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Assessment of the sustainability of industrial fisheries producing fish meal and fish oil

Final report to the Royal Society for the Protection of Birds by *Poseidon Aquatic Resource Management Ltd* and *The University of Newcastle-upon-Tyne*

Poseidon
Aquatic Resource Management Ltd

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To the
Royal Society for the Protection of Birds
By
Poseidon Aquatic Resource Management Ltd
and
the University of Newcastle-Upon-Tyne

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FOREWORD BY THE RSPB

The global production of marine capture fisheries has been increasing over the past 50 years in the face of rapid technological advances and an expanding human population. However, there is now growing evidence that world marine fisheries are failing, with many stocks over-exploited and at risk of collapse.

As a result of this decline and consequent gap between demand and supply of fish for human consumption derived from wild capture fisheries, aquaculture has become the fastest growing sector in the world food economy. As stocks of wild-caught fish dwindle further, aquaculture and mariculture are projected by the FAO to increase dramatically in the next few decades.

This anticipated expansion will result in an increased demand for fish meal and oil for feed. Fish meal/oil are derived predominantly from wild stocks of pelagic fish harvested by 'industrial' fisheries. Indeed, three of the world's five largest fisheries are for industrial species. However, despite the size and importance of these fisheries, there is still uncertainty about their sustainability.

It has been argued that many industrial stocks are susceptible to large fluctuations in biomass and could be prone to collapse under intensive harvesting regimes. There are also concerns about the wider ecosystem effect of these fisheries and the impacts on commercial fish and wildlife dependent on them. For example, many species of seabird are dependent on small shoaling fish such as sandeels and anchovies that are caught in industrial fisheries for fish feed in, respectively, EU waters and off South America. Conversely, many of those involved in these fisheries argue that they are a sustainable and efficient use of marine resources.

In light of this uncertainty, concern and conflicting views, in autumn 2003 the RSPB commissioned Poseidon Aquatic Resource Management Ltd to evaluate the sustainability of industrial fisheries used in fish meal and oil production. Their research is presented in this report. We believe that this objective and scientific assessment is a valuable contribution to ongoing discussions about the future management of the fisheries themselves and, more widely, the use of fish meal/oil in aquaculture and livestock feeds.

Finally, we would like to note that the contractors undertook this study as independent research. The report has, therefore, been published as received. Hence, its content and conclusions do not necessarily reflect the policy of the RSPB.

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Disclaimer and Report Information

This report has been prepared with the financial support of the Royal Society for the Protection of Birds (RSPB). The views expressed in this study are purely those of the authors and do not necessarily reflect the views of the RSPB or of its members. This report in no way anticipates the RSPB's future policy in this area. The content of this report may not be reproduced, or even part thereof, without explicit reference to the source.
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Acronyms

CFP	Common Fisheries Policy
DEFRA	Department for the Environment, Food and Rural Affairs
DELASS	Development of Elasmobranch Assessments
DIFRES	Danish Institute for Fisheries Research
EC	European Commission
EEZ	Exclusive Economic Zone
ELIFONTS	Effects of Large-scale Industrial Fisheries On Non-Target Species
ENSO	El Niño Southern Oscillation
EP	European Parliament
EU	European Union
FAO	Food and Agriculture Organisation
FIN	Fishmeal Information Network
FTE	Full Time Equivalent
GEF	Global Environment Facility
ICES	International Council for the Exploration of the Seas
IFFO	International Fishmeal and Fish Oil Organisation
ILO	International Labour Organisation
IMPARPE	Instituto del Mar del Perú
IMPRESS	Interaction between the Marine environment, PREdators and prey: implications for Sustainable Sandeel fisheries
IUCN	International Union for the Conservation of Nature
MSC	Marine Stewardship Council
MSFOR	Multispecies Forecast Programme
NGO	Non-Governmental Organisation
RSPB	Royal Society for the Protection of Birds
SPS	Phyto-sanitary measures
SSB	Spawning Stock Biomass
STECF	Scientific, Technical and Economic Committee for Fisheries (of the EC)
TAC	Total Allowable Catch
UK	United Kingdom
WTO	World Trade Organisation
WWF	World Wide Fund for Nature

EXECUTIVE SUMMARY

This report has been commissioned by the RSPB and evaluates the overall sustainability of fisheries used in the production of fish meal and fish oil. In particular it examines, using the specific examples of the North Sea sandeel and South American anchovy fisheries, what elements make such 'feed fisheries' sustainable and examines the barriers and constraints to achieving this sustainability.

At present South America provides the bulk (37%) of the global landings (21.5 million tonnes) destined for fish meal and oil, the Far East (27%) and South East Asia (12%) are also major sources of raw material. In Europe, Denmark, Iceland and Norway are all significant suppliers, each providing around 5% of the global supply. The South American supply mostly consists of anchovy (35% of the global total) with capelin (6% of global supply) the main constituent of European supplies. Sandeel represents around 4% of the global total but is the main EU feed fishery, largely from the Danish fleet.

Sustainability Issues

Typically, those teleosts (bony fish) used in the production of fish meal and oil forage low in the food chain and are preyed upon by fish, marine mammals and seabirds at higher trophic levels. Fishing of feed fish results in the direct removal, damage or disturbance of target and non-target species. The indirect effects of fishing may also include changes in predator-prey relationships, decreases in recruitment and loss of genetic diversity at the population level and changes in species composition at the community level. The population dynamics of many small feed fish species is characterised by their high fecundity and early maturity, which allows them to respond rapidly with increases in stock size in favourable conditions of abundant prey items, coupled to optimum climatic and hydrological conditions. Conversely in unfavourable conditions, stocks of feed fish may exhibit significant decreases in abundance, eg during the El Niño in the south-east Pacific. The highly variable recruitment dynamics of feed fish make predicting stock trends and the impacts of fishing on them over time difficult. Researchers, however, consider that hunting small, fecund pelagic species to extinction is unlikely to occur, although smaller, discrete sub-populations may be more vulnerable to extirpation.

The indirect effects of fishing include the by-catch of other species in targeted fisheries. This is not necessarily high – for instance the by-catch of commercially important fish species in the Danish sand-eel fishery is only around 3.5-6% and has been reduced by the use of conservation areas and gear measures. Direct bird by-catch tends to be low as most feed fisheries use trawls, although the purse-seining of anchovy may lead to some avian by-catch. Industrial fisheries may affect seabirds by reducing prey stock biomass – although seabirds only consume an insignificant proportion of North Sea sandeel stocks compared with fish predators, this relationship is sensitive to the population levels of key predators such as mackerel and gadoids which are currently low in the North Sea. In the Pacific, declines in seabird abundances after El Niño events are likely due to competition for food with the fishery. Marine mammals are known to be taken in the Peruvian anchovy fisheries, but there is little information on the effects on local populations, while in the North Sea sandeel fisheries marine mammal by-catch is not thought to be a conservation issue. The relative consumption of industrial fish by cetaceans varies widely and is often highly localised – therefore industrial fishing may impact these marine mammal populations in certain areas although their ability to switch to other prey is not really known. The body condition of some seal species may be linked to

local sandeel availability in the North Sea, although this may not be strongly linked to actual breeding success.

Fish predation on teleost feed fish is much higher than industrial fisheries removals, although may be declining as stocks of large demersal predators weaken. 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 has previously been the case and may potentially affect gadoid stock recruitment and slow recovery. Habitat impacts of these essentially pelagic fisheries are not generally an issue.

Sustainability of Global Industrial Fisheries

Most feed fisheries are in reasonable condition when considered from the traditional single stock perspective (see table below). However there is still only a weak understanding of the relationship between these fisheries and the wider ecosystem, both in terms of (i) their impact on non-target species and the trophic interactions resulting from fishing mortality and (ii) the relative importance of climate/oceanography in determining population dynamics. This lack of knowledge is particularly prevalent to the South American feed fisheries, although it is recognised that there are fewer closely associated carnivorous species compared to, say, the North Sea. Information on some of the Western Pacific fisheries eg that of the People's Republic of China (PRC), is lacking.

Area	Species	Stock Status	Comment
NW Atlantic	Capelin	Within safe biological limits	Variable SSB, currently strong.
	Sandeel (North Sea)	Currently considered as 'uncertain'	Interactions with non-target species poorly understood.
	Sandeel (Shetland / W Scotland)	Unknown	Fishing mortality below natural mortality. Interactions with non-target species poorly understood.
	Blue whiting (W Scotland)	Outside safe biological limits.	Fishing mortality high.
	Norwegian pout (W Scotland)	Unknown	Little managed small-mesh trawl fishery
	Norwegian pout (North Sea)	Within safe biological limits.	Low fishing mortality compared to natural mortality.
	Sprat	In good condition	May be associated with herring by-catch.
SE Pacific	Pacific anchovy	Biomass recovering as catches fall. Northern stock in safe biological limits but southern stock uncertain.	Stock dependent upon climate /oceanography rather than fishing pressure. Increasingly regulated.
	South American pilchard	Stock recovered from earlier over fishing and El Niño.	
	Chilean mackerel	Uncertain - stock falling since 1996	Highly regulated

Sustainability Criteria for Feed Fisheries

This study has adopted, with some modifications, the Marine Stewardship Council's (MSC) principles and criteria for sustainable fishing through a demonstration of:

- The maintenance and re-establishment of healthy populations of targeted species;
- The maintenance of the integrity of ecosystems;
- The development and maintenance of effective fisheries management systems, taking into account all relevant biological, technological, economic, social, environmental and commercial aspects;
- Compliance with relevant local and national laws and standards and international understandings and agreements, and
- The provision of economic benefits in an equitable manner that does not disadvantage local, national or external stakeholders through unfair competition, employment opportunities or displacement.

Based on these criteria, a number of indicators have been prepared and used to assess the sustainability of both the North Sea sandeel and South American anchovy fisheries. It is important to emphasise that this assessment represents a preliminary analysis and cannot be considered either definitive or representative of even a MSC pre-assessment for these fisheries. However it serves to illustrate the main sustainability issues for these fisheries and the information available – or not – that informs this process.

The North Sea Sandeel fishery: the main elements of sandeel ecology and population structure in the North Sea have been well researched, although the nature of local sub-populations may be under-represented. The high natural mortality of sandeel populations and the few year classes make stock size and catching opportunities largely dependant upon incoming year classes which complicates forward-looking management. The linkages between industrial fisheries and non-target species have been investigated in detail, but the complex nature of marine ecosystems means that there is still only as partial understanding of the relationships and interactions. The fisheries are implemented under strictly controlled conditions with high compliance levels. The fishery has a high number of participants that constrains the level of reinvestment but does assist in the redistribution of wealth within the sector and restricts efforts into other fisheries. Most of the vessels and fish meal plants are operated within a share system.

Peruvian Anchovy Fishery: there is considerable research into the stock ecology and biology and the impacts of fishing, but much of the resulting information is contained in grey literature and difficult to compile and subject to quality assessment. There are also apparent gaps in the information on the effects of fishing on the different stocks' reproductive capacity. Funding limitations have also severely restricted the ability of resident researchers to examine the wider ecosystem implications for stock removal and the impacts on non-target species. In addition, compared with the Danish sandeel fishery, it is difficult to assess the success of Peruvian monitoring efforts and compliance levels are less well documented. In the absence of this information, it is difficult to conclude the fishery is currently sustainable or not. The recently introduced ITQ (quota) system has induced rationalisation into the previously unconstrained fleet structure and further reductions in capacity are expected.

Current and Predicted Demand for Fish Meal and Fish Oil

World production of fish meal averaged 6.3 million tonnes over 1997-2000, around 23% of the global fish catch. Peru and Chile account of 55% of this total, PR China with 12% and the EU (predominately Denmark) with 9%. Fish body oils are largely a by-product of fish meal production, with global supply at around 1.1 million tonnes per annum, mainly supplied by Peru and Chile (47%) and the EU (16%). The PRC is the largest consumer of fish oil whilst Chile and Norway use the majority of fish meal, largely in the manufacture of salmonid aquaculture feed.

Aquaculture currently accounts for 34% and 56% of fish meal and fish oil consumption respectively but these figures are likely to rise to nearly 50 and 80% by 2010. Whilst fish meal supplies are likely remain sustainable, it is considered that fish oil availability may become increasingly limited over the next 5-10 years as demand from aquaculture nearly doubles. Fish meal and fish oil use from agriculture are set to fall substantially.

Soya, which is produced in much higher quantities than fish meal, is cheaper but less nutritionally effective, particularly in fish feeds, which has been the main barrier in using soya as a substitute. A number of alternatives exist, such as plant proteins, small marine crustaceans and biotechnology products but cost, effectiveness and waste production considerations continue to restrain their commercial adoption. Whilst adequate, favourably priced fish meal products exist, which may be supplemented by increased utilisation of fish processing by-products, the uptake of alternative fish meal products will continue to be slow over the medium term.

The study has also examined factors that contribute to, and constrain, sustainable fishing (see Appendix F for details):

Factors Contributing to Sustainable Fishing

- Adequate information and research
- Impacts on the ecosystem are understood and where possible, managed
- Management systems are in place and enforced

- Fishers recognise sustainability issues and contribute to their understanding.

Factors Constraining Sustainable Fishing

- Natural variations in large scale atmospheric or oceanic forcing
- Overexploitation under weak management conditions when (i) profits are high or (ii) there is sufficient information to allow effective stock management
- Evidence of 'ecological failure' is often only apparent once severe damage has already occurred
- Other factors of 'unsustainability' include:
    - No or low resource rent
    - Lack of access conditions
    - Targeting behaviour: may lead to discarding of low value, non-target species
    - International trade opportunities: works through maximising of short-term profits
    - Fish technology policy: may support – or undermine – management systems
    - Subsidies: may increase exploitation levels by reducing costs.
    - Lack of understanding of fish communities
    - Equity issues: may lead to regional transfer / monopolisation of fishing rights
    - Habitat degradation and pollution: impacts of bottom trawl fisheries on pelagic productivity

Recommended Strategies for Sustainable Fish Meal and Fish Oil Supplies

Increasing the sustainability of raw materials supplies to the fish meal and fish oil industries through:

- Supplementing target fisheries raw material with other fish processing wastes
- Consider utilising currently discarded bycatch – especially that with high post-discard mortality rates – for fish meal and oil production
- Reduce the use of fish meal and oils in aquaculture and agriculture through the continued development of vegetable substitutes for fish meal and fish oils in aquafeeds and animal diets. However this continues to be constrained by the nutritional superiority of fish-derived products and their modest price, as well as legislative constraints on their use. The increasing public demand for Omega 3-rich fish oils also constrains their substitution.

EU and UK Policy Development

A number of recommendations are made to EU and UK policy that may both increase the sustainability of feed fisheries and reduce the dependence of fish meal and fish oil production on these fisheries. This includes:

- Fisheries management needs improved stock status information and to reduce the current uncertainty in estimating stock size and dynamics. Where necessary, improved stock monitoring may be necessary.
- Consideration needs to be given to the use of indices of environmental status in setting industrial feed fishery TACs (currently under consideration by the EC's Scientific, Technical and Economic Committee for Fisheries (STECF).
- Increased research into the linkages between feed fisheries and the wider ecosystem, including their predators and the predator/prey interactions and the trophic consequences of removing substantial biomass from the bottom of the food chain. Feed fish species are an important prey to fish, birds and other species and their harvesting is likely to have a major effect on these animals.
- Introduction of mechanisms to encourage Member States to better recover and utilise fish wastes (esp. trimmings) for use in fish meal and oil production. This might include the establishment of a network of fish meal plants within 800 miles of major fishing ports to reduce the costs associated with transport and maintain the quality of the raw material.
- The benefits – and costs – of a wider discard ban in EU fisheries might also be examined in relation to feed fisheries and their sustainability. The use of discards to produce fish meal and fish oil should be investigated, but with extreme caution. There is a danger that this could develop into a demand for juvenile fish and result in its own directed fishery. Adoption of this strategy should be accompanied by continued efforts to reduce discarding. Maintaining a strong price differential between marketable fish and the 'trash' will ensure that fishers have an incentive to fish selective and to avoid capture of juveniles.
- Further research on viable alternatives to fish meal, including improving the quality of feeds produced from plant material
- EC legislation regarding the use of genetically modified ingredients and other potentially useful substitutes should be reviewed in the light of long-term demands for protein needs and risks.

1 STUDY OBJECTIVES AND DEFINITIONS

1.1 INTRODUCTION

The fish meal and oil industry started in northern Europe and North America at the beginning of the 19th century. Initially based mainly on surplus catches of herring from seasonal coastal fisheries, this was essentially an oil production activity, the oil finding industrial uses in the lubrication of machinery and leather tanning, and in the production of soap and glycerol and other non-food products. The residue was originally used as fertilizer, but since the turn of the twentieth century it has been dried and ground into fish meal for animal feed. The fish meal and fish body oils sector has now developed into a major supplier of raw material for agricultural and aquaculture feeds.

The demand for aquafeeds continues to increase, yet the overall global supply of fish meal and fish oil is relatively fixed (SEAFeeds, 2003). This implies that there will be increased pressure on the fisheries that supply these commodities unless alternative substitutes become both available and acceptable. Whilst there is no real reason why feed fisheries should not continue to supply the aquaculture industry in the future, adequate sustainability assurances need to be in place.

1.1.1 Objectives and Approach of the Study

The objective of this study is to evaluate the overall sustainability of industrial fisheries used in the production of fish meal and fish oil (see Terms of reference in Appendix A). This report does not pretend to be an extensive global review (see Scope below) but does aim to provide the reader with a reasonable understanding of the current thinking on (i) what makes an industrial fishery sustainable and (ii) the existing barriers and constraints to achieving sustainability of these fisheries.

The approach has been to identify suitability criteria and apply these to two examples, the North Sea sandeel and Peruvian anchovy fisheries. These cases will be used to examine the level of information available for sustainable management and identify applied research needs. The study will also look more widely at the global demand for fish meals and fish oils and examine opportunities for their substitution with other more readily available materials.

Based on this, the report will make recommendations for improving the ssustainability of these feed-fisheries with particular reference to EU and UK policy on the development and conservation of these fisheries, their management and the use of their products in aquaculture and agriculture.

1.1.2 Scope

Fish meal and fish oils are derived from either targeted fisheries or as by-products from processed fish. Fish taken in 'industrial fisheries' (as opposed to 'human consumption' fisheries) can be divided into two groups. Firstly, those industrial fisheries that produce fish meal and oils as ingredients to animal and fish feeds are referred to as '*feed fisheries*'. These feed[1] fisheries are the focus of this report.

The second group of industrial fisheries produce fish oils, predominantly for the health and pharmaceutical industries. These include shark species that are targeted directly for liver oils which produce squalene, a key ingredient to medical

[1] This definition was recently outlined as the appropriate terminology at the SEAFeeds Workshop (SEAFeeds, 2003). Industrial fishing is often used by some to describe large-scale trawling (e.g. for gadoids) so can confuse.

treatments. Fish oils may also be produced as by-products from human consumption fisheries, for example cod liver oil. As these latter products are effectively '*food fisheries*', they are excluded from the report.

1.1.3 Structure of the Report

This report consists of four main sections:

Status of Global Industrial Feed Fisheries (**Section 2** on page 5): a brief review of the world's industrial feed fisheries is presented to provide an overview of the fisheries, products and markets relevant to the study. This is followed by an examination of the main sustainability issues facing feed fisheries in terms of the direct, indirect and socio-economic effects.

Identification and Application of Sustainability Criteria for Feed Fisheries (**Section 3** on page 30): a series of sustainability principles and criteria are developed from the Marine Stewardship Council's standard for responsible fisheries. These are then applied at a basic level to the Peruvian anchovy and North Sea sandeel fisheries to provide an elementary analysis of their relative degree of sustainability on a 'principle by principle' basis.

Towards Sustainable Fish Meal and Fish Oil Supplies (**Section 4** on page 561): based on, but not limited to, the above analysis, a series of assessments are made of (i) the current and predicted demand for feed fishery products and the likely outlook for their use and substitution and (ii) the factors contributing to, and constraining the development of, sustainable feed fisheries.

Recommendations for Improving the Sustainability of Feed Fisheries (**Section 5** on page 81): a series of recommendations on (i) increasing the sustainability of raw materials available to the fish meal and fish oil industries, (ii) the ways in which alternatives might be developed and (iii) policy recommendations at both industry and government level for improving the sustainability of feed fisheries.

1.2 CONCEPT OF SUSTAINABILITY FOR INDUSTRIAL FISHERIES

Sustainability has been described as: "*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). When assessing sustainability, a number of points need to be considered:

- The environment encompasses a wide range of assets, including (i) the physical environment, (ii) biodiversity (ecosystem, habitat, species or genetic diversity), and (iii) social and cultural heritage.
- Maintaining diversity at one level will have very different requirements to conserving at another.
- It may not be possible to preserve all environmental assets from the pressures of population growth and increased consumption – choices and trade-offs may have to be made and an acceptable degree of loss determined.
- Environmental assets often have an economic value to humans – however these values are often difficult to quantify and to identify who are the ultimate beneficiaries.

1.2.1 Overview of Natural Resource Sustainability

The exploitation of wild living resources, such as industrial fish species, needs to be conducted at a sustainable level, i.e. at a level which will allow the exploited population to replace those individuals that are removed and which can be maintained at a level which will support the human harvester and dependent predators. Any concept of sustainability must include both environmental and socio-economic factors, therefore international agreements have agreed that sustainable practices need to be encouraged. The States which ratified the Rio Declaration on Environment and Development (1992) agreed that it is the States' responsibility to 'reduce and eliminate unsustainable patterns of production and consumption'. The Kyoto Protocol (1997) promotes the concept of 'sustainable development' to alleviate poverty without destroying the natural environment, whilst the Johannesburg Declaration on Sustainable Development (2002) is an agreement to encourage and promote the development of programmes which support a movement towards sustainable consumption and production. The latter declaration aims to 'promote social and economic development within the carrying capacity of ecosystems by addressing and, where appropriate, de-linking economic growth and environmental degradation'.

The Johannesburg Declaration specifically includes a section on fisheries. It urges that, where possible by 2015, States should maintain or restore depleted fish stocks to levels that can produce the maximum sustainable yield. It also pushes for the FAO 'International Plans of Action' to be put into effect by the agreed dates in order:

- for the management of fishing capacity by 2005; and
- to prevent, deter and eliminate illegal, unreported and unregulated fishing by 2004.

1.2.2 Fisheries and Sustainability

Most fishery theory and practice is geared towards determining sustainable yield, which is the amount of biomass, or the number of units, that can be harvested currently in a fishery without compromising the ability of the population/ecosystem to regenerate in the future (FAO, 1997). Traditionally, focus in fishery sciences has been mainly on determining a maximum sustainable yield in the form of a total allowable catch (TAC).

In recent years, it has become apparent that focussing merely on sustainable yield is inherently restricted, since its emphasis on extracting a defined biomass/number of units does not take into account of the processes underpinning the fisheries and is at odds with the provisions of the Rio conference on sustainable development (Agenda 21). This consideration of the wider system can be termed the 'ecosystem approach': an approach that considers ecosystem interactions and the 'health' of the marine ecosystem in the management of marine resources. However, it is important to realise that the human element is integral to the marine ecosystem. Therefore an ecosystem approach to fisheries management needs to balance diverse societal objectives by taking into account the knowledge and uncertainties about biotic, abiotic and human components of ecosystems and their interactions and applying these in an integrated and holistic approach to fisheries within ecologically meaningful boundaries (FAO, 2003). Thus the goal of the ecosystem approach to is to develop and manage fisheries in a manner that addresses the multiple needs and desires of societies, without jeopardising the ability of future generations to benefit from the full range of goods and services provided by marine ecosystems. Hence, sustainability is at the core of ecosystem approach.

2 STATUS OF GLOBAL INDUSTRIAL FEED FISHERIES

2.1 IDENTIFICATION AND REVIEW OF KEY GLOBAL INDUSTRIAL FEED FISHERIES

The principal areas of fishing activity for feed fish fisheries include South America, Northern Europe (EU and non EU countries), the Far East and South East Asia (Table 1). Far Eastern and South East Asian fisheries include a large element of trash fish (fish caught as a by-catch in other directed human consumption fisheries). The countries with dedicated feed fish fishing activity comprise Peru, Chile, Denmark, Iceland, Norway, China, Russia and Iran.

Table 1: Average landings (‘000 tonnes) by country of fish destined for fish meal

Region / Country		Landings ('000 tonnes)	Proportion (%)
South America	Peru	6,540	30%
	Chile	1,445	7%
	Other South America	32	0%
	Sub-total	***8,017***	***37%***
European Union	Denmark	1,043	5%
	Other EU	481	2%
	Sub-total	***1,524***	***7%***
Other Europe	Iceland	1,089	5%
	Norway	1,010	5%
	Others	294	1%
	Sub-total	***2,393***	***11%***
Other regions	North America	350	2%
	Far East	5,829	27%
	South East Asia	2,688	12%
	Middle East	770	4%
	Sub-total	***9,637***	***45%***
GRAND TOTAL		**21,571**	**100%**

Source: FAO

Table 2 overleaf summarises the main species targeted and landed as feed fish fisheries. The largest of these is Peruvian anchovy, accounting for 35% of the global total. In the period 1997-2001 annual catches ranged in each year from 2.4 million tonnes to 12.4 million tonnes (see Figure 1 on page 8 – this figure shows the range 1992-2001). The low catch of 1998 is directly linked to El Niño.

Capelin is the next most significant species, accounting for 6% of the total. Capelin accounts for 84% and 24% of the Icelandic and Norwegian feed fish catches respectively. Greenland and Russia also prosecute these fisheries. Russia reports that capelin is used for human consumption.

Blue whiting and sandeel feature as the next most significant species. Blue whiting is caught in the North Sea and Eastern Atlantic. The fishery is targeted as feed fish by Norway, Denmark and to a very small extent by the Faeroes, the UK and Ireland. The fishery is also targeted for human consumption by vessels fishing from the Netherlands, Germany, France, Spain and the UK. Blue whiting accounts for 51% and 5% of the Norwegian and Danish feed fish supply. There are specific concerns in respect to the sustainability of this fishery, mainly due to the paucity of information on the biology and ecology of this species and the expansion of effort by all countries (EU and non EU) at a very rapid rate.

Table 2: Average landings (1997-2001) of species destined for fish meal

Supply breakdown by species	**Landings**	
	'000 tonnes	**%**
Anchovy	7,502	35%
Capelin	1,318	6%
Blue whiting	924	4%
Sandeel	879	4%
South American sardine	515	2%
Sprat	498	2%
Herring	193	1%
Norway pout	96	<1%
Horse mackerel	8	<1%
Other	9,637	45%
Total	**21,570**	**100%**

Source: FAO

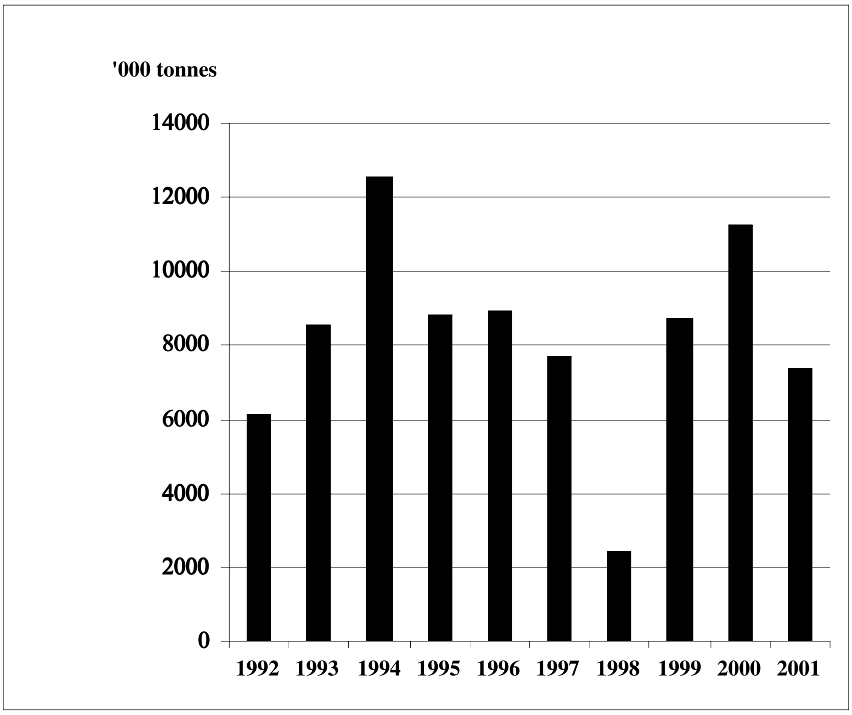
Sandeels form the main source of supply for the EU fish meal sector. Forty two per cent of the EU feed fish supply is derived from North Sea sandeels. Denmark has historically caught around 600,000 tonnes per annum, and sandeels represent 60% of the raw material throughput into Danish factories. Catches show a marginal decline, but the fishery is associated with peaks and troughs (Figure 2, page 8) because of extrinsic forcing (response to large scale environmental change). There are 405 Danish vessels active in this fishery, of which only 60 can be described as dedicated industrial trawlers. The remaining 345 vessels target a combination of both human and feed fish fisheries throughout the year.

Norway, Sweden and the UK also target sandeel. Norway's catch has averaged 240,000 tonnes between 1997 and 2001. This represents 23% of their total feed fish catch. Norwegian fishing activity predominantly takes place in the EU EEZ. Swedish and UK catches of sandeels have been in decline in the last five years. Both countries only catch around 25,000 tonnes each and activity is limited to nine and 10 vessels for the UK and Sweden respectively. These vessels will only take advantage of the fishery as an adjunct to food fish activities between July and September. Sandeels are targeted by the Danes and Norwegians between April and June.

Landings of South American sardines have fallen dramatically since the late 1997 when they were just under 1 million tonnes, largely because of TAC cuts. Landings in 2001 were no more than 135,000 tonnes. Peru, Chile and Ecuador target these species. The number of active fishing vessels expanded without control up to the mid 1990s causing a position of extreme overcapacity. Whilst a licensing regime has been established allied to a system of transferable quotas, the overcapacity position prevails and there is considerable under utilisation of the fleet.

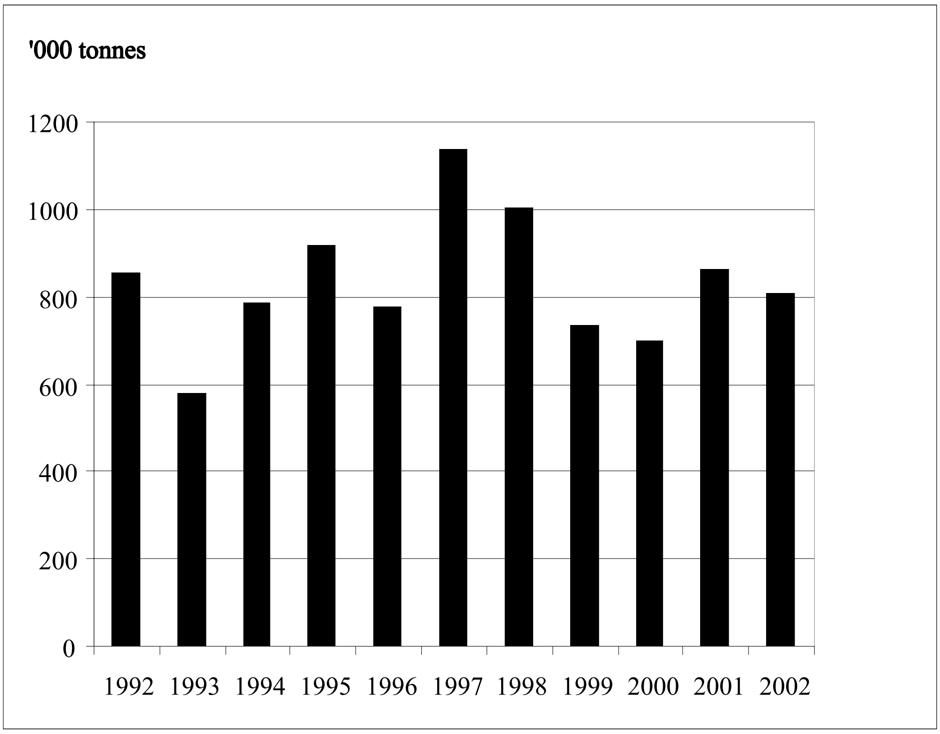
Sprat and herring represent the next most significant species for the EU fleet. Sprat is a targeted fishery for Danish vessels in the North Sea, for Danish and Swedish vessels in the Kattegat and Skagerrak, and for Danish, Swedish, Finnish and Polish vessels in the Baltic. Herring may be taken as a by-catch to sprat fisheries or in specifically directed fisheries. EU vessels are allowed to target herring specifically as fed fish in the Baltic because the fish are deemed largely unsuitable for human consumption. Sprat and herring account for 31% and 12% of the EU's feed fish supply respectively. Norway pout has largely declined in significance as a feed fish. It is perhaps one of the most controversial of fisheries since it has been traditionally associated with high by-catches of juvenile gadoid species. However, the application of both by-catch management restrictions and strict enforcement measures has seen a significant decline in the targeting of Norway pout.

Figure 1: Landings of South American Anchovies, 1992-2001



Source: ICES

Figure 2: Landings of North Sea Sand eels, 1992-2001



Source: FAO

This study focuses on two species for detailed analysis: **Peruvian anchovy** and **North Sea sandeels**. Peruvian anchovy is chosen because of its significance as the most important source of supply of fish meal. Sandeel is selected in preference to three other important European feed fish fisheries (capelin, blue whiting and sprat) because of the interactions with seabirds as a source of feed, because of its importance to the EU fish meal sector, and because of the strength of the scientific information available for this fishery. The focus of attention on the sandeel fishery is on the Danish fleet activity because Denmark catches 68% of the North Sea sandeel TAC, although they can land 727,472 mt (88%) of the 826,200 mt 2004 TAC for North Sea sandeels (including Skagerrak & Kattegat).

2.2 REVIEW OF SUSTAINABILITY ISSUES IN FEED FISHERIES

As reflected in the previous section, feed fisheries are notable simply for their sheer scale. Apart from the possible effects of the removal of large quantities of stock biomass on the target species populations, fears have also been raised about the implications for the often numerous predators of these stocks and the impacts of by-catch of non-target species. Defenders of the industry maintain that robust, independent fish stock management and the implementation of TACs and effective control measures ensure that industrial feed fisheries supplying fish meal are not over-exploited (FIN, 2003). Other researchers and stakeholders have raised concerns over the impact of these fisheries on both stocks and the wider ecosystem and have questioned both the wisdom and sustainability of relying on fish meals and fish oils for use in the rapidly expanding aquaculture industry (Tuominen and Esmark, 2003).

In light of these differences of opinion, the following section aims to provide a brief overview of the main issues in feed fish sustainability.

2.2.1 Biological and Ecological Sustainability

The following review has been made from the abundant literature on the subject. However, the majority of studies have been directed at European and North American fisheries and this is reflected in the subsequent text.

Direct Effects of Feed Fisheries

The removal of large numbers of individuals of fish from an ecosystem may directly impact their prey, predators and the viability of target and by-catch populations. The physical effect of fishing activity will also affect the ecosystem directly through the disturbance of habitats (Auster *et al*., 1996; Langton and Auster, 1999) and the death and injury of non-target species (Kaiser and Spencer, 1995).

<u>Feed fish stocks</u>

Teleost feed fish species caught for the production of fish meal and fish oil include the South American sardine (*Sardinops sagax*), capelin (*Mallotus villosus*), Peruvian anchovy (*Engraulis ringens*), sandeels (*Ammodytes* spp.), herring (*Clupea harengus*), sprat (*Sprattus sprattus*), Norway pout (*Trisopterus esmarki*) 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 at higher trophic levels.

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).

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. Beverton concluded that although the likelihood of harvesting small pelagic species to extinction was remote, a major population collapse may result in subtle changes to the ecosystem which may change the biological structure of the community.

Others also consider harvesting an entire industrial fish species to extinction seems unlikely (Hutchings, 2000; Sadovy, 2001) but the treatment of stocks as single, panmictic populations means that if there are relatively local and sedentary stocks, overall catches could conceal community extirpation. For instance, this has implications for the management of localised sub-stocks such as in the case of the North Sea sandeel (see next section).

The population dynamics of many small feed fish species is characterised by their high fecundity and early maturity. The recruitment patterns are highly variable and may rapidly influence stock size due to the short life span of the species, coupled with extrinsic environmental drivers such as sea temperature and associated climatic/hydrological patterns eg the North Atlantic Oscillation (NAO) and the El Niño in the south-east Pacific. This will inevitably lead to uncertainty in the stock forecasts.

Habitats

The pelagic gear and purse seines used to target many industrial fish species - such as sprats, blue whiting and Peruvian anchovy - are deployed in the water column and have minimal contact with the sea floor. Demersal otter trawls are used to catch some species, such as sandeel and Norway pout, and these may have more of an impact on the sea bed and benthos. The degree of impact depends on the targeted species and the location, as specific gears will be used to target specific species, and the impact on the sea floor will rely on both the substrate type and the physiology of the animals which live there.

Typically, in the sandeel fishery the trawl is kept close to the seabed, which is usually sandy (Wright *et al.*, 2000) but actual contact is kept to a minimum. The gear is also lighter than the other demersal trawls. The effect of this disturbance on the more dynamic sand habitats is less significant than disturbance in areas of lower energy such as muddy substrates and in deep water, as the level of natural disturbance in the more dynamic areas is likely to be greater than that caused by fishing (Kaiser *et al.*, 1998).

Although the impact to the seabed and benthos by each individual tow may be less than with comparable demersal otter trawling operations as the gears are lighter, the way the fishery operates suggests that local impact on the seabed and invertebrate communities may be quite intense. This is because the same trawl path tends to be fished repeatedly over a period of several days by several boats operating in any particular region (Frid *et al*, 2003). Mitigating against this, however, is the fact that these fisheries are seasonal. The local impact may be intense, but it is followed by long periods of recovery. The fishery for Norway pout occurs primarily through the winter months, with little fishing occurring during the summer which allows six to eight months of the year for the benthos to recover. The sandeel fishery is constrained by the hibernation of the species in winter.

Indirect Effects of Fishing

There are a number of indirect effects of fishing feed fish stocks, largely due to their foraging low in the food chain and therefore being preyed upon by fish, marine mammals and seabirds of higher trophic levels. 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 or climatic conditions. There are also the genetic effects, involved with removing large amounts of the gene pool, which may adversely affect populations over long periods. Indirect effects may also 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).

By-catch

The incidental catch of non-target species, and in particular 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. In North Atlantic waters, juvenile herring are known to shoal with sprat (Hopkins, 1986) whilst 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; Eliasen, 2003). By-catch levels are not necessarily high – the by-catch in the Danish and Norwegian North Sea sandeel fishery (mainly herring, saithe and whiting) has averaged 3.5% over 1997-2001 (ICES, 2003b). Whilst levels are low, given the scale of the feed fisheries being prosecuted, actual quantities of bycatch can be significant. 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, the sprat fishery took 27,972 t of by-catch. Landings of roundfish in the North Sea were estimated at 250,000 tones in 2002 (ICES, 2004).

By-catch and subsequent discard is a function of the gear type/species prosecuted. Garthe *et al*. (1996) calculated a by-catch for the roundfish species at approximately 25% of the total landing. Alverson *et al.* (1994) calculated for cods, hakes and haddocks a global discard average of approximately 20%. While Cotter *et al*. (2002) estimated the discarding of demersal fish species in the North Sea to be 20-48%, 30-41%, and 51-65% of the total numbers of cod, haddock and whiting respectively. Thus, if on average the by-catch in the roundfish fishery is 25%, approximately 50,000 tonnes of roundfish were by-caught in 2002.

The survival of discarded animals is highly variable and dependent on tolerance to aerial exposure, the level of injury to the animal, environmental factors and the density of scavengers in the discarding area. Many fish species do not survive discarding and die either as a result of their capture (Chopin and Arimoto, 1995; Kaiser and Spencer, 1995) or are eaten by scavengers (Tasker *et al*., 2000). The mortality of discarded fish in commercial hauls was examined by Fonds and Groenewold (2000) and is shown in Table 3.

Table 3: Discard Mortality Rates of Coastal and Offshore Beam Trawls

Species	**Coastal areas (4m beam trawl)**		**Offshore areas (12m beam trawl)**	
	Mortality (%)	***No. in trials***	***Mortality (%)***	***No. in trials***
Dab	98	138	99	87
Plaice	93	158	95	852
Flounder	74	68		
Sole	78	126	95	57
Turbot and Brill	89	93		
Gurnards	96	123	100	20

Source: Fonds and Groenewold, 2000

There is recent evidence of declining by-catch in the sandeel fisheries and the blue whiting fishery as seen in the Danish feed fish catches (Table 4). By-catch is an issue in the sprat fisheries, where increased herring by-catch is largely a result of relative increases in abundance (ICES, 2003e).

Table 4: Landings and By-catch from Four Danish North Sea Industrial Fisheries
1998-2001 average and 2002

Catch species composition	Landings of Four Industrial Feed Fisheries ('000 mt)							
	Sandeel		*Sprat*		*Norway pout*		*Blue whiting*	
	1998-	*2002*	*1998-*	*2002*	*1998-*	*2002*	*1998-*	*2002*
Sandeel	**564.3**	**622.1**	6.1	4.1	0.0	0.0	0.1	0.0
Sprat	6.6	1.0	**152.8**	**140.6**	0.2	0.0	0.0	0.0
Norway	1.6	0.0	0.4	0.2	**53.8**	**43.2**	3.5	3.7
Blue whiting	1.4	0.7	0.0	0.0	2.6	4.7	**31.1**	**21.1**
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	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**
% by-catch	**5.8%**	**3.7%**	**13.1%**	**19.9%**	**4.1%**	**6.7%**	**1.3%**	**0.6%**

Source: DIFRES

The composition and volume of catches from the Norwegian industrial fisheries, which target both blue whiting and Norway pout, was reported by ICES (2003a). Between 2000-2002, the average annual landings from the mixed fishery were 109,000 tonnes. Blue whiting formed an estimated 58% of this catch whilst Norway pout formed approximately 17%. The remaining 15%, 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 1,000 t in this fishery. This length distribution analysis suggests that the by-catch of these species consisted primarily of immature individuals.

In the North Sea 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 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. 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.

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 considering that the natural mortality of haddock and whiting is very high.

By-catch in the Peruvian anchovy fishery is monitored by IMARPE. If vessels land catches over a three-day period with over ten percent of the catch containing juveniles of target and non-target species, the landing port is closed to fishing vessels for a three-day period. On opening, if the juvenile by-catch continues to be high, the port closes for a week. The incentive is for the fishers to move to another area to fish rather than remain in the areas with juvenile by-catch (pers. comm. Renato Guevara Carrasco, IMARPE, November 2003). There is an appreciation of the juvenile by-catch issue, but no assessments of the impact of the fishery on the recruitment of target and non-target species have been found

Seabirds

By-catch mortality: the methods for catching fish species depend on the behaviour of the fish. Many fish species shoal and small mesh trawls and gillnets are used to capture the shoaling fish. Many of the feed fish fisheries use trawls, and birds are less likely to be caught by this type of gear (Tasker *et al*., 2000). A study in the Baltic assessing the by-catch of common guillemot (*Uria alga*) indicated that a small unquantified degree of mortality could be attributed to trawls, but the researchers did not identify the trawls as specifically targeting an industrial fish species (Österblom et *al*., 2002). By-catch of birds is potentially an issue in the purse-seining for anchovy but the level of interaction is little researched. (Majluf *et al*. 2002), and there are anecdotal reports of by-catch (pers comm. Stefan Austermühle, Mundo Azul, 2003, November).

Availability as prey: seabirds are long-lived, producing few fledglings that only breed if they survive several years and normally have various mechanisms to overcome periods of low food supply. Specialist seabirds, such as small, surface feeding species with energetically expensive foraging methods are the most vulnerable to local depletion and (natural) variability in prey availability. The relationship between the reproductive success in black-legged kittiwakes on Shetland and sandeel abundance has been proposed as an indicator of local sandeel availability in the North Sea (ICES, 2003c). Potential conflicts between fisheries and seabirds are likely to arise only on a local or regional scale (Tasker *et al*, 2000). Industrial fisheries can affect seabirds by reducing prey stock biomass leading to declining recruitment or alterations in the food web structure. Although seabirds consume only an insignificant proportion of North Sea sandeel stocks compared with fish predators (Bax, 1991; ICES, 1997; Gislason, 1994), this relationship is sensitive to the population levels of key predators such as mackerel and gadoids which are currently low in the North Sea.

A classic example of how the removal of large quantities of feed fish by industrial fisheries might reduce food supply to seabirds has been reported in Peru. Extrinsically driven dramatic decreases in numbers of guano seabirds occur regularly during El Niño events, but, historically, species were shown to recover between events showing cyclic fluctuations in populations. However, as the Peruvian anchovy fishery increased, seabird numbers began to fail to recover after El Niño driven crashes, and the seabird population fell to only a small fraction of its earlier numbers (Duffy 1983). Jahncke *et al*. (2003) modeled the guano producing seabirds (cormorant *Phalacrocorax bougainvillii,* booby *Sula variegata* and pelican *Pelecanus thagus*) that feed almost exclusively on *Engraulis ringens* to determine if there is a response in the annual population size of the birds to changes in primary and secondary production of the Peruvian upwelling system. The seabirds were shown to respond to the increased productivity of the Peruvian upwelling system, and that declines in seabird abundances after El Niño events were likely due to competition for food with the fishery.

Marine mammals

By-catch mortality: The 'Ecological Quality Objective' for by-catch of small cetaceans adopted under the Bergen Declaration[2] requires anthropogenic mortality to be below 1.7% per annum. No by-catch of marine mammals has been reported in the industrial fisheries (Dalskov and Eliasen pers. comm., October 2003), but Huse *et al.*, 2003 provides anecdotal evidence that there are occasional by-catches of cetaceans in the North Sea sandeel fishery. The opportunistic feeding behaviour of cetaceans and pinnepeds 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 in the North Sea. Should this prove significant in areas or in certain seasons, pingers could prove an effective management measure (Larsen, 1999),

By-catch of cetaceans is potentially an issue in the purse-seining for anchovy (Majluf *et al*. 2002). The dusky dolphin (*Lagenorhynchus obscurus*) is known to take *E. ringens* as a major component of its diet (McKinnon, 1994) and the species was reported as caught by purse seines before cetaceans were protected in the region (law No. 26585: 1996) (Read *et al*., 1988). Van Waerebeek *et al*. (1997) conducted a survey of Peruvian fishermen to estimate mortality on 722 by-caught cetaceans (and direct takes), species reported in multi-filament gillnets were 82.7% dusky dolphin (*Lagenorhynchus obscurus*), Burmeister's porpoise (*Phocoena spinipinnis)*, 2.4% long-beaked common dolphin (*Delphinus capensis*) and 2.4% bottlenose dolphin *(Tursiops truncatus*). Van Waerebeek *et al*. (1997) found that there was no indication of a reduction in dolphin mortality in the industrial purse-seine fisheries, and that large numbers of long-beaked common dolphins are known to be by-caught. Currently catches are thought to occur, but evidence is anecdotal (pers comm. Stefan Austermühle, Mundo Azul, 2003, November).

Availability as prey: diet composition analyses of cetaceans shows the presence of industrial feed fish species in the diet of harbour porpoise (*Phocoena phocoena*), Bottlenose dolphin (*Tursiops truncates*), White-beaked dolphin (*Lagenorhynchus albirostris*), common dolphin (*Delphinus delphis)*, Risso's dolphin (*Grampus griseus*), Atlantic white-sided dolphin (*Lagenorhynchus acutus*) and minke whale (*Balaenoptera acutorostrata*) (Borjesson *et al*., 2003; Couperus, 1997; Fontaine *et al*., 1994; Kastelein *et al*, 2002; Olsen 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 in the North Sea may therefore impact marine mammal populations by

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[2] Fifth International Conference on the Protection of the North Sea (the 'BergenDeclaration') of 20-21 March 2002

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 not breeding, but reproductively capable females, and the number of breeding failures amongst marked animals, was positively 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 an inadequacy in hunting behaviour. 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 and, thus, 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).

Ecosystem Changes

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 (eg 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, eg 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 VIIa and Sandeel in Division VIa. However, assessing ecological dependence is problematic as evidence for the effects of strong ecological interactions on some stocks, eg 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.

Commercial species as predators of feed fish 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 species’ (including some 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 Bering Sea, the North Sea and the Barents Sea, and calculated that consumption of fish by predatory fish was 5-56t km^{-2} compared to fisheries (of all types) which consumed 1.4-6.1t km^{-2}, marine mammals which consumed 0-5.4 t km^{-2} and seabirds which consumed 0-2t km^{-2}. 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, which shows industrial fish species are a valuable food resource to predatory fish.

Table 5: Diet composition (%) of the main predators in the North Sea

Predator / Prey	Cod	Haddock	Whiting	Saithe	Mackerel	Horse mackerel
Norway Pout	7.7	6.3	8.9	32.2	7.3	0.0
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

>0–1% >1%–10% >10%–50% >50%

Note: Recalculated from Greenstreet, 1996. For each species, the food items that were found in the stomachs are highlighted.

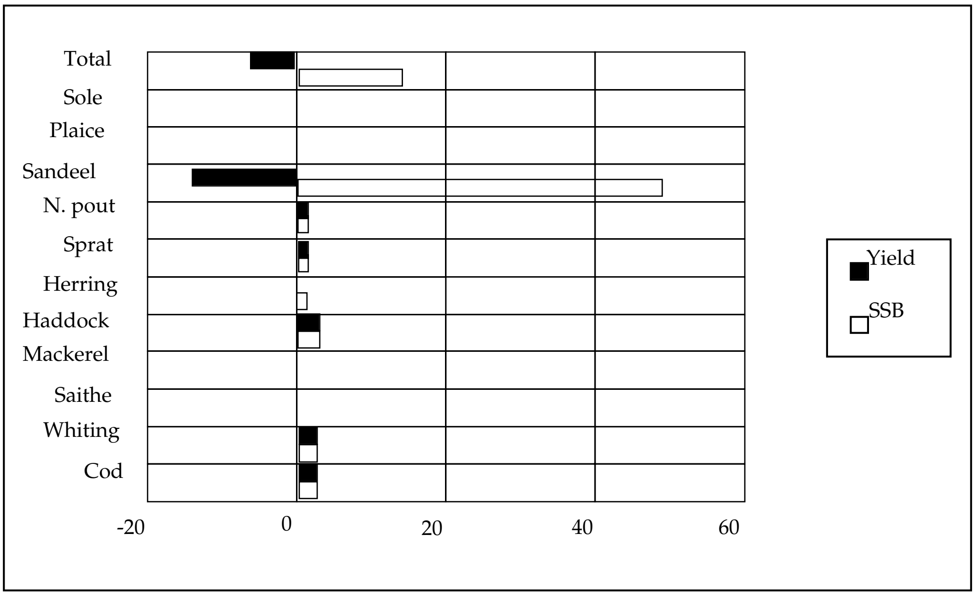
However, whilst bioenergetic estimates of sandeel consumption in the North Sea show that fish are important predators, predation on sandeels is declining (Furness, 2002) as stocks of large gadoid predators are weak and their spawning stock biomass is declining (Sparholt *et al.* 2002). Sparholt *et al*. 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 small 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. 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 Sub-area IV and Division IIIa (ICES, 2003e) indicate 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 3). 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 data is available. 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 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 to ensure that prey items are available to predatory fish.

Figure 3: MSFOR Predictions of the Percentage Change in Yield and SSB in the North Sea

For 11 North Sea Species upon a 40% Reduction in Sandeel Fishing



Source: from Gislason and Kirkegaard, 1998

<u>Teleost feed fish as predators of commercial species</u>

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), 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.

Genetic Impacts

Over-fished populations may exhibit the 'Allele effect'. This is an inverse density dependence at low densities eg 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 (reported in Beverton, 1990) concluded that the Georges Bank herring, which reappeared after a collapse in 1977 to 1/1000th of the 1967 peak of over one million tonnes, 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 (Ulltang, 1980; Winters and Wheeler, 1985). 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.

Summary

Feed fisheries can, as explained above, have a range of direct impacts upon target fish populations and the environment and wider indirect effects on the marine ecosystem. There is a body of research on these effects, as reviewed above. In simple terms the effects and impacts can be summarised as:

Direct effects

- Possible effects on target populations. However, given the variable recruitment dynamics of feed fish, predicting stock trends and determining the effects of fishing on these stocks is difficult. Determining, and further clarifying, indicators of *environmental drivers/regime states*, which pertain to the recruitment dynamics of both sandeels and anchovy, would be of great benefit to their management.
- If discrete local populations exist there may be a possibility of local extirpation by fishing, but this is considered unlikely.
- Possible habitat damage, but only associated with trawl fisheries in sensitive habitats. The Peruvian anchovy fishery has no observable effect on habitats as the fishery operates in the pelagic zone. The sandeel fishery causes intense disturbance to sandy sediments, but such dynamic systems are more resilient to fishing effects than, for example, sensitive marine benthic habitats such as *Lophelia* reefs. Trawling is also seasonal due to the nature of fishery there are recovery periods between fishing.

Indirect effects

- Possible competition for food with feed fish predators. Feed fish are an important link in the food web to higher predators. It is necessary to ensure that there are sufficient prey items available to other fish, birds and marine mammals, especially on local scales.
- Bycatch of non-target fish species. By-catch of other fish species in industrial fisheries is controversial. By-catch appears to be managed effectively in the North Sea sandeel fishery and there is evidence of decline in the numbers of by-caught species over time. The data on by-catch landings are comparable with other industrial and roundfish fisheries. There is less information/data available to make assessments of the fish by-catch issue in the Peruvian anchovy fishery.
- Bycatch of marine wildlife. By-catch mortality of seabirds and marine mammals in the sandeel fishery is low and is not considered to be a conservation issue. While analyses of cetacean by-catch and anecdotal evidence in the South American waters indicate that by-catch from industrial fisheries is likely to a significant pressure on cetacean populations but more research is required to substantiate this view.

2.2.2 Management and Control Issues Associated with Industrial Fishing

EU Control measures for industrial teleosts

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

The TAC for Norway pout and sprat has been the key access control measure since 1983 (EC Regulation 170/1983). TACs for sandeels and blue whiting were first introduced in 1998 (EC Regulation 847/96) and (EC Regulation 1570/1999) respectively. Additional control measures applied to these fisheries are specific limits set aside for by-catches. In addition, there is a set of technical measures restricting by-catch (EC Regulation (EC) 850/98). These are summarised in the table below:

Table 6: Mesh Size Ranges, Target Species and Required Catch Percentages

Applicable to the use of a single mesh size range

Mesh size (mm)	**<16**	**16-31**	**32-54**	**70-79**	**80-99**		**≥100**
Min % of target sp. / **Target sp.**	**95**	**90/60** (see note below)		**35**	**30**	**70**	**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

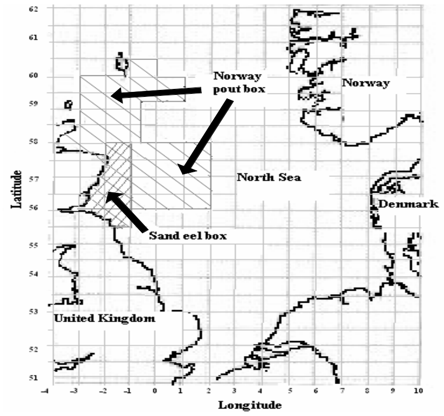
Note: TOWED GEARS: EU Regions 1 and 2, except Skagerrak and Kattegat
Source: Council Regulation 850/98 ANNEX I

The most relevant of controls are as follows: fishing for sandeel (1) may only take place in the North Sea from 1 March to 31 October, During this period vessels may use 16 mm mesh if the target species is greater than or equal to 95% of the catch composition. Sandeel (2) refers to fishing in the North Sea from 1 November to end February. When fishing for sandeels, sprat, Norway pout and Blue whiting, a combination of minimum mesh sizes may be used:

- Between 16-31 mm
  - 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 mm 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.

A number of closed areas apply to feed fish fisheries (see Figure 4, below). These are adjacent to the UK coast and apply to Norwegian pout and sandeels as follows.

Figure 4: Areas closed to industrial fishing



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_. The Norway pout Box was introduced in order to prevent the fishing for feed fish fisheries in areas that were deemed to be important juvenile feeding grounds for gadoid (cod, haddock and whiting) species (Eliasen (2003)).

Sandeel[3]

- 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

This prohibition has been established since the 2000 and covers 18,000 km_. The aim of the sandeel box is to reduce levels of fishing mortality on sandeel in order to increase the availability of sandeel as a food base 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 into 2003 and now 2004, and may be introduced as a permanent Annex to the EU's conservation regulation.

Additional closed areas also exist for sprat.

Unilateral control measures

In 1996, Denmark introduced a series of follow up measures to ensure compliance with the EC Regulations. The Danish Government introduced stringent control

[3] Council Regulation (EC) No 1298/2000

measures as a means to limit by-catches in industrial species. The system has the following elements (Eliasen, 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))[4]. Since 2001, the Fisheries Directorate has also applied an additional penalty of loss of trip catch revenue.

Sweden has endorsed and adopted similar procedures (S. Mattsson, Fiskeriverket, (2003) pers com, 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 excesses 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% 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 that fish for feed fish are dependent on other fisheries. The Directorate of Fisheries has produced a guidance note on revocation of permits[5].

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 (Eliasen, pers. comm., August 2003). 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 pre defined limits. It should also be noted that enforcement has also been complemented by the use of Vessel Monitoring Systems (VMS)[6]

The number of permit revocations has steadily increased from 47 in 1996 to 112 in 2002 (Table 7). It should be noted that the increase in revocations reflects the number and type of offences that have evolved over time. For example, a by-catch control system introduced in the Western Baltic from 2002 resulted in an increase in

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[4] Banks *et al* (2000), identified the av. 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 1 in 3 trips.

[5] http://www.fd.dk/info/sjle3/Inddragelsesvejledning.htm

[6] VMS is a satellite tracking system which transmits the position of a fishing vessel at regular intervals.

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.

Table 7: Danish industrial fishing permit revocations, 1996-2002

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: Danish Fisheries Inspectorate

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

Control measures for Industrial Teleosts Outside the EU

Table 8 below identifies specific management restrictions applying to the three feed fisheries that fall outside the umbrella of the EU.

Table 8: Management Restrictions for Selected Industrial Feed Fisheries

SPECIES	Total Catch Limit	Area Catch Limit	Min Mesh Sizes	Fleet Capacity Controls	Closed Areas	Seasonal Bans
Anchovy	Π	Π	Π	Π	Π	Π
Blue whiting	Π		Π			
Capelin	Π	Π	Π		Π	Π

Government controls applied to Peruvian vessels include:

- Boats fitted with satellite tracking systems
- Closed fishing seasons, eg February and March to protect growth of juveniles; August to October to protect spawning stock
- Vessels have to be licensed to fish in 200 mile limit
- Limits on minimum size of fish landed – short term fishing closures if too small
- Considerations of stock assessment results in setting harvest limits, such as IMARPE's hydro-acoustic evaluation of pelagic resources along entire Peruvian coastline in February 2002.

Government controls applied to Chilean vessels include:

- Government has introduced legislation to set a maximum catch limit for each company
- In North Chile closed seasons for anchovy and sardine spawning stocks are set annually between August and September, and December to February to protect anchovy
- In the central south, closed seasons are set for anchovy and sardine to protect spawning over the periods July and August and mid-December to mid-January
- Boats are fitted with satellite tracking systems

Government controls in Norway, Iceland, Faeroes and Greenland

North-East Atlantic Fisheries Commission has agreed to implement a long term management plan to ensure catches limited to a sustainable level. EU autonomous TACs have been established by the EU for fishing in international waters, but not by Norway, which accounts for the greater proportion of fishing effort in the International Blue whiting fishery.

Capelin fishing is managed by a system of TACs, closed areas and closed seasons.

Vessel Monitoring Systems (VMS) are being applied progressively in bilateral fisheries agreements, i.e. EU/Norway, EU/Faeroe Islands

2.2.3 Economic and Societal Considerations

The Marine Stewardship Council's definition of a 'sustainable' fishery is that it includes, along with various environmental criteria, that:

a) it is managed and operated in a responsible manner, in conformity with local, national and international laws and regulations;

b) it maintains present and future economic and social options and benefits;

c) it is conducted in a socially and economically fair and responsible manner

MSC acknowledge that their standard does not fully address economic or societal 'sustainability' and expects fisheries to adopt other initiatives to address these issues where this is considered to be necessary. A number of such initiatives have developed and are briefly reviewed below. There are a significant number of other issues relating to the social and economic sustainability of the fisheries. This includes the use of artificial subsidies or trade barriers to promote a certain fishery to the possible detriment of another, as well as practices that dictate unequal distribution of employment opportunities, which may also be applicable to large-scale industrial feed fisheries.

The International Labour Organisation (ILO) was created in 1919 primarily for the purpose of adopting international standards to cope with the problem of labour conditions involving "injustice, hardship and privation". The ILO standards take the form of international labour conventions and recommendations. Eight ILO conventions have been identified by the ILO's Governing Body as being fundamental to the rights of human beings at work. They are conventions: No. 87 (1948) and No. 98 (1949) on freedom of association and collective bargaining; No. 29 (1930) and No. 105 (1957) on the abolition of forced labour; No. 111 (1958) and No. 100 (1951) on discrimination and equal remuneration; and No. 138 (1973) and No. 182 (1999) on the elimination of child labour.

Fairly Traded Fish and Seafood[7]: The goal of the Fairly Traded Fish and Seafood initiative is to improve the living and working conditions of marine artisan fish workers through better economic incentives by establishing as direct a link as possible between artisanal fish worker organisations and Fair Trade buyers. The project was launched at the Bremen Fish Fair in March 2000. It is founded on a partnership-based arrangement between the Fair Trade and marine fish worker associations in developing countries. To qualify for partnership, the fish worker association has to comply with four sets of criteria.

The first is a general set of criteria for all Fair Trade partners, and stipulates that it should be an independent, democratic and transparent association, and that it should strive to uphold the core labour standards of ILO.

The other three sets of criteria are developed through informal consultations with fish worker organisations and support groups in developing countries. These are:

- The organisation should be an association of fishers who actually participate in fishing with unmotorised, wind-powered, out-powered or in-powered vessels (at the lower end of the horsepower range) and who undertake their fishing operations from the beach, cove, lagoon, estuary, or piers, using fishing gear and techniques that avoid "unnecessary" by-catch and discards, and without resorting to the use of poisons/explosives.
- Second, the promotion of fair trade should not lead to negative externalities and should not threaten the nutritional security in fish producing countries, by way of higher prices and reduced supply to the local population. It should

[7] Text adapted from Mathew, S. 2003 [Richard reference – I have no idea where he got this from]

also not threaten traditional processing and marketing structures, especially in contexts where women play an active role.

- Third, only 15 per cent or less of total fish landings of the members would be brought under the scope of Fair Trade, and would include only low-value species that are in surplus after meeting local demand, and high-value species that are not normally consumed by the poor.

3 IDENTIFICATION AND APPLICATION OF SUSTAINABILITY CRITERIA FOR FEED FISHERIES

3.1 IDENTIFICATION OF MAIN CRITERIA FOR SUSTAINABLE FISHING

As discussed above, the concept of sustainability is a complex one, and therefore has implications for the selection of criteria for 'sustainable fishing'. The most widely accepted generic model is the principles and criteria for sustainable fishing developed by the Marine Stewardship Council[8] (MSC). These have been developed over a long consultation period (see Appendix C) and have provided the basis for the following criteria and the sustainability index. Whilst the MSC criteria respond well to fisheries and ecosystem issues, they do not provide an assessment of the economic nor social elements. These were briefly assessed at the SEAFeeds[9] conference in April 2003 and have been included in the modified criteria below.

The MSC principles and criteria consider whether a fishery is sustainable depending upon a demonstration of:

- The maintenance and re-establishment of healthy populations of targeted species;
- The maintenance of the integrity of ecosystems;
- The development and maintenance of effective fisheries management systems, taking into account all relevant biological, technological, economic, social, environmental and commercial aspects; and
- Compliance with relevant local and national laws and standards and international understandings and agreements.

Below we reproduce the MSC 'Principles and Criteria' that we have applied in their entirety as the basis for our assessment of the sustainability of industrial fisheries. However, in the following sub-sections, the three MSC Principles and their criteria have been slightly modified to focus specifically on industrial fisheries by the addition of a list of the main considerations (the 'indicators', see section 3.2) to be applied in the assessment of each criterion. Furthermore, a fourth Principle and Criteria has been developed specifically to address the economic and societal elements of 'sustainability'.

3.1.1 Principle 1: Fishing Pressure and Stock Sustainability

A fishery must be conducted in a manner that does not lead to over-fishing or depletion of the exploited populations and, for those populations that are depleted, the fishery must be conducted in a manner that demonstrably leads to their recovery.

Intent: To ensure that the productive capacities of resources are maintained at high levels and are not sacrificed in favour of short term interests. Thus, exploited populations would be maintained at high levels of abundance designed to retain their productivity, provide margins of safety for error and uncertainty, and restore and retain their capacities for yields over the long term.

Criteria:

[8] www.msc.org

[9] EC 'Quality of Life and Management of Living Resources' Programme (Key Action 5.1.2 under the 5th Framework). See http://www.SEAFeeds.net/home%20.html

1. The fishery shall be conducted at catch levels that continually maintain the high productivity of the target population and associated ecological community relative to its potential productivity. *Considerations include: (i) understanding of life history and stock distribution, (ii) knowledge of fishing methods, effort and mortality, (iii) existence of acceptable reference points, (iv) existence of a harvest strategy, (v) whether input and output controls are embedded as a management tool, (vi) whether there is a robust stock assessment and (vii) are the stocks at appropriate precautionary reference level.*
2. Where the exploited populations are depleted, the fishery will be executed such that recovery and rebuilding is allowed to occur to a specified level consistent with the precautionary approach and the ability of the populations to produce long-term potential yields within a specified time frame.
3. Fishing is conducted in a manner that does not alter the age or genetic structure or sex composition to a degree that impairs reproductive capacity. *Considerations include information on (i) fecundity/recruitment dynamics, (ii) age and sex/genetic structure and (iii) historic changes in structure indicating alteration of reproductive capacity.*

3.1.2 Principle 2: Structure, Productivity, Function and Diversity of the Dependant Ecosystem

Fishing operations should allow for the maintenance of the structure, productivity, function and diversity of the ecosystem (including habitat and associated dependent and ecologically related species) on which the fishery depends.

Intent: The intent of this principle is to encourage the management of fisheries from an ecosystem perspective under a system designed to assess and restrain the impacts of the fishery on the ecosystem.

Criteria:

1. The fishery is conducted in a way that maintains natural functional relationships among species and should not lead to trophic cascades or ecosystem state changes. *Considerations include (i) knowledge of relevant ecosystem factors, (ii) general risk factors, (iii) knowledge of impact of gear-use and loss and (iv) the level of ecosystem management, and (v) an assessment of ecosystem impacts.*
2. The fishery is conducted in a manner that does not threaten biological diversity at the genetic, species or population levels and avoids or minimises mortality of, or injuries to endangered, threatened or protected species. *Considerations include (i) knowledge and implications of interactions and (ii) whether management objectives are set for impact identification and avoidance.*
3. Where populations of non-target species are depleted, the fishery will be executed such that recovery and rebuilding is allowed to occur to a specified level within specified time frames, consistent with the precautionary approach and considering the ability of the population to produce long-term potential yields. *Considerations include an understanding of (i) the information necessary to determine necessary changes to allow recovery of depleted non-target species populations and (ii) the nature and effectiveness of management mechanisms.*

3.1.3 Principle 3: Information, Organisational and Legislative Capacity for Sustainable Management

The fishery is subject to an effective management system that respects local, national and international laws and standards and incorporates institutional and

operational frameworks that require use of the resource to be responsible and sustainable.

Intent: The intent of this principle is to ensure that there is an institutional and operational framework for implementing Principles 1 and 2, appropriate to the size and scale of the fishery.

A. Management System Criteria:

1. The fishery shall not be conducted under a controversial unilateral exemption to an international agreement.

The management system shall:

2. Demonstrate clear long-term conservation objectives consistent with MSC Principles and Criteria and contain a consultative process that is transparent and involves all interested and affected parties so as to consider all relevant information, including local knowledge. The impact of fishery management decisions on all those who depend on the fishery for their livelihoods, including, but not confined to subsistence, artisanal, and fishing-dependent communities shall be addressed as part of this process;
3. Be appropriate to the fishery's cultural context, scale and intensity – reflecting specific objectives, incorporating operational criteria, containing procedures for implementation and a process for monitoring and evaluating performance and acting on findings;
4. Observe the legal and customary rights and long term interests of people dependent on fishing for food and livelihood, in a manner consistent with ecological sustainability;
5. Incorporates an appropriate mechanism for the resolution of disputes arising within the system;
6. Provide economic and social incentives that contribute to sustainable fishing and shall not operate with subsidies that contribute to unsustainable fishing;
7. Act in a timely and adaptive fashion on the basis of the best available information using a precautionary approach particularly when dealing with scientific uncertainty;
8. Incorporate a research plan – appropriate to the scale and intensity of the fishery – that addresses the information needs of management and provides for the dissemination of research results to all interested parties in a timely fashion;
9. Require that assessments of the biological status of the resource and impacts of the fishery have been and are periodically conducted;
10. Specify measures and strategies that demonstrably control the degree of exploitation of the resource, including, but not limited to:
    a) setting catch levels that will maintain the target population and ecological community's high productivity relative to its potential productivity, and account for the non-target species (or size, age, sex) captured and landed in association with, or as a consequence of, fishing for target species;
    b) identifying appropriate fishing methods that minimise adverse impacts on habitat, especially in critical or sensitive zones such as spawning and nursery areas;
    c) providing for the recovery and rebuilding of depleted fish populations to specified levels within specified time frames;
    d) mechanisms in place to limit or close fisheries when designated catch limits are reached;

e) establishing no-take zones where appropriate;

11. Contains appropriate procedures for effective compliance, monitoring, control, surveillance and enforcement which ensure that established limits to exploitation are not exceeded and specifies corrective actions to be taken in the event that they are.

Considerations include that the fishery has (i) clearly defined institutional and operational responsibilities, (ii) a clear legal basis, (iii) a consultative and dispute resolution strategy, (iv) a clear research plan to address information needs, (v) a monitoring and evaluation system for fisheries and ecosystem effects and (vi) suitable management control mechanisms.

B. Operational Criteria

Fishing operation shall:

12. Make use of fishing gear and practices designed to avoid the capture of non-target species (and non-target size, age, and/or sex of the target species); minimise mortality of this catch where it cannot be avoided, and reduce discards of what cannot be released alive;
13. Implement appropriate fishing methods designed to minimise adverse impacts on habitat, especially in critical or sensitive zones such as spawning and nursery areas;
14. Not use destructive fishing practices such as fishing with poisons or explosives;
15. Minimise operational waste such as lost fishing gear, oil spills, on-board spoilage of catch, etc.;
16. Be conducted in compliance with the fishery management system and all legal and administrative requirements; and
17. Assist and co-operate with management authorities in the collection of catch, discard, and other information of importance to effective management of the resources and the fishery.

Considerations include (i) implementation of operational measures to reduce impacts on habitats and non-target species, (ii) management measures that discourage operational wastes and destructive practices, (iii) fisheries are aware of and compliant with managerial, administrative and legal requirements and (iv) fisheries are involved in catch, discard and other relevant data collection.

The MSC Principles and criteria have been applied to a range of fisheries globally, with seven fisheries now certified as meeting these criteria. Around 20 other fisheries are currently undergoing pre- and full assessment, including the North Sea herring (*Clupea harengus)* fishery. As yet, none of the fisheries certified can be classed as industrial, although it is understood that a number of such fisheries are interested in undergoing assessment (Brad Norman, MSC, pers. comm.).

3.1.4 Principle 4: Economic and Societal Considerations

A fishery should be exploited in such a manner that it provides economic benefits in an equitable manner and does not disadvantage local, national or external

stakeholders through unfair competition, employment opportunities or displacement of opportunities.

Intent: The intent of this Principle is to ensure that fisheries are implemented in a fair and equitable manner that provide and sustain a wide range of social and economic benefits to a cross section of society without nationalistic, regional or cultural discrimination.

Criteria:

1. Respects the needs of fisheries-dependent communities, historic fishing rights and the cultural aspects of the local fishing industry
2. Local employment opportunities are not unreasonably disadvantaged and labour conditions conform to ILO standards regarding (i) freedom from forced labour, (ii) the freedom of association and collective bargaining, (iii) no discrimination on the basis of race, gender, religion and social origin and (iv) the non-use of child labour; and
3. The fishery does not prejudice food security for any group through price or supply limitations.

There are currently a large number of gaps in our knowledge of the economic or social implications of industrial fishing activities in respect to South America. Whilst there are a number of simple existing economic indicators that could be adopted, there is a need to agree clear objectives and indicators for 'socio-economically sustainable' feed fishing. This is beyond the scope of this study and therefore the indicative criteria provided above should not be considered as comprehensive.

3.2 INDICATORS

As mentioned, a series of additional considerations – indicators - have been developed to assist in determining the sustainability of industrial fisheries. Expressly, these have been developed to clarify the criteria and help assist in the assessment of whether the two test fisheries in this study meet the above sustainability criteria. These indicators have been summarised in Table 9 overleaf and have been adapted from the MSC indicators and scoring guideposts.

Under the MSC certification system, their indicators are used to assist the scoring of fisheries 'sustainability'. For each indicator, there are three 'scoring guideposts' that assist assessors in determining the score out of 100. For instance there are guideposts for what passes at 60, 80 and the ideal score for 100 (i.e. 100% compliance).

The indicators provided overleaf correspond to the criteria provided in sections 3.1.1-3.1.4 above. One exception is the criteria for Principle 3 that have been nested from the 17 criteria to 7 management and 4 operational criteria. These indicators are cross-referenced to the appropriate criteria in the table.

Table 9: Summary of Principles, Criteria and Corresponding Indicators

Principle	Criterion (C)		Indicator
1. Fishing Pressure and Sustainability	1.1 High productivity maintained		a) Level of understanding of species & stock biology
			b) Knowledge of fishing methods, effort & mortality
			c) Existence of acceptable reference points
			d) Existence of defined harvest strategy
			e) Robust and regular assessment of stocks
			f) Are the stocks at appropriate precautionary reference level
	1.2 Fishery's ability to rebuild to a predefined level within a specific time frame		
	1.3 Reproductive capacity of stock maintained		a) Information on fecundity and recruitment dynamics
			b) Information of stock age / sex structure
			c) Evidence of changes in reproductive capacity
2. Structure, Productivity, Function & Diversity of Dependent Ecosystem	2.1 Natural functional relationships between species maintained without ecosystem state changes		a) Understanding of ecosystem factors relevant to target species
			b) General risk factors known and understood
			c) Impacts of gear use and loss known
			d) Ecosystem management strategy developed
			e) Ecosystem assessment shows no unacceptable impacts
	2.2 Fishery does not threaten biodiversity		a) Level of knowledge and implications of interactions
			b) Management objectives set for impact identification / avoidance
	2.3 Recovery of non-target species populations permitted		a) Information on necessary changes to allow appropriate recovery
			c) b) Management measures permit adaptive change to fishing
			d) c) Management measures allow recovery of affected populations
3. Information, Organisational and Legislative Capacity for Sustainable Management	3.1 Management System Criteria	C2	a) Clearly defined institutional and operational framework
		C1, 2, 3	b) Management system has clear legal basis
		C2, 5, 7	c) Has a consultative and dispute resolution strategy and pathways
		C6	d) Subsidies or incentives exist that affect fishing practices
		C8	e) Adequate, operational research plan to address information needs
		C7, 9, 10	f) Monitoring and evaluation system for fisheries management objectives
		C11	g) Control mechanisms for enabling and enforcing management objectives
	3.2 Operational Criteria	C12, 13	a) Operational mechanisms to reduce impacts on habitats and non-target species
		C14, 15	b) Measures to discourage operational wastes and destructive practices
		C16	c) Fishers aware of / compliant with - managerial, administrative and legal requirements
		C17	d) Fishers involved in catch, discard and other relevant data collection
4. Economic and Social Considerations	4.1 Respects the needs of fisheries dependent communities, historic rights and cultures		a) Does not impact resource availability or access, directly or indirectly
			b) Fisheries and fishers demonstrate understanding and sensitivity to traditional practices and ways of life
	4.2 Labour conditions conform to ILO standards		a) Freedom from enforced labour
			b) Freedom of association and collective bargaining
			c) Lack of discrimination of individuals and organisations
			d) Non-use of child labour
	4.3 Fishery does not prejudice food security		a) Pricing structure operates within market norm
			b) Supply operates within market norm

3.3 APPLICATION OF SUSTAINABILITY CRITERIA

3.3.1 Introduction to the Fisheries

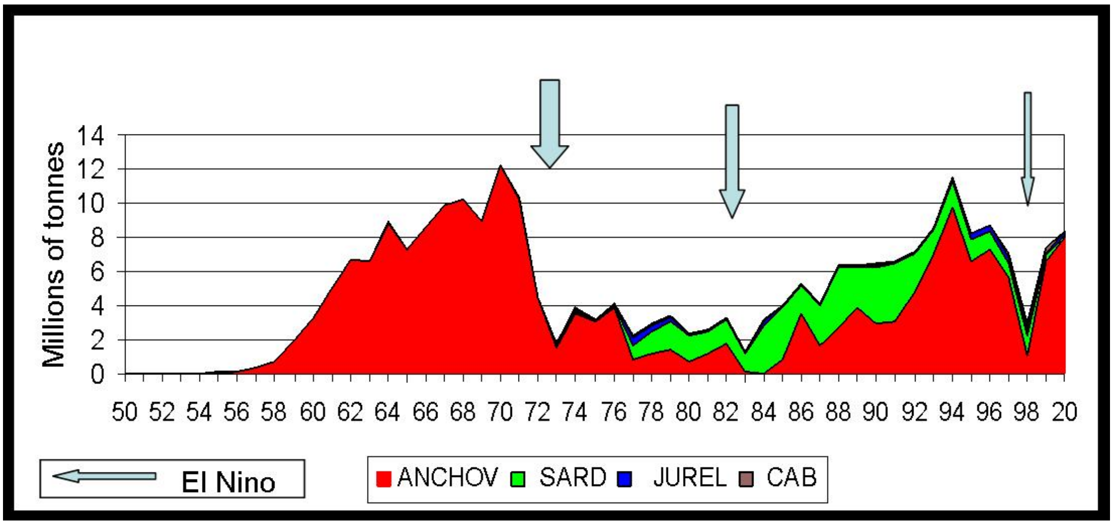
Peruvian Anchovy Fishery

<u>The Resource</u>

In Peru, the industry is dominated by the small pelagic anchovy (*Engraulis ringens*). The Peruvian anchovy fishery lies in the region of the Peruvian upwelling, a region characterized by high productivity. Upwelling in this region occurs on the coastal boundaries where Coriolis' force results in the deflection of a long shore current offshore, deep water upwells to fill the void created by the water driven offshore, forcing nutrient-rich cool water to the surface, resulting in high phytoplankton and zooplankton productivity in the region.

The Peruvian industrial fishing industry started to grow during the mid-1950s (Figure 5), responding to the global demand for animal feed. Between 1955 and 1959, an average of 972 000 tonnes was landed by Peruvian fishermen. In 1955, this represented about 4 percent of Peruvian exports or 0.2 percent of the country's GDP. Between 1960 and 1964, production had skyrocketed to almost 6.5 million t and represented 12 percent of Peruvian exports. Fisheries catches continued to climb at a very high rate throughout the 1960s (the catch being dominated by anchovy - 99 percent of catch between 1960-1972) reaching a plateau in 1970 (Deligiannis, 2000).

Figure 5: Landings of Pelagic Resources in Peru (1950-2000)



In the early 1970s, and in 1997-1998, catches were reduced by the El Niño Southern Oscillation (ENSO) event (a hydrographic phenomenon that effects the movement of water masses in the Pacific, which consequently reduces plankton food availability to other organisms). Catches after the ENSO events in the 1970s and early 1980s remained low, and this was presumed to be primarily due to extrinsic drivers affecting the stock (pers. comm. Renato Guevara Carrasco, IMARPE, 2003). However, populations of the short-lived fecund species have recovered post the late 1990s event and catches have been increasing since, with a brief hiatus due to the ENSO event over 1997-98.

Instituto del Mar del Perú (IMARPE) informs the Ministry of Fisheries in Peru of scientific information and the recommendations on which to based fishery-resource management decisions. Acoustic and boat surveys are mainly used for estimating the abundance and location of the pelagic stocks. Two stocks are prosecuted in the Peruvian region a northern/central stock and a southern stock. The latter stock is shared with Chile and politics in the region affects management of this stock, including the application of TACs and closed seasons.

<u>The Fishery</u>

The Peruvian anchovy fleet is predominantly owned and managed by the processing sector. There are 712 vessels dependent on this fishery: 627 purse seiners, 67 trawlers and 18 multi purpose vessels. The fleet is reported as being in overcapacity, consequently vessels are subject to Individual Boat quotas, which are traded between vessel owners.

There are 350 fish processing plants in Peru, 143 of these specialise in the production of fish meal. The fish meal plants produce 751 metric tonnes of product per hour.

North Sea Sandeel Fishery

<u>The Resource</u>

In the North Sea five species of sandeel are present, although in the fishery some >90% catch comprises of *Ammodytes marinus*. The assemblage/population is consumed by numerous species of fish (eg Greenstreet, 1996), seabirds (eg Monaghan, 1992; Tasker and Furness 1996; Wanless *et al*. 1998) and marine mammals, including seals and cetaceans (eg Brown *et al*., 2001, Brown and Pierce, 1998; Santos *et al*., 1994; Santos *et al*., 1995; Tollit *et al*. 1998)).

The industrial fishery for sandeels in the North Sea started to develop in the early 1950s and, by 1970, a yield of about 200,000 tonnes was harvested. The fishery continued to expand with the mean annual landing reaching 482,000 t during the 1970s and 734,000 t during the 1980s.

Sandeels (including those fished in the West of Scotland and the Shetland Isles) account for 45% of the EU's feed fish catch. The catches of sandeel are known to fluctuate (Figure 6). The TAC in the North Sea (which also includes ICES areas IIa, IIIa, IV) is reported to have been considerably undershot in 2003 and participants continually under-fish the TAC, on occasions by up to 20% (uptake for the years 1998-2002 averaged 80% of the total). The EU, largely Denmark, is the dominant participant in this North Sea sandeel fishery with Sweden and the UK taking 10 and 30%, respectively (ICES / National fishery departments' statistics).

Figure 6: EU Sandeel Catches and Spawning Stock Biomass (1993-2003)

Source: ICES, 2003a

The effect of industrial fishing on species targeted for human consumption is relatively small in comparison to the directed fisheries (see section 2.2.1). Sandeels are a prey important species for many marine predators. However there is still relatively little information on the ecosystem effects of industrial fisheries or the effects of variations of the sizes of most industrial fisheries on their predators. This subject is currently under investigation by the EC funded IMPRESS (Interaction between the Marine environment, PREdators and prey: implications for Sustainable Sandeel fisheries) project[10]. IMPRESS is focussing particularly on assessing the food requirements and foraging behaviour of inshore and offshore avian sandeel specialist predators compared with the more opportunistic wide-ranging northern gannet.

The Fishery

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 10 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 10: The composition of the Danish industrial fleet (2002)

Gear type	No. of vessels	Av. no. of persons employe	Dependency on industrial species %	FTE	Total earnings M €	% group dependency		
						Sand-eel	Sprat	Other
Trawl 15-18m	131	2	11	29	2.76	17	76	7
Trawl 18-24m	110	3	16	53	4.39	37	53	10
Industrial trawl 24-40m	47	5	97	228	16.68	58	26	16
Other trawl 24-40m	87	4	25	87	5.64	65	18	17
Industrial trawl > 40 m	13	5	93	60	9.03	51	51	32
Other trawl > 40m	19	6	46	52	5.52	59	6	35
Total	**407**			**509**				

Source: FOI (Denmark)

The important characteristics of the fleet are:

- There are 407 vessels in Denmark which fish for industrial species.
- 60 vessels can be described as permanently dependent.
- There are also 347 vessels that 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) fishermen dependent on industrial fishing.

[10] see http://www.nioz.nl/en/deps/mee/projects/impress/impress.htm

- 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. Nine 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[11]:

- 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

FOI (Danish Institute for Food Research)[12] 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.

3.3.2 Application of the Criteria

Scoring

For each of the criteria under the four Principles described in Section 3.1, a simple scoring system has been applied as follows:

?= **Insufficient information available** (inadequate information available to the research team)

0= **Does not meet criteria** (clear inadequacies that indicates that sustainability criteria are not met)

1= **Partially meets criteria** (some aspects do not clearly meet sustainability criteria or there may be some information gaps)

2= **Fully meets criteria** (clearly meets or exceeds sustainability criteria - anything less than "fully meeting" does not warrant this classification).

The results of this preliminary assessment are presented in the following pages. In each case, a score is presented together with comments and reference sources.

Weighting

No weighting between the four Principles is applied, as all are considered of equal importance. A full MSC assessment will normally weight all the criteria and sub-

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[11] Derived from, the Fisheries Economics and Management Division, Danish Research Institute of Food Economics

[12] Andersen J and Løkkegaard J: Industrifiskeriets _konomiske Betyding for Dansk Fiskeri, FOI Rapport 134, 2002

criteria using a decision support software package that is based on the Analytic Hierarchy Process (AHP), enabling pair-wise comparisons of different criteria. Whilst this is suitable for the detail required for full MSC fisheries assessments, the less detailed nature of this particular investigation means that the application of such a complex weighting system would be unsuitable. Therefore, a formal criteria weighting system is not used. However, the summary assessments in the next section do consider the relative importance of each criterion and their performance for both test fisheries.

Principle 1 – Fishing Pressure and Stock Sustainability

Criterion	Indicator	Peruvian Anchovy		North Sea Sandeels	
		Score	*Comment*	*Score*	*Comment*
1.1 High productivity maintained	a) Level of understanding of species & stock biology	**1**	IMARPE carries out research into the anchovy stock biology. There are two stocks. Northern/central stock and the southern stock which is shared with Chile. Information on target stocks in the Peruvian system is detailed, although much is contained in grey literature, and its quality and comprehensiveness cannot easily be assessed.	**1**	Research has been carried out on the species and stock biology eg ELIFONTS (Harwood, J. (1999) and Wright *et al*. (1998), but there are still questions regarding the status of the stock / sub-stocks and the species biology.
	b) Knowledge of fishing methods, effort & mortality	**1**	IMARPE has detailed information on fishing methods, effort and mortality. As 1.1a much of this is contained in grey literature and cannot be assessed	**1**	EU legislation (1639/2001) requires annual reporting on fishing methods, effort and mortality. There are, however, identified uncertainties eg inconsistencies in the catch and the calibration data to assess the fishery over time. (ICES 2003e).
	c) Existence of acceptable reference points	**?**	Reference points exist for the northern/central stock (prosecuted by Peru) based on bi-annual stock assessments. Reference points exist for the southern stock (prosecuted by Peru/Chile), but the fishery is subject to political dissent and they may not be closely followed. The Peruvian marine system is characterised by a high degree of climatic/oceanographic variability. Governmental scientists appreciate the difficulty in managing a dynamic system.	**1**	Precautionary reference points are set for the whole sub-area IV, which may not take account of the existence of local populations eg Wright *et al*. (1998)
	d) Existence of defined harvest strategy	**1**	Harvesting is determined by the reproductive condition of the stock eg targeting the southern stock when the northern stock is reproducing, and there are seasonal controls to protect the recruitment growth of juveniles. By-catch control for juveniles exists. Port closures occur if vessels land catches consisting of more than 10% juveniles over three consecutive days.	**1**	Harvesting strategy is closely defined with, for example, TACs and precautionary approach reference points. However, the few year classes of this species make longer-term stock size and catching opportunities difficult to predict. The strategy is also in place for the North Sea as a whole rather than sections

Criterion	Indicator	Peruvian Anchovy		North Sea Sandeels	
		Score	*Comment*	*Score*	*Comment*
	e) Robust and regular assessment of stocks	**1**	Time series analysis of landings and stock structure are available. We cannot rate the robustness of these analyses, as we cannot gain access to the data.	**1**	Assessment of the stocks by ICES is regular and is based on a seasonal age-based assessment using commercial and survey data. But does not take into account local sub-populations
	f) Are the stocks at appropriate precautionary reference level	**1**	Northern stock - is considered to be at the precautionary reference level, as near as can be assessed due to the dynamic nature of the marine environmental regime in the region. Southern stock – the management and assessment of the fishery is more problematical due to the dual prosecution of the stock, for example, TACs are not applied at this time. Determining if stocks are at a precautionary reference level is not possible.	**1**	ICES considers the sandeel stock (ICES, 2003e) in the North Sea to be "uncertain". A weak 2002 year class means the 2004 SSB will be low.
1.2 Fishery's ability to rebuild to a predefined level within a specific time frame		**1**	Stocks are known to be affected by extrinsic drivers (El Niño), and historically stocks have recovered after an El Niño event, predicting rate of recovery is not possible	**1**	Stocks are known to be affected by extrinsic drivers, predicting rate of recovery is not possible, although recovery is presumed to occur (Beverton, 1990)
1.3 Reproductive capacity of stock maintained	a) Information on fecundity and recruitment dynamics	**1**	IMARPE has data on size classes and seasonality. This information is used by IMARPE to advise the government on TACs and other management measures.	**1**	ICES working group reports and scientific literature (eg Arnott and Ruxton, 2002; Arnott *et al.*, 2002; Wright *et al.*, 1998) have information on fecundity and recruitment dynamics.
	b) Information of stock age / sex structure	**1**	IMARPE hold information on stock age / sex structure	**1**	ICES working group reports have information on mortality and age / sex structure.
	c) Evidence of changes in reproductive capacity	**0**	No studies of this nature have been carried out. IMARPE hopes to begin research into the reproductive capacity and genetics of the sub-stocks in 2004. The institute is constrained by limited funding.	**1**	May be difficult to prove with this short-lived species. As sandeels are fished with a range of small meshed trawls in the North Sea (<16–100mm) and since there is a minimum landing size presumably the effects of size-specific fishing are minimal.

Scoring Summary – Principle 1: Fishing Pressure and Stock Sustainability

<table>
<tr><th>Scoring</th><th>Peruvian Anchovy</th><th>North Sea Sandeels</th><th>Summary</th></tr>
<tr><td colspan="3">Criterion 1.1: High productivity maintained</td><td rowspan="20">Research into the sandeel ecology/biology and population structure in the North Sea is detailed. However, the extrapolation of aspects of research, eg the existence of local populations, has not been taken on board in whole North Sea (ICES IV) stock assessments. The sandeel stock is considered to be ‘uncertain’ at this time (ICES, 2003e). The high natural mortality of sandeel and the few year classes in the fishery make the stock size and catch opportunities largely dependent on the size of the incoming year classes. The current 2002 year class is considered weak, and the data (at present) indicated that the 2003 year class is not strong. There is conflicting information coming from the Danish and Norwegian fisheries on the size of the remaining 2001 year class as age 2/3 in 2003, leading to uncertainty as to the survival to age 2. Prior to the current assessment, the SSB of sandeel has been fluctuating around 1 million tones with an increasing trend from 1989 to 1995 and a decreasing trend from 1998 to 2002 (ICES 2002a; ICES, 2004). Examination of the trends in SSB over time has indicated that here is a general pattern of large SSB being followed by a low SSB and this is thought to be due to a similar fluctuation in recruiting year classes (ICES, 2004). This highlights the inherent uncertainty in assessing stocks of short-lived, fecund species such as the sandeel over time. ICES could not recommend a TAC setting in 2004 and recommended that the fishery be managed through effort and capacity control. The EC (Council Regulation (EC) No 2287/2003) set a TAC of 826 200mt for 2004, which is a reduction of 10% from the previous year’s TAC, in addition, a temporary system to manage the fishing effort has also been set in place. The effectiveness of this strategy cannot be assessed at this time.

IMARPE carries out research into the anchovy and stock ecology/biology, and there is detailed information on fishing methods, effort and mortality, but much of the information is contained in grey literature and it is not possible to rate the robustness of these analyses. The northern anchovy stock is considered to be at an appropriate precautionary reference level, however, the southern stock is considered to be ‘uncertain’.</td></tr>
<tr><td>Fully meets criteria (2)</td><td>-</td><td>-</td></tr>
<tr><td>Partially meets criteria (1)</td><td>5</td><td>6</td></tr>
<tr><td>Does not meet criteria (0)</td><td>-</td><td>-</td></tr>
<tr><td>Insufficient information (?)</td><td>1</td><td>-</td></tr>
<tr><td colspan="3">Criterion 1.2: Fishery’s ability to rebuild to a predefined level within a specific time frame</td></tr>
<tr><td>Fully meets criteria (2)</td><td>-</td><td>-</td></tr>
<tr><td>Partially meets criteria (1)</td><td>1</td><td>1</td></tr>
<tr><td>Does not meet criteria (0)</td><td>-</td><td>-</td></tr>
<tr><td>Insufficient information (?)</td><td>-</td><td>-</td></tr>
<tr><td colspan="3">Criterion 1.3: Reproductive capacity of stock maintained</td></tr>
<tr><td>Fully meets criteria (2)</td><td>--</td><td>-</td></tr>
<tr><td>Partially meets criteria (1)</td><td>2</td><td>3</td></tr>
<tr><td>Does not meet criteria (0)</td><td>1</td><td>-</td></tr>
<tr><td>Insufficient information (?)</td><td>-</td><td>-</td></tr>
<tr><td colspan="3">PRINCIPLE 1: SUMMARY: FISHING PRESSURE AND STOCK SUSTAINABILITY</td></tr>
<tr><td>Fully meets criteria (2)</td><td>-</td><td>-</td></tr>
<tr><td>Partially meets criteria (1)</td><td>8</td><td>10</td></tr>
<tr><td>Does not meet criteria (0)</td><td>1</td><td>-</td></tr>
<tr><td>Insufficient information (?)</td><td>1</td><td>-</td></tr>
</table>

			The population dynamics of sandeels and anchovy are characterised by their high fecundity and early maturity. The recruitment patterns are highly variable and may rapidly influence stock size due to the short life span of the species. They are responsive to extrinsic environmental drivers, such as sea temperature and associated climatic /hydrological patterns, which complicates predicting both the sandeel and anchovy fisheries' ability to rebuild in a specific timeframe. ICES and IMARPE has detailed information on the target stocks' biology/ecology and structure, but there is an apparent gap in knowledge regarding the effect of fishing on the different stocks' reproductive capacity. The size selective effects of fishing are presumed to be minimal as small meshes are used in the fisheries.

Principle 2: Structure, Productivity, Function & Diversity of Dependent Ecosystem

Criterion	Indicator	Peruvian anchovy		North Sea sandeels	
		Score	*Comment*	*Score*	*Comment*
2.1 Natural functional relationships between species maintained without ecosystem state changes	a) Understanding of ecosystem factors relevant to target species	**0**	IMARPE carries out research into the anchovy. The focus is on the prosecution of the fishery and the anchovy stocks' status. There is an appreciation of the environmental drivers and research in climate driven effects, but due to inadequacies in funding and staffing, the budget is directed to funding monitoring target stocks over research into ecosystem functioning and other species.	**1**	ICES and independent scientists have carried out research, eg ELIFONTS (Harwood, J. (1999)) and IMPRESS. Biology and environmental requirements of sandeels well known in the North Sea. Non-target by-catch is known to be low. Predator-prey interactions are complex and still not fully understood vis á vis seabirds and is under investigation by IMPRESS. The Current ICES ACFM report (autumn 2003) notes that further analysis of the ecological impact of industrial fisheries is required.
	b) General risk factors known and understood	**0**	As 2.1.a	**1**	By-catch is low (3.5-6%) although historic concerns over juvenile cod by-catch exist (Camphuysen *at al*, 2002). Slippage of catch prior to hauling may be an issue.
	c) Impacts of gear use and loss known	**1**	Pelagic gear is used on the anchovy fishery and impacts on habitat will be low. No specific references, but presumed to be difficult to quantify the impact of ghost fishing from industrial fishing from evidence from other fisheries (Jennings *et al.*, 2001).	**1**	Gear is light and mainly restricted to dynamic sandy habitats (Wright *et al.*, 2000). No specific references applicable to otter trawl ghost fishing exist but it is presumed to be difficult to quantify the impact of ghost fishing due to industrial fishing, from evidence from other fisheries (Jennings *et al.*, 2001).

Criterion	Indicator	Peruvian anchovy		North Sea sandeels	
		Score	*Comment*	*Score*	*Comment*
	d) Ecosystem management strategy developed	**?**	There is indication of development of ecosystem management, eg due to the consideration of D.S. N°017-92-PE. This regulation refers to closed areas, specifically for the protection of non-target species and habitats, but not specifically anchovy There are MPAs in Peruvian waters and other areas important to non-target species and juvenile fish have been identified. Further establishment of marine protected areas in the region of the 'Islas Lobos de Afuera' for conservation purposes have been recommended to the government. They are not yet in place. See also 2.1a	**1**	There are existing ecosystem management strategies, eg assessments of the viability of seabird populations as a proxy of sandeel stock conditions in the region supported by the 'sandeel box' (which covers the inshore area from eastern Scotland down to NE England). There is also a seabird-sensitive management regime in place in the Shetland area. These plans are, however, local rather than considering the whole North Sea, but can be considered as progress towards a coherent ecosystem approach.
	e) Ecosystem assessment shows no unacceptable impacts	**0**	Ecosystem assessments are restricted by funding issues and the dynamic nature of the Peruvian ecosystem complicating assessments (Chavez *et al.*, 2003).	**1**	Impacts have been linked indirectly to sandeel stock condition, eg viability of local seabird populations. Research strategies are in place to further determine impacts of industrial fisheries eg IMPRESS. (the project terminates in November 2004),
2.2 Fishery does not threaten biodiversity	a) Level of knowledge and implications of interactions	**?**	IMARPE is conducting research eg, "Problemática de las 5 millas en el sur del Perú y alternativas técnicas para su manejo" (Problems of the five mile zone in the south of Peru and technical alternatives for its development), which has implications of species interactions with respect to biodiversity. See also 2.1.a	**1**	ICES and independent scientists have carried out research, eg ELIFONTS (Harwood, J. , 1999) and currently IMPRESS.
	b) Management objectives set for impact identification / avoidance	**1**	The main management objective which loosely pertains to biodiversity in the anchovy fishery are the by-catch regulations (see main text)	**1**	Objectives have been set to determine the impact of sandeels fisheries on seabirds.

Criterion	Indicator	Peruvian anchovy		North Sea sandeels	
		Score	*Comment*	*Score*	*Comment*
2.3 Recovery of target and non-target species populations permitted	a) Information on necessary changes to allow appropriate recovery	**0**	IMARPE is working to acquire information of this nature but they are currently constrained by limited funding.	**1**	IMPRESS is studying predator-prey interactions in marine ecosystems. Threshold values of prey density are to be established below which foraging and reproductive output by seabirds is sufficiently impaired to impact adversely on population status. The knowledge obtained within IMPRESS should suffice to give fishery managers high quality advice with respect to exploitation strategies that mitigate the impact on top-predators of the marine foodweb.
	b) Management measures permit adaptive change to fishing	**1**	Management of the target stocks by necessity is adaptive with respect to the extrinsic drivers affecting the target stocks, but there is less funding available to assess the affect on the non-target species.	**1**	This stock is treated by ICES in the context of a mixed fishery. Annual assessments would consider whether impacts warranted changes to management practices.
	c) Management measures allow recovery of affected populations	**?**	Unknown at this time to this research team.	**1**	The 'sandeel box' closure was driven by the ELIFONTS research and occurred to benefit struggling populations of kittiwakes in the local area.

Scoring Summary – Principle 2: Structure, Productivity, Function & Diversity of Dependent Ecosystem

<table>
<tr><th>Scoring</th><th>Peruvian Anchovy</th><th>North Sea Sandeels</th><th>Summary</th></tr>
<tr><td colspan="3">Criterion 2.1 Natural functional relationships between species maintained without ecosystem state changes</td><td rowspan="20">Since the complex nature of marine ecosystems makes predicting both the direct and, especially, indirect effects of fishing on target/non-target species and habitat difficult, this means that at the current level, research and knowledge in both the EU and South America can only partially meet the criteria in all cases - although the degree and level of understanding/knowledge of different indicators varies.

The appreciation that the ecosystem-approach to fisheries management is needed is relatively recent. Our understanding of the ecosystem impacts of fisheries is in its infancy and the management tools are currently being created or are evolving from other fields. Consequently, the introduction of management measures and strategies to avoid, minimise, mitigate and restore impacts upon the ecosystem from fisheries is currently limited.

In the North Sea there is a focus on the affects of industrial fishing for sandeels on charismatic species such as seabirds and marine mammals. 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 and black-legged kittiwakes in addition to the biology/population dynamics of sandeels during 1997-1998 in the Firth of Forth and Moray Firth, Scotland. Management recommendations, objectives and scenarios have grown out of ELIFONTS pertaining to the sustainability of the structure and functioning of the local ecosystem. A currently running 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. The work is ongoing and should result in management advice to define fishing strategies that mitigate the impact on the top-predators of the marineecosystem. Identification of robust, environmental indicators linking to the population dynamics of the sandeel would be of great benefit in reducing uncertainty in the assessment of the sustainability of the sandeel stocks. Furthermore, clarification of the effects of fishing on the many species, other than birds and marine mammals, in the North Sea that prey on the sandeel would be useful. Researchers and fisheries managers in Europe are aware of these issues.

Similarly in Peru, fisheries scientists and managers are aware that there are ecological, functional and ecosystem structural consequences of industrial fishing. But the Peruvian research structure (government laboratories and universities) is constrained by funding limitations</td></tr>
<tr><td>Fully meets criteria (2)</td><td>-</td><td>-</td></tr>
<tr><td>Partially meets criteria (1)</td><td>1</td><td>5</td></tr>
<tr><td>Does not meet criteria (0)</td><td>3</td><td>-</td></tr>
<tr><td>Insufficient information (?)</td><td>1</td><td>-</td></tr>
<tr><td colspan="3">Criterion 2.2 Fishery does not threaten biodiversity</td></tr>
<tr><td>Fully meets criteria (2)</td><td>-</td><td>-</td></tr>
<tr><td>Partially meets criteria (1)</td><td>1</td><td>2</td></tr>
<tr><td>Does not meet criteria (0)</td><td>-</td><td>-</td></tr>
<tr><td>Insufficient information (?)</td><td>1</td><td>-</td></tr>
<tr><td colspan="3">Criterion 2.3 Recovery of non-target species populations permitted</td></tr>
<tr><td>Fully meets criteria (2)</td><td>-</td><td>-</td></tr>
<tr><td>Partially meets criteria (1)</td><td>1</td><td>3</td></tr>
<tr><td>Does not meet criteria (0)</td><td>1</td><td>-</td></tr>
<tr><td>Insufficient information (?)</td><td>1</td><td>-</td></tr>
<tr><td colspan="3">PRINCIPLE 2 SUMMARY: STRUCTURE, PRODUCTIVITY, FUNCTION & DIVERSITY OF DEPENDENT ECOSYSTEM</td></tr>
<tr><td>Fully meets criteria (2)</td><td>-</td><td>-</td></tr>
<tr><td>Partially meets criteria (1)</td><td>3</td><td>10</td></tr>
<tr><td>Does not meet criteria (0)</td><td>4</td><td>-</td></tr>
<tr><td>Insufficient information (?)</td><td>3</td><td>-</td></tr>
</table>

			universities) is constrained by funding limitations affecting the amount and nature of research. Their focus, for the most part, is on the exploited stock, but there is a little research into the ecosystem effects of industrial fishing, and most is held in the 'grey' literature.

Principle 3 – Information, Organisational and Legislative Capacity for Sustainable Management

Criterion	Indicator	Peruvian Anchovy		North Sea Sandeels	
		Score	*Comment*	*Score*	*Comment*
3.1 Management Systems Criteria	a) Clearly defined institutional and operational framework	**2**	Ministry of Economics and Finance, Sistemas de Ordenamiento Pesquero en el Peru. Documento de Trabajo. Lima, July 2000.FAO/MIPE-CP/PER/4451 There is an approved general law, Decreto Ley Nº 25977, del 07DIC1992, for fisheries sector, which has ramifications for the Peruvian anchovy. Article 12 dictates the creation of a system in order to: • Depending on the fishery, control access • Quotas • Control effort/magnitude of the fisheries • Impose closed fishing seasons • Minimum capture size • Designate prohibited or reserve areas	**2**	EU countries controlled under the CFP and enabling legislation. Norway controlled by the Ministry of Fisheries advised by the Management Council.
			• Gear eg minimum mesh size • Methods of monitoring and control		

	b) Management system has clear legal basis	**2**	Management system has a legal basis that consists of the fishery general law.	**2**	EU countries controlled under the CFP and enabling legislation. Norway controlled by the Ministry of Fisheries advised by the Management Council.
	c) Has a consultative and dispute resolution strategy and pathways	**1**	When a dispute exists, the parties can approach the ministry in the first instance. If the parties do not agree they can go to the national judicial system.	**1**	EC consultation routinely takes the form of green and white papers. Dispute and resolution strategies through fishers' representatives. Similarly, in Norway dispute and resolution strategies occur through fishers' representatives.
	d) Subsidies or incentive exist that affect fishing practices	**?**	Unknown to this research team	**2**	There are no tax breaks or vessel subsidies - no direct financial incentives relevant to the fishery
	e) Adequate, operational research plan to address information needs	**1**	IMARPE carries out research into the anchovy and informs the government regarding targeted stocks. There is less information/research into non-target species and ecosystem impacts.	**1**	ICES through the Working Groups eg Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak, and independent scientists
	f) Monitoring and evaluation system for fisheries management objectives	**1**	There is a detailed monitoring and evaluation system into the target stocks. This includes, for example, observers on fishing vessels and stock assessment surveys on research vessels.	**2**	ICES through the Working Groups eg Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak, and independent scientists
	g) Control mechanisms for enabling and enforcing management objectives	**1**	Fishmeal Information Network (2002) indicated that all fishing vessels are monitored with satellite tracking systems. The surveillance system is the responsibility of the ministry. There are observers on fishing vessels and at ports. The efficacy of this system is not known.	**2**	EU countries controlled under the CFP and enabling legislation.

3.2 Operational Criteria	a) Operational mechanisms to reduce impacts on habitats and non-target species	**1**	Closed areas are being created specifically for the protection of non-target species and habitats (D.S. N°017-92-PE). No controls over habitat impacts but these are likely to be minor for the pelagic gear used in the anchovy fishery.	**1**	By-catch limits and closed area to address impacts on non-targets, no controls over habitat impacts but these are likely to be minor for this light gear.
	b) Measures to discourage operational wastes and destructive practices	**?**	Mechanisms exist in the judicial system to discourage operational waste and destructive practices – no details are available to the research team	**2**	Operational wastes (offal etc) negligible. No destructive practices used.
	c) Fishers aware of - and compliant with - managerial, administrative and legal requirements	**1**	Post the Fujimori government, fishers are more compliant with requirements, but this is not 100%. During ENSO events, fishers are more likely to follow restrictions.	**2**	Compliance levels are high (for all industrial fisheries), esp. in the Danish and Swedish fisheries. Large industrial trawlers (85% are >40m) have catch inspected 1 in 3 landings (Frid *et al*., 2003)
	d) Fishers involved in catch, discard and other relevant data collection	**0**	Fishers are not involved in the collection of data	**1**	To some extent, but also subject to development (ICES, 2003b). Fishery subject to EC 1639/01 data collection regulations.

Scoring Summary – Principle 3: Information, Organisational and Legislative Capacity for Sustainable Management

<table>
<tr><th>Scoring</th><th>Peruvian Anchovy</th><th>North Sea Sandeels</th><th>Summary</th></tr>
<tr><td colspan="3">Criterion 3.1: Management system criteria</td><td rowspan="16">Both the Peruvian anchovy and the sandeel fisheries are subject to clearly defined management systems. Control mechanisms and surveillance of fisher/fisheries are present in both Peru and the EU. It is, however, difficult to assess the success of the Peruvian system of monitoring. Mechanisms allowing for consultation and the resolution of disputes exist for fishers (and their representatives), although the effectiveness of the Peruvian system is unknown. There are government laboratories and university in both the EU and South America focusing on the biology /ecology of the target stocks on although there are funding limitations on research in the Peru.

Mechanisms exist in both fisheries to create closed areas to protect habitats and non-target species, they are however, generally on a small scale with respect to the fishery area. By-catch regulations also exist for both fisheries and mechanisms to reduce operational waste.

Compliance levels are high in the EU. The Peruvian situation is more complex, and compliance is not considered to be high (pers. comm.. Renato Guevara Carrasco, IMARPE, 2003, November).) although there is a respect and understanding of the implications of ENSO events in the region, and fishers are more likely to comply with managerial, administrative and legal requirements during ENSO events.

Fishers are not involved in data collection in Peru. There is a degree of fisher involvement with data acquisition in the EU, but there is room for improvement.

Whilst clearly defined management systems are in place for both fisheries, it should be noted that this does not necessarily equate to being effectively managed fishery, as intended in this Principle. Data on the effectiveness of the system and individual management measures is less clear and is not available to the research team.</td></tr>
<tr><td>Fully meets criteria (2)</td><td>2</td><td>5</td></tr>
<tr><td>Partially meets criteria (1)</td><td>4</td><td>2</td></tr>
<tr><td>Does not meet criteria (0)</td><td>-</td><td>-</td></tr>
<tr><td>Insufficient information (?)</td><td>1</td><td>-</td></tr>
<tr><td colspan="3">Criterion 3.2: Operational criteria</td></tr>
<tr><td>Fully meets criteria (2)</td><td>-</td><td>2</td></tr>
<tr><td>Partially meets criteria (1)</td><td>2</td><td>2</td></tr>
<tr><td>Does not meet criteria (0)</td><td>1</td><td>-</td></tr>
<tr><td>Insufficient information (?)</td><td>1</td><td>-</td></tr>
<tr><td colspan="3">PRINCIPLE 3: INFORMATION, ORGANISATIONAL AND LEGISLATIVE CAPACITY FOR SUSTAINABLE MANAGEMENT</td></tr>
<tr><td>Fully meets criteria (2)</td><td>2</td><td>7</td></tr>
<tr><td>Partially meets criteria (1)</td><td>6</td><td>4</td></tr>
<tr><td>Does not meet criteria (0)</td><td>1</td><td>-</td></tr>
<tr><td>Insufficient information (?)</td><td>2</td><td>-</td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

Principle 4 – Economic and Social Considerations

Criterion	Indicator	Peruvian Anchovy		North Sea Sandeels	
		Score	*Comment*	*Score*	*Comment*
4.1 Respects the needs of fisheries dependent communiti es, historic rights and cultures	a) Does not impact resource availability or access, directly or indirectly	**?**	No information readily available.	**1**	Direct impacts are unlikely but questions remain over the indirect impact of sandeel fishing on other fisheries.
	b) Fisheries and fishers demonstrate understanding and sensitivity to traditional practices and ways of life	**1**	No information readily available. As a deep sea fishery, this point may be less relevant to this fishery.	**2**	Sandeels are prosecuted by communities with a long-held association with fishing.
4.1 Fishery and market operate under natural conditions	c) Fishery operates in an economically efficient manner	**1**	95% of fleet activity is reliant on pelagic species. 78% of the catch is anchovy. The fleet has grown without capacity constraints. An ITQ system now exists. This has facilitated rationalisation within the existing fleet structure. Greater reductions in capacity are expected	**2**	Fishery is an efficient return on capital but is impaired by high number of participants. This constrains reinvestment but assists distribution of wealth in the sector and reduces effort in other fisheries (Andersen, J. and Løkkegaard, 2002).
	d) Product trade is not artificially favoured by trade barriers or protectionism	**?**	Peru is an APEC Member which allows for the removal of trade barriers between participating countries	**2**	None exist. Free global trade in products.
4.2 Labour conditions conform to ILO standards	a) Freedom from enforced labour	**?**	No information readily available.	**2**	None. Many fishermen operate within share schemes. Three out of the four Danish fish meal plants are owned by fishermen's groups.
	b) Freedom of association and collective bargaining	**?**	The sector is highly competitive. Vessels owned by processing factories	**2**	
	c) Lack of discrimination of individuals and organisations	**?**	No information readily available	**2**	Danish permit scheme based on historic rights but there are no formal barriers to entry.
	d) Non-use of child labour	**?**	No information readily available	**2**	None.
4.3 Fishery does not prejudice food security	a) Pricing structure operates within market norm	**2**	No evidence of restricted practices.	**2**	Responsive to global commodity trade competition (i.e. soya & rape seed oil).
	b) Supply operates within market norm	**2**	Supply dominates world market. Prices respond to demand, particularly from the largest market (China)	**2**	Supply is highly seasonal but competes on the global commodity market (see 4.3 (a) above.

Scoring Summary – Principle 4: Economic and Social Considerations

Scoring	Peruvian Anchovy	North Sea Sandeels	Summary
Criterion 4.1: Fishery and market operate under natural conditions			Both fisheries respond to normal market conditions. Peru is the main supplier, with China representing the largest market for fish meal. Prices respond to global market demand for fish meal and oil and the price of substitute products. Substitution is less likely to take place for fish oils than for fish meal. No information on labour conditions is available for Peru. European fish meal activity is conducted by share fishermen. All participants have access to predefined agreements in wage shares linked to the catch. There is no apparent exploitation of labour in EU and other European fisheries. In Denmark, 407 vessels and 1,354 fishermen are linked to the industrial feed fish fishing industry. 58% of the total number of Danish vessels over 15 m are fully or partially dependent on the industrial fishery. 41% of the total number of Danish fishers have full or partial dependency on this stock. This fishery scores highly on this principle as there is a high degree of vertical integration in the sector that results in fishing communities achieving in a high degree of control of the downstream post-harvest chain.
Fully meets criteria (2)	-	1	
Partially meets criteria (1)	1	1	
Does not meet criteria (0)	-	-	
Insufficient information (?)	1	-	
Criterion 4.2 Labour conditions conform to ILO standards			
Fully meets criteria (2)	-	4	
Partially meets criteria (1)	-	-	
Does not meet criteria (0)	-	-	
Insufficient information (?)	4	-	
Criterion 4.3 Fishery does not prejudice food security			
Fully meets criteria (2)	2	2	
Partially meets criteria (1)	-	-	
Does not meet criteria (0)	-	-	
Insufficient information (?)	-	-	
PRINCIPLE 4: ECONOMIC AND SOCIAL CONSIDERATIONS			
Fully meets criteria (2)	2	7	
Partially meets criteria (1)	1	1	
Does not meet criteria (0)	-	-	
Insufficient information (?)	5	-	

3.4 SUMMARY

In both fisheries, there is a better understanding of the Fishing Pressure and Stock Sustainability (Principle 1) than the other three Principles. There are still areas requiring additional focus, eg should the sandeel stock assessments in the North Sea be considered as a single stock or should the assessment be broken into regions within the North Sea? Similarly, there is a need to identify whether there are further sub-stocks in the northern and southern Peruvian anchovy stocks.

Research into the ecosystem approach in the sandeel fisheries in the North Sea is ongoing with dedicated research being undertaken at governmental institutes and research facilities to understand the complicated interactions in the North Sea system and formulate management advice. The advent of the ecosystem approach to fisheries management in Peru is in its infancy. Peruvian scientists interviewed are well aware of the need to move towards an ecosystem approach, but are under serious financial limitations restricting research in this direction.

Both fisheries have management strategies in place. In the EU there are stringent controls affecting fishers and fishing effort to limit and control fishing mortality on sandeel populations and compliance with management is high. It is difficult to assess the effectiveness of these strategies at the stakeholder level in the Peruvian system. Furthermore, the southern stock of Peruvian anchovy is under dual prosecution (Peru and Chile) and management of this stock is known to be not as effective as management of the northern stock (fished only by Peru). Table 11 below presents a summary of the scoring of both fisheries against all criteria.

Table 11: Summary Scoring against All Criteria

	Peruvian Anchovy	North Sea Sandeels
Fully meets criteria (2)	4 (10%)	15 (38%)
Partially meets criteria (1)	18 (46%)	24 (62%)
Does not meet criteria (0)	6 (15%)	0 (0%)
Insufficient information (?)	11 (28%)	0 (0%)

It is clear that both fisheries scored 1 against many of the criteria (46% and 62% of the criteria assessed for anchovy and sandeel respectively). This indicates that many of the criteria were only being partially met. This is an important conclusion. Its shows that both fisheries need to improve their performance and in some critical areas if they are to be deemed sustainable.

The rather broad reach of the 'partially meets criteria' category (i.e. score of '1') hides an additional conclusion that became obvious during the assessment. Often both the anchovy fisheries and the sandeel fishery scored a figure of 1, but the degree of understanding or partial fulfilment of the criteria differs. In general, there is more information relating to the state of the sandeel stocks, ecosystem impacts of sandeel fisheries and ramifications of the management on the sandeel stock and stakeholders than there is of the Peruvian anchovy fishery.

As is also evident from the table, there was insufficient information to score the performance of the anchovy fishery against 14 of the 39 criteria (28%). Of most concern is the lack of information on (i) on the food chain, other fish species, marine wildlife and the wider ecosystem and (ii) the effectiveness of the current fisheries management measures.

Without such information, this assessment cannot categorically conclude whether the fishery is or is not approaching sustainability. The conclusion is that significant additional work is required to understand the environmental performance of the fishery.

Finally, it is apparent that the sandeel fishery scored higher than the Peruvian anchovy fishery. Partly this was due to the relative lack of information for the latter. However, the sandeel fishery did achieve more of the 'Fully meets criteria' category (38% versus 10%). It could be concluded that management efforts in the sandeel fishery are more likely to be successful in achieving the goals of conservation and sustainable use of the resources than the Peruvian anchovy fishery.

4 TOWARDS SUSTAINABLE FISH MEAL AND FISH OIL SUPPLIES

4.1 CURRENT AND PREDICTED DEMAND FOR FISH MEAL AND FISH OIL

4.1.1 Production

Fish meal

World production of fish meal averaged 6.3 million tonnes between 1997 and 2001 (FAO, 2001). This accounts for approximately 22 million tonnes live weight, or 23% of the world catch[13]. Peru and Chile account for 55% of total supplies, followed by China with 12% (Table 12).

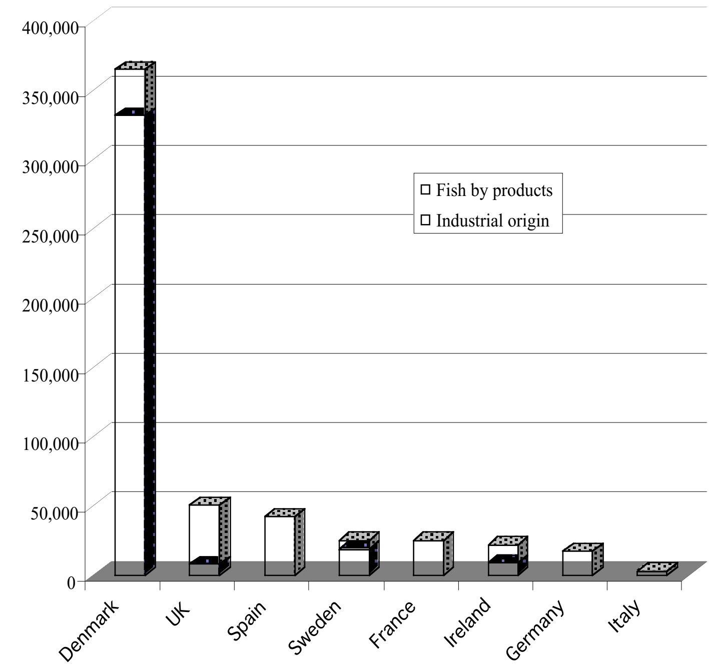
Table 12: International Production of Fish Meal

A. Production by Country / Region B. EU Breakdown by Country (2002)

[13] 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.

(average 1997 – 2001)

Country/Region	Av. production	
	'000 mt/yr	**%**
Peru	1,959	31%
Chile	803	13%
China	733	12%
EU (see left)	597	9%
Thailand	389	6%
Japan	357	6%
USA	305	5%
Iceland & Faeroes	285	5%
Norway	255	4%
Others	632	10%
TOTAL	**6,315**	**100%**



Source: A FAO 2003;

B Extracted from national fishery departments and fish meal manufacturers

In the EU, Denmark is by far the most significant of producer of fish meal and oil, but is significantly more reliant on feed fish (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.

There are four different products sold as meal:

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

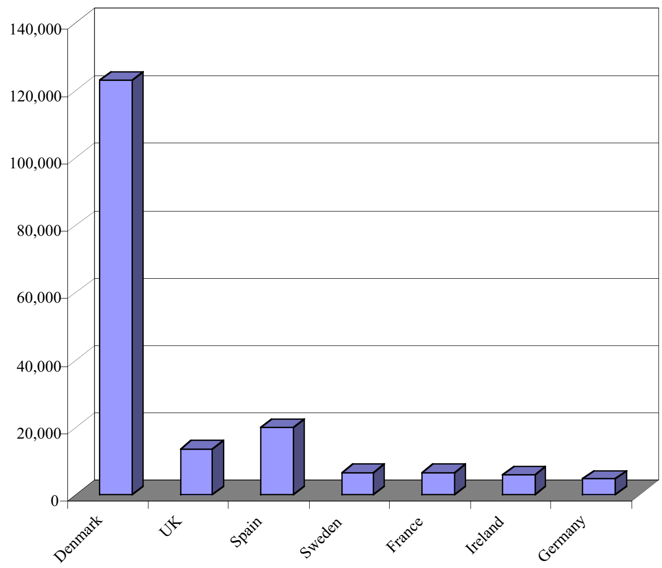
Fish Oils

Fish body oil is a co-product of fish meal where it represents around 5-6% of the total raw material body weight. World production of fish body oils averaged 1.1 million tonnes between 1997 and 2001. 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 13: International Production of Fish Oils

A. Production by Country / Region (average 1997 – 2001) *B. EU Breakdown by Country (2002)*

Country/Region	Av. production	
	'000 mt/yr	**%**
Peru	372	31%
EU (see left)	186	16%
Chile	155	13%
Iceland & Faeroes	113	10%
USA	113	10%
Norway	80	7%
Others	163	14%
Total	**1182**	**100%**



Source: A FAO 2003; B Extracted from national fishery departments and fish meal manufacturers

Countries within the EU produce a total of 186,000 tonnes of fish body oil annually. Of this, Denmark produces 71% (*c.* 120,000 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.

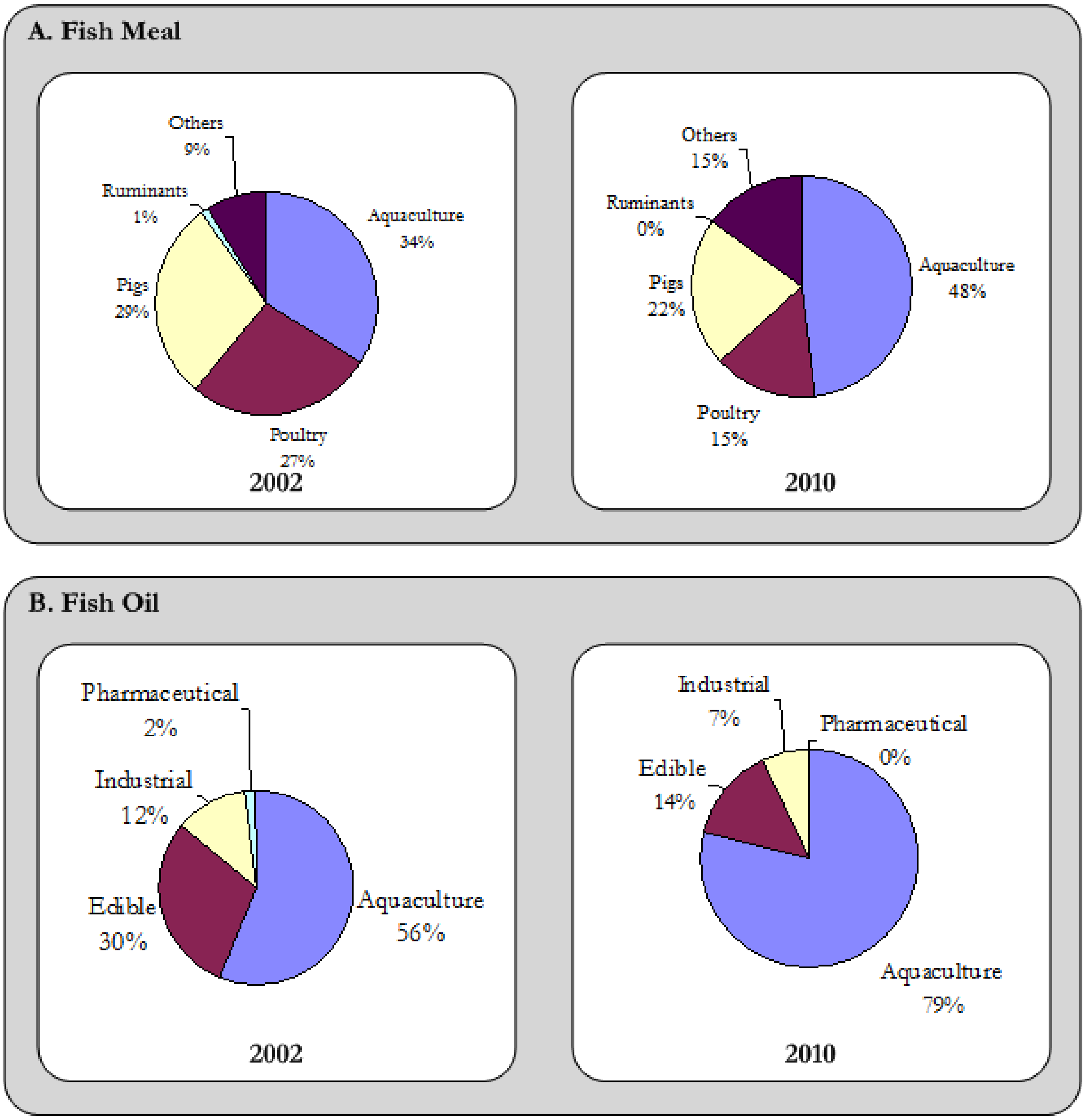
4.1.2 Consumption

The People's Republic of China (PRC) is by far the largest consumer of **fish meal**, accounting around a quarter of the global usage (see Appendix E: Global Consumption of Fish Meal and Fish Oils (1997 – 2001) on page 95), with Japan and Thailand also major consumers. Consumption fluctuates from year to year, largely due to the influence of the El Niño on South American production, but the overall change (between 1997 and 2001) has been negligible (down 4%).

Similarly, the consumption of **fish oils** have also little changed over the past five years, although again there is strong inter-annual variation (see also Appendix E). The main users are Chile and Norway (236,000 and 213,000 mt in 2001 respectively), reflecting the high level of salmonid production in these countries.

Industrial fish are used mainly to produce fish meal and fish oils for use in aquaculture and agriculture. Figure 7 shows the current fate of fish meals and fish oils by user. This indicates that aquaculture will continue to dominate **fish meal** use, and is predicted by IFFO to reach almost 50% of the supply by 2010. Assuming that 6.5 million tonnes of fish meal is still being produced, this leaves a considerable scope for more to go into aquafeeds as the aquaculture industry grows, if the other existing uses of fish meal decline. However, the same cannot be said for fish oils, where the demand from aquaculture will exceed other uses and is likely to become constrained by supplies within a decade, presuming that no alternatives are developed (see Section 5.1.2).

Figure 7: Fish Meal and Fish Oil Usage (2002 and Predicted 2010)



Source: Barlow (2002)

Table 14 examines the situation in Europe over the last few years and illustrates that the market share of fish meal has remained constant for the pig and poultry sectors (although the totals consumed by these sectors have declined). There has been an increasing demand from aquaculture, although the ban on feeding fish meal to ruminants has meant that overall there has been reduced consumption of fish meal in the EU between 1998 and 2002. If this ban were to be lifted, there could be significant increase in the EU's demand for fishmeal, although this is unlikely in the short-term.

Table 14: Average Annual Fish Meal Consumption in the EU (1998 and 2002)

Use	Annual Consumption ('000 mt)	
	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. pet feeds	39 (4%)	50 (6%)
Total consumption in EU	**995 (100%)**	**781 (100%)**

Source: Ian Pike, pers. comm.. (2003)

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

a) 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 born the brunt of this impact, in particular 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.

b) The UK, being the largest EU 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 producers, 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.

Aquaculture

Aquaculture is the largest consumer of both *fish meal* and *fish oil* – however the nature of their inclusion and the level of their use are very different and must be examined separately.

Fish meal: the global use of fish meals in 2000, and the predicted use in 2010, is shown below.

Table 15: Global Fish Meal Usage in Aquaculture in 2000 and 2010 (predicted)

Species	Inclusion rate in feed			Fish meal use ('000 m		
	2000	2010	Change	2000	2010	Change
Carp	5%	3%	60%	350	516	147%
Tilapia	7%	4%	57%	55	60	109%
Shrimp	25%	20%	80%	372	485	130%
Salmon	40%	30%	75%	491	569	116%
Marine fish A	45%	40%	89%	508	892	176%
Trout	30%	25%	83%	189	202	107%
Catfish	3%	0%	0%	15	-	0%
Milkfish	12%	5%	42%	36	28	78%
Marine fish B	55%	45%	82%	127	585	461%
Eels	50%	40%	80%	173	114	66%
TOTAL				**2,316**	**3,451**	**149%**

Source: IFFO (2001)

Marine fish A: flounder, turbot, halibut, cod, sole and hake

Marine fish B: bass, bream, yellow tail, grouper, carangids, mullets

Change is the percentage change from the 2000 baseline.
The figures in this table indicated two distinct trends:

1. The rates at which fish meal is included in aquaculture diets is considered to drop to between 57% and 80% of the year 2000 values. This may well be an underestimate – Nutreco consider that further developments in aquaculture nutrition may allow inclusion rates of 25%, 20% and 40% for salmon, trout and bass/bream respectively by 2010 (Gallemore and Roem, Nutreco, pers. comm., September 2003).
2. Even though inclusion rates are set to fall, the overall consumption of fish meal is still predicted to increase by half again to around 3.45 million tonnes by 2010. The increase is predominantly found in the expansion of bass and bream farming operations but will also reflect rises in other newer marine fish such as halibut and cod, as well as the expansion of established species such as shrimp and salmon. An increase in the use of fish meal from carp culture reflects both the expansion and intensification of carp farming in Asia.

Fish oil: As Table 16 shows below, it is not considered that fish oil inclusion rates, which are already low, will change significantly. However overall demand is predicted to increase from the use of 717,000 tonnes in 2002 to over 1.2 million tonnes in 2010. This is just under the 2001 *total* global consumption of fish oil (see Appendix E) and indicates that fish oil supply is likely to be increasingly limiting to the future aquaculture development.

Table 16: Global Fish Oil Usage in Aquaculture in 2000 and 2010 (predicted)

Species	Inclusion rate in feed			Fish oil use ('000 mt		
	2000	2010	Change	2000	2010	Change
Carp	0%	0.5%	-	-	103	-
Tilapia	1%	0.5%	50%	8	9	113%
Shrimp	2%	3%	150%	30	73	243%
Salmon	25%	20%	80%	307	379	123%
Marine fish A	20%	15%	75%	226	335	148%
Trout	15%	15%	100%	95	121	127%
Catfish	1%	0%	0%	5	-	0%
Milkfish	2%	2%	100%	6	11	183%
Marine fish B	10%	12%	120%	23	156	678%
Eels	5%	8%	160%	17	23	135%
TOTAL				717	1,210	169

Source: IFFO (2001)

Marine fish A: flounder, turbot, halibut, cod, sole and hake

Marine fish B: bass, bream, yellow tail, grouper, carangids, mullets

Agriculture

With fish meal and fish oil production predicted to remain stable over the next decade (Stuart Barlow, pers. comm., IFFO, Nov. 2003), and the proportion being utilised by aquaculture increasing considerably, there is likely to be a fall in the proportion utilised by agriculture.

Table 17: Fish Meal and Fish Oil Use in Agriculture (2002 and 2010 (predicted))

Consumer	Fish meal use ('000 mt)		
	2002	2010	Change
Poultry	1,755	975	56%
Pigs	1,885	1,430	76%
Ruminants	65	-	0%
Others	585	975	167%
Total	**4,290**	**3,380**	**79%**

Consumer	Fish oil use ('000 mt)		
	2002	2010	Change
Edible	375	175	47%
Industrial	150	88	58%
Pharmaceutical	25	-	0%
Total	**550**	**263**	**48%**

Source: Derived from Barlow (2002)

For most domestic animal species, fish meal is included as a feed supplement in order to increase the protein content of the diet and to provide essential minerals and vitamins. In general fish meal 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 fish meal 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 fish meal 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 fish meal 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. Several studies have shown improvements in animals' immune competency following consumption of fish meal, and the increased provision of antioxidant vitamins naturally present in fish meal may also be of health benefit to the animal. The pattern of PUFA (poly unsaturated fatty acid) present in fish meal 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.

Typical inclusion rates for fish meal in animal diets are around 2-10% for terrestrial animal species, Efficiencies of conversion of feed to live weight gain are usually quoted in terms of feed conversion ratio (FCR, units of weight gain per unit of feed consumed). 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 fish meal in poultry and pig diets, production per kilogram of edible product from these species requires an order of magnitude less fish meal than for fish products.

<u>The use of fishmeal in ruminant diets</u>[14]: although sheep and cattle consume diets that 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 fish meal in these situations has considerable advantages over other protein sources such as soybean 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 fish meal 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 fish meal show improved growth rates and wool production (Masters *et al*., 1996) and there are some reports of improved fertility, and enhanced colostrom production which may be due to improvements in immune status (Robinson and MacDonald, 1989).

<u>The use of fishmeal in diets of non-ruminants</u>: fishmeal use in pig diets accounts for approximately 32% of total fish meal use and it is recognised as a key protein source with a good balance of essential amino acids. Pigs fed diets containing fish meal show improved feed conversion efficiencies 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 with fish meal 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 fish meal 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.

<u>Use of fishmeal in diets of poultry</u>: As with diets for mammalian species, fish meal is considered a natural, balanced ingredient for poultry diets with a high protein, high mineral and high micronutrient content. The protein in fish meal is readily digested by poultry and it contains all the essential amino acids necessary for adequate

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[14] Currently the inclusion of fish meal and fish meal 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 fish meal, the ban was introduced in response to fears about possible contamination of fish meal products with processed animal proteins. The regulations are currently under review and the ban on the use of fish meal in ruminant feeds is expected to be lifted later this year (DEFRA, 2002).

growth and production, especially the growth limiting amino acid lysine. However, as with pig diets, the quality of the fish meal can seriously affect protein digestion and biological value. Inclusion of fish meal in poultry diets at about 4% results in improved feed conversion efficiency and growth rates. Laying performance is also improved by feeding fish meal. 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.

Summary

Globally, the EU is the fourth largest manufacturer of fish meal after Peru, Chile and China and produces 9% of the total global production. Within the EU, Demark is the most significant producer of fish meal and oil. Approximately 90% of the material for the Danish market is derived from feed fish caught in directed fisheries. The material for most other EU fish meal producing countries is derived from the by-products of the commercial fish processing.

Fish meal and fish oils are used internationally as feed for farmed animals and are considered a high quality source of proteins, minerals and vitamins. The heating and processing of the fish meal for conversion into animal feed differs according to the end user. Carnivorous fish for instance, require more protein than herbivorous fish and the meal is produced accordingly.

China is the largest consumer of fish meals and takes approximately a quarter of world production.

4.1.3 Assessment of Alternate Protein and Oils Sources

Alternatives to animal feed produced from fish meal and fish oils have been developed but their use is limited and their success has been mixed. Substitution of fish meal with other protein sources is difficult as fishmeal provides an excellent balance of amino acids, but the major factor is the cost of the replacement meal ingredients.

The factors that limit the substitutability of fish oils also include:

- EU legislation on additives and GM ingredients constrains high levels of substitution;
- Fish have complex 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, hence 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 (Frid *et al*., 2003).

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

<u>Use of fisheries by-catch and discards</u>

The use of discards (or 'trash') fish to produce fish meals and oils is a common practice in many fish meal producing nations in South America and the USA. Alverson *et al*., (1994) estimated that between 17.9 and 39.5 million tonnes (average 27.0 million) of fish are discarded globally each year by the commercial fisheries. Within Europe, Norwegian plants derive 140,000 tonnes or 14%[15] of throughput supplies from fish caught as by-catch. This supply chain was established after Norway imposed a discard ban, whereby fishers have to land everything they catch, to promote selective fishing. Currently, none of the EU fish meal plants rely on the landing of discards for raw material.

Given that a high proportion of fish and invertebrates die following discarding, then there is a powerful argument for their use in the fish meal and fish oil industry. However, there are major drawbacks to a ban on discarding at sea. Juveniles of both target and non-target stocks are strongly impacted by discard mortality (Stratoudakis *et al*., 2001) and it may be better to concentrate on improving gear selectivity than maintain the current levels of by-catch and discarding for use by other industries. Myers *et al*., (1997) argued that the discarding of young fish was a major factor in the crash of Canadian populations of Atlantic cod. There is also the danger of developing a market, and therefore demand, for juvenile fish, which would have very serious impacts on the stocks, targeted human consumption. Thus adoption of this strategy should be accompanied by continued efforts to reduce discarding. Maintaining a strong price differential between marketable fish and the 'trash' will ensure that fishers have an incentive to fish selective and to avoid capture of juveniles.

The implementation of discard bans have been discussed within the EC, but the consensus is that in the very mixed fisheries of the EC, such a ban would simply force discarding to continue in a hidden fashion (Frid *et al*., 2003) Moreover, the possibilities of obtaining successful prosecutions for breaches of a discarding ban would be slight without observers on every vessel. Although the benefits of a discard ban are likely to protect processes at an ecosystem level, they may have implications for the breeding populations of scavenging seabirds, esp. the greater skua (*Catharacta skua*) and most gull species (Reeves and Furness, 2002

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 introduce 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.

Use of Trimmings and Processing Wastes

Some EU fish meal and fish oil processing countries are dependent entirely on the trimmings and offal produced by the processors of fish for human consumption (Table 18). When fish are filleted and processed for market, more than half the fish is considered waste. Trimmings account for approximately 33% of the raw material supplied to the fish meal and body oil sector in Europe.

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[15] Bjørn Myrseth, Marine Farms ASA, Norway

Table 18: Raw Material Sources for Fish Meal and Fish Body Oil (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)

Further use of fish trimmings and offal could be used to increase the supply of raw material to the fish meal and fish oil industries, especially if demersal wastes that are currently disposed of at sea were returned to land for disposal. This could be intensified by controls on the cost of disposing of the waste compared to that of collecting, storing and transporting the material. The quality of the fish is reduced rapidly if it is not stored correctly (EC, 2003) thus there are costs associated with keeping it refrigerated or frozen. Table 19 provides an analysis of the relative revenue and costs associated with various options

Table 19: Revenue generated from 1 tonne of trimmings

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

Note: sales price minus operational costs - * minus figures are costs

Source: FIN (2003)

A number of fish meal manufacturers have suggested that logistically, it makes practical and economic sense for plants to be located no more than 800 miles a part, as it becomes uneconomic to transport fish waste beyond distance (De Rome, *SoproPêche*, 2003, pers. comm., August; Korsager, *UFI*, 2003, pers. comm, September).

<u>Substitution by plant material</u>

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).

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.

It may not be possible to maintain the direct substitution of fish meal with plant proteins because of the lower oil content of plants and the increased carbohydrate content, which may result in poorer feed conversions. The removal of structural carbohydrate from plant proteins would minimise the energy shortfall, but processing costs are high. 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). Intake of diets deficient in essential amino acids may also result in reduced feed intake and further inefficiencies (De la Higuera et al., 2001).

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.

<u>Use of marine crustaceans</u>

Small marine crustaceans, eg 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. In addition, there are concerns about the wider ecosystem effects of harvesting organisms such as krill that are even lower down the marine food chain than feed fish.

<u>Biotechnology (bio-fermentation products using bacteria and algae to grow the relevant fatty acids)</u>

At present, fish oils and cultured phototrophic micro algae 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 neutraceuticals 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 micro organisms, 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). .

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 actually occurred. Further research and development is needed before these become viable large scale alternative to fish meal and oil from feed fisheries. There will also need to be the application of environmental safeguards to ensure that the production and use of substitutes has minimal environmental impacts.

4.2 ASSESSMENT OF THE SUSTAINABILITY OF GLOBAL INDUSTRIAL FISHERIES

4.2.1 Overview

South America, Europe (EU and non EU countries), and the South East Asia (China) are major producers, i.e. the countries targeting feed fish for the production of fishmeal and fish oil (SEAFeeds, 2003). The FAO (2002b) forecasts (1997-2030) of fish consumption, net export and production trends, suggest that Latin America, Europe and China will continue to supply most of the fish used for non-food uses in the near future. Small pelagic species (used as inputs for aquaculture production) will continue to dominate the fish species targeted world wide.

Industrial fisheries in the South East Pacific Ocean

Peru: In Peru the industry is dominated by the small pelagic anchovy (*Engraulis ringens*). In 1997-1998, catches were reduced due the El Niño event. However, populations of the short-lived fecund species have recovered and catches have been increasing since (FAO, 2002b). The Northern stock of anchovy is within safe biological limits, but the state of the southern stock is less certain.

Chile: The industry utilises anchovy, jack mackerel (*Trachurus murphyi*) and sardine (*Sardinops sagax*) - also known as the South American pilchard. The sardine is also targeted by Peru and Ecuador. The sardine fishery is small in comparison to the other industrial fisheries in the region (325,000 tonnes landed in 2001). The anchovy total catch in Chile has declined in recent years but this is mainly due to management measures eg the reduction of quotas. There has been a decrease in the stock of the Chilean jack mackerel since 1996 (WWF, 2003), but FIN (2003) reports that landings of approximately 1.65, 1.24 and 1.22 million tones in 1999, 2000, and 2001 respectively. According to the FAO (2002b), Chilean jack mackerel and the South American sardine stocks are in poor condition, thus the state of both stocks is regarded as uncertain, given the conflicting information available.

The pelagic fisheries in the South East Pacific Ocean were characterised as fully exploited in 2001 (SEAFeeds, 2003; WRI, 2001).

North East Atlantic

Industrial teleost fish species in the EU waters may be divided into three categories according to their use:

a) <u>Not used for human consumption</u>: the extracted products are used only for the production of fishmeal/fish oil, i.e. sandeel (*Ammodytes* spp.) and Norway pout (*Trisopterus esmarkii*).
b) <u>May potentially be used for human consumption</u>: but their main use is for the production of fishmeal/fish oil i.e. blue whiting (*Micromesistius poutassou*) and sprat (*Sprattus sprattus*).
c) <u>Primarily used for human consumption</u>: but any surplus may be used for fishmeal/fish oil production, i.e. herring (*Clupea harengus*)

Summary of the state of the stocks of the main EU prosecuted feed fish stocks (ICES 2003e and STECF, 2003):

<u>In ICES areas</u>

<u>Sandeel</u>

Sub-area IV. The state of the stock is considered uncertain.

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 sub-area 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 Fpa. 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 000in 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.

Summary – North-East Atlantic

The fisheries in the North East Atlantic were characterised as “fully fished” in 1983, and as over-fished in 1994 (WRI, 2001). The FAO (2002b) notes that the European fisheries show little scope of increase in production from the various stocks. Some feed fish stocks are un-assessed because they are not fished heavily, eg sandeel in the Shetland fishery and Norway pout in Division VIa, so data are insufficient to determine the state of these stocks. The sandeel stock in the North Sea has currently been assessed as uncertain by ICES, and regulation by effort and capacity has been advised to prevent over exploitation of the stock. The high natural mortality of feed fishes and the few year classes in the fisheries make the stock size and catch opportunities largely dependent on the size of the incoming year classes, thus increasing uncertainty in any long term (more than a few years) assessments of the stocks’ condition. Additionally, among the industrial fisheries in the EU, the situation for the blue whiting causes the most concern. The species is harvested outside safe biological limits, there appears to be little consideration of the species’ biology and ecology in harvesting strategies, leading to concerns about the state of the stock, and of course, sustainability.

South East Asia

China: There is a great deal of uncertainty about the details available of the Chinese industrial fisheries and production statistics (FAO, 2002b) making it difficult to make any evaluations of the state of the stocks.

4.2.2 Factors Contributing to Sustainable Fishing

As explained in section 3.1, the three principles used in the MSC are designed to determine and assess the sustainability of a fishery from a fisheries/ecosystem perspective:

Principle 1: Fishing Pressure and Stock Sustainability;

Principle 2: Structure, Productivity, Function and Diversity of the Dependant Ecosystem;

Principle 3: Information, Organisational and Legislative Capacity for Sustainable Management,

The fourth principle takes account of the economic and social elements relating to the fishery.

Principle 4: Economic and Societal Considerations

These principles can be used as a guide to understanding the factors that contribute to sustainable fishing. If a fishery scored the highest rating for all of the indicators of the various criteria under the four principles, in this ideal system, confidence in the assessment of the sustainability of the fishery/effects on the ecosystem would be high.

Principle 1 determines the sustainability of the targeted stock, i.e. ensuring that the harvests are sustainable and if depletions occur they are identified and reversed. Information and research is at the core of understanding the nature of the stock, now and in the future. Similarly, Principle 2 requires information/research on the maintenance of the structure, productivity, function and diversity of the ecosystem, that is, the habitat and associated dependent and ecologically related species on which the fishery depends. This is, however, not simply ensuring those aspects which support the fishery remain un-impacted, but that the impacts of the fishery on the ecosystem are understood and managed.

The third Principle revolves around ensuring that there is a managerial system to allow for the implementation of Principles 1 and 2. An unmanaged fishery is likely to be one that is prosecuted unsustainably. The fourth Principle is aimed at ensuring that the social and economic benefits of the fishery are implemented in a fair and equitable manner to society. Sustainable fisheries presumably result in sustainable communities, and as sustainable communities are likely to remain self-supporting, there is an added benefit to the larger community/government as a whole. At the core of the fourth Principle is that conflict is reduced, promoting co-operation between stakeholders.

4.2.3 Factors Constraining Sustainable Fishing

Even in the absence of exploitation, a fish stock faces threats to its sustainability as a result of natural variations in large-scale atmospheric or oceanic forcing. Industrial feed fish are especially responsive to the climatic/oceanographic regime (Arnott and Ruxton, 2002; Chavez *et al*., 2003). Archaeological records show large fluctuations in the deposition of sardine and anchovy scales off the coast of California over a period of two millennia (Baumgartner *et al*., 1992). Similarly, fluctuations in the herring and pilchard abundance in the Atlantic have been linked with fluctuation in climate (Southward *et al*., 1998). Fluctuations in climate cannot be regulated for, nor the ecosystem be directly managed - only the fishery. Fishing is thought to accelerate the collapse of stocks that are stressed by unfavourable regimes (Beverton, 1990). So management regimes should explicitly take account of the climate/hydrological conditions.

Management, its presence and absence, affects the sustainability of a stock. Cunningham and Maguire (2002) provide a detailed matrix of the factors that may lead towards unsustainability under different management systems (see **Appendix F: Factors of Unsustainability**). A lack of management can lead to overexploitation of a resource especially when profits are high. Management can also lead to overexploitation, when due to lack of knowledge the stock is not managed effectively. There is an inherent uncertainty in predicting fish stock trends, in part due to the complex intrinsic and extrinsic drivers affecting the biology and ecology of commercially important fish species. Addressing uncertainty led to the adoption of the precautionary approach. The precautionary approach has two essential elements: the probability of an event happening and the consequences if the event occurs. Where the evidence of a threat to a component of an ecosystem – in this case a fish stock - is not (yet) conclusive, action is taken to protect the fish stock since waiting until there is conclusive proof that there is a threat may be too late to save the fish stock in question. In both the Peruvian anchovy and North Sea sandeel fisheries there is a gap in the knowledge of the understanding of the ecosystem effects of the industrial fisheries. There are, however, fundamental difficulties in determining ecosystem level impacts of a fishery, in part due to the complex nature of ecosystems (Bax, 1998; Link 2002).

4.2.4 Synthesis

The sustainability of meeting the current demand for fishmeal and oil for aquaculture feed via the exploitation of stocks of small fish has being questioned (SEAFeeds, 2003; WWF, 2003). The MSC set of Principles and Criteria are designed to determine if a fishery is being managed on a sustainable basis. In this rudimentary assessment of the Peruvian anchovy and the North Sea sandeel fisheries, the MSC criteria/indicators are weighted equally. Both fisheries failed to fully meet the majority of the 39 criteria assessed (35 for anchovy and 24 for sandeel). Whilst many were partly met, it is clear that there is still improvement needed if the fisheries are to meet the standards of sustainable management. Whilst the sandeel fishery in the North Sea scored higher than the Peruvian Anchovy fishery, the current assessment of the sandeel stock by ICES (2003e) is that the stock condition is uncertain. Furthermore, the linkages between industrial fisheries and non-target species are a focus of research in the North Sea; but the complex nature of marine ecosystems means that there is still only as partial understanding of the relationships and interactions. Research into the ecosystem impacts of the Peruvian industrial fishing is currently restricted by financial limitations. Ensuring that the ecological and functional relationships in an ecosystem are maintained is fundamental to sustainability and at this time the ecosystem based approach to management is not in place for the anchovy fishery and is a new, developing process in the sandeel fishery, and is limited to a local scale.

As the demand for fish meal and oil products continues to grow there is the possibility of a market-led overexploitation, particularly if suitable alternatives cannot be found. Despite close monitoring and management, the demand to maintain supplies, especially when there are great economic incentives to fish, means that fisheries and stakeholders are prone to exploit a targeted resource unsustainably. Effective management supported by timely and accurate scientific advice and enforcement is required to check this incentive to over fish.

Feed fish fisheries are vulnerable to extrinsic drivers, this adds to the uncertainty of the stock forecasts, sudden stock changes may occur regardless of the level of fishing pressure on the stocks. Since these stocks are typically highly sensitive to changes in the environmental regime this needs to be adequately considered and buffers incorporated in the management.

The principal aspects of sustainability which require additional research in both the Peruvian anchovy fishery and the North Sea sandeel fishery are:

- Decreased uncertainty in the stock assessments;
- Increased understanding of the effectiveness of the current fisheries management measures; and
- Increased understanding of the fishery - ecosystem interactions.

5 RECOMMENDATIONS FOR IMPROVING THE SUSTAINABILITY OF FEED FISHERIES

5.1 INCREASING THE SUSTAINABILITY OF RAW MATERIALS

5.1.1 Increased Use of Fish Waste and Discards

The raw material for the production of fish meal and fish oil come from two sources, the targeted feed fisheries and waste from the human consumption fisheries sector. There are two powerful and persuasive arguments for looking at the latter as the source for additional growth in fish meal and fish oil supplies.

Firstly, the current targeted feed fisheries are operating at, or close to, their maximum sustainable level. This level is highly dependent on the environmental regime. There is little scope for additional expansion of this sector. Indeed, given the spectre of climate change and the wider ecosystem issues there may need to be a reduction in catch to match environmental conditions.

Secondly, as a principle of sustainability it is better to recover waste in preference to exploiting another resource. Better use of the catch from mixed fisheries and waste from the fish processing industry could increase the sustainability of the raw material supplied to the fish meal and fish oil industry. Since the fisheries which target stocks for human consumption will continue to operate in order to satisfy demand, the further exploitation of the uptake of their waste products for conversion into fish meal would reduce the quantity of industrial fish which would require harvesting to meet current demands or supply the growth in demand without additional impact on the ecosystem.

5.1.2 Development of Alternative Protein Sources

Substituting proteins and oils from sources other than industrial feed fish or trimmings is dependent on the price and quality of the alternatives. According to SEAFeeds (2003), 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, although this may be optimistic, certainly over the short to medium term (Nutreco, pers. comm. 2003).

Biotechnology can be used to create genetically modified plants containing nutritionally valuable, fatty acid rich oils. However, these approaches may not be acceptable to the EU community until further research is conducted. EU legislation on genetically modified (GM) ingredients constrains high levels of substitution (EC, 2000; 2001).

5.1.3 Recommendations

- Increase the utilisation of by-products and trimmings from the commercial fish processing sector
- Further research into improving the quality of feeds produced from plant material
- With caution, we would recommend that discards be better utilised. Adoption of this strategy should be accompanied by continued efforts to reduce discarding. Maintaining a strong price differential between marketable fish and the ‘trash’ will ensure that fishers have an incentive to fish selective and to avoid capture of juveniles.

- Examine the use and effects of biotechnology. This is currently not a viable resource due to legislation on additives and GM foods. Further investigation into the safety of this material may prove useful.

5.2 IMPROVING THE SUSTAINABILITY OF FEED FISHERIES

5.2.1 Industrial Fisheries Policy

As discussed in 3.4 and 4.2.4, industrial fisheries are characterised by a lack of information on some key aspects, such as their interactions with the marine ecosystem. There is also a degree of uncertainty due to the influence of environmental parameters on stocks. It is essential, therefore, that the precautionary approach to managing these stocks is fully embraced in industrial fisheries policy and management. As a first step, we would recommend that new and existing feed fisheries be subject to an initial and periodic review of their direct and indirect environmental impacts.

The introduction of the ecosystem approach to fisheries throughout the EU has been endorsed by the reformed CFP (2002). It is recommended that industrial fish stocks should be managed within this framework, especially as they are such an important prey for commercial fish, such as cod, and birds, such as kittiwakes. This could, for example, mean:

- setting catch limits that reflect the critical role of many feed fish in the marine ecosystem
- setting environmental indicators for feed fisheries (eg bycatch limits for non-target species; ecosystem indicators such as the productivity of seabirds dependent on specific feed fish stocks)

5.2.2 Improved Information Basis for Industrial Fisheries Management

In EU waters, most of the targeted industrial fish stocks, for which data are available, are considered to be within safe biological limits. However, the state of some stocks is unknown (i.e. sandeel in Western Scotland and Shetlands, Norwegian pout off Western Scotland and Chilean mackerel). To improve the sustainability of the industrial fisheries, an assessment of the state of the un-assessed stocks is essential, and measures to improve the security of current stock assessments are required. Industrial fish stocks cannot be exploited further and remain sustainable without a better understanding of stock dynamics. As well as improving the certainty in the stock assessments, as has been concluded elsewhere in this report, additional research to increase understanding of the fishery - ecosystem interactions is also needed.

In summary, we would recommend the following:

- A monitoring programme needs to be established for those industrial fish stocks which are not currently monitored, and for which the state of the stocks which is unknown.
- Building a robust scientific basis through a research programme prioritised to understanding the ecosystem and the interaction of feed fishing activities with it
- Further research on the ecosystem effects of industrial fishing. These species are an important prey to fish, birds and other species and their harvesting is likely to have a major effect on these animals.

- Establish a network of fish meal plants within 800 miles of major fishing ports to reduce the costs associated with transport and maintain the quality of the raw material.
- Further research on viable alternatives to fish meal.

Appendix A: Terms of Reference

An Assessment of the Sustainability of Industrial Fisheries used in the Production of Fish Meal and Fish Oil. RSPB

1. Purpose of the project

The purpose of this project is to evaluate the sustainability of industrial fisheries used in fish meal and oil production.

2. Background and project rationale

The global production of marine capture fisheries has been increasing over the past 50 years in the face of rapid technological advances and an expanding human population. However, there is now growing evidence that world marine fisheries are failing as many commercial fish stocks become over-exploited and face collapse.

As a result of this decline and consequent gap between demand and supply of fish for human consumption, aquaculture has become the fastest growing sector in the world food economy. It is expected to grow significantly in the coming decades - as stocks of wild-caught fish dwindle further, aquaculture and mariculture are projected by the FAO to increase dramatically.

This anticipated expansion in aquaculture will result in an increased demand for fish meal and oil for feed. Fish meal/oil are derived predominantly from wild stocks of pelagic fish harvested by 'industrial' fisheries. Three of the world's five largest fisheries are for industrial species. However, despite the size/importance of these fisheries, there is still uncertainty about the sustainability of these fisheries.

It has been argued that many of industrial stocks are susceptible to large fluctuations in biomass and could be prone to collapse under intensive harvesting regimes. There are also concerns about the wider ecosystem effect of these fisheries and the impacts on commercial fish and wildlife dependent on them. For example, many species of seabird are dependent on small shoaling fish such as sandeels and anchovies that are caught in industrial fisheries for fish feed in EU waters and off South America. Conversely, many of those involved in these fisheries argue that they are a sustainable and efficient use of marine resources.

In light of the uncertainty, concern and conflicting views, this study is intended as an objective/scientific assessment of the sustainability of these fisheries. There is a need to understand the sustainability of fish meal/oil fed to farmed fish and livestock in order to inform decisions about:

- Future management of the fisheries themselves.
- The use of fish meal/oil in aquaculture feeds in light of predicted expansion of fish farming.
- The use of fish meal/oil in livestock feeds.
- Other uses such as fertilisers, dietary supplements, fuel etc.

3. Project Objectives

3.1 Identify criteria by which the sustainability of industrial fisheries can be measured.

3.2 Apply these indices/criteria to measure and describe the status of global industrial fisheries, particularly in terms of environmental impacts, ecosystem effects, stock conservation and wider sustainability.

3.3 Identify future barriers and constraints to the sustainability of industrial fisheries and recommend specific changes/solutions to address these barriers.

4. Project tasks

4.1 Identify sustainability criteria for industrial fisheries.

4.2 Review the views of the industrial fisheries sector, governmental and non-governmental organisations and fisheries research scientists on the current sustainability of fish meal and oil production fisheries.

4.3 Identify and assess the environmental and sustainability effects of fish meal and oil production and use at global, national and local scales.

4.4 Describe the current sustainability of those pelagic fish stocks used in fish meal and oil. Discuss the availability and validity of the data.

4.5 Discuss the findings on the sustainability of industrial fisheries in light of:

- the current and predicted global demand for fish meal and oil.
- the necessity, or otherwise, of fish meal oil use in aquaculture and agriculture feeds.
- the viability and relative sustainability of fish meal and oil production from alternative sources to wild fish (eg discards, off cuts).
- the relative sustainability of substitutes for fish meal and oil production, taking account of potential environmental impacts of these alternative sources (eg soya).

4.6 Make recommendations for improving the sustainability of fish meal and oil fisheries. Recommend specific changes in terms of:

- Industrial fisheries policy.
- Industrial fisheries management (eg recommendations about improved management such as Technical Conservation Measures)
- EU, UK & devolved policy on fish meal/oil production and use within the aquaculture and agriculture industries.

5. Outputs

- Final report clearly presenting the findings of the above research and including an Executive Summary. The report should be supplied in hard copy (5 copies) and on disc (2 copies) in a format compatible with Microsoft Word.
- Separate project summary presented in the form of a short advocacy publication suitable for wider circulation to decision makers and stakeholders.

6. Methods

It is anticipated that the project will largely be a desk-based study. However, consultation with relevant interests and agencies will also be necessary. Anticipated methods include the following, although potential contractors are invited to submit a more detailed proposed methodology not constrained to this list:

- Collation and review of published information, legislation, policy documents etc;
- Interviews & consultation with the industry, civil servants, statutory bodies, NGO's, fisheries scientists;
- Identification of good practice case studies;
- Assessment of alternative management frameworks.

7. Project Timing

- Appoint contractor – Oct 2003
- First meeting with Steering Group – Oct 2003
- Interim Steering Groups meeting with contractor to discuss an interim progress report – Jan 2004
- Draft report submitted – Feb 2004
- Final report submitted – Mar 2004

8. Project management

This project has been initiated by RSPB and will be managed through an Internal steering group. The contractor will be asked to contact BirdLife International Partners in Denmark and relevant South American countries to ensure their views are built into the research.

Appendix B: Literature Cited and Bibliography

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Appendix C: The MSC Standard for Sustainable Fisheries

The following description of MSC has been derived from their website at http://www.msc.org

The Marine Stewardship Council (MSC) is an independent, global, non-profit organisation with its head office based in London, UK. The MSC has developed an environmental standard for sustainable and well-managed fisheries. It uses a product label to reward environmentally responsible fishery management and practices. Consumers, concerned about overfishing and its environmental and social consequences will increasingly be able to choose seafood products which have been independently assessed against the MSC Standard and labelled to prove it. This will assure them that the product has not contributed to the environmental problem of overfishing. Though operating independently since 1999, the MSC was first established by Unilever, the world's largest buyer of seafood, and WWF, the international conservation organisation, in 1997.

The MSC Strategy

- encouraging independent certification of fisheries to the MSC Standard;
- identifying, through the MSC's eco-label, products from certified fisheries;
- encouraging all those who buy and sell seafood to source MSC eco-labelled products;
- assessing and accrediting independent third party certifiers;
- promoting our work and that of our partners to increase public awareness of, and support for, our programme;
- monitoring, evaluating and developing the MSC Standard and programme to ensure their continued relevance and credibility.

At the centre of the MSC is a set of *Principles and Criteria for Sustainable Fishing* which are used as a standard in a third party, independent and voluntary certification programme. The MSC Standard is based on the FAO Code of Conduct for Responsible Fisheries and was a result of eight workshops and two expert drafting sessions.

These Principles reflect a recognition that a sustainable fishery should be based upon:

- The maintenance and re-establishment of healthy populations of targeted species;
- The maintenance of the integrity of ecosystems;
- The development and maintenance of effective fisheries management systems, taking into account all relevant biological, technological, economic, social, environmental and commercial aspects; and
- Compliance with relevant local and national local laws and standards and international understandings and agreements

The Principles and Criteria are further designed to recognise and emphasise that management efforts are most likely to be successful in accomplishing the goals of conservation and sustainable use of marine resources when there is full co-operation among the full range of fisheries stakeholders, including those who are dependent on fishing for their food and livelihood.

The MSC promotes equal access to its certification programme irrespective of the scale of the fishing operation. The implications of the size, scale, type, location and intensity of the fishery, the uniqueness of the resources and the effects on other ecosystems will be considered in every certification.

The MSC further recognises the need to observe and respect the long-term interests of people dependent on fishing for food and livelihood to the extent that it is consistent with ecological sustainability, and also the importance of fisheries management and operations being conducted in a manner consistent with established local, national, and international rules and standards as well as in compliance with the MSC Principles and Criteria.

The Principles & Criteria are intended to guide the efforts of the Marine Stewardship Council towards the development of sustainable fisheries on a global basis. They were developed assuming that a sustainable fishery is defined, for the purposes of MSC certification, as one that is conducted in such a way that:

- it can be continued indefinitely at a reasonable level;
- it maintains and seeks to maximise, ecological health and abundance,
- it maintains the diversity, structure and function of the ecosystem on which it depends as well as the quality of its habitat, minimising the adverse effects that it causes;
- it is managed and operated in a responsible manner, in conformity with local, national and international laws and regulations;
- it maintains present and future economic and social options and benefits;
- it is conducted in a socially and economically fair and responsible manner.

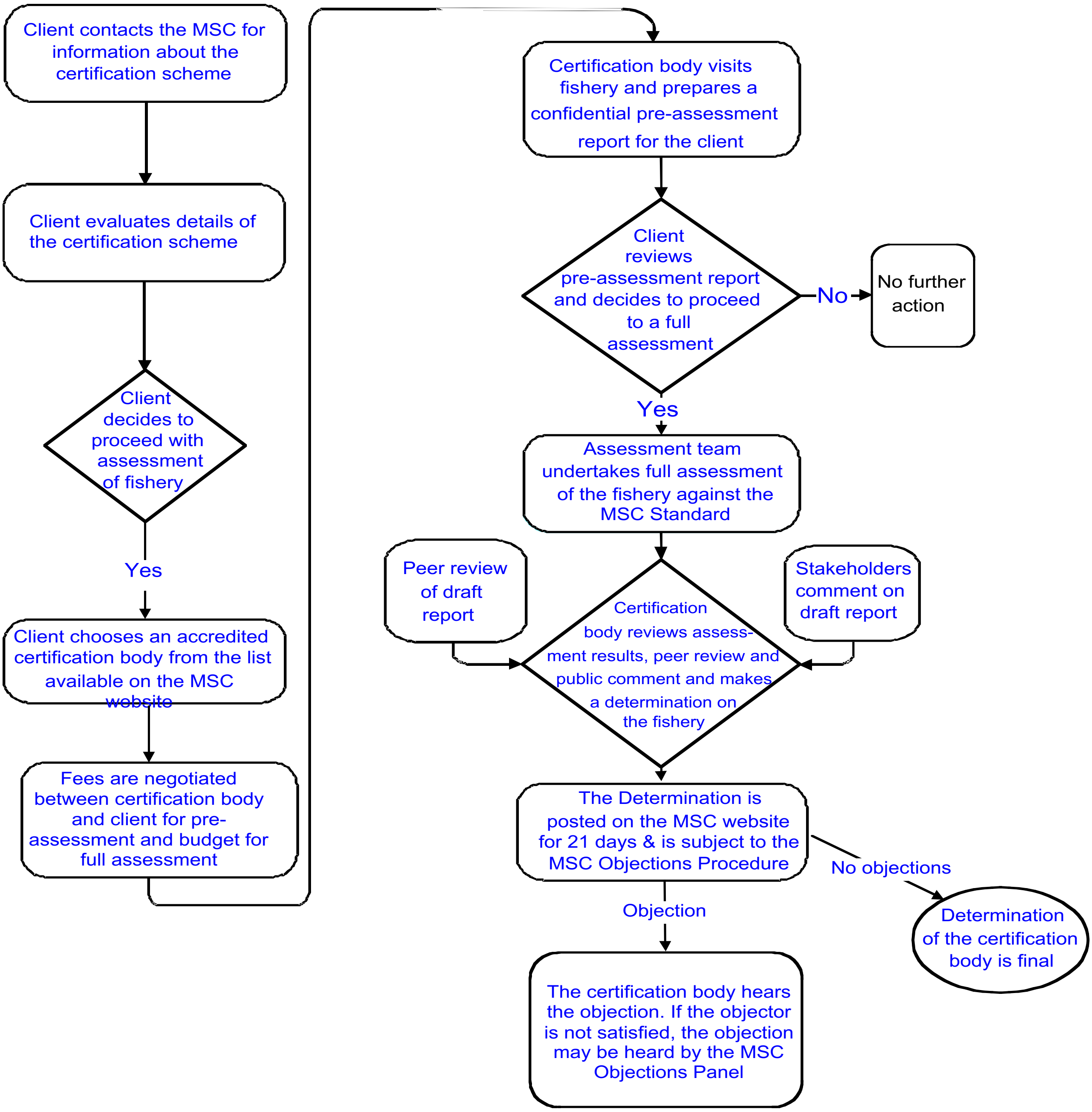
The Principles represent the overarching philosophical basis for this initiative in stewardship of marine resources: the use of market forces to promote behaviour which helps achieve the goal of sustainable fisheries. They form the basis for detailed Criteria which will be used to evaluate each fishery seeking certification under the MSC programme. Although the primary focus is the ecological integrity of world fisheries, the principles also embrace the human and social elements of fisheries. Their successful implementation depends upon a system which is open, fair, based upon the best information available and which incorporates all relevant legal obligations. The certification programme in which these principles will be applied is intended to give any fishery the opportunity to demonstrate its commitment to sustainable fishing and ultimately benefit from this commitment in the market place.

The scope of the MSC Principles and Criteria relates to marine fisheries activities up to but not beyond the point at which the fish are landed. However, MSC-accredited certifiers may be informed of serious concerns associated with post-landing practices.

The MSC Principles and Criteria apply at this stage only to wild capture fisheries (including, but not limited to shellfish, crustaceans and cephalopods). Aquaculture and the harvest of other species are not currently included.

Issues involving allocation of quotas and access to marine resources are considered to be beyond the scope of these Principles and Criteria.

Figure 8: MSC Fishery Certification Process



Source: http://www.msc.org

Appendix D: SEAFeeds - Information Required for the Effective Assessment of the Sustainability of Feed Grade Fisheries

Criteria	Stock	Ecosystem	Management Systems	Economic	Societal
	• SSB • Fish mortality • Safe biological limits • Based on sound science • Etc ….	• Discards and by-catch • Habitat impact • Trophic shifts • Ecologically related species • External environmental impacts • Etc …	• Monitoring and enforcement • Appropriate management systems • Stakeholder involvement	• Full local, national; and global economic consideration • Impact ands effect of subsidies and barriers to trade	• Local involvement (in management and fair employment) • Food security • Lifestyle
S. America • Anchovy • Sardine • Jack Mackerel • Horse Mackerel **Europe/N Atlantic** • Sandeel • Sprat • Norway Pout • Capelin • Mackerel • Blue Whiting **Elsewhere** • Menhaden (US) • Asian market =20%, but not for export	Good information published by ICES and collated by IFFO Information shows that most are above safe biological limits with the notable exception of Blue Whiting and the feed grade fisheries of Asia It is therefore estimate that in the region of 75% if the feed grade fisheries which supply the aquaculture industry are within safe biological limits.	Little or no information is available to establish with any certainty the wider ecosystem impacts Need more research but unclear who would pay. Habitat and discards/by-catch impacts are likely to be less for pelagic fisheries. Trophic impacts may be greater. Industry, in collaboration with Governments need to develop ecosystem objectives and targets and monitor appropriate indicators.	Fair information is available from ICES and others collated by IFFO This relates mainly to the nature of management regimes but rarely includes analysis of the performance of management measures, their monitoring and enforcement. For the most exploited feed grade fisheries, there are management checks in pace designed to ensure sustainable exploitation of the stock. These systems do not address the wider sustainable management objective, such as ecosystem and local equity.	There are currently big gaps in the detailed understanding of the economic implications Need more research to establish benchmarks. A range of simple economic indicators are already available that could be implemented.	Again there are big gaps in this area of knowledge Need more research to establish benchmarks. Industry/government need to agree objectives and indicators.

Source: SEAFeeds. (2003)

Appendix E: Global Consumption of Fish Meal and Fish Oils (1997 – 2001)

A. Fish Meal

Country	**Annual Consumption ('000 mt)**					
	1997	**1998**	**1999**	**2000**	**2001**	**Average**
China	1,516	1,110	1,354	2,023	1,741	1,549
Non EU Other	1,464	1,228	1,810	1,472	1,289	1,453
Japan	792	712	721	685	804	743
Thailand	465	418	481	477	472	463
USA	361	241	257	230	252	268
Taiwan	332	174	306	309	308	286
Norway	320	249	224	363	276	286
UK	313	271	256	278	267	277
Russia	250	248	201	186	231	223
Spain	161	137	145	185	177	161
Denmark	141	115	131	141	121	130
France	92	91	94	75	47	80
Italy	80	42	67	76	85	70
Germany	58	68	57	101	22	61
Netherlands	55	39	24	36	30	37
Belgium	48	39	40	35	26	37
Finland	38	23	17	19	20	23
Greece	36	40	38	54	77	49
Hungary	35	37	34	35	26	33
Ireland	32	28	28	35	34	31
Czech	26	22	20	23	15	21
Portugal	22	14	17	18	17	18
Poland	22	13	12	13	34	19
Cyprus	7	7	7	8	8	7
Total	**6,666**	**5,366**	**6,341**	**6,875**	**6,379**	**6,379**

Source: FAO

B. Fish Oils

Country	Annual Consumption ('000 mt)					
	1997	**1998**	**1999**	**2000**	**2001**	**Average**
Chile	172	124	180	245	236	191
Norway	156	154	181	214	213	184
Peru	132	80	160	178	64	123
Japan	114	107	107	122	142	118
UK	80	58	57	54	69	64
Netherlands	73	11	47	66	24	44
Denmark	60	47	55	53	99	63
Germany	44	12	16	19	14	21
Canada	30	34	38	24	52	36
France	26	21	27	24	32	26
Spain	21	36	31	35	42	33
Italy	21	19	28	29	22	24
Belgium	18	1	1	4	1	5
China	13	10	38	49	30	28
Finland	9	6	5	3	4	5
Ireland	6	4	6	5	5	5
Poland	2	1	1	1	2	1
Sweden	1	0	0	4	4	2
Austria	1	1	1	1	1	1
Portugal	0	1	1	1	1	1
Czech	0	0	0	0	0	0
Other	282	205	273	297	192	250
TOTAL	**3,258**	**2,930**	**3,252**	**3,428**	**3,250**	**1,225**

Source: FAO

Appendix F: Factors of Unsustainability

Factors that impinge upon sustainability and how different kinds of management affect the situation (Cunningham and Maguire, 2002).

Factor	Sub-factor or comment	Exploitation, but no management	Technical conservation measures	Input controls	Output controls	Use rights	Market measures
Profitability	Increased profitability leads to increased desired exploitation rates	Exploitation rates simply increase leading to overcapacity and to eventually overfishing	Technical conservation measures have no effect on desire to increase exploitation rates in profitable fisheries. May improve exploitation pattern and help ecological sustainability.	Increased demand for rights pushing up their price rather than the exploitation rate. May be attempt to increase exploitation within the constraint of the number of licenses.	Competitive TACs lead to a race for the fish. Exploitation rates increase up to TAC. If TAC binding, unnecessary investment in capital follows, leading to the TAC being caught in short periods of time.	Increased demand for rights pushes up their price rather than the exploitation rate. May be attempt to increase exploitation within the constraint.	Increased profitability offers opportunity to increase tax revenues rather than the exploitation rate.
Profitability can increase for a number of reasons. Includes increased demand, linked among other things to international trade, variation in landings and decreased input costs. Input costs may decrease for a number of reasons, such as decreased fuel costs, but increases in efficiency are particularly important. They are covered separately under improved technology.							
Resource rent		Neither extracted nor capitalised, so perceived by fishers as profits, driving the fishery to higher exploitation rates	Measures may create rents in short run, but this will encourage increased effort (new entry or existing participants). Resource rents dissipated	Resource rents become capitalised into price of licenses. Provides opportunity to extract rents if desired. If not may give rise to equity issues. Possible rent-seeking behaviour.	Similar to technical conservation measures. TACs may create rents in short run, but this will encourage increased effort Resource rents dissipated	Resource rents are capitalised in the price of rights. Provides opportunity to extract rents if desired. If not may give rise to equity issues. Possible rent-seeking behaviour	Tax systems offer possibility to extract rents and to reduce exploitation rates.
Access conditions		Under no management, access is free and	Similar effect as no management.	Input controls by licensing has generally been	Overall TAC controls, without input controls,	Similar to above on resource rent.	

Factor	Sub-factor or comment	Exploitation, but no management	Technical conservation measures	Input controls	Output controls	Use rights	Market measures
		open leading to overexploitation.		introduced once exploitation rates are too high, or it has become uneconomic to fish.	will lead to new entrants. In combination with input controls, it may lead to increased fishing efficiency because of the race for fish.		
Uncertainty	The nature of uncertainty, its effects, and whom it affects varies according to the management scenario. Under no management, natural variability in stock sizes and markets are the main sources of uncertainty. As management progresses, more sources of uncertainty are introduced. Uncertainty is an important factor leading to unsustainability. If the fishery management agency had perfect knowledge, it would make the correct decisions all the time and would also implement them perfectly.						
	Species resilience	Species have different resilience to exploitation, and within species, different populations will also have different resilience. The resilience of individual species is not known, and it is likely to vary over time with climatic changes. Some species with low reproduction rates, such as shark and rays, are generally expected to be less resilient than more prolific species such as cod and herring. No management implies that all species will eventually become overexploited and perhaps depleted. Once management starts, it generally aims at avoiding depletion of a target species. In multispecies fisheries, low productivity by-catch species could become depleted even in the absence of a directed fishery.					
	Scientific assessment	Uncertainty in the scientific assessments have no effect under no management. Assessments may even not exist.	Under technical conservation measures, the expected effects of the measures adopted may not materialise because of assessment uncertainties.	There are considerable uncertainties about the fishing effort necessary to generate the Maximum Sustainable Yield or a fraction of it. These play a direct role towards unsustainability under input controls.	Catch based output controls are subject to considerable assessment uncertainties, not only with respect to current population parameters and status, but even more so with respect to future ones.	Depends on the nature of the rights.	Depends on the nature of the market shares.

Factor	Sub-factor or comment	Exploitation, but no management	Technical conservation measures	Input controls	Output controls	Use rights	Market measures
		In output control fishery management systems, TACs are often adjusted yearly in order to keep fishing mortality below an accepted threshold or to aim at a target. In order to do so, practice is often to assess current stock status and project future trajectories. This requires information on future recruitment, future weights at age, future exploitation rates, future natural mortality etc..					
	Ecosystem functioning	Sustainable development, in particular the principle of intergenerational equity, calls for letting future generations having similar options to those we presently have. This requires that the functioning of ecosystems, if not all their constituents be protected. There is limited understanding of how this can be achieved, and what exactly needs to be protected. Failure to protect ecosystem functioning leads first to ecological unsustainability, but eventually, under all components.					
	Management units	This is particularly relevant for ecological unsustainability. The aim is to manage fisheries on the basis of meaningful biological units that should respond similarly to management measures. Too large a management unit, comprising several distinct biological units, may run the risk of depleting some of the more easily accessible ones. Too small a management unit could lead to confusion about the developments of the unit. Small and large in the sentences above are relative to the real nature of the biological unit. Problems can be expected when a management boundary is not adequate for all dimensions (ecological, socioeconomic, community and institutional).					
Data requirements		By definition, no data are needed in support of management.	Relatively limited data are needed in either time or space once the potential effect of a management measure have been validated.	Long time series of data are needed to evaluate MSY and the effort corresponding to MSY. Continued monitoring is needed to assess changes in efficiency.	Large quantities of detailed data are required on a continued basis.	Depends on the nature of the rights.	Depends on the nature of the market shares.
Targeting behaviour		Targeting may lead to discarding of non-target low value species.	Mostly similar effect as no management or made worse by some measures (eg fish size limits).	Discarding of low-value non-target species.	If TAC binding, may lead to discards of both target and by-catch species.	High-grading of catch likely in order to maximise value of landed catch.	Discarding of low-value non-target species.
Input substitution		No incentive to use other than economically optimal input combination	Control of one or more inputs will encourage substitution	Input-based rights likely to encourage expansion of uncontrolled	If TAC binding, race for fish worsens encouraging investment in	Output-based control should mean choice of optimal input set	Depends on how tax applied in detail. Attempts to tax effort may have similar

Factor	Sub-factor or comment	Exploitation, but no management	Technical conservation measures	Input controls	Output controls	Use rights	Market measures
				inputs	speed		effects to input-based rights
Asymmetric entry/exit (Lack of alternatives)		Capital non-malleability and/or low opportunity cost of labour (due to lack of economic alternatives) may lead to ratchet effect. Entry attracted in good years but does not exit in poor years.	Since access not controlled, short term improvements will attract new entry leading to longer run problems (depending on exploitation levels)	May make it difficult and/or expensive to achieve licence reductions if licensing introduced once capacity built up	Since access not controlled, short term improvements will attract new entry leading to longer run problems (depending on exploitation levels)	May lead to conflict unless equity issues carefully considered	May mean that very high rentals would be required to reduce effort levels

Factor	Sub-factor or comment	Exploitation, but no management	Technical conservation measures	Input controls	Output controls	Use rights	Market measures
International trade opportunities	Will work through profitability, hence impact similar	Improved trade opportunities may be a threat to sustainability because of impact on short-term profits	Threat	Opportunity but potential longer term threat through input substitution	Threat	Opportunity	Opportunity for management authorities but potential threat if rentals not adjusted
Rent-seeking behaviour		N/A	N/A	Likely to be encouraged, mainly via input substitution	N/A	Likely to be encouraged mainly via highgrading	Depends on institutional arrangements. Can be expected to be a problem

Factor	Sub-factor or comment	Exploitation, but no management	Technical conservation measures	Input controls	Output controls	Use rights	Market measures
User participation and compliance		N/A	Situation varies according to management systems. Frequently antagonistic relationship between managers and fishers. Compliance poor and enforcement expensive	Give fishers a stake in the fishery. Compliance likely to be good.	Because output controls often lead to overcapacity, compliance often poor, especially when output reductions required because fishers cannot survive economically on reduced catches.	Give fishers a stake in the future of the fishery. Expectation that compliance and peer-based enforcement will improve, but highgrading appears a problem.	Depends on institutional arrangements. A significant proportion of benefits may disappear in compliance and enforcement costs.
Choice of unsustainability		Whatever the management system, policymakers may choose to trade-off sustainability in one area in return for benefits in another					
Fishing technology policy	States have often sponsored technological improvements	N/A	Technical advance tends to undermine management system	Policy of improving technology likely to push the fishery towards less sustainable situation, unless accompanied by mechanisms to reduce number of licences	Technical advance tends to undermine management system leading to increased catch up to TAC and increased capacity once constraint binds	Investment only if costs reduced or revenue increased. Policy can be better targeted once rights exist	May be a problem if rentals difficult to adjust

Factor	Sub-factor or comment	Exploitation, but no management	Technical conservation measures	Input controls	Output controls	Use rights	Market measures
Subsidies	Often an important element of technology policy but may be used more generally. Main effect to reduce fishing costs	N/A	By lowering costs, subsidies will tend to increase exploitation levels.	Subsidies reduce costs and hence profits. This will push up licence prices, encouraging input substitution. Example of buybacks as subsidy - difficult to design so as to be effective	By lowering costs, subsidies will tend to increase exploitation levels up to TAC constraint. Once constraint binds, encourage investment in redundant capacity	Subsidies will affect the price of rights rather than exploitation levels. Possibility to use selective subsidies (eg environmentally friendly gear)	If fishery being managed by taxation, it would not make sense to have a policy of general subsidies, although targeted subsidies still possible
Lack of understanding of fisher behaviour		N/A	Fishers have generally changed their behaviour in order to minimise the impact of management measures.	Failure to understand fisher behaviour has often led to simplistic views of possible results of licence programmes.	In the absence of sufficient enforcement (the rule rather than the exception), output controls have led to misreporting, dumping, discarding and high-grading in order to maintain income despite the restrictions.	Need to understand economic basis of behaviour, especially if rights to be used to achieve goals other than economic efficiency. Need to avoid unintended consequences.	Use of taxes should provide correct incentives for fishers, but still need to understand behaviour to be able to predict response.
Desire for stable fishing opportunities		N/A	N/A	If stability is interpreted in terms of number of licences, may be too much capacity locked into the fishery	May lead to attempt to maintain TACs in face of ecological (and other) variability and uncertainty	Unwarranted attempts to maintain TACs may be resisted by fishers concerned about the value of their rights	Once fishing effort brought into line with available opportunities, some possibility to stabilise by varying taxes to compensate for other changes

Factor	Sub-factor or comment	Exploitation, but no management	Technical conservation measures	Input controls	Output controls	Use rights	Market measures
Failure to distinguish between income and wealth	Often an important element of technology policy but may be used more generally. Main effect to reduce fishing costs	N/A	N/A	Depending on the precise nature of the licensing scheme, licences may take on a substantial value. The main effect will be on wealth, not on income. Confusion of these effects may lead to inequitable outcomes and unsustainable management systems	N/A	Effect similar to input controls but economically efficient systems (such as individual catch rights or spatial monopolies) are likely to have an even greater wealth effect, on a sustainable basis. Need for clarity on resource ownership, use rights, equity and sustainability of management system.	Royalties also will influence wealth and income. Need to clarify resource ownership issue, and who is to benefit from the resource and in what way.
General economic policy		Fishery responds to general economic incentives - eg taxation rules may allow depreciation of capital assets at rates providing incentive to over-invest	Fishery responds to general economic incentives - eg taxation rules may allow depreciation of capital assets at rates providing incentive to over-invest	Although fishery will still respond to general economic incentives, existence of rights should remove incentive to over-invest. Depending on precise nature of rules, could still be some distortion	Fishery responds to general economic incentives - eg taxation rules may allow depreciation of capital assets at rates providing incentive to over-invest	Although fishery will still respond to general economic incentives, existence of rights should remove incentive to over-invest. Depending on precise nature of rules, could still be some distortion	In setting tax levels in fishery, need to take overall fiscal situation into account. Could still be some distortion
Equity issues	**Regional shifts**	N/A	N/A	If licences are transferable, they may not continue to be held in the same regions as	N/A	Similar issue to input controls but may be more severe in case of transferable catch	N/A

Factor	Sub-factor or comment	Exploitation, but no management	Technical conservation measures	Input controls	Output controls	Use rights	Market measures
				before, leading to threats to community sustainability in some areas.		rights because relatively easy to transfer these to existing vessels in other areas.	
Equity issues (continued)	**Monopolisation of rights**	N/A	N/A	A system of transferable licences will open the possibility for some monopolisation. This could threaten community sustainability and the management system itself if it is felt to be inequitable	N/A	Similar problem to input controls but perhaps more severe because may be easier to monopolise catch rights.	N/A
	Political acceptability	N/A	General acceptability to use such measures	Political will to introduce licences but often too late. Less will to reduce number of licences in line with resource availability	Output controls often accompanied by unwillingness to reduce TACs in line with scientific advice	Much resistance to introduction of use rights	Generally unacceptable (except for foreign fishers). Problem that rentals may have to be increased when fishery already stressed.
Beggar-my-neighbour policies	In the case of capacity reduction	N/A	N/A	Impact of capacity reduction programmes by foreign States depends on how licences allocated. If new licences easily available at low cost,	Capacity reduction programmes may lead to excess capacity being exported	Fishers will invest in cheap capacity only if costs lower. But some potential conflict because only some sectors likely to have access to cheap	Fishers likely to be interested in cheap capacity

Factor	Sub-factor or comment	Exploitation, but no management	Technical conservation measures	Input controls	Output controls	Use rights	Market measures
				availability of cheap capacity may lead to increased exploitation		capacity (eg industrial versus small-scale fishers)	
Habitat degradation	Activities of other sectors (or sometimes the fishery sector itself) may destroy key habitat	Under these arrangements, both habitat degradation and pollution are likely to be serious sources of non-sustainability for the fishery sector. The value of the fish resource is likely to insufficiently identifiable.	If licences are transferable and take on some value, fishers are seem likely to have a more clearly identified self interest in protecting the resource and their activity.	Issue likely to be similar to first case. Fishery management agency must take the lead in defending the sector.	Similar to input controls. Valuable use rights should provide an incentive (and the legal basis) for the sector to seek to protect itself.	Economic benefits of resource exploitation will go to the State (as custodian) in the form of royalties. Up to the State to ensure that such royalties are not undermined.	
Pollution	Activities of other sectors (or sometimes the fishery sector itself) may lead to pollution						

Source: Cunningham and Maguire, 2002



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The RSPB is the UK charity working to secure a healthy environment for birds and wildlife, helping to create a better world for us all.

Puffin with sandeels and trawler by Chris Gomersall, guillemots by Andy Hay, fish processing by Euan Dunn (all rspb-images.com)

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