

## **“LINKAGE BETWEEN FARMED AND WILD FISH – FISHMEAL AND FISH OIL AS FEED INGREDIENTS IN THE CONTEXT OF SUSTAINABLE AQUACULTURE”**

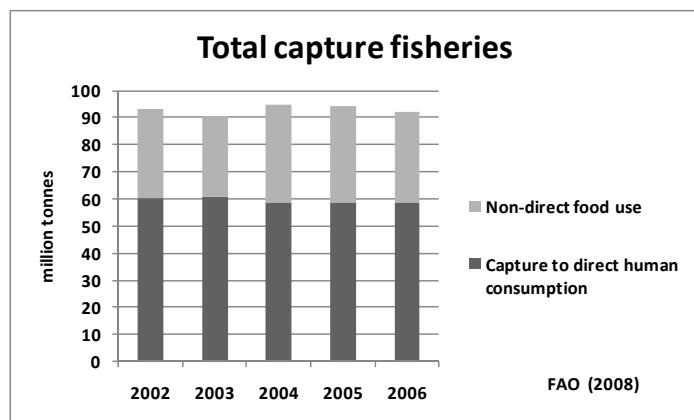
Andrew Jackson and Jonathan Shepherd  
International Fishmeal and Fish Oil Organisation (IFFO)  
2 College Yard, Lower Dagnall Street, St Albans, Hertfordshire, AL3 4PA, United Kingdom

### **1. Introduction**

According to the latest FAO estimates (FAO, 2008), the annual global fish catch (excluding aquaculture) of around 90 million metric tonnes includes approx 30 million metric tonnes representing fish which go for non-direct food use (Fig 1). Of this 30 million metric tonnes around 16.5 million metric tonnes goes for fishmeal and fish oil production, the remainder going for a range of uses, including direct feeding as wet fish to animals (particularly fish and crustaceans in Asia), as well as pet foods and fur-producing animals.

The main use of the fishmeal and fish oil derived from that 16.5 million metric tonnes of whole fish is as feed ingredients for the farming of aquatic animals by means of aquaculture, although other uses include pig and poultry feed as well as fish oil supplements for human health. In addition to this fishmeal and fish oil produced from whole fish, an increasing proportion of fishmeal and fish oil is derived from trimmings as a by-product of fish processing (approx. 5 million metric tonnes in 2008). The purpose of this study is to survey the changing usage pattern of fishmeal and fish oil as components of aquaculture feed and to comment on the implications for sustainable aquaculture.

Figure 1



### **2. The use of fishmeal and fish oil as feed ingredients**

Fishmeal was originally a by-product from fish oil production when fish oil was a low cost oil for margarine production. Fishmeal is now increasingly used as a specialist feed ingredient in aquaculture, young pigs and poultry. The main nutritional benefits of fishmeal are that it is high in protein with an excellent amino-acid profile as well as being highly digestible with no anti-nutritional factors. Fig 2 shows the changing use of fishmeal from 1960 when it was roughly split 50/50 between pigs and chicken and 2008 when 59% was used by aquaculture, 31% by pigs and only 9% by poultry. In 2008 just over 3 million metric tonnes of fishmeal were used in aquaculture and Fig 3 explains that salmonids represented 29% of aquaculture use, crustaceans were 28% and marine fish were 21%, followed by a variety of other freshwater fish.

Figure 2

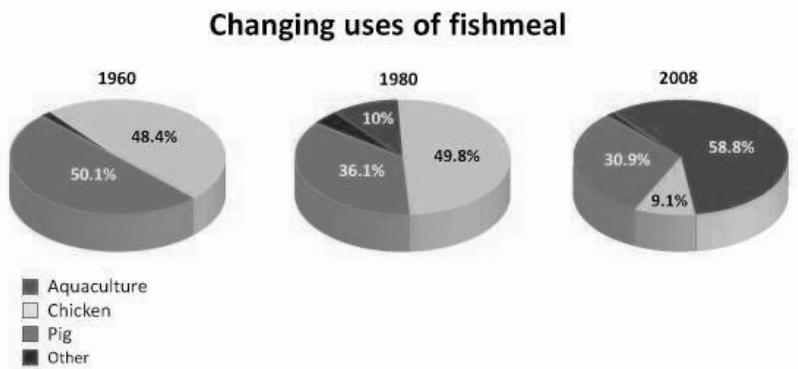
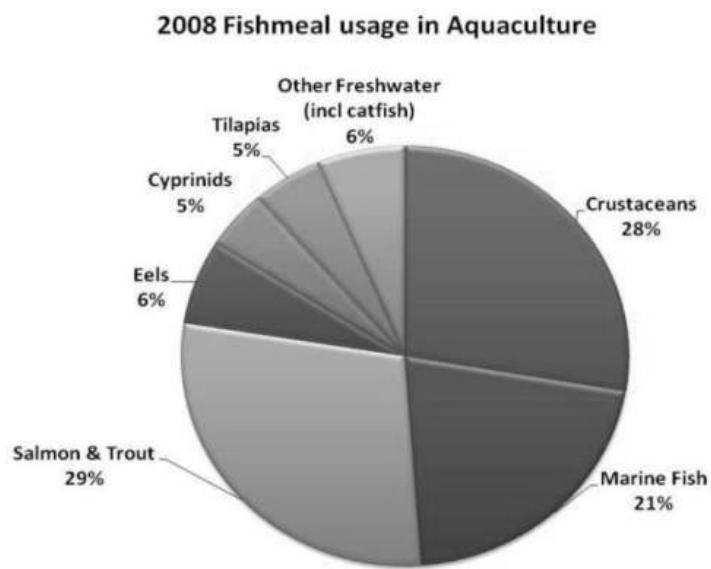


Figure 3



Fish oil was used in the 1960s and 1970s as a low cost source of oil for margarine following hydrogenation, but with the wish to move to unsaturated vegetable margarine, fish oil fell out of favour with margarine manufacturers. However, fish oil is very appropriate for fish feed use being natural, liquid at low temperature and rich in very long chain omega-3 fatty acids, especially EPA and DHA. This last characteristic has fuelled a growth in the market for fish oil as human nutritional supplements for health use mainly via capsules. Fig 4 shows the changing use of fish oil from 1970 when it was split 80% between hardened edible oil and 20% industrial usage to the situation in 2010 when it is estimated that 80% will be used for aquaculture, 12% as refined oil for human use and 7% industrial usage. Thus the predominant use of fish oil is in aquaculture and Fig 5 shows that this is dominated by salmonids at 76% of total aquaculture use.

Figure 4

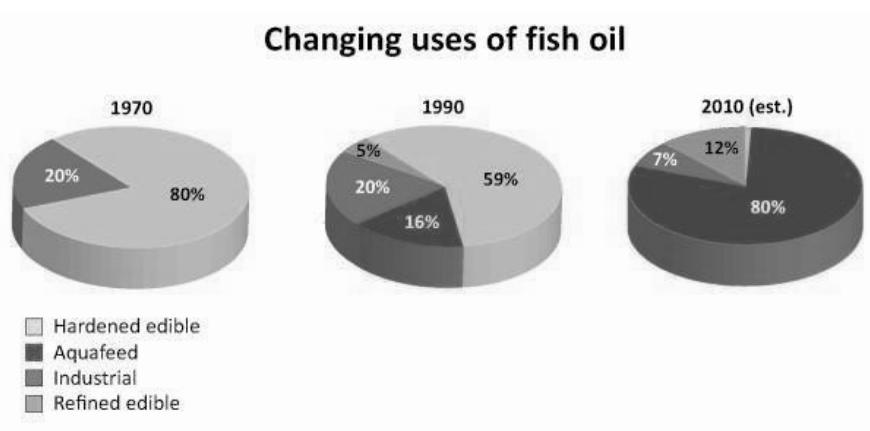
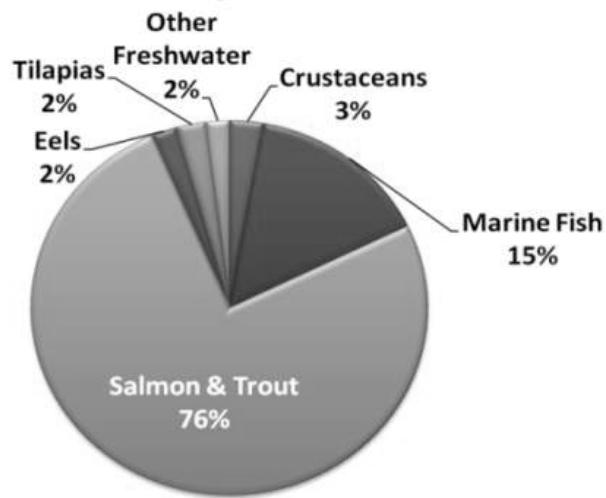


Figure 5

### Use of fish oil in Aquaculture 2008



### 3. Global overview of fishmeal and fish oil production and consumption

Fig 6 shows that the use of fishmeal for aquaculture rose during the period 2000 to 2004 and then reached a plateau at about 3.1 million metric tonnes. This compares with total fishmeal supply in 2008 of approx 4.9 million metric tonnes (the balance being taken up mainly by pigs and poultry). It can be seen that the annual use of fish oil for aquaculture over the period 2000 to 2008 remained fairly constant at between 700,000 and 800,000 metric tonnes compared with a total annual supply of around 1.0 million metric tonnes.

Figure 6

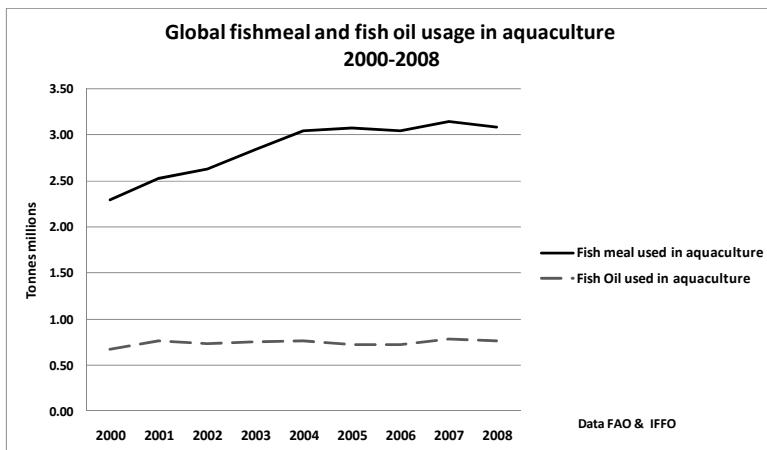


Fig 7 and tables A, B and C are mass balance calculations derived from data by FAO (2009), IFFO (unpublished), and Tacon & Metian (2008). The model shows that in 2008 16.473 million metric tonnes of wild fish were harvested and processed for fishmeal and fish oil, together with 5.491 million metric tonnes of process trimmings from human consumption fisheries. These inputs yielded 4.942 million metric tonnes of fishmeal, 1.032 million metric tonnes of fish oil and 15.990 million metric tonnes of water (the water obviously remained at the site of production released as water or steam).

Table A and Table B are the result of analysing where the outputs of fishmeal and fish oil are used and the amount of raw material and whole fish that can be attributed to each activity on the basis of each marine product separately. The resulting whole fish attribution is then used to calculate a Fish-In:Fish-Out ratio (FIFO) for each fed aquaculture activity (using the definition of fed aquaculture used by Tacon, 2005). These tables show clearly why looking at fishmeal and fish oil attribution separately gives a distorted view. For example, it can be seen that according to Table B, to produce the 120,000 metric tonnes of fish oil going for direct human use, such as capsules, required over 2 million metric tonnes of fish. Whilst being correct, this implies that the fish were only caught for their oil. This is of course not the case since almost as much as five times the amount of meal is extracted as oil.

Given that both fishmeal and fish oil currently yield about the same revenue per tonne (US\$1000-1500/tonne), the fishmeal and fish oil are therefore equally valued and equally important in determining the profitability of the enterprise. It therefore seems logical to combine the fishmeal and fish oil production and conduct a full mass balance analysis of the global system for their production. Table C is the result of such a mass balance analysis which accounts for all raw materials entering the system and the resulting outputs (meal, oil and water) and their attribution to each destination activity.

Taking fed aquaculture alone it can be seen that, if the inputs and outputs are compared by species, 27.495 million metric tonnes of 'fed' aquaculture were produced in 2008 using feed derived from 10.684 million metric tonnes of whole wild 'feed' fish representing a Fish-In:Fish-Out ratio of 0.39:1. This is further broken down to show the corresponding ratios for species groupings, ranging from 2.26:1 for farmed eels down to 0.03:1 for carp, with salmonids at a ratio of 1.77:1. It should be noted that this mass balance approach gives FIFO ratios that are lower than those calculated by Tacon & Metian (2008) using the single ingredient approach, but is consistent with those calculated by Jackson (2010).

Figure 7 Mass Balance in the global production of fishmeal and fish oil - 2008 (IFFO data)

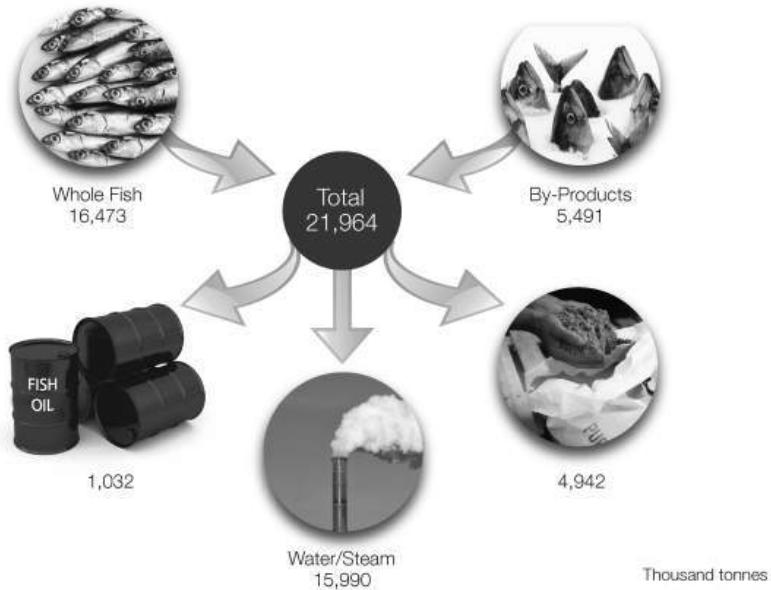


Table A. (Based on IFFO data for 2008; thousand tonnes)

Fishmeal used in farmed production and the resultant whole fish FIFO ratio		
	FM	Raw Material
Chicken	440	1957
Pig	1263	5613
Other Land Animals	160	711
Crustaceans	786	3494
Marine Fish	738	3281
Salmon & Trout	916	4069
Eels	186	825
Cyprinids	130	577
Tilapias	143	636
Other Freshwater	180	800
Aquaculture Sub-total	3079	13683
Total	4942	21964
		16473

Farmed Production	FIFO
N/A	N/A
N/A	N/A
N/A	N/A
4673	0.56
2337	1.05
2365	1.29
244	2.53
13037	0.03
2737	0.17
2102	0.29
27495	0.37

Table B.(Based on IFFO data for 2008; thousand tonnes)

Fish oil used in farmed production and the resultant whole fish FIFO ratio		
	FO	Raw Material
Human Consumption	126	2689
Other uses	110	2340
Crustaceans	28	589
Marine Fish	115	2455
Salmon & Trout	604	12857
Eels	15	320
Cyprinids	1	24
Tilapias	18	376
Other Freshwater	15	313
Aquaculture Sub-total	796	16934
Total	1032	21964
		16472

Farmed Production	FIFO
N/A	N/A
N/A	N/A
4673	0.09
2337	0.79
2365	4.08
244	0.98
13037	0.00
2737	0.10
2102	0.11
27495	0.46

**Table C.** (Based on IFFO data for 2008; thousand tonnes)

Mass Balance for Fish Oil & Fishmeal combined including overall whole fish FIFO ratio					
	FO	FM	Water	Total	Whole Fish
	Farmed Production	FIFO			
Chicken	0	440	1178	1619	1214
Pig	0	1263	3380	4643	3482
Other Land Animals	0	160	428	588	441
Other oil uses	110	0	294	404	303
Human Consumption	126	0	337	463	347
Crustaceans	28	786	2178	2992	2244
Marine Fish	115	738	2285	3138	2354
Salmon & Trout	604	916	4069	5588	4191
Eels	15	186	537	738	554
Cyprinids	1	130	350	481	361
Tilapias	18	143	430	591	443
Other Freshwater	15	180	521	716	537
Aquaculture Sub-total	796	3079	10371	14246	10684
Total	1032	4942	15990	21964	16473
				4673	0.48
				2337	1.01
				2365	1.77
				244	2.26
				13037	0.03
				2737	0.16
				2102	0.26
				27495	0.39

#### 4. The impact of innovation on feed formulation for aquaculture

Worldwide a whole range of different species is being cultured, from herbivorous species of carp through omnivorous fish, such as tilapia and pangasius, to carnivorous species, such as salmon, seabass and eels. However, all species of fish, even herbivorous species of carp, have a very high protein requirement when in the early fry or juvenile stage. In the wild these young fish will feed on small microscopic animals or zooplankton and in some extensive farming systems an environment rich in zooplankton can be created by fertilising the pond. However, the commercial rearing of fish under most intensive conditions now requires the production of protein-rich fry feeds which yields the maximum number of healthy, fast growing fry for on-growing. This means that it is very difficult to meet the high protein requirement of young fish and crustacean of different species without the inclusion of fishmeal under farming conditions.

In some farmed species which were formerly fed diets containing a high proportion of fishmeal (e.g. salmon and shrimp), a growing knowledge of their nutritional requirements is allowing the partial substitution of the marine ingredients with complementary ingredients, particularly those that are plant-derived. The ability to achieve this substitution is most marked at the latter part of the growth cycle when using on-growing diets and it is being aided by two important developments. Plant breeding has produced new varieties of plants like soya and rapeseed which contain fewer harmful anti-nutritional factors and higher protein levels. This has been combined with new techniques for processing the products post-harvest, which makes the nutrients more bio-available; such techniques include both heat and enzyme treatment.

As regards the security of long-term supply, the limited volumes of fish oil produced globally have led some to speculate that aquaculture production will be limited in the future more by availability of fish oil than of fishmeal. This is likely to be avoided in the short to medium term as fish feed companies have learnt how to make existing volumes of fish oil go further by developing techniques of including a blend of different vegetable oils (e.g. rapeseed oil) in diets with the dietary fish oil. These diets combined with special feeding regimes, can give excellent growth performance, when done carefully within appropriate limits and will produce finished aquaculture products, which although lower in total EPA and DHA, have sufficient for fish welfare and to provide some health benefit to the final consumer.

In the longer-term a number of plant breeding companies are working on producing genetically modified varieties of oil seeds which will contain long-chain omega-3 fatty acids. This has now been achieved and the resulting products are currently going through the lengthy licensing process.

The practical result of such innovation is demonstrated by the falling inclusion levels of marine ingredients in salmon and trout diets worldwide over the period 2000 – 2008 (Fig 8), which is continuing. The technology of substitution in salmonids is now sufficiently well-developed that, if the price ratio of soyabean meal to fishmeal gets much higher than the long-run average of 3:1 (Fig 9), there is reduced demand for fishmeal due to increased substitution of fishmeal by soyabean meal. In a similar way there is a close relationship between the prices of fish oil and rapeseed oil with increased substitution of fish oil if the price climbs above that of rapeseed oil (Fig 10), despite the advantage of fish oil's omega-3 content. The challenge for the fish feed formulator is optimising feed costs while meeting nutrient needs of the farmed fish against a background of changing raw material costs.

Fig 11 clearly shows that increasing global aquaculture production during 2000 – 2008 has taken place against a simultaneous pattern of stable (or even slightly declining) usage of fishmeal and fish oil for aquaculture. The consequence is that the use of fishmeal and fish oil for aquaculture has not risen since 2004 and 2001 respectively despite 10% annual growth in global aquaculture. This is due mainly to innovations enabling improved efficiency of use and substitution by complementary ingredients. Also given that some cross-substitution of demand exists between fishmeal and fish oil with vegetable proteins and oils, the market has played a role in balancing supply and demand for feed ingredients. At the same time it's clear that demand for marine ingredients by aquaculture has been stronger than for their use in feed for poultry and (grower) pigs at the prices prevailing over the last decade in particular. Whereas it is possible to replace increasing proportions of fishmeal and fish oil with proteins and lipids from non-marine sources, fishmeal and fish oil continue to be vital strategic ingredients for farmed fish and crustaceans, especially at the critical growth stages.

Figure 8

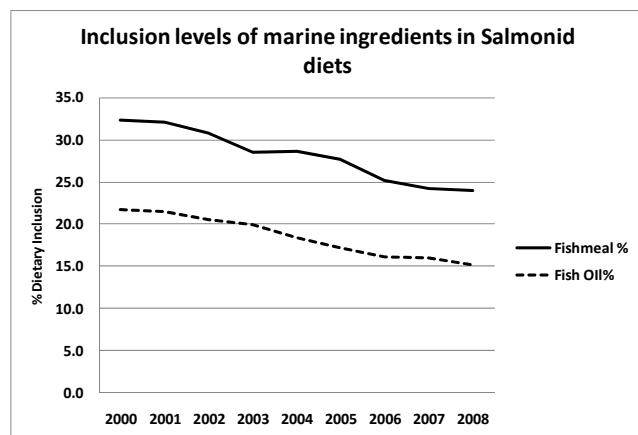


Figure 9

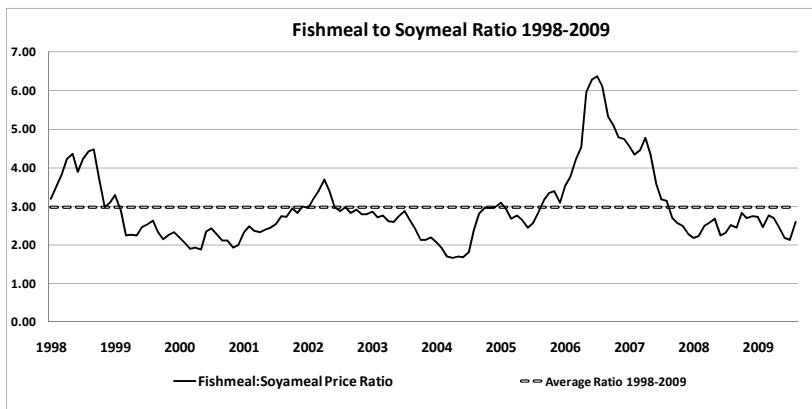


Figure 10

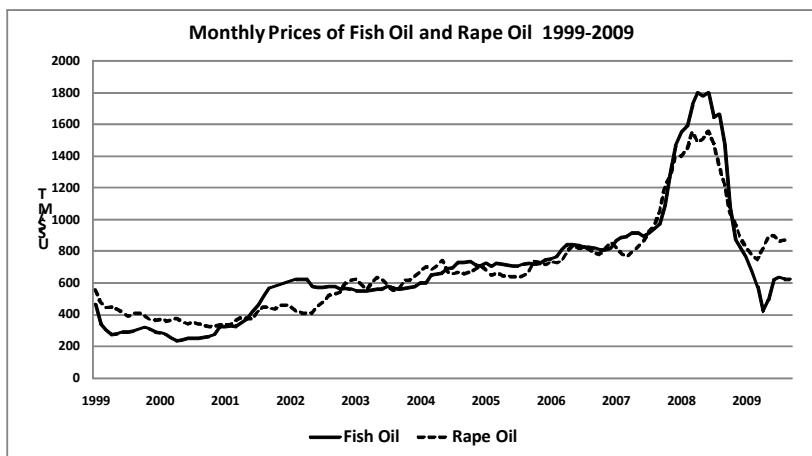
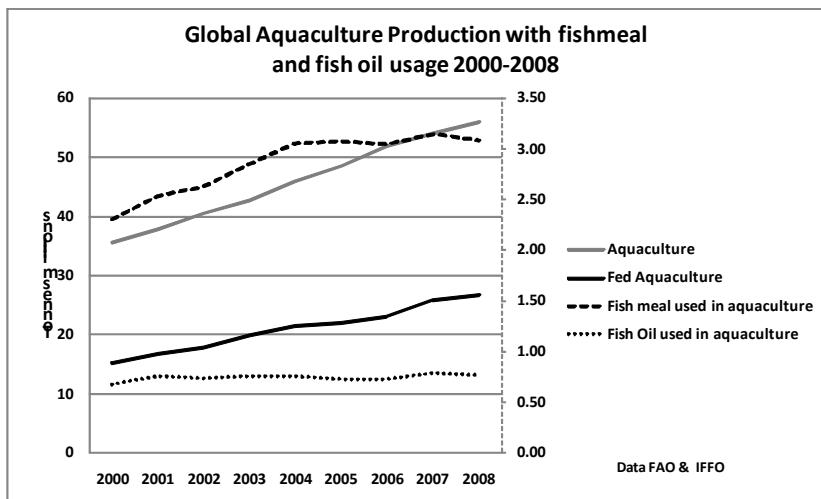


Figure 11



## **5. Compliance with the FAO code of Responsible Fishing**

Almost all feed fishing takes place within national waters and, as with all fishing, there is the potential risk that short-term benefit will drive over-exploitation. By far the largest feed fishery in the world (and the largest fishery with 6.14 million metric tonnes in 2009) is that for the Peruvian anchovy and it is noteworthy that Peru has in place the following controls to avoid overfishing:

### Biomass controls

- Statutory seasons when the fisheries are open and closed
- Annual and seasonal total catch limits
- Only artisanal boats are permitted to fish within five miles of the coast
- Rapid closure when limits are reached or more than 10% juveniles in catch
- Maximum catch limits per vessel (MCLV), a form of catch share

### By-catch controls

- By-catch limit 5% (actual 2007 3.6%)
- Minimum mesh size of 1/2 inch (13mm)

### Unloading

- Formal declaration of hold capacity
- Closed entry to new fishing boats
- Licences required to fish within the 200 mile limit and to land catch
- Security sealed satellite tracking of all boats operating outside the 5 mile limit
- 24 hour independent recording of landings at 134 unloading points
- Fines and revoking of licences for breaches of rules

The 1995 United Nations FAO Code of Responsible Fishing is the only internationally recognised reference for responsible fisheries management at an intergovernmental level. How closely a country implements the Code is a good measure of the quality of their fisheries management. Compliance with the code is therefore an important objective in focusing efforts to ensure long-term sustainability of fisheries, whether for feed use or human consumption.

The aquaculture supply chain is increasingly demanding assurance that products are produced sustainably; in the case of marine ingredients this is often over and above indications from the government statistics for the fishery in question. The Marine Stewardship Council's (MSC) eco-label is the most widely recognised evidence for sustainable fishing for human consumption and cross-references to the FAO Code. However, as of today (Feb 2010) there is virtually no fishmeal and fish oil that comes from MSC approved fisheries and their scheme is focused on the fishery and fish processing plants, whereas fishmeal and fish oil have a different supply chain.

IFFO has recently established a Global Standard for the Responsible Supply of fishmeal and fish oil as a Business-to-Business accreditation scheme with two elements: Responsible Sourcing (i.e. demonstrating fishery stocks are responsibly managed in compliance with the FAO code, including avoidance of illegal, unreported, or unregulated (IUU) fish); and Responsible Production (i.e. demonstrably well managed factories with control systems to prevent contamination).

Such schemes are a valuable tool to differentiate and reward good practice and to drive up standards and lie at the heart of progress towards sustainable fisheries. At the same it should be noted that the FAO code avoids reference to sustainability and refers instead to responsible practice. However, a problem can arise where ecolabels or accreditation schemes can become a barrier to trade, particularly from poorer regions, if they act in practice to prevent the export of farmed fish or other products to customers demanding accreditation. One way of managing this situation, without in any way diluting the standard, is to construct some form of improvement scheme which offers an incentive for upgrading resources over a transitional period until the improver is able to apply for the

standard in question. In the short term a mutually-agreed improvement plan might be followed in order to give some confidence to buyers who might not otherwise wish to source such product; but the main practical difficulty is likely to be a lack of capital to allow the necessary upgrading.

## 6. Responsible feed practices to promote sustainable aquaculture

Feed is the highest cost input to most forms of aquaculture and also one of the areas under most scrutiny with regard to sustainability. It is therefore important that aquaculture pays particular attention to the efficient use of feeds and the inclusion of responsibly sourced ingredients. The use of direct 'trash fish' feeding for aquaculture, mainly in South East Asia, is an area of concern leading to increased risk of health and hygiene problems and also water pollution, when compared with the use of compounded dry diets. The dominance of feed cost encourages farmers to focus on achieving the best conversion from feed to fish and since fish are excellent converters of feed, many farming systems operate with a feed conversion rate (FCR) of approx. 1:1, although there are always trade-offs between achieving maximum growth, minimum FCR and optimum earnings. However, the optimum solution from a short-term commercial farming standpoint may well differ from that based on optimising resource allocation from a longer term perspective.

With regard to the sustainability of ingredients, this logically applies to *all* ingredients, whether of marine origin or not. As already discussed, marine ingredients should come from fisheries managed under the key principles of the FAO Code of Responsible Fishing. As regards the sourcing of other ingredients, we would suggest that at the minimum they conform to the Brundtland Commission definition of sustainability as production that "meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987). Wherever possible some form of independent verification should be adopted to demonstrate sustainable sourcing & production; in the case of marine ingredients this could include MSC or IFFO (which offer a more rational approach than utilising Fish-in:Fish-out ratios as has been suggested). More work is needed to construct a comprehensive, practical model as a basis for evaluating the overall sustainability of different aquaculture feeds.

## REFERENCES

- Brundtland, G.H., 1987. The Report of the Brundtland Commission: *Our Common Future*. Oxford University Press
- FAO, 1995 Food & Agriculture Organisation of the United Nations *The FAO Code of Responsible Fishing*
- FAO, 2008, Food & Agriculture Organisation of the United Nations *The State of World Fisheries and Aquaculture (SOFIA)*
- FAO, 2009 Food & Agriculture Organisation of the United Nations *FAO FISHSTAT*
- Jackson, A.J., 2010. Fishmeal and Fish Oil: Prime feed ingredients not limiting factors for responsible aquaculture. *Global Aquaculture Advocate* January/February, 14-17
- Tacon, A.G.J., 2005. Salmon aquaculture dialogue: status of information on salmon aquaculture feed and the environment. *International Aquafeed* 8, 22–37.
- Tacon, A.G.J. and Metian, M. 2008. Global overview on the use of fish meal and fish oil in industrially compounded aquafeeds: trends and future prospects. *Aquaculture* 285, 146–158.

## LIST OF FIGURES

Fig 1 Global fish catch comparing fish caught for feed use and for human consumption

Fig 2 Changing use of fishmeal from 1960 to 2008

Fig 3 Use of fishmeal by different aquaculture species in 2008

Fig 4 Changing use of fish oil from 1970 to 2010

Fig 5 Use of fish oil by different aquaculture species in 2008

Fig 6 Global aquaculture usage of fishmeal and fish oil from 2000 to 2008

Fig 7 Mass balance in the global production of fishmeal and fish oil

Fig 8 Inclusion levels of marine ingredients in salmonid diets from 2000 to 2008

Fig 9 Global aquaculture usage of fishmeal and average price ratio of soyabean meal to fishmeal from 2000 to 2008

Fig 10 Prices of fish oil and rapeseed oil from 1999 to 2009

Fig 11 Global aquaculture production and aquaculture usage of fishmeal and fish oil from 2000 to 2008

## **LIST OF TABLES**

Table A Mass balance of fishmeal with farmed production

Table B Mass balance of fish oil with farmed production

Table C Mass balance of fish oil and fishmeal combined including overall FIFO