	-	-	-	-	-
Molluscs	7,321	0	0	-	-	-	-	-
Total	24,400		5,634				10,695	1.90

(It was assumed that compound feed was used for producing farmed fish, and that wild fish converted at a ratio of 5:1 to fishmeal, with one-sixteenth of fishmeal produced from by-products of processing. Marine finfish include flounder, halibut, sole, cod, hake, haddock, redfish, sea bass, congers, tuna, bonito and billfish. Fed carp refers to carp species that are sometimes fed compound feeds. Filter-feeding carp are silver carp, bighead carp and catla.)

Source: Naylor *et al.*, 2000

## 5.17. Management and control issues associated with industrial fishing

### 5.17.1. EU Control measures for industrial teleosts

Controls on feed fish catch are applied in the form of Total Allowable Catches (TACs). These change annually subject to advice from the Scientific, Technical and Economic Committee for Fisheries (STECF) and the annual year end EC Council Decision on TACs and quotas. Each participating Member State, with a history of fishing for specific species is allocated a national quota. TACs and national quotas apply to all feed fish species.

The TAC for Norway pout and sprat have been the key access control measure since 1983 (EC Regulation 170/1983). TACs for sandeels and blue whiting was first introduced in 1998 (EC regulation 847/96), and 1999 (EC Regulation 1570/1999) respectively. Additional control measures applied to these fisheries are specific limits set aside for by-catches. In the case of Norway pout, the Norwegian sector has a by-catch limit of 800 tonnes of cod, haddock, saithe, and whiting and 400 tonnes of horse mackerel (specifically applied to

Swedish effort). These are introduced annually into the TACs and quota Regulation (EC 2341/2002). Specific by-catch quotas are also set aside for herring in industrial species. These are presently:

- 54,000 tonnes for the North Sea out of a total quota of 319,000 tonnes, or 16% of the total North Sea herring allocation (including the human consumption fishery of 265,000 reserved for human consumption).
- 21,000 tonnes herring for Kattegat/Skagerrak out of a total quota of 101,000 tonnes, or 26% of the total Kattegat/Skagerrak fishery (including the human consumption fishery of 80,000 tonnes).
- 80,000 tonnes herring by-catch in the Baltic. EC Regulation 1434/98 allows for additional targeting of herring in the Baltic for industrial purposes.

In addition, there are a set of technical measures which focus on the correct amount of target species and by-catches (EC Regulation 850/98). These are summarised in the table below:

**Table 5.7. Mesh size ranges, target species, and required catch percentages applicable to the use of a single mesh size range (TOWED GEARS: Regions 1 and 2, except Skagerrak and Kattegat)**

Mesh size mm	<16	16-31	32-54	70-79	80-99	≥100	
	Minimum percentage of target species						
Target species	95	90/60 (3)	90/60 (4)	35	30	70 (6)	none
Sandeels (1)	X	X	X	X	X	X	X
Sandeels (2)		X	X	X	X	X	X
Norway pout		X	X	X	X	X	X
Sprat		X	X	X	X	X	X
Blue Whiting		X	X	X	X	X	X

Source: Council Regulation 850/98 ANNEX I

The most relevant of controls for the industrial feed fisheries are as follows:

Fishing for sandeel (1) may take place in the North Sea from 1 March to 31 October.

During this period, vessels may use a mesh size below 16 mm if the target species is greater than or equal to 95% of the catch. 95% is also the agreed minimum target species when fish outside the North Sea in other areas of Regions 1 and 2 (except for the Kattegat and Skagerrak) outside the pre-described fishing season.

Fishing for sandeel in the North Sea is banned from 1 November to the last day of February. When fishing for sandeels, sprat, Norway pout and blue whiting, a combination of minimum mesh sizes may be used:

Between 16-31 mm (3) can be used when:

- at least 90% of any mixture of two or more target species, or
- at least 60% of any one of the target species and no more than 5% of any mixture of cod, haddock and saithe and no more than 15% of any mixture of a further 35 species.

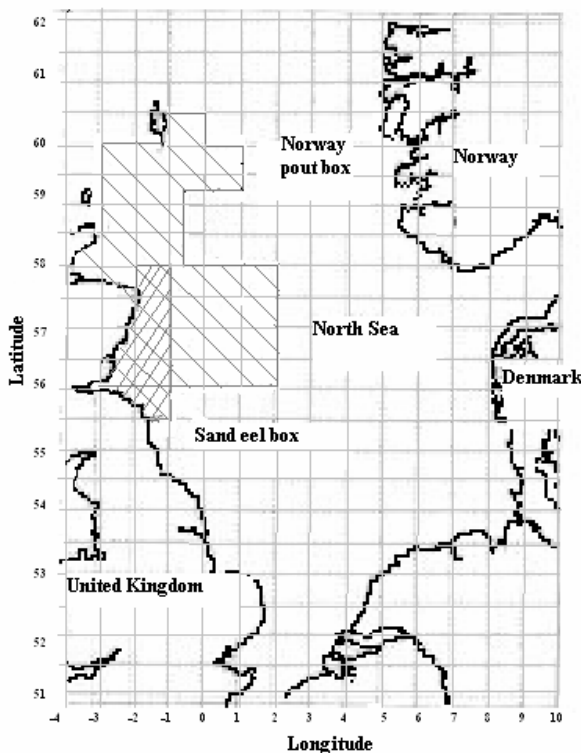
Between 32-54 (4) the catch retained on board must consist of:

- at least 90% of any mixture of two or more target species, or
- at least 60% of any one of the target species and no more than 5% of any mixture of cod, haddock and saithe and no more than 15% of any mixture of a further 32 species.

Provisions regarding limitations on catches of herring which may be retained on board when taken with nets of 16 to 31mm mesh size are stipulated in Community legislation fixing, for certain fish stocks and groups of fish stocks, total allowable catches and certain conditions under which they may be fished.

A number of closed areas apply to feed fish fisheries (Figure 5.2). These are adjacent to the UK coast and apply to:

**Figure 5.2. Areas closed to industrial fishing (ICES, 2003c)**



(Eliassen, 2003).

#### *Norway Pout:*

- a point at 56° N on the east coast of the United Kingdom as far as 2° E,
- running north to 58° N, west to 0° 30' N, west of the coast of the Shetland Isles, then west from 60° N, west to longitude 0° 00',
- North to 60° 30' N, west to the coast of the Shetland Isles, then west from 60° on the west coast of the Shetlands to 3° W, south to 58° 30' N,
- West to the coast of the United Kingdom.

This prohibition has been established since the 1970s and covers 95,000 km<sup>2</sup>. The Norway pout Box was introduced in order to prevent the fishing for feed fish fisheries in areas which were deemed to be important juvenile feeding grounds for gadoid (cod, haddock and whiting) species

#### *Sandeel<sup>24</sup>*

- a point from the east coasts of England at latitude 55° 30' N,
- latitude 55° 30' N, longitude 1° 00' W,
- latitude 58° 00' N, longitude 1° 00' W,
- latitude 58° 00' N, longitude 2° 00' W,
- the east coast of Scotland at longitude 2° 00' W.

<sup>24</sup> Council Regulation (EC) No 1298/2000.



This prohibition has been established since the 2000 and covers 18,000 km<sup>2</sup>. The aim of the Sandeel Box is to reduce levels of fishing mortality on sand eel in order to increase their availability as prey for bird populations on the East coast of the UK. The measure was to be introduced up until the end of 2002, whereupon it was to be reviewed on the basis of scientific advice. The measure has been rolled over and may be introduced as a permanent Annex to the EU's conservation regulation.

*Sprat* closed areas include:

- (a) from the period 1 January to 31 March , and from 1 October to 31 December along the UK east coast (along latitude 55° 00' N to a point longitude 1° 00' W. to a point due north to latitude 55° 30' N, from there due west to the UK coast
- (b) from 1 January to 31 March and from 1 October to 31 December, within the inner waters of the Moray Firth and the Firth of Forth
- (c) from 1 July to 31 October, within the geographical area bounded by the following co-ordinates
  - the west coast of Denmark at latitude 55° 30' N
  - latitude 55° 30' N, longitude 7° 00' E
  - latitude 57° 00' N, longitude 7° 00' E
  - the west coast of Denmark, latitude 57° 00' N

As part of the reform of the CFP all boxes are subject to review and reassessment made on the basis of scientific evidence (EC, 2002).

## **5.18. The CFP Reform**

### **5.18.1. Background to the reforms**

In March 2001, the Commission published the report on the fisheries situation in the Community, foreseen by the current legislation, and a Green Paper on the Future of the Common Fisheries Policy, discussing the weaknesses and challenges facing the CFP and presenting a number of options for its reform. The background to the review is as follows:

(1) The first shortcoming of the CFP is the alarming state of many fish stocks that are outside safe biological limits. Stock sizes and landings have declined dramatically over the last 25 years. For many commercially important demersal stocks, the numbers of mature fish were about twice as high in the early 1970's than in the late 1990's. If current trends continue many Community fish stocks will collapse.

(2) At the same time, the fishing capacity of the Community fleets far exceeds that required to harvest the available fishery resources in a sustainable manner. The most recent scientific advice from ICES suggests that the level of fishing mortality of the main Community fish stocks needs to be reduced by between one-third and one-half, depending on the type of fishery (flatfish, other demersal, pelagic) and area concerned, in order to ensure sustainable fishing.

(3) Besides a shrinking resource base and fleet overcapacity, most of the Community fisheries sector faces economic fragility, poor financial profitability and steadily declining employment. Over the period 1990-1998, there has been a loss of 66,000 jobs in the catching sector, an overall decrease of 22%. Over the same period, employment in the processing sector has declined by 14%.

(4) Current control and enforcement arrangements have been insufficient to ensure a level-playing field across the Union undermining the credibility of the CFP.

(5) Increasing demand for fisheries products and high prices for fish reflecting its scarcity have sheltered fishermen against the effects of declining stocks. This trend should reduce the need for public financial support to the fishing industry.

Industrial fisheries is also cited for attention:

*'Fishing for conversion to fish meal should target fish for which there is no market for direct human consumption. The enforcement of management measures adopted by the Community has already greatly reduced by-catches of other species which are targets for fisheries for direct human consumption. Industrial fishing, like other types of fishing, will be subject to the conservation and management measures developed under the CFP, including multi-annual management plans.*

*The Commission will request ICES to carry out an evaluation of the impact of industrial fishing on marine eco-systems. It will continue to monitor the conduct of industrial fisheries to ensure that their impact on human consumption fish species and other marine species remains low. Improved management of fish stocks which are of interest for both industrial use and human consumption, such as blue whiting, will also be proposed'.*

#### **5.18.2. Issues that relate to industrial fisheries**

- **Feed fish fisheries**

A number of relevant comments are made in respect to the above.

(1) Most EU landings of industrial species show marginal reductions in catch and almost all the main stocks are regarded as inside safe biological limits and are sustainable (BOX 5.1). There are two exceptions to this. The first is Norway pout, where, whilst sustainable, there has been a very significant reduction in effort. This fishery is reported as being less popular because of the by-catch regulations. As such effective management and protection of juvenile species is an overriding management factor. The second is blue whiting where there is a consistent increase in catch. Expansion in effort is both by EU and other foreign vessels and there is urgent need for multilateral management action.

(2) Fishing capacity in the feed fish fisheries is below that required to harvest the available fishery resources. In fact, the alternative of targeting feed fish fisheries represents a very important relief valve for vessels dependent on some of the already over-exploited stocks. Nevertheless, Denmark has included industrial vessels as a priority for decommissioning in its past programmes (Banks, 1998). This appears to have been more in response to external political pressure.

(3) The economic state of the fleet and processing sector is vulnerable to changes in world market prices. This has brought about peaks and troughs in profitability which in the case of the processing sector has either resulted in ability for the larger companies to re-invest, or for the smaller companies to be subsumed. Moreover, there is no evidence of economic drivers / windfall gains in the industrial fleet. Vessels owners tend to spread the impact of the bad years with the good years (Jensen, *Triple Nine*, 2003, pers. comm. September), and profits are insufficient to allow for any regeneration of investment.

(4) By-catch limits, closed areas and closed seasons are aimed at protecting marine habitats and juvenile and non-commercial fish species, cetaceans, birds etc. These can be said to have been effective in terms of reducing industrial effort, but may not have resulted in any appreciable change to the vulnerability of these other species, which may be affected more by other externalities.

(5) Most species targeted by industrial trawlers are almost exclusively feed fish with no potential for human consumption – sandeels, Norway pout, and sprat. This is because these fish are small, boney and are expensive to process for human consumption. Some species which were traditionally prosecuted as industrial species – horse mackerel, anchovies, sardines and pilchards, are now rarely prosecuted because of their change in status to human consumption fisheries, driven to a large extent by market drivers. Blue whiting is an exception however. France, Spain, the Netherlands and Germany prosecute blue whiting for human consumption. Catches by these countries represent 50% of the EU catch. Industrial fishermen are also allowed to target Baltic herring for feed fish. The reason for this is largely because of the unsuitability of the herring for the market. Nevertheless, there are conflicting arguments. Denmark, for example, refuses to take advantage of the derogation to fish for Baltic herring as feed fish. The two candidate countries of Lithuania and Latvia also prohibit the targeting of Baltic herring for anything other than for human consumption. In contrast, Sweden and Poland have switched their entire effort to fishing Baltic herring as feed fish. The EC Directive on dioxins may have had some impact on this shift in activity.

(6) Multi-annual management plans (MAPS) have not developed for these fisheries.

Most of these points are inherent in the management regimes for most feed fish fisheries, with the exception of blue whiting.

The CFP reform focuses on a number of action points (EC, 2002a).

MAPs are required to:

- *Be based on the best available scientific methods and advice and be designed to ensure sustainable exploitation.*

The level of research into industrial fishing is probably greater than into most other fisheries (Dalskov, 2003, *DIFRES*, pers. comm., October).

- *Be consistent with the precautionary approach, in that they will be designed to avoid the risk of collapse, especially by keeping stock size and fishing mortality rates within long-term safe levels.*

Most of the stocks exploited by the industrial feed fish fisheries have not deteriorated over the last twenty years, and especially not over the last ten years (EC, 2002a). Current management has therefore been relatively successful. There are notable exceptions however.

- Be designed to ensure safe recovery of depleted stocks

The stocks are not depleted, although uncontrolled expansion in effort may have such an effect

- Take into account the need to conserve biodiversity and minimise the impact on habitats

Many of the industrial fishing management measures already applied to industrial fisheries (closed areas, closed seasons and by-catch restrictions) do specifically this. Some of these management measures have only recently been applied to other fisheries, when they have been operational in the industrial fishery for many years.

- Within these constraints, be designed to ensure high and stable yields.

Yields are consistently high but susceptible to large scale annual fluctuations due to the short lived nature of these species and their response to extrinsic drivers.

Specific technical measures are to be considered under the auspices of the review might include:

- The introduction of more selective fishing gear, such as nets with larger meshes, square-mesh / panels, separator grids, and changes in design and rigging of such gear in order to improve selectivity. THE EC also makes provision for consultation through the Advisory Committee on Fisheries to explore possibilities for the adoption of fishing practices which consistent with the FAO Code of Conduct.
- The net wings presently used have larger meshes (with wing meshed presently between 12 and 20 M)
- Restrict fishing to protect juvenile fish, sensitive non-target species and habitats

Many of these restrictions are already in place. Some have been operating since the 1970s

The Commission advocates a long-term strategy to promote the protection of vulnerable species, such as cetaceans, sharks, skates and rays and marine birds, and habitats by such means as gear restrictions and closed areas and seasons.

Specific measures to limit fleet capacity:

- New fleet “reference levels” will be fixed, based on the final objectives of MAGP IV. Any new entry will have to be accompanied by at least an equivalent withdrawal of capacity (entry/exit ratio of 1 to 1).
- The industrial fleet is largely stable. There would appear to be little scientific reasoning for a reduction in effort. However, if the Commission’s rules apply decommissioning will inevitably result in a smaller industrial fleet

Specific measures for control and enforcement:

- Proposed changes will include the facility to revoke permits and impose administrative fines

Such enforcement mechanisms are already applied to both the Danish and Swedish industrial fishing fleet.

- Industrial shark fishing

A number of basic conclusions should be considered within the context of the reform. The most important is that the Commission advocates a long-term strategy to promote the protection of vulnerable species, such as cetaceans, sharks, skates and rays and marine birds, and habitats by such means as gear restrictions and closed areas and seasons. The Commission presently outlaws finning because of its impact on the stock and yet appears to tolerate the existence of this fishery.

Other considerations include:

- (1) Urgent management action is required in fisheries specifically targeting elasmobranchs.
  - (2) Fishing capacity in the industrial shark fishery is above that required to harvest fishery resources.
  - (3) More vessels could be attracted to the fishery if there was a corresponding increase in the price of oil. Access is only tempered by declining stocks.
  - (4) No management restrictions apply to this fishery. Closed areas and closed seasons could be investigated. A ban already applied in the fishing for basking sharks.
- (1) Scientific research into European deepwater shark species is very poor.

The Danes have already implemented many of the measures required under the reformed CFP (EC, 2002a). These are detailed below in Box. 5.3.

### **Box 5.3 The Danish management example**

In 1996, Denmark introduced a series of follow up measures to ensure compliance with the EC Fisheries Regulations. The Danish Government introduced stringent control measures as a means to limit by-catches in industrial species. The system has the following elements (Eliassen, 2003):

All fishing for industrial species requires special permits. These permits are subject to revocation in the event of an infringement.

- All vessels are required to pre-notify the authorities on landing (at least 3 and not more than 5 hours prior to discharge).
- All vessels are subject to a random monitoring system. The pre-notification is based on the following groups:
 

○ < 20 GT:	3.6% (corresponding to 1 in 28 landings)
○ ≥ 20 GT- <150 GT	9.0% (corresponding to 1 in 11 landings)
○ ≥ 150 GT	32.4% (corresponding to 1 in 3 landings)

It should be noted that the level of inspection greatly exceeds the average inspection level typical of other EU fisheries (Banks *et al.*, 2000)<sup>25</sup>.

Since 2001, the Fisheries Directorate has also applied an additional penalty of loss of trip catch revenue.

Sweden has endorsed and adopted similar procedures (Mattsson, *Fiskeriverket*, 2003 pers comm, October). Licenses may be revoked by the National Board of Fisheries, vessels are required to pre-notify the authorities on landing, and 10% of landings are subject to inspection.

The Danish Fisheries Directorate has set specific limits for by-catches of herring. The expectation is that by-catches should be below 10%. By-catch in excess of 20-30%, result in the revocation of a permit for half a month. Herring by-catches in excess of 30% result in the confiscation of a permit for one month.

The Norway pout fishery allows for 60% of the target fishery to be caught but no more than 5% cod and haddock. If the by-catch is 5.5% the offending vessel will lose its licence for half a month. If by-catch exceeds 7.5%, the offending vessel will lose its licence for a month.

Consistent offences can result in the revocation of other non industrial fishing permits. 215 vessels fish for feed fish are dependent on other fisheries.

The Directorate of Fisheries has produced a guidance note on revocation of permits<sup>26</sup>.

All vessel by-catches are analysed from week to week. Consistently high by-catches will result in the closure of a fishery. The ability to close fisheries when by-catches are high complements the management measures. It has also increased the focus of fishers on compliance (Eliassen, *Danish Fisheries Directorate*, 2003 pers. comm., August). For example, the start of the North Sea sprat season is delayed until 4 August because prior to that juvenile herring by-catches are likely to exceed the predefined limits. It should also be noted that enforcement has also been complemented by the use of Vessel Monitoring Systems (VMS)<sup>27</sup>

The number of permit revocations has steadily increased from 47 in 1996 to 112 in 2002 (Table 5.8). It should be noted that the increase in revocations reflects the number and type of offences which have evolved over the years. For example, a by-catch control system was introduced in the Western Baltic as from 2002. This resulting in an increase in penalties applied. The number of offences detected relative to the number of industrial landings represents an average compliance level of between 1.5 and 4%. Equivalent levels of compliance measured in other fisheries (Banks *et al.*, 2000) were 10% for all Danish fisheries, 12% for England, 20% for Scotland and 17% for France.

<sup>25</sup> Banks *et al* (2000), identified the average rate of inspection of a select number of EU fleets as 7% probability of being checked, or 3 inspections out of 40. Danish industrial trawlers have a probability of being inspected on 33% of the time.

<sup>26</sup> <http://www.fk.dk/info/sjle3/Inddragelsesvejledning.htm>

<sup>27</sup> VMS is a satellite tracking system which transmits the position of a fishing vessel at regular intervals.

**Table 5.8. Danish industrial fishing permit revocations, 1996-2001**

Year	No. of permit revocations in industrial fishing	No of industrial landings by Danish fishing vessels
1996*	47	6,063
1997	40	12,688
1998	42	8,017
1999	66	6,832
2000	67	6,847
2001	84	8,205
2002**	112	7,257
Note	* 1996 from 15 July	
	** 2002 new Baltic scheme in Western Baltic	

Source: Dansk Fiskeridirektoratet, 2003

Foreign vessels landing into Denmark are also subject to the same cross checking procedure.

### Voluntary restrictions

The Danish sector has introduced a number of self regulatory measures. *TripleNine* (TN), the largest of the Danish meal manufacturers, and accounting for two thirds of the total supply has instigated its own regulatory system<sup>28</sup> (Jensen, *TripleNine*, 2003, pers. comm., September). If whitefish throughput exceeds 6% landed, 12% is applied to his overall price of meal<sup>29</sup>. Triple Nine is also reviewing penalty arrangements for herring by-catches.

The Danish Fishermen's Association (Fiskerforening) has also pointed to a number of self induced voluntary restrictions. Some of these have been reduced in a conscious effort to increase selectivity, against the background of peer pressure from fellow food fish fishermen. TN has a price penalty procedure for landings of large whitefish. If they land more than 6%, then there is a penalty of 12%. This reduces the incentive to catch whitefish. Also of note, the nets are configured to minimise the catch of non-industrial gadoids such as cod, haddock and whiting, with up to 20 meshes in the wings. By-catch still occurs but is much reduced on previous years. To achieve this, the following measures have been taken:

1. Net configuration. The meshes in the wings of the net are large. The net is 300 m long, and wing meshes are between 12 and 20 m. This allows some pre-selectivity of gadoids, haddocks and whiting escaping from the net by swimming upwards and cod downwards. Pelagic species are less affected by gear configurations and will be influenced by the shadow of the net and will follow one another into the cod end.
2. When commencing fishing, a few vessels will undertake trials in different areas and will signal to the rest of the fleet if conditions are correct. Heavy by-catches by groups of fishermen are thus avoided.
3. Some by-catches will still occur, but fishers lift a part of the cod end to check net contents. High by-catches will allow fishers to slip the net. The level of mortality from such slippages is unknown.

<sup>28</sup> Two of the three Danish meal manufacturers are wholly owned by the fishing industry. All fish landed is sold through the Company.

<sup>29</sup> The Fisheries Directorate argues that these restrictions are already mandatory.

4. Fishermen can usually distinguish between species by swim bladders, though distinguishing between sprat and herring can be a problem.

5. Fishers will not fish when by-catches are consistently high.

Whilst it has to be acknowledged that the Danish sector is striving to reduce by-catches through the above limits, there are two specific reservations to the above.

Slipping<sup>30</sup> is an acknowledged issue in the Norway pout fishery (Wichman, *Danish Fishermen's Association*, 2003, pers. comm., August). Consistently high levels of by-catch will result in vessels moving to alternative grounds.

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<sup>30</sup> When trawls are hauled to the vessel, prior to discharging the catch, fishermen can inspect the net for catch composition. If they find that the contents of the net are unsuitable, for example, containing a high quantity of herring as opposed to sprat, or a high by-catch of haddock, whiting or saithe, skippers will release the net. This is referred to as 'slipping'



## 6. EVALUATION OF THE ECONOMIC ASPECTS OF FISH MEAL AND FISH OIL CONSUMPTION IN THE EU

### 6.1. Protein content

Table 2.4. identified the relative importance of fish meal in an array of products. The price ratios shown in the table also reflect the usage across a band of products: FAQ, LT, and Prime.

As and when prices change, and margins are squeezed, the level of demand changes. More specifically, lower quality fish meal may substitute higher quality, but the feed mixes will have to compensate for the loss by increasing the proportion of lower priced meal, or substituting with other raw materials such as soya (Pike, IFFO, 2003, pers. comm. October). The constraints of substitution are linked largely to the impact on growth rates. Some aquaculture species may be less sensitive to change. Table 6.1 illustrates the likely levels of substitution which may be achieved in aquafeeds. Information on other feeds (pig/poultry concentrate, pig - early weaned, UGF in poultry, pig - later weaned, pig – growers and poultry starters) was unavailable. The view is that there is some potential to reduce fish meal content in animal feeds but a reduction, particularly in young animals runs the risk of increased mortality and poorer growth (Pike, IFFO, 2003, pers. comm. October).

**Table 6.1. Possible changes to feed ratios for aquafeeds**

	Fish meal inclusion in feed processed	
	Current fish meal inclusion	Possible % inclusion
Salmon	35	25
Bass & Bream	45	40
Trout	30	20
	Fish oil inclusion in feed produced	
	2003	2010
Salmon	25	20
Bass & Bream	18	10
Trout	28	18

Source: Nutreco, 2003

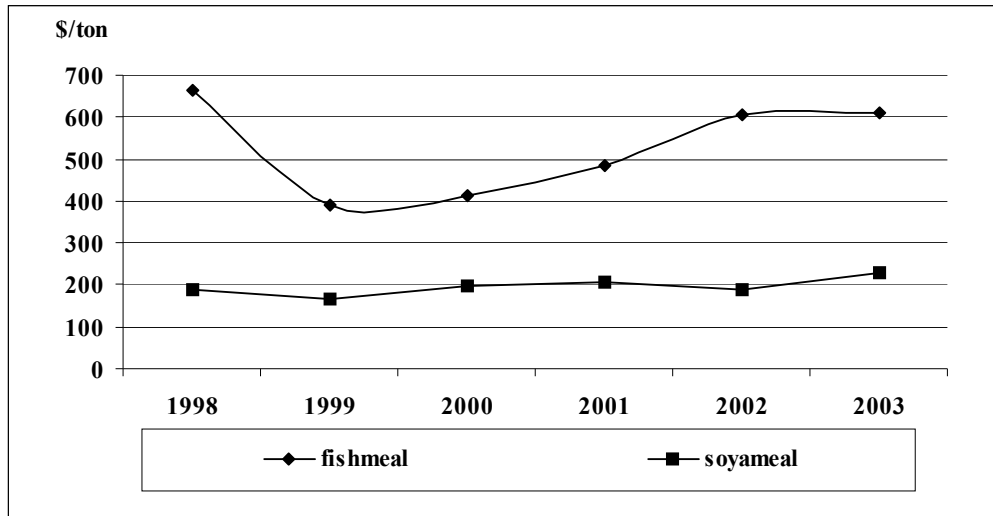
### 6.2. The price of competitor products

Soya is the main competitor product to fish meal. The price ratio of soya to fish is presently 1:2.72. Its lowest has been 1:2.14 and highest 1:3.75. There has never been parity between the two prices (Figure 6.1.). The main variable influencing fish meal price is supply. Increased availability of meal from South America results in lower prices (Jensen, *TripleNine*, 2003, pers. comm., September). Demand from the Far East<sup>31</sup> is probably the second most important price determinant. The ability to substitute soya for fish meal is influential on price but only to the extent that the perceived quality of the meal is not adversely affected. The ratio of meal (and oil) in aquafeed may change in time, but there are presently no signs of any significant shifts in percentage meal and oil utilisation (Pike, IFFO,

<sup>31</sup> The Far Eastern countries account for 60% of the world's consumption of fish meal.

2003, pers. comm. October). The high ratios also suggest that the cross price elasticity (i.e. the relationship between the price of one product and the price of other) is low. This is largely because fish meal has significant attributes which cannot be replaced, and that the world supply of fish meal relative to soya is small. Fish meal accounts for 5% of the total quantity of meal available on the market (IFFO, 2002) and most of the alternatives are derived from soya.

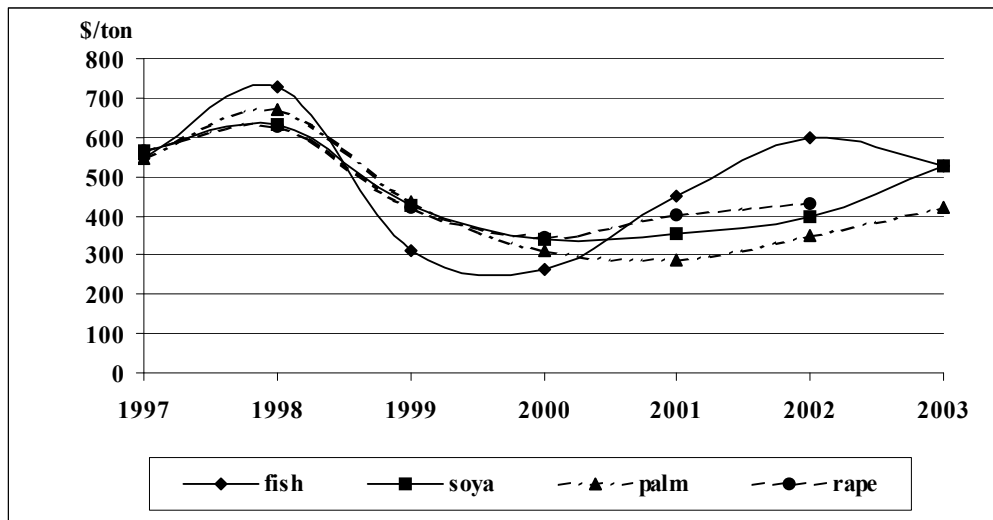
**Figure 6.1. The absolute price of fish meal and soya meal**



Source: IFFO (2002)

Figure 6.2. shows the price of fish oil relative to plant oils. Oil price ratios are more comparable and as such in some cases, usage of fish oils in animal feeds are more susceptible to substitution (Pike, IFFO, 2003, pers. comm. October). Whilst usage of fish oil in aquafeeds is substitutable by up to 50-80% in salmonids and up to 60% in marine fish diets, the effect that substitution may have on immunity, growth and the ability to sustain OMEGA 3 fatty acids (see Chapter 7) still suggests that the high demand for fish oils will continue, with some substitution taking place as a result of price fluctuations. A sustained growth in aquaculture production will also ensure that fish oils will be fully utilised.

**Figure 6.2. The absolute price of fish body oil and plant oils.**



Source: IFFO (2002)

### 6.3 Substitution

Given the price fluctuations and the prospect of shortages of supply of meal and oil some substitution of fish meal and oil with plant products is inevitable (Pike, IFFO, 2003, pers. comm. October). The traditional sources of EPA and DHA<sup>32</sup> are fish oils. Commercial interest in the production of n-3 PUFA from alternative sources for the use in aquaculture, functional foods and human nutraceuticals has fuelled recent research into the molecular biology of n-3 PUFA production in prokaryotes. At present, fish oils and cultured phototrophic microalgae are the main commercial sources of n-3 PUFA. The possible decline of commercial fish stocks and the relatively complex technology required to commercially produce microalgae have promoted research into possible alternative sources of n-3 PUFA. For a microalgal EPA process to be competitive with fish oil derived EPA, microalgal biomass needs to be obtained at less than \$5 per kilogram (Belarbi *et al.*, 2000). Microalgae have long been considered to be the major *de novo* producer of n-3 PUFA in the marine food webs. However, the ability of marine bacteria to also produce n-3 PUFA is now well established (Nichols, 2003). N-3 PUFA producing bacteria actively grow in the intestines of deep-sea fish and account for a large proportion of the bacterial community. These microorganisms, especially the culture of thraustochytrids and other n-3 PUFA producing microheterotrophs, are currently under scrutiny as potential commercial sources of n-3 PUFA. Several strains have been shown to produce relatively large amounts of n-3 PUFA, in one incidence production of up to 3.3g DHA per litre per day was obtained from a fermenter culture (Nichols *et al.*, 1999). However, to achieve marketable products, several important stages need to be investigated: firstly, collection, screening and maintenance of n-3 PUFA producing bacterial strains; secondly, optimisation of n-3 PUFA production; thirdly, determination of appropriate conditions for storage of microbial cells and products; and finally, refinement of techniques for achieving an efficient and safe transfer of microbiologically produced n-3 PUFA to the consumer (Nichols *et al.*, 1999). Nevertheless, development of economically viable technologies for the production of microbial n-3 PUFA for aquaculture, livestock and human diets is presently the subject of considerable worldwide research and several thraustochytrid-based products are already on the market (Lewis *et al.*, 1999). Recent studies have demonstrated that Antarctic bacteria can be used to enrich rotifers, who are used as live feed for larvae, with n-3 PUFA. The greatest level of EPA enrichment in rotifers was 5.8% dry weight, whereas for DHA it was 0.3% dry weight (Nichols *et al.*, 1999). These studies provide an important step in the development of novel sources of n-3 PUFA for aquaculture. Furthermore, it suggests that the Antarctic environment has naturally selected for bacterial strains capable of maintaining membrane lipid fluidity through the production of n-3 PUFA and that these strains could be considered for the industrial production of n-3 PUFA.

Intake of n-3 PUFA with the western-style diet is usually too low. Due to its influence on health (see chapter 7) an increase in the intake of EPA and DHA is commonly recommended. Enrichment of regularly consumed foods with n-3 PUFA is a new way to increase the intake of n-3 PUFA without radical changes of eating patterns. This is especially a very attractive alternative in some EU countries in which fatty fish consumption is low (see chapter 7).

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<sup>32</sup> In the 1970s, evidence from observational research showed that the Greenland Inuits, a population that consumes large amounts of fatty fish and marine animals, showed a low mortality rate from coronary heart disease despite their high intake of fat (about 40% of their total caloric intake). This so-called "Eskimo paradox" was later attributed to the presence of omega-3 polyunsaturated fatty acids ( $\omega$ -3 PUFA or n-3 PUFA) in their diet. The n-3 PUFA eicosapentaenoic acid (EPA; 20:5n-3, i.e. 20 carbon atoms with 5 double bonds) and docosahexaenoic acid (DHA; 22:6n-3) are mostly found in fatty fish and fish oils and are scarce or absent in land animals and plants.

Enrichment of foods with n-3 PUFA can be achieved through new innovative so-called functional foods. However, n-3 PUFA are prone to oxidation because of the high number of unsaturated double bonds in the fatty acid chain. This limits their shelf-life to 6 months when stored at 4°C in closed containers under nitrogen (Schrooyen *et al.*, 2001). Micro-encapsulation by emulsion spray-drying has been used successfully to increase the shelf-life of n-3 PUFA to more than 2 years, and allows their use in a large variety of foods such as infant formulas, bread mixes and spreadable fats (Schrooyen *et al.*, 2001; Kolanowski *et al.*, 2001). Spreadable fats can be enriched by up to 1% EPA and DHA with no significant influence on sensory acceptability. Daily consumption (25 - 30g/day) of these fats can provide 0.2-0.3g EPA and DHA providing levels above those eaten normally (Kolanowski *et al.*, 2001).

Factors which limit the substitutability of fish oils include:

- EU legislation on additives and GM ingredients constrains the degree of substitution (greater cost and feed conversion performance).
- The fish has a wide array of immune systems many of which are poorly understood.
- Substitution of marine oils with oils rich in omega-6 fatty acids will compromise the immune system with the likelihood of increased disease and mortality.
- Omega-6 rich oils should be avoided.
- A marked lowering of the content of long chain omega-3 fatty acids in the diet may make fish more vulnerable to low oxygen levels in the water and stress situations generally. Substitution with certain plant oils rich in linolenic acid, provided they replace only part of the marine oils, are less likely to make the fish more susceptible to disease.
- Substituting plant oils rich in omega 3 may maintain the omega 3 levels, but will reduce longer chain EPA and DHA because of the insufficient ratio of omega6:omega 3.
- Increased particulate waste and organic pollution may be associated with higher plant protein diets.

Substitution of fish oils for plant oils may not have a marked effect on short term growth of carnivorous species; longer term growth may be jeopardised if substitution is too extensive, especially during early growth stages. Evidence suggests changes in immune competence must be taken into account. In the finishing stages fish oil will be required to maintain the content of long chain omega-3 polyunsaturated fatty acids (LCω3PUFAs) in the fish. It would be prudent to produce farmed fish with the fat of which has a composition in terms of LCω3PUFAs and ω3: ω6 ratios similar to that of their wild counterparts. The conclusion is thus that it may be safe to have a degree of substitution but the ability to substitute in its entirety is highly limited because of the impact on fish immune systems.

Attempts to replace fish meal with plant proteins have been reported over many years. Success has been mixed. Where fish grow slowly, as in small tanks, partial replacement has shown little if any loss of growth. But in faster growing fish, growth generally has been reduced when more than one-quarter of the fish protein is replaced. The growth targets set by the Institute of Aquaculture, Sunndalsøra in Norway (Austreng *et al.*, 1987) are still not achieved in many of the reported trials.

Much of the reported work is with salmonids. Where good growth rate was achieved up to one quarter of the dietary fish protein could be replaced by plant protein with little if any adverse effect on growth. The trials achieving this used good quality plant proteins correctly

treated to minimise anti-nutritional factors. With slow growing fish up to 50% substitution could be achieved without adversely affecting growth.

Because plant proteins are lower in energy and digestible amino acid content than fish meal, it may not be possible to maintain these in practical diets. Poorer feed conversion may result. Removal of structural carbohydrate from plant proteins will minimise the energy shortfall, but processing costs to do so are high.

The economics of substitution should take into account the need for more feed being required and generally higher loss of nitrogen, etc. from the fish. Substitution should be avoided in areas vulnerable to nitrogen pollution, e.g. where water movement is poor - in lochs, for example.

There is increasing evidence that the immune system can be adversely affected, especially when the plant oils are rich in omega-6 fatty acids. Omega-3 and 6 PUFAs are precursors of eicosanoids (prostaglandins, thromboxanes and leukotrienes) which are signal substances (cell messengers) having a widely different effect on biological activity. Many regulate physiological and immunological reactions – both non-specific (innate) immunity, e.g. phagocyte (killer cell) production and inflammatory reactions, and specific (acquired) immunity including antibody producing B-cells and T-cells. Fish rely more on non-specific immunity than mammals, especially cold water fish species (Waagbø *et al* (1994)).

It has subsequently been shown that in perch whilst to a limited extent they can produce EPA from linolenic acid 18:2 (n-3) and DHA from EPA, the presence of omega-6 fatty acids result in preferential use of  $\Delta 4$  desaturase effectively blocking chain elongation of linolenic acid (from plant oils) to EPA and DHA. A similar response is likely in salmonids. This may adversely affect the response of fish to stress – high mortality was found when fish fed omega-6 rich diets were transported in contrast to no mortality during transport of fish fed fish oil rich diets (Sargent, 2002).

Some indications of the consequences for fish (trout) challenged with bacteria and viruses was demonstrated by Kiron *et al*, 1995. They replaced marine oils rich in long chain (LC) omega-3 PUFAs with plant oils rich in omega-3 (linolenic acid) or omega-6 (linoleic acid). Monitoring the killing of pathogenic bacteria by macrophages isolated from the fish (non-specific immunity), more were killed with those from marine oil fed fish than with those from plant oil fed fish providing omega-3 as linolenic acid (56.7 v 52.1% killed). Even fewer were killed (26.9%) with the omega-6 plant oil (linoleic acid). Antibody production in response to immunisation with *Aeromonas salmonicida* was similar in fish receiving omega-3 fatty acids from marine or plant oils but depressed with omega-6 fatty acid (linoleic). Fish challenged with IHN virus had higher mortality with dietary omega-6 fatty acids (linoleic).

An improvement in non-specific immunity when dietary LC omega-3 PUFAs increase was shown. They challenged Atlantic salmon with *Vibrio salmonicida*.

A few years ago Scotland suffered from serious salmon losses due to the septicaemic disease Furunculosis. It was found that fish made a better recovery where diets were based on marine oils as the only form of lipid (SQS).

Physiological processes are affected by dietary PUFAs. Work by McKenzie *et al*. (1997, 1999), Agnisola *et al*. (1996) and Erdal *et al.*, (1991) has shown poorer uptake and use of oxygen in fish (eels and sturgeon) receiving coconut oil depresses long chain omega-3 PUFA

intake. Heart function was adversely affected, as was tolerance of low water oxygen levels. This effect of reducing long chain omega-3 PUFAs may make fish more vulnerable to stress – such as that noted during transport referred to earlier. High levels of plant oils in fish feeds have been associated with fin erosion and skin inflammation problems.

The composition of fatty acids in the diet is closely reflected in the composition of membrane phospholipids which can affect cell permeability. It has been noted that the meat from fish receiving diets high in plant oils may tend to ‘leak’ oil – especially fillets in vacuum packs and smoked salmon (SQS<sup>33</sup>). This could be a result of increased cell membrane permeability to oil or the lower viscosity of the plant oils used (soya, rape, etc.) compared with marine oils.

The substitution of fish oil with plant oils can result in changing fatty acid composition of the fish. Whilst the use of plant oils rich in omega-3 fatty acids may maintain the omega-3 content of the fish, the short chain (C<sub>18</sub>) linolenic acid content will increase whilst longer chain (C<sub>20</sub>, C<sub>22</sub>) EPA and DHA will decrease. The former can be utilised by humans. Conversion (by chain elongation) to EPA and DHA however is very limited, because in most western diets – particularly in Northern Europe (excluding Scandinavia) and the USA, the dietary ratio of omega-6:omega-3 is over 10:1 (Leaf *et al.*, 1987); recent estimates put it at 15:1 (Bjerve, K.S *et al.*, 1987). A ratio of 5:1 or less is regarded as ideal. With ratios of 10:1 chain elongation of linolenic acid is believed to virtually cease. Fish are unique in the levels of EPA and DHA, they can provide (Givens, 2000). They reduce dependence on chain elongation by providing the required EPA and especially DHA preformed. Hence the recommendation by authorities that fish, preferably oily fish should be eaten at least once a week as part of a balanced diet (e.g. UK’s COMA<sup>34</sup>). It would be prudent to feed farmed fish in such a way that their content of EPA and DHA is similar to that of their wild counterparts. This can be achieved by restoring fish oil in the diet in the final stage of growth.

As more is learnt about the health and nutritional benefits of n-3 PUFA, demand for n-3 PUFA rich products is expected to rise. Due to the possible decline of commercial fish stocks, alternative production of n-3 PUFA through microalgae or thraustochytrids bacteria strains could form an important part in the supply of such products in the not too distant future.

#### **6.4. Its importance for the fish farming sector**

The predicted production of fish which receive diets containing fish meal and fish oil are shown in the Table 6.2.

These estimates for output are likely to be fairly optimistic. There has been a recent slow down in EU growth relative to international production (Pike, 2003). However, these projections should also be seen against the background of a decline in the availability of wild caught fish and the stated objective the EC Aquaculture Strategy is that aquaculture must fulfil some or all of this void.

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<sup>33</sup> Scottish Quality Salmon, Perth, PH2 7HG, U.K.

<sup>34</sup> COMA Nutritional Aspects of Cardiovascular Disease, HMSO 1994.

**Table 6.2. Previous and projected outputs from EU aquaculture (tonnes produced).**

Species	2001	% annual change	2002	2005	2010
Salmon	160,000	4%	173,056	179,978	227,730
Trout	244,000	1%	248,904	251,393	266,859
Bass & Bream	80,000	10%	96,800	106,480	188,636
Other	20,000	15%	26,450	30,418	70,358

Source: MEP, 1999<sup>35</sup>

Table 6.3. shows the amount of feed required currently in the EU, based on an assessment of feeding practices (mainly estimates of dry feed production) and typical feed conversion achieved from FAO and also fish feed companies (Gallemore and Roem, *Nutreco*, 2003, pers comm., September). The latter have provided information about the expected incorporation levels of fish meal and oil in these feeds in 2010. The assumption is that levels will fall in the future given more substitution in feeds for established farmed fish, but less so for the newer species.

**Table 6.3. EU Aquafeed feed utilisation, 2003**

Species	Current feed consumption '000 tonnes	% meal consumption	Current fish meal % consumption	% oil consumption	Current oil utilisation '000 tonnes
Salmon	230	35%	80.5	25%	64.4
Trout	315	30%	94.5	20%	88.2
Bass & Bream	150	45%	67.5	18%	18
Other marine	35	40%	14	15%	2.8
Total	730		256.5		173.4
International consumption			6,244		1,120
% international consumption			4%		15%

Source: IFFO (2003), *Nutreco* (2003)

Estimates of future EU fish meal and oil requirements have been produced for the years 2003 to 2010 (IFFO, 2002; *Nutreco*, 2003) (Table 6.4.). The projections show that even if substitution were to occur, the existing levels of EU fish meal and oil consumption would again be reached by 2005 and 2004 respectively. Thus in order to keep pace with changes in production, fish meal and oil required by the EU in 2010 would represent 5% and 29% of the world market supply. This compares with the current EU levels of consumption 3% and 17% for fish meal and oil respectively. This projects an extreme shortage in the availability of fish oils, and the likelihood of increasing world competition for fish meal.

<sup>35</sup> Forward Study of Community aquaculture, Macalister Elliot & Partners, Prepared for DG Fish 1999.

**Table 6.4. Projected consumption of EU aquafeed (fish meal and oil ingredients)**

Species	Consumption of fish meal (‘000 tonnes)			Consumption of fish oil (‘000 tonnes)		
	2003	2005	2010	2003	2005	2010
Salmon	60	65	79	48	52	63
Trout	64	65	68	57	58	61
Bass & Bream	66	80	129	46	56	89
Other marine	16	21	43	43	57	114
Total	206	231	318	194	222	327
International consumption	6,244	6,244	6,244	1,120	1,120	1,120
% international consumption	3%	4%	5%	17%	20%	29%

Source: Extrapolated from Table 6.2. and Table 6.3.

Feed conversion ratios for salmon and sea bass are reported as 1.2 and 1.9 respectively by the fish meal manufacturers Nutreco (2003). Table 6.5. calculates the prospective change in utilisation and the margin effect on production costs, were substitution to take place. For fish meal, using the fish meal inclusion ratios of 35% for salmon and 45% for sea bass/sea bream (Table 6.3.), it can be calculated that each kilogram of salmon and sea bass/sea bream is fed on 0.42 kg and 0.86 kg of fish meal respectively ((a)\*(c) = (d)). Thus at a fish meal cost of € 543/tonne (\$610), the fish meal in the diet under current rates of utilisation would cost € 0.23/kg and 0.46/kg ((d)\*(b)=(e)). The new feed utilisation rates would suggest a change in costs to an equivalent of € 0.16/kg and € 0.41/kg (h) for salmon and sea bream/sea bass. This would mean, assuming that the costs of substitute products remain constant, that fish meal costs would have to exceed €760/tonne (up 40%) and €611/tonne (up 12.5%) prior to having a negative impact on production costs. This would suggest that meal cost increases are likely to be more prohibitive for sea bass and sea bream, and as such a reduction in supply could impact more seriously on aquaculture development in the Mediterranean.

**Table 6.5. The prospective change in utilisation and the margin effect on production costs**

	Fish meal	Current utilisation/cost ratios				Utilisation/cost ratios with substitution			
		Current average price (€/tonne)	Fish meal inclusion in feed	Feed utilisation (weight of fish meal as% weight of meal produced)	Cost of fish meal/kg feed	Fish meal utilisation	New kg of fish meal	Fish meal cost/weight of fish produced	Price/cost flexibility (€/tonne)
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)
Salmon	1.2	543	35%	0.42	0.23	25%	0.30	0.16	760
Sea Bass	1.9	543	45%	0.855	0.46	40%	0.76	0.41	611
	Fish oil	Current utilisation/cost ratios				Utilisation/cost ratios with substitution			
		Current average price (€/tonne)	Fish oil inclusion in feed	Feed utilisation (weight of fish oil as% weight of meal produced)	Cost of fish oil/kg feed	Fish oil utilisation	New kg of fish oil	Fish oil cost/weight of fish produced	Price/cost flexibility (€/tonne)
Salmon	1.2	467	25%	0.30	0.14	20%	0.24	0.11	584
Sea Bass	1.9	467	18%	0.34	0.16	10%	0.19	0.09	841



For fish oils, using the inclusion ratios of 25% for salmon and 18% (c) for sea bass/sea bream, it can be calculated that each kilogram of salmon and sea bass/sea bream requires 0.30 kg and 0.34 kg of fish oil respectively (d). Thus at a fish oil cost of € 467/tonne (\$525), the fish oil in the diet under current rates of utilisation would cost € 0.14/kg and 0.16/kg. The new feed utilisation rates would suggest a change in costs to an equivalent of € 0.11/kg and € 0.09/kg for salmon and sea bream/sea bass. This would mean, assuming that the costs of substitute products remain constant, that fish oil costs would have to exceed €584/tonne (up 25%) and €841/tonne (up 80%) prior to having a negative impact on production costs. This would suggest that the proposed substitution rates can offset quite a substantial increase in price. However, with growth, a shortage of oil is more likely than a shortage of fish meal, as less oil is produced for the same quantity of meal. As such prices of fish oil are likely to increase at a faster rate than prices for fish meal.

The major factor will be the cost of fish meal replacement ingredients.

### **6.5. Debate on the use of fish feed in aquaculture**

The EU's overall supply base of feed fish is fairly constant at around 1.5 million tonnes per annum. There are some worrying developments within this context. In the past 10 years there have been some marginal declines in both sandeel and sprat supplies. The sector is presently buoyed up by supplies from the blue whiting and Baltic herring fisheries (Table 2.1.), and has simultaneously had to sustain supply flows by attracting imports of raw material from Norway (Table 2.2.). Trimmings, whilst a valuable component to the fish meal and fish oil sector, rely on supplies from demersal and pelagic by-products. Within this, the balance of supply has shifted from whitefish to pelagic raw material. Most EU pelagic fisheries are stable (ICES, 2003) and some of the principal pelagic processing centres are expanding production (Banks *et al.*, 2003). In contrast, most gadoid fisheries are in decline (ICES, 2003). Whilst, the processing sector has been able to source whitefish from outside the EU (Banks *et al.*, 2003) there has been some decline in throughput in the last decade. This suggests that some of the current fish meal producers relying solely on whitefish may become more vulnerable (Korsager, *UFI*, 2003, pers. comm. September).

World aquaculture production is increasing against the background of a largely constant supply of meal and oil (SEAfeeds, 2003). EU aquaculture production is presently constant (Pike, IFFO, 2003, pers. comm. October), but is set to increase (MEP, 1999). The EU is deficient in its own supplies. Given the above, this deficiency may increase with some further rationalisation in the onshore sector. The EU, even with substitution (Table 6.4.) is thus likely to have to rely more heavily on international supplies. Using the estimates of changes in demand (Table 6.5.), a change in fish meal demand from 206,000 to 318,000 tonnes and fish oil from 194,000 to 327,000 tonnes from 2003 to 2010, is likely to make the EU deficient in supplies of meal by 67.9% and oil by 45.5% (from the present 44% and 27%). The results of a workshop to examine the interactions between feed fish and aquaculture (SEAfeeds, 2003) is shown in Chapter 5, Section 5.17.



## 7. ANALYSIS OF THE INTERACTION BETWEEN FISH MEAL AND FISH OIL CONSUMPTION AND HUMAN ANIMAL AND HEALTH

### 7.1. The nutritional value of fishmeal in animal diets

For most domestic animal species and fish, FM (fishmeal) is included as a feed supplement in order to increase the protein content of the diet and to provide essential minerals and vitamins. Nutritionally, the drying process is important in determining the quality of the final product. Over-drying can significantly reduce the protein digestibility from values which are in excess of 0.92 in well-produced FM. Likewise, the proportion of food protein which can be utilised by the animal for synthesising body tissues and compounds (biological value, BV) of the FM product is much higher than cereal protein sources (range 0.74-0.89) but can be reduced if FM is heated too strongly during the drying process. In general, however, FM is considered an excellent protein source for all animal species and fish, being rich in essential amino acids for non-ruminants, particularly lysine, cysteine, methionine and tryptophan which are key limiting amino acids for growth and productivity in the major farmed species. Manipulation of protein quality during FM production is important in the manufacture of specialist feed supplements. For example, low temperature (high digestibility and BV) products are used in diets for fish and young piglets and poultry, whereas products for ruminant diets are heated differently to reduce the breakdown of the protein by the rumen microflora (and thus increases the content of rumen undegradable protein, RUP) and to reduce the soluble nitrogen content.

Since FM is produced from the whole fish, including bones and offal, it also has high concentrations of minerals, including a good balance of calcium and phosphorus, and is also a rich source of water soluble and fat soluble vitamins. Dietary FM should also be considered as an energy source which, since the product contains little or no carbohydrate, is mainly in the form of protein and fat; the latter predominantly as oil.

Typical inclusion rates for FM in animal diets are around 2-10% for terrestrial animal species, but can rise to in excess of 40% for fish diets (FIN, 2003), with use by the aquaculture, pig and poultry industries each accounting for approximately one third of EU FM consumption in 2002. Efficiencies of conversion of feed to liveweight gain are usually quoted in terms of feed conversion ratio (FCR, units of weight gain per unit of feed consumed). For most farmed fish FCR values range between 1.2 and 1.5 on a whole-fish basis (Naylor *et al.*, 2000), but these values take no account of other inputs or non-edible carcass components. Overall efficiencies of conversion of FM to fish carcass are, at best, between 20% (Naylor *et al.*, 2000) and 30% (Asgard & Austreng, 1995). The latter authors calculated that, in general, efficiencies of feed conversion are higher for fish compared with poultry, pigs and sheep at 30%, 18%, 13% and 2%, respectively (Asgard & Austreng, 1995). It is important to note, however, that with the lower inclusion rates of FM in poultry and pig diets, production per kilogram of edible product from these species requires an order of magnitude less FM than for fish products.

Recent interest has also focussed on the pattern of fats present in fish oil, as they are particularly rich in PUFA which has implications for the health and well-being of animals fed FM. Several studies have shown improvements in animals' immune competency following consumption of FM, and the increased provision of antioxidant vitamins naturally present in FM may also be of health benefit to the animal. The pattern of PUFA present in FM may also be important in the manipulation of fatty acid profiles in products used in the human

food chain, and provide a route through which n-3 fatty acid consumption can be enhanced in the general population.

#### **7.1.1. The use of fishmeal in ruminant diets**

Although sheep and cattle consume diets which are predominantly forage based, there is increased use of concentrate diets and supplements at times of increased productivity such as during pregnancy and lactation and during rapid growth. The use of FM in these situations has considerable advantages over other protein sources such as soyabean meal and bone meal in supplying RUP at times when metabolisable protein requirements may be greater than those that can be supplied by microbial protein synthesis and forage RUP. Including FM in diets fed to dairy cows results in increased milk yield with increased protein output and reduced fat percentage (a key benefit in payment strategies based on payments for milk protein content) (Doreau & Chilliard, 1997; Santos *et al.*, 1998). Sheep fed FM show improved growth rates and wool production (Masters *et al.*, 1996) and there are some reports of improved fertility, and enhanced colostrum production which may be due to improvements in immune status (Robinson *et al.*, 1989).

Supplementation of fat in ruminant diets results in an increase in the proportion of fat in the carcass (Chilliard, 1993). However, due to extensive hydrogenation of fats in the rumen the composition of body fat is not modified to a large extent with most lipid sources. However, long chain PUFA from fish oils appear to avoid hydrogenation in the rumen and are completely absorbed in the small intestine (Ashes *et al.*, 1992), thus the potential to change the fatty acid profile of ruminant products remains a possibility. Dawson *et al* (1991) and Ashes *et al* (1992) have reported changes in phospholipid profiles in muscle tissues following consumption of FM. Ponnampalam *et al* (2002) have, similarly, reported changes in the fatty acid profile of meat from lambs fed FM and in this experiment demonstrated that feeding FM had no effect on eating quality, which is in contrast to a report from Mandell *et al* (1997) that beef from cattle fed FM had a lower intensity beef flavour than control animals. Veira *et al* (1994) and Vatansever *et al* (1998) have also reported that detectable 'fishy' flavour was stronger with increasing levels of FM in the diet of cattle. Thus changes in the flavour of meat remains a concern and this may be different for sheep and cattle but should be considered when including FM in the diets of all ruminant livestock.

The evidence that PUFA from fish oils are transferred to milk fat is equivocal, with conflicting data on the efficiency of this process (Mansbridge and Blake, 1997). Recent data from Wright *et al* (2003), however, clearly indicates the potential for changing the DHA content of milk from cows fed FM, although there was no effect on EPA concentrations and the response was dependent on the level of supplementation, with reduced efficiencies of transfer at higher inclusion rates in the diet. Jensen (2002) has questioned the applicability of the dietary manipulation method for changing milk fat composition because it is less expensive to incorporate fish oil directly into milk products with standard manufacturing procedures. However, this is an area in which further research is likely to prove valuable.

#### ***Note on the feeding of fishmeal to ruminant animals***

Currently the inclusion of FM and FM products in feed for ruminant animals is banned under EU legislation as a consequence of the BSE crisis. Whilst there is no inherent risk of the transfer of transmissible spongiform encephalopathies (TSE) from FM, the ban was introduced in response to fears about possible contamination of FM products with processed

animal proteins. The regulations are currently under review and the ban on the use of FM in ruminant feeds is expected to be lifted later this year (DEFRA, 2002).

### **7.1.2. The use of fishmeal in diets of non-ruminants**

Fishmeal use in pig diets accounts for approximately 32% (Table 3.4.) of total FM use and it is recognised as a key protein source with a good balance of essential amino acids. Pigs fed diets containing FM show improved feed conversion efficiencies (greater weight gain per unit weight of feed consumed) and generally produce leaner carcasses (Wood *et al.*, 1999). The protein is well tolerated in pigs of all ages and has a high digestibility. As a feed ingredient, FM has a high proportion of protein making it an ideal balance to cereal protein sources in the diet and inclusion at relatively low concentrations can, therefore, produce a relatively high protein content. The composition of fish muscle protein is virtually identical to that of most mammalian species, and as such it contains all the essential amino acids in proportions which compliment those found in pig tissues. As with FM used in ruminant diets, however, processing has a significant impact on protein quality in pig diets. Excessive heat treatment results in a significant reduction in digestibility and biological value, due mainly to loss of lysine, a key limiting amino acid in growing pigs. One major environmental benefit in the use of FM in pig diets is the high digestibility of the added protein resulting in an improved efficiency of dietary protein use with a concomitant reduction in the production of high N-containing effluent.

A further environmental advantage of the use of FM in the diets of pigs is the high availability of dietary phosphorus compared with phosphorus of plant origin (which is predominantly in the form of phytates). Inclusion of FM reduces the need for inorganic phosphate supplementation and reduces phosphorus loss in effluent compared with cereal-based diets. The high bioavailability of phosphorus in FM may also contribute to the improvements in bone mineral status observed in pigs fed FM which has implications in animal development and welfare (Liesegang *et al.*, 2002).

There has been concern in the use of FM in the diet of pigs about the introduction of taint or a 'fishy' taste in meat products (Melton, 1990). However, fish taint is most often associated with (a) poor storage and preparation of FM resulting in peroxidation of constituent fish oil lipids, and (b) use of high levels of fish oil supplements immediately prior to slaughter. Good practice in FM production with the addition of antioxidants during manufacture, coupled with storage of feedstuffs in tightly in sealed containers should prevent peroxidation of fishoils and reduce the risk of taint. Addition of vitamin E to the diet will further reduce oxidation of n-3 fatty acids in muscle tissues of the pig and has the added benefit of increasing overall shelf life of the product.

In pigs, the nature of adipose tissue strongly reflects the nature of dietary fatty acids (Lebret *et al.*, 1996). PUFA from fish oils are readily incorporated into pig tissues, and this can result in a significant increase in n-3 fatty acids in pig meat which has clear implications in the production of a 'healthier' meat for the human diet (Wood and Enser, 1997).

### **7.1.3. Use of fishmeal in diets of poultry**

As with diets for mammalian species, FM is considered a natural, balanced ingredient for poultry diets with a high protein, high mineral and high micronutrient content. The protein in FM is readily digested by poultry and it contains all the essential amino acids necessary for adequate growth and production, especially the growth limiting amino acid lysine. However,

as with pig diets, the quality of the FM can seriously affect protein digestion and biological value. Inclusion of FM in poultry diets at about 4% results in improved feed conversion efficiency and growth rates. Laying performance is also improved by feeding FM.

Poultry respond to the inclusion of PUFA in the diet in the same way as pigs, and feeding of fish oils can result in a significant increase in the n-3 fatty acid content of chicken breast (Huang and Miller, 1993), without affecting eating quality.

Recently eggs have gained attention as an alternative to fish and oilseeds as a source of n-3 fatty acids (Hargis and Van Elswyk, 1993). The use of FM and marine algal products in poultry diets readily promotes the deposition of n-3 fatty acids into egg yolk as well as muscle and adipose tissues (Van Elswyk, 1997). Thus as with pig meat, the production of 'designer' health foods is possible. However, the high levels of cholesterol in egg yolk is seen as a disincentive to consumers and needs to be overcome if eggs enriched with n-3 fatty acids are to be seen as advantageous to health by the general public.

#### **7.1.4. The use of fishmeal in aquaculture**

The dependence of salmonid and marine-fish farming on the use of FM and fish oil has developed for two main reasons. Firstly, these fish species are almost exclusively carnivorous with a high demand for protein (40 – 50% of diet on a dry matter basis) with high concentrations of essential amino acids. Secondly, fish have a high demand for PUFA of the n-3 series, reflecting the high concentrations of these compounds in fish tissue. Protein is a basic component of fish diets, both in terms of quality and quantity, protein requirements being higher than those of other animal species (Cowey, 1975). Fishmeal provides the perfect balance of amino acids, and thus substitution of FM with other protein sources is difficult, particularly as direct substitution with plant protein will also reduce the energy content of the feed because of the lower oil content of plants and the carbohydrate content which is poorly utilised, especially structural carbohydrate. In addition, the pattern of amino acids found in plant protein is not ideal, and may require additional supplementation with individual amino acids. This has, however, proved successful when soy protein has been supplemented with methionine (Viola *et al.*, 1982), although the relative uptake of free amino acids compared with intact protein may result in reduced utilisation efficiencies (Sánchez-Muros *et al.*, 2003). Intake of diets deficient in essential amino acids may also result in reduced feed intake and further inefficiencies (De la Higuera *et al.*, 2001). An additional environmental consideration which must be taken into account is the impact of introducing rapidly digested protein sources on nitrogen excretion from the fish.

In addition to supplying energy, fish oils present in FM or as fish oil supplements supply highly unsaturated fats of the n-3 and n-6 series including EPA and DHA, respectively. Freshwater fish species, including trout and salmon which spend time in freshwater before moving to sea water, are capable of converting linolenic acid (18:3n-3) to EPA. Likewise freshwater fish can convert linoleic acid (18:2n-6) to DHA (Sargent *et al.*, 1995). Since marine fish cannot convert C<sub>18</sub> to C<sub>20</sub> and C<sub>22</sub> PUFA, diets of farmed fish must contain adequate levels of these fatty acids pre-formed in order to ensure successful survival and growth (Sargent *et al.*, 1999). Although freshwater fish do not have an obligate requirement for EPA and DHA, these species including trout and salmon have a higher growth performance when fed these products than when fed diets containing PUFA of the C<sub>18</sub>-series (Sargent & Tacon, 1999). In addition, fish of both fresh water and marine species have a higher demand for n-3 than n-6 fatty acids especially during larval development (Sargent *et*

*al.*, 1999) thus in the absence of FM or fish oil, there must be an adequate supply of 18:3n-3 in the diet from alternative sources. For freshwater species, this can be provided from aquatic plant chloroplast lipids; in the case of carnivorous fish it must be provided from prey. This provides the opportunity for substitution of some, but not all, FM and fish oil in the diets of larval fish with plant-seed oils. Achieving the appropriate balance between the supply of essential fatty acids and energy-yielding fatty acids is, therefore, critical in diet formulation and data suggests that a minimum of 10% of the diet of larval fish should be in the form of marine phospholipids (Sargent *et al.*, 1999).

As for terrestrial animal species there is evidence to suggest that the immune function of fish may be affected by dietary fatty acids although the role of n-3 and n-6 fatty acids in fish immune response is unclear, reports are not conclusive and are very often contradictory. Some authors have reported negative effects of high dietary levels of n-3 PUFA (Erdal *et al.*, 1991, Li *et al.*, 1994), whereas other reports show positive effects of n-3 fatty acids on the immune response (for example, Ashton *et al.*, 1994). In addition, inadequate levels of dietary n-3 PUFAs have been shown to reduce antibody production and *in vitro* killing of bacteria by macrophages in rainbow trout (Kiron *et al.*, 1995) and depleted alternative complement pathway activity in gilthead seabream (Montero *et al.*, 1998). Changes in the fatty acid profile of feeds, therefore, may result in adverse metabolic changes with implications to fish welfare, especially in intensive farming situations.

The principle advantage of the continued production of aquaculture products is the supply of foodstuffs into the human food chain which are not only of high nutritional (protein) value but may also confer potential health benefits as a dietary sources of essential PUFA. Changing the pattern of fatty acids fed to farmed fish has implications for the fatty acid composition of the final product, which can easily be altered (Sargent & Tacon, 1999). However, feeding of plant oils such as rapeseed oil and palm oil at the expense of FM at high levels of inclusion may adversely affect the concentrations of n-3 fatty acids which compromises the nutritional quality of the product for the human consumer (Bell *et al.* 2001; 2002). In addition, changes in membrane properties and the taste characteristics of the product with possible consequences on storage and handling need to be further investigated to evaluate their possible impact in the industry.

#### **7.1.5. Summary**

Inclusion of FM in diets for the animal and aquaculture livestock industries provides a major benefit for animal/fish production. It results in improved efficiencies of production across all the major farmed species and has potential for the dietary manipulation of tissue/product composition to produce 'healthier' foods for use in the human food chain. Animal health, and hence welfare, is improved through feeding of FM, and waste products contain less nitrogen and phosphorus reducing the environmental impact of effluent disposal.

#### **7.2. Effect of fish and fish oil products on human health**

In the 1970s evidence from observational research showed that the Greenland Inuits, a population that consumes large amounts of fatty fish and marine animals, showed a low mortality rate from coronary heart disease despite their high intake of fat (about 40% of their total caloric intake). This so-called "Eskimo paradox" was later attributed to the presence of omega-3 polyunsaturated fatty acids ( $\omega$ -3 PUFA or n-3 PUFA) in their diet. The n-3 PUFA eicosapentaenoic acid (EPA; 20:5n-3, i.e. 20 carbon atoms with 5 double bonds) and docosahexaenoic acid (DHA; 22:6n-3) are mostly found in fatty fish and fish oils and are

scarce or absent in land animals and plants. The content of n-3 PUFA varies from 0.48g/100g in white fish (cod) to 0.68g/100g in crustacea (mussels) to 0.98g/100g in roe and 5.33g/100g in fatty fish (mackerel). Mackerel, herring, sardines, kippers, salmon and trout are among the richest sources of EPA and DHA in the Western diet. The seven fish consumed most frequently in Europe, representing 70% of intake of the whole cohort are cod (18.7%), herring (12.8%), salmon (11.0%), hake/burbot (9.9%), tuna (8.4%), mackerel (5.4%) and trout (3.6%) (Welch *et al.*, 2002). Recommended fish consumption of 2.5 - 3 times per week would provide a combined intake of 500mg of EPA and DHA per day. EPA and DHA comprise 20 - 30% of the fatty acids in a typical preparation of fish oil, which means that a 1g fish oil capsule can provide 200 - 300mg of EPA plus DHA.

Fish intake varies greatly throughout Europe by a factor of 6 in women and more than 7 in men (Table 7.1.). Fish consumption is generally higher in areas with greater coastal access due to traditional patterns of consumption and the short shelf life of fresh fish. As a percentage of total fish consumption, intake of fatty fish is greater in the coastal areas of northern Europe (Denmark, Sweden) and in Germany than in central and southern Europe (Table 7.1.). The lowest values of EPA and DHA were found in Italy and The Netherlands and the highest values in Denmark and not Spain, as expected. This is because the consumption of fatty fish in Denmark forms a higher percentage of total fish intake (48%) than in Spain, where it is 32% (Welch *et al.*, 2002).

**Table 7.1. Mean daily intake of all fish, fish products and total fatty fish in men and women across 8 European countries**

	Total fish and fish products (g/day)		Total fatty fish (g/day)		% of fatty fish relative to all fish and fish products	
Country	Men	Women	Men	Women	Men	Women
Greece	52.4	30.8	18.9	9.0	35.7	28.0
Spain	91.6	62.2	29.7	19.1	31.9	31.5
Italy	29.8	23.6	11.4	10.0	39.9	40.4
Germany	20.5	17.9	13.9	9.9	65.8	54.6
The Netherlands	17.6	13.4	8.0	6.3	45.8	47.1
UK	33.3	21.5	14.0	8.7	44.9	44.9
Denmark	44.9	34.2	22.4	16.8	48.5	47.9
Sweden	37.3	29.9	16.8	14.1	47.9	48.0

Source: adapted from Welch *et al.*, 2002

The current mean adult combined intake of EPA and DHA is far too low in some European countries and approaches only 13 - 20% of recommended target levels (Lee and Lip, 2003). Although the amount of n-3 PUFA present in meat is considerably lower than that found in oil-rich fish, meat and fish are significant sources of preformed n-3 PUFA in the diet, and so any increase in n-3 PUFA concentration in meat (see above) will make a useful contribution to overall intake. Given the relatively low consumption of oil-rich fish in some European countries, meat could rival fish as a source of n-3 PUFA (British Nutrition Foundation, 1999). However, distinct differences in meat consumption patterns were demonstrated across Europe (see Table 7.2.). The Mediterranean countries revealed higher proportions of



beef/veal and poultry and less pork or processed meat than observed in central or northern European countries (Linseisen *et al.*, 2002). The contribution of total dietary meat intake to total daily lipid intake varied from 13.1-26.5% in men and from 8.9-21.2% in women (Table 7.2.).

On the other hand, foods fortified with fish oil or n-3 PUFA extracted from algae and fungi, such as particular margarines and spreads, may become an important source of EPA and DHA. In Japan and Korea, for example, many products enriched with DHA are available, ranging from dairy products and pork to teas, confectionery and biscuits (British Nutrition Foundation, 1999).

**Table 7.2. Contribution of dietary total meat intake (g/day) to total energy intake (%) as well as total daily lipid intake (%) in men and women across 8 European countries**

	Dietary total meat intake					
	g/day		% of daily energy intake		% of daily lipid intake	
	Men	Women	Men	Women	Men	Women
Greece	78.8	47.1	8.1	7.0	10.9	8.9
Spain	170.4	99.2	16.0	13.6	26.5	21.2
Italy	140.0	86.1	11.5	10.4	19.8	16.9
Germany	154.6	84.3	15.0	10.8	25.4	18.5
The Netherlands	155.6	92.7	14.5	11.4	22.9	17.5
UK	108.1	72.3	9.3	8.5	13.1	12.3
Denmark	141.1	88.3	11.7	9.5	19.1	15.3
Sweden	138.8	91.9	12.9	10.9	20.3	17.1

Source: adapted from Linseisen *et al.*, 2002

EPA and DHA are major structural components of membrane phospholipids of tissues throughout the body. Once incorporated into membrane phospholipids, they influence membrane fluidity and the structure of membrane receptors. They play a role in the regulation of cell surface protein expression, cell-cell interactions, cytokine release and energy supply from lipids. It is therefore of little surprise that these fatty acids have been studied extensively in a wide spectrum of human diseases. In this review, we have restricted the impact of omega-3 fatty acids from fish and fish oils on three main areas of clinical importance to human health, i.e. cardiovascular disease, inflammation and brain development and function.

### 7.2.1. Fish consumption and prevention of cardiovascular disease

Significant benefits of both EPA and DHA from fish oil have been observed at several different stages of the cardiovascular disease process. These include effects on lipoprotein metabolism, platelet/ vessel wall interactions, cardiac arrhythmia, ischaemic damage to heart muscle, proliferation of smooth muscle and growth of atherosclerotic plaque (Abeywardena and Head, 2001; Lee and Lip, 2003; Leaf *et al.*, 2003; He *et al.*, 2003).

The endothelium plays a key role in vascular function and endothelial dysfunction therefore reflects an imbalance between the vasoconstriction and vasodilator compounds and is associated with several cardiovascular risk factors. Fish oil derived n-3 PUFA have been shown to positively modulate the vascular endothelium through modifying the eicosanoid biosynthesis and through increased endogenous nitric oxide production (Abeywardena and Head, 2001). EPA and DHA therefore reduce blood pressure and improve endothelial relaxation by reducing thromboxane A<sub>2</sub> concentration and inducing nitric oxide production. The specific inhibitory effect of n-3 PUFA on thromboxane A<sub>2</sub> synthesis is not explained by the changes in the availability of precursor fatty acids alone. DHA and EPA have been shown to act as antagonists at the thromboxane A<sub>2</sub>/ prostaglandin H<sub>2</sub> receptor in human platelets. DHA has been found to be a more potent antagonist than EPA. Furthermore, DHA has shown to mediate an inhibitory effect at the thromboxane A<sub>2</sub> synthetase level (Abeywardena and Head, 2001). In addition to their direct influence on vascular contractility, n-3 PUFA also influence vascular function through reducing proliferation of vascular cells with a reported higher potency for EPA than DHA. Vascular, endothelial and intracellular adhesion molecules (i.e. VCAM-1, E-selectin, ICAM-1) regulate the adhesion of circulatory leukocytes to the vascular endothelium and the subsequent infiltration of monocytes into the vascular wall which is a major step in the development of atherogenesis. Expression of these adhesion molecules was shown to be reduced by both DHA and EPA (Abeywardena and Head, 2001).

Importantly, a series of secondary prevention placebo controlled trials in individuals who had previously suffered a myocardial infarction have demonstrated that modest increases in n-3 PUFA intake result in a significant decrease in coronary heart disease mortality (Burr *et al.*, 1989), in cardiovascular events, non-fatal myocardial infarction and stroke, and in total mortality and cardiovascular death (Valagussa *et al.*, 1999). Most striking however is the finding that modest dietary intake of fatty fish decreases risk of sudden cardiac death by 40 - 50% (Siscovick *et al.*, 2003; Lee and Lip, 2003; Leaf *et al.*, 2003). The new diet-heart hypothesis is characterised by the alteration of cardiac ion channel function through n-3 PUFA which modify the cardiac action potential and reduces myocardial vulnerability to ventricular fibrillation, the major life-threatening arrhythmia that results in sudden cardiac death. Only one fatty fish meal a week is associated with the marked decrease of 40 -50% in sudden cardiac death, and there is little evidence from epidemiological studies that greater dietary intake of fatty fish will give a better protection. Additionally, consumption of fried fish in contrast to fatty fish was not associated with a lower risk of fatal arrhythmic death among older adults (Siscovick *et al.*, 2003).

However, many of the experimental studies conducted to date have assessed the impact of EPA and DHA doses on CHD risk outcomes in middle-aged male populations. Data of responsiveness to physiological doses in other population subgroups, and in particular in women, is distinctly lacking. In addition, uncertainty remains regarding the potential deleterious impact of these unsaturated fatty acids on LDL oxidation and overall circulating LDL-cholesterol levels. Increases in LDL-cholesterol ranging from 0-30% following fish oil supplementation have been reported in the literature (Harris, 1997; Minihane *et al.*, 2000; Mori *et al.*, 1991). The physiological determinants and underlying mechanisms of this heterogeneous LDL-cholesterol response are not known, although apolipoprotein E genotype is likely to be a primary factor (Minihane *et al.*, 2000). The increase in LDL-cholesterol was largely attributed to apolipoprotein E4 carriers who experienced an average 16% increase. In addition, limited data suggests that diet-gene effects on plasma lipids may also be gender sensitive (Ordovas *et al.*, 2002).

In summary, n-3 PUFA exert beneficial effects on several different cardiovascular risk factors including favourable influences on plasma triglycerides, blood pressure, platelet function, coagulation and fibrinolysis. They further reduce platelet aggregation and the induction of abnormal vascular growth. Collectively, the data suggests that n-3 fatty acids have the ability to modulate certain key biologically active proteins involved in the pathogenesis of atherosclerosis through gene expression and protein synthesis levels independent of their modulatory effects on eicosanoid metabolism. Prevention intervention trials have firmly established the protective cardiovascular effect of fish consumption on sudden cardiac death. However, data is distinctly missing for other population subgroups than middle aged men.

### 7.2.2. Immune function

The immune system acts to protect the host against pathogenic invaders. There are two types of immunity, innate and adaptive. Innate, or non-specific, immunity is present at all times and is fully functional before infectious agents enter the body whereas adaptive immunity is the specific reaction of the immune system towards an immunogen. Inflammation is the response to tissue damage and is non-specific. Oedema, redness, pain and heat are the four cardinal symptoms of inflammation. Under normal circumstances, it is a protective and beneficial process when it occurs in response to an acute event. However, if the response is exaggerated or chronic, it can lead to long-term damage.

Fish oils have been shown to possess anti-inflammatory effects. Consumption of high levels of fish oil (more than 2.4g of EPA and DHA per day) has been reported to decrease neutrophil and monocyte chemotaxis, superoxide production and production of pro-inflammatory cytokines such as TNF, IL-1 and IL-6 (Calder and Field, 2002). The effects of n-3 PUFA are probably dose-dependent as studies providing more modest amounts of EPA and DHA have not consistently demonstrated these effects on the innate immune system. In acquired immune function, fish oils have shown to inhibit lymphocyte proliferation, IL-2 and interferon (IFN)- $\gamma$  production. Again, feeding moderate amounts of n-3 PUFA is not clearly immunosuppressive, although feeding high amounts might be (Calder and Field, 2002).

Several mechanism of how n-3 PUFA act on the immune and inflammatory response have been proposed, including alterations in membrane structure and fluidity, changes in membrane mediated cell signalling molecules and eicosanoids, changes in gene expression and their influence as fuel partitioners (Calder and Field, 2002; Calder and Grimble, 2002; Grimm *et al.*, 2002). Firstly, the fluidity of the plasma membrane is likely to be important in the functioning of immune cells since it is an important regulator of phagocytosis (Calder and Grimble, 2002). The interaction of cytotoxic T-cells with target cell membranes is affected by the fluidity of the plasma membrane of the T-cells. When fish oil is consumed the proportions of EPA and DHA in immune cells are significantly elevated in a dose dependent manner. The degree of enrichment of EPA is greater than that of DHA with 300% versus 95% (Yaqoob *et al.*, 2000). The incorporation of these n-3 PUFA is at the expense of arachidonic acid and is considered maximal 4 weeks after a dietary change (Yaqoob *et al.*, 2000). Changes in plasma membrane structural characteristics can change the activity of proteins that serve as ion channels, adhesion molecules, transporters, receptors, signal transducers or enzymes. Many of the established cell signalling molecules are generated from membrane phospholipids (e.g. inositol-1,4,5-triphosphate, diacylglycerol, phosphatidic acid, choline, ceramide, platelet activating factor, arachidonic acid) which have important roles in regulating the activity of proteins involved in immune cell responses. The concentration and composition of these

signalling molecules have been shown to be sensitive to n-3 PUFA availability in the diet (Calder and Field, 2002).

The key link between n-3 PUFA and inflammation however is a group of mediators termed eicosanoids. Eicosanoids are involved in modulating the intensity and duration of inflammatory and immune responses, particularly PGE<sub>2</sub> and the 4-series leucotrienes which are derived from arachidonic acid. The pro-inflammatory effects of PGE<sub>2</sub> include inducing fever, increasing vascular permeability, enhancing pain and oedema. On the other hand, PGE<sub>2</sub> suppresses lymphocyte proliferation and natural killer cell activity and inhibits production of TNF- $\alpha$ , IL-1, IL-6, IL-2 and TNF- $\gamma$ . Leucotrien B<sub>4</sub> also increases vascular permeability, induces release of lysosomal enzymes, inhibits lymphocyte proliferation but promotes natural killer cell activity. Since arachidonic acid gives rise to a range of eicosanoids that exert opposing effects to one another, the overall physiological effect will be determined by their concentration, their production and the sensitivities of target cells (Calder and Grimble, 2002). Because the membranes of most cells contain large amounts of arachidonic acid, this fatty acid usually is the principle precursor for eicosanoid synthesis via the enzymes cyclooxygenase (COX) and lipoxygenase (LOX). However, compared to arachidonic acid, EPA is the preferential substrate for lipoxygenase which explains for the higher formation of EPA derived products at the expense of arachidonic acid derived metabolites when both free fatty acids are simultaneously available (Grimm *et al.*, 2002). Since dietary fish oil leads to decreased PGE<sub>2</sub> production, it is often stated that it should reverse the effects of PGE<sub>2</sub> by simply acting as a PGE<sub>2</sub> antagonist. However, the situation is more complex as PGE<sub>2</sub> is not the sole eicosanoid produced from arachidonic acid and the range of eicosanoids produced has varying, sometimes opposite actions. There is now emerging evidence that n-3 PUFA regulate the expression of genes for cytokines, adhesion molecules, COX, inducible nitric oxide synthase and other inflammatory proteins (Calder *et al.*, 2002; Grimm *et al.*, 2002). Fish oil derived EPA has been shown to inhibit arachidonic acid induced nuclear factor kappa B (NF $\kappa$ B) activation, which has shown to induce a number of the inflammatory genes. Another group of transcription factors that is regulated by n-3 PUFA is the peroxisome proliferator-activated receptor (PPAR). Through the activation of PPAR, fish oils induce the transcription of genes encoding proteins of lipid oxidation and thermogenesis. EPA and DHA also control lipogenic gene transcription through another family of transcription factors, the sterol regulatory binding proteins (SREBP). There is evidence that n-3 PUFA suppress SREBP-1 expression by accelerating the rate of SREBP-1 mRNA decay. Fish oil derived fatty acids therefore improve the energy supply to immune cells since they direct fatty acids towards oxidation by activating PPAR and downregulate lipogenic gene induction by suppressing SREBP-1 expression (Grimm *et al.*, 2002).

There have been a number of clinical trials assessing dietary supplementation with fish oils in several chronic inflammatory diseases in humans. To date, there have been 13 randomised controlled trials of fish oil in rheumatoid arthritis, all of which were undertaken in patients with late disease (mean disease duration >10 years). The most consistent benefits have been reduced morning stiffness and decreased tender joint count (Cleland *et al.*, 2003). However, anti-inflammatory effects have been shown with doses between 2.6 - 7.1g/day, but were not seen with a moderate dose of 1g/day. Nevertheless, fish oil seems to have a beneficial effect in stable rheumatoid arthritis and should be regarded as an adjuvant therapeutic perspective if combined with conventional therapy. Fish oil preparations employed in Crohn's disease showed a benefit for high-risk patients in remission in terms of a reduced relapse rate and was shown to improve histological findings and to reduce the requirement for antiinflammatory drugs in ulcerative colitis (Grimm *et al.*, 2002).

In summary, n-3 PUFA possess the most potent immunomodulatory activities among the fatty acids. Some of the effects of n-3 PUFA may be due to the amount and type of eicosanoids made but others are exerted through eicosanoid independent mechanisms, including actions upon intracellular signalling pathways and transcription factor activity. Although fish oils have been shown to alleviate some of the symptoms of rheumatoid arthritis, implementation of the clinical use of fish oil has been poor since they do not receive the marketing input that underpin the adoption of usual pharmacotherapies. The most valuable effects of fish oils could be to enable sufferers to reduce their use of pain-relieving drugs which sometimes have severe side effects.

### 7.2.3. Essentiality of fish oil in relation to development and function of the brain

The brain is the organ with the second greatest concentration of lipids, the majority of these comprising polyunsaturated fatty acids such as DHA. In man the anatomical and functional specialisation of neurons proceed from the last trimester until early adulthood, and it has been suggested that this period of brain development may be the origin of human behavioural flexibility (Wainwright, 2002). DHA and arachidonic acid accure rapidly in the human brain during this period. It is hypothesised that the evolution and expansion of the human brain requires a plentiful source of DHA, which is necessary for brain structures and growth. n-3 PUFA can influence neural function in various ways, i.e. they can alter the physical properties of the membrane and in this way influence ion channel transport, endo- and exocytosis and the activity of membrane bound proteins (see above). The concentration of polyunsaturated fatty acids in the nerve membrane influences various aspects of neurotransmission and function. Chronic n-3 PUFA deficiency is associated with reduced dopamine receptor binding and increased serotonin receptor density in the frontal cortex. These observations suggest that specific developmental processes may be susceptible to the influence of dietary n-3 PUFA deficiency, particularly those related to the frontal dopamine system (Wainwright, 2002).

*Homo sapiens* is unlikely to have evolved a large, complex, metabolically expensive brain in an environment which did not provide abundant dietary n-3-PUFA. The richest source of DHA is, as mentioned above, the marine food chain. Until recently, we believed that the origin of mankind, the African Savannah, offered very little marine food for the early *Homo sapiens*. However, recent fossil evidence indicates that fish intake was high at the time brain expansion took place suggesting that the transition from archaic to modern humans took place at the land/water interface (Broadhurst *et al.*, 2002).

Several recent studies, in which human infants were fed formulas supplemented with DHA, indicated that DHA may provide some advantage with respect to mental development and for the function of the visual pigment of rods (Lauritzen *et al.*, 2001). However, the immediate connection between the cellular effects of DHA and improved visual acuity and cognitive abilities in infants receiving dietary DHA is not obvious. This is due to the fact that predictive validity of look duration as a measure of visual recognition in infants has not yet been established, and that language scores used as other cognitive measures appear to have been transient and the predictive validity or early language with respect to later cognitive function is controversial (Wainwright, 2002).

Decreases in DHA concentration in the brain are associated with cognitive decline during ageing and with onset of sporadic Alzheimer disease. A prospective study conducted from 1993 through to 2000 found that participants who consumed fish once per week or more had 60% less risk of Alzheimer disease compared with those who rarely or never ate fish (Morris

*et al.*, 2003). These associations held even after adjustment for education and other important risk factors, including cardiovascular condition that could potentially account for the observed relative risk. Some researchers have suggested that low intake of polyunsaturated fatty acids or excessive breakdown of these in the nerve membrane may be associated with Schizophrenia and attention-deficit hyperactivity disorder. However, DHA did not show a significant therapeutic effect relative to placebo and further carefully designed, randomised clinical trials are needed to evaluate the therapeutic effect of DHA supplementation in schizophrenia (Fenton *et al.*, 2000).

In summary, small changes in dietary fat intake (i.e. a regular consumption of oily fish for 2 x a week) can alter the neuronal membrane lipid composition and therefore influence specific neurotransmitter systems. There is some evidence that DHA may provide some advantage in mental development especially in early life. It is provocative to ponder whether diet could be used to induce formation of membrane structures that are more resistant to specific insults that cause degeneration or that diet could even reverse degenerative changes that occur in neuronal membrane structure and function as in Alzheimer disease and Schizophrenia.

## 8. SYNTHESIS AND CONCLUSIONS

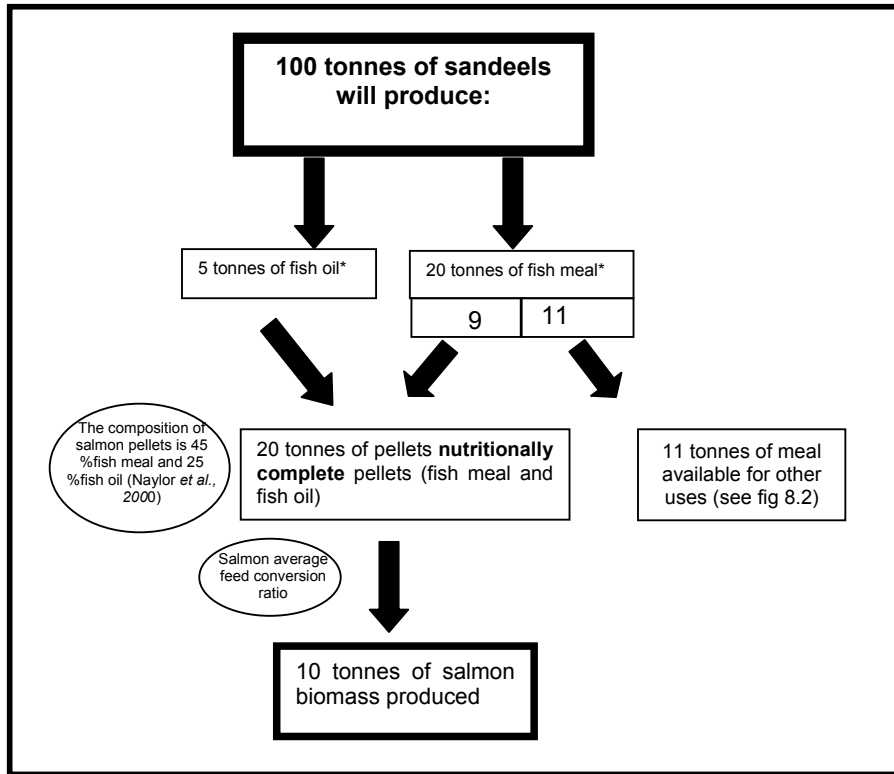
### 8.1. An evaluation of the efficiency of converting fish into fish meal and fish oil as a means of obtaining human food

The transfer of energy through a food chain is not 100% efficient as at each trophic level, as energy is used for metabolic maintenance and some is lost to other systems such as the decomposition pathways. Studies have found that around 10% of the energy is passed up to the next trophic level (Lindeman, 1942; Slobodkin, 1961). More recent studies have recognised that ecological efficiency does vary (Baumann, 1995; Kemp *et al.*, 2001, Manickchand-Heileman *et al.*, 1998). For example, Jennings *et al.* (2002) estimated ecological efficiencies of between 3.7 to 12.4% in the central North Sea food web. The value of 10% however is accepted as good general approximation (Bromley *et al.* 1993; Christensen and Pauly, 1993; Pauly *et al.* 2000).

The final product of fish meal and fish body oils are fish pellets. These pellets are formulated according to their intended consumer, but the production of these pellets is limited by the different quantities of oil and meal which can be extracted from the same quantity of fish. For instance, 100 tonnes of sandeels can only produce 20 tonnes of fish pellets suitable for salmon (Figure 8.1.). Another 122 tonnes of sandeel are required to provide the oil for the remainder of the fish meal (figure 8.2.). With the additional oil, 44.4 tonnes of fish pellet may be produced from the fish meal obtained from 100 tonnes of sandeel. The conversion efficiency of this process from 222 tonnes of sandeels to 22.2 tonnes of salmon biomass is 10%. Equivalent to the typical ecological efficiency of the wild food chain.

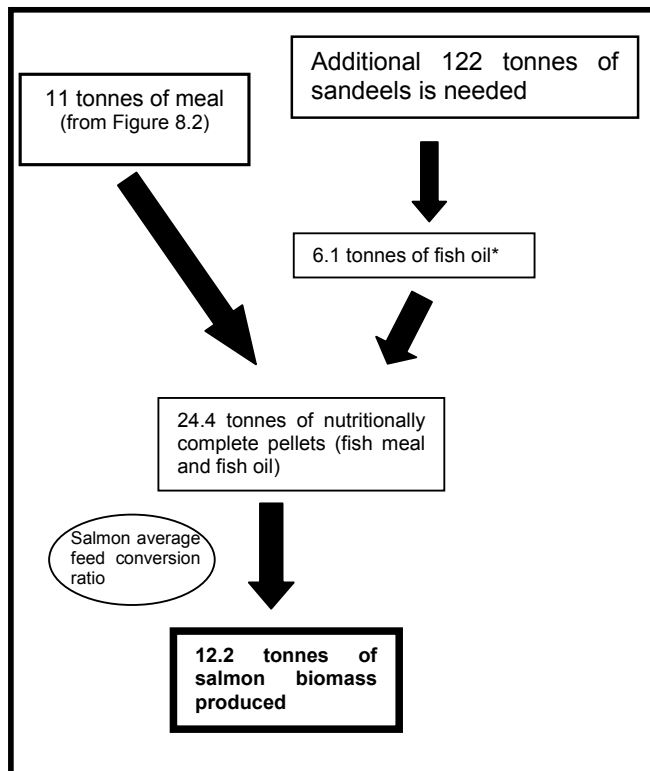
The quantity of feed pellets produced from a particular quantity of fresh feed fish will vary depending on the type of feed produced, and to some extent substitution of components caused by market forces (see Chapter 6). However, particularly in aquaculture feeds, the degree of substitution currently possible is limited. If we take the current average composition of feed pellets (Naylor *et al.*, 2000), then the yield from the feed fish supply is limited by the oil yield (Figure 8.1.). However, if we allow substitution of fish oil with plant oils up to the levels predicted by the feed supply industry (Pike, *IFFO*, 2003, pers. comm.) then the yield of meal from the feed fish is the limiting factor (Figure 8.2.).

Figure 8.1. Converting sandeels to salmon



\*The percentage conversion factors of converting fish to fish meal and fish oil were obtained from J. Nilsen (*TripleNine*, 2003). The quoted feed conversion ratio (FCR, units of weight gain per unit of feed consumed) is from Naylor *et al.* (2000).

Figure 8.2. Converting sandeels to salmon, utilising the fish meal from the previous conversion requiring the extraction of additional oil





Feed conversion ratios (FCR) differ between organisms. For most farmed fish, FCR values range between 1.8 and 2.2 on a whole-fish basis (Naylor *et al.*, 2000). Farmed animals (cows, pigs and sheep) do not process feed as efficiently as the marine finfish. Ruminants are the least efficient at converting feed to body mass, followed by non-ruminants and then poultry, which are the most efficient. Asgard and Austreng, (1995) calculated the general efficiencies of the feed conversion of poultry, pigs and sheep at 18%, 13% and 2%, respectively.

The energetic efficiency of converting sandeels into feed pellets which are fed to farmed salmon varies depends on the feed conversion ratio used (Table 8.1.). In the case of salmon feeding on fish meal and fish oil pellets, the overall biological conversion can be as high as 17% (using a feed conversion ratio of 1.2 as used by animal feed company Nutreco). Using a feed conversion ratio of 1.2 means that it is more efficient for humans to obtain food via the fish meal and farmed animal route than by directly consuming wild fish that have fed on sandeels. However, a feed conversion value of 2 for salmon (the mid point of the range given by Naylor *et al.*, 2000) and a value common in the Scottish industry in the 1980s (Gowan and Bradbury, 1987), would make the efficiency equivalent to the wild food chain (Table 8.1.). The SEAfeeds (2003) report estimates that the conversion efficiency of capture fish to farmed salmonids is between 2.6-3.3 (kg per kg fresh weight) which is comparable to the Naylor *et al.*, (2000) estimate of 3.16. The difference in the values may relate to the use of fresh weight to fresh weight conversions used in studies of ecological efficiencies, as opposed to the dry weight to fresh weight conversions which tend to be used to calculate feed conversion efficiencies by industry.

The ecological efficiency of aquaculture production based on feed comprising a significant proportion of non-fish material will seem much more efficient when calculated against feed fish input as baseline (Table 8.1). This is because the production system for the vegetable oil and cereal fillers has been ignored. Thus assessing the efficiency of utilising industrial teleost fish species to produce food for human consumption is complicated, but is, depending on the feed composition and the FCR of the animals being cultured, can be comparable to humans consuming the industrial teleost fish directly (e.g. salmon and sea bass on current diets), or is less efficient (livestock).

**Table 8.1. Ecological conversion efficiencies from sandeel to product under various feed conversion rates. Figures are given for production of nutritionally complete pellets (100t sandeel yields 20 t feed) and sandeel meal and vegetable oil pellets (100 t sandeels yields 44.4 t feed)**

Feed conversion ratio	Overall conversion efficiency of sandeels into fish fed on pellets limited by fish oil yield	Overall conversion efficiency of sandeels into fish fed on pellets with the addition of oil from other sources	Source and notes
1.2	16.7%	37.0%	Maximum efficiency of salmon production (Nutreco, pers comm., 2003)
2.0	10.0%	22.2%	Typical global conversion efficiency (Naylor <i>et al.</i> , 2000) and for salmon in the 1980s (Gowan & Bradbury, 1987).
1.9	10.5%	23.4%	Efficiency of feed conversion for sea bass(Nutreco, pers comm., 2003)

There may be benefits to using processed feeds however, as they can be supplemented with other substances and be made more efficient at adding body weight with respect to the food consumed, than consuming unprocessed food, e.g. consuming fish directly.

### **8.1.2. Substitutability**

Whilst EU aquaculture production has stabilised in the last 2 to 3 years, it is projected to increase again (MEP, 1999). This will increase the demand for fish meal and oils by 2010 from 206,000 to 318,000 tonnes and 194,000 to 327,000 for meal and oil respectively. Without any corresponding change in the EU feed fish supply base and allowing for substitution, the EU's deficiency in production is likely to rise from 44% to 68% for fish meal, and from 27% to 47% for fish oil. Demand for fish oils is likely to reach critical levels by 2010.

- **Alternatives to fish meal and fish oil**

Soya is the main competitor product to fish meal. The price ratio of soya to fish is presently 1:2.72. Soya is cheaper than fish meal but nutritionally poorer. Substitutions of soya for fish meal are influenced by price, but only provided that the perceived quality of the meal is not adversely affected. The world supply of fish meal relative to soya is small (fish meal accounts for 5% of the total quantity of meal available on the market, soya forms 21% and the rest consists of other plant based meals).

- **Substitutions for fish meal and fish oil**

The options for replacing and supplementing current industrial fish usage include:

- **Use of fisheries by-catch and discards**

The use of discards and by-catch from commercial fisheries may provide more raw material for the fish meal and fish body oil industry. This should not be a reason to inhibit management measures to reduce by-catch and discarding however. Instead, given that there will never be zero discards, this could be a beneficial use for material that is currently wasted.

- **Substitution by plant material**

Plant oils and fish oils are relatively close in price so fish oils are more susceptible to substitution in animal feeds. Substitution of marine oils with plant oils rich in n-6 PUFA (with respect to other fatty acids) are thought to compromise the immune system of cultured fish with the likelihood of increased disease and mortality. Also, substitution of fish oil with plant oils can change the fatty acid composition of the fish to the detriment of fish health and product quality. Therefore although the fish oils in aquafeeds are substitutable by up to 80% in salmonids and up to 60% in marine fish diets, a high demand for fish oils is likely to continue, with some substitution taking place as a result of price fluctuations. The continuous growth in aquaculture production will also ensure that fish oils will be fully utilised.

Research on salmonids showed where a good growth rate was achieved, up to one quarter of the dietary fish protein could be replaced by plant protein, with little if any adverse effect on growth. The trials achieving this used good quality plant proteins correctly treated to minimise anti-nutritional factors. With slow growing fish, up to

50% substitution could be achieved without adversely affecting growth. However, because plant proteins are lower in energy and digestible amino acid content than fish meal, it may not be possible to maintain these in diets as a poorer feed conversion may result. Removal of structural carbohydrate from plant proteins will minimise the energy shortfall, but the processing costs to do so are high. In addition, increased particulate waste and organic pollution may be associated with high plant protein diets.

- **Use of marine crustaceans**

Small marine crustaceans, e.g. krill and copepods, feed directly on diatoms and dinoflagellates rich in n-3 PUFA (especially eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA)). Problems harvesting these organisms, due to their complex population dynamics related to seasonality and extrinsic drivers, mean that culturing may be a method of obtaining sufficient quantities of nutritionally rich krill and copepod based feed.

- **Biotechnology (bio-fermentation products using bacteria and algae to grow the relevant fatty acids)**

At present, fish oils and cultured phototrophic microalgae are the main commercial sources of n-3 PUFA. Commercial interest in the production of n-3 PUFA from alternative sources for the use in aquaculture, functional foods and human nutraceuticals has fuelled recent research into the molecular biology of n-3 PUFA production in prokaryotes.

N-3 PUFA producing bacteria grow in the intestines of deep-sea fish and account for a large proportion of the bacterial community. These microorganisms, especially the culture of thraustochytrids and other n-3 PUFA producing microheterotrophs, are currently under scrutiny as potential commercial sources of n-3 PUFA. Several strains have been shown to produce relatively large amounts of n-3 PUFA, in one incidence production of up to 3.3g DHA per litre per day was obtained from a fermenter culture.

Furthermore, such bacteria can be used to enrich rotifers and other invertebrate larvae with n-3 PUFA. Subsequently, the enriched organisms can be used as live feed.

Biotechnology could be used to create genetically modified plants to produce nutritionally valuable, fatty acid rich oils. These approaches may not be acceptable to the EU community. EU legislation on additives and genetically modified (GM) ingredients constrains high levels of substitution

A note of caution should be applied to the above fish meal and fish oil substitutions. These alternative sources of supply have been acknowledged for some time, but very few developments have occurred.

### **8.1.3. Human health implications**

The benefits of consuming n-3 PUFA present in fish oil are considerable. The demand for these essential fatty acids is likely to increase greatly as their benefits to human health become more widely recognised. n-3 PUFA is a major structural component of cell

membranes and are important to human health and have cardiovascular, immune and brain development functions. Ecologically, it is more efficient to consume the fish directly to obtain the oil rather than dietary supplements. However, the recommended intake of EPA and DHA is 500mg a day, which is equivalent to consuming fish 2.5-3 times a week. A 1g fish oil capsule can provide 200 - 300mg of n-3 PUFA. In many countries, especially those of northern Europe, where the consumption of fish is considerably less than that recommended, the use of fish oil capsules is an effective method of ensuring the human population receives the recommended dosage of n-3 PUFA.

Functional foods (foods enriched with health supplements) are a new way of increasing the intake of n-3 PUFA without radically changing the eating habits of the population. This is an especially attractive strategy in some EU countries where the consumption of oily fish is low. The limited shelf life of foods enriched with n-3 PUFA is a drawback however. Functional foods enriched with n-3 PUFA have a shelf life of up to 6 months if stored at 4°C, although new developments, such as micro-encapsulation, are capable of increasing their shelf-life to more than 2 years. This enables their use in a large variety of foods such as infant formulas, bread mixes and spreadable fats. Spreadable fats can be enriched by up to 1% n-3 PUFA with no significant influence on sensory acceptability. Daily consumption of these fats (25-30g.day<sup>-1</sup>) can provide 0.2-0.3g n-3 PUFA supplying levels above those eaten normally.

## **8.2. Analysis of the compatibility of the fish meal and fish oil industry with the economic and ecological objectives of the new CFP**

### **8.2.1. Ecological objectives of the CFP**

The ecological objectives of the reformed CFP (EC, 2002b) of most relevance to the industrial fisheries are:

- ◆ reducing overall fishing pressure,
- ◆ improving fishing methods to reduce discards, incidental by-catch and impact on the sea bed,
- ◆ implement the Biodiversity Action Plan for fisheries,
- ◆ further fulfilment of the Birds and Habitats Directive.

### **8.2.2. Reducing overall fishing pressure**

The reformed CFP has called for a reduction in fishing pressure on fishing grounds to sustainable levels. However, most industrial fisheries for small teleost feed fish are considered to be within safe biological limits, e.g. the sandeel in the North Sea, Baltic sprat and Norway pout, although they are currently being exploited to the maximum capacity. For stocks of a few industrial feed fish however, too little is known about the state of the stocks e.g. North Sea sprat and blue whiting in the North Atlantic (ICES stock assessments, 2002d, 2003a), which is of some concern given the current levels of effort expansion by EU states, Norway and a number of other participants.

The deep water shark fisheries have been exempted from any form of scrutiny and their exploitation is not an ecologically sustainable process. The biology and life histories of elasmobranchs (late maturity and low fecundity) mean the resilience of the population to the removal of individuals is weak (Greenstreet and Rogers, 2000; Hill *et al.*, 2001; Jennings *et al.*, 1999; Jennings *et al.*, 1998; Stevens *et al.*, 2000; Walker and Hislop, 1998). Currently,

the data provision of direct and by-catch elasmobranch harvesting is inadequate, making stock assessments uncertain. The Commission advocates a long-term strategy to promote the protection of vulnerable species, such as cetaceans, sharks, skates and rays and marine birds, and habitats by such means as gear restrictions and closed areas and seasons. The Commission presently outlaws finning because of its impact on the stock and yet appears to tolerate the existence of this fishery.

### **8.2.3. Improving fishing methods to reduce discards, incidental by-catch and impact on the sea bed**

Most catches of teleost feed fish caught for industrial purposes are considered free of non-target species. However there are some exceptions (e.g. Norway pout) when juveniles of other commercially important fish, such as haddock and whiting, shoal with feed fish species. This only occurs at certain times of the year and in certain locations and by-catch restrictions have been introduced to protect these fish e.g. closed areas. Also, a preliminary analysis of the Danish and Norwegian industrial fisheries (ICES, 2003c), indicates that mortality to young haddock and whiting due to industrial fishing can be considered small in comparison with the total estimated survivors in the juvenile haddock and whiting year class, given that the natural mortality of juvenile fish is high.

No research has been published on industrial fishing accidentally catching sea birds and mammals as by-catch in EU waters. However, a study by BirdLife International (1999) considered that trawls (which are the primary gear used in the industrial fisheries) were less likely to capture birds than gill nets.

The impact of industrial fisheries on habitats is likely to be small, although no direct studies on the effect of the industrial fisheries on sea floor habitats and benthos have been conducted (ICES, 2003c). The purse seines used in the industrial fisheries have no direct impact on the sea floor as they operate within the water column. The boards of the otter trawls may disturb the sea floor although the gears used are lighter than those used in comparable demersal otter trawling operations. Industrial fishing is seasonal, so any damage will be followed by a period of recovery.

### **8.2.4. Implementing the Biodiversity Action Plan for fisheries**

The Biodiversity Action Plan for Fisheries (EC, 2001) has identified four areas requiring action. Amongst these the BAP for fisheries seeks:

- To promote the conservation and sustainable use of fish stocks and feeding grounds through control of exploitation rates and through the establishment of technical conservation measures to support the conservation and sustainable use of fish stocks. Measures available include *inter-alia* fishing exclusion areas (mainly for the protection of dense aggregations of juvenile fish), and mesh sizes. Each measure should be applied according to its merits and expected conservation effect (see Section 8.2.3. above).
- To reduce the impact of fishing activities and other human activities on non target species and on marine and coastal ecosystems to achieve sustainable exploitation of marine and coastal biodiversity.

There is a great deal of research on the ecosystem effects of fishing for sandeels which has been driven primarily by their interaction with the population dynamics and biology of other animals, such as seabirds and marine mammals. The interaction between sandeels and seabirds is especially apparent at local scales (Lewis *et al.*, 2001; Furness and Tasker, 2000). The reproductive success of the kittiwake (*Rissa tridactyla*) and grey seals (*Halichoerus grypus*) have been correlated with the availability of sandeel near colonies (Harwood *et al.*, 1999). Closed areas, where industrial fishing for sandeels is prohibited, have been established to ensure the availability of prey items to high trophic predators. These closed areas are subject to review.

#### **8.2.5. Economic objectives of the new CFP**

The economic objectives of the Common Fisheries Policy are to ensure:

- an economically viable and competitive fisheries and aquaculture industry which will benefit the consumer;
- a fair standard of living for those who depend on fishing activities.

Many of the points proposed by the reformed CFP have already been introduced to industrial fisheries. These include:

- A fleet which is well within the levels required to ensure sustainable production.
- A consistently high level of research applied to most species.
- Management measures already applied to industrial fisheries have been created to conserve biodiversity and minimise the impact on habitats (e.g. closed areas, closed seasons and by-catch restrictions).
- Enforcement mechanisms proposed by the reformed CFP are already applied to both the Danish and Swedish industrial fishing fleet.

#### **8.2.6. Socio-economic factors concerning the industrial feed fish fisheries**

The industrial feed fish fisheries account for 21% of the total EU catch but only 2.1% of the economic value added from the total fishing industry. Direct employment in the sector is 2,216 in Full Time Equivalents. This is only 0.5% of those employed in the EU's fish processing and catching sector. Nevertheless, the Danish, Swedish, Finnish and increasingly the Polish fishing industries have a significant stake in the industrial fisheries within the EU. Many of the fishers in Denmark, Sweden and Finland are either partly or wholly dependent on fishing and equal to 41% of total fisher employment in Denmark and 61% in Sweden. No dependency figures are available for Finland. This represents 1,585 fishers. Moreover, removal of industrial fishing will have a significant consequence on both Danish and Swedish fishing communities, reducing fisher related employment by 25%, or a loss of 900 jobs.

Other onshore employment is not especially significant to the sector relative to, for example whitefish, since many of the fish meal operations (catching, handling and processing) are fully integrated and already included in the figure of 2,216.

If catches are constrained, as a result of management objectives, it is important to not only single out the economic impact on specific groups within the fishing sector, but to also acknowledge the importance of feed fish to the aquaculture sector and to human health. Increasing competition for imports allied to increasing shortages in fish trimmings and a sustained long term growth in aquaculture production provides ample economic justification

for the retention of a directed fishery for feed fish as a major ingredient to aquaculture. Aside from those employed directly in the sector, the linkage with the farming and aquaculture sector (63,189 farm workers and 4,549 aquafeeds and downstream support workers) is of significance. If the EU is 44% dependent on aquaculture supplies, 29,800 workers can be directly linked to the EU feed fish and trimmings sector.

#### **8.2.7. The contribution from the fish trimmings sector**

Approximately a third of the sector's supplies come from trimmings which may be sourced from fisheries which are not as sustainable as the industrial fisheries. Trimmings are the only source of supply in Spain, France and Germany. In other cases which use a mixture of feed fish and trimmings, such as the UK and Ireland, the economics of production suggest that without fish trimmings, factories would cease to operate. This would have serious cost implications for fish processors as a result of having to forgo sales revenue for offal and having to incur additional costs of disposal. This might create some casualties in the processing sector which are already operating on low margins, increase prices to consumers, and would reduce prices offered to fish producers.

#### **8.2.8. Economic factors concerning the industrial shark fisheries**

The industrial feed fish and shark fisheries within the EU are very different and a number of points need to be made regarding the shark fishery within the context of the reformed CFP. These include:

- 1) Urgent management action is required in fisheries specifically targeting elasmobranchs.
- 2) Fishing capacity in the industrial shark fishery is above that required to harvest fishery resources
- 3) More vessels could be attracted to the fishery if there was a corresponding increase in the price of oil. Access is only tempered by declining stocks.
- 4) No management restrictions apply to this fishery. Closed areas and closed seasons could be investigated. A ban already applied in the fishing for basking sharks.

### **8.3. Conclusions**

The raw materials used in the fish meal and fish oil industry are derived from targeted industrial fisheries and by-products of other fisheries. Economically, the industrial fisheries are substantially smaller than the fisheries for human consumption, but in some EU countries, large proportions of the fishing fleet are dependent on the capture of industrial feed fish.

The products of the fish meal and fish oil industry are considered important to aquaculture, the farming of livestock and to human health. The fish meal and fish oil industry therefore also affects employment in sectors such as fish trimmings, the fish meal and oil processing sector, and farming and aquaculture.

The production of fish meal, fish body oils and fish liver oils are dependent on two groups of fish whose vulnerability to industrial fishing activities are very different. Most stocks of industrial teleost feed fish are harvested in a sustainable manner and are considered to be

within their safe biological limits. However, too little is known about a few of these stocks, e.g. blue whiting in the North Atlantic, which are of serious concern. The extremely dynamic population size of feed fish, which is strongly related to extrinsic forcing, means it is essential that a precautionary approach is used when managing these stocks.

The harvesting of elasmobranchs for liver oil however, is currently not sustainable. The biology and life histories of these fish makes their populations particularly vulnerable to exploitation. The lack of protection and management measures applicable to the majority of elasmobranch species needs to be addressed as a matter of urgency.

The by-catch of juvenile fish of commercial importance is one of the most controversial aspects of industrial fishing. Sandeel shoals are considered 'clean' of other species. However, in other fisheries, mixed shoals of fish which include industrial teleost species and juveniles of commercial gadoids can occur at certain times of the year in certain areas. These can be managed by combination of measures including by-catch restrictions and area closures at certain times of the year in the affected areas. These restrictions need to be reassessed continually. Management measures are only effective if control regimes and fishermen's compliance accompanies these. The experience gained from this study shows that the enforcement authorities strictly monitor compliance and that the fishers themselves have the highest compliance levels throughout the EU.

The data collected on industrial teleost species suggests that most stocks are currently exploited within safe biological limits. The predicted increase in demand for fish meal and fish oil for aquaculture, as a result of reducing pressure on wild fish caught for human consumption, means there is an urgent need to develop alternatives to fish meal and fish oil in the near future. It will need to be sourced outside of the fisheries.

#### 8.4. Recommendations

- ◆ The total allowable catch (TACs) of feed fish should include a component related to the environment, as extrinsic factors are capable of causing massive changes in population size.
- ◆ Shark catches need to be reduced and monitored as a matter of urgency.
- ◆ The by-catch issue, with regards to juvenile fish, needs to be stringently monitored and requires more research.
- ◆ The predicted increased demand for fish meal and fish oil from the aquaculture sector must not increase the pressure on feed fish stocks if these fisheries are to remain sustainable. Further investigation into cheap and high quality alternatives to fish meal and fish oil must be conducted<sup>36</sup>.

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<sup>36</sup> Currently, the most likely substitutes are derived from plant oils which may jeopardise the growth of carnivorous fish if substitution is too extensive, especially during early growth stages, and affect fish immune systems. Although substitutes are used by manufacturers, concerns about the growth and health of the farmed animals must be addressed to increase their use.



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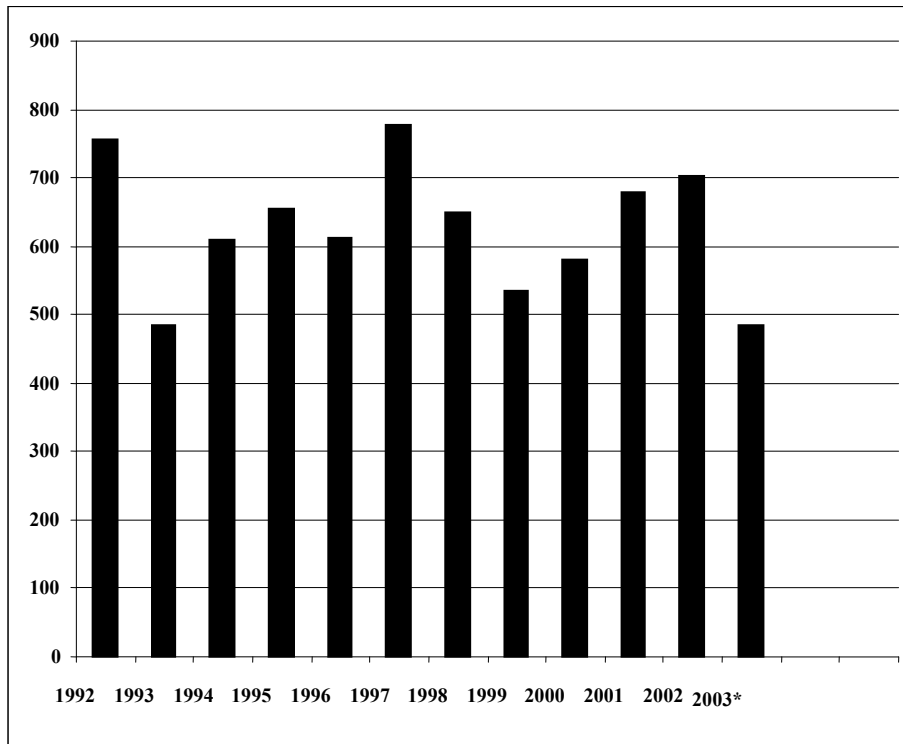




## APPENDICES

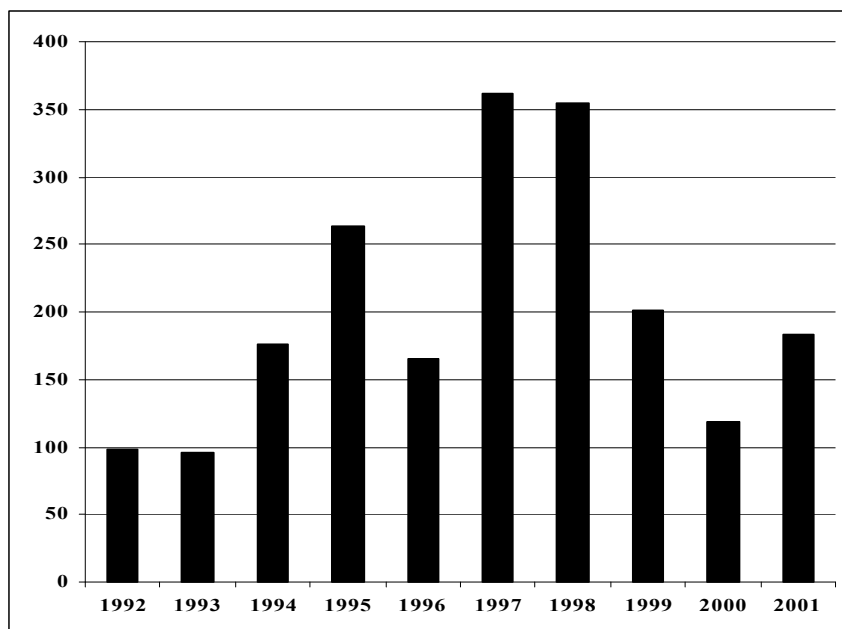
### Appendix 1: Summary catch data 1992/1993 – 2001/2003 (Source: ICES, 2003)

**Figure A.1.1. EU Sandeel catches, 1992-2001 ('000 tonnes)**



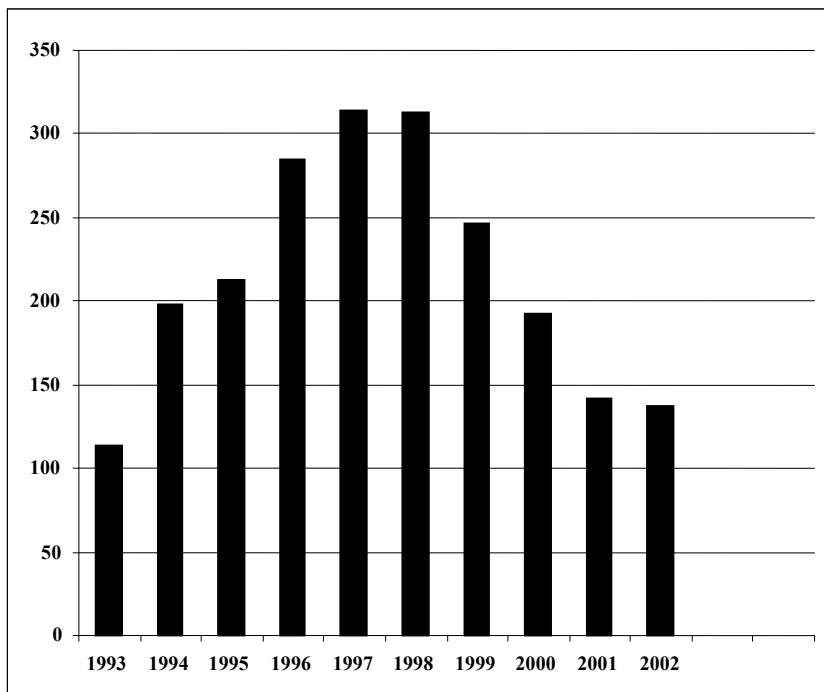
Sources: ICES, 2003

**Figure A.1.2. Non EU Sandeel catches, 1992-2001 ('000 tonnes)**



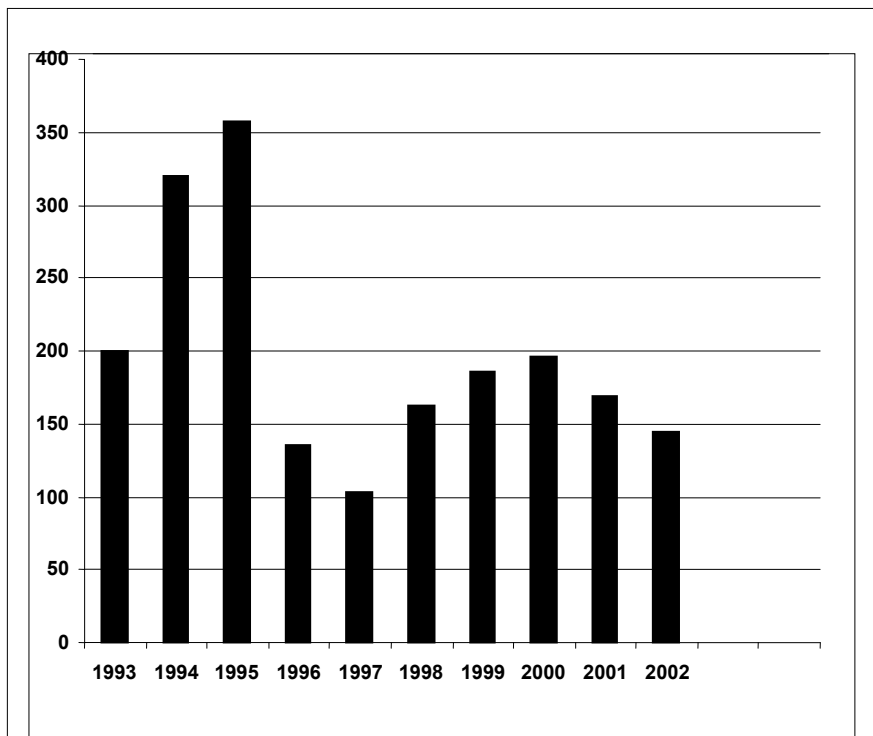
Source: ICES, 2003

**Figure A.1.3. EU Sprat catches, 1993-2002, Baltic sub areas 23-32 ('000 tonnes)**



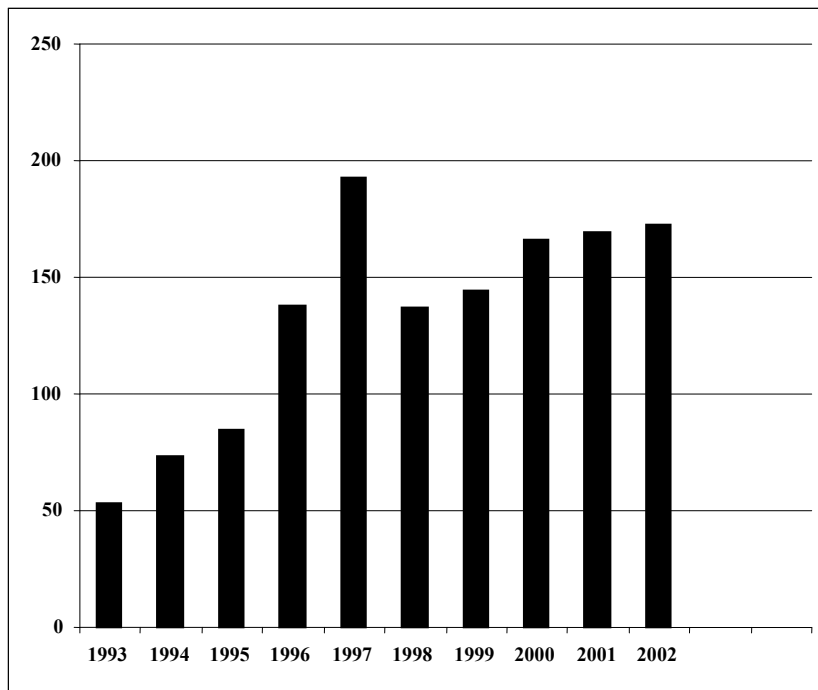
Source: ICES, 2003

**Figure A.1.4. EU North Sea Sprat catches, 1993-2002 ('000 tonnes)**



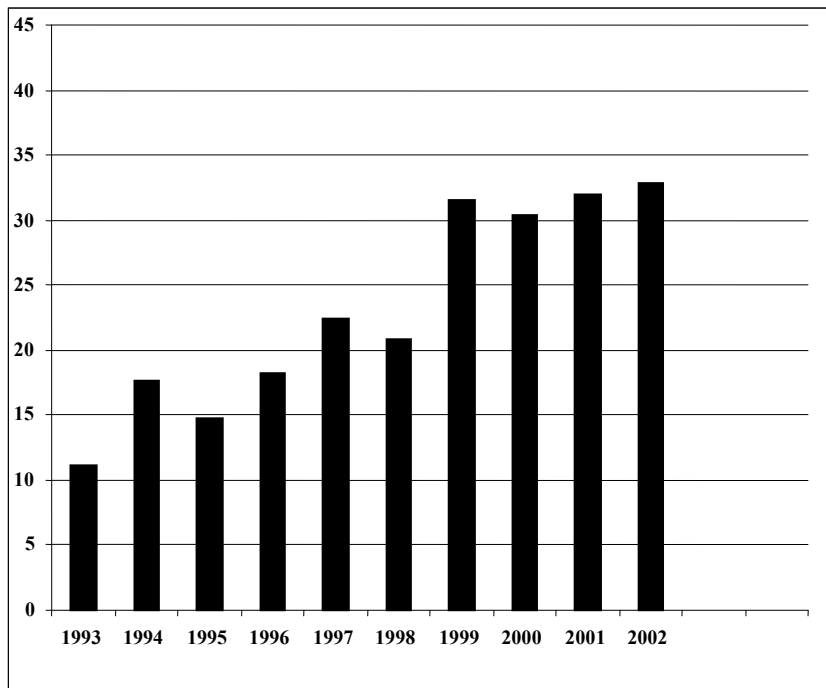
Source: ICES, 2003

**Figure A.1.5. EU Candidate country Sprat catches, 1993-2002, Baltic sub area (23-32) ('000 tonnes)**

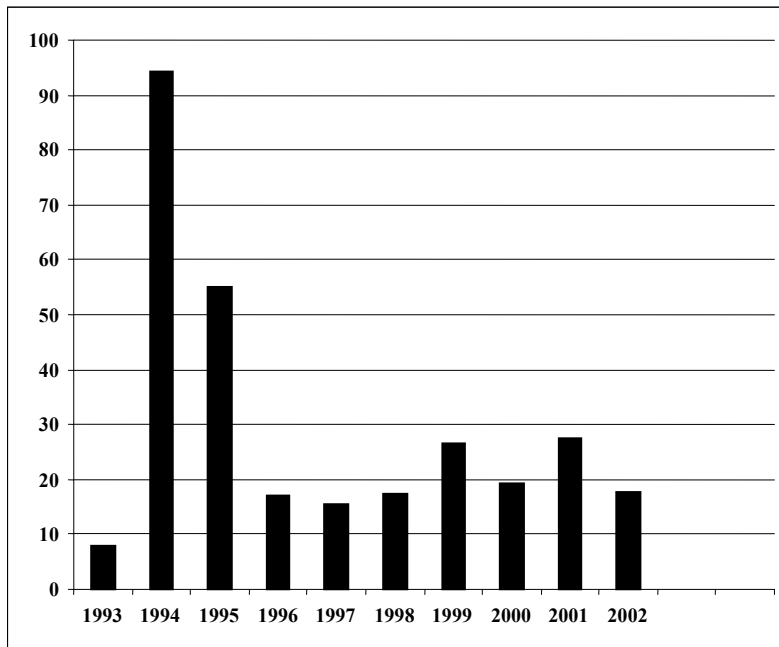


Source: ICES, 2003

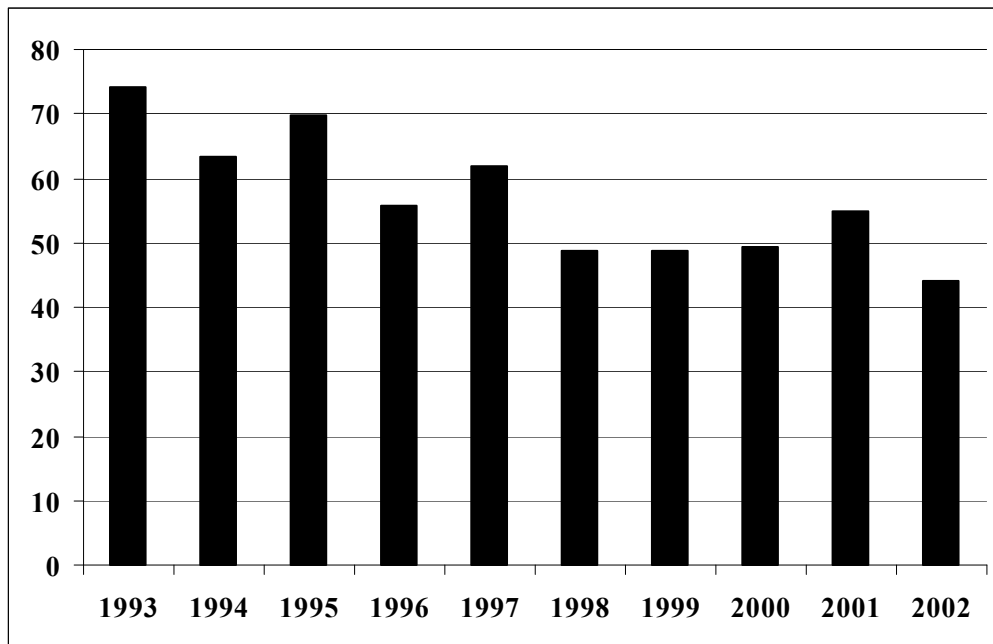
**Figure A.1.6. Non EU country Sprat catches, 1993-2002, Baltic sub area (22-32) ('000 tonnes)**



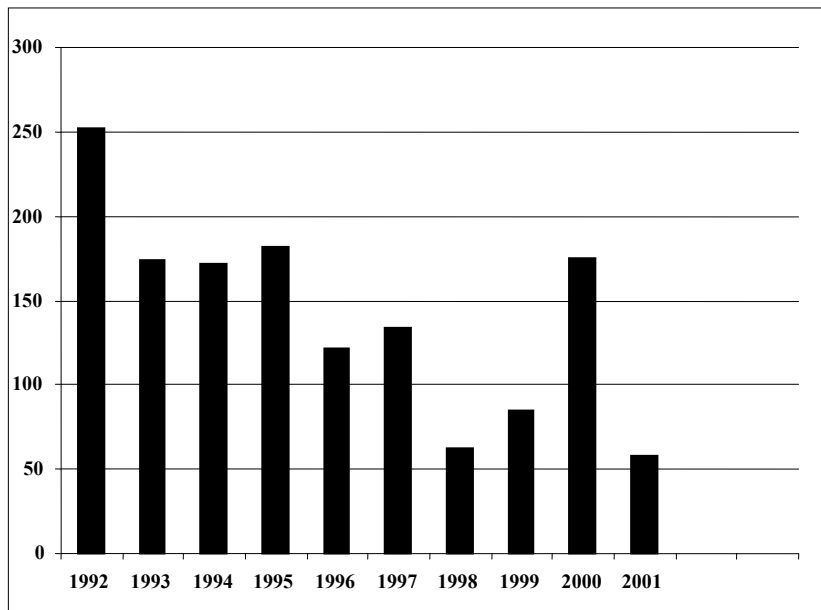
Source: ICES, 2003

**Figure A.1.7. EU sprat catches, 1993-2002, Kattegat/Skagerrak (IIIa) ('000 tonnes)**

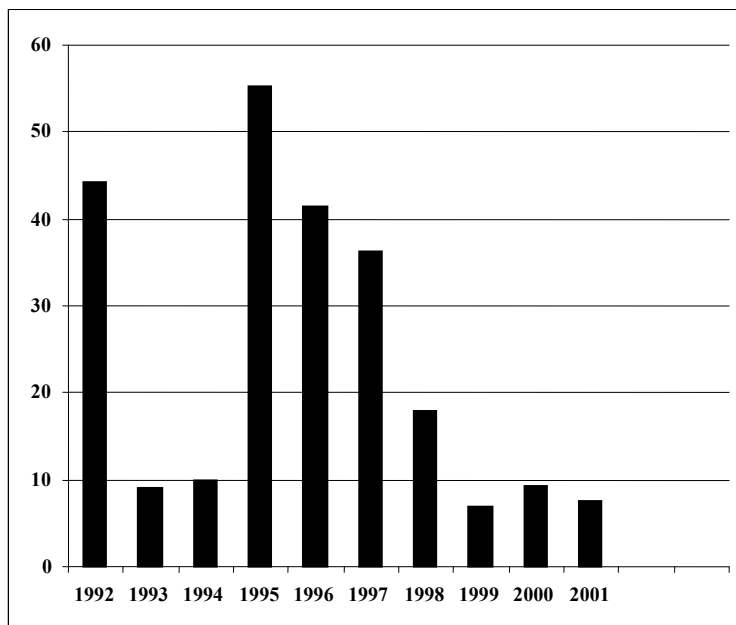
Source: ICES, 2003

**Figure A.1.8. EU Baltic Herring catches, 1993-2002, ('000 tonnes)**

Source: ICES, 2003

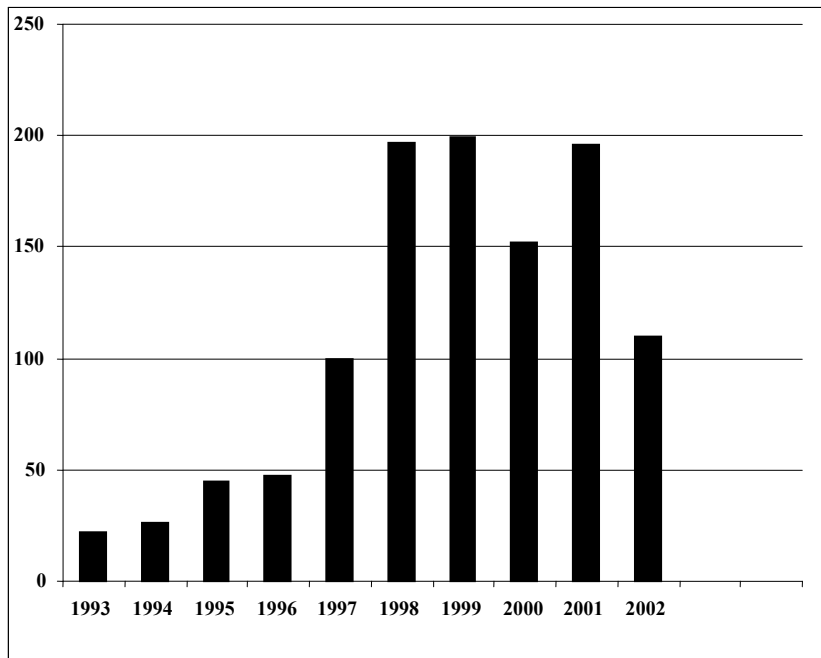
**Figure A.1.9. EU Norway pout catches, 1992-2001, (Subarea IV and Division IIIa) ('000 tonnes)**

Source: ICES, 2003

**Figure A.1.10. Non EU Norway pout catches, 1992-2001, (Subarea IV and Division IIIa) ('000 tonnes)**

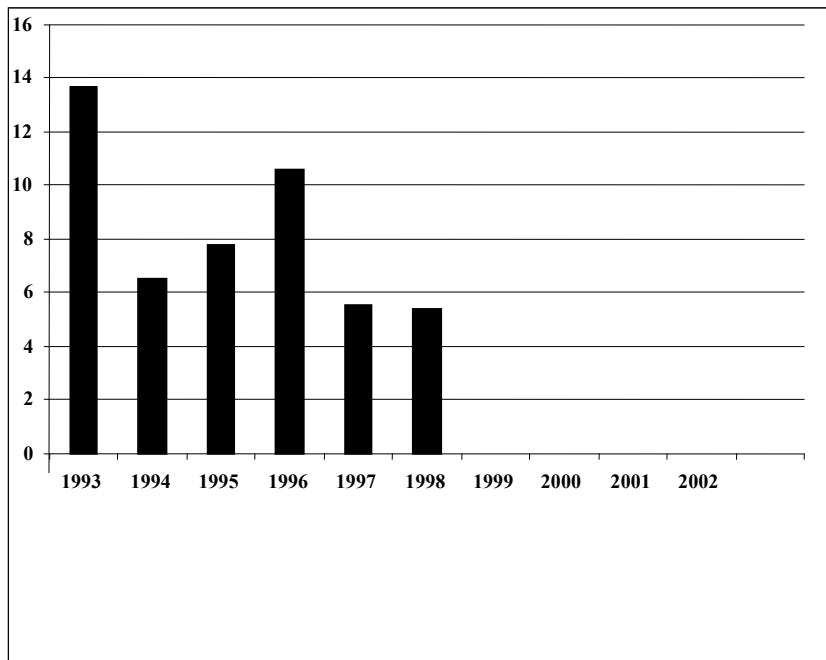
Source: ICES, 2003

**Figure A.1.11. EU Blue whiting catches, 1993-2002**  
**(Division Vb,Vla,b, VIIb,c. VIIg-k and Sub-area XII) ('000 tonnes)**



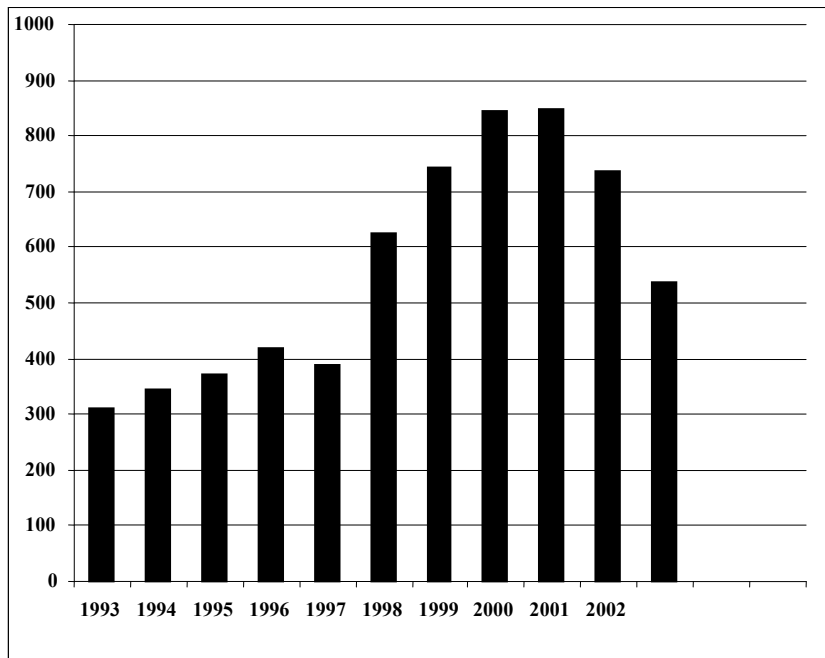
Source: ICES, 2003

**Figure A.1.12. EU Candidate country Blue whiting catches, 1993-2002**  
**(Division Vb,Vla,b, VIIb,c. VIIg-k and Sub-area XII) ('000 tonnes)**



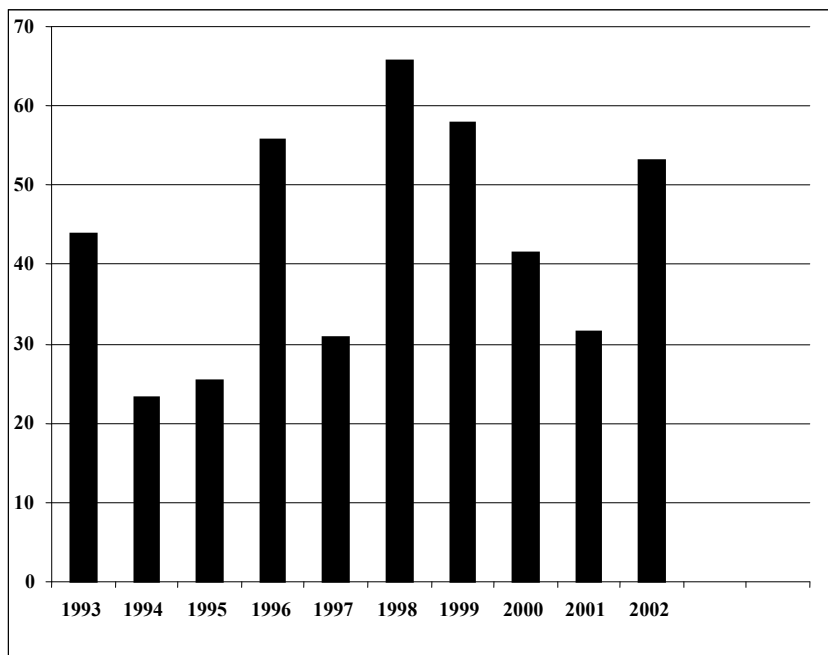
Source: ICES, 2003

**Figure A.1.13. Non EU Blue whiting catches, 1993-2002**  
**(Division Vb,Vla,b, VIIb,c, VIIg-k and Sub-area XII) ('000 tonnes)**



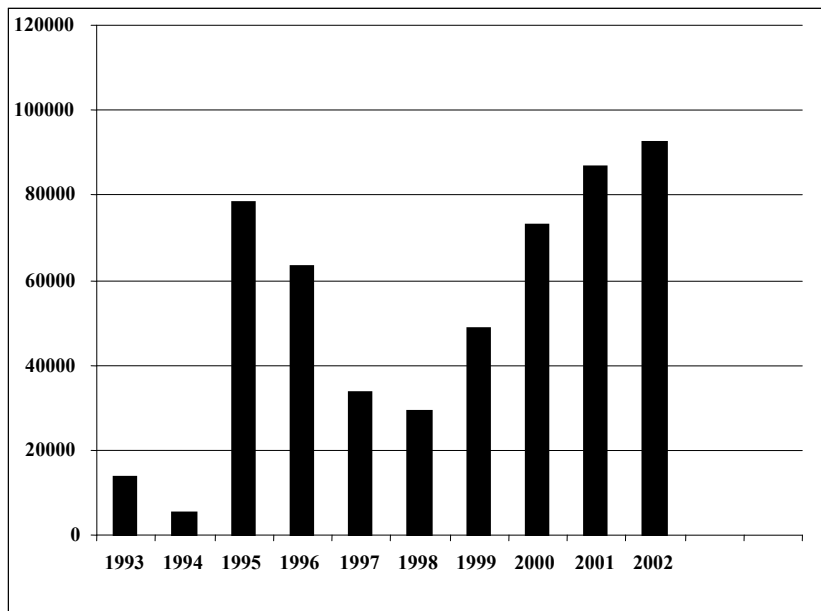
Source: ICES, 2003

**Figure A.1.14: EU Blue whiting catches, 1993-2002, (Divisions IIIa, IVa) ('000 tonnes)**



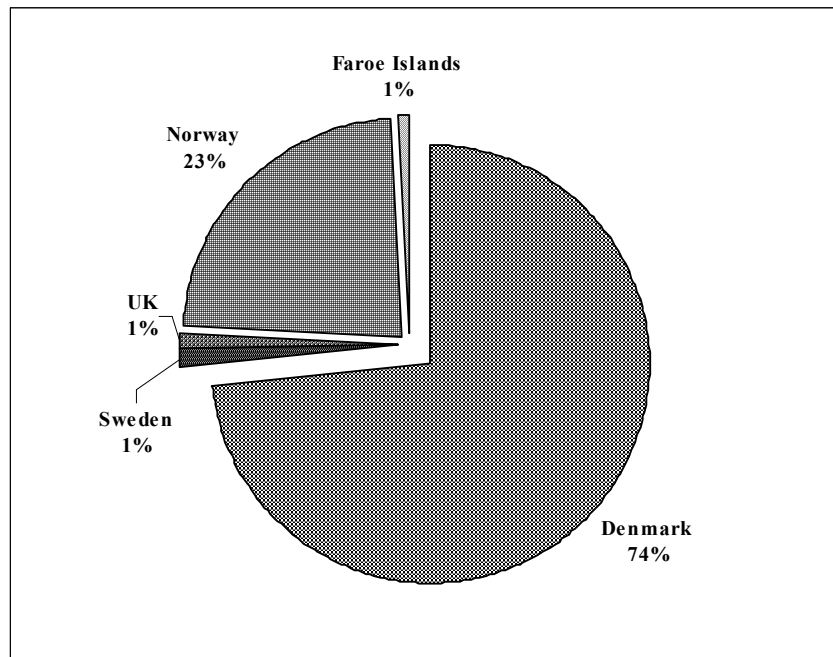
Source: ICES, 2003

**Figure A.1.15. Non EU blue whiting catches, 1993-2002, (Divisions IIIa, IVa) ('000 tonnes)**



Source: ICES, 2003

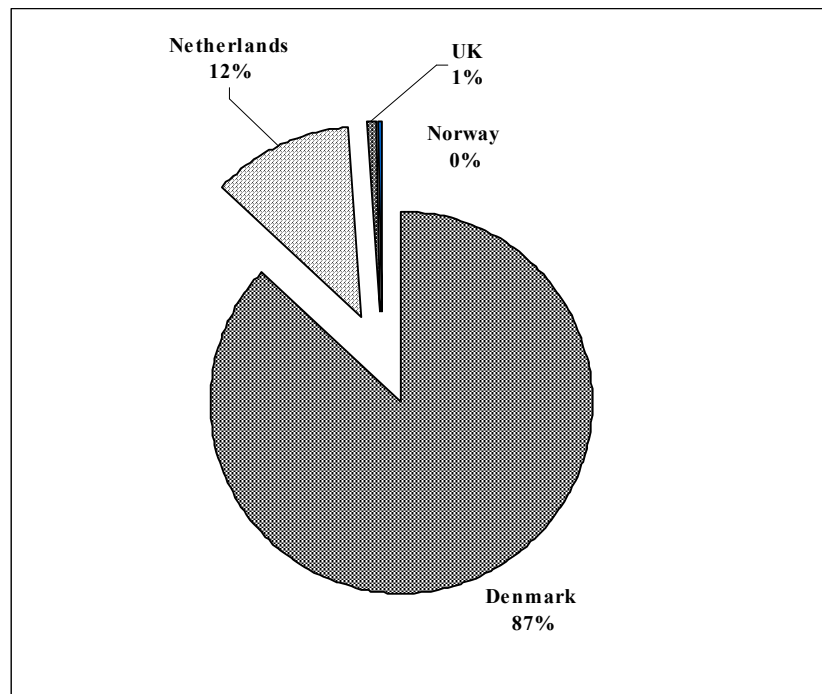
**Figure A.1.16. International share of North Sea Sandeel catches**



Source: ICES, 2003

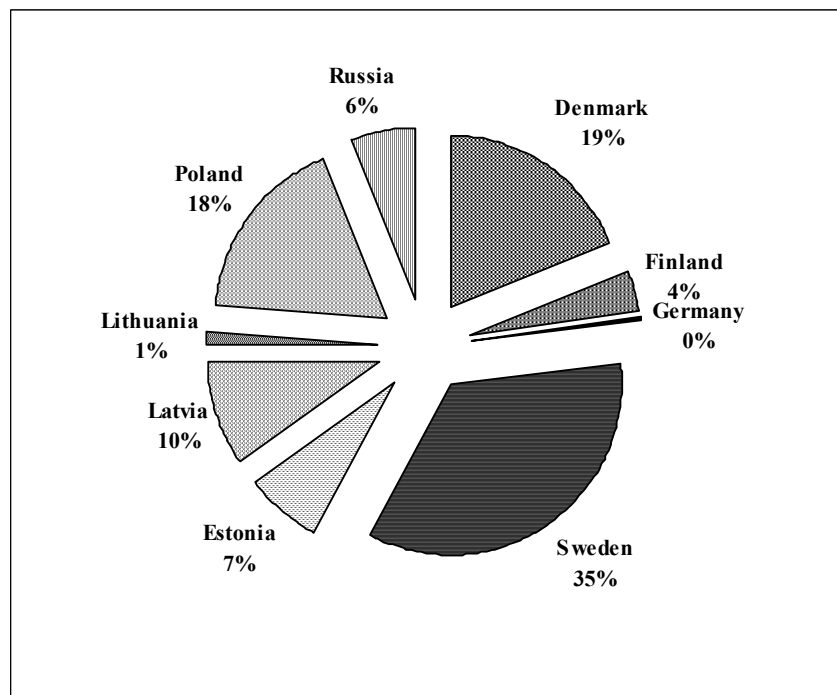


**Figure A.1.17. International share of North Sea Sprat catch**



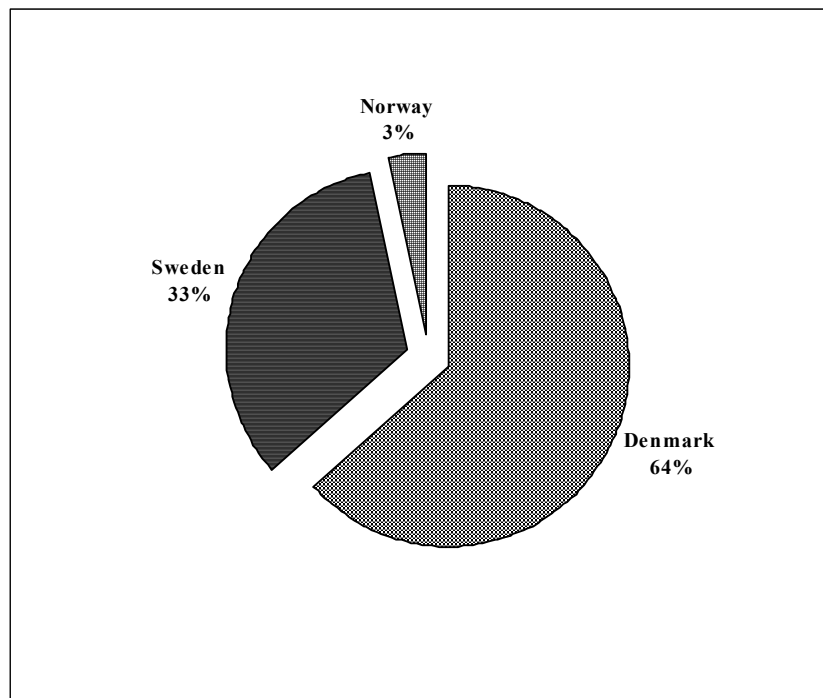
Source: ICES, 2003

**Figure A.1.18. International share of Baltic sprat catches (23-32)**



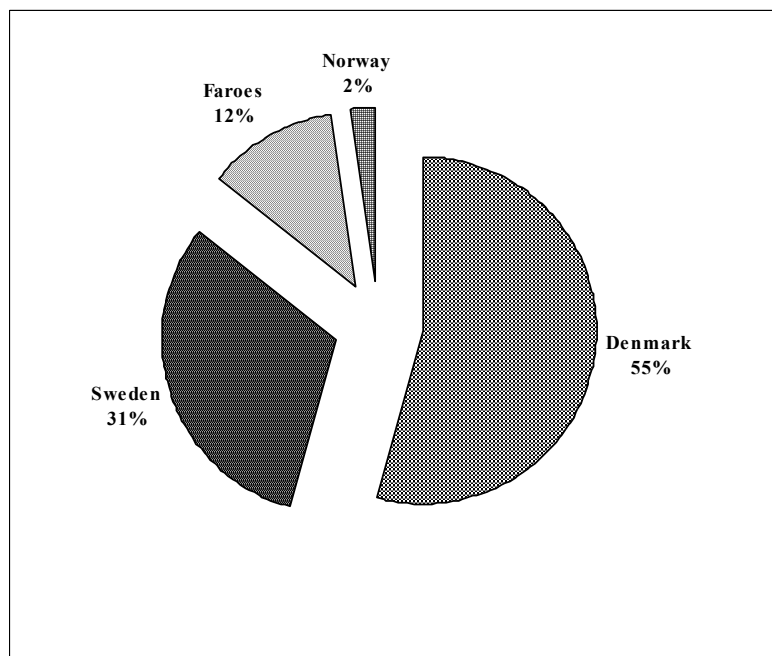
Source: ICES, 2003

**Figure A.1.19. International share of Kattegat/Skagerrak sprat catches (IIIa)**



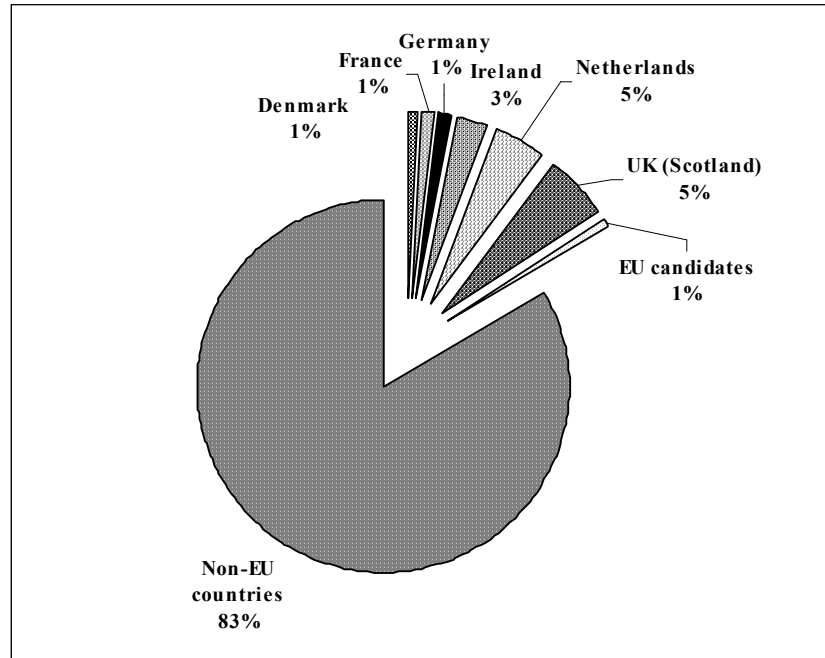
Source: ICES, 2003

**Figure A.1.20. International share of Norway pout catches, (Subarea IV and Division IIIa)**



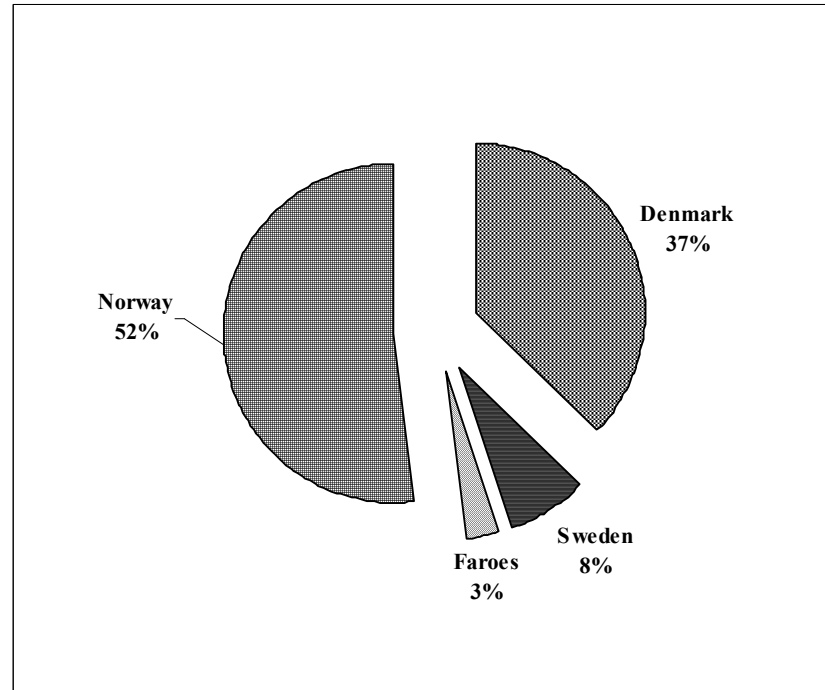
Source: ICES, 2003

**Figure A.1.21. International share of blue whiting (International Waters)**



Source: ICES, 2003

**Figure A.1.22. International share of blue whiting catches,(Divisions IIIa, IVa)**



Source: ICES, 2003



## Appendix 2: Exports of fish meal from Denmark, 2001

**Table A.2.1. Exports of fish meal from Denmark, 2001**

<b>Country</b>	<b>000 tonnes</b>
Greece	48.1
Norway	47.5
Italy	30.1
Japan	18.7
Spain	14.4
Egypt	13.9
Netherlands	10.6
Taiwan	11.7
USSR	12.9
Cyprus	9.3
Finland	5.7
France	4.8
UK/Ireland	2.7

*Source: Fisheries Directorate, Denmark*



### Appendix 3. Consumption and Imports of fish body oils

**Table A.3.1. Consumption of fish body oils ('000 tonnes)**

Country	1997	1998	1999	2000	2001	Average	% change
Chile	172	124	180	245	236	191	137%
Norway	156	154	181	214	213	184	137%
Peru	132	80	160	178	64	123	48%
Canada	30	34	38	24	52	36	173%
China	13	10	38	49	30	28	241%
Japan	114	107	107	122	142	118	125%
UK	80	58	57	54	69	64	79%
Denmark	60	47	55	53	99	63	105%
Netherlan	73	11	47	66	24	44	61%
Spain	21	36	31	35	42	33	159%
France	26	21	27	24	32	26	99%
Italy	21	19	28	29	22	24	112%
Germany	44	12	16	19	14	21	48%
Finland	9	6	5	3	4	5	58%
Ireland	6	4	6	5	5	5	87%
Belgium	18	1	1	4	1	5	28%
Sweden	1	0	0	4	4	2	167%
Austria	1	1	1	1	1	1	88%
Portugal	0	1	1	1	1	1	205%
1							
Poland	2	1	1	1	2	1	64%
Czech	0	0	0	0	0	0	80%
Total EU	280	159	218	243	247	229	82%
Other	282	205	273	297	192	250	89%
World	1,261	933	1,252	1,427	1,248	1,224	97%

Source: FAO

**Table A.3.2. Imports of fish body oils ('000 tonnes)**

Country	1997	1998	1999	2000	2001	Average	% change
Norway	206.7	158	219.5	237.3	246	213.5	119%
Japan	69.8	28	26.4	51.5	92.7	53.68	133%
Chile	11.4	12	64.5	94.6	81	52.7	711%
Canada	30.4	34	40.1	24.6	51	36.02	168%
China	4.9	5.1	2.7	25.8	3.9	8.48	80%
Netherlands	137.1	43.1	108.5	132.7	68.8	98.04	50%
UK	77.8	53	47.5	44.9	60.5	56.74	78%
France	39.7	27.7	37.1	39.4	47	38.18	118%
Spain	15.9	18.5	20.7	19.8	27.8	20.54	175%
Denmark	33	15.8	20.2	29.2	26.2	24.88	79%
Italy	21.3	19.4	28.1	28.7	21.8	23.86	102%
Germany	42	12.6	12.8	14.4	13.3	19.02	32%
Finland	9.1	5.6	4.9	3.3	3.7	5.32	41%
Belgium	19.3	1.8	1.6	4.3	1.6	5.72	8%
Austria	1	1	0.8	0.9	0.7	0.88	70%
Sweden	1.7	0.5	0.4	0.6	0.6	0.76	35%
EU	397.9	199	282.6	318.2	272	293.94	68%
	397.9	199	282.6	318.2	272	293.94	68%

Source: FAO



## Appendix 4. Consumption and Imports of fish meal

**Table A.4.1. Consumption of fish meal ('000 tonnes)**

Country	1997	1998	1999	2000	2001	Average	% change
China	1,516	1,110	1,354	2,023	1,741	1,549	115%
Japan	792	712	721	685	804	743	102%
Thailand	465	418	481	477	472	463	102%
Taiwan	332	174	306	309	308	286	93%
Norway	320	249	224	363	276	286	86%
USA	361	241	257	230	252	268	70%
Russia	250	248	201	186	231	223	92%
Non EU Other	1,464	1,228	1,810	1,472	1,289	1,453	88%
UK	313	271	256	278	267	277	85%
Spain	161	137	145	185	177	161	110%
Denmark	141	115	131	141	121	130	86%
France	92	91	94	75	47	80	51%
Italy	80	42	67	76	85	70	107%
Germany	58	68	57	101	22	61	38%
Greece	36	40	38	54	77	49	213%
Belgium	48	39	40	35	26	37	54%
Netherlands	55	39	24	36	30	37	55%
Ireland	32	28	28	35	34	31	106%
Finland	38	23	17	19	20	23	54%
Portugal	22	14	17	18	17	18	77%
<b>Candidate countries</b>						81	
Hungary	35	37	34	35	26	33	74%
Poland	22	13	12	13	34	19	152%
Czech	26	22	20	23	15	21	57%
Cyprus	7	7	7	8	8	7	111%
EU 25	1,166	986	987	1,130	1,006	1,055	86%
<b>Total</b>	<b>6,666</b>	<b>5,366</b>	<b>6,341</b>	<b>6,875</b>	<b>6,379</b>	<b>6,379</b>	

Source: FAO

**Table A.4.2. Imports of fish meal ('000 tonnes)**

Country	1997	1998	1999	2000	2001	Average	% annual change
China	985	416	661	1,235	1,062	986	8%
Japan	437	330	346	338	478	388	9%
Taiwan	320	172	294	299	295	296	-8%
Indonesia	121	40	77	118	112	102	-7%
Iran	63	63	77	67	42	62	-33%
USA	64	57	33	36	51	40	-20%
Norway		100	145	185	143	158	12%
UK	285	239	221	241	233	232	-18%
Denmark	87	95	140	131	126	132	45%
Spain	93	61	90	120	107	106	15%
France	83	83	93	92	61	82	-27%
Italy	88	48	68	76	87	77	0%
Germany	292	252	233	303	197	244	-33%
Greece	36	40	38	54	77	56	113%
Netherlands	55	39	24	36	30	30	-45%
Belgium	48	39	40	35	26	33	-46%
Finland	31	21	14	16	26	19	-16%
Portugal	13	11	13	15	14	14	8%
Ireland	1	1	6	6	10	7	1481%
Candidate	115	115	66	68	73	69	
Poland		2	2	4	21	9	708%
Hungary		37	34	35	27	32	-24%
Czechoslovakia		69	23	22	19	21	269%
Cyprus		7	7	8	6	7	-17%
EU		1,158	1,112	1,260	1,139	1,170	-7%

Source: FAO

## Appendix 5. Management measures in the European Union

Industrial fisheries by European Union members

Details of status of stocks and management measures of industrial fish species destined for fishmeal (not including those primarily used for human consumption).

### In ICES areas

#### Sandeel

The fishery is seasonal, taking place mostly in spring and summer.

#### **Source of management advice**

ICES based on a seasonal age-based assessment using commercial and survey data.

#### **State of stock/exploitation**

Sub-area IV The stock is considered within safe biological limits.

#### **Precautionary reference points in sub-area IV**

ICES considers that:	ICES proposes that:
$B_{lim}$ is 430 000 t	$B_{pa}$ is 600 000t

#### **Technical basis**

$B_{lim}$ is 430 000t, the lowest observed biomass	$B_{pa}$ is set to $1.4 * B_{lim}$
$F_{lim}$ non advised	$F_{pa}$ non proposed

**Sandeel in Division IIIa (Skagerrak – Kattegat)** Based on the available information ICES was unable to assess the state of the stock or identify safe biological limits.

**Sandeel in Division VIa** There is no current information on which to evaluate the state of the stock. The current management regime uses a multi-annual TAC of 12 000 t per year with the fishery closed from 31 July. Access is limited to vessels with a track record. These arrangements took effect in 1998 for a period of three years and were renewed in 2001.

**Sandeel in the Shetland area** Safe biological limits have not been defined for this stock. It is believed that fishing mortality is well below natural mortality. This means that natural processes largely drive stock variations.

#### **Management advice**

ICES recommends that fishing mortality should not be allowed to increase because the consequences of removing a larger fraction of the food-biomass for other biota are unknown. Local depletion of sandeel aggregations by fisheries should be prevented, particularly in areas where predators congregate.

## Management systems

### TAC

Zone	TAC	UE	BE	DK	DE	ES	FR	IR	NL	PO	FI	SU	UK	NR
IV (Norwegian waters) IIa, IIIa, IV	NA 918000	131000 863000		124450 814067									6550 17794	31139
Total	918000	994000		938517									24344	

Minimum mesh sizes are in appendix O.K

### Closed area

Industrial fishing in the 'sandeel box' (figure A5.1.) (which covers the inshore area from eastern Scotland down to NE England) is closed if the breeding success of kittiwakes in the nearby colonies falls below 0.5 chicks per pair for 3 successive years. The fishery does not reopen until breeding success has been above 0.7 for 3 consecutive years. A 3-year closure, from 2000 to 2002, was decided and the Commission was requested to produce annual reports to the Council on the effects of the restrictions in the sandeel fishery in the Firth of Forth area. As of 2003, the restrictions on the 'sandeel box', were continued and in the future the area may become a permanent conservation area.

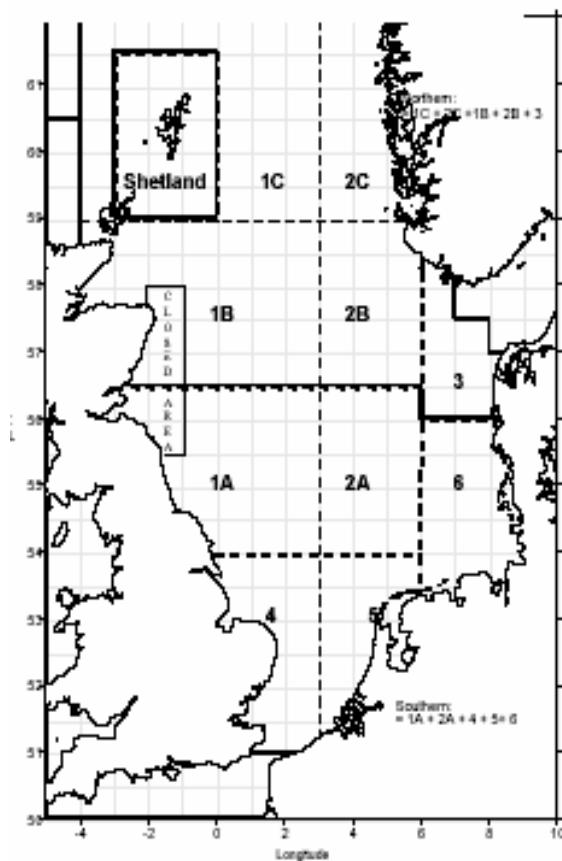


Figure A.5.1. Sandeel closed area

**Norway Pout****Norway Pout in ICES subarea IV and Division IIIA****Source of Management Advice**

ICES. The assessment is analytical using catch-at-age analysis based on quarterly catch and CPUE data.

The Norway pout fishery is mainly carried out by Danish and Norwegian (large) vessels using small mesh (minimum mesh size in 32 for Norwegian vessels and 35mm for EU vessels) trawls in the northern North Sea at Fladen Ground and along the edge of the Norwegian Trench. The fishery operates throughout the year, but mainly targets 0-group fish in the 3rd and 4th quarters as well as 1- groups in the 1st quarter of the following year. The fishery targets both Norway pout and blue whiting, with the latter being mainly caught in the deeper parts of the Deeps.

There was no management objective set for this stock in 2001 and 2002. The present fishing mortality levels indicate that the status of the stock is determined more by natural processes and less by the fishery.

The ACFM advice for 2001 and 2002 was that the stock was considered to be within safe biological limits and the stock could on average sustain current fishing mortality. Recruitment is highly variable and influences stock size rapidly due to the short life span of the species.

However, there is a need to ensure that the stock remains high enough to provide food for a variety of predator species. By-catches of other species should also be taken into account in management of the fishery. Huse *et al.* (2003) notes that very large by-catches of juvenile haddock and whiting are caught in the combined Norway pout and blue whiting fishery.

**Precautionary reference points**

Biological reference points for the stock have been set by ICES (unchanged since 1997) at **Blim** = 90 000 t as the lowest observed biomass and a **Bpa** of 150 000 t. This affords a high probability of maintaining SSB above **Blim**, taking into account the uncertainty of assessments (below this value the probability of below-average recruitment increases).

**Management Advice**

The stock can on average sustain current F. However, in managing this fishery, by-catches of other species should be taken into account, in particular haddock and whiting. Existing measures to protect other species should be maintained.

**Norway pout in Division VIa (West of Scotland)****State of the stock/exploitation**

There is no current information on which to evaluate the state of the stock. No data are available on by-catches in this fishery. Since no age compositions are available, data are insufficient for an assessment of this stock.

**Management objectives**

There are no specific management objectives for the fisheries exploiting this stock.

## Management systems

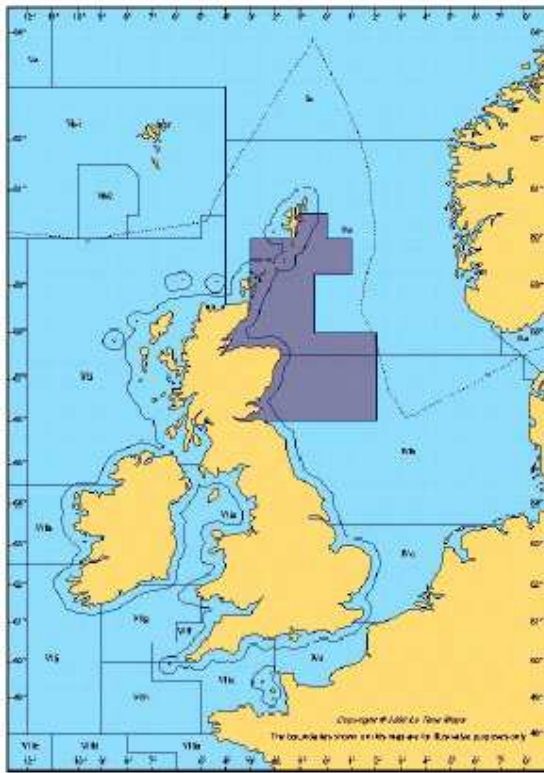
### Norway pout in ICES Subarea IV and Division IIIa and IIa TAC

Zone	TAC	UE	BE	DK	DE	ES	FR	IR	NL	PO	FI	SU	UK	NR
IIa, IIIa, IV IV	198000	173000		172840	33				127					
Norwegian Waters	NA	50000		475000									25000	
Total	198000	223000		220340	33				127				25000	

Minimum mesh sizes are in appendix O.K

### Closed areas

Currently, industrial fishing for Norway Pout is not allowed in the area (figure A5.2). Defined in EC Regulation No 3094/86, the aim of the Norway Pout Box is to protect juvenile stocks of haddock and whiting from industrial fishing for Norway Pout.



**Figure A.5.2. Norway Pout Box**

### Note:

The Norway pout stock assessed by ICES currently provides advice for Subarea IV /Division IIIA and VIa but there is some evidence that, unlike sandeel, there appears to be one stock. But ICES recommends further assessment before amalgamating the currently separately assessed stocks.

## **Blue Whiting**

### **Blue whiting in ICES sub-areas I-IX, XII and XIV**

#### **Management advice**

ICES. The assessment is based on catch data, acoustic surveys and commercial CPUE data.

This species is distributed throughout the North Atlantic extending from the Strait of Gibraltar to the Barents Sea.

The species is also found in the Mediterranean. The fish in these areas are assessed as one stock, despite evidence that there may be different stocks.

The blue whiting fishery is split into two types:

- A directed fishery, where by-catches of other species are thought to be insignificant and the landings are used for human consumption or for meal and oil production.
- A mixed fishery, where varying proportions of blue whiting are caught together with Norway pout or other species and the majority of these landings are for meal and oil production.

Most of the catches are taken in a directed pelagic trawl fishery in the spawning areas (Vb, VIab, VIIbc), but catches are also taken in I, II, Va, XIVa,b. The mixed fishery occurs mainly in IV and IIIa.

#### **State of stock/exploitation**

The stock is harvested outside safe biological limits. The spawning stock biomass for 2001 at the spawning time (April) is inside safe biological limits while the SSB for 2002 is expected to be below  $B_{pa}$ . The incoming year classes seem to be strong.

#### **Precautionary approach reference points**

ICES considers that:	ICES proposes that:
$B_{lim}$ is 1.5 mill t	$B_{pa}$ be set at 2.25 million t
$F_{lim}$ is 0.51	$F_{pa}$ be set at 0.32

#### **Technical basis**

$B_{lim}: B_{loss}$	$B_{pa} = B_{lim} \exp(1.645 \cdot \sigma) \sigma=0.25$
$F_{lim}: F_{loss} (0.51)$	$F_{pa}: F_{med} (1998)$

There has been an observed shift in the dominance to younger ages in the stock. The reasons for this e.g. an overall increase in fishing mortality and increased recruitment, a change on fishing patterns or extrinsic drivers, is unclear. The precautionary approach reference points thus may not be appropriate, but ICES consider that the biological reference points should only be revised once an analytical assessment of the stock is available.

**Management systems****TACs in regions**

<b>Zone</b>	<b>TAC</b>	<b>UE</b>	<b>BE</b>	<b>DK</b>	<b>DE</b>	<b>ES</b>	<b>FR</b>	<b>IR</b>	<b>NL</b>	<b>PO</b>	<b>FI</b>	<b>SU</b>	<b>UK</b>	<b>NR</b>
Ila, IV	NA	27650		26846	44				81			87	592	
IV (nor waters)	NA	19000		18050									950	
I, II (nor waters)	NA	1000			500		500							
Vb (Faroese water)	NA	16000		7040									7040	1920
V, XIV (Greenland waters)	NA	15000		1500	12000		1500							
V, VI, VII, XII, XIV	NA	107281		2218	8582	14304	11944	17165	26963	1073			25032	
VIIIabde	14654	14654				5530	4291			829			4004	
VIIIc, IX, X, Cefac 34.1.1.	30415	30415				24332				6083				
<b>Total</b>	<b>45069</b>	<b>231000</b>		<b>55654</b>	<b>211126</b>	<b>44166</b>	<b>18235</b>	<b>17165</b>	<b>27044</b>	<b>7985</b>		<b>87</b>	<b>37618</b>	

**Closed areas**

Iceland introduced a measure in 2002 to limit the number of immature fish taken around Iceland (area Va). If the catch comprises of 30% or more fish smaller than 25cm a temporary closure is imposed. ICES (2003 – latest stock advice) recommends that this measure be extended to other areas where significant numbers of juvenile fish are taken in the directed fisheries. ICES also note that the introduction of a minimum size limit may control the directed fishery for juveniles but may lead to increased discarding.

A variety of mesh sizes are used in the directed fisheries for blue whiting but the majority are approximately 40 mm. The fisheries where blue whiting is taken as by-catch uses trawls with mesh sizes between 16 and 36 mm.

**Sprat****In the North Sea and in IIa****Source of management advice**

ICES. No attempt to produce an assessment has been made since the 1980s.

**State of stock/exploitation**

The sprat stock is in good condition, although status cannot be evaluated relative to safe biological limits because reference points have not been set. The biomass seems to have increased in recent years, but there is a relatively low abundance of older sprat (2+) in the population.

**Precautionary Reference Points**

No precautionary reference points have been proposed for sprat in IIa and the North Sea.



### Management Advice

Sprat fisheries have a by-catch of juvenile herring, hence the exploitation of sprat will in some periods be limited by the restrictions imposed on fisheries catching juvenile herring, particularly if sprat abundance is low.

### Sprat in the Baltic

#### Source of Management Advice

ICES. The assessment is based on analysis of catch at age data calibrated with acoustic survey data.

The sprat (*Clupea sprattus*) distributed through most of the Baltic Sea are generally regarded as a single stock. Sprat spawn in open waters in the Baltic Proper, the Gulf of Riga and the Gulf of Finland between March and August. The Gulf of Bothnia is not saline enough for sprat to spawn in.

Sprat is fished both for human consumption and, more widely, for processing into fish-meal and oil. The annual catch increased after the early 1990s, peaking at 530,000 tonnes in 1997. Reduced predation by cod and favourable environmental conditions for hatching during the 1990s is thought to have contributed to an increase in the Baltic sprat stock

#### State of stock/exploitation

Based on the most recent estimate of SSB and fishing mortality ICES classifies the stock as being inside safe biological limits. SSB has decreased since 1997 to 1.2 million t in 2003, but is 30% above the long-term average. In the most recent years the fishing mortality has almost doubled compared to the early 1990s and is now close to  $F_{pa}$ . Since 1994 a number of strong year classes have entered the stock. Also the 2000 year class is predicted to be strong.

#### Precautionary Approach reference points (unchanged since 2000)

ICES considers that:	ICES proposes that:
$B_{lin}$ is 200 000 t	$B_{pa}$ be set at 275 000 t
$F_{lim}$ is not yet defined	$F_{pa}$ be set at 0.40

#### Technical basis:

$B_{lin}$ : MBAL	$B_{pa}$ : $B_{lim} \cdot 1.38$ ; some sources of uncertainty in the assessment are taken into account
$F_{lim}$ : —	$F_{pa}$ : ~ average $F_{med}$ in recent years, allowing for variable natural mortality

#### Management objectives

In Resolution XIII, September 2000, the IBSFC agreed to implement a long-term management plan for sprat in the Baltic:

*“The IBSFC agreed to implement a long-term management plan for the sprat stock which is consistent with a precautionary approach and designed to ensure a rational exploitation*

*pattern and provide for stable and high yields. This plan shall consist of the following elements:*

- 1. Every effort shall be made to maintain a level of spawning stock biomass (SSB) greater than 200 000 t.*
- 2. A long-term management plan, by which annual quotas shall be set for the fishery, reflecting a fishing mortality rate of 0.4 for relevant age groups as defined by ICES shall be implemented.*
- 3. Should the SSB fall below a reference point of 275 000 t, the fishing mortality rate referred to under paragraph 2 will be adapted in the light of scientific estimates of the conditions then prevailing, to ensure safe and rapid recovery of the spawning stock biomass to levels in excess of 275 000 t.*
- 4. The IBSFC shall, as appropriate, adjust management measures and elements of the plan on the basis of any new advice provided by ICES.*

*A review of this arrangement shall take place not later than in the year 2003.”*

ICES considers that the agreed management plan is consistent with the precautionary approach, provided the reference points are used as upper bounds on F and lower bounds on SSB, and not as targets.

Most sprat are taken in mixed pelagic fisheries together with herring. If the status of the Central Baltic herring (in Subdivisions 25–29 and 32 (excluding Gulf of Riga)) is the dominating concern, management should ensure that herring catches in the mixed pelagic fisheries do not contribute to overexploitation. There are indications that herring at present constitutes about 35% (2002-2002 average = 37%) of the catches in the mixed pelagic fishery. Therefore, a sprat catch as low as 217 000 t in the mixed pelagic fishery in 2004 may use all available herring in Subdivisions 22-29+32 (80 000 t + 46 000 t = 126 000 t). However, there are important herring fisheries in these Subdivisions with little sprat by-catch. In addition, some sprat can be caught without much herring in the deep areas of the Central Baltic. Therefore, setting a TAC for sprat requires decisions on the amounts of herring set aside for these fisheries and on the amount of sprat allocated to deep-sea sprat fisheries.

### **Sprat in Division IIIa**

#### **State of stock/exploitation**

The state of the stock is unknown. Sprat in this area is short-lived with large annual natural fluctuations in stock biomass.

#### **Management objectives**

There are no explicit management objectives for this stock.

ICES considers that management of this stock should follow herring management advice in Subarea IV, Division VIIId, and Division IIIa. It is further noted that if there is an especially strong year class of sprat in this region there is a corresponding reduction in by-catch of herring, but such year classes emerge and disappear very quickly, making management difficult.

**Sprat in Divisions VIIId,e**

**State of stock/exploitation:** The state of the stock is not known.

**Management objectives:** There are no specific management objectives for this stock.

Zone	TAC	UE	BE	DK	DE	ES	FR	IR	NL	PO	FI	SU	UK	NR
IIIa	50000	46250		33504	70							12676		
IIIbcd	310000	122468		27497	17420						14394	63157		
IIId (Latvian Waters)	310000	6000												
IIId (Lithuanian waters)	310000	13000		5817	1546							2637		3000
Ila, IV	257000	240000	2761	218515	2761		2761		2761			1330	9111	
VIIId,e	9600	63000	20	3120	50		670		670				5040	
total	1246600	437318	2811	288453	21847		3431		3431		14394	79800	14151	3000

Minimum mesh sizes are in appendix O.K

**Mediterranean**

France, Greece, Italy and Spain have important, and often locally significant, fisheries in the Mediterranean. Although there is a common EU fisheries policy, the fisheries in the Mediterranean fisheries have traditionally been subject to separate EU fish stock management measure to those applied in the north east Atlantic and Baltic regions.

TACs have not been applied to small industrial teleost fisheries in the Mediterranean.

The core of the EU Mediterranean fisheries management measures are in the EU technical conservation Regulation 1626/94. These management measures are to be revised in 2003, however, no details of the new measures are available, therefore based on the existing documentation:

**Minimum mesh sizes**

The minimum mesh size for towed nets (bottom trawls, surface trawls, anchored seines, etc.) is 40 mm. but for surface trawling of sardine and anchovy, the minimum mesh size is reduced to 20 mm where these species account for at least 70 % of the catch after sorting. The minimum mesh size for encircling nets: 14 mm.

**The minimum landing size**

European anchovy 9cm

Sprat set to the length of first maturity

### **European Anchovy**

The gears used in the fisheries are mainly purse seines (with and without light) and mid water pair trawls. Mid water trawl fishing is forbidden in Greece and Spain.

#### **Source of management advice**

GFCM (General Fisheries Commission For The Mediterranean).

#### **State of stock/exploitation**

Stock assessment is problematical, time series data is only available for the Alboran Sea, Northern Spain, Gulf of Lions and the Northern Adriatic) with fragmental data for the other regions. The anchovy populations studied experience high, most likely environmentally induced, inter-annual fluctuations, typical of small pelagic fish (GFCM, March 2002).

Stocks of anchovies for which the most recent scientific analyses (e.g. DEPM (Daily Egg Production Method) surveys) show an evident risk of recruitment overfishing (GFCM Subcommittee for stocks assessment, May 2002)

#### **Precautionary reference points**

No reference points have been defined for this stock.

#### **Management advice**

It is generally advised that there should be no increase in fishing effort and that it is advisable to avoid the catch of fish smaller than their first maturity size.

### **Sardine**

Sardine is exploited both at juvenile and adult stages by purse seine and mid water pair trawlers.

#### **Source of management advice**

GFCM (General Fisheries Commission For The Mediterranean).

#### **State of stock/exploitation**

Only limited information on stocks in certain areas is available, making assessments problematical.

#### **Precautionary reference points**

No reference points have been defined for stocks.

#### **Management advice**

The GFCM Working Group held in 2002 recommended that the minimum legal landing size of small sprats should be set to the length of first maturity.

## Appendix 6: Legislation protecting elasmobranchs

**CITES** (Convention on International Trade in Endangered Species of Wild Fauna and Flora) is an international agreement between Governments. The convention lists the basking shark (*Cetorhinus maximus*) in Appendix II (international trade in its products should be accompanied by permit and a 'no-detriment finding' that states that the harvest of the species is sustainable. Therefore the convention requires stock assessment to determine sustainable levels of harvest for this species.

**The Barcelona Convention for the Protection of the Mediterranean Sea** Protocol concerning specially protected areas and biological diversity in the Mediterranean has listed three elasmobranchs (white shark *Carcharodon carcharias*, basking shark *Cetorhinus maximus*, and giant devil ray *Mobula mobular*) in Annex II, Endangered or threatened species. These should receive full protection when the Convention is ratified. Annex III, species whose exploitation is regulated, has listed the shortfin mako *Isurus oxyrinchus*, porbeagle *Lamna nasus*, blue shark *Prionace glauca*, white skate *Raja* (*Rostroraja*) *alba*, and angel shark *Squatina squatina*.

### **UN Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks 1995**

This Agreement relates to the conservation and management of high seas fish stocks ((UN Convention on the Law of the Sea (UNCLOS)). The Agreement been ratified and is in force for each State or entity that has acceded to it. The Agreement establishes rules and conservation measures for high seas fishery resources (and is complemented by the FAO Code of Conduct for Responsible Fisheries which sets out principles and international standards of behaviour for responsible practices). The Agreement calls for Parties to minimise pollution, protect marine biodiversity, monitor fishing levels and stocks, provide accurate reporting of and minimize by-catch and discards, and gather reliable, comprehensive scientific data as the basis for management decisions. It mandates a precautionary, risk-averse approach to the management of these species when scientific uncertainty exists. The Agreement also directs States to pursue co-operation in relation to following elasmobranch species (Bluntnose Six-gill Shark *Hexanchus griseus*, Basking shark *Cetorhinus maximus*, Whale Shark *Rhincodon typus*, and species of Thresher Sharks Alopiidae, Requiem sharks Carcharhinidae, Hammerhead Sharks Sphyrnidae and Mackerel Sharks Lamnidae) through sub-regional fishery management organisations or arrangements, as appropriate.

**Bern Convention is the Convention on the Conservation of European Wildlife and Natural Habitats.** The Convention aims to conserve wild flora and fauna and their natural habitats, especially those species and habitats whose conservation requires the co-operation of several States, it also aims to promote such co-operation. Emphasis is given to endangered and vulnerable species, including endangered and vulnerable migratory species. The basking shark *Cetorhinus maximus* and devil ray *Mobula mobular* are listed in Appendix II (Strictly protected fauna). The mako shark *Isurus oxyrinchus*, porbeagle shark *Lamna nasus*, blue shark *Prionace glauca*, white skate *Raja* (now *Rostroraja*) *alba*, and angel shark *Squatina squatina*. are listed in Appendix III (regulation of species populations to keep them out of danger). The Species listed on this Convention may be added to the EU Habitats Directive (Council Directive 92/43/EEC on the conservation of natural habitats and of wild flora and fauna) in the future.

**Bonn Convention on the Conservation of Migratory Species of Wild Animals (CMS)**

The convention relates to the necessity for countries to cooperate regarding the conservation of species that move/migrate across national boundaries or between areas of national jurisdiction and the high seas if they are to be protected across the species whole range. The convention provides a framework within which parties may either adopt strict protection measures for migratory species that have been categorised as endangered (Appendix I) or conclude Agreements for the conservation and management of migratory species that have an unfavourable conservation status (Appendix II). The white shark *Carcharodon carcharias* is listed in both Appendixes.

**The Quinquennial Review of protected species, UK**

The Quinquennial Review of the Wildlife and Countryside Act (1981) advises the UK Government on which animals and plants should be legally protected by listing on Schedule 5 (animals) and Schedule 8 (plants) of protected species. No basking shark (*Cetorhinus maximus*) are allowed to be caught within 12 miles of the coast and none landed even if caught outside territorial limits. The following species of elasmobranchs have been proposed for addition to Schedule 5; angel shark *Squatina squatina*, common skate *Dipturus batis*, black skate *Dipturus nidarosiensis*, long-nose skate *Dipturus oxyrinchus* and white skate *Rostroraja alba*.