seafeeds

sustainable environmental aquaculture feeds

April 8 – 9, 2003

Stirling Management Centre

A workshop organised and chaired by Nautilus Consultants

in association with the Stirling University Institute of Aquaculture

UNIVERSITY OF STIRLING

Nautilus Consultants

Natural resource economists

Contents

1 Introduction

SEAfeeds is an accompanying measure funded under the EU 5th Framework Research Programme. The project comprises a European Workshop held at the Stirling Management Centre on the 8th and 9th April 2003, an associated website, and publications. The project did not undertake any original research but sought rather to bring together existing research, information and opinion on the key issue of promoting more sustainable feeds for aquaculture production. This document summarises the deliberations and outputs from the workshop.

This was a unique approach to advancing the debate surrounding sustainability of the European aquaculture industry, which brought together a range of interests and perspectives in open and frank debate. There were significant points of overall agreement and clear consensus over the general direction in which both the industry and the environmental groups are keen to move.

Objectives and outputs

The project had 6 major objectives:

1. To facilitate development of an informed consensus across all stakeholders on issues relating to the sustainability of aquaculture feeds.
2. To develop an accessible synthesis and summary of advances in aquaculture feed technology to sustain future aquaculture development
3. To address both industry and environmental concerns relating to feed for aquaculture.
4. To establish appropriate sustainability criteria for labelling aquaculture feed.
5. To encourage reasoned debate on these issues by disseminating findings to a wider audience.
6. Develop potential international collaborative research needs and ideas

Corresponding to these objectives, the workshop sought to generate the following outputs:

1. An objective synthesis of important information or "facts".
2. A concise and objective presentation and analysis of fish-feed sustainability issues.
3. Agreed priority sustainability criteria relating to each major issue.
4. A statement of consensus on the key sustainability issues.
5. An outline for a broad strategy and priorities to promote increased sustainability in relation to the sourcing, production, and use of fish feeds.

The workshop largely achieved its objectives, with the exception of generating a simple set of sustainability criteria for labelling aquaculture feed. Although some sustainability criteria were agreed, corresponding standards were not. The setting of such standards will require a much more comprehensive and consultative process.

Workshop representation

Thirty expert delegates were invited to the workshop (*Chapter 5*). Care was taken in the selection of delegates to ensure balanced representation of countries, expertise and opinion. Delegates were selected primarily on the basis of their knowledge and experience, and were encouraged to draw back from representation of organisations or interest groups. The following sub-sectors and areas of knowledge were represented:

- Feed grade fisheries
- Fishmeal production
- Aquaculture feeds production
- Fish nutrition research
- Environmental management and protection
- Aquaculture production
- Certification and labelling
- Retailing

Workshop activities

Day one of the workshop was devoted to presenting and exploring the "facts", and scoping the issues. Key note presentations were followed by sub-group discussions with major conclusions recorded on flip charts. The following presentations were made:

Sustainable aquaculture feeds: an overview and global perspective	**Albert Tacon, Aquatic Farms Hawaii**
Industrial fisheries: management and sustainability	**Ian Pike IFFO**
Sustainability criteria for fisheries management	**Derek Staples Consultant, FAO**
Aquaculture feeds: the future (research perspective)	**Sadasivam Kaushik, Director INRA (France)**
Aquaculture feeds: present and future (fish farmers perspective)	**Bjorn Myrseth, Marine Farms ASA**

In addition a panel discussion was convened on certification and labelling, with the following panel members:

Chair: Simon Pepper (WWF)

- Audun Lem (FAO)
- Jeremy Hooper (Tesco)
- Stefan Bergleiter (Naturland)
- Chris Grieve (Marine Stewardship Council)
- John Webster (Scottish Quality Salmon)

Workshop activities

Day two was devoted entirely to working groups and plenary discussions. Each group was tasked to address a key issue arising from the deliberations on day 1. These were:

- **Sustainable feed grade fisheries** (current status; future pressures; objectives and measures of progress; constraints to progress)
- **Fish oil and fishmeal reduction and substitution in aquaculture feeds** (supply and demand; objectives/where we want to be; alternative sources; constraints and trade-offs)
- **Efficiency and sustainability measures and criteria** (the dimensions of efficiency; some important current figures; trade-offs; comparison with other sectors; desirable shifts/targets).

In the afternoon, these same groups re-convened to consider strategy to promote increased sustainability, taking account of existing economic drivers and possible alternatives in the form of market driven approaches; government driven approaches; industry driven approaches; and more effective and accurate information and communication.

A final plenary drew together overall pointers for strategy.

This report

Our objective was to present a "concise and accessible synthesis" of the issues relating to sustainable aquafeeds.

We initially present the main points of consensus reached by the delegates. We then identify key questions and issues, and present preliminary conclusions and recommendations related to these. Finally, we provide a broad but concise review of current information and issues as presented and discussed in the workshop.

Chapter 4 contains abstracts of the key-note presentations, and a bibliography of key publications (Chapter 6), derived from our own research plus additions suggested by delegates.

The report has been checked, supplemented where appropriate, and agreed by all participants.

Main Points of Agreement

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

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

3 In the long term there should be a drive toward holistic sustainability targets with the inclusion of more ecosystem based approaches to fishery management, in line with the Johannesburg commitments for all fisheries by 2015 and the new FAO guidelines on the ecosystem approach to fisheries management[1]. The fishmeal and oil producers accepts the need to play their part in collecting appropriate information and supporting this process.

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

[1] FAO (2003) The ecosystem approach to fisheries. Technical Guidelines for Responsible Fisheries, No 4 Suppl 2. Rome, 112pp

Important questions and preliminary conclusions

The sustainability of feeding fish to fish

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

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

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

The sustainability of feed grade fisheries

4 By conventional criteria (related to sustained yield of the target stock) as used by organisations such as ICES, FAO, and IMARPE[2], most feed grade fisheries are in a relatively healthy state (within safe biological limits, or with increasing stock bio-mass) and subject to specific management regimes. A notable exception is the Blue Whiting (West Scotland) fishery.

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

The fishmeal and fish-oil gap

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

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

[2] FAO Food and Agriculture Organisation of the United Nations; ICES International Council for the Exploration of the Sea; IMARPE Institute of Fisheries research (Peru)

Important questions and preliminary conclusions

Reductions in the fishmeal content of aquafeeds

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

9 Substitution of fish meal and oils will reduce the level of some undesirable substances in the final product.[3] Unfortunately, unless compensated by other means, it will also reduce the levels of some desirable substances such as Omega 3 highly unsaturated fatty acids (HUFA).

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

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

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

Alternative species

12 At a global level, many herbivorous and omnivorous species can be grown in fertilised ponds with little or no artificial feeding. Most of these can also be reared more intensively using feeds with much lower fishmeal and oil content than that required for carnivorous species. These species and systems are likely to become more price competitive as the cost of fish meal and oil rises.

13 Unfortunately, apart from Common Carp, few such species can be grown in Northern Europe. However, they may be expected to enter international trade more sustainably hitherto.

14 These fish have lower Omega 3 HUFA content and are therefore less desirable in terms of human health.

[3] European Commission, Scientific Committee on Animal Nutrition, 2000

Important questions and preliminary conclusions

Untapped sources of high quality marine protein and oil

15 Krill and copepods are small marine animals rich in protein, oils and other nutrients. Unfortunately, much energy is required to catch them, and they degrade very rapidly requiring special preservation techniques. Krill have a high fluorine content which would preclude their use in animal and fish feeds, at significant levels, under current EU legislation. There are also important questions relating to the wider ecosystem effects of harvesting organisms low in the food chain.

16 Biotechnology (bio-fermentation products using bacteria and algae etc) and GM plants could probably generate quality proteins and oils, but may meet with consumer resistance.

17 Discards and by-catch from food grade fisheries could be used to generate more fishmeal and reduce waste. This is already practised in some other non-EU countries such as Norway, but is not currently legal under the EU fisheries regime. The use of discards or by-catch should not however prejudice measures to reduce by-catch – itself a key measure in the sustainability of capture fisheries.

The role of price mechanisms in matching supply and demand

18 Economists predict that the looming gap between supply and demand will be closed through market and price mechanisms. As price rises, existing resources will be used more efficiently. Less will be used in animal feeds, where substitution is relatively straightforward, and a greater proportion will be directed to aquafeeds. As price continues to rise, rates of use will then fall in aquafeeds. Finally, as limits to substitution are reached, alternative sources will be developed.

19 While this will undoubtedly occur, there will almost certainly be mismatches in supply and demand in the short term, with potential for rapid (if temporary) increases in price and consequent hardship to the fish farming industry. There may also be negative social effects in terms of a greater proportion of fish caught being reduced for fishmeal and oil rather than used for direct human consumption, and increased pressure on some fisheries, although the quota system will constrain this in European waters.

20 Strategic research and policy interventions may therefore be required to minimise these risks.

Roles and responsibility

21 In principle responsibility for the sourcing of sustainable raw materials should apply to all points in the production chain.

22 Responsibility for providing information on which raw material users (feed manufacturers and fish farmers) can make an informed sustainable choice rests with the fishing companies, and fishery managers, and fishmeal producers.

23 In practice these groups may lack the capacity, the resources, and the incentive to provide information on some of the more complex and wide ranging ecosystem issues, except where this information is already available.

Recommendations

1 Clear and consistent objectives are needed for the sector. Different sub-groups in the workshop suggested different objectives, including the following:

- Maintain growth in aquaculture independent of feed grade fisheries;
- Reduce dependence on fish oil and fishmeal by 50% within ten years;
- Utilise available resources efficiently;
- Ensure and demonstrate the sustainability of feed grade fisheries used to source fishmeal and oil for aquaculture feeds

While some environmental interests question the desirability of continuing growth implied in the first objective, and the capacity of the environment to accommodate such growth, the others are widely agreed. However, the meaning of efficient resource use is not clear and requires further specification and agreement.

2 National and European strategies should set out clear and specific objectives of this kind.

3 Producers of fishmeal and fish-feed, fish farmers and retailers all need clear sustainability and efficiency criteria relating to their raw materials if they are to be asked to be more responsible. While specific targets relating to these criteria will be difficult to justify or agree, the criteria themselves will nonetheless allow for the measurement of progress.

4 The contradictions and trade-offs between different sustainability criteria must be taken into account when defining appropriate sets of sustainability criteria, and these should be consistent between different economic activities.

5 Better information is required relating to wider ecosystem and socio-economic impacts of feed grade fisheries. ICES is currently working on this for European Fisheries. IFFO will seek to compile further information for the South American Fisheries in line with the new FAO guidelines[4] on ecosystem based management.

6 IFFO will explore the possibility of putting a feed grade fishery forward for certification under the Marine Stewardship Council, and support the development of agreed sustainability criteria for the industry.

7 The aquafeed industry should substitute fishmeal and fish oil as far as is compatible with cost, consumer/retailer demand, fish health and welfare, and EU legislation. It should avoid the use of fishmeal from fisheries which are outside safe biological limits and are poorly managed according to ICES assessments.

[4] The ecosystem approach to fisheries (2003) FAO Technical Guidelines for Responsible Fisheries, No 4 Suppl 2. Rome, 112pp

Recommendations

8 The EU should continue to fund research on fishmeal and fish oil substitution, alternative species, and alternative sources of high quality marine and vegetable protein and oil as feed ingredients. Given their significance for human health and food safety, particular emphasis should be placed on developing new sources of Omega 3 HUFA principally, DHA and EPA, maintaining current levels in farmed fish, and ensuring low levels of hazardous substances.

9 The whole issue of sourcing, managing and allocating Omega 3, EPA and DHA resources and ensuring maximum benefits for human health and nutrition at global levels requires further technical, economic and environmental research.

10 Comprehensive economic and environmental assessment, using consistent assessment criteria, should be applied to all the alternative approaches to meeting the shortfall in fish meal and oil. This should ensure that the more sustainable aquaculture feeds are identified and developed and provide the basis for rational certification criteria or retailer product filter criteria. Opportunities for joint funding of these initiatives should be explored.

11 In the light of this work, the EU should examine the extent to which current national and EU legislation constrains the development of sustainable aquaculture feeds, and forces specific social, economic and environmental trade-offs .

12 In addition to improved knowledge of alternative feeds, much better communication, in particular relating to the trade-offs between different options is required. Alternatively consumers should be assured that a system is in place which adequately addresses such trade-offs. R6 above should underpin this requirement.

13 A European steering group to explore broader sustainability issues related to aquaculture feeds and ecosystem based management of source fisheries should be established. This would review knowledge and information, co-ordinate research, sponsor reviews, underpin networks, convene workshops and develop/implement definitions and standards. The scope of membership might be similar to that of the delegates at the SEAfeeds workshop.

The following represents a précis of the information presented by speakers and delegates, and the main points raised in the ensuing discussions.

The source of fishmeal and fish-oil for European aquaculture feeds

More than 6 million tonnes of fishmeal and over a million tonnes of fish body oil is produced globally. The quantity produced shows no overall long term trends up or down, although El Nino events normally cause a significant fall in production, especially of oil. Peru, Chile and Scandinavia dominate production. The main fish species used to produce fish meal and oil are Anchovy, Sardine, Horse Mackerel, Jack Mackerel, Sandeel, Sprat, Norway Pout, Blue Whiting, Capelin and Herring.

The status of feed grade fisheries

Fisheries have traditionally been managed in accordance with the objectives of sustained yield. With the exception of some of the European sandeel fisheries, little attention has been paid to wider ecosystem or socio-economic objectives. The information available on the status of the fisheries reflects these priorities.

Table 1: Status of feed grade fisheries

Fishery	Status (traditional measures) and management	Ecosystem and socio-economic issues
Anchovy Peru	Biomass increasing following last El Nino; licensing; satellite tracking; closed seasons; minimum landing size.	Little studied and poorly understood; population appears to be controlled by climate/oceanography rather than fishing pressure.
Anchovy, Sardine Chile	Closed seasons; company catch limits	Little studied and poorly understood.
Sandeel North Sea	Within safe biological limits; current year class strong; no management objectives.	Closed season/area related to Kittiwake and other seabirds breeding; fishing mortality a small proportion of total mortality: 20% of stock caught as feed fish; interaction with cod and other fish species poorly understood.
Sandeel Shetland	TAC; safe biological limits not set	Seabird breeding seasonal closure; fishing mortality well below natural mortality; interaction with other fish species poorly understood.
Sandeel West Scotland	Multi-annual TAC; closed season; limited access state of stock currently not known	No information
Blue whiting West Scotland	Outside safe biological limits; fishing mortality high; catches above ICES recommendations; no TAC (under discussion); no management objectives; NEAFC to develop a plan.	No information
Norway pout West Scotland	Unknown status; no management; small mesh trawl	No information
Norway Pout North Sea	Within safe biological limits.	Low fishing mortality compared with natural mortality
Herring North Sea	Autumn spawning stock within safe biological limits; Spring spawning stock outside safe biological limits	No information
Herring Icelandic	Within safe biological limits	No information
Herring Norwegian Spring spawning	Within safe biological limits	No information
Capelin Barents Sea	Within safe biological limits	Possible interaction with cod poorly understood
Capelin Icelandic	Healthy, according to Icelandic Ministry of Fisheries	Possible interaction with cod poorly understood
Horse mackerel	State of stock not known	No information
Sprat	Stock in good condition	May be associated with herring by-catch – some corresponding restrictions. Complex predator-prey-predator interaction between sprat and cod.

Source: ICES, IFFO

3 Review of information and issues

Many of the feed grade fisheries are in good condition as measured by traditional single stock criteria (as reported by ICES etc). However, information is poor for several stocks and their status unknown. Blue Whiting (W Scotland) is outside biological limits and subject to very limited management. Information and understanding relating to wider ecosystem and socio-economic issues (such as global equity and nutrition) is very limited at the present time, and there is no consistent and standardised monitoring and reporting. However, substantial work has been done on the relationship between sandeel and seabirds, and this has been translated into corresponding management measures for N Sea and Shetland fisheries for this species. ICES, the European Commission, FAO and other agencies are currently actively engaged in developing indicators for ecosystem and sustainability reporting.

Most feed grade fisheries have characteristics which makes them differ from other fisheries in management terms:

1 Most are small short lived species with a rapid reproductive cycle, with the potential to recover rapidly from adverse environmental conditions or excessive fishing mortality. In this sense they are more resilient than larger longer lived species such as cod.

2 Most are low in the food chain. This means that:

- they are more abundant and productive than fisheries higher up the food chain;
- removing a significant proportion of these fish may have very wide knock on effects on the rest of the food chain and the wider ecosystem.

3 Most are pelagic, implying that habitat damage is not generally an issue (trawls etc are not used) and by-catch/discard problems tend to be less, since dense single species shoals are typically targeted.

Concern has been expressed that feed grade sandeel and sprat fisheries may undermine the potential for recovery of cod stocks. The interactions between these species are complex. For example, not only does cod prey on sprat, but sprat may prey on juvenile cod. There is no clear scientific understanding of these issues, and the research required is very costly. Nonetheless, some existing models suggest that a moratorium on feed grade fisheries might deliver a 5% increase in the rate of cod recovery, but perhaps more substantial benefits to wild salmon fisheries.

Understanding of the effects of the South American feed grade fisheries on other species is even less well understood, although there are fewer closely associated carnivorous species.

Constraints to improved sustainability reporting

Improvements in ecosystem and sustainability reporting for fisheries and other economic activities are anticipated. However, this will be a slow and gradual process as there are many constraints, and this must be taken into account while developing policy and strategy.
Key constraints include:

- Lack of widely accepted standards and criteria, and lack of consensus on needs and scope for ecosystem and sustainability reporting
- Lack of clarity of roles and responsibility for reporting, monitoring and responding;
- Lack of information – including integration of different kinds of information (social, economic, environmental) and lack of access to existing information
- Lack of capacity and ability to collect, analyse and communicate consistent, coherent and complete data;
- Lack of resources – for collection, co-ordination and communication
- Short-termism – political and commercial

Supply and demand: a looming gap

In 2000 around 7mmt[5] of fishmeal and 1.35mmt of fish oil was produced. Production has remained roughly around these levels for the past 15 years, with dips and peaks following El Nino events.

Around 37% or 18mmt of aquaculture production depends on feed inputs. Most aquaculture feeds are used to produce carps, salmon and trout, and shrimps (see figure 1). Other forms of aquaculture, such as seaweed, mollusc and extensive shrimp and fin-fish culture depend on natural nutrients and food, although substantial use is made of fertilisers to enhance natural food production in pond production systems.

Most high quality fish feeds use fishmeal as the main source of protein, and salmonid diets in particular are currently dependent on a proportion of fish oils to generate a high quality product. Feeds for species such as carps, Tilapia and shrimp usually have a lower fishmeal and fish oil content.

In 2001 total fishmeal and fish oil used in aquaculture was 2.6 and 0.6mmt, corresponding to 43% and 54% of supply respectively. The balance is used primarily for animal feeds, mainly for poultry, pigs and cattle[6].

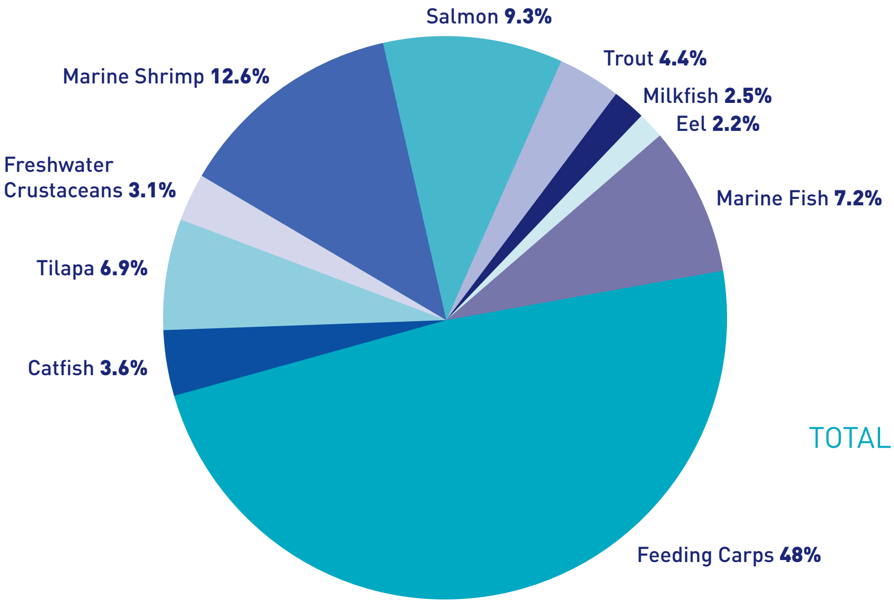
[5] mmt - Million metric tonnes

[6] The EU currently bans the use of fishmeal (an all animal protein) in cattle feeds

Figure 1: (After Tacon 2003: This workshop)

Estimated Global Compound Aquafeed Production in 2001 for Major Farmed Species

(values expressed as % total aquafeed production, dry as-fed basis)



TOTAL ESTIMATED COMPOND AQUAFEED PRODUCTION IN 2001 – 16.70MMT

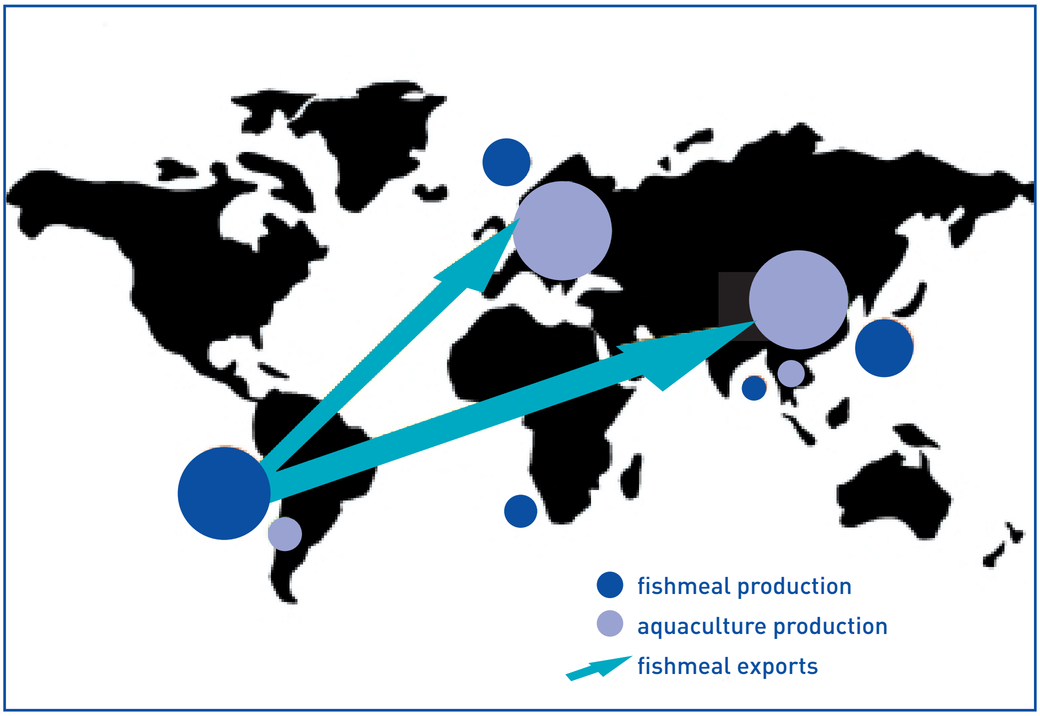
Table 2: (After Tacon 2003: This workshop)

In 2001 the aquafeed sector consumed:

	Fish meal: 2.62 mmt	Fish oil: 0.59 mmt
Salmonids	29.4%	64.5%
Marine fish	22.6%	20.3%
Shrimp	19.3%	7.0%
Carps	15.3%	-
Eels	6.9%	2.5%
Tilapia	2.7%	1.9%
Milkfish	1.4%	0.7%
Catfish	0.9%	1.0%

Total fish meal and fish oil used in 2001 3.21 mmt
43.1% of total 6.08 mmt, 53.6% of total 1.10 mmt

Figure 2: Major flow of fishmeal and use in aquaculture



While production of fishmeal and fish oil have remained steady in recent years, aquaculture production globally has continued to increase at close to 10% pa. At the same time there is an increasing tendency for producers in Asia (which dominates aquaculture production) to intensify and use compound feeds to increase productivity and to allow for increased production in cages as well as ponds. Expansion of aquaculture production in Asia and Europe is set to continue. The major global salmon production companies intend to continue to increase salmon production, and increased production of alternative species such as cod, turbot and halibut is also planned. Tuna farming in the Mediterranean (requiring very high inputs of fresh feed fish) is also set to increase. Production aspirations in Asia are huge.

There may also be substantial increased demand for fish oils as human health supplements, as the merits of Omega 3 HUFA becomes more widely known. This may result in increased demand for oils for direct human consumption, and/or such oils becoming recognised as an important ingredient in a wider range of products. Demand for high quality health enhancing pet foods is also increasing rapidly.

It is also sometimes argued that a greater proportion of feed grade fisheries should be upgraded to deliver a human food grade product, thus meeting some of the global demand for high quality protein for the poor. At the present time the scope for doing this – from technical, economic and market perspectives is unclear. The immediate constraint is quite simply demand: the cost of getting it to human markets in good condition probably exceeds its value. In the absence of specific purchasing and/or processing interventions by aid agencies, the fish will continue to go primarily for meal and oil.

Irrespective of demand for direct human consumption, it is clear that a fishmeal gap, and more pressingly a fish-oil gap is inevitable in the not so distant future. Prices will rise, causing a shift in allocation to activities most dependent and most willing to pay. Increased price is also likely to result in increased pressure on the fisheries, although there is uncertainty as to the nature and magnitude of this effect because of the special characteristics of feed grade fisheries.

Reductions in supply in the past corresponding to El Nino events, coupled with increased demand from aquaculture have not had a dramatic impact on price, partly because countries such as China have produced more for themselves, and partly because fishmeal is readily substituted in most animal feeds with vegetable proteins and oils. Aquaculture itself has been able to increase the efficiency of utilisation of fishmeal and oil through improved understanding of nutrition and feed formulation, and has been able to absorb modest price changes without serious detriment to production or profitability.

This situation will change in the future as aquaculture continues to grow rapidly world wide and as more intensive production techniques are adopted in developing countries. The industry may adapt to these changes in various ways:

1. Channel an increased proportion of fishmeal and oil to aquaculture feeds;
2. Reduce fishmeal and oil content of fish feeds;
3. Shift to species requiring less fishmeal and oil;
4. Make more efficient use of existing resources;
5. Develop new sources of marine protein and oil

The potential for each of these options is summarised in the next section.

Meeting the challenge

Allocation to alternative uses

Most experts believe that the proportion of fishmeal and oil channelled into aquaculture feeds will increase and the proportion used in animal feeds will decline. This is because protein and energy substitution is relatively straightforward in most animal feeds, although small amounts of marine oil and proteins are likely to be required for optimum animal health and growth. Price itself is likely to drive this change since marine oil and protein is more valuable for aquaculture production.

The likely increased demand for fish oils as a human health supplement may reduce the extent to which aquaculture can draw on the existing "slack" currently taken up in animal feeds, although this demand might be partly met through the extraction of oils from farmed salmon processing waste, which is currently not available for recycling into salmon feeds under EU legislation.

Reduction of fishmeal content in fish feeds

Reducing fish meal and oil content of aquafeeds has implications for both product quality and food safety. Reductions in fish oils in aquafeeds will result, on the one hand, in undesirable reductions in health enhancing omega 3 fatty acids, and on the other, beneficial reductions in fat soluble undesirables (e.g. dioxins and dioxin-like PCB's) in the product. A balance in product quality and safety will need to be found when developing strategies to reduce fish oil use.

Carnivorous finfish such as salmon, seabass, seabream, cod, turbot and halibut all require high protein diets with high protein quality. However they differ in their requirement for protein and oil, and the efficiency with which they convert food ingredients. Cod for example requires higher protein but less oil than salmon. Seabass and seabream also require less oil, but do not convert food as efficiently as salmonids.

By substituting high quality plant oils and protein the fishmeal and fish oil content of aquafeeds can be reduced substantially – for salmon 50% protein and up to 80% oil, and for marine fish and trout 50-80% protein and up to 60 and 80% of fish oil respectively - without any significant loss in fish welfare, performance or quality. Further reductions are possible if animal by-products (such as blood, bone and feather meal) are included. Higher levels of fishmeal substitution are currently constrained by "anti-nutritional factors" found in many plant protein meals, decreased fish health and welfare, and the higher cost of complex balanced formulations and additives. Further research should lead to the potential for further reductions, although this is likely to become steadily more difficult and costly as we approach zero fish oil/meal formulations.

However, there are significant non-technical constraints to substituting plant oil and protein or animal by products for fishmeal:

- At the present time use of fishmeal is more cost effective in meeting objectives of fish productivity, welfare, and product quality and safety. This is likely to change as the fishmeal and oil gap opens up.
- Beyond a certain point, there will be an effect on product quality. Substantial reductions in fish oil will result in reductions in Omega 3 HUFA in the product, and this may reduce the popularity and value of the product[7]. This can be countered in part by feeding high Omega 3 fish oil diets towards the end of the production cycle.
- Some quality marks (notably Label Rouge) specifically require salmon to be fed exclusively with protein and oil of marine origin.
- The food conversion efficiency will decline as the proportion of plant proteins increases. This will lead to greater losses of nutrients and solid organic matter to the environment.
- A significant proportion of plant oil and protein meal is derived from GM plants which may reduce acceptance to consumers or limit their use under EU legislation.
- Animal by-products cannot be used in the EU, although they can and are used in the USA, Canada, Chile and many other countries[8]. There are also restrictions on additives, including certain amino acids which are desirable to enhance the performance of vegetable proteins.

Alternative species

Many species of fish and crustacean are less demanding in terms of their requirement for high quality fishmeal and oil. Marine and freshwater crustaceans, milkfish, catfish, Tilapia, carps, and a range of other less well known species can be grown well with low or zero fishmeal/oil diets. Other than some of the carps and catfish these are mainly tropical and sub-tropical species. As the price of fishmeal and oils rises, these species will become relatively cheaper and more competitive.

However, by the same token, these species are lower in Omega 3 HUFA, and less desirable from the perspective of human nutrition. It may be appropriate to consider salmonids as a vehicle to deliver fatty acids, and species such as carp and Tilapia largely as the vehicle to deliver protein, although they do deliver lower, but significant, amounts of Omega 3 HUFA.

Alternative sources of marine oils and proteins

If levels of marine oil and protein are to be maintained in fish diets to satisfy consumer demand, EU legislation, and in order to maximise fish health, then alternative sources will soon be required. There are several possibilities including:

- Discards, by-catch and trimmings
- Krill and Copepods
- Biotechnology
- Niche products – marine worms
- Plant products

[7] in practice consumer demand for HUFA and for oil related taste characteristics vary between countries

[8] Even in these countries some companies do not use them, both to allow export to Europe, and to meet retailer requirements.

Large amounts of marine protein are wasted under current EU fisheries management regimes, which prohibit the landing of certain species or sizes of fish. This encourages discarding at sea, commonly seen as a huge waste of scarce marine resources. However, there is a possible ecosystem benefit here, since the historically high seabird populations, and possibly some marine mammals, may have benefited. Much of this material could be used to produce fishmeal. However, in the medium/long term the objective should be to reduce by-catch and discards – in which case this resource will decline.

Trimmings from the processing of human grade fish is available and indeed already used in fishmeal production, although this is typically not oil rich. Use of trimmings is however controversial, since it may actually increase pressure on the fishery. It should therefore only be used from secure and well managed stock.

Trimmings from aquaculture itself – waste from salmon processing for example – represents a substantial resource, but its use for salmonid culture contravenes EU legislation designed to prevent loop feeding and its associated health risks.

Krill (a very small shrimp like creature abundant in the Antarctic) represents a huge resource of marine protein and oil that is highly enriched with valuable carotenoids as well as Omega 3 HUFA. Stocks probably exceed 100 million tonnes. Unfortunately there are technical difficulties both in catching (the fine mesh nets require tremendous power to move through the water) and preservation (the small animals begin to degrade very rapidly). Furthermore, krill is rich in fluorine, and current EU legislation relating to animal feeds would preclude its use. Krill is a key species in the food web in Antarctic waters, and any major fishery would need a management regime which took full account of ecosystem effects.

The copepod Calanus is even more abundant, but even smaller and more difficult to catch, preserve and process. Serious research has only just begun on commercial scale harvesting of copepods.

Biotechnology processes could generate high quality proteins rich in omega 3 from intensive production of bacteria, algae or zooplankton, but costs are high and research and development activity limited. Current research suggests that prices of bio-fermentation-derived Omega 3 HUFA would have to be reduced by 95% to be competitive with fish meal and oil. However, it is known from the cultivation of marine worms that omega 3 can be synthesised by a variety of micro-organisms in marine sediments. While the culture of marine worms themselves is unlikely to fill the gap (although it may become an important niche product) biotechnology processes based on micro-organisms may have more potential for large scale production.

Genetic modification of plants and or micro-organisms to produce higher quality proteins and oils is likely to be possible, but restrictions on GM products are a major constraint.

Table 3: Costs and benefits of alternative approaches to filling the fish oil/fishmeal gap

Strategy	Costs/problems	Benefits
Substitute plant proteins	Lower EFAs in product; Lower concentration of protein, associated with increased FCR and associated organic pollution; Anti-nutritional factors, negative to animal welfare, fish health and performance. Many plant oil/protein sources are GM; Legislation constraining the use of supplemented amino acids; Consumer perception	Reduced phosphorus and associated pollution; Lower level of protein and oil associated undesirables; Consumer perception
Substitute plant oils	Consumer perception; Reduced EFA (but manageable to a point); Anti-nutritional factors; Possible negative fish health and welfare at substitution rates over 70% for salmon	Consumer perception; Less consumption of fish oils to provide energy; Availability and consistent quality; Lower levels of lipid soluble undesirable substances (dioxins and PCBs); Conforms to EU animal feeds legislation
Non-fish marine proteins (krill; copepods; phytoplankton)	High fluorine (infringes feed legislation); High energy cost of catching; Difficulty of preservation; Public perception?	Huge resources; High natural carotenoid and phospholipids (nutraceuticals); High nutritional value
Animal by-products (meat meal; blood meal; bone meal; poultry meal; feather meal)	Consumer perception; Knowledge of prions; Legislation; Traceability and loop feeding	Low cost; High availability; Nutritional value; Efficient recycling/use of resources
Bio-engineered	High nucleotides; GMO association; Scale issues; Amino acid composition	Consistent; Predictable; High quality
Trimmings	May increase pressure on fishery resource where management regime ineffective	Efficient use of resources
By-catch/discards	Not available in EU	Efficient use of resources
Aquaculture wastes	Legislation; loop feeding	Efficient use of resources
Herbivorous/omnivorous species and low feed input pond production systems	Lower market demand (Europe); lower Omega 3 content; fewer opportunities in North temperate countries	Efficient protein production; comparative advantage for tropical and sub-tropical developing countries

Efficiency and sustainability issues

There has been much debate in the literature about the "efficiency" of aquaculture compared with fisheries, and specifically much argument over how much wild fish, in the form of fishmeal, is required to produce one kg of farmed fish.

This can be looked at from a variety of perspectives, and to date different numbers have been used to promote different perspectives.

It is estimated that in 2001 between 13 and 16mmt of wild fish was converted into fishmeal and oil for use in aquafeeds, and 4mmt of fresh fish were fed directly to farmed fish, generating in total roughly 18mmt of (artificially fed) farmed fish and crustacean production (Tacon, this workshop), and corresponding to an overall conversion of close to 1:1. A further 30mmt of aquaculture production required no feed inputs (seaweed, molluscs and extensive pond aquaculture).

There are major differences between species and production systems which currently utilise feed inputs (Table 4), and these differences explain in part the different figures presented by different interests.

Table 4:
Conversion efficiency of capture fish to farmed fish (kg per kg fresh weight) **(from Tacon, this workshop)**

Species group	pelagic input per unit of production
eels	3.4 – 4.2
marine fish	2.9 – 3.7
salmonids	2.6 – 3.3
marine shrimp	1.7 – 2.1
freshwater crustaceans	1.0 – 1.3
milkfish	0.3 – 0.4
catfish	0.3 – 0.4
tilapia	0.2 – 0.3
feeding carp	0.1 – 0.2

Do these figures have any relevance to questions of sustainability? There was no clear agreement at the workshop as to what desirable, "sustainable", or target levels of conversion should be – other than that they should improved as far as possible.

Comparisons with capture fisheries are complex and difficult. Wild cod or salmon require more wild prey fish to grow. The "natural" conversion rate of prey to predator fish is typically closer to 10:1. But capturing pelagics, processing them, distributing them and feeding them to salmonids may require more energy/transportation compared with capturing carnivorous fish from a well managed stock. There again, such a fishery is very unlikely to deliver as much product as aquaculture, or to introduce as much marine oil to the human food chain. The question "is capture fisheries of salmon or cod more sustainable than farmed production?" is therefore simplistic. The answer depends on the different weightings given to the many dimensions of sustainability.

Two working groups sought to identify and prioritise criteria for measuring efficiency and sustainability – in relation to feeds and feeding; and in relation to feed grade fisheries.

The first group generated a set of criteria and assessed their overall importance and value, their technical value, their communication impact, and current industry performance in terms of both level of the indicator and/or degree of progress (*Table 5*). They also noted the major barriers to achieving progress.

Table 5: Efficiency/sustainability criteria relating to aquaculture feeds

Criteria Value	Importance Impact	Technical	Communication	Performance[9]	Barriers to Progress	Trade-offs
1 Quantity of fish going into quantity of aquaculture – gross amounts of feed grade material (mass balance sheet)	8	6	10	6		7, 11
2 Inputs from sustainable/ unsustainable sources	10	10	9	9	knowledge, economics, regulation	7, 11
3 Inputs from food grade v feed grade	5	5	5	8	regulation; technical	7, 11
4 Other materials entering the feed other than marine proteins and lipids	8	8	9	4		7, 11
5 Input-output of protein and lipid –specific ratios	8	8	9	4		
6 Energy – use of manufactured energy[10]	7	9	5	8	knowledge; economics; technical	
7 Origin – location and transport indicators[11]	7	5	9	7		1,2,3,4
8 Profitability ,value added per input, employment (better separated?)	10	10	10	9	economics; regulation; consumer	
9 Equity and distribution of benefits	5	5	5	8	knowledge	
10 CBA – environmental economics	6	9	4	8	knowledge	
11 Environmental impact	9	9	9	6		1,2,3,4

The group noted that it may not be possible to improve against all criteria – there are trade-offs in some cases (last column) . Thus, for example, the mass balance sheet and environmental impact might be improved – but at the cost of using a greater proportion of unsustainably sourced raw material, or higher transportation or processing energy costs. In order to measure overall progress in terms of improved sustainability, we need widely agreed weightings.

The second group mapped out the main dimensions of sustainable fisheries, and information needed to assess these dimensions. Their output is presented in Table 6. The major gaps in current information and reporting systems relate to wider ecosystem, social and economic impacts.

[9] How far are we from being sustainable? 0 – 5 things moving on, so progress occurring; 5 – 10 large need for further progress.

[10] ref. John Forester in world aquaculture and Geoff Allen

[11] organic certification already requires "local" sourcing of feed ingredients.

Two key issues should be addressed in any move to improve reporting and assessment for feed grade fisheries:

- The extent to which feed grade fisheries have wider ecosystem impacts (e.g. on predatory fish, mammals and seabirds)
- Whether a higher proportion of what are currently feed grade fisheries could go for direct human consumption, whether this would be a more rational, equitable and sustainable use of resources, and what interventions (if any) would be required to promote such a shift.

Table 6. Information required for effective assessment of the sustainability of feed grade fisheries

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

Image of the industry – confusion and communication

The industry feels hard done by. It is being pulled in different directions, but is highly constrained in the degree to which it can respond. Different consumers and different interest groups have different demands, sometimes contradictory. Many consumers and media want high Omega 3 HUFA. They also want low dioxins and other contaminants. Some want fish produced exclusively on marine oils and proteins. Others are concerned about feeding fish to fish. Feed producers are increasingly constrained by EU legislation related to food safety. The EU has banned the use of animal by-products which would allow for greater reductions in fishmeal content. Substitution using plant proteins may also be problematic because many are GM. Reduced fishmeal may result in worse food conversion, which has been a benchmark of performance in the industry and is related to environmental impact.

While the industry is happy to respond to environmental concerns, it feels that the trade-offs are poorly understood. It cannot satisfy a range of incompatible requirements. It would like to see better information, more balanced reporting, and a more informed debate, leading to more consistent legislation and public/consumer demand.

Human health and the management of EFAs

Marine oil will reach critical supply constraints before fish meal. It is now well established that Omega 3 fatty acids (and specifically the ratio between Omega 3 and Omega 6) are essential for a healthy diet. Protein production globally is a political-economic issue, and no longer a technical problem. Marine oils on the other hand are a production limited commodity, and while there are alternative sources and possible new means of synthesis, these are likely to be significantly more expensive than current sources.

The main natural source (of EFAs etc) at present is small pelagics. Market demand for these species for human consumption is currently limited, and it may be difficult and costly to get them to markets in suitable condition. It has therefore been suggested that converting them to an attractive food product may be an efficient and rational way of introducing them to the human food chain, especially in developed countries. On the other hand, improved post harvest handling and distribution could generate a valuable direct source of these oils for poor people in developing countries.

At the present time however this channels a significant proportion of such oils to the wealthier peoples of developed countries, and little ends up in the stomachs of the poor. The demand from aquaculture is likely to drive up the price of fishmeal and oil in the medium/long term. This may have negative impacts in terms of the proportion of pelagics available for direct human consumption, and availability to the poor.

There has been very little research undertaken on the management and distribution of these oils throughout the world, and the potential of interventions to improve health and nutrition amongst the poorest.

Economic drivers

It is inevitable that as demand for fishmeal and oils for aquaculture increases in the context of strictly limited supply, the price will rise, resulting in increased allocation to aquaculture, decreased fishmeal and fish oil content in aquaculture feeds, and increased incentive to harvest alternative sources or synthesise marine oils. It may also lead to relatively higher cost of species using a high proportion of fishmeal and oil in the feed, and increased competitiveness of species using less fishmeal and oil - although this will be modified according to consumer demand for Omega 3 HUFA rich products.

The question is whether these price and market responses will be rapid enough to deliver a sustainable and profitable aquaculture industry in Europe. There were significant doubts amongst the delegates as to whether this would be the case, and agreement that steps should be taken to prepare for the shortfall, and thereby minimise negative price impacts. Substitution will take place easily and rapidly in the first instance as prices rise. But the cost of substitution will increase as the degree of substitution increases, with negative impacts on profitability, especially of the more demanding salmonids.

Increased price of fishmeal and oil will also drive up the price of raw material, with two possible secondary effects. A greater proportion of some fisheries production may be directed to fishmeal rather than human grade fish, which might be seen as contrary to some sustainability criteria. There will be an increased incentive to invest in feed grade fisheries, and in the absence of strong management regimes, this could result in a decline in the status of some fisheries.

The role of certification and labelling

Retailers are already driving meal/oil levels in fish feeds. The criteria typically relate to human nutrition and health, and not the fishmeal/oil source, except for organic products. In Europe (UK?) around 5% of consumers are "green"; 10% "light green" and the rest care much more about price and quality. A highly negative portrayal of salmon farming on a BBC programme in 2002 had negligible impact on demand for salmon.

Well established generic labels, such Label Rouge and Organic are used in their own right to promote particular product qualities and segment the market. Label Rouge has a greater focus on product quality, and feed inputs (such as high levels of marine oil and protein) may be specified to deliver this. Organic on the other hand places more emphasis on wider environmental and sustainability issues, and places more emphasis on limiting the content of fishmeal and oil and ensuring sustainability of source fishery. A catch 22 with respect to promoting sustainability through these labels is that they exist by virtue of the premium they command, which in turn depends on being a niche market. If they were to become more of an industry standard they would lose their premium.

Sector labels such as Scottish Quality Salmon, are typically used as product quality filters for major retailers, and are not normally "sold" at a relative premium. There is a feeling amongst retailers that the last thing consumers want is more labelling relating to sustainability; rather they want to have faith in the retailing company, and the quality and sourcing of its products. Furthermore, a major retailer would not wish to introduce a new niche label which might undermine the value of equivalent non-labelled products.

It would appear therefore that there is rather limited potential to promote improved feed sourcing and management through more eco-labelling, at least in the UK. Rather efforts might be more effectively directed at refining the criteria used by existing major labels, and refining the product/supplier filters used by the major retailers themselves. The more aware retailers and feed manufacturers already take account of ICES assessments of stock health, and some pressure is applied to suppliers to source raw materials accordingly. Thus some feed manufacturers (and retailers) have already requested minimal use of Blue Whiting in their fishmeal supplies. It seems likely that retailers could be persuaded to require that their salmon be fed on feeds sourced from a sustainable feed grade fishery, so long as the sustainability criteria were widely agreed and accepted. The constraint to progress here is the lack of sufficiently simple, well reported and agreed sustainability criteria, which go beyond the current scope of ICES assessments.

The benefit of accreditation to feed grade fisheries, and labelling related to the sustainability of the fisheries themselves, is not yet clear. The costs of collecting, analysing and reporting information relating to wider sustainability issues will be significant, and recouping these costs through premia on labelled products may be difficult at the present time. The links to final consumer are complex, and consumer concerns about broader sustainability issues are unclear. The fishers and managers of these fisheries are unlikely to institute change unless and until demand and price for accredited fishmeal rises significantly. The pressure must therefore come primarily from the retailer.

To date no feed grade fisheries have been certified under the Marine Stewardship Council initiative. There is no obvious reason why this should be the case – they have many features which make them suitable.

Roles and responsibilities

Sustainable source fisheries

There are significant constraints to the development of improved reporting and sustainable management of fisheries. They include:

- A lack of clarity of roles and responsibilities (though traditionally responsibility assigned to government);
- Lack of capacity to undertake the research/reporting required;
- Lack of resources – specifically for co-ordination and communication between different interests;
- Lack of information, and a lack of integration and access to information;
- Lack of consensus and acceptance of sustainability criteria and standards;
- Lack of independence of reporting;
- Short-term political and economic interests dominating fishery management

Responsibility for reporting conventional indicators of fisheries status and yield is clear and well established, and undertaken in most cases by 3rd parties (e.g. ICES) and governments. The World Summit on Sustainable Development (WSSD) in Johannesburg 2002, agreed that work must begin in implementing an ecosystem approach to fisheries using a broader set of indicators and reference points. Although, in principle, both states and users have obligations in this regard[12], neither the indicators and associated standards, nor the responsible parties are yet clearly defined, and significant policy development is required if this process is to be applied meaningfully and consistently across a wide range of fishing and other economic activities.

The fisheries sub-group proposed the following initiatives and associated responsibilities to take things forward (Table 8)

Table 8: Strategy to deliver improved sustainability reporting

Issue	Action/strategy	Responsibility
Lack of clarity of roles and responsibilities	Audit of roles and responsibility	Fisher organisations; fishmeal producers through government and fish industry representatives
Lack of capacity	Assess capacity; build capacity; influence and pressure to direct money/resources to capture fisheries	FAO Shared responsibility: industry; NGOs
Information	Audit of information and gaps (linked to issue 1); Propose research strategy	Fishing organisations; fishmeal producers through government and fish industry
Standards/criteria	Industry to establish what criteria and standards should be and seek external endorsement; Industry to seek 3rd party assessment of feed grade fishery against e.g. MSC standard	Collective industry advised by competent authorities (e.g. ICES)

[12] FAO Code of Conduct for Responsible Fisheries

This implies a strong and pro-active role for IFFO and other industry representative bodies. However, the industry (and IFFO in particular) feels itself inadequate to address all the dimensions of sustainability - since by definition they involve other interests and stakeholders, and will therefore require both strong support and higher level initiatives.

Notwithstanding the need for higher level initiatives (some of which are currently being developed at the European level), the IFFO is keen to move forwards and:

- seek to integrate currently available information, and
- seek ways to collect additional necessary information in line with FAO guidelines

so that improved reporting and assessment can take place, especially in respect of South American feed-grade fisheries. In addition IFFO will explore further the opportunities for certifying one or more feed grade fisheries under 3rd party certification schemes such as MSC.

Further along the chain, the aquafeed manufacturers and fish farmers are keen to demonstrate that their feeds are sourced from sustainable fisheries. This information will in turn be used by retailers as the basis for broad filtering of aquaculture products or for labelling premium products. Any improved reporting is therefore likely to be used, and this in turn may drive further improvements in information collection, reporting and analysis. Given that at the present time many of the feed grade fisheries appear to be in a reasonable state, the disincentive to effective reporting will be minimal. This represents a significant opportunity to get things in place before problems arise.

At the same time, it should be the responsibility of the industry to ensure that despite the current cost effectiveness of using fish meal and oil, it will be able to adapt to future rising prices. Further research will be required to make lower fishmeal and oil diets equally cost effective, and this should be largely funded by the industry itself.

It is hard to see how the industry itself can address some of the broader environmental, social and economic issues associated with sustainability (such as equity; food security; ecological risk etc) in the absence of detailed guidance, legislation or consumer demand. Governments must therefore interpret and apply international commitments in this regard, and provide an appropriate development framework within which the industry can prosper sustainably.

In the first instance more research and policy development is required related to relatively simple and practical sustainability criteria. This should be driven and supported by government, but should also engage the industry. A possible way forward is to establish a steering group made up of technical specialists, industry representatives, consumer, retailer and NGO interests. The balance and composition might be similar to that of the delegates to this workshop. Such a group would be charged to review knowledge and information, co-ordinate research, sponsor reviews, underpin networks, convene workshops and develop/implement definitions and standards.

Sustainable aquaculture feeds: an overview and global perspective

Albert G.J. Tacon
Aquatic Farms Ltd, 49-139 Kamehameha Hwy.,Kaneohe, Hawaii 96744, USA
agjtacon@aol.com

There is no doubt that the third millennium will herald marked changes in our global food production systems. The over-riding reason for these changes is the stark realisation (after years of environmental abuse) that our planet has it's limits, both in terms of it's available natural resources (i.e., land, water, energy, nutrients, natural biota), and through its ability and capacity to harness and recycle these resources and sustain life as we currently know it. All too often our planet has been viewed as a limitless resource for the sole exploitation and enjoyment of mankind, rather than as a fragile living ecosystem of inter-dependent plants and animals. Well the bells are ringing loud and clear, and the message is there for all to see: through the activities of our modern societies (and the development of our towns, cities, agriculture and industries), we are now negatively impacting all things, from the air that we breath, the water that we drink, the food that we eat, the land that we live on, to the very weather of our planet and the well-being of all living things.

The upshot of the above is that aquaculture (the farming of aquatic plants and animals), like all other food production systems, will have to become increasingly more environmentally and ecologically responsible if it is be truly sustainable in the long run and be socially accepted as an economically viable means of producing food for an ever hungry population. With world population expected to reach 8 billion by 2030, pressure on the environment will continue to mount. The challenge of the coming years is to produce enough food to meet the needs of an additional 2 billion people while preserving and enhancing the natural resource base upon which the well-being of present and future generations depends.

Aquaculture's contribution toward total global fisheries landings continues to grow, increasing from 5.3% in 1970 to 34.1% of total fisheries landings by weight in 2001. Moreover, aquaculture continues to out-pace all other animal food producing sectors in terms of its growth; the sector growing at average Annual Percent Rate (APR – average annual compounded growth rate in percent) of 8.8% per year since 1970, compared with 1.2% for capture fisheries and 2.9% for terrestrial farmed meat production systems over the same period. Total aquaculture production in 2001 was reported as 48.4 million metric tons (mmt) by weight and valued at US $ 61.5 thousand million, with production up by 6.0% by weight and 6.3% by value since 2000. Over half of total global aquaculture production in 2001 was in the form of finfish (24.43 mmt, valued at $ 33.65 thousand million), followed by molluscs (11.27 mmt, $ 9.96 thousand million), aquatic plants (10.56 mmt, $ 5.78 thousand million), crustaceans (1.98 mmt, $ 11.58 thousand million), amphibians and reptiles (121,629 mt, $ 464 million), and miscellaneous aquatic invertebrate animals (43,254 mt, $ 37 million).

Of this total production only about 18 mmt or 37% was in the form of finfish and crustacean species whose production is dependent upon the supply and use of external off-farm nutrient inputs in the form of compound aquaculture feeds. Industrially compounded aquafeed production in 2001 was estimated to be about 16.8 mmt, with aquafeed production currently representing about 3% of total global industrial animal feed production (estimated at 604 mmt in 2002). Major species groups currently dependent upon the use of compound aquafeeds in 2001 included the non-filter feeding carps (8.0 mmt of aquafeeds used in 2001), marine shrimp (2.1 mmt), salmon (1.56 mmt), marine finfish (excludes mullets; 1.21 mmt), tilapia (1.16 mmt), trout (0.74 mmt), catfish (0.69 mmt), freshwater crustaceans (0.52 mmt), milkfish (0.42 mmt) and eels (0.37 mmt).

At present the production of aquafeeds for finfish and crustaceans species is highly dependent upon capture fisheries for sourcing essential dietary lipids (in the form of fish oil) and high quality animal proteins (in the form of fish meal, and to a lesser extent molluscan and crustacean by-product meals). It is estimated that compound aquafeeds consumed about 2.62 mmt of fish meal and 0.59 mmt of fish oil in 2001 (in 2000 this was equivalent of about 35% and 41% of the total global production of fish meal and fish oil, respectively). On a species group level salmonids consumed the largest proportion of fish meal and fish oil in 2001 (29.4% and 64.5% of total used in aquafeeds, respectively), followed by marine fish (22.6% and 20.3%), marine shrimp (19.3% and 7.0%), feeding carp (15.3% in the case of fish meal) and eels (6.9% and 2.5%). The total use of fishmeal and fish oil within compound aquafeeds is almost certainly higher than the figure given above, as an additional 2.6 mmt of finfish and crustacean production (equivalent to 10% total finfish and crustacean production) was not included in these calculations (includes unknown freshwater fish species (2.26 mmt in 2001), marine crabs and other marine crustaceans (0.2 mmt), Mandarin fish (0.12 mmt), and other miscellaneous freshwater fish species (Colossoma sp., Snakeheads, Gourami etc.).

The total estimated use of fishmeal and fish oil within aquafeeds (3.2 mmt in 2001, dry basis) was equivalent to the use of 12.8 to 16.1 mmt of pelagics (using a dry meal/oil to wet fish weight equivalents conversion factor of 4 to 5) for the production of 17.69 mmt of the major farmed-fed finfish and crustacean species in 2001. As in previous years, net fish consumers included marine eels (pelagic input per unit of production 3.4-4.2), marine fish (2.9-3.7), salmonids (2.6-3.3), marine shrimp (1.7-2.1), freshwater crustaceans (1.0-1.3), whereas, net fish producers included milkfish (0.33-0.42), catfish (0.28-0.35), tilapia (0.24-0.29), and feeding carp (0.15-0.19).

Moreover, coupled with the use of trash fish as a direct food source for farmed fish and crustaceans within some Asian countries (China reportedly using 4 mmt of trash fish as feed for marine finfish and crustaceans in 2000), it is estimated that the aquaculture sector consumed the equivalent of 17-20 mmt of fish as feed in 2001 (either in the form of fishmeal, fish oil or trash fish, expressed in live weight equivalents) for the total production of 17.69 mmt of aquafeed-based farmed fish and crustaceans in 2001. However, in contrast to the 8 to 11% annual growth rate of the aquaculture sector over the past decade, the proportion of the fish catch destined for use as animal feed has remained relatively constant, fluctuating between a low of 25 mmt in 1998 to a high of 34 mmt in 1994.

In the opinion of the author the aquaculture and aquafeed sector in the coming decade will have to overcome numerous challenges if it is to continue to grow and mature into a truly sustainable global food production sector. These largely inter-dependent challenges can be listed as follows, namely:

1. The need for the finfish and crustacean aquaculture sector to reduce it's current dependence upon potentially food-grade feed resources as nutrient inputs, including fishmeal and fish oil (produced from food-grade marine fishery resources), and food-grade cereals, pulses and oilseeds. Alternative dietary nutrient sources which should be used/evaluated include suitably processed terrestrial animal byproduct meals, fish/crustacean by-catch/processing waste, single cell proteins, and feed-grade agricultural plant by-product meals.
2. The need for the finfish and crustacean aquaculture sector to promote the production of aquatic species feeding low on the aquatic food chain which are capable of utilizing feed-grade agricultural/fishery by-products, filtering natural living biota from the water column, /or are tolerant of non-potable/poor water quality conditions. Examples of such species include cyprinids, tilapia; catfish, milkfish, mullet and rabbit fish.
3. The need for the finfish and crustacean aquaculture sector to improve resource-use efficiency and reduce potential negative environmental impacts through the development of closed biosecure culture systems based on water/nutrient recycling, pathogen/pest exclusion, and/or integration with conventional agricultural crop and livestock production activities. Examples of such systems include the development of zero-exchange culture systems for marine shrimp and the recent growing interest in organic aquaculture.
4. The need for improved feed and food quality assurance schemes, including the need for greater transparency and traceability in the feed and food production process, so as to improve feed/food quality and safety, and consequently increase consumer confidence in the quality and safety of aquaculture produce.
5. The need to promote the nutritional benefits of consuming farmed aquatic produce (as compared with other modern-day terrestrial farm produce), including the positive health attributes ascribed to seafood and aquaculture products to combat the major global issue of malnutrition, including under-nutrition and over-nutrition related disorders. The important role which can be played by compound aquafeeds in the manipulation and/or enhancement of the nutritional value of farmed aquatic produce cannot be understated.

As mentioned at the start of this paper, the aquaculture sector (like any other food production sector) will have to become increasingly more environmentally and ecologically responsible if it is be truly sustainable in the long run and be socially accepted and trusted as an economically viable means of producing safe and wholesome food. In particular, the sector will have to embark on a path of greater transparency (through improved traceability and documentation) in the food production process so as to improve consumer trust and confidence, starting from the feed mill where the aquafeed is manufactured, the farm where the animal is produced, the processing plant where the farm produce is processed prior to shipping, to the nutritional content and safety of the processed food product to the consumer at the end of the supply chain.

Feed Grade Fisheries – Management and Sustainability

Ian Pike. IFFO

With catches of wild fish for human consumption having peaked, further demand for fish will have to come from fish farming. In 2002 production of farmed fish/crustacean reached an estimated 39mlnT [13]. The fish oil used in aquaculture required 14mlnT of inedible wild fish – the so-called 'feed' grade fish – that is, farming produced an output almost trebling the wild fish input – a net gain of around 25mlnT fish/crustacea.

Fishery controls in South America and European waters to ensure sustainability are outlined. Use of satellite trackers to locate fishing boats allow more effective enforcement of period fishery bans (vedas). They are now widely used both in South America and Europe.

The feed grade fish in South America are generally small short-lived species. Government enforced controls to ensure these fish breed to sustain the stock would appear to have been successful, with stable stock levels except during periods of El Niño. El Niños dominate stocks, with periodic depression during the maximum sea temperature anomalies and recovery thereafter. This relatively quick recovery is a further indication of effective management controls of fishing to protect breeding stock.

Controls on fishing in Europe have been largely successful, particularly with respect to Capelin and Sand-eel. As in South America, fish stock management has been independent, with Government enforcement coupled with some voluntary measures to protect sensitive areas for seabird breeding, such as the cessation of fishing in such an area when Kittiwake fledgling production falls.

Currently in European waters only the fishing of blue whiting is of questionable sustainability. The stocks of the former are improving. Mandatory TAC's for blue whiting are expected in the near future.

Balancing fishing to feed man, ensure sustainability and protect wild-life is a delicate balance. Improvements in stock control in recent years are going a long way towards achieving an optimum balance.

[13] Based on 2001 production of 37.85mlnT – from FAO 'The State of World Fisheries and Aquaculture' 2002

Sustainability criteria in the context of ecosystems, fisheries, fishmeal, stocks/resources and aquafeeds.

Derek J Staples
Consultant, FAO

The term "sustainable" has been used to describe just about every activity and commodity known to man, ranging from sustainable existence, sustainable management, sustainable fishery, sustainable resource, sustainable environment etc. The original concept from which these rather loose uses of the term (and hence the concept) came from was Sustainable Development. This is a unifying concept that provides a decision framework to balance the economic, social and ecological dimensions of development to ensure that development itself is sustainable ie providing for the needs of today without compromising the ability of future generations to meet their own needs (Brundtland Report, Our Common Future 1987). FAO have developed Technical Guidelines in the context of an Ecosystem Approach to Fisheries on how to set operational objectives that meet the goals of sustainable development that can be measured and monitored to evaluate progress towards these goals. I will present an outline of the methodology that will highlight some of the policy issues and conflicting objectives that could arise in harvesting small pelagic resources in the context of sustainable development, poverty alleviation and food security. These considerations have added impetus following the recent emphasis placed on the importance and vulnerability of small-scale fisheries and the ecosystem approach endorsed by the Committee on Fisheries (COFI) in Rome, 24-28 February 2003.

AQUACULTURE FEEDS : Research Perspective

S.J. Kaushik
UMR NuAge « Nutrition Aquaculture & Genomics »
Unité Mixte INRA-IFREMER-Bordeaux I
Unité d'Hydrobiolgie, 64310 St-Pée-sur-Nivelle, France
Email : kaushik@st-pee.inra.fr

Abstract

In the Bangkok declaration on aquaculture development (NACA/FAO, 2000), it was clearly stipulated that "Nutrition and feeding strategies play a central and essential role in the sustainable development of the aquaculture sector. Feed development will need to give increased emphasis on efficient use of resources and reduction of feed waste and nutrient discharge. Fishmeal reduction in diets will be important to reduce feed costs and avoid competition with other users".

In the context of sustained development of aquaculture, current research focuses on several issues that are directly linked with feed resource availability, reduced environmental impacts, nutritional quality and food safety assurance. Much progress has indeed been made towards the reduction of feed derived nutrient losses at the source through (i) improvement of feed quality and (ii) appropriate feeding strategies. Serious research programs are under way in the area of fishmeal and fish oil replacement. Data already available show clearly that a significant reduction in the level of incorporation of fish meal is possible, without affecting growth rate or flesh quality in several species of interest to the EU aquaculture. As regards the use of fish oils, one might question the validity of using such important w3 fatty acid sources for energy purposes. A significant reduction in fish oil usage is possible even in marine finfish, without any adverse effect on growth or feed efficiency, provided the EFA needs are met. In order to ensure the nutritional value of fish, there is also much potential for tailoring flesh FA composition using adequate pre-harvest feeding strategies.

There are several other issues which might require our attention. From a practical, resource management point of view, for the most efficient use of renewable feed-stuffs for aquaculture, quality standards need to be developed with particular reference to their potential for aquatic animals.

5 Delegate List

Name	Expertise	Representing
Bell, Gordon	Replacements	Institute of Aquaculture, Stirling
Bergleiter, Stefan	Certification	Naturland
Berntssen, Marc	Replacements / Food safety	National Institute for nutrition and seafood research (Norway)
Cappell, Rod	Assistant to Chair	Nautilus Consultants
Crowe, William	Production	Federation of European Aquaculture Producers / SSGA
Esmark, Maren	Environmental	WWF Norway
Findlay, Chris	Production	Loch Duart
Fresland, Ola	Fishmeal and Aquaculture Research	Norwegian Institute of Fisheries
Garcia, Raul	Environmental	WWF Spain
Grieve, Chris	Certification	Marine Stewardship Council
Halseth, Viggo	Feed/ Production	Skretting
Hambrey, John	Chair	Nautilus Consultants
Hilbrands, Aldin	Certification	SGS
Hooper, Jeremy	Retail / consumer	Tesco
Jensen, Henrik	Fisheries	Danish Institute of Fishereies Research
Kaushik, Sadasivam	Replacements	National Institute for Agricultural Research (France)
Kindleysides, Darren	Environmental	Royal Society for the Protection of Birds, UK
Lem, Audun	Fisheries	Food and Agriculture Organisation
Macdonald, Niall	Feed	EWOS
Minck, Frank	Fishmeal	Association of Fishmeal and Fishoil Manufacturers in Denmark
Morris, Paul	Replacements / Feed	Skretting
Muir, James	Co-chair	Institute of Aquaculture, Stirling
Myrseth, Bjorn	Production	Marine Farms
Olive, Peter	Replacements	Seabait / Newcastle University
Pepper, Simon	Environmental	WWF Scotland
Pike, Ian	Fishmeal	International Fishmeal & Fish Oil Organisation
Sandison, David	Production	Shetland Salmon Farmers Association
Smullen, Richard	Feed	Biomar
Southall, Tristan	Assistant to Chair	Nautilus Consultants
Staples, Derek	Fisheries	Food and Agriculture Organisation
Tacon, Albert	Production/ Feed	Aquatic Farms Ltd
Webster, John	Production	Scottish Quality Salmon / Webster Rae Associates

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Web resources

Fishstat, FAO fisheries department, **www.fao.org/fi/default.asp**

Intrafish – news stories, archives and market reports **www.intrafish.com**

FIS - news stories, archives and market reports www.fis.com

Fishmeal Information Network - industry-supported resource collating information on state of fisheries resources used in the production of fishmeal. **www.gafta.com/fin/fin.html**

Australia's Ecologically Sustainable Development (fisheries) site **http://www.fisheries-esd.com/c/home/index.cfm**

And UK's site **http://www.sustainable-development.gov.uk/**