
WWF
SCOTTISH WILDLIFE TRUST
Joint Marine Programme
RSPB
Feeding the fish
How sustainable is the fish feed used by Scotland's aquaculture industry?

Recommendations for action

In light of this report and to fulfil the commitments expressed in the Scottish Executive's Strategic Framework for Scottish Aquaculture (SFSA), WWF Scotland, the Scottish Wildlife Trust and RSPB Scotland call on the Scottish Executive to lead, through the SFSA, the preparation and implementation of a detailed plan of action to ensure the sustainability of fish feeds used in the Scottish aquaculture industry. The feed and fish production industries and other relevant interests should be involved in this process, which should include:

1 Development and adoption by the Scottish industry of a structured method for assessing fish feed sustainability based on the best available information and best international standards for assessing the environmental sustainability of fisheries and feed transport.

2 Development and adoption of an industry-recognised sustainable-sourcing policy that is independently verifiable. This should minimise and, where possible, eliminate, the use of those species considered unsustainable. This sustainable-sourcing policy should be regularly updated and must be time-bound, taking a step-wise approach.
- Short-term – reducing, and where possible, eliminating the purchase of unsustainably-fished species such as blue whiting.
- Medium-term – developing alternatives to enable the cessation of the purchase of all species where sustainability is in question.
- Long-term – developing alternative sustainable protein and oil substitutes for fishmeal and fish oil, and setting a date for the sourcing of all fishmeal and oil from independently-verified sustainable fisheries.

3 Securing the commitment of feed and fish production industries to avoid the use of blue whiting until the international management plan is agreed and fully implemented by all parties fishing the stocks.

4 A requirement on fish feed purchasers to secure improved traceability and chain of custody of the constituent components of fish feed products. This information should be readily available to the retailer and the consumer to improve public understanding.

5 Support to the Scottish fish farming industry for the development of a marketing strategy based on a "sustainable brand" in line with the agreed sustainable-sourcing assessment methods. This should encourage feed suppliers to move towards targets for achieving sustainable supplies and to develop a discerning customer base.

6 Support for SARF to engage in research aimed at improving feed sustainability. This could include, for example, the development of sustainable alternatives to fishmeal and fish oil and the development of decision-support software to provide information on options for substituting different species at different times of year to achieve the required fish feed quality.

7 Removal of obstacles to the incorporation of fish processing wastes into fish feed production.

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Disclaimer and Report Information

This report has been prepared with the financial support of the Scottish Wildlife Trust (SWT), the Royal Society for the Protection of Birds (RSPB) and WWF Scotland (WWF-S).

Huntington, T.C. (2004). '**Feeding the Fish: Sustainable Fish Feed and Scottish Aquaculture**. Report to the Joint Marine Programme (Scottish Wildlife Trust and WWF Scotland) and RSPB Scotland.

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ACRONYMS

AIC	Agricultural Industries Confederation
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 Feed fisheries On Non-Target Species
ENSO	El Niño Southern Oscillation
EP	European Parliament
EU	European Union
FAO	Food and Agriculture Organisation
FCR	Food Conversion Ratio
FEMAS	Feed Materials Assurance Scheme
FIN	Fishmeal Information Network
FTE	Full Time Equivalent
GAFTA	Grain and Feed Trade Association
GEF	Global Environment Facility
GMO	Genetically Modified Organism
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
SARF	Scottish Aquaculture Research Forum
SPS	Phyto-sanitary measures
SSB	Spawning Stock Biomass
STECF	Scientific, Technical and Economic Committee for Fisheries (of the EC)
TAC	Total Allowable Catch
TVN	Total Volatile Nitrogen
UFAS	Universal Feed Assurance Scheme
UK	United Kingdom
WTO	World Trade Organisation
WWF	WWF – the Global Environment Network

EXECUTIVE SUMMARY

This study has been commissioned by the Joint Marine Programme, a partnership between the Scottish Wildlife Trust and WWF Scotland, and RSPB Scotland. It is intended to examine the sustainability of fish feeds used in the Scottish finfish aquaculture industry, and to make recommendations on how the industry and the Scottish Executive can work towards a more sustainable aquaculture industry in Scotland. The work has been conducted by independent consultants Poseidon Aquatic Resource Management Ltd.

Scottish Fish Farm Production and Feed Supplies

Finfish farming in Scotland is dominated by salmon (96%) and trout (3.7%) production together with a small but growing marine finfish sector (currently less than 0.5% production). An important rural employer, the industry has seen a steady growth since its start in the 1970s and despite a number of challenges, such as disease and growing competition from abroad, is still anticipated to expand further by around 16% by 2010.

The feeds used by finfish aquaculture are typically high in protein with a fishmeal content of between 35 to 45% and with an oil range of 15-38%. Despite substantial efforts to substitute fishmeal with other protein sources, success has been limited by growth and performance constraints. Therefore the fishmeal content of salmonid feeds is unlikely to fall by more than 25% before 2010, although the replacement of up to 50% of fish oil with vegetable substitutes is technically possible but may face retail and consumer resistance. However there is also some doubt about the sustainability of some of the substitutes themselves.

95% of feeds used by the Scottish industry are manufactured by three companies, all with feed mills in or near Scotland. Current fishmeal consumption by these plants for aquaculture use is around 105,000 tonnes (t) per annum and is sourced from the UK (24%), Iceland (22%), Norway (16%), Denmark (12%), Chile (10%) and Peru (9%) with the balance from other sources such as Ireland. Therefore South American imports contribute between 15-30% of Scottish aquaculture-directed consumption, with the majority (70 – 85%) coming from Northern European sources. Of the 50,000 t oil used for Scottish fish feeds, the majority is from Iceland with some from South American sources and 20% is of Irish and UK origin.

Industry figures suggest that currently (2003) around 54% of feed fish-derived fishmeal comes from Northern Hemisphere sources, 28% from the Southern Hemisphere resources and the balance from whitefish trimmings and pelagic offal. These figures also suggest a small (5%) increase in the Southern Hemisphere proportion by 2010, with the contribution of trimmings and offal-derived fishmeal staying more or less static. The proportion of fish oil purchased from Northern Hemisphere sources is even higher at nearly 66% against the 17% from the Southern Hemisphere and 18% from trimmings and offal – again industry sources suggest a greater contribution from southern hemisphere feed fishes at the expense of those from the Northern Hemisphere.

The main species used for making Scottish fish feeds from the Northern Hemisphere countries are blue whiting, capelin, sandeel, horse mackerel, Norwegian pout and sprat, whilst those from the Southern hemisphere include Peruvian anchovy with some Chilean jack mackerel and sardine. The domestic (UK) production destined for aquaculture feeds in Scotland consists of herring and mackerel offal, blue whiting, sandeel and whitefish trimmings.

The purchasing and specification of fishmeals for aquaculture feeds is a complex issue. Decision-making is based on a combination of forward pricing together with a demand for quality (principally freshness) and the specification of the material required (depends upon the age, species and their special dietary needs), usability (i.e. based upon the suitability for the miller's machinery). Whilst most feed manufacturers state that they only procure from 'sustainable' sources, this is usually based upon the Fishmeal Information Network (FIN) Sustainability Dossier, an annually updated assessment initiated by the Grain and Feed Trade Association (GAFTA) and funded by the UK Seafish Industry Authority (SFIA). This is essentially limited to examining stock assessment reports and the presence of regulatory frameworks and does not include some key elements such as wider ecosystem impacts, the depth of knowledge supporting management of the industry and how regulatory compliance is effected.

Sustainability of Feed Fish Stocks Used

This study builds upon an earlier report produced for RSPB Scotland, whereby a series of criteria and indicators for the sustainability of feed fisheries have been developed, mainly from the internationally-recognised Marine Stewardship Council 'Principles and Criteria for Sustainable Fishing' (see http://www.msc.org). The MSC model, and the adapted model used in this study, incorporate a set of sustainability principles fundamental to assessing the sustainability of fisheries, including information of the non-target species impacts, regulatory compliance levels, availability of key information and knowledge relevant to sustainability as well as economic and social factors.

The assessment looks at six of the main feed fish species used for fishmeal and oil production in Scottish finfish aquaculture (Peruvian anchovy, jack mackerel, capelin, blue whiting, sandeel and horse mackerel) and serves to demonstrate the sustainability of feed fish stocks is still far from certain. Efforts have been made to regulate sandeel and capelin catches more effectively. Nevertheless, the sustainability of these stocks remains uncertain due to their rapid achievement of maturity, lack of information on stock size and on measures needed to take account of climate change, as well as on the impact of the fisheries for these important prey species upon other fish, mammals and seabirds and the recovery of depleted fish stocks. The Peruvian anchovy stock may be in reasonable shape, but not enough is known about recovery rates after El Niño events, the effects of an increasing pelagic fleet or the wider environmental impacts of this large fishery which contributes to over half the global fish meal supplies. It is therefore impossible to conclude whether this fishery is sustainable or not. The other fisheries, in particular the blue whiting in the North-east Atlantic, cannot be described as sustainable in their current form. The blue whiting is overfished and dependent upon previous good year classes that have protected the stock from severe depletion.

The study also briefly examines the environmental costs of importing fishmeal and oils from South America in terms of fossil fuel consumption and exhaust emissions. The low levels of lipophilic Persistent Organic Pollutants (POPs) found in these oils compared to some Scandinavian oils may contribute to a preference for the South America fish oils. In addition, despite their lower protein levels and digestibility, the demand for Chilean or Peruvian fishmeal is mainly driven by its suitability for small fish (<1 kg) diets where their high histidine levels are advantageous. Thus there is usually a steady demand for these fishmeals, usually amounting to between 10 and 30% of that consumed in Scottish aquaculture. The transport of these materials by bulk or container transport inevitably incurs some environmental costs (e.g. producing around 4,900 t CO_2 per year) that could be avoided if supplies were procured solely from nearby European sources. However, given the preferred use of histidine-rich meals from South America for starter diets[1], this is unlikely – indeed the industry is forecasting that the proportion of these meals will increase by 2010 (see above).

Practical Constraints to Supplying Sustainable Feeds

There are practical constraints that must be overcome if feed manufacturers are to supply the Scottish industry with sustainable fish feed. These include:

Feed Fish Sustainability Criteria: as recognised by FIN (Anne Chamberlain, pers. comm.), the FIN Sustainability Dossier does not provide a holistic framework for assessing the sustainability of feed fish stocks. The MSC-derived framework used by this study is considered an important step forward here, but this needs to be further developed so that it can act as an independently verifiable mechanism for assessing the degree to which a fishery is achieving sustainability over a wide range of criteria and where further research, management and operational improvements can be made.

Traceability: many fishmeals and oils lack traceability, especially those that are blended. However this situation is changing, as the industry is adopting the Universal Feed Assurance Scheme (UFAS) that will demand full traceability of feed materials by the beginning of 2005.

Nutritional Performance: seasonal and stock-related characteristics may mean that certain less sustainable meals are either superior in quality or may only be available for a certain period when more sustainable stocks are closed or fully utilised.

[1] Artificial histidine is banned and retailers are averse to the use of blood meal that contains high levels of histidine.

Supply assurance: if fish mills were to restrict their purchasing to sustainable supplies only, this would restrict the already narrow supply base and inevitably impact prices. In the case of fish oils, where it is predicted that demand will overtake supply in the medium term, this is of particular concern, especially considering the resistance of retailers and consumers to using vegetable oil substitutes.

Buying power: the Scottish finfish industry is a relatively small player in the fishmeal market, consuming only about 2.5% of the world supply[2]. Therefore the freedom to choose certain fishmeals and oils may become more restricted. This lack of leverage in the global market is one of the industry's greatest concerns over moving to only 'sustainable' sources of fish meal and fish oil.

Recommendations and Integration of the Study's Findings into the Strategic Framework for Scottish Aquaculture

A series of draft standards, in the form of purchasing guidelines have been included in this study. These include:

- Development of a structured sustainability framework to be adopted by the industry that reflects a more holistic view of which fisheries are sustainable and those which are not.
- The feed manufacturers should insist on greater traceability from their suppliers – this is likely to develop as the adoption of the UFAS (Universal Feed Assurance Scheme) and FEMAS (Feed Materials Assurance Scheme) schemes takes place towards 2005.
- Fish feed manufacturers should adopt a time-bound strategy for sourcing fishmeal from sustainable sources only. This should include other options such as reducing overall fishmeal and fish oil use through substitution and improved feeding practices. This move will have to have the support of the farming sector and retailers as this cannot be achieved by the feed industry alone.
- To assist in developing sustainable supplies, fish feed manufacturers should consider the use of decision-support software that provides forward looking information on sustainable feed fish availability, quality and pricing.
- Feed suppliers could look at incorporating Environment Management Systems (EMS) to ISO 14001 or equivalent that supports environmentally responsible buying practices and strategies. Experience shows that these can often be cost-effective in the longer-term.
- The Scottish fish farming industry should engage this as a positive opportunity to further develop their 'premium brand' image through a strategy to minimise and phase out use of unsustainable feed fish species.

The recommendations made above build upon the Strategic Framework for Scottish Aquaculture that considered the development of sustainable fishmeal and fish oil supplies as one of four priority research topics for the Scottish Aquaculture Research Forum (SARF). This study essentially provides the first part of the Feed Sustainability Study' proposed in the Framework. The next step for the Scottish Executive and Scottish fish farming and feed production industry is to create a detailed strategy for sustainable fish feed within the Framework. This should build on the draft standards recommended by this study, with the ultimate aim of encouraging the more sustainable feed fisheries to become independently certified, promoting the development of sustainable alternatives to fish meal and fish oil and the incorporation into fish feed of fish processing waste and unavoidable discard material.

[2] The People's Republic of China (PRC) is by far the largest consumer of fishmeal (27%), with Japan (13%) and Thailand (7%) 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. The main users are Chile (7.3%) and Norway (6.6%) in 2001 respectively, reflecting the high level of salmonid production in these countries. Total UK use of fishmeal and fish oils in 2001 was 4.2% and 2.1% of global consumption respectively.

1 INTRODUCTION

1.1 BACKGROUND

Scottish aquaculture has been described as "the single most important economic development in the Highlands and Islands for the past 30 years" (SQS website, June 2004). Salmon farming alone supports the livelihoods of around 2,000 directly (and between 4,000 and 5,000 in the supporting sectors), of which around half live in remote rural communities and contributes some £100 million to local pay packets. The industry generates annually more than £500m of turnover at 'farm gate' and through secondary processing, and now accounts for around 50% by value of all Scottish food exports (Strategic Framework for Scottish Aquaculture, 2003).

This success story has been accompanied by growing concern over the environmental impact and sustainability of the industry. This has mainly been based around the localised impact upon the production sites, concern over the impact upon wild salmon and sea trout stocks as well as wider ecosystem effects. One of the factors considered in the latter category is the need for considerable volumes of fish meal and fish oil in carnivorous fin fish diets. The majority of this is produced from the so-called 'feed fisheries' such as the Peruvian anchovy or the sandeel and the concern has been raised over the consequences of removing large numbers of fish from an ecosystem on their prey, predators and the viability of target and by-catch populations. Indeed, the Scottish Aquaculture Research Forum (SARF) ranks the sustainability of fish meal and fish oil as one of four major priority research areas of "effects which pose a risk of cumulative, long-term or irreversible changes to ecological systems".

However it is important to place this issue in a global context. According to the Scottish Executive (2002), the Scottish fish farming industry consumes an estimated 0.8% of world fish meal demand, although our own assessment of around 2.5% considers this an underestimate. The People's Republic of China (PRC) is by far the largest consumer of fish meal, accounting around a quarter of the 6.38 million tonnes per annum global usage (FAO, 2002) 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 has also little changed over the past five years, although again there is strong inter-annual variation. The main users are Chile and Norway (236,000 and 213,000 t in 2001 respectively), reflecting the high level of salmonid production in these countries.

Aquaculture is a major 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. The global use of fish meal in 2000, and the predicted use in 2010, is shown below.

Table 1: Global Fish Meal Usage in Aquaculture in 2000 and 2010 (predicted)

Species	Inclusion rate in feed			Fish meal use ('000 mt)		
	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%	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: bass, bream, yellow tail, grouper, carangids, mullets

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

Change is the percentage change from the 2000 baseline (100%).

The figures in this table[3] indicated two distinct trends:

1. The rates at which fish meal is included in aquaculture diets, according to IFFO, 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 (Gallimore 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 2 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 and indicates that fish oil supply is likely to be increasingly limiting to the future aquaculture development.

Table 2: 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%	-	0	103	High
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%	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: bass, bream, yellow tail, grouper, carangids, mullets*

[3] The IFFO figures in Table 1 maybe an underestimate of salmon fishmeal usage in 2000.

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

Change is the percentage change from the 2000 baseline (100%).

Within Europe and the UK, there have been a number of initiatives to address this issue. The European Parliament commissioned a study entitled the *Fish Meal and Fish Oil Industry: Its Role in the Common Fisheries Policy* (Banks *et al*, 2003). The European *SEAfeeds Workshop*, organised by Nautilus Consultants in association with Stirling University Institute of Aquaculture in April 2003, reached agreement on a number of points, including:

1. There is a poor understanding of, and lack of agreed criteria for sustainability for the broader dimensions of sustainability relating to effects on other fisheries and wider ecosystem and socio-economic impacts;
2. That demand for fish meal and oil is likely to exceed supply soon. This is predicted to reduce the proportion used for animal feeds and increase that used for aquafeeds;

3. That responsibility for sustainability should apply to all points in the production chain. The responsibility for providing information to enable informed choice rests with fishing companies, fishery managers, fishmeal producers, but they lack capacity, resources and incentive to provide information;
4. The need for producers, fish farmers and retailers to have clear sustainability and efficiency criteria that allow for measurement of progress; and
5. The need for an EU steering group on this topic.

Following this workshop, in September 2003, the Royal Society for the Protection of Birds (RSPB) let a contract (*Assessment of the Sustainability of Feed Fisheries used in the Production of Fish Meal and Fish Oil)* to Poseidon Aquatic Resource Management Ltd and Newcastle University to:

1. Develop sustainability criteria and a 'sustainability index' for global feed fisheries, taking into account the needs of ecosystems as well as human needs;
2. Review the status of global feed fisheries according to this sustainability index (with a focus on North Sea sandeels and Peruvian anchovy fisheries); and
3. Review the drivers for fish oil and fish meal use and make recommendations for policy change that will assist RSPB/BirdLife with its promotion of ecologically sustainable fisheries.

The resulting report (Huntington *et al*, 2004) showed that although there is substantial knowledge of fishing pressure and stock sustainability, there is still only a basic understanding of ecosystem responses to industrial fishing. This situation is complicated by the susceptibility of these early maturing fish to external pressures such as climatic events (e.g. the El Niño Southern Oscillation), long-term oceanographic cycles and the unknown effects of climate change.

1.2 PURPOSE OF STUDY

Following this RSPB-funded study, the Joint Marine Programme of the *Scottish Wildlife Trust* and *WWF Scotland*, together with the *RSPB Scotland* decided to investigate this issue further with specific reference to the Scottish fish farming industry, which is currently the third largest consumer of fish meal and fish oils for aquaculture after Norway and Chile. The purpose of this project therefore is to answer the question 'How sustainable are the fish feeds used in Scottish aquaculture?'

The objectives of the study are to (see Appendix A for details):

1. Identify the main sources of fish feeds used in Scottish aquaculture;
2. Assess the relative merits of these different sources of fish feeds;
3. Recommend a core set of minimum standards that could be placed upon fish feed supplies to move the industry towards more sustainable supplies;
4. Assess some of the constraints for the Scottish aquaculture industry in adopting such standards;
5. Contribute to the work of the Strategic Framework in encouraging a more sustainable aquaculture industry in Scotland; and
6. Raise the profile of the fish feed issue amongst decision-makers, the media and consumers.

1.3 METHODOLOGY

This has been a desk-based exercise depending upon the current body of literature available on the subject, together with extensive telephone consultation with the fish farming industry and their feed suppliers. The work was subdivided into a number of discrete tasks as show below:

Task 1: Identify feed use and fish meal sources in Scottish aquaculture: conduct a frame survey of the industry to identify the main feed suppliers, the key sources and quantities of fish meal used, and the historic and likely future trends in demand and supply. This will also briefly examine current fish meal inclusion levels and the potential for substitution by non-fishmeal based materials.

Task 2: Comparative assessment of relative feed sustainability: evaluate the different fish meal sources in terms of their adherence to the criteria developed in the previous RSPB report, which will be aggregated into a 'performance matrix'. This will provide a comparative assessment of the different sources based on (i) fishing pressure and stock sustainability, (ii) fishery ecosystem effects and (iii) the ability to effectively manage and regulate the fishery in an informed fashion. Further factors, such as transport costs and contaminants levels, will also be factored in.

Task 3: Development of minimum standards for sustainable feed supplies: based on the results of Task 2, a set of guidelines for fish feed manufacturers will be drafted to assist them develop a responsible fish meal purchasing strategy.

Task 4: Assess industry constraints in achieving criteria: the draft standards will be discussed with key industrial representatives in order to better understand, and integrate, the practical constraints that buyers face in order to finalise a set of realistic standards and guidelines for fish meal purchasing.

Task 5: Provide guidance on feed supply sustainability to the Strategic Framework: after a brief assessment of the Strategic Framework, formulate recommendations for improving the sustainability of feed supplies to the Scottish aquaculture industry.

Task 6: Raise profile of fish feed sustainability issues: prepare an Executive Report of the above that can be readily developed into a public advocacy paper.

2 FISH MEAL USE IN SCOTTISH AQUACULTURE

This section briefly examines the fish farming sector in Scotland and its current direction, the volumes and nature of feeds used and the sources of their fishmeal and fish oil constituents.

2.1 OVERVIEW OF THE SCOTTISH FIN FISH FARMING SECTOR

2.1.1 Current Status

The finfish farming sector in Scotland is dominated by the production of Atlantic salmon (*Salmo salar*) that represents around 95% of Scottish output by volume (see Table 3 below). There has been a constant currently gradual increase in salmon production resulting from improved yields from smolts and increased productivity per person (FRS, 2003) as well as a trend towards bigger sites (52% of sites produced over 500 tonnes in 2002).

Rainbow trout (*Oncorhynchus mykiss*) production has also increased from 3,334 tonnes in 1991 to 6,659 tonnes in 2002, largely due to increased production by the larger farms i.e. >200 tonnes per annum.

Of the other species, there is particular continued interest in diversification to marine fish, especially as profit margins on salmon remain tight, but progress is limited.

Table 3: Current Fin Fish Production in Scotland (tonnes)

Species	Year				
	1999	**2000**	**2001**	**2002**	**2003***
Atlantic salmon	126,686	128,959	138,519	145,609	176,596
Rainbow trout	5,834	5,154	5,466	6,659	6,500
Brown trout	92	138	105	175	400
Halibut	4	5	80	187	292
Cod	<1	16	15	-	144
Arctic charr	3	7	4	7	17
Total	**134,617**	**136,278**	**146,190**	**154,639**	**183,949**

* 2003 figures farmer' estimates based on stocks being on-grown

Source: FRS Scottish Fish Farms Annual Production Survey 2002[4]

2.1.2 Future Outlook

Salmon: the recent steady increase in salmon production shown in Table 3 above, whilst reflecting a modest growth in the industry, also demonstrates a recovery from the Infectious Salmon Anaemia (ISA) outbreak in 1998. The market for farmed salmon remains strong and demand is estimated to be increasing at around 10% per year (FSAP, 2002). Growth in the salmon farming industry is primarily constrained by the availability of on-growing sites and the strong regulatory environment, together with uncertainty over competition from foreign producers. It is expected that production is likely to remain static for the next two years (Brian Simpson, SQS, pers. comm.) but has the potential to rise to between 180,000 and 200,000 by 2010, especially if prices are maintained through international supply limit agreements. A fall in the 2003 and 2004 imports of fishmeal into Scotland and hence an estimated reduction of more than 10% in fish feed production suggests that production will actually fall in 2004.

Trout: Scottish trout production has changed little over the past five years following the increases earlier in the 1990's. This reflects a similar problem to salmon production in obtaining marine sites as well as difficulties in finding new or expanding freshwater sites. It is likely there will be modest growth in Scottish rainbow trout production, possibly of up to 10% per annum (FSAP, 2002), with between 8,000 and 10,000 t being produced by 2010 and 13,000 t by 2013 (Jane Davis, BTA, pers. comm.).

[4] The 2003 production figures had been compiled by FRS but not released at the time of writing

Halibut, cod and other marine finfish: these marine species have more complex artificial reproduction requirements than the salmonids mentioned above and are likely to remain a relatively 'niche' production. Halibut is particularly difficult to breed and wean, and has a long production period due to the large market size (c. 4 kg), but currently benefits from a high market price. Despite Marine Harvest's recent decision to move their halibut production to Norway, the prospect for this species is reasonably good, with production of between 3,000 – 4,000 t forecast for 2010 (Richard Slaski, British Marine Finfish Association Ltd, pres. comm.), so long as prices remain reasonably firm. The production of cod and other gadoids is likely to rise faster, to around 20,000 t by 2010, but is limited by the marginal economics of production resulting from competition with capture fisheries landings. A small haddock production of around 1,000 t by 2013 is also considered realistic.

2.2 FEED USE AND SUPPLY

2.2.1 Feed Usage

The Agricultural Industries Confederation (AIC) have compiled feed production information from Scottish fish feed producers contacted as part of this study. This survey indicates that around 215,385 t of salmon and 18,700 t trout diets were used by the Scottish industry over 2003, reflecting a small reduction since 2002 (see Table 4 below).

Table 4: Feed Usage by Scottish Aquaculture (2002 and 2003)

Feed type		2002	2003
Salmon starter diets		5,720	4,765
Salmon grower diets		215,250	210,620
Trout starter diets		595	530
Trout grower diets		17,690	18,170
Other finfish diets	Marine Fish	2,340	2,825
	Freshwater Fish	910	1,090
TOTAL		**242,505**	**238,000**

Source: Agricultural Industries Confederation, pers. comm.

These feeds vary highly in their protein and oil levels, depending upon the species being fed and the stage at which the feeds are being fed. It can be seen from Table 5 below that starter diets are typically rich in protein and lower in oil than grower feeds. As discussed later on, smaller fish also have different nutritional requirements that might favour the use of particular fishmeals, such as the histidine-rich South American feeds. It should also be remembered that starter feeds represent a smaller volume than grower feeds, as it is the latter that is mainly used to contribute to stock biomass.

Table 5: Typical Composition of the Main Feeds used in Scottish Aquaculture

Feed type		Protein %	Oil %	Typical FCR
Salmon starter diets		50-55	14-23	0.90-1.00
Salmon grower diets		34-50	22-38	1.20-1.30
Trout starter diets		50-57	14-22	0.80-0.95
Trout grower diets		38-50	8-33	0.9-1.3
Other finfish diets	Marine Fish	50-60	12-24	1.10-1.40
	Freshwater Fish	31-55	7-18	

Source: Agricultural Industries Confederation, pers. comm.

The fish feed and the fishmeal component used by the Scottish industry has been estimated based on current production, food conversion ratios (FCR's)[5] and fishmeal inclusion rates. This is not intended to be a definitive assessment but provides an understanding of the volumes involved. These have also been projected for 2010. Here slightly lower fishmeal inclusion rates have been used, as are the current FCR's.

Table 6: Current (2003) and Projected (2010) Fishmeal Usage by Scottish Aquaculture

Species	2003				2010			
	Fish production (mt)	Feed consumption (mt)	Fishmeal content (%)	Fishmeal consumption (mt)	Fish production (mt)	Feed consumption (mt)	Fishmeal content (%)	Fishmeal consumption (mt)
Atlantic salmon	176,596	215,385	45%	96,923	180,000	250,100	35%	87,535
Rainbow trout	6,500	18,700	45%	8,415	10,000	22,300	30%	6,690
Marine fish	436	2,825	55%	1,554	3,000	17,500	40%	7,000
Freshwater fish	417	1,090	45%	491	20,000	2,500	40%	1,000
Total	**183,949**	**238,000**		**107,383**	**213,000**	**292,400**		**102,225**

These figures indicate that whilst fish production is expected to increase to 116% of current levels, fishmeal usage will decline around 95% of current usage. This is a result of the lower fishmeal inclusion rates that are expected to result from improved formulations as well as new options for substitution that overcome past performance problems (see Section 2.3.5 on page 12).

2.2.2 Feed Supply

The supply of fish feeds to Scottish aquaculture is dominated by three companies, all of whom have invested in production facilities in the UK.

Table 7: Major Feed Suppliers to the Scottish Aquaculture Industry

Company	Primary Location in the UK	Head Office	Estimated market share (2003)
BioMar	Grangemouth	Denmark (BioMar Group)	25%
Ewos	Bathgate, West Lothian	Norway (Cermaq)	20%
Skretting	Northwich, Cheshire	Netherlands (Nutreco)	55%
Imports	Danafeed, Aller Moller, Le Goussant and Havsbrun		5%

Other companies, such as DanaFeed A/S of Denmark, Aller Moller, and Le Gouessant also provide some feed direct from their continental Europe production facilities, but in relatively low volumes. Finished fish feedstuffs manufactured by a Norwegian company called Havsbrun are imported into Scotland and particularly into Shetland.

[5] The FCRs used reflect dry to wet weight of the total annual use (e.g. c. 1.3) rather than those for a single year class that might be significantly lower FCR e.g. 1.1 to 1.2 for salmon.

2.3 SOURCE OF FISH MEAL AND FISH OIL

This section looks at the main sources of fishmeal and fish oil for Scottish fish feeds and then examines both the particular requirements of aquaculture feeds (*vis a vis* agriculture feeds) as well as the purchasing requirements and approaches by aquaculture feed manufacturers.

2.3.1 Global Fishmeal Supply

Fishmeal is essentially traded as a commodity, competing against other protein meals for buyers. 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[6] are all significant suppliers, each providing around 5% of the global supply. The South American supply mostly consists of anchovy, with capelin the main constituent of European supplies (see Table 8 below).

Table 8: Origin of Global Fishmeal by Region and Species

Region	Species	%
South America	Anchovy	57%
	Jack mackerel	7%
	Sardine	2%
	Sub-total	***66%***
Europe	Capelin	10%
	Blue whiting	7%
	Sandeel	5%
	Horse mackerel	3%
	Sprat	2%
	Herring	1%
	Norway pout	1%
	Sub-total	***29%***
USA	Menhaden	5%
TOTAL		**100%**

Source: IFFO, 2004

2.3.2 Fishmeal Imports and Production in the United Kingdom

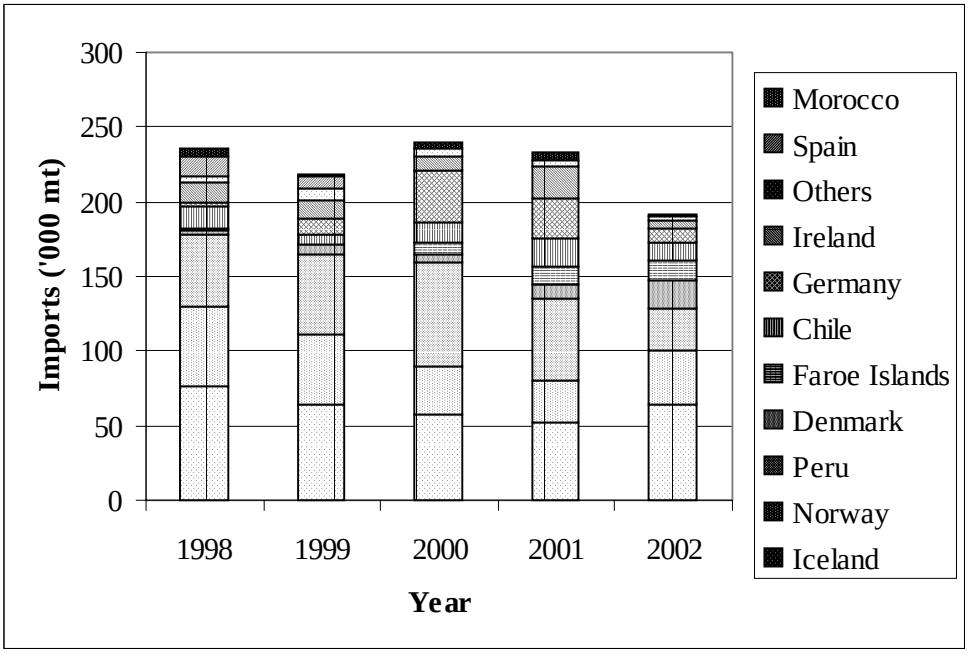
UK annual fishmeal consumption by both aquaculture and agriculture has declined from an average of 280,000 tonnes between 1995 and 2000 to 229,000 tonnes in 2003 and an expected 190,000 tonnes in 2004. The contribution of domestic production has been relatively steady at 45,000 to 50,000 tonnes per annum, of which around 90% comes from the members of the IAWS Group plc (i.e. United Fish Products in Aberdeen and the Shetlands as well as and United Fish Industries in Grimsby) and the remainder from small operations such as Interfish in Plymouth. Typically up to 10,000 tonnes has been exported, mainly as internal transfers by fish feed companies to Ireland with some trades to Denmark. Fish feed production used 20% of total UK supply in 1996 but by 2002 this share had risen to 50%. Conversely both the share of meal supply and the percentage used in agricultural feeds declined over the same period - the EC ban on feeding fishmeal to ruminants was a major factor in this decline.

Industry figures (see Table 9 on page 10) suggest that currently around 54% of feed fish-derived fishmeal comes from Northern Hemisphere sources, 28% from the Southern Hemisphere resources and the balance from whitefish trimmings and pelagic offal. These figures also suggest a small (5%) increase in the Southern Hemisphere proportion by 2010, with the contribution of trimmings and offal-derived

[6] Norway is a net importer of fish oil and fishmeal because of the high demand and consumption in salmon farming.

fishmeal staying more or less static. The proportion of fish oil purchased from Northern Hemisphere sources is even higher at nearly 66% against the 17% from the Southern Hemisphere and 18% from trimmings and offal – again industry sources suggest a greater contribution from southern hemisphere feed fishes at the expense of those from the Northern Hemisphere.

Figure 1: Fishmeal Imports into the United Kingdom (1998 – 2002)



Source: IFFO (2003)

An assessment of fishmeal usage by the Scottish fish farming industry indicates that of the 95-110,000 t fishmeal currently utilised by the industry, around a quarter will come from domestic fishmeal production[7] (see Table 10 overleaf), followed closely by Icelandic (22%), Norwegian (16%) and Danish (12%) sources. South American fishmeals currently only account for around 19% but the amount can vary year to year and may occasionally increase to around 30%. Faroese contributions are very low at the moment and although a large producer most is used domestically or exported to Denmark. It is also possible that a proportion of the Danish fishmeals may include Faroese and Icelandic meals as re-exports.

A preliminary analysis of these figures indicates that blue whiting, capelin and sandeel-based meals are the mainstay of the North-East Atlantic sourced materials whilst Peruvian anchovy represents the bulk of the South American material. Over half (around 55%) of fishmeal for fish feed use is imported direct into Scotland by the feed companies, 20% via traders with the rest from domestic sources.

Of the 50,000 t of **fish oils** used, 20% will be of Irish and UK origin with the bulk from Iceland and some from South America. Little oil is imported from Denmark and Norway anymore (David Mack, pers. comm.).

The **agriculture sector** uses predominantly Peruvian meals and Icelandic meals with Morocco and other minor sources making up the balance.

With the current hiatus in fish farming both in the UK and elsewhere fish feed companies have seen this annual growth of 5-8 % stop and indeed reverse in 2003 to the point where in 2004 as much meal will be used by agriculture as aquaculture. This trend change is likely to be reversed again in 2 years time when the cutbacks in salmon supply should allow sufficient price recovery to enable growth in salmon farming to resume.

[7] Domestic production of fishmeal (from United Fish Product's Shetland and Aberdeen plants) consists mainly of herring and mackerel offal, white fish trimmings and some blue whiting and sandeels (Helge Korsager, UFP, pers. comm.).

Table 9: Current and Predicted Fishmeal and Fish Oil Utilisation by the Scottish Fish Farming Industry

Year	Protein Sources								Oil Sources						
	Whole fishmeal						Protein derivatives		Fish oil						Vegetable oils
	Northern Hemisphere		*Southern Hemisphere*		*Trimmings & offal*		*Oilseeds & legumes*	*Gluten*	*Northern Hemisphere*		*Southern Hemisphere*		*Trimmings & offal*		
2003	53,140	54%	27,600	28%	16,900	17%	24,400	19,250	41,200	66%	10,600	17%	11,000	18%	300
2010	44,500	49%	30,100	33%	16,000	18%	38,000	27,200	31,300	56%	13,000	23%	12,000	21%	20,000

Source data: Agricultural Industries Confederation, pers. comm.

Table 10: Current Sources of Feed Fish Used by Scottish Fish Feed Manufacture

Country of Origin	Volume		Main Species										
	Tonnes	*%*	*Anchovy*	*Jack mackerel*	*Sardine*	*Capelin*	*Blue whiting*	*Sandeel*	*Horse mackerel*	*Sprat*	*Norway pout*	*Pelagic offal*	*White fish trimmings*
UK	24,000	24%					+	+				+++	++
Iceland	22,000	22%				+++	+++						
Norway	16,000	16%				+	+++		+		++		
Denmark	12,000	12%					+	+++		++	+		
Chile	10,000	10%	++	++	+								
Peru	9,000	9%	+++	+	+								
Ireland	6,000	6%					+					++	++
Other	1,000	1%											
TOTAL:	**100,000**	**100%**											

Key: +++ High importance
++ Medium importance
+ Low importance

2.3.3 Characteristics and Requirements of Fishmeal for Use in Aquaculture

Whilst there are a bewildering number of fishmeal products available, they can be classified into three broad quality categories which generally reflect the production equipment used and the freshness of the raw material and correlate with the internal specifications of fish feed companies. Animal feeds compounders have lagged behind the aquaculture sector both in their understanding of fishmeal quality and in their use of the higher grades.

First quality: Nearly all produced using indirect steam dryers or LT direct dryers, and usually offered with Total Volatile Nitrogen (TVN) details (below 50 in raw material, below 180 in the meal) and a histamine guarantee. Protein levels 68/69 (Peruvian/Chilean/Irish) 70/71 (Scandinavian).

Second quality: nearly all produced using indirect steam dryers or LT direct dryers (especially in Peru). Sellers may offer additional quality parameters such as TVN of the raw material or the meal and histamine guarantees. Protein levels for South American meals slightly lower than top grades at 67/68. Oil and moisture often 10% not 12% compared to lower grades.

Third quality: includes most flame-dried meals, usually from lower quality raw material. Sometimes thus designated because of lower protein levels reflecting species used but may be of good quality as regards technical parameters such as digestibility. Sold on fat, moisture and protein content only. Typically 64-65/12/10 (all percentages) for Peruvian meals, 70/12/10 for Icelandic meals. Salt/sand and ash may be offered too. It is rare to find Chilean, Danish, Norwegian or Irish product in this category.

Most producing countries classify the final product according to the TVN of the raw material as follows.

- fish with a TVN of <50 produces the highest quality
- fish with a TVN between 50 and 100 produce the second or middle quality band
- fish above 100 produce the third or lowest quality band

Aquaculture formulators look for high digestibility which usually reflects the TVN levels. However even first quality material will not produce first quality meal unless produced using modern equipment and in particular a low temperature (LT) dryer. Meals so produced are usually referred to as LT or steam dried meals. Older flame or direct dryers normally reduce the digestibility of the meal

2.3.4 Fishmeal Specification and Procurement for Scottish Aquaculture Feeds

Fish feed companies tend to use 'higher' quality meals than animal compounders. They usually buy the majority of their meals direct from the producer and import and ship large quantities without using traders, brokers or other "middlemen". The three companies manufacturing fish feeds in Scotland source their fishmeal from a wide variety of sources that may vary through the year. The main sourcing criteria for **fishmeal** are as follows:

- Price: fishmeal is a global commodity whose price is interlinked with that of its main competitor, soyabean meal. The level of substitution within fish feeds is limited however and varies between different dietary formulations (i.e. for starter, grower and finisher diets). Therefore feed manufacturers can increase or decrease fishmeal incorporation levels within predefined limits.
- Quality: an important factor that also has an influence on price. The quality of fishmeal depends upon its freshness (measured by its volatile nitrogen content at conversion), the process used (e.g. processing temperature) and stabilisation techniques used.
- Specification: Fishmeals from North Atlantic stocks tend to be high in protein content (68% to 71%) than southern hemisphere fishmeals (65 - 68%), reflecting the species used. Northern Hemisphere fishmeals tend to have higher levels of digestibility – for instance an Icelandic 71% protein meal from capelin/herring with a digestibility of 92% gives 65.2% digestible protein (DP) as against only 58.8% DP from the best Chilean sardine meal. Certain fishmeals (e.g. high performance feeds for some species / growth stages) might be selected to achieve a particular amino acid profile.
- Contamination levels: Persistent Organic Pollutants (POPs) accumulate in oily fish and have become subject of a major food safety issue in the EU. Fishmeal sources from oceanic pelagic

stocks in South America tend to have less POPs that those from the continental shelf stocks in the NE Atlantic. Although the resultant meals have to be within legal limits – and the technology exists to reduce them further through filtration – this may be an influence on purchasing.

- Usability: individual producers' machinery characteristics can rule out the use of fishmeals from some origins
- Sustainability: most feed manufacturers will claim that sustainability is an important buying criterion but not to the same level as quality and price. Indeed one of the main problems has been characterising what is sustainable and what is not which make 'sustainability' difficult to use as a buying decision. The most commonly used 'standard' is the FIN Sustainability Dossier[8] that provides annually updated advice on the status of different feed stocks as gathered from sources such as ICES.

For **fish oils** the buying criteria are similar except for the following:

- Specification: individual processors may avoid or prefer certain fish oils. For example Tobis oil is avoided by some producers of trout feeds because of its colour, yet is sought by shrimp feed producers for the same reason. When seeking to augment or preserve Omega 3 fatty acid levels in the fish South American oils have an advantage. But tight supply conditions, higher saturate levels and hence lower digestibility act as possible disincentives to such use.
- Contamination levels: are particularly prevalent as oils store high levels of lipophilic POPs (see also Section 3.4 on page 22).

2.3.5 Trends and Emerging Technologies

There are a number of important factors influencing the future use of fishmeal by the Scottish aquaculture industry. As discussed in the Introduction, the aquaculture industry in Scotland is relatively a very small component in the global aquaculture field and could be badly affected by changes in the supply and price of fishmeal and fish oils. The Scottish salmon industry currently achieves only low profit margins and is unlikely to sustain fish feed price rises as easily as sectors with higher margins of profit.

Substitution of Fishmeals and Fish Oils with Alternative Materials: substitutes for fishmeal protein and marine fish oils are continuously being sought and progress is being made. Protein substitutes are already used in fish feed in the UK and Norway with up to 25% of the protein in the feed derived from plant origin. The uptake of fish oil substitutes has been slower. Concerns over the dioxin and polychlorinated biphenyl (PCB) levels in the northern hemisphere fish oils have increased the pressure on fish oil manufacturers to produce oils with reduced levels of dioxins. Scottish Quality Salmon (SQS) has revised its Quality Manual (Product Certification Scheme for Scottish Quality Farmed Salmon) to allow up to 25% of the oils added to the fish feed to be derived from a plant-based origin. However the level of substitution of fish-based meals and oils possible is limited by their lack of essential amino acids (such as lysine and methionine and histidine) that may limit growth at higher substitution levels. Another issue facing the plant meal and oil substitution option in Scotland is consumer opinion and the affect that this may have on the continued acceptance of Scottish salmon as a 'high quality' product similar to its wild counterpart. To produce a product as 'near to the wild product as possible', research is also focusing on the 'dilution' of vegetable oils in the flesh when the fish are fed diets containing 100% marine fish oils for 6 months prior to harvest. In addition, vegetable oil substitutes do not necessarily improve the environmental sustainability of the product – e.g. increased soybean production may lead to further rainforest clearance.

Improved feed formulation and feed delivery: further efficiencies in fish meal and oil usage can result from improved feed formulation and delivery. Continued research into the dietary requirements of particular species reared under particular conditions will refine formulations and improved feed delivery, though increasingly automated feeding and consumption monitoring systems will all lead to potential improvements in the food conversion ratio (FCRs) achieved. However, these are already low (between 0.9:1 and 1:1.2 dry to wet weight) so this is unlikely to have a dramatic impact on demand.

[8] See www.gafta.com/fin/sustainability.pdf

3 COMPARATIVE ASSESSMENT OF FEED FISH SUSTAINABILITY

3.1 SUSTAINABILITY AND FEED FISH FISHERIES

3.1.1 Sustainability

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.

The exploitation of wild living resources, such as feed 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, dependent predators and other dependent ecosystem functions. Any concept of sustainability must include both environmental and socio-economic factors, therefore international agreements have agreed that sustainable practices need to be encouraged.

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 which in Europe takes 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 environmental 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. The goal of the ecosystem approach 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. Thus the ecosystem approach should be at the core of sustainability.

3.1.2 Overview of Feed Fish Stocks

Typically those teleost fishes 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 open populations means that if there are relatively local and sedentary stocks, overall catches could conceal their possible demise. For instance, this has implications for the management of localised sub-stocks such as in the case of the North Sea sandeel.

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 e.g. the North Atlantic Oscillation (NAO) and the El Niño in the south-east Pacific. This issue is exacerbated through climate change and the impact on primary production. This will inevitably lead to uncertainty in the stock forecasts and strongly indicates the need for precautionary management of these small pelagic stocks.

3.2 CRITERIA FOR SUSTAINABLE FISHING

3.2.1 Fishmeal Information Network (FIN) 'Sustainability Dossier'

When most feed manufacturers state that they only procure from 'sustainable' sources, this is usually based upon the Fishmeal Information Network (FIN) Sustainability Dossier, an annually updated assessment initiated by the Grain and Feed Trade Association (GAFTA) and funded by the UK Seafish Industry Authority (SFIA). This is essentially limited to examining stock assessment reports and the presence of regulatory frameworks and does not include some key elements such as wider ecosystem impacts, the depth of knowledge supporting management of the industry and how regulatory compliance is effected. This limitation is fully recognised by FIN who are looking to widen the criteria used (Karen Green, FIN, pers. comm.)

3.2.2 Marine Stewardship Council (MSC) 'Principles and 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 that developed by the Marine Stewardship Council (MSC), based on principles and criteria for 'sustainable fishing'. These were developed over a long consultation period with a broad spectrum of stakeholders at national and international levels. Any model for assessing the sustainability of fishing practices must, as a guiding principle, take account of the impacts of fishing on wider ecosystem health, consider the effectiveness, rather than the existence of, regulation, and highlight where gaps in information may reflect on sustainability. It is not adequate to consider each fish stock in isolation. The MSC model addresses both fisheries management and ecosystem issues well. While it does not provide separate headline principles for economic or social elements, it does incorporate them as part of an assessment of the fishery management system and fishing operations conducted in a fishery.[9]

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

[9] Principle 3 of the MSC's Principles and Criteria for Sustainable Fishing which deals with the management system and operations applied to a fishery, specifically cite certain economic and social Criteria – C3 that the management system is appropriate to cultural context, scale and intensity of the fishery; C4 that it observes the legal and customary rights and long term interests of people dependent on fishing for food & livelihood…; C6 provides economic and social incentives that contribute to sustainable fishing.

- 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.

This study does not use the full MSC 'Fisheries Certification Methodology', which requires a more detailed independent analysis by a team of experts who meet the MSC's requirements, and stakeholder consultation on the Principles, Criteria, Indicators and Scoring Guideposts. The key principles, criteria and indicators used in this study are, however, taken directly from the MSC model, with the addition of a separate principle to cover 'Economic and Social considerations' more explicitly. The study uses its own simplified scoring system against the key criteria and this is explained in 3.2.4 below

3.2.3 Indicators

Under the full MSC fisheries certification methodology, performance indicators are used to assist the scoring of fisheries 'sustainability'. These indicators would normally be articulated anew for each fishery being assessed in order to account for the differences in size, scale, location and intensity of the type of fishery under assessment. There would be three narrative 'scoring guideposts' that assist independent assessors in determining the score out of 100 for each indicator. For example, 60 signifies a minimum conditional pass, 80 signifies an unconditional pass for best practice and the highest score is 100 for a theoretically perfect fishery.

In this study indicators drawn from the MSC indicators have been used to assist in the assessment of whether the six fisheries examined meet the sustainability criteria. These indicators are summarised in Table 11 overleaf and correspond to the criteria provided in Appendix C.

3.2.4 Scoring

We have used a simple scoring system developed in an earlier study (Huntington *et al*, 2004) that indicates the degree of sustainability. For each of the criteria under the four Principles described in **Appendix C**, 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).

3.2.5 Weighting

No weighting between the four Principles is applied, as all are considered of equal importance. The MSC model requires that its three Principles have an equal weighting applied at the highest level. A full MSC assessment will normally weight all the criteria and sub-criteria using a decision support software package that is based on the Analytic Hierarchy Process (AHP), enabling pair-wise comparisons of different criteria. While 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 the various 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 inform this process.

3.2.6 Information Sources

Information for Peruvian anchovy and North Sea sandeels have been taken from the previous report by Huntington *et al* (2004), which contains a more detailed review of the sustainability of these stocks. Otherwise information for the other European stocks is largely derived from the ICES Advisory Committee for Fisheries Management (ACFM). Other references are acknowledged in the text.

Table 11: 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
			a) Management measures permit adaptive change to fishing
			b) 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 Fishery and market operate under natural conditions.		a) Fishery operates in an economically efficient manner
			b) Product trade is not artificially favoured by trade barriers or protectionism
	4.3 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
	4.4 Fishery does not prejudice food security		a) Pricing structure operates within market norm
			b) Supply operates within market norm

3.3 SUSTAINABILITY ASSESSMENT

We have taken these basic elements and conducted a preliminary analysis on the six top feed fisheries that support the fishmeal industry. Together, these account for nearly 90% of total global fish meal production (see Table 8). The results of this assessment are included in Table 13 overleaf. A brief summary is given in Table 12 below and a synthesis by species is provided following Table 13.

Table 12: Summary of Comparative Sustainability Assessment

Principle	Criterion	Peruvian Anchovy	Jack mackerel	Capelin	Blue whiting	Sandeel	Horse mackerel
1. Fishing Pressure and Sustainability	1.1 High productivity maintained	1	0	1	0	1	0
	1.2 Ability to rebuild to a certain level within a specific time frame	1	0	1	0	1	0
	1.3 Reproductive capacity of stock maintained	1	?	1	0	1	0
2. Structure, Productivity, Function & Diversity of Dependent Ecosystem	2.1 Natural functional relationships between species maintained	0	0	1	0	0	1
	2.2 Fishery does not threaten biodiversity	?	?	1	0	1	1
	2.3 Recovery of non-target species populations permitted	?	?	1	?	1	?
3. Capacity for Sustainable Management	3.1 Management System Criteria	1	1	2	0	2	1
	3.2 Operational Criteria	1	1	2	1	2	1
4. Economic and Social Considerations	4.1 Respects fisheries dependent communities, rights and cultures	1	?	1	2	2	2
	4.2 Fishery and market operates under natural conditions	1	1	2	2	2	2
	4.3 Labour conditions conform to ILO standards	?	?	2	2	2	2
	4.4 Fishery does not prejudice food security	2	1	2	2	2	2
SUMMARY (proportion of scores achieved)	**?= Insufficient information available**	3 (25%)	5 (42%)	-	1 (8%)	-	1 (8%)
	0= Does not meet criteria	1 (8%)	3 (25%)	-	6 (50%)	1 (8%)	3 (25%)
	1= Partially meets criteria	7 (58%)	4 (33%)	7 (58%)	1 (8%)	5 (42%)	4 (33%)
	2= Fully meets criteria	1 (8%)	-	5 (42%)	4 (33%)	6 (50%)	4 (33%)
	Total	12 (100%)	12 (100%)	12 (100%)	12 (100%)	12 (100%)	12 (100%)

Score

? = **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).

3.3.1 Summary of Sustainability by Species

Peruvian anchovy *Engraulis ringens*: 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 whether 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.

Table 13: Preliminary Sustainability Analysis of Key Feed Fisheries

Principle	Criterion	Peruvian Anchovy		Jack mackerel		Capelin		Blue whiting		Sandeel		Horse mackerel	
		Score	*Comment*	*Score*	*Comment*	*Score*	*Comment*	*Score*	*Comment*	*Score*	*Comment*	*Score*	*Comment*
1. Fishing Pressure and Sustainability	1.1 High productivity maintained	**1**	2 anchovy stocks, northern (N) stock and the southern (S) stock (shared with Chile). Info' on stocks is detailed but poorly accessible. N stock is at the precautionary reference level; S stock difficult to assess due to the dual prosecution.	**0**	Stock difficult to assess as subject to El Niño fluctuations. However generally considered overfished as fishing increasingly results in undersize fish being caught.	**1**	Info' mainly from acoustic surveys. Main Icelandic stock ICES sub-areas V & XIV and Div IIIa. Biology well known. SSB highly variable as dominated by one age group (3). No reference points defined	**0**	Single stock covering NE Atlantic. Age composition weight at age well known. Natural mortality less well understood. Management plan agreed but not implemented due to dispute over TAC allocation. SSB currently within precautionary limits but fishing mortality unacceptably high.	**1**	Info' on fishing methods, effort and mortality but inconsistent. Harvesting strategy is closely defined but stock size difficult to predict. ICES consider the NS stock to be "uncertain".	**0**	Stock units (Western, North Sea and Southern) are still not well understood and the state of the stocks are not known. Stock (esp. W) characterised by infrequent (e.g. last one in 1982), extremely large recruitment. There is insufficient net information for robust harvest controls.
	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	**0**	Jack mackerel in Chile slow to recover from overfishing. Catches had been steadily increasing from 1.24 million tonnes in 1999 and up to 1.65 million tonnes in 2001 but has decreased overall since 1996 (WWF, 2003)	**1**	Stocks affected by extrinsic factors and high spawning mortality.	**0**	Current high mortality is only being sustained by recent good year classes without these the stock would be severely depleted when recruitment levels return to normal.	**1**	Stocks are known to be affected by extrinsic drivers, predicting rate of recovery is not possible, although recovery is presumed to occur.	**0**	The high level of juvenile fishing mortality is of concern in both Western and North Sea stocks and juvenile and adult mortality needs to be independently restricted. TAC is too high to ensure the long-term sustainability of the stock.
	1.3 Reproductive capacity of stock maintained	**1**	IMARPE has data on size classes, stock age / sex structure & seasonality (used by to advise on TACs etc). IMARPE may research reproductive capacity of the sub-stocks in 2004. The institute is constrained by limited funding.	**?**	Insufficient data available to the study team.	**1**	ICES have information on fecundity, recruitment dynamics, mortality and age / sex structure. Recent difficulty in locating juvenile part of stock, poss. due to environmental change, may be problematic.	**0**	Notwithstanding the excessive fishing mortality noted above, recovery rates are normally high. However The share of catches in areas where juveniles are predominant have increased from 2000 (28% by weight) to 2003 (59% by weight).	**1**	ICES have information on fecundity, recruitment dynamics, mortality and age / sex structure. Evidence of changes in reproductive capacity may be difficult to prove with this short-lived species. Effects of size-specific fishing are presumed to be minimal.	**0**	Recent age readings for the W. stock have improve catch at age figures. Otherwise there is little other data (e.g. maturity) on which to base definitive management approaches, esp.. for the North Sea stocks.
2. Structure, Productivity, Function & Diversity of Dependent Ecosystem	2.1 Natural functional relationships between species maintained without ecosystem state changes	**0**	Understand importance of issue but dynamic environment and funding limits monitoring to target stocks. Low benthic impact through use of pelagic gear. Increased use of MPAs to protect non-target species and habitats.	**0**	Understand importance of issue but dynamic environment and funding limits monitoring to target stocks.	**1**	Ecosystem factors reasonably well known. Icelandic waters have extremely variable hydrographic conditions that impact primary production. Gear impacts are considered minimal.	**0**	Extent of discarding is not known. Fishery mainly prosecuted by Iceland, Faeroes, Norway and Russia. Gaps in basic biology and ecosystem interactions still exist.	**0**	Biology of sandeels well known in the North Sea. Predator-prey interactions complex & still not understood. By-catch low (3.5-6%). Gear light and restricted to dynamic sandy habitats. Some progress towards ecosystem management strategies. Impacts linked indirectly to sandeel stock condition, e.g. viability of local seabird populations.	**1**	Some information exists on environmental factors affecting stocks, esp.. hydrodynamic flows between the Atlantic and the North Sea.
	2.2 Fishery does not threaten biodiversity	**?**	Some limited research into ecosystem interactions. Have incorporated by-catch regulations to reduce incidental catch.	**?**	Some limited research into ecosystem interactions.	**1**	Recognised as an important forage species for cod, saithe, Greenland halibut, baleen whales and seabirds and reflected in TAC.	**0**	Little appears to be known about the impact of the fishery on biodiversity and the ecosystem. Blue whiting is an important prey fish for as ling, cod, haddock and some cetaceans.	**1**	ICES / independent scientists have carried out research, e.g. ELIFONTS and IMPRESS. Objectives have been set to determine the impact of sandeels fisheries on seabirds.	**1**	Pelagic trawling to the SW of Ireland (VIIk-j) has been implicated in by-catch of cetaceans (Couperus, 1997) but otherwise by-catch is restricted to other quoted pelagic species.
	2.3 Recovery of non-target species populations permitted	**?**	Information limited and research constrained by funding issues.	**?**	Information limited and research constrained by funding issues.	**1**	By-catch generally considered low, although may be higher in Danish purse seines (Alverson et al, 1994)	**?**	Information is limited.	**1**	IMPRESS is studying predator-prey interactions in marine ecosystems. Stock is treated by ICES in the context of a mixed fishery. 'Sandeel box' closure was driven by the ELIFONTS research to benefit local seabird populations.	**?**	Information is limited - juvenile herring are an important prey item of horse mackerel.

Score

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

Table 13: Preliminary Sustainability Analysis of Key Feed Fisheries (continued)

Principle	Criterion	Peruvian Anchovy		Jack mackerel		Capelin		Blue whiting		Sandeel		Horse mackerel	
		Score	*Comment*	*Score*	*Comment*	*Score*	*Comment*	*Score*	*Comment*	*Score*	*Comment*	*Score*	*Comment*
3. Information, Organisational and Legislative Capacity for Sustainable Management	3.1 Management System Criteria	1	Management system has a legal basis. There is detailed monitoring and evaluation of target stocks. Includes observers on fishing vessels and stock assessment surveys on research vessels. FIN (2002) indicated that all fishing vessels are monitored with VMS.	1	Controlled by company catch limits, VMS and closed seasons (FIN, 2004)	2	Based on maturing capelin & regulated by preliminary catch quotas set prior to fishing season. TACs based on 1&2 yr old capelin. Fishing bans may be imposed in cases of low stock abundance.	0	Management agreement exists has not been implemented. Norwegian, Russian and Faroese fisheries are not limited by TACs over 2004.	2	EU countries controlled under the CFP. No direct financial incentives relevant to the fishery. Monitoring via ICES through the Working Groups and independent scientists.	1	EU countries controlled under the CFP. No direct financial incentives relevant to the fishery. Monitoring via ICES through the Working Groups and independent scientists. Management planning for NS stock limited by insufficient biological information.
	3.2 Operational Criteria	1	Closed areas created for protecting non-target species and habitats. Mechanisms exist to discourage operational waste and destructive practices. Fishers now more compliant, but not 100%. During ENSO events, fishers more likely to follow restrictions. Fishers are not involved in the collection of data.	1	Several fishing bans have been imposed during the year to protect small-sized fish. Minimum landing sizes are applied.	2	Closed season to protect stocks, no controls over habitat impacts but these are likely to be minor for this light gear. Operational wastes negligible. No destructive practices used. Compliance levels are high (for all industrial fisheries), Some data contribution from fishers.	1	Iceland has set size limitations on landings of blue whiting. If the catch consists of 30% or more of fish smaller than 25 cm, a temporary area closure is imposed.	2	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. Operational wastes negligible. No destructive practices used. Compliance levels are high (for all industrial fisheries), Some data contribution from fishers.	1	TAC's closed areas and seasons and mesh size limits in place with varying levels of compliance.
4. Economic and Social Considerations	4.1 Respects the needs of fisheries dependent communities, historic rights and cultures	1	Pelagic fleet has grown without capacity constraints. ITQ system now exists, facilitating fleet rationalisation (greater reductions in capacity are expected). Peru is an APEC Member which allows for the removal of trade barriers between participating countries.	?	Possible conflict with artisanal sector when jack mackerel catches are low and industrial seiner industry switches to inshore anchovy & sardines.	1	The fishery was subject to limited entry and individual vessel quotas for licence holders until 1986, when in conjunction with an increasing transferability of demersal vessel quotas, capelin vessel quotas became partly transferable.	2	Impacts of this pelagic feed fishery on traditional communities are not known but likely to be minor.	2	Direct impacts unlikely some indirect impact on other fisheries. Sandeels fished by traditional fishing communities. Fishery efficient return on capital but impaired by high participant numbers, constraining reinvestment but assists wealth distribution. No protectionism & free global trade in products.	2	Impacts of this pelagic feed fishery on traditional communities are not known but likely to be minor.
	4.2 Fishery and market operates under natural conditions	1	Fleet has grown without capacity constraints but now an ITQ system exists that has led to rationalisation of the fleet and reductions in capacity are expected.	1	Little information is available.	2	Fishery is highly efficient. No trade barriers or issues known.	2	Fishery is highly efficient. No trade barriers or issues known.	2	Fishery is highly efficient. No trade barriers or issues known.	2	Fishery is highly efficient. No trade barriers or issues known.
	4.3 Labour conditions conform to ILO standards	?	Little info' available. The sector is highly competitive. Vessels owned by processing factories	?	Little info' available. The sector is highly competitive. Vessels owned by processing factories	2	No labour issues are known.	2	No labour issues are known.	2	Many fishermen operate within share schemes – 3 out of 4 Danish fish meal plants are owned by fishermen's groups. Danish permit scheme based on historic rights but there are no formal barriers to entry.	2	No labour issues are known.
	4.4 Fishery does not prejudice food security	2	No evidence of restricted practices. Supply dominates world market. Prices respond to demand, particularly from the largest market (PR China).	1	Jack mackerel is used for human consumption (ie canned) , esp. in western Africa, so potential conflict exists.	2	The fishery is of great economic importance to Iceland. Supply is highly seasonal but competes on the global commodity market.	2	There is no evidence that this fishery prejudices food security.	2	Responsive to global commodity trade competition (i.e. soya & rape seed oil). Supply is highly seasonal but competes on the global commodity market.	2	There is no evidence that this fishery prejudices food security.

Score

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Chilean jack mackerel *Trachurus murphyi*: recruitment into this stock is highly subject to environmental and climatic conditions (in particular the El Niño event) and is thus difficult to assess. However it is generally considered to be overfished, with an increasing proportion of smaller fish being caught. The stock is recovering from previous overfishing and has still to recover to previous (1996) levels, despite tight controls on effort.

Capelin *Mallotus villosus*: the capelin is a small species whose biology is reasonably well known. The fishery is based upon maturing capelin of ages 3 and 4 and the abundance of the immature component is difficult to assess before recruitment to the adult stock at ages 2 and 3. Given that recruitment is highly dependent upon environmental variables, its high spawning mortality and it importance as a forage fish, a precautionary approach to capelin management is required.

Blue whiting *Micromesistius poutassou*: the Blue whiting is a pelagic gadoid (i.e. of the cod family) that is widely distributed in the eastern North Atlantic. Its biology is reasonably well known, and a management plan has been formulated and agreed. However this plan has not yet been implemented and fishing mortality remains unacceptably high, far above the agreed TAC and is only being sustained by recent good year classes. ICES currently considers this fishery to be harvested unsustainably. The dispute over catch allocation has led to the last quota of 650,000 tonnes set by the North East Atlantic Fisheries Commission being exceeded four-fold; fishermen caught 2.3m tons in 2003. It should be argued that until the management plan is implemented and TACs fall within the agreed level this species cannot be recommended as a component stock of fishmeal or oil. This issue with blue whiting is recognised by the fishmeal industry that fully supports implementation of the proposed management plan, yet has little direct influence in progressing its adoption (Anne Chamberlain, FIN, pers. comm.).

Sandeel *Ammodytes* spp.: 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 feed fisheries and non target species have been investigated but the complex nature of marine ecosystems means that there is still only a partial understanding of the relationships and interactions, thus indicating a need to be precautionary in the management of this stock. 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.

Horse mackerel *Trachurus trachurus:* the horse mackerel has three main stocks – North Sea, Western and southern. Most of the catch destined for fish meal is by-catch from other pelagic fisheries, although there is a directed fishery in western waters. The stock is dependent upon infrequent and very high recruitment pulses, the last major one being in 1982. The current TAC is considered to be too high to sustain the fishery, especially in combination with high levels of juvenile mortality from fishing. Information on the horse mackerels interactions with other species is limited, but is known to be an important predator of juvenile herring.

3.3.2 Synthesis

This preliminary analysis demonstrates that the sustainability of feed fish stocks is still far from certain. Some species, such as sandeel and capelin, are well regulated and provided that they continue to be managed in a precautionary manner, these fisheries should not have a long-term impact on the target stock. However even in these more robust cases there are still questions over the wider sustainability of these stocks, given the lack of information on stock size, on the measures needed to take account of climate change, as well as on the impact of the fisheries for these important prey species upon other fish, mammals and seabirds. The Peruvian anchovy stock may be in reasonable shape, but not enough is known about recovery rates after El Niño events or the wider environmental impacts of this large fishery which contributes to over half the global fish meal supplies. It is therefore impossible to conclude whether this fishery is sustainable or not. The other fisheries, in particular the blue whiting in the North-east Atlantic, cannot be described as sustainable in their current form, being considered overfished and dependent upon previous good year classes to prevent the stock from severe depletion.

3.4 OTHER ENVIRONMENTAL ISSUES FOR CONSIDERATION

Whilst the status, knowledge and management of the fish stocks providing the raw material for the fish meal and oil are the primary considerations in assessing the sustainability of fish feeds, this study has been asked to assess the issue of fish meal contamination and its impact on the sourcing of fish meal and fish oils, and in particular the environmental implications of long-distance transport.

Salmon and trout are relatively oily fish that easily bioaccumulate lipophilic Persistent Organic Pollutants (POPS) such as PCBs, dioxins and Polybrominated Diphenyl Ethers (PBDEs) should they be present in the diet. It is widely recognised that contamination levels of forage fish from the industrialised waters of the Baltic and coastal waters elsewhere in the North-eastern Atlantic are higher than those found in Pacific waters and this may be mirrored in feeds manufactured from fishmeals originating from these waters[10]. This was brought to wide public attention with a much criticised study reported in the journal *Science* (Hites, *et al*, 2004) that investigated contaminants in a variety of fish feeds and farmed salmon products. One interesting consequence of this was that Swedish authorities banned the sale of wild salmon (which had relatively high levels of contamination due to their diet of Baltic-derived feeds) as the farmed fish were largely fed on relatively less contaminated fish feeds. Manufacturers maintain strict control on POP levels when sourcing raw materials in order to meet increasingly strict EU legislation on permissible contaminant levels[11].

Scottish Quality Salmon, whose members include feed suppliers, has already taken steps to maximise levels of beneficial omega-3 essential fatty acids and minimise the chance of these environmental contaminants occurring by a variety of techniques including:

- sourcing of the highest quality raw materials – fish meal and fish oils used in the feedstuffs - from areas least affected;
- investing in additional processing technology to further reduce levels (see below);
- examining the potential benefits of incorporating different types of high quality plant-derived oil; and
- an ongoing testing regime to verify successful progress.

There is much current research and trialling of methods to remove contaminants from fishmeal and fish oils, the focus being on the latter as this is where most lipophilic contaminant accumulates. These show that between 85-90% of dioxins and 25% of PCBs can be removed at a cost of around US$30 - 40/t.

The consequence of this is that one of the decisions raw material procurement managers make when sourcing fish meal is whether to buy the relatively lowly contaminated Pacific species such as anchovy or purchase European material that might be relatively high in contaminants. Whilst the quality issue itself is an important part of the buying consideration (see Section 2.3.2), other less obvious factors may be ignored. One of these is the environmental cost of transporting large volumes of fishmeal from South America in terms of fossil fuels burnt, CO_2 emissions and the production other noxious by-products.

Bulk and container shipment is a reasonably efficient way of transporting large volumes of goods and accounts for 95% of global goods movement. It is fuel efficient (costing around 12-30 kg fuel per tonne goods transported), depending upon the container filling rate. As a result it also has relatively low CO_2 emissions, which at 20g per tonne km are about 15% of the equivalent road transport. However because of the nature of the fuels used SO_2 emissions are much higher – approximately 30 times that of road transport per tonne material transported. Shipping currently accounts for some 2 percent of total global emissions of carbon dioxide, about 7 percent of sulphur dioxide and 11-12 percent of nitrogen oxide emissions. Emissions from international shipping and air transport are much more lightly regulated than other sources, and for the time being also exempt from the Kyoto treaty. This is mainly because it has

[10] IFFO are currently implementing a study to examine POP contaminant levels in feed fisheries (Ian Pike, IFFO, pers. comm.). These vary according to species, size, foraging area and seasonal variations in oil content.

[11] The most recent EC Directive 2003/57/EC (published 17 June 2003 and effective 1 August 2003 stipulate maximum levels of dioxin for fish products as: (i) fish oil 6.0 ng/kg product; (ii) fish meal 1.25 ng/kg product; and compounded fish feed 2.25 ng/kg product. EC limits for PCBs are forthcoming in 2005.

proven impossible to agree on global regulations, especially taxes. Shipping rates have been on a downward slope for several decades, not least because of the introduction of efficient container ships and are around half of what they were in 1965.

Regarding the contribution of fishmeal imports destined for fish feed manufacturer to greenhouse gas emissions, these have been estimated in Table 14 below.

Table 14: Fuel Consumption and Gas Emissions from South American Fishmeal Imports

Year	Fishmeal imports (mt)	Fuel used (mt)	Gas emissions (mt/year)		
			CO_2	SO_2	NO_x
2003	27,600	552	4,416	42	115
2010	30,100	602	4,816	46	125

Fishmeal imports derived from Table 9

To put this in perspective a typical family car produces around 5 t CO_2 per year whilst the entire UK transport network produced 123 million t CO_2 in 1998 (EuroStat, 2001). The purpose of this comparison is simply to illustrate that fishmeal purchasing decisions do have more environmental consequences than might appear at first glance. These factors can be integrated into both purchasing strategies as well as environmental management systems that should factor in environmental transport costs. For instance, improvements in environmental performance can be made by consciously improving container filling rates, cooperating with carriers to improve fuel efficiency and emissions performance and selecting the most effective mixture of road, rail and ocean transport. Such an approach will also produce cost-efficiency dividends over the long run.

4 PROPOSED STANDARDS AND GUIDELINES FOR SUSTAINABLE FISH FEED SUPPLIES

4.1 PRACTICAL ISSUES, CONSTRAINTS AND OPPORTUNITIES

As discussed in Section 2.3.4, beyond ensuring that fish is purchased from stocks that are managed within national and international laws and agreements, there is little real attempt to limit fishmeal procurement to 'sustainable sources'. There are a number of obstacles that must be overcome if the feed supply chain for the Scottish industry is to become more sustainable. Many of these reflect a short-term approach to fish production in the interests of immediate economic competitiveness. It is important to recognise, however, that the long-term future of the aquaculture industry is entirely dependent on sustainably-managed fisheries, and that change is needed to take full account of this.

4.1.1 Lack of Recognised Criteria for Sustainable Sourcing

At present the aquaculture industry does not demand that fishmeal constituents are sourced from a fishery that is sustainably certified, for example by the Marine Stewardship Council. The feed manufacturing industry currently uses the FIN Sustainability Dossier for guidance on sustainable sourcing but this is essentially limited to examining stock assessment reports and regulatory frameworks. It does not include some of the elements included in the assessment criteria used in this study, such as non-target species impacts, regulatory compliance levels, availability of key information and knowledge relevant to sustainability as well as economic and social factors. An industry policy that recognises the need to source from certified fisheries would be a significant improvement on the FIN Dossier, and one that should be adopted more widely. Recognition by the aquaculture industry of existing criteria reflecting the fundamental principles of environmental sustainability, and the systematic assessment of fisheries against them, will ultimately enable both fish producer and consumer to purchase selectively, creating a market for a sustainable product. Despite the current absence of certified feed fisheries, the industry can move towards sourcing from fisheries certified by MSC or a similarly robust scheme. They can also take action to address some of the most unsustainable elements of the current system. For example, while the management plan for blue whiting remains unimplemented, this species should be considered an unacceptable component of fish feed products.

4.1.2 Traceability

Although the traceability of feed ingredient sources is improving rapidly, it may be difficult to ensure the origin of all fishmeals. For instance some of the better quality fishmeals (such as the Norwegian LT94 or Danish from 999 or Skagen) are often blended to give constant characteristics of density, flow, digestibility and protein content. Thus species identity tends to be uncertain. Much of the Peruvian FAQ (Fair Average Quality) meals used for trout feeds are blended on loading of tankers (both ship and road) and hence cannot be traced beyond that point. Traceability is high on the feed industry's agenda and the three main UK suppliers, through their membership of AIC, will adopt the UFAS (Universal Feed Assurance Scheme) and FEMAS (Feed Materials Assurance Scheme) schemes takes place towards 2005. This may well prevent the purchase of feed products where there is not a full traceability chain (Nick Bradbury, BioMar, pers. comm.) Full traceability is a prerequisite for ensuring sustainability, and it should be noted that MSC already sets a traceability (Chain of Custody) standard which is independently audited.

4.1.3 Fishmeal Nutrition Performance

Restrictions on certain stocks may have implications for fishmeal nutritional performance. For instance, smaller fish (i.e. salmon <1 kg) need high levels of the amino acid histidine that is found in much higher levels in South American fishmeals – exclusion from these would necessitate much higher fishmeal inclusion levels of European meals and thus higher levels of consumption. There is the potential for substitution with porcine blood meal but this is likely to meet retail and consumer resistance. Conversely for larger fish, the use of northern hemisphere LT meals is favoured because they are higher in protein and of the highest digestibility. For instance, blue whiting meal produces a highly digestible meal and whilst some users dislike its higher ash level, most processors find it worthwhile using and may be reluctant to reduce its use.

4.1.4 Contaminants and Transport

It has been demonstrated earlier that purchasing fishmeal and fish oils from distant sources may also incur other environmental costs associated with transport. Therefore decisions to buy from these sources, whether for quality or economic reasons, should be tempered with a recognition of these costs and their rationalisation through an environmental management system. For instance, improvements in environmental performance can be made by consciously improving container filling rates, cooperating with carriers to improve fuel efficiency and emissions performance and selecting the most effective mixture of road, rail and ocean transport. Such an approach will also produce cost-efficiency dividends over the long run.

4.1.5 Supply Assurance

Should the industry start becoming selective for more sustainable stocks, this will increase the demand for these fish products. This has a number of implications:

- Supply may be restricted for reasons outside the control of fishmeal manufacturers and their clients e.g. the wide inter-annual variability of South American production through the El Niño events.
- Connected with the point above, prices may become more variable, with a general shift upwards, as the supply base is effectively reduced.
- Increased pressure will be put upon sustainable stocks. However this should not be an issue if they are well regulated and controlled (as they should be if deemed as sustainable).
- Risk reduction – formulators like a mix of fish meals from different sources to reduce the risk of unforeseen quality or contamination problems.

These concerns are only really valid over the short-term - longer-term supply assurance depends on the sustainable management of feed fisheries, and that the industry may have to review its approach to fishery exploitation if it is to continue to be viable in the future.

4.1.6 Seasonal Availability

Most fishmeal manufacturers use several species throughout the year to reflect seasonal availability and condition (i.e. oil content). Although it is possible to choose or avoid a particular fish species, to do so necessitates an increase in purchases of other meals possibly at higher cost and, given shipping and storage constraints, having to keep higher stocks to get past the seasons involved. Producers are reluctant to hold stock for more than a few months. When forced to do so, the price usually falls to clear stock out. If buyer storage is unavailable then spot buying is incurred. That is almost always above the market and since aquaculture buyers generally beat the market by buying long and at lows in the cycle wherever possible, it severely impacts their buying strategy. Some aquaculture companies have very long term frame contracts with fishmeal producers. Evidence for the existence of these is in the UK official import statistics showing shipments from Peru at anomalously low prices compared to the spot market.

Agriculture feed buyers source fishmeal in smaller quantities, use traders and have shorter term buying positions. There are many more of them as opposed to the oligopoly in aquaculture feeds and so their behaviour is more of an approximation to a perfect market.

4.1.7 Buying Power

China's burgeoning pig and poultry industries consume more fishmeal than the aquaculture industry in the Western world and this is as big a factor in determining world price and availability. Aquaculture buyers can no longer call the shots in Peru and elsewhere to the degree they did formerly. Norway has become a net importer rather than, as once, an exporter. Chile is now a net importer of fish oil. So, freedom to avoid /choose certain meals could be constricted by this factor.

4.1.8 Synopsis

The consequence of restricting the purchase of raw material to those only from traceable sources of stocks considered as sustainable is an inevitable increase in costs as a result of ensuring traceability and a reduced and possibly more variable supply base as discussed above. With feed raw materials representing almost 70% of sales costs, any changes likely to influence this will be closely examined and possibly resisted. However it might be argued that this is the cost of ensuring the long-term survival of the fish farming industry, especially in the light of increasing demand for fishmeal elsewhere in the world, especially from the Far East. Furthermore the creation of a market for 'sustainable feed' will help counter the costs of being more environmentally acceptable. In the final analysis, the long-term survival of the fish farming industry depends upon its ability to secure cost-effective, sustainable supplies of suitable protein sources, and that feed fisheries will continue to be an important component of this. Therefore it is essential that these are sourced only from sustainable fisheries.

4.2 DRAFT STANDARDS

While there are recognised standards with which to identify sustainable fisheries, there are at the time of writing no industrial fisheries which have been independently certified. Industry needs to place greater emphasis on sourcing from certified stocks and where these remain absent efforts should made to move towards such certification. In the meantime it is both possible and useful to provide a set of guidelines for the industry to enable it to incorporate sustainability principles into its sourcing policies and to ensure environmentally responsible purchasing:

1. The UK fish feed and the fishmeal industry should develop a more structured assessment of feed fisheries sustainability criteria, possibly based around those outlined in this study and that of Huntington *et al*, 2004. Once developed, these should be used to assess the key feed fisheries stocks and updated on a regular (i.e. annual) basis. A decision will also have to be made on who conducts this assessment – FIN has expressed a willingness to take on this task Karen Green, FIN, pers. comm.) but may be considered by some as too close to the industry for a truly objective review, so an alternative independent body might be preferable.
2. Fishmeal purchasers should request improved information on fishmeal species constituents and origin, together with improved traceability and chain of custody. Such information should be made fully available to the public domain to provide assurance of the industry's transparency.
3. Purchasers should develop a purchasing strategy that minimises and where possible eliminates the use of those species considered unsustainable. This could be prepared at a number of different timescales:
    a. Short-term: reducing the purchase of less sustainable species such as blue whiting or jack mackerel where possible;
    b. Medium term: developing approaches to halting purchases of less sustainable species through a detained analysis of alternatives; and
    c. Long-term: developing alternative protein and oil substitutes for fishmeal and fish oil; setting a date and approach to purchasing all fish meal and fish oils sources from independently-verified 'responsibly managed' and sustainable fisheries.

    This purchasing strategy could be updated regularly to reflect changes in different fishing practices and the latest 'sustainability assessments', together with emerging trends in fish nutrition and alternative materials.
4. Greater knowledge should be developed on the options for substituting different species at different times of year to obtain a required fishmeal quality and specification. Computerised decision-support software models could assist this process and be developed to assess the quality / price / specification implications and possible trade-offs for increased species selectivity during procurement.
5. Where possible, procurement departments should utilise an Environmental Management System (EMS) such as ISO 14001 to ensure that procurement strategies minimise the environmental

implications of purchasing, such as utilising best available techniques for reducing transport costs. These could be built into the computerised decision-support models mentioned above.

6. The Scottish fish farming industry itself, in partnership with their own customers, should seek to develop its premium brand image by encouraging their feed suppliers to move towards targets for achieving sustainable supplies.

5 FEED SUSTAINABILITY AND THE STRATEGIC FRAMEWORK FOR SCOTTISH AQUACULTURE

5.1 OVERVIEW OF THE STRATEGIC FRAMEWORK FOR SCOTTISH AQUACULTURE

The Strategic Framework for Scottish Aquaculture was developed and produced by the Scottish Executive's Ministerial Working Group for Aquaculture in 2002. It provides a vision for the future of the Scottish aquaculture, based around the central pillars of environmental, economic and social sustainability. There are a number of elements relevant to this study.

1. Improvement of feed conversion and reduction of wastage (Section 2.29): states that the industry "must also continue to develop efficient and cost-effective ways of reducing polluting emissions per unit of production. This may involve investment in new technology such as systems to improve feed conversion and reduce wastage, and careful management of sea bed sediments to prevent unacceptable impacts. Such impacts may also be reduced through careful siting, design and husbandry".

2. Utilisation of sustainable fish feeds (Section 2.32): states that "The industry should utilise fish feeds which can be sourced sustainably, including from wild fisheries deemed sustainable by national or international regulatory authorities. It will also consider using unavoidable fish industry discards and waste from fish processing (while safeguarding against intra-species recycling of discards and waste to avoid the potential risks of disease spread) and new non-marine feed sources as alternative feed stocks. An assessment of feed sources should include a multinational analysis of all the above options".

3. Uses of GMO technology in aquaculture (Section 3.22). Advocates the "use of GMO vegetable products in fish feed, where their potential value lies in their contribution to the sustainability of feed ingredients as well as to more stable feed prices. However, so long as their use is linked with consumer concern, the industry in Scotland has declared that it will not use them." The industry has also stated (AIC, pers. comm.) that the use of GM free ingredients will become increasingly difficult as the number of GM crops and GM-sourced additives increases.

4. Prioritising research into the sustainability of feed supplies (Section 3.56): Top priority is given to those effects "which pose a risk of cumulative, long-term or irreversible changes to ecological systems, with transient impacts assuming second priority". The Scottish Aquaculture Research Forum (SARF) is therefore encouraged to recognise the sustainability of feed supplies (fish meal and fish oil) as one of four major areas as first priority for research.

5. Feed Sustainability Study (Sections 3.59 and 3.60): Finally, but of great relevance the document recognise the doubts over the sustainability of the feed fisheries supplying fish feeds as well as their impacts on other species of fish and birds. It therefore requests that "A full understanding of the sustainability of fish meal/oil fed to farmed fish therefore urgently needs to be developed internationally to inform decisions about the future expansion of fish farming in Scotland, both of salmon and trout, and of more recently farmed species such as halibut and cod. At present, supplies of industrial fish are monitored and assessed scientifically by FAO and ICES, but only very limited supplies of sustainably managed fish meal or oil (and hence feed) are available which are independently certified (for example, by the Marine Stewardship Council) and the UK organic aquaculture standard has to rely on fish processing by-products."

   It then goes on to say (Section 3.60) that "Both the industry and its stakeholders need to be reassured - on the basis of the best scientific knowledge available - that ingredients used in feed supplies are sustainable and what the options are. The European SEAfeeds Workshop is due to report in April 2003 on the sustainability criteria developed by participants. In the light of its findings, the Scottish Aquaculture Research Forum will consider what further study of global aquaculture feed supplies, their sustainability and the options is necessary to provide an understanding, not only of how aquaculture feed supplies might be sustainably secured in the future, but also how they might be sourced cost-effectively and in the best health interests of the consumers of Scotland's aquaculture production. Such a study is likely to require multinational participation".

5.2 INTEGRATION OF THE STUDY'S FINDINGS

This study essentially provides the first part of the 'Feed Sustainability Study' proposed in Section 3.59 of the Framework. Although to date no feed fisheries have been independently certified as 'sustainable', this is a first attempt to use a wider set of established criteria to assess the relative sustainability of the main feed fisheries supplying the fish feed manufacturing industry in Scotland.

However, this is only the first step. This report is fairly narrow in its scope in that it does not delve deeply into the future trends in feed fisheries and their management, nor does it assess the likely contribution of more efficient feeding practices – or opportunities for substituting fish-based proteins and oils with sustainably produced alternatives. The next step is therefore to provide a detailed strategy (within the Framework) for ensuring the sustainability of fish feeds in the Scottish fish farming industry whereby:

- These feed fisheries that are currently demonstrating precautionary management, supported by robust scientific advice and industry participation are encouraged to further develop sustainable fisheries practices with the ultimate objective of becoming independently certified (for example to the Principles and Criteria developed by the Marine Stewardship Council). Linkages with standards for 'responsible aquaculture' production will then be possible[12].
- The development of sustainable alternatives to fishmeal and fish oil that provide similar economic and nutritional performance to current feeds
- Further integration of whitefish and other processing wastes into fishmeal production. This will require improved traceability to ensure that pathogen reintroduction is prevented.
- Engagement of the farming and retail sector, together with consumers and their representatives, in the debate to maximise the options available for ensuring the sustainability of fish feeds and the products that are derived from them.

[12] The certification of 'responsibly produced' aquaculture products have been hindered by the uncertainty over the sustainability of fish feeds.

Appendix A: Terms of Reference

Sustainable Fish Feed and Scottish Aquaculture – a Contribution to the Debate
Joint Marine Programme (WWF-S and SWT), RSPB Scotland and WWF Scotland

Purpose

The purpose of this project is to answer the question 'How sustainable are the fish feeds used in Scottish aquaculture?'

Background

The absence of methods to measure or ensure the sustainability of 'industrial' feed fisheries from which fish feed is produced is a key area of concern. Scotland is the third largest producer of farmed salmon and a major consumer of fishmeal/oil. This consumption has potential impacts on global fisheries and seabird populations, and is a potential obstacle to the sustainability of the Scottish aquaculture industry.

In September 2003, The RSPB let a contract (*Assessment of the Sustainability of Feed fisheries used in the Production of fish meal and fish oil)* to Poseidon Aquatic Resources Management Ltd and Newcastle University to:

1. develop sustainability criteria and a 'sustainability index' for global feed fisheries, taking into account the needs of ecosystems as well as human needs.
2. review the status of global feed fisheries according to this sustainability index (focus on North Sea sandeels and Peruvian anchovy fisheries).
3. review the drivers for fish oil and fish meal use and make recommendations for policy change that will assist RSPB/BirdLife with its promotion of ecologically sustainable fisheries.

This RSPB contract follows on from the report of the **Seafeeds** workshop, organised by Nautilus Consultants in association with Stirling University Institute of Aquaculture in April 2003. This workshop reached agreement on a number of points, including:

1. there is a poor understanding of, and lack of agreed criteria for sustainability for the broader dimensions of sustainability relating to effects on other fisheries and wider ecosystem and socio-economic impacts
2. that demand for fish meal and oil is likely to exceed supply soon. This is predicted to reduce the proportion used for animal feeds and increase that used for aquafeeds
3. that responsibility for sustainability should apply to all points in the production chain. The responsibility for providing information to enable informed choice rests with fishing companies, fishery managers, fishmeal producers, but they lack capacity, resources and incentive to provide information
4. the need for producers, fish farmers and retailers to have clear sustainability and efficiency criteria that allow for measurement of progress
5. the need for an EU steering group on this topic

Since the launch of the Scottish Strategic Framework for Aquaculture in March 2003, the Scottish Executive has established a range of working groups to achieve a more sustainable Scottish industry. The Scottish Aquaculture Research Forum (SARF) is tasked to include sustainable fish feed issues in its research programme.

This additional research is intended to complement the Poseidon report commissioned by the RSPB, developing a Scottish aquaculture focus and contributing to the aims of the Strategic Framework.

Objectives

1. To identify the main sources of fish feeds used in Scottish aquaculture.
2. To assess the relative merits of these different sources of fish feeds.
3. To recommend a core set of minimum standards that could be placed upon fish feed supplies to move the industry towards more sustainable supplies.
4. To assess some of the constraints for the Scottish aquaculture industry in adopting such standards
5. To contribute to the work of the Strategic Framework in encouraging a more sustainable aquaculture industry in Scotland
6. To raise the profile of the fish feed issue amongst decision-makers, the media and consumers

Outputs

A short, informative but readable report (max.20 pages) including the following:

- An executive summary, which could be adapted to form the text of an advocacy document
- A brief overview of the sources of fish feed used in Scottish aquaculture, including discussion of information gaps and expected future trends in source.
- A recommended set of minimum standards that could be placed upon fish feed supplies to move the industry towards more sustainable supplies. This should include brief consideration of the transport costs versus contaminant levels issue.
- A brief review of industry policy on the sustainability of fish meal/oil and fish feeds including constraints for the industry in adopting standards of sustainability.
- A summary of the relative sustainability of the different sources of fish feeds used in Scotland, perhaps through the development and application of a 'performance matrix'. This should take consideration of the transport costs versus contaminant levels issue.

Methods

It is anticipated that this will be largely a desk-based study. However, there will be an element of structured telephone interview with a range of key interests - principally International Fishmeal and Fish oil Organisation (IFFO), major feed companies and major feed consumers. We expect this additional contract to draw heavily on the conclusions of the core RSPB-Poseidon contract.

Timescale

The report by Poseidon is to be published in July 2004.

This contract is intended to be a separate piece of work, which would begin in June 2004.

Audiences

1. Scottish Executive, SEPA and Scottish Aquaculture Research Forum.
2. Fish feed producers and consumers
3. The media

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Appendix C: Principles and Criteria for Sustainable Fishing adapted from the MSC

Below are listed the MSC 'Principles and Criteria' used as the basis for our assessment of the sustainability of the key feed fisheries supplying Scottish fish feed manufacture. While most of the original text of the MSC's Principles and Criteria has been reproduced here, the three MSC Principles and their criteria have been slightly modified to focus specifically on feed 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'.

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:

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.*

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.

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.).

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 nor 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.

For more information on MSC and the original MSC Principles and Criteria for Sustainable Fishing, visit their website at http://www.msc.org

Organisations and Persons Consulted

Organisation	Contact
Agricultural Industries Confederation	Judith Nelson
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British Marine Finfish Association Ltd	Richard Slaski
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Dana Feed A/S	Tim Rees
Ewos Ltd	Ian Carr
Fishmeal Information Network (FIN)	Anne Chamberlain
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International Fishmeal & Fish Oil Association IFFO	Dr. Ian Pike
Joint Marine Programme (WWF Scotland & Scottish Wildlife Trust	Rebecca Boyd
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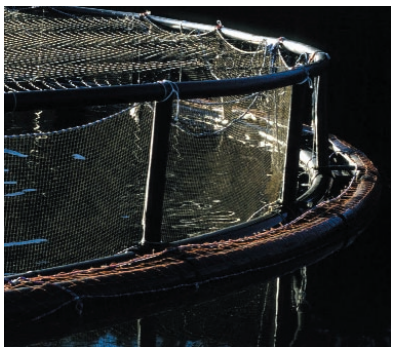
Marine Stewardship Council	Brad Norman
Nutreco Ltd	Anne-Marie Maddock
	John Williamson
RSPB	Euan Dunn
Scottish Quality Salmon	Brian Simpson
United Fisheries Products Ltd	Helge Korsager



Fish farming in Scotland has expanded rapidly over three decades. Scotland is responsible for approximately 90 per cent of all UK aquaculture production and ranks third amongst the world producers of Atlantic salmon after Norway and Chile.

Salmon and trout need high-protein diets, and depend largely on fishmeal and oil from wild fish caught by industrial fisheries in the North Atlantic and off South America. Three of the largest fisheries in the world are for fish destined for aquaculture and livestock feed. It is expected that by 2010 the global demand for fishmeal for aquaculture will increase by 50 per cent to 3.45 million tonnes and demand for fish oil will double to 1.2 million tonnes. There are growing concerns about the impacts of these fisheries on the target stocks and on the marine food chain, but little action is being taken to explore or tackle these concerns.

The long-term future of the aquaculture industry as well as the health of the marine environment depends on healthy populations of these fish. As a leading aquaculture producer, Scotland has an opportunity to lead the way and ensure that the feed we use on fish farms in Scotland is not contributing to the plunder of the worlds seas.

WWF SCOTTISH WILDLIFE TRUST
Joint Marine Programme

The **Joint Marine Programme** (JMP) in Scotland is a partnership between WWF Scotland and the Scottish Wildlife Trust aimed at ensuring the conservation of marine wildlife and a healthy marine and coastal environment for Scotland.

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RSPB Scotland is part of the RSPB, the UK-wide charity working to secure a healthy environment for birds and wildlife, helping to create a better world for us all.

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