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Fish for Feed vs Fish for Food

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Fish for Feed vs Fish for Food

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Aquaculture is the fastest-growing food producing industry sector in the world. Demand for feed ingredients, particularly for preferred protein sources such as fishmeal, fish oil and 'trash fish', has also increased, raising questions about sustainability and uses of fish for aquaculture feeds or directly as human food.

Approximately 30 million metric tonnes (MMT) of fish from capture fisheries are used each year to produce fishmeal and fish oil. The species used are not usually consumed directly by humans. Production of fishmeal and fish oil has remained relatively static over many years, with the increasing amount going to aquaculture feeds being balanced by reducing amounts going to other animal feeds.

Trash fish are generally smaller or lower-value species captured in the wild and are increasingly used to directly feed aquaculture species in Asia. Although there is no reliable estimate of the total amount of trash fish used by aquaculture, the figure is probably >5 MMT y^{-1} . As aquaculture expands, the potential for conflict between uses and

users of different fish products is increasing. There is an urgent research priority to identify potential impacts of increasing demand on trash fish for aquaculture on fish resources and to identify practical alternatives.

The identification and use of alternative ingredients for aquaculture feeds has been an international research priority for at least 15 y, and significant advances have been made. Fishmeal has been completely replaced in feeds for many species and included at very reduced levels in feeds for many others. These trends need to continue and ongoing research in this field remains a priority.

Research to replace fish oil is more difficult, but blends of vegetable oils have been used to successfully reduce reliance on fish oil for a number of species. Coldwater marine algae called thraustochytrids, with very high contents of 'marine' fatty acids, may provide an alternative if industrial-scale fermentation can be made cost effective.

Introduction

Aquaculture is the fastest-growing food producing industry sector in the world. This rapid growth has been accompanied by a rapid increase in the amount of aquaculture feeds (aquafeeds) used throughout the world. I will examine the issues surrounding the increasing use of fish and fish products, such as fishmeal and fish oil, as aquafeeds or as ingredients in aquafeeds.

Why is aquaculture growing so rapidly? Fish is the most important source of protein in the world, representing around 25% of total protein intake in many developing countries and around 10% in North America and Europe (FAO 2000; Delgado *et al.* 2003). Increased demand for fish (aquatic protein) is being driven mainly by population growth. Global population reached 6 billion in 2000 and is predicted to reach 6.8 billion by 2010. Average global per-capita annual consumption of

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fish has also increased from about 12 kg in 1973 to nearly 16 kg in 1997 (Delgado *et al.* 2003). These factors have been responsible for an increase in total consumption of food fish from 40 MMT in 1970 to 86 MMT in 2000 (Fig. 1). Consumption is predicted to reach 110 MMT by 2010 (FAO 1999) and, using the same extrapolation, nearly 140 MMT by 2025.

These demands are met from two distinct supply sectors, capture fisheries and aquaculture. While seafood consumption doubled between 1973 and 1997 and increased by 31% from 1990 to 1997 (Delgado *et al.* 2003), from 1970 to 2002, total landings from capture fisheries increased by only 1.2%. The increase in demand was met from an average compound growth rate for aquaculture production of 8.7% p.a. (Tacon 2004). Over 50% of ocean fisheries are fully exploited and 70% listed as in need of urgent management (MacLennan 1995; FAO 1999). Future increases in seafood supply from capture fisheries to meet projected future requirements (Fig. 2) are unlikely.

Just as all agricultural production and capture fisheries production has environmental impacts, so too does aquaculture. As production increases, especially where this increase is driven from intensification in farming practices, the potential for negative environmental impacts increases. One of the key issues associated with various types of

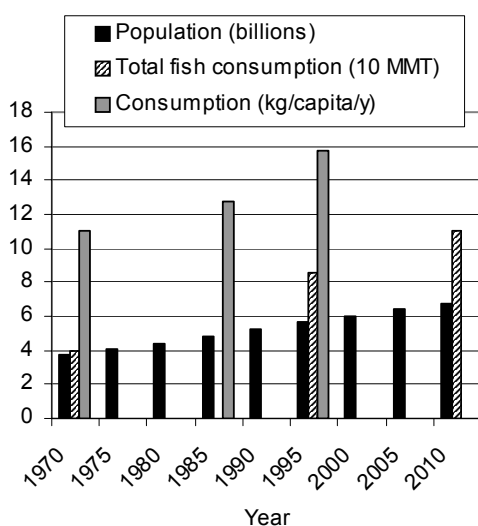


Figure 1. Population growth, total fish consumption and per-capita fish consumption from 1970 to 2010 (Data from FAO 2002; Delgado *et al.* 2003; Tacon 2003).

aquaculture include the practice of feeding other fish (fishmeal, fish oil, trash fish = feed fish) to aquaculture species. This has the potential to cause conflicts between the use of these resources for aquaculture and their use for human consumption.

Feeding fish to fish

Approximately 30 MMT of fish from capture fisheries each year are used to produce fishmeal and fish oil (Pike and Barlow 2003). Fishmeal and fish oil are highly regarded ingredients in aquaculture feeds, and their use in aquafeeds has increased considerably over the last two decades. Fears have been raised that this trend may have disastrous consequences for marine ecosystems (Naylor *et al.* 2000) and even that the practice is driving 'baitfish' fisheries to extinction. It has also fuelled concerns that aquaculture is not contributing to net supplies of fish.

The species used are called 'bait fish' or 'industrial fish' and include anchovies, sardines, anchovetta, herring, capelin, sand eels and other generally small, short-lived species. While humans eat small quantities of some of these species, in general, they are small, oily and bony and

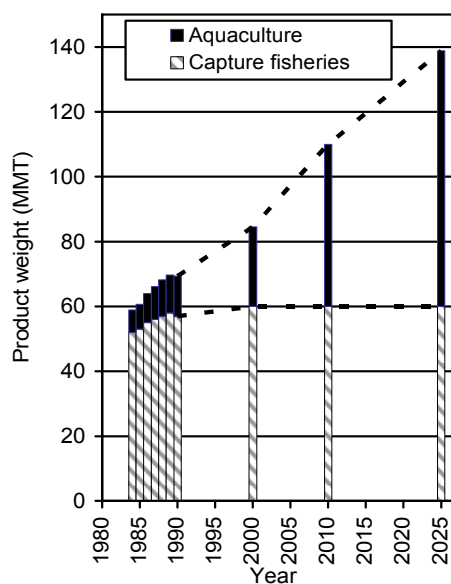


Figure 2. Production from capture fisheries and aquaculture and projected requirements to 2025. Data are based on actual production figures to 2000 (Tacon 2003) while projections are based on population growth and consumption trends.

not highly regarded (Pike and Barlow 2003). In addition, they are more suited to industrial processing than processing for human consumption, partly because of the damaging methods that are used to capture and store these fish. Fishmeal and fish oil are traded on the world protein meal and oil markets respectively and compete with products like soybean meal and vegetable oils. In the past, fishmeal was used mainly as a protein source for terrestrial animal feeds and as a fertiliser, while fish oil was used as an energy source in animal feeds, as a component in edible products and for industrial applications (Pike and Barlow 2003).

Figure 3 shows total aquaculture production, estimated total aquafeed production, fishmeal and fish oil requirements for different aquaculture sectors for 2000. Data are based on estimates of the proportion of the culture of various species groups that are 'fed', the average feed conversion ratio (ratio of dry formulated aquafeeds to wet fish) and the average content of fishmeal and fish oil in the ration. These data show that about 16.3 MMT of aquaculture production comprises species that are 'fed'. The remainder of the 35.6 MMT of food fish produced (excluding aquatic plants from the 45.7 MMT total aquaculture production for 2000) includes species that are filter feeders (including species of fish and molluscs)

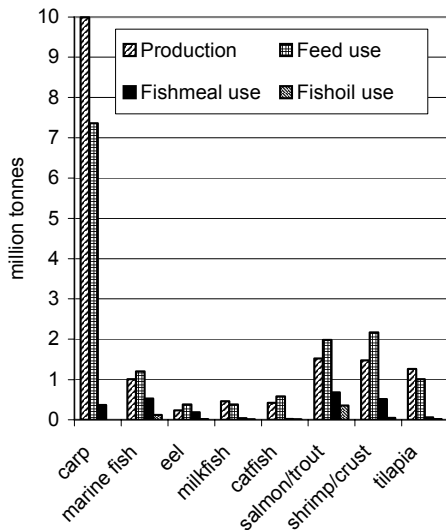


Figure 3. Production, estimated total aquafeed, fishmeal and fish oil requirements for different aquaculture sectors for 2000 (Data are from Tacon 2003).

(Tacon 2003). About 15 MMT of aquafeed is used to produce the fed species. This gives an average food conversion ratio of less than 1:1. This is low because, even for fed species, production is subsidised by natural foods (i.e. natural pond production of food organisms). The total fishmeal and fish oil used in aquafeeds is 2.4 MMT and 0.55 MMT, respectively (Tacon 2003). The equivalent amount of bait fish used to produce this amount of fishmeal and fish oil is 14.8 MMT (Tacon 2003).

Examination of the production statistics for bait fish landings, fishmeal production and aquaculture shows that there has been no significant relationship between the steeply increasing aquaculture production and landings of baitfish (Fig. 4). This is because while use of fishmeal for aquaculture has increased, use for other purposes has decreased (the same applies to fish oil).

Aquaculture is taking a greater share (18% of total supplies of fishmeal in 1988 compared with 34% in 2002) (Figs 5 and 6).

Clearly this reallocation of fishmeal and fish oil to aquaculture cannot continue indefinitely, and if aquaculture is to continue to grow, aquafeeds with reduced contents of fishmeal and fish oil are needed. This is happening. The identification and use of alternative protein and lipid sources has

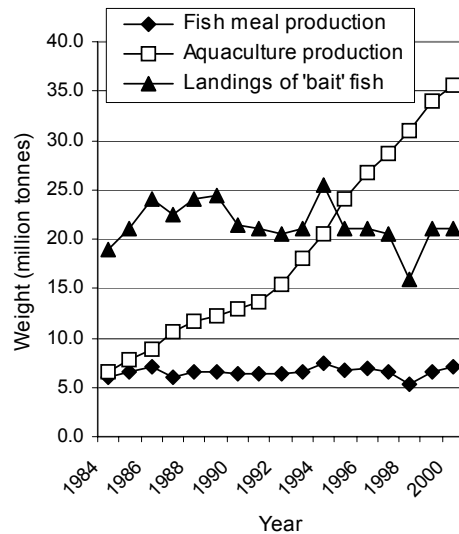


Figure 4. Aquaculture production in relation to fishmeal production and baitfish landings (Data from Tidwell and Allan 2001; New and Wijkstrom 2002; Tacon 2003).

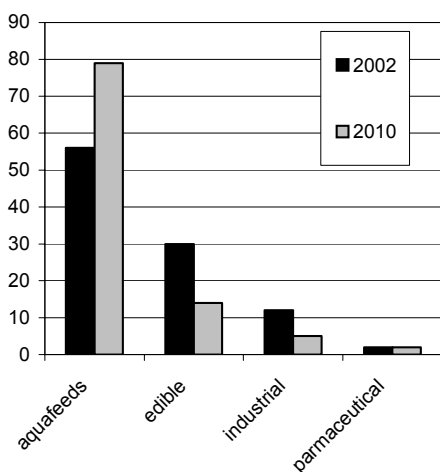
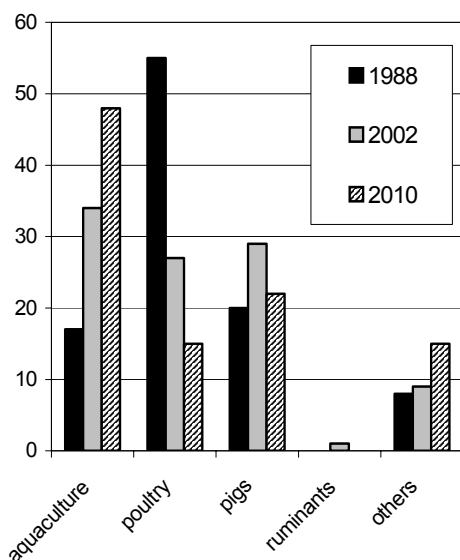
been an international research priority for at least 15 y, and significant advances have been made. Fishmeal has been completely replaced in diets for many species and included at very reduced levels in feeds for many others. Even fish oil can now be included at much lower contents — even in diets for coldwater marine carnivores. Improved research is leading to better feeds and lower feed conversion ratios. Tacon (2003) predicts that the use of bait fish for aquaculture may actually decline over the next 20 y as these improvements deliver reduced reliance on aquatic

protein sources.

In addition to the use of fishmeal and fish oil in aquafeeds, whole fish are used to directly feed several species of mostly marine fish and crustaceans in Asia and some other regions. The species used are usually collectively called trash fish because, in the past, this was the component of the wild catch that was discarded. The species comprising marine trash fish in Vietnam are listed in Edwards *et al.* (2004) and are likely to be representative of the species used throughout Asia.

Although there are no global estimates of the total amount of trash fish used in aquaculture, it is likely that total use of trash fish for aquaculture exceeds 5 MMT annually. China totally dominates aquaculture production, including of species fed trash fish, and use of trash fish in China for aquaculture was estimated at 4 MMT annually in 2001 (D’Abramo *et al.* 2002). Probably the second-largest user of trash fish in Asia is Vietnam. Edwards *et al.* (2004) conducted a survey of trash fish use in Vietnam and the estimated use for inland and coastal aquaculture ranged from 64.8 to 71.8 and 180.0 to 323.3 thousand t annually respectively. Edwards *et al.* (2004) found that trash fish was by far the most important component of the capture fishery in Vietnam, representing an estimated 36% of total catch. With the single exception of a new fishery established at Cat Lo in south-eastern Vietnam, there are no specific fisheries for trash fish in Vietnam. trash fish is a by-product of fishing for higher-value fish, crustaceans and molluscs. However, although there is wide recognition that the inshore fishery of Vietnam is heavily over-fished, the total catch continues to rise, as does the proportion of trash fish in the catch (Edwards *et al.* 2004). There was no indication that the species comprising trash fish are over-exploited, yet. However, there is uncertainty about the relationship between depleted inshore fisheries and increasing supplies of trash fish (Edwards *et al.* 2004). Understanding the dynamics of trash fish species and other parts of the marine ecosystem is an urgent priority, not only for Vietnam but for the Asian region as a whole.

The price of trash fish in Vietnam has recently doubled, reflecting increased demand for aquaculture, and the consensus is that regardless of the status of the fishery, availability of trash fish as a direct feed for aquaculture is likely to limit future



Figures 5 and 6. Percentage use of fishmeal (top figure) and fish oil (bottom figure) for aquafeeds and feeds for other animals in 1988 and projected for 2002 and 2010. (Data from Pike and Barlow 2003).

growth of aquaculture, although the extent is both species- and area-specific (Edwards *et al.* 2004).

In Australia, large quantities of baitfish are also used to feed southern bluefin tuna farmed in South Australia. This \$240 million y^{-1} industry is based on on-growing wild-caught tuna. About 95% of the 5265 t Australian bluefin tuna quota for South Australia is on-grown in sea cages off Port Lincoln (Rob Van Barneveld, Tuna Nutrition Principal Investigator, Aquafin CRC, *pers. comm.* 2004). Collectively the tuna increase in weight by about 3000 t and require between 50 000 and 60 000 t of pilchards (van Barneveld, *pers. comm.*).

Formulated feeds are being developed to replace the use of trash fish for several aquaculture industries in Asia. These trends need to continue, and ongoing research in this field remains a priority. Development of cost-effective techniques to concentrate the protein in cereals, oilseeds and grain legumes is needed, and the on-going evaluation of these products in aquaculture feeds is required.

Summary of research

There has been significant progress with the search for alternative protein sources to fishmeal. In Australia, coordinated research on a number of species has shown that fishmeal can be completely replaced in feeds for omnivorous silver perch and carnivorous barramundi provided the nutrient profile of the diet is maintained (digestible protein and digestible energy are the most important), and more than two-thirds of fishmeal can be replaced in feeds for prawns (Allan *et al.* 1999; Allan and Rowland *in press*). Replacement protein sources include grains (e.g. lupins, soybean meal, peas and beans and wheat products) and terrestrial animal meals (e.g. meat meal and poultry meal) (Allan *et al.* 1999).

For marine fish species, total replacement of fishmeal has been less successful. However, research into this area is increasing and there are more and more reports of successful partial fishmeal replacement in feeds for carnivorous species. Coutteau *et al.* (2002) concluded that very promising results are being reported for partial replacement (up to 25–50%) of fishmeal and fish oil, but that higher levels of replacement will be more difficult. For Australian snapper (= Japanese red sea bream), Quartararo *et al.* (1998) found up to 50% of fishmeal was successfully substituted

with a mixture of soybean meal and poultry offal meal, and more recent studies with this species have shown that provided digestible energy and protein are balanced, feeds with as little as 16% fishmeal (substituted with a blend of 5% meat meal, 18% poultry meal and 20% soybean meal) produced similar growth to diets with 25% or 60% fishmeal (Booth and Allan, unpublished data 2004). These data indicate that substantial replacement of fishmeal is possible, particularly with blends of alternative protein sources.

With abundant grain and meat meal production, there is potential for Australian agricultural products to be used in increasing amounts in aquafeeds. Already about 20–25 thousand t of dehulled lupins are used in aquafeeds, mainly in Norway, Japan and Australia (Brett Glencross, WA Fisheries, *pers. comm.* August 2004). Other grain products with potential for increased use in aquafeeds include protein concentrates from lupins and soybeans, wheat gluten products and corn gluten.

Constraints to increased substitution include limited availability and perceived problems with terrestrial animal meals, especially meat meals, anti-nutrients in plant ingredients, the high cost of protein concentration to make plant ingredients more attractive for use in aquafeeds, and problems with pellet stability when increasing amounts of some types of alternative ingredients are used. Barriers to replacement of trash fish include difficulties with availability of formulated diets (including cash-flow problems experienced with many small-scale fish farmers making it difficult for them to purchase formulated feeds in advance) and a general distrust of the efficacy of such diets. For some species, e.g. tuna, acceptance of formulated feeds remains an issue. Understanding of nutritional requirements, even for digestible energy and protein, is lacking for many species, especially tropical marine carnivores.

Research to replace fish oil is more difficult, but blends of vegetable oils have been used to successfully reduce reliance on fish oil for a number of species. Glencross *et al.* (2003) studied effects of replacing up to 100% of fish oil with either soybean oil or canola oil in feeds for Australian snapper. There were no significant effects when 100% of fish oil was replaced by soybean oil or 75% by canola oil, although changes in the fatty acid profiles of the fish were reported.

Replacement of fish oil in aquafeeds will affect fish carcass composition, and the reduction in long-chain, essential fatty acids such as eicosapentaenoic acid (20:5 n-3) and docosahexaenoic acid (22:6 n-3) is a likely consequence that will impact on the health benefits of eating fish. Suggested approaches to deal with this are the use of fish oil replacements in the diets for most of the culture cycle, with the use of finisher diets high in essential fatty acids (fish oil) prior to harvest. In the longer term, selective breeding or genetic engineering to increase the proportion of n-3 essential fatty acids in vegetable oils has been proposed (Coutteau *et al.* 2002).

Thraustochytrids are common marine microalgae that naturally contain very high contents of essential fatty acids. For example, some species of thraustochytrids (e.g. *Schizochytrium* sp.) have yielded a biomass of up to 48 g L⁻¹ with 77% total lipid and 36% docosahexaenoic acid (Lewis *et al.* 1999). These microalgae, or extracts from them, are already being used in aquaculture diets, but usually for very high value larval diets or enrichment diets. However, if (when?) mass techniques for biofermentation improve, these coldwater marine algae are likely to play a role in finisher diets and possibly even regular grow-out diets.

Conclusion

Aquaculture is growing rapidly and will continue to do so, fuelled by increasing demand from a growing population wishing to increase seafood consumption. Intensification of aquaculture, leading to increased reliance on formulated aquafeeds, and development of industries for new species, will continue. Aquatic protein and lipid sources (mainly fishmeal and fish oil) will remain highly sought-after ingredients for use in aquafeeds. This is especially true in Asia where the direct use of wild caught fish as a feed source for aquaculture (trash fish) will continue although, increasingly, formulated feeds will replace this practice.

Claims that the increasing demand for aquafeeds will destroy the stocks of bait fish used as trash fish, and to produce fishmeal and fish oil, are not supported by the evidence to date. Despite massive increases in aquaculture over the last 20 y, catches of species used to make fishmeal and fish oil have remained stable. The increased use of these species for aquafeeds has been possible because of a reduction in their use in feeds for ter-

restrial animals, mainly pigs and poultry. At least in Vietnam, the catches of trash fish are actually increasing, possibly fuelled by increased effort as well as the removal of natural predators through other fishing practices.

While catches are stable, there is little prospect that trash fish catches will increase, and for aquaculture to continue to grow, substitutes must be found. Research has identified a number of potential replacements from both terrestrial animal meals and plant ingredients. Increasing amounts of grains are now being used in aquafeeds and this trend will continue. Fish oil is more difficult to replace, but even here, significant advances are being made. The use of 'finisher' feeds high in essential, long-chain fatty acids should allow fish oil substitution for grow-out feeds without negatively affecting the health benefits of eating cultured fish.

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