

Use of wild fish and other aquatic organisms as feed in aquaculture – a review of practices and implications in Africa and the Near East

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SUMMARY

Global aquaculture production has more than tripled over the last 15 years. The 45.6 million tonnes of produce derived from aquaculture in 2004 made a notable (47.7 percent) contribution towards total global fish, crustacean and mollusc production. However, there is concern that the contribution by aquaculture to global food security is misleading because aquaculture is the single largest consumer of fishmeal and fish oil. In 2003, just over 53 percent of the total fishmeal production (i.e. 2.94 million tonnes of 5.54 million tonnes was used by aquaculture). Similarly, 87 percent of world fish oil production was used in aquaculture in 2003 (i.e. 0.8 million tonnes of a world total of 0.92 million tonnes). Hence, there is a growing concern that some of the world's feed-fish fisheries are not being used with adequate consideration for human requirements, and that a portion of these resources could be better used to contribute towards food security in developing nations.

Aquaculture production in Africa grew by 358 percent between 1995 and 2004. As in Asia, this increase is largely attributed to the culture of non-carnivorous species. Therefore, unlike the global average where more than half of the fishmeal is consumed by fish farming, aquaculture is not a major fishmeal consumer in most African countries. To make estimates on fishmeal production and use with any reasonable degree of confidence is difficult because the entire region, except for isolated instances, is extremely data poor, and the actual consumption of fishmeal and fish oil by the animal feed industry (including the aquafeed industry) in almost all African countries is unknown. However, based on available animal feed production figures and average fishmeal inclusion rates it was possible to estimate a fishmeal consumption of approximately 425 000 tonnes. Annual fishmeal production in Africa and the Near East approximates 200 000 tonnes, suggesting that about 47 percent of the fishmeal used in the region is locally produced. Based on aquafeed production data, it was estimated that the total consumption of fishmeal by the aquafeed industries in the region is between 25 000 and 76 000 tonnes.

Although there are adequate species-specific data on small pelagic landings in Africa and the Near East, the majority of fishmeal production is not reported at the species level. It is, therefore, difficult to estimate spatial and seasonal availability of the commodity. Some pelagic fisheries in the region have been subject to unsustainably high levels of fishing in the past. Recent findings suggest that these stocks are not as resilient as previously assumed, which leads to the conclusion that most fisheries in the region are not adequately managed and that this requires urgent attention to ensure the long-term sustainability of the resources. On the whole, except for South Africa and Morocco, fishmeal production in Africa is a relatively minor small-scale type of activity in relation to the rest of the world, hence the region is extremely data poor. South Africa has the only dedicated reduction fishery in the region, although Morocco has the largest small pelagic fishery. Until recently, fishmeal production in Morocco was considered as a surplus activity. It was estimated that up to 40 percent of the small pelagic landings in Africa and the Near East is reduced to fishmeal.

Although much of the world's small pelagic catch is not used for direct human consumption in the developed world, there is a ready and large demand for this fish as food in the developing world. There are numerous examples in Africa where communities that were once reliant on small pelagics as part of their diet no longer have ready access to these resources mainly because of the growing demand by the animal feed industry. In some instances, the increase in animal production (including aquaculture), which is largely reliant on fishmeal, can improve the standard of living and level of food security among poor communities, due to employment opportunities that are created. However, this is only possible if the fishmeal is used locally and the production of the "secondary" product creates employment. Although most of the fishmeal produced in Africa and the Near East is used locally, the production of a "secondary" product does not always create employment among the communities that would otherwise have used the fish for direct consumption. A comparison of post-harvest losses and the proportion of the region's small

pelagic catch that is reduced to fishmeal highlights the urgent need to focus on improved post-harvest technologies, such that spoilage can be avoided.

By way of some examples, the report illustrates that the reduction of fish can either have negative or positive impacts on the poor. Hence, it is difficult to make broad regional recommendations with respect to reduction fisheries and, of course, this is further compounded by the fact that there are no reduction fisheries, *sensu stricto*, in Africa and the Near East, except for South Africa. In conclusion, and principally on the basis that there are only two fishmeal and fish oil-producing countries of substance in the region, it is recommended that steps be taken to; (1) improve monitoring and reporting of fishmeal and fish oil production and consumption; (2) improve monitoring such that analyses to determine the financial benefits of fish reduction versus loss of food security can be undertaken; and (3) create greater awareness of the potential benefits of small pelagic fisheries with respect to food security and poverty reduction, particularly in areas where imbalances already exist and where the reduction of fish may exacerbate the problem of low food security in the future.

1. INTRODUCTION¹

1.1 Background

World capture fisheries have reached a plateau at approximately 94 million tonnes (FAO, 2006b). Recent estimates suggest that 52 percent of marine stocks are fully exploited, 17 percent are over exploited and 7 percent are totally depleted (FAO, 2005a); however, human population and the demand for marine and other aquatic resources continue to increase. Global aquaculture has made a considerable contribution towards bridging the gap between supply and demand. Total production (excluding aquatic plants, corals and amphibians) in 2004 amounted to just over 45 million tonnes, contributing 47.7 percent to total global fish production (FAO, 2006a, 2006b). Globally, aquaculture production has more than tripled in the last 15 years (FAO, 2006a). Most notable have been the increases in production in China and Chile.

Fishmeal and fish oil are important feed ingredients in aquaculture, and by 2003 the consumption of fishmeal and fish oil by the sector had increased to 2.94 million and 0.80 million tonnes, representing 53.2 and 86.8 percent of global production, respectively (Tacon, Hasan and Subasinghe, 2006). Naylor *et al.* (2000) argue that the farming of carnivorous fishes, in particular, has placed undue pressure on world fishmeal supplies by using up to five times more fish protein than that which is produced. Although there are discrepancies in the ratio of wild-fish consumed to farmed-fish produced, there is general agreement that species such as salmon, trout and other carnivorous marine finfish consume considerably more fish protein than they produce (FIN, 2004). However, this is not the case for herbivorous, omnivorous, detritivorous and planktivorous species, which produce considerably more fish protein than they consume (Naylor *et al.*, 2000). The growth of the aquaculture industry is fortunately skewed in favour of non-carnivorous species, which are produced by more extensive and traditional methods of aquaculture (i.e. with little to no fishmeal in the diet). It is mainly for this reason that the balance is tipped in favour of aquaculture (Roth *et al.*, 2002). Nonetheless, aquaculture is reported to be the single largest user of fishmeal, using in excess of 53 percent of the global supply (Tacon, 2004; Tacon, Hasan and Subasinghe, 2006). This review is a contribution towards the overall goal of the project as outlined in Footnote 1.

2. OVERVIEW OF AQUACULTURE IN AFRICA AND THE NEAR EAST

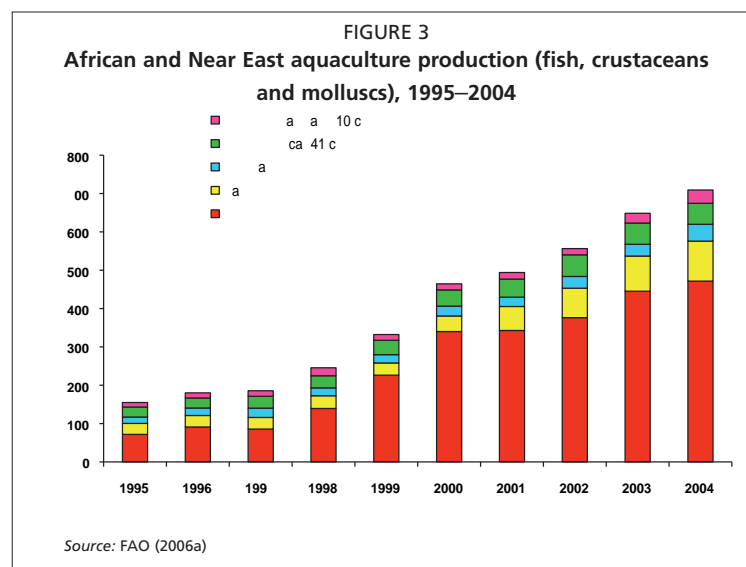
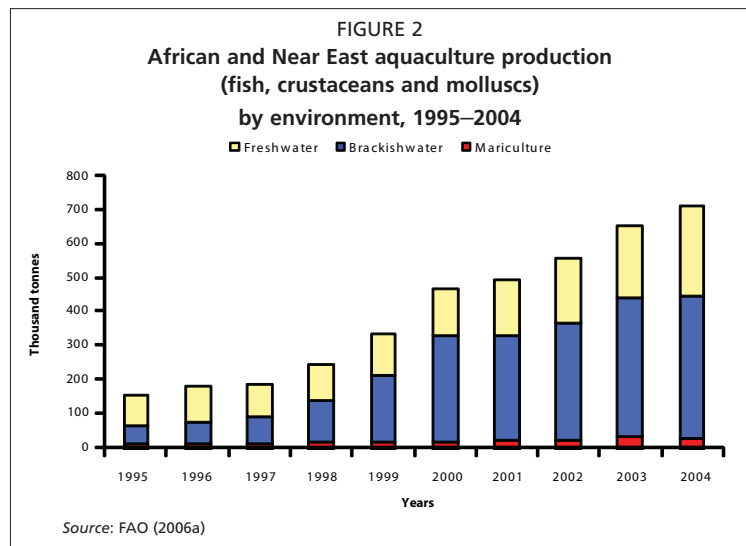
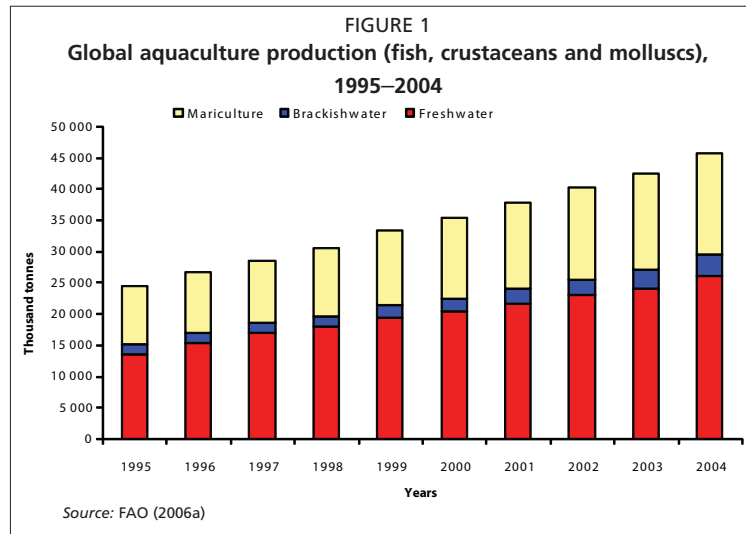
2.1 Current status and trends

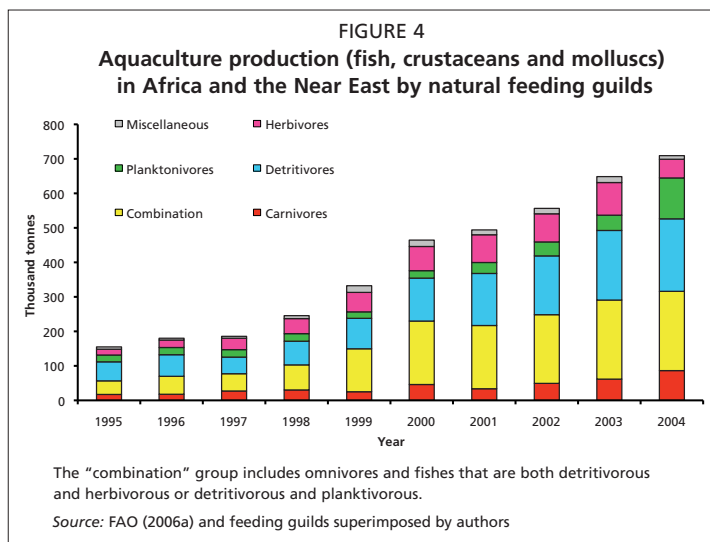
Globally, aquaculture production has almost doubled during the course of the last ten years. Approximately 24.4 million tonnes of fish, molluscs and crustaceans were produced in 1995, and by 2004 production had increased to 45.6 million tonnes (FAO, 2006a). Aquaculture in Africa (particularly in North Africa) and the Near East has also grown substantially over the last decade, and although this region still makes a relatively small contribution to global production, its potential for aquaculture is recognized. This is evident in the increased contribution to global aquaculture (from 0.005 percent in 1995 to 1.19 percent in 2004) (FAO, 2006a) by the region. Growth of the sector in Africa and the Near East exceeds the global growth rate. Total aquaculture production in this region increased from 166 525 to 721 645 tonnes between 1995 and 2004, which represents a growth rate of 334 percent compared to the global increase of 90 percent for the same period (Figures 1 and 2). The greatest proportion of growth in

¹ The countries included in this review are listed in Appendix 1 and are limited to those countries of Africa and the Near East that were reported by FAO to have produced aquaculture products and those countries reported to have produced, consumed, imported or exported fishmeal and fish oil. The term “fishmeal” is inclusive of white-fishmeal, oily-fishmeal, tuna meal, clupeoid fishmeal and crustacean meal. The term “fish oil” is inclusive of all fish and marine mammal body and liver oils, fats and solubles. It is important to note that the region is extremely data poor with respect to reduction fisheries, except for Morocco and South Africa. Moreover, in many instances there is conflicting information and data on reduction fisheries such that the reliability of many sources is questionable.

Africa and the Near East has taken place in brackishwater aquaculture (most notably, in Egypt) and to a lesser degree in freshwater (Hecht, 2006). This is not the case for global aquaculture, where most growth has taken place in marine and freshwater (Figures 1 and 2)

Aquaculture in Africa and the Near East is dominated by Egypt, the Islamic Republic of Iran and Nigeria, which collectively contributed 87.4 percent to the region's production, which in 2004 amounted to some 471 535, 104 330 and 43 950 tonnes, respectively (Figure 3). The other main aquaculture-producing countries (i.e. >5 000 tonnes) include Iraq, Saudi Arabia, Madagascar, Syrian Arab Republic, South Africa, Tanzania, Uganda and Zambia, which together produced 63 400 tonnes in 2004 (FAO, 2006a). The balance (i.e. 25 931 tonnes) was produced by 42 countries in the African and the Near East region. However, some of these smaller-producing countries have experienced the fastest rates of growth in production during the last ten years. For example, reported production in Togo grew from 20 tonnes in 1995 to 1 525 tonnes in 2004 (FAO, 2006a), a 76-fold increase, while in Zimbabwe total production increased from 150 to 2 955 tonnes over the same period when one large Nile tilapia cage-culture operation was established on Lake Kariba (Hecht, 2006; Blow and Leonard, 2007). Similarly, Uganda has shown a remarkable 1 058 percent increase in production





between 1998 and 2003, from 475 to 5 500 tonnes (Hecht, 2006).

Similar to the situation in Asia, most of the fish produced in Africa and the Near East are non-carnivorous species. Only 12 percent of production in 2004 was attributed to carnivorous species (Figure 4). The implications of this on fishmeal use are discussed in greater detail later in this report.

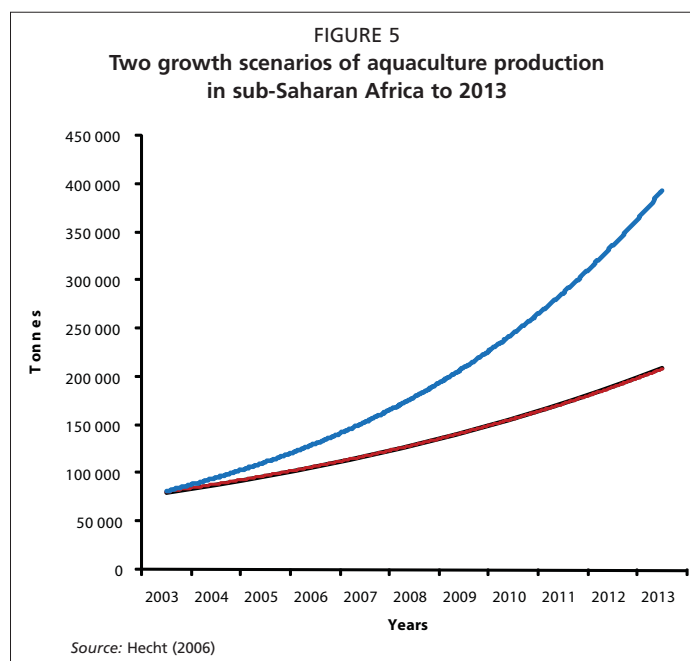
2.2 Future outlook

Food insecurity remains a serious problem in the developing world, particularly in Africa.

There have been many attempts to promote aquaculture as a means to address poverty and food security in Africa, although with limited success. There is no reason to dwell on the reasons why the sector has not performed as expected, as these have been dealt with previously (FAO, 1975, 2000; ICLARM and GTZ, 1991; Hecht, 2000; Moehl, Halwart and Brummett, 2005). In looking forward, there have been numerous calls (FAO, 2000; Hecht, 2000, 2006) for a paradigm shift in thinking to strongly promote the commercialization of aquaculture in Africa (Halwart *et al.* 2008; Moehl, 2008). The recent expansion of the aquaculture sector in Africa (Hecht, 2006) and the Near East (Poynton, 2006) is likely to continue. While the value of small-scale or subsistence aquaculture in Africa is recognized as making significant contributions to improved nutrition at the family level (Miller, 2009), it is highly unlikely that this sector will make a noticeable contribution to food security and poverty alleviation at the national level in Africa (Hecht, 2006). However, as commercial enterprises expand and as the industry grows, it will most certainly, as elsewhere in the world, contribute towards improving food security and employment. Some 86 700 people are employed in the aquaculture sector in the Near East, of which the majority (60 000) are employed in Egypt (Poynton, 2006), while in ten sub-Saharan African countries for which data are available, the sector employs around 200 000 people (Hecht, 2006). Clearly, the sector as a whole already makes some contribution to employment and will continue to do so in the future and particularly so when governments in sub-Saharan Africa begin to promote and support commercial aquaculture more strongly (Hecht, 2006).

The potential of aquaculture in Africa was once described as a sleeping giant (New, 1991), and it has been predicted that the developing world is where the bulk of aquaculture production will come from in the future (New, 1991; Hecht, 2000). The growth of the industry in Africa and the Near East over the last ten years is testimony to this potential (see also Aguilar-Manjarrez and Nath, 1998).

On the basis of several assumptions, Hecht (2006) made some projections on the growth of the sector in sub-Saharan Africa and suggested that by 2013 total fish production would be somewhere between 200 000 and 380 000 tonnes per annum (Figure 5). The outlook in North Africa differs from that of sub-Saharan Africa and the Near East, largely due to the impact that Egypt has in the region. Aquaculture in Egypt has already doubled approximately seven times in the last decade, and Egypt is currently ranked the twelfth largest aquaculture-producing country in the world (El-Sayed, 2007). Although there are no projections for North Africa or the Near East, El-Sayed (2007) in his review of Egypt and Poynton (2006) in her regional review of North Africa and the Near East both predicted continued and sustained growth of aquaculture in the region.



3. STATUS ON AND TRENDS IN THE USE OF FISHERIES RESOURCES AS INPUTS IN THE ANIMAL FEED INDUSTRY IN AFRICA AND THE NEAR EAST

3.1 Landings of fish destined for reduction and other uses

Currently, almost 82 percent of global fishmeal production and 55 percent of global fish oil production is not reported at the species level (Tacon, 2004), and there is a more acute lack of information for Africa and the Near East. This makes it almost impossible to determine any spatial or seasonal patterns of availability.

A five-year summary of small pelagic catches for Africa and the Near East is shown in Table 1. Unfortunately the data cannot be disaggregated for reduction, human consumption and other uses.

TABLE 1

Small pelagic landings (tonnes) for Africa and the Near East, 2000–2004*

Country		2000	2001	2002	2003	2004	5-year average
Morocco	Africa	562 684	812 551	707 874	677 635	653 474	682 844
South Africa	Africa	441 650	534 680	528 950	591 399	611 159	541 568
Senegal	Africa	250 715	244 754	210 692	281 723	276 340	252 845
Ghana	Africa	223 624	166 173	139 668	183 069	166 674	175 842
Nigeria	Africa	108 620	92 907	93 519	100 676	97 070	98 558
Algeria	Africa	76 405	99 873	100 750	100 372	99 600	95 400
Other**	Africa	450 075	397 836	408 229	404 570	453 815	422 905
Other***	Near East	81 595	97 624	76 739	71 127	81 396	81 696
Total		2 195 368	2 446 398	2 266 421	2 410 571	2 439 528	2 351 658

*Countries with an annual mean catch of less than 50 000 tonnes were grouped.

**Other African countries (23 countries).

***Other Near Eastern countries (9 countries).

Source: FAO (2006b)

Unlike Peru, Chile and Iceland, among other countries, that have dedicated reduction fisheries (Tacon, Hasan and Subasinghe, 2006), most of the small pelagic fisheries in Africa and the Near East target fish for human consumption. South Africa is the only exception in that it has a dedicated reduction fishery (S. Malherbe, Chairperson, South

African Pelagic Fish Processors Association, personal communication, 2006). While Morocco has the largest small pelagic fishery in the region (Table 1), fishmeal and fish oil production has until recently been considered a surplus activity (Atmani, 2003).

The pelagic fishery in Morocco is based on the European pilchard (*Sardina pilchardus*), sardines (*Sardinella* spp.), the European anchovy (*Engraulis encrasicolus*), chub mackerel (*Scomber japonicus*) and horse mackerel (*Trachurus* spp.) (Atmani, 2003; FAO, 2006b). With a catch of 653 474 tonnes in 2004, the Moroccan small pelagic fishery is currently the largest in the region. South Africa's small pelagic fish catch of 614 153 tonnes in 2004 (Table 2) mainly consisted of the South American or southern African pilchard (*Sardinops sagax*), southern African anchovy and Whitehead's round herring (*Etrumeus whiteheadi*) (Fishing Industry Handbook, 2005). The Namibian pelagic catch in 2004 amounted to some 35 506 tonnes of southern African pilchard, anchovy and round herring and 314 538 tonnes of cape horse mackerel (*T. capensis*) (FAO, 2006b). Namibian reduction figures for clupeoid catch are not available (Van Zyl, 2001); however, 10 percent of the 2004 cape horse mackerel catch was reduced to fishmeal (Animal Feed Manufacturers Association of South Africa, personal communication, 2006). Both Algeria and Angola have clupeoid fisheries (FAO, 2006b), although no reliable reduction statistics are available. Landings in Algeria in 2004 amounted to 99 600 tonnes, and Angola landed 58 569 tonnes in the same year (FAO, 2006b). Angola recognizes that reduction fisheries can potentially have a serious impact on the supply of fish for human consumption and proposes to develop its pelagic fisheries such that the potential impact is minimized (S.J.L. Xirimimbimbi, Minister of Fisheries, Angola, personal communication, 2006).

TABLE 2
South African pelagic catches, 2002–2004 (tonnes)

Species	2002	2003	2004
Sardine (directed catch)	244 743	271 148	365 792
Anchovy	213 446	258 877	190 093
Sardine (bycatch)	16 141	15 847	8 035
Horse mackerel	8 149	1 012	2 048
Round herring	54 798	42 529	47 234
Chub mackerel	82	250	480
Lantern fish	23	69	471
Total	537 382	589 732	614 153

Source: Fishing Industry Handbook (2005)

In Kenya the most important species destined for reduction is the silver cyprinid (*Rastrineobola argentea*, local name: “dagaa”, also known as “omena” and “mukene” in Uganda and Tanzania). To a lesser degree, Nile perch (*Lates niloticus*) trimmings from Lake Victoria are also reduced to fishmeal (Abila, 2003). Between 50 and 65 percent of the Kenyan ‘dagaa’ catch from Lake Victoria is reduced to fishmeal (Abila, 2003). In 2004, the total recorded “dagaa” catch was 31 659 tonnes (FAO, 2006b), suggesting that 15 800 to 20 500 tonnes of fish were reduced to fishmeal. Significant catches of this species are also made by Uganda (90 000 tonnes per annum; J. Rutaisere, Uganda Department of Fisheries, personal communication, 2007) and Tanzania, although it is not known what proportion of the catches are reduced to fishmeal. Ghana recorded a total anchovy catch in 2004 of 52 629 tonnes (FAO, 2006b). Up to 50 percent of the anchovy catch in Ghana is reduced to fishmeal annually (Directorate of Fisheries, Ghana, 2003), which equates to approximately 26 000 tonnes of anchovy.

The total catch of small pelagics in the Near East region is around 82 000 tonnes (see Table 1) and comprises some 12 species.

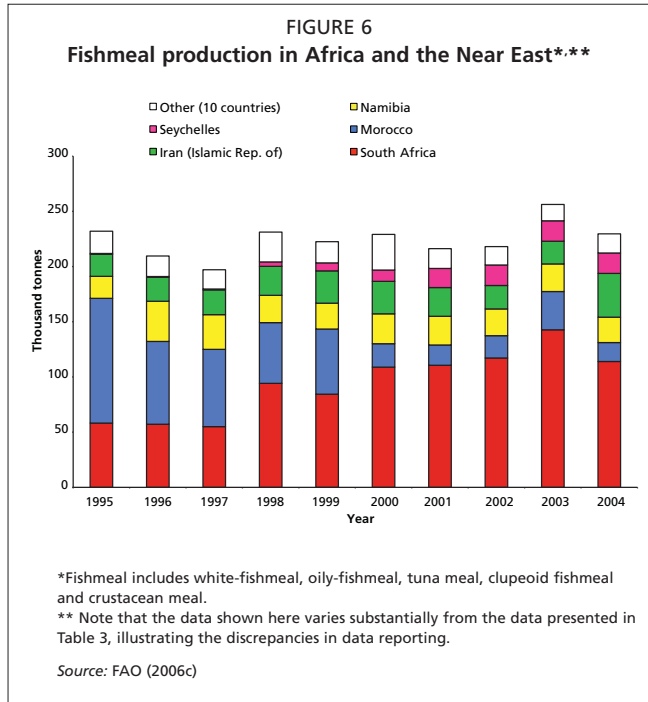
There are no disaggregated data for fishmeal and fish oil production from trimmings, bycatch and whole fish for Africa and the Near East, except for Seychelles

and Mauritius, where all fishmeal is made from tuna trimmings. This requires remediation, such that a more accurate picture can be obtained on the use of different fisheries products. Nonetheless, it is reported that 5.6 million tonnes of “trimmings” (i.e. the off-cuts and offal of processed foodfish) and reject foodfish were reduced globally during 2002 (FIN, 2005), which accounts for approximately 17 percent of world fishmeal production over the same period. There appears to be a global trend towards increasing the use of trimmings for the production of fishmeal. For example, it is estimated that on average 33 percent of fishmeal produced in the European Union (EU) is manufactured from food-fish trimmings (Tacon, 2004). In Spain, France, Germany and Italy, 100 percent of fishmeal originates from trimmings, while in the United Kingdom, Ireland, Sweden and Denmark, trimmings accounted for 84, 60, 25 and 10 percent of total fishmeal production, respectively (Tacon, 2004; Tacon, Hasan and Subasinghe, 2006). Similar estimates are not available for Africa and the Near East. However, there are reports that fishmeal is produced from tuna trimmings in Ghana (Directorate of Fisheries, Ghana, 2003), Nile perch frames in Kenya (Abila, 2003) and Uganda (Hecht, 2007), milled dry wastes of smoked tilapia and catfish in Cameroon (Poumogne, 2007) and tuna cannery by-products in Egypt (El-Sayed, 2007) and, as mentioned above, all fishmeal produced in Seychelles and Mauritius is made from tuna cannery trimmings. There are several smaller plants in South Africa that produce fishmeal from hake and other groundfish trimmings. Hecht (2007) also reports that in many sub-Saharan African countries small quantities of dried fish are reduced to fishmeal for human consumption and for use in fish feeds. Unfortunately, these activities are not quantified.

According to Ames (1992), the physical post-harvest loss of fish in inland fisheries in Africa amounts to between 20 and 25 percent and in some countries may be as high as 45 percent. On the assumption that losses due to spoilage in Africa have been reduced since then to 15 percent for inland fisheries and 5 percent for marine fisheries, this amounts to some 571 362 tonnes of fish that were unavailable for human consumption in 2004 (FAO, 2006b). This scenario can be viewed in two ways. With improved technologies, greater supply chain efficiency and removal of other hindrances, this quantum of fish could either be available for direct human consumption and have an immediate impact on food security, or if not fit for human consumption, could be reduced to fishmeal and used in the rapidly growing animal feed industry and hence contribute to the creation of employment and wealth through the production of secondary products.

3.2 Fishmeal and fish oil production, exports and imports

As mentioned earlier, South Africa has the only dedicated reduction fishery in the region and is also the largest producer of fishmeal in Africa and the Near East. Mean annual production is approximately 100 000 tonnes (Figure 6), with a current value of around US\$71 million (S. Malherbe, Chairperson, South African Fishmeal Manufacturers Association, personal communication, 2006). The pelagic fishery is divided into two distinct sectors, a reduction fishery that targets anchovies (*E. encrasicolus*) and round herring (*E. whiteheadi*), and a fishery directed mainly at pilchard (*S. sagax*) for human consumption and bait. Approximately 60 000 to 70 000 tonnes of the pilchard catch is canned, and the value of this component of the pelagic fishery is currently estimated at between US\$107 and 125 million, while the bulk of approximately 130 000 tonnes is packed and used for bait in the tuna pole fishery (local and foreign) and in the recreational fishery. The split in the use of the pelagic catch is largely determined by market demand. Currently there are three dedicated fishmeal factories as well as several smaller plants that form part of the demersal fish-processing industry. The pelagic fishery is managed on the basis of an operational management procedure (OMP) that determines the total allowable catch (TAC) and the closed season. On the whole, the fishery is considered to be fairly well managed (D. Butterworth, University of Cape



Town, personal communication, 2007). A total of 100 763 tonnes of fishmeal was produced in 2004/2005 (AFMA, 2006) at an average reduction rate of 23 percent (S. Malherbe, Chairperson, Pelagic Fish Processors Association of South Africa, personal communication, 2006), suggesting that ca. 409 476 tonnes of the small pelagic catch were reduced to fishmeal in 2004/2005. As mentioned previously, a small, although unspecified, portion of the South African fishmeal originates from groundfish trimmings.

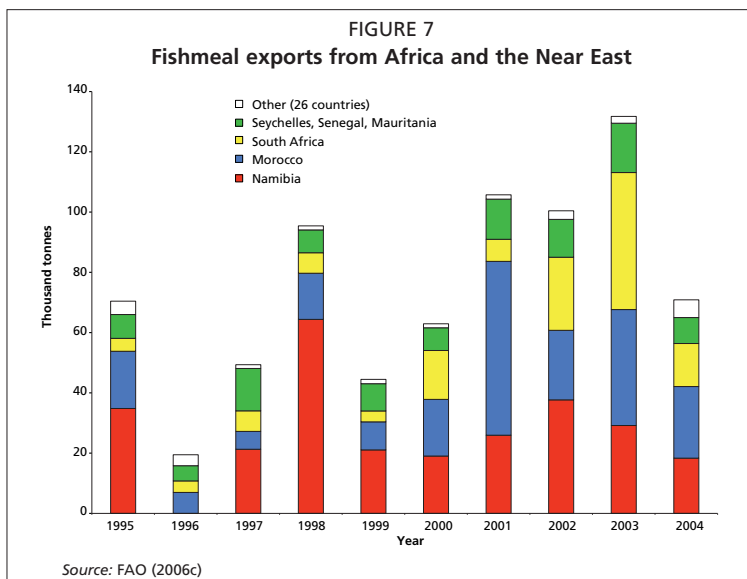
In 2004, Morocco produced approximately 63 000 tonnes of fishmeal, which at a reduction rate of 24 percent equates to around 40 percent of the total pelagic catch of 653 474 tonnes. Fishmeal and fish oil production in Morocco was until recently considered a surplus activity

to absorb fish that cannot be canned due to inefficiencies in canning, inadequate storage facilities and poor fish quality due to inappropriate handling (Atmani, 2003). For example, 70 percent of the catch landed at Laayoun (one of the main pelagic fishery ports in Morocco) was reduced due to insufficient canning infrastructure, even though the fish were fit for human consumption (Atmani, 2003).

South Africa, Morocco, Namibia, the Islamic Republic of Iran and Seychelles collectively produced 91 percent of the reported fishmeal production in the region over the last ten years (Figure 6). Over this period, Morocco, Namibia, Seychelles and Senegal were, in that order, the largest net exporters of fishmeal (Figure 7). Similarly, the Islamic Republic of Iran, South Africa, Egypt, Israel, Syrian Arab Republic and Saudi Arabia were the largest net importers of fishmeal (Figure 8). The Islamic Republic of

Iran is the largest producer of fishmeal in the Near East region and in 2003, produced approximately 10 300 tonnes, while all other countries for which data are available produce less than 300 tonnes per annum (Poynton, 2006).

Morocco was the largest producer of fish oil in Africa and the Near East, with an annual average of 16 606 tonnes between 1995 and 2004 (Figure 9). Morocco, South Africa and Namibia were the only significant producers and together produced 94.3 percent of the fish oil in Africa and the Near

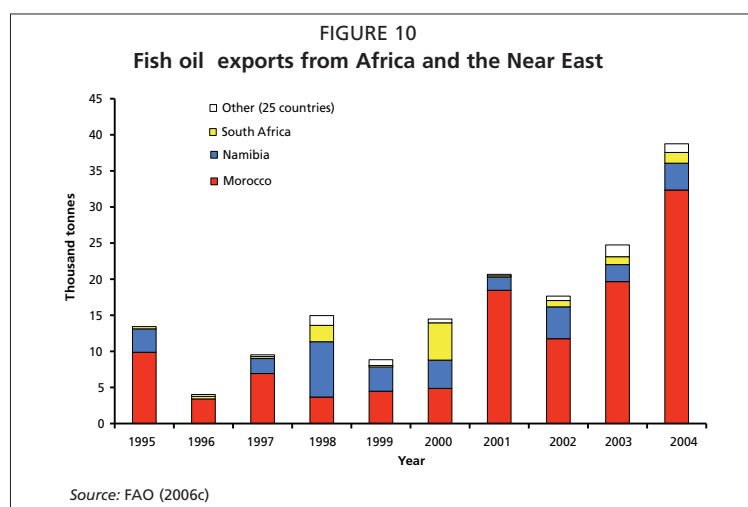
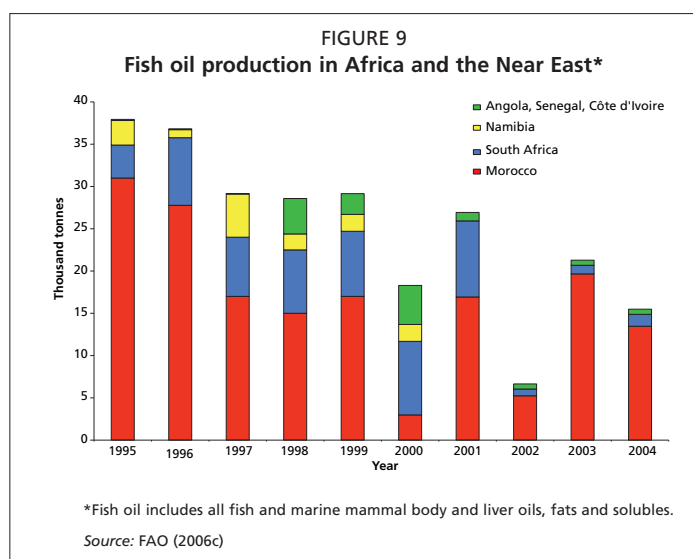
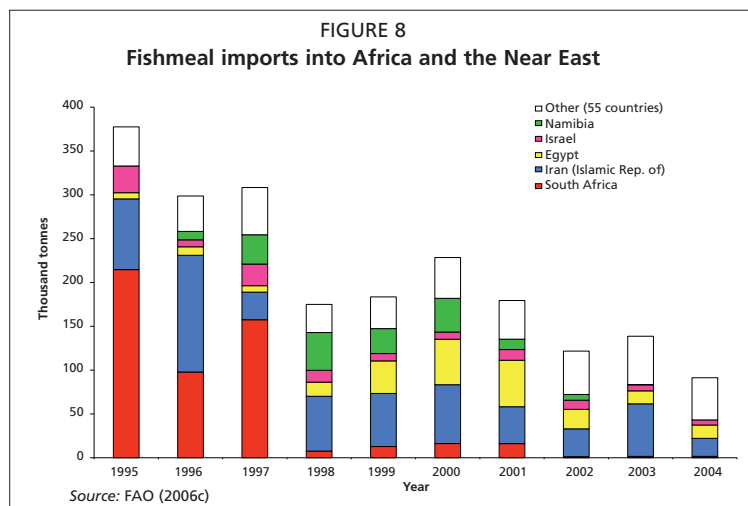


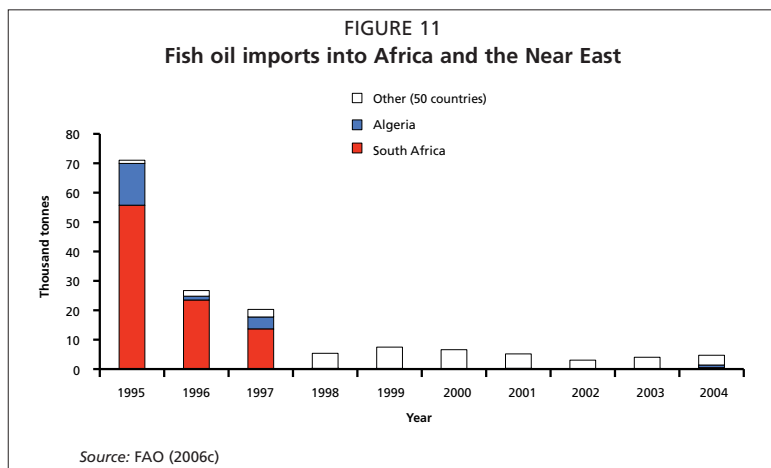
East (Figure 9). South Africa, Algeria, Israel, United Arab Emirates, Saudi Arabia, Syrian Arab Republic, the Islamic Republic of Iran and Nigeria were (in that order) net importers of fish oil, while Morocco, Namibia and Angola were (in that order) net exporters (FAO, 2006c).

The quantity of oils and solubles exported from the region increased during the course of the ten year period from 1995 to 2004, primarily due to increased exports from Morocco (Figure 10). The opposite trend was observed for imports, with a considerable drop in the volume of marine oils and solubles imported into South Africa and Algeria during the late 1990s (Figure 11).

The fishmeal production figures and the volume of fish reduced to fishmeal for Africa and the Near East are summarized in Table 3. Overall, the available information and data suggest that just over 200 000 tonnes of fishmeal were produced per annum or that just under 860 000 tonnes of pelagic fish were reduced to fishmeal and fish oil at a reduction rate of 24 percent. The data used to develop this summary table consisted either in published information on the quantum of fish reduced to fishmeal or the volume of fishmeal production. This allowed for the calculation of fishmeal production or alternatively, back calculating the quantum of fish that was reduced to fishmeal.

There are significant differences between the data presented in Figure 6 and in Table 3 that reflect the considerable inconsistencies in the reported production, export and import figures for fishmeal and fish oil in the region. For example, the Ministry of Fisheries in Ghana reported that





anchovy is a widely consumed commodity by low-income communities in the country and, even so, as much as 50 percent of the anchovy catch is reduced to fishmeal (Directorate of Fisheries, Ghana, 2003). Since the anchovy catch in Ghana totalled 52 629 tonnes in 2004 (FAO, 2006b), this would equate to the reduction of approximately 26 300 tonnes of anchovy

during the same year. However, there is no record of fishmeal production in Ghana in the FAO statistics (FAO, 2006c). These inconsistencies are problematic in undertaking a review of this nature. While both data sets should be viewed with circumspection, it is likely that the data presented in Table 3 are closer to reality than the data reported to FAO. Similarly, FAO (2006c) reports that fish oil production in Morocco totalled 13 474 tonnes in 2004, whereas the Fishmeal Information Network estimates the production for Morocco at around 25 000 tonnes for 2004 (FIN, 2005), which is almost double the figure cited by FAO (2006c).

Similarly, there are inconsistencies in reported export quantities of fishmeal. For example, Atmani (2003) reports that fishmeal used to be exported from Morocco to Europe. However, because of the demand by the domestic animal feed industry, fishmeal exports have been suspended. FAO statistics, however, show that an average of 21 831 tonnes per annum was exported from Morocco over the last ten years (FAO, 2006c) and, although there is considerable annual variation, there was no evidence of a reduction. Furthermore, FIN (2005) reports that fishmeal was exported from Morocco for the first time in 2000 and that 34 000 tonnes were exported in 2004. This is 43 percent more than that cited by FAO (i.e. 23 766 tonnes; FAO, 2006c) and moreover, fishmeal exports from Morocco have been reported as far back as 1976 (FAO, 2006c).

TABLE 3
Reduction of small pelagic fish to fishmeal and fish oil in Africa and the Near East, 2004–2005 (tonnes)

Country**	Wet weight fish	Fishmeal production
Morocco	262 500*	63 000
South Africa	449 013*	107 763
Ghana	26 300	6 312*
Namibia	31 454	7 548*
Egypt	521*	125
Kenya	18 150	4 356*
Angola	20 833*	5 000
Senegal	2 950*	708
The Islamic Republic of Iran	42 937*	10 305
Yemen	3 212*	771
Libyan Arab Jamahiriya	1 629*	391
Total	859 499	206 279

*Calculated figure based on a reduction rate of 24 percent.

** Excluding countries that produce fishmeal from tuna cannery trimmings (e.g. Seychelles and Mauritius).

Source: Directorate of Fisheries, Ghana (2003); Fishing Industry Handbook (2005); AFMA (2006); El-Sayed (2007); FAO (2006c); Poynton (2006); Hecht (2007)

These are just a few examples, among many, of inconsistent information. Contradictory data obstruct efficient management and decision-making, particularly when there are considerable differences between sources, as has been shown here. It also makes it very difficult to undertake credible reviews of reduction fisheries, unless one has direct access to industry facts and figures.

3.3 Current use of and demand for fishmeal and fish oil in aquafeed and in animal feed

The available data do not allow for a reliable summary of current use and demand patterns for fishmeal and fish oil in the region. At best it is possible to provide some estimates based on extrapolations when reasonable data are available. However, these estimates should also be viewed with circumspection. Overall, it is fair to state that the contribution by feed-fish fisheries to the economies of the countries is important only on a local basis, but their contributions to gross domestic product (GDP) are negligible. For example, the total processed value of the pelagic fishery in South Africa and Morocco contributes 0.000098 percent and 0.000074 percent to GDP, respectively.

It has been reported that some 20 000 tonnes of fishmeal were used by the Egyptian aquafeed industry in 2004, of which less than 200 tonnes were produced locally from sardine, anchovy, mackerel and tuna cannery by-products (El-Sayed, 2007). However, there is some doubt as to the accuracy of this estimate, and there are no reliable fishmeal consumption data for the aquafeed industries in the other countries. Hence, this had to be estimated using an alternative approach. The available aquafeed production data (Table 4) and fishmeal inclusion rates of between 5 and 15 percent suggest that the total use of fishmeal in aquaculture for Africa and the Near East ranges somewhere between 25 000 and 76 000 tonnes per annum. The relative proportion of fishmeal used in aquafeeds and in the poultry and pig feed industries in six African countries (for which relatively good animal feed data are available) was calculated on the basis of average fishmeal inclusion rates of 15 percent for fish feed, 3 percent for poultry feed and 6 percent for pig feed (Tacon, Hasan and Subasinghe, 2006). The results are shown in Table 5, from which it is evident that total fishmeal consumption by the animal feed industry in these African countries amounted to some 424 872 tonnes per annum of which 69 440 tonnes were attributed to aquafeeds, 276 647 tonnes to poultry feed and 78 777 tonnes to pig feed. On the assumption that the figures are a realistic reflection of the situation on the ground, then aquaculture accounts for approximately 16 percent of the total quantity of fishmeal used in animal feeds in the region.

TABLE 4

Estimated fishmeal consumption by the aquafeed industry in Africa and the Near East

Region	Total aquafeed production	Fishmeal inclusion rates		
		5 percent	10 percent	15 percent
North Africa and Near East	462 600	23 130	46 260	69 390
Africa (8 countries)*	42 027	2 101	4 202	6 304
Total		25 231	50 462	75 694

* Cameroon, Ghana, Kenya, Malawi, Nigeria, South Africa, Uganda and Zambia, which collectively contributed approximately 70 percent to the total sub-Saharan aquaculture production (FAO, 2006a).

Source: Poynton (2006); Hecht (2006, 2007)

TABLE 5
Estimated volumes of fishmeal used in animal feeds produced in African countries that are the major aquaculture producers (tonnes)

Country	Cameroon	Egypt	Kenya	Nigeria	South Africa	Zambia
Year	2004	2004	2004/2005	2001	2000/2001	2005/2006
Aquafeed	40 ¹	420 000 ²	104 ¹	35 570 ¹	3 263 ⁴	750 ⁵
Poultry feed	52 910 ¹	3 148 000 ³	256 440 ¹	2 591 732 ¹	3 109 828 ⁴	62 700 ⁵
Pig feed	15 120 ¹		32 630 ¹	1 084 214 ¹	177 407 ⁴	3 600 ⁵
Fishmeal – aquafeed	6 ^a	63 000 ^a	16 ^a	5 335 ^a	978 ^d	113
Fishmeal – poultry feed ^b	1 587	94 440 ^d	7 693	77 752	93 294	1 881
Fishmeal – pig feed ^c	907		1 958	65 052	10 644	216
Fishmeal country total	2 500	157 440	9 667	148 139	104 916	2 210

^a Assumes average of 15% fishmeal inclusion level.

^b Assumes 3% fishmeal inclusion level.

^c Assumes 6% fishmeal inclusion level.

^d Assumes 30% fishmeal inclusion rate.

Source: ¹ Hecht (2007); ² Poynton (2006); ³ El-Sayed (2007); ⁴ Animal Feed Manufacturers Association of South Africa (www.afma.co.za) and Abalone Farmers Association of South Africa; ⁵ Bentley and Bentley (2005)

3.4 The potential use and demand of reduction fishery products for direct human consumption

The international fishmeal industry reports that 90 percent of the fish that is reduced to fishmeal is “feed grade”, for which there is little or no demand for human consumption (FIN, 2004). This is a developed-world perspective. In many African countries, small pelagic fish, if fresh, would be readily accepted for direct human consumption (Kurien, 1998). This is substantiated by the fact that large quantities of frozen small-pelagics, particularly horse mackerel, are imported into almost all African countries from Namibia (Van Zyl, 2001) and in particular, by Nigeria, Cameroon, the Democratic Republic of Congo and the Republic of the Congo. Moreover, in many African coastal and island states, the small pelagic catch is often simply not available for human consumption (Abila, 2003), as it is processed into fishmeal on board or is piped or trucked directly to land-based fishmeal processing plants.

In Kenya, the production of fishmeal limits the availability of low-value pelagic fish to rural communities. Silver cyprinid, *Rastrineobola argentea*, locally known as dagaa or “omena” is a small, pelagic, “sardine-like” fish that is caught in Lake Victoria. It is readily eaten by low - to middle-income communities and when available, 89 to 95 percent of rural households in the vicinity of the lake consume this fish (Abila, 2003). During the early 1990s, the entire catch was used for human consumption. However, due to increasing demands for fishmeal by the animal feed industry, it is estimated that between 50 and 70 percent of the catch is now reduced to fishmeal (Abila, 2003; Nyandat, 2007; Hecht, 2007). The animal feed industry is capable of paying more for the fish than the local people, leaving limited and insufficient quantities for human consumption (Abila, 2003). The capacity for Kenya to absorb the dagaa that is reduced to fishmeal is substantiated by reports that all of the fish caught during the rainy season (when catches are high) and when factory trucks are unable to reach the beaches is sold on the local markets for human consumption (Abila, 2003). This situation is no doubt mirrored in Uganda, where annual dagaa landings are in the region of 90 000 tonnes. The fact that Uganda does not permit the importation of fishmeal means that the animal feed industry is totally reliant on dagaa, which as reliance continues to grow, will reduce the availability of the fish for human consumption (J. Rutaisere, Uganda Department of Fisheries, personal communication, 2007).

The views expressed so far are one sided and somewhat simplistic. For example, the needs of the animal feed industry, upon which the poultry industry is dependent, also should be considered, particularly in view of the fact that the demand for meat in

many African countries exceeds the demand for fish (Hecht, 2006). Moreover, industry inefficiencies such as those that occurred in Morocco (Atmani, 2003) and most likely in several other countries, also need to be considered. Where such inefficiencies exist, it is better to reduce the fish to fishmeal than to write them off as a post-harvest loss. This point is clearly illustrated by Naji (2003), who noted that each kilogram of fish exported from Morocco, in whatever form, generates sufficient foreign revenue to allow for the importation of 3.92 kg of staple foods. However, despite this fact, Naji (2003) recommends that fish resources would be better directed towards human consumption than for inclusion in animal feeds.

The use of the pelagic resource is, however, largely driven by market forces. For example, Namibia has significant horse mackerel resources, yet only 10 percent of the catch is reduced to fishmeal, while the bulk is exported to other countries in Africa as a frozen product for human consumption (Van Zyl, 2001). The reason for this is that there is little demand for fresh or frozen horse mackerel on the local market and export profit margins are higher than those for fishmeal. Similarly, the processing of the pelagic catch in South Africa is also entirely market driven, which, in essence, is no different from the use of the “daga” resource in Kenya, although it does not have the same social consequences. This implies that if small pelagic fish are to make a greater contribution to food security, then this can only be achieved through legislation. This in turn would be against free market principles to which many African countries are now committed, either by choice and/or by international design.

The FAO *Code of Conduct for Responsible Fisheries* (FAO, 1995) advocates that: “States should encourage the use of fish for human consumption and promote consumption of fish whenever appropriate...” and countries should discourage the use of fish for feeding animals when it is fit for human consumption (FAO, 1995). While governments no doubt recognize and promote the principles of the code, it is often not possible to give effect to the required practicalities due to inadequate local infrastructure. Thorpe *et al.* (2004) on reviewing the *Poverty Reduction Strategy Papers* of African countries (these documents remain one of the main conditions for concessional lending to developing countries by the International Monetary Fund and World Bank), suggest that “... most [but not all] African governments generally do not regard fisheries as one of the sectors that could assist in the achievement of national food security and the reduction of poverty”. As such, the reduction of edible fish to fishmeal does not appear to have been identified as a problem in many countries. Food security is a serious problem in many African countries. For example, in Ghana where 25 percent of children below five years of age are undernourished (Kurien, 2003), as much as 50 percent of the anchovy catch is reduced to fishmeal (Directorate of Fisheries, Ghana, 2003). However, the possible benefits of redirecting a portion of the anchovy catch for direct human consumption are not mentioned in the *Post Harvest Fisheries Review* prepared by the Directorate of Fisheries, Ghana (2003).

In summary, there appears to be a dichotomy with respect to the use of small-pelagics in the region. In some countries (e.g. Kenya and Morocco), the small pelagic catch is reduced to fishmeal, even though the fish would have been absorbed by local markets for direct human consumption had they been available. That there is a need for more fish to improve food security is unquestioned. Per capita fish consumption in sub-Saharan Africa fell from 9 to 7 kg (i.e. 22 percent) between 1990 and 1997, due to dwindling fish stocks and increased competition with fish exports (Teutscher, 2000). Similarly, Hecht (2006) reports a decline of 2.1 kg per capita in sub-Saharan Africa for the period 1980 to 2002. Conversely, in other countries (e.g. Namibia and South Africa) the variable use of the small pelagic catch is largely determined by demand and, therefore, the catch appears to be used for optimal economic and social benefits. Unfortunately, the paucity of data on the use of small pelagic fish in Africa and the Near East precludes a more detailed analysis and prognosis. This can only be achieved if local authorities

acknowledge that pelagic fisheries can contribute to alleviating food security and if more detailed records of fish use are collected and disseminated. In reality, however, it is the market that dictates the fate of fish. If profit margins from reduction products such as fishmeal and fish oil exceed those of selling fresh fish into the market, there is little that governments can do other than by direct intervention into free-market systems that are encouraged by the World Bank, donors and development agencies. As alluded to earlier, central to the contribution by fish to food security and poverty reduction in many African countries is the need for a concerted effort to reduce physical and economic post-harvest losses. The conservative estimate of around 571 000 tonnes of fish lost due to spoilage in Africa (see above) is significant on a continent where food security and poverty still prevail in the twenty-first century. Hecht (2006) showed that the average price of fish in 16 African countries is around US\$2.43 per kg. Even an average price of US\$2 per kg translates into an estimated economic loss of around US\$1.4 billion. The recent initiatives by NEPAD (The New Partnership for Africa's Development) and the WorldFish Center (NEPAD, 2005) to address the problem of post-harvest losses are to be welcomed and must be supported.

3.5 "Trash fish" and other fishery by-products used as feeds in aquaculture

Unlike Asia where trash fish is a major feed in aquaculture (Tacon, Hasan and Subasinghe, 2006), the use of this commodity in Africa is extremely limited. There are some records of trash fish being used as fish feed in Cameroon, Nigeria and Ghana (Hecht, 2007). However, the absence of any substantive data suggests that the use of trash fish in aquaculture in Africa is negligible. Similarly, Poynton (2006) in her review of aquaculture in the Near East concludes: "From the limited data available on use of trash fish and raw fish, it appears that these resources are relatively little used in aquaculture in the Near East and North Africa. In the major producer country, Egypt, there is limited use of raw fish (sardines, silversides, small shrimp and tilapia) for seabass and meager (*Argyrosomus regius*) farming, where the raw fish are used to enhance the final flavour of the cultured stock. In Libyan Arab Jamahiriya, sardines are used in bluefin tuna farming. In Saudi Arabia, trash fish or raw fish are used as additional feed supplements for broodstock of some cultured marine species; for example, fresh mackerel are fed to seabass, and fresh squid are fed to shrimp. In the United Arab Emirates, trash fish (Carangidae, Lethrinidae, Haemulidae, Sparidae and tuna) from the Dubai fish market are collected and used to produce fishmeal."

In South Africa, approximately 30 percent of the pilchard catch (130 000 tonnes in 2004/2005) is destined for use as bait in tuna pole and longline fisheries and the recreational fishery and exported as feed for tuna in cages (G. Christy, Christie and Sons Fishing Enterprises, St Francis Bay, South Africa, personal communication, 2007). Although it was not possible to obtain any specific figures for other countries in the region, there is no doubt that a proportion of the small pelagic fisheries catch is used for similar purposes, e.g. in Angola, Libyan Arab Jamahiriya, Morocco, Mozambique, Mauritania, Senegal and Ghana.

4. SUSTAINABILITY ISSUES OF REDUCTION FISHERIES

The effects of over fishing on ecosystem health are well documented (Pauly *et al.*, 1998). Until recently, small pelagic fish populations, because of life history characteristics such as high fecundity, early sexual maturation and rapid growth rates, were considered to have the ability to bounce back rapidly from periodic collapses (Adams, 1980). While there are examples of small pelagic stocks bouncing back rapidly, others have collapsed. More recently, however, the important role of ecosystem functioning, climate variability, El Niño Southern Oscillation events and species dominance shifts on stock abundance of small pelagic species has been highlighted (Sharp, 1987; Lluch-Belda *et al.*, 1989; Patterson, 1992). In a seminal paper on the subject, Freon *et al.* (2005) state that: "The

majority of small pelagic exploited stocks are threatened by exploitation, often out of phase with strong and not always well understood variations in abundance, in relation to environmental variability (short- and long-term) and/or the internal dynamics of the ecosystem. Environmental changes can affect fisheries either at the level of catchability or at the level of resource abundance. The lack of understanding of most of the processes still limits short-term forecasts of abundance. Process-oriented studies (modelling approach interacting with orientated data collection and experiments, etc.) and emphasis on combined analysis of different sources of spatialized environmental, ecological, and fishery data are required to improve our knowledge.” Their review paper highlights the extreme complexity of factors that effect short-, medium- and long-term variability in abundance of small pelagic stocks and clearly shows that small pelagic fisheries appear to be as vulnerable to overfishing as demersal fish stocks, which is also highlighted by Sadovy (2001), and are highly sensitive to meso-scale ecosystem disturbances and climate variability and may take a long time to recover. The review by Freon *et al.* (2005) suggests that none of the present management options are fully adapted to both the short- and long-term variability in abundance of most small pelagic fish stocks, and hence, recommends a two-tier approach. The first step would be “based on simple modifications of the existing management plan, based on a total allowable catch (TAC) that will vary annually according to current estimation of fish stock biomass from direct (e.g. acoustic survey; preferred for short-lived pelagic fish) and/or indirect (e.g. Virtual Population Analysis (VPA); preferred for medium- and long-lived species) stock assessment methods”. The second tier should address the problem of interdecadal variations in the abundance of pelagic fish that induce counterproductive investments in the fishing sector. Their excellent review clearly illustrates the need for more comprehensive research to adequately manage pelagic fish stocks on a sustainable basis.

For example, many Namibian fisheries were severely overfished by foreign fishing fleets between 1968 and 1990, and even though strategies were implemented to rebuild the stock, the pilchard fishery in Namibia has still not recovered (FAO, 2005b). Similarly, the South African pilchard fishery collapsed in 1966 due to overfishing and environmental factors and has only recovered in recent years, i.e. in 2003 and 2004, 40 years down the line (FAO, 2005c). The collapse of the pilchard fishery saw a rise in anchovy catches during the mid-1960s, which resulted in a fairly constant total pelagic catch in South Africa over this period. The complex dynamics of species dominance shifts in the South African small pelagic fishery that occurred between 1967 and 1996 is discussed by Lluch-Belda *et al.* (1989) and De Oliveira and Butterworth (2004). In lieu of the complex population dynamics and the value of the fishery, among other reasons, the fishery is now managed on the basis of an Operational Management Procedure (OMP). Recognizing the complexity of managing pelagic fisheries has more recently led South Africa and Namibia (and now Angola through the Benguela Current Large Marine Ecosystem (BCLME) programme) to adopt an ecosystems approach to fisheries management. With respect to the small pelagic fisheries of north and west Africa, it has been recommended (FAO, 2002) that the precautionary approach be adopted towards managing the stocks on a sustainable basis and that the basis for setting the TAC and fishing capacity for the next year should not exceed the average annual catch during the last five years. More recently, Senegal has also recognized the need to adopt an ecosystems approach for fisheries management (Samb, undated). Unfortunately, it would appear from recent reports that the pelagic resources in Morocco are being overfished by foreign fleets (FAO, 2005d), and it has been suggested that the FAO *Code of Conduct for Responsible Fisheries* should be implemented more rigorously to better manage these fisheries.

Industry and consumer bodies also play an important role in promoting the sustainable use of small pelagic fisheries. *The Fishmeal Information Network*

Sustainability Dossier (FIN, 2001) compiled by the fishmeal industry aims to provide factual information regarding the industry and the fisheries upon which the industry depends, and is based on independent documented evidence. The sustainability of the fish stocks that are described and discussed in the dossier is crucial to the sustainability of the fishmeal industry, so it is in the interest of the industry to provide accurate assessments and reporting and to manage itself according to sustainable principles. The dossier contains information that is useful and applicable to the sustainability of reduction fisheries. Understandably, the focus of the dossier is on the major reduction fisheries of the world and, therefore, unfortunately contains no information on the reduction fisheries in parts of the world that do not contribute significant proportions to global supply. The dossier plays a very important role in developing and maintaining sustainable reduction fisheries. However, it would be of great value if the Fishmeal Information Network (FIN) were to expand its mandate and also consider the competition that exists for small pelagic resources in the developing world. In addition, the Marine Stewardship Council (MSC) is an independent non-profit organization that promotes responsible fishing practices, which it does through a document entitled *Principles and Criteria for Sustainable Fishing* (MSC, 2002). This document, as well as the promotion of sustainable reduction fisheries by the FIN, is founded on the *FAO Code of Conduct for Responsible Fisheries* (FAO, 1995). The MSC principles are similar to those of FIN (2001) and are comprised of a set of broad principles based on sustainable management practices and the social responsibilities of fisheries worldwide. Further, the MSC offers certification and accreditation to fisheries that adhere to its principles and criteria, and these now play an ever increasing and important role in the global marketing of fisheries products in the developed world, although fisheries in the developing world are somewhat disadvantaged by the current principles (Uwe Scholz, Gesellschaft für Technische Zusammenarbeit (GTZ), Germany, personal communication, 2007).

Briefly summarized, the principles and criteria of the MSC (2002) rebuke overfishing and promote sustainable exploitation only. They endorse strategies that aim to restore depleted stocks and that focus on a holistic ecosystems approach to fisheries management. To ensure that the primary principles are achievable, the MSC makes use of local, national and international institutional structures. In addition to its ecologically sustainable approach, the principles published by the MSC Executive (MSC, 2002) also consider social sustainability and responsibility. This is of particular importance to resource users in parts of Africa and the Near East where there appear to be imbalances in access to small pelagic fish resources by rural communities and fishmeal producers. More specifically, the criteria state that management systems should “observe the legal and customary rights and long term interests of people dependent on fishing for food and livelihood” (MSC, 2002). There is evidence to suggest that the interests of people that depend on the small pelagic fisheries for food in parts of Africa and possibly the Near East are not always taken into consideration. The implementation of the principles and criteria advocated by the MSC would address these imbalances, although the localized nature of the market of some of these fisheries may make it difficult for the resource users to accede to certification and accreditation.

5. ENVIRONMENTAL IMPACTS OF AQUACULTURE IN AFRICA AND THE NEAR EAST THAT RESULT PRIMARILY FROM REDUCTION FISHERIES AS FEED INPUTS

Compound aquafeeds with a high fishmeal content contribute to nitrogen and phosphorus loading in the immediate environment (Tacon, 2004). The way in which nitrogen and phosphorus wastes enter the environment and their impact, which may be positive or negative, depends on the nature of the aquaculture system. For example, effluent water from land-based aquaculture systems enters the environment either

periodically (during flushing or harvesting) or continuously (in the case of flow-through systems). All effluent, however, enters the environment at a point source. This is different under cage-culture conditions, where soluble wastes are often subject to rapid dissipation, although solids may accumulate below the cages, with serious impacts on the environment and which may also affect the operator. For aquaculture to be sustainable requires that whatever wastes are returned to the environment need to be matched by the carrying capacity of the environment. However, the assessment of environmental carrying capacity is an expensive exercise requiring high-level expertise that is not available in most African and Near East countries. Despite the fact that most countries in Africa and the Near East have legislation pertaining to aquaculture, there are, as far as could be ascertained, no specific waste management standards for aquaculture (see <http://www.fao.org/fishery/nalo/search/en> for National Aquaculture Legislation Overviews). South Africa is the only country that has a set of water quality guidelines that specify the requirements for cultured organisms (Department of Water Affairs and Forestry, 1996). However, depending on the type and size of operation, an Environmental Impact Assessment is required in most countries, which is then considered in relation to other relevant legislation, e.g. that dealing with pollution, environmental conservation, health or water. Several countries (e.g. Mozambique) have developed innovative ways to ensure environmental standards and sustainability. Because of the high cost of monitoring water quality in remote areas of the country, the Mozambique Department of Fisheries (Aquaculture Division) has restricted shrimp farmers to operate only at extensive or semi-intensive stocking densities, which ensures environmental sustainability (F. Ribeiro, Instituto de Investigação Pesqueira, Maputo, personal communication, 2007).

The addition of either phosphorus or nitrogen to aquatic systems may cause eutrophication and algal blooms. Phosphorus is usually the most limiting element for plants (i.e. algae) in freshwater systems, whereas nitrogen is more limiting in the marine environment (Cho and Bureau, 2001). It is possible to directly measure the amount of nitrogen and phosphorus levels that enter the environment in the effluent of pump-ashore and land-based aquaculture systems. This is almost impossible in cage-culture, where there is no steady flow of effluent out of the system. However, it is possible to predict the volume of waste produced in these systems by formulating a nutrient budget, which is based on biomass carried by the aquaculture system and the dietary ingredients of the feed, which is the primary source of phosphorus and nitrogenous waste. Simplified, the nutrient load in farm effluent is estimated by subtracting the protein, lipid and carbohydrate requirements of the fish for maintenance, growth and reproduction from the total available nutrients in the diet, the difference of which is excreted as by-products of metabolism as either solid or dissolved waste (Cho and Bureau, 2001).

For example, the effluent that is produced by growing 1 tonne of salmon under intensive aquaculture conditions includes 240 kg of total solids, 10 kg of solid nitrogen, 4 kg of soluble nitrogen, 4 kg of solid phosphorus and 2 kg of dissolved phosphorus (Cho and Bureau, 2001). However, these volumes vary considerably with the quality of the feed (Cho and Bureau, 2001). Similarly, different species farmed under different culture conditions produce varying levels of waste. For example, the volume of nitrogen discharged per tonne of channel catfish (*Ictalurus punctatus*) is similar to that produced during salmon production, i.e. approximately 9 kg of nitrogen/tonne of catfish (Lucas and Southgate, 2003); however, the volume of phosphorus is considerably less at 0.6 kg per tonne of catfish, while the intensive production of 1 tonne of gilthead seabream (*Sparus aurata*) in earthen ponds results in 48 kg of nitrogenous discharge, 3 kg of phosphorus and 9 105 kg of total suspended solids (Lucas and Southgate, 2003).

Irrespective of the culture system used, there is an intricate balance between the volume of phosphorus and nitrogenous waste that is produced and the capacity for the

environment to maintain the system without any negative environmental effects. This balance is determined by the physical properties of the environment (for example, water depth, current or drawdown in the case of cage culture and water availability and volume and natural down stream biological filtration in the case of land-based systems), which in turn governs the nature and size of the aquaculture operation. Provided environmentally responsible aquaculture practices are employed and environmental carrying capacities are not exceeded, the impact that nitrogenous and phosphorus wastes from aquaculture have on the environment can be minimized.

Aquaculture in most of Africa and the Near East is pond based. For example, in Egypt only 10.6 percent of the 450 000 tonnes was produced in cages in 2003 (El-Sayed, 2007). Throughout the region pond-based aquaculture ranges from extensive to semi-intensive and approximately 88 percent of the fish produced are non-carnivorous. By implication, therefore, the overall total nitrogen and phosphorus waste from the use of fishmeal in Africa is currently still considered to be negligible. However, local impacts can be severe and have led to the closure of some operations in South Africa. While most countries, as mentioned above, have regulations in place to ensure that aquaculture development is environmentally sustainable, very few have the resources to monitor the growing commercial aquaculture sector (Hecht, 2006). Given the increasing interest by the industrial sector in aquaculture in Africa, there is a need to develop appropriate water quality legislation for aquaculture.

6. CURRENT AND POTENTIAL ALTERNATIVE USES OF FISH AND THE RELATED MACRO-LEVEL IMPACT ON FOOD SECURITY AND POVERTY ALLEVIATION

The global fishmeal industry claims that there is no demand (i.e. for direct human consumption) for 90 percent of the wild-caught fish that is reduced to fishmeal (FIN, 2004). From a global perspective this is probably correct. However, on a regional or on an individual country basis evidence is presented that suggests that a good proportion of the reduction fishery products are simply not available for human consumption (Abila, 2003), although if available, they would certainly have been consumed (Kurien, 1998). Moreover, the available data for Africa and the Near East show that 60 percent of the small pelagic catch is used for food and only 40 percent is reduced to fishmeal. In several countries and in particular in Morocco and South Africa, a sizeable proportion (see above) of the small pelagic catch is canned, while in other countries the fish is sold fresh on the market.

Nonetheless, the fish that is reduced to fishmeal generates revenue, which in turn contributes to job creation. The questions that, therefore, need to be asked are: *Does the revenue that is generated from the sale of fishmeal filter back to the people who would have benefited by eating the fish had the fish not been reduced?*; and *Do the people who no longer have access to the reduced fish for direct human consumption receive any benefit from the reduction fishery and, if so, how does this benefit compare to that from direct human consumption?*

These questions, which require detailed data from farmers, the fishmeal industry and the fisheries authorities, are answered by way of an example. Such detailed data could only be obtained for the South African abalone farming industry. The South African abalone culture industry is the fastest growing industry in the local aquaculture sector, and the majority of the employees in the industry are people who no longer have access rights to local fisheries. Although abalone (*Haliotis midae*) are herbivorous, the industry is partly dependent on a fishmeal-based artificial diet and will become more so as it grows and ocean-harvested kelp becomes limiting (Troell *et al.*, 2006). South Africa is a net consumer of fishmeal and was ranked the thirteenth largest consumer in the world in 2004 (101 000 tonnes) (FIN, 2005). It produces the bulk of its own consumption: in 2004, South Africa produced and imported 114 000 and 1 599 tonnes of fishmeal, respectively, and exported only 23 766 tonnes (Figures 6, 7 and 8).

The abalone culture industry in South Africa used approximately 320 tonnes of artificial feed in 2005 (Jones and Britz, 2006), which equates to ca. 96 tonnes of fishmeal. The fishmeal reduction yield that is accepted as an industry standard in South Africa is 23 percent (S. Malherbe, Chairman, South African Pelagic Fish Processors Association, personal communication, 2007), meaning that ca. 420 tonnes of live fish were reduced to produce the 96 tonnes of fishmeal for the abalone culture industry. The minimum daily protein requirement for a person is 1.38 g dry protein/kg/day (Scrimshaw, 1977). Assuming that the average employee supports a family of four with a total average weight of 180 kg (i.e. a minimum dry protein requirement of 248 g/family/day) and that the protein content of fresh fish is 16 percent (Miles and Jacob, 2003), then it is possible to estimate that the fish that were reduced to fishmeal to feed the abalone culture industry would have sustained ca. 741 families for a year had they utilized the fish directly. However, the abalone culture industry employed 814 people in 2004 (Troell *et al.*, 2006), who use their salaries to purchase substantially more than their protein requirement. This example suggests that the “secondary” use of reduction fishery products is able to sustain more families indirectly than it would have sustained directly.

The example shows that the fish were not “wasted” by reducing and feeding them to abalone. However, *would the community have been better off selling them for human consumption?* Had the fishmeal not been reduced and had the farm workers retained their fishing rights, the catch would have realized US\$1.5 million, i.e. US\$1 778/worker/year, before fishing expenses are taken into account. If it is assumed that abalone farm workers earn the minimum wage for South African farm labourers (i.e. ZAR871.58/month; Hall, 2004) they would have earned a net salary of US\$1 687/worker/year (this assumes an exchange rate of ZAR6.20 to US\$1.00). From this it may be concluded that the reduction fishery has not placed the abalone farm workers at an economic disadvantage.

Can the above example be extrapolated and used to estimate the beneficial or detrimental effects of reduction fisheries on livelihoods in the rest of Africa and the Near East? The example assumes that (1) the fishmeal is utilized locally and (2) that the production of the “secondary” products (i.e. the animals to which the fishmeal is fed) results in local employment among sectors of the populations that might have benefited from the fishery pre-reduction. The first assumption is largely met in most African and Near East countries, because most locally produced fishmeal is not exported; with the exception of Morocco, Senegal and Saudi Arabia, all countries that were recorded as fishmeal producers produced considerably more fishmeal in 2004 than they exported during the same year (FAO, 2006c). However, it is in the second assumption that the application of this example will differ considerably between countries and even areas within a country, and there is no evidence to suggest that this assumption is applicable for all African and Near East countries. Fish processing activities create substantial employment in some countries while not in others (Kurien, 2003). Similarly, employment created through the production of secondary products differs in different parts of the region, suggesting that the poor in some countries will benefit from reduction (e.g. people employed in the abalone culture industry in South Africa are better off receiving a wage than they would have been had the fish that was fed to the abalone been consumed directly by the farm workers), and those in other countries will remain worse off as a result of these fisheries (e.g. the reduction of fish, which was previously consumed by them, left them without a protein source and has not created employment in these communities). The model presented here can be adjusted and could be used to determine the beneficial or detrimental effects of reduction fisheries for all areas in the region with reliable employment statistics.

From the above example, it could be concluded that the reduction of fish had a net benefit for the employees in the abalone farming industry and this is no doubt similar

to other industries, including the fishmeal processing industry. Therefore, it would be erroneous to collectively condemn all reduction fisheries on the grounds that they perform a “social injustice”. At the same time, the costs of some reduction fisheries in the developing world probably outweigh the benefits, as production of the “secondary” product does not always result in employment, leaving the poorest of the poor worse off without access to protein or a monetary income. Further investigations are required to seek ways in which to reduce social conflict among potential users of the resource, where this exists.

7. REGIONAL ISSUES ON THE USE OF FISH AND/OR OTHER AQUATIC SPECIES AS FEED FOR AQUACULTURE

The main issue of regional importance in Africa and the Near East is that of food security and poverty, and these are not just national problems. There are 1.1 billion people in the world living in acute poverty, at least 25 percent of whom live in sub-Saharan Africa (World Bank, 2004). While poverty (people that earn less than the local equivalent buying power of US\$1/day) in North Africa and the Near East has improved over the last 20 years and hovers around 2 to 3 percent, the number of people living in poverty in sub-Saharan Africa has nearly doubled over the same period (World Bank, 2004). Countries where more than 50 percent of the population earn less than US\$1/day include Zambia, Burundi, Central African Republic, Nigeria, Niger, Mali and Sierra Leone (World Bank, 2004). Directly linked to poverty is a lack of food security and child mortality. In 2002, there were 15 countries in the world that experienced more than 200 infant deaths per 1 000 live births; 14 of these countries were in sub-Saharan Africa (World Bank, 2004). Furthermore, in low-income countries one child in eight dies before reaching five years; this compares to one in 143 in high-income countries (World Bank, 2004).

The examples from Morocco and Kenya (Abila, 2003; Naji, 2003; Nyandat, 2007), where fish protein that was affordable to the poor in the past is now no longer available because of “value-adding”, raise social responsibility questions and issues. Clearly, where such imbalances exist, they need to be addressed by governments and fishing companies such that the distribution of the resources is equitable and does not have a detrimental effect on basic nutritional needs of local communities. The pelagic fisheries for dagaa in Lake Victoria, as for almost all fisheries for smallpelagics, involve straddling stocks and hence, need to be managed by way of multinational fisheries management procedures. These should take particular cognisance of the social consequences in each country, as the action of one user in a multiuser fishery can affect the returns and, in some cases, the food security of others. Therefore, regional cooperation in managing shared fish resources using principals that promote sustainability is imperative.

7.1 National, regional and international organizations/institutions working in the region on related issues

As far as could be ascertained, there are no organizations that are currently working specifically on the use of wild fish as feed in aquaculture or on how this practice may impact on food security and poverty reduction in the region. However, as indicated elsewhere in the study, the implications of the practice have been recognized by the Kenya Marine and Fisheries Research Institute and the Departments of Fisheries in Uganda and Tanzania and no doubt, by authorities in most countries. In particular, these three agencies have recognized the impact of the increasing demand for “dagaa” (*Rastrineobola argentea*) by the animal feed industry on food security around the shores of Lake Victoria. Similarly, the Institute Nationale de Recherche Halieutique (INRH) in Morocco has recognized the impact of reduction fisheries on food security and is strongly promoting improved efficiency in the supply chain such that more fish are available for human consumption (either canned or fresh) instead of being reduced

to fishmeal out of necessity, as has been the case in the past. In 2003, approximately 75 000 tonnes of fishmeal were produced in Morocco (Poynton, 2006), and at a reduction efficiency ratio of 24 percent, this amount equates to about 312 500 tonnes of fresh fish that was not available for human consumption. This estimated amount of fresh fish used for reduction is equivalent to 46.1 percent of the Moroccan pelagic catch (677 635 tonnes, Table 1) and 34.9 percent of total capture fisheries production (896 262 tonnes in 2003) (Poynton, 2006).

As mentioned elsewhere in this report, the available information suggests that the discarding of bycatch, particularly from shrimp trawling and shark finning, and physical and economic post-harvest losses through spoilage may have a much greater impact on food security and poverty than any or all of the reduction fisheries in the entire region. This problem has been recognized and addressed by various international agencies such as the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP), the Department for International Development of the United Kingdom (DFID), and the WorldFish Center, among others. Fortunately the flurry of good work that was undertaken by many organizations in collaboration with national fisheries departments and academic institutions in Africa during the 1990s until around 2001–2002 has recently been revived. For example, the Canadian International Development Agency (CIDA) and the Association of Canadian Community Colleges (ACCC) have recently (2005) provided funding to the Memorial University of Newfoundland to initiate several projects to address the problem in Malawi and Mozambique (anon., 2006). Moreover, the “Fish for All” summit in Abuja, Nigeria (22–25 August 2005) adopted the Declaration on Sustainable Fisheries and Aquaculture in Africa, whose action plan identified the reduction of post-harvest losses as an urgent investment need. Unless there is a sustained long-term commitment by development agencies to holistically address these issues, including legislation and fish trade, the gross wastage of fish and its negative impact on food security will persist. This is of greater urgency in the region than the impact of reduction fisheries on poverty and food security.

8. CONCLUSIONS AND RECOMMENDATIONS

Global aquaculture makes a considerable contribution to world fish supply. Although the contribution from Africa and the Near East remains small, this region has shown phenomenal growth over the last decade. This underpins the potential of the region to contribute significantly towards meeting its own future demand for fish.

The global aquaculture industry is now the single most important consumer of fishmeal. However, the bulk of fish production in Asia, Africa and the Near East is composed of species low in the food chain. It is for this reason that the formal and informal aquafeed industry only uses approximately 16 percent of the total fishmeal consumed by the animal feed industry in the region.

Several examples have been provided that show fishmeal production competing with poor people for fish in parts of Africa. Historically, the predominant use of small pelagic fish in Africa was for direct human consumption. Competition from the animal feed industry has now reversed the situation in some countries, resulting in an imbalance in resource allocation. In some cases the secondary use of fishmeal has improved the standard of living and level of food security among poor communities, due to the employment that is generated. However, this is only so if the fishmeal is used internally in the country of origin and the production of the secondary product creates employment among the poor in that country. Although most of the fishmeal produced in Africa and the Near East is used in the countries in which it is produced, the production of secondary products does not always create employment among the communities that would otherwise have used the fish for direct consumption.

Therefore, in countries where rural people now have reduced access to fish as a result of reduction, it is incumbent upon governments to invoke the *FAO Code of Conduct for Responsible Fisheries* (FAO, 1995). However, the state of fisheries management and the generally data-poor nature of the region make it very difficult to implement the code. It has been shown that the reduction of fish into fishmeal can have a net benefit for the poor. However, there are instances where people are worse off as a direct result of fishmeal production. In instances where reduction of fish exacerbates the problem of low food security, steps should be taken to redress the imbalances.

It has been shown that post-harvest losses and bycatch discards globally and in Africa are enormous (Ames, 1992; Alverson *et al.*, 1994) and may very well have a larger net impact on food security and poverty than reduction fisheries in Africa. Hence, it is recommended that the initiatives to address post-harvest losses by NEPAD, WorldFish Center and FAO be strongly supported.

8.1 Recommendations

The following actions are recommended:

- Where appropriate, governments need to be made aware of the impact of fishmeal production in countries where there is a net deficit in food security.
- Where appropriate, governments need to be made aware of the potential that small pelagic fisheries have to improve national food security.
- Where necessary, sustainable fisheries management procedures need to be implemented, with particular emphasis on inland pelagic fisheries.
- Tertiary-level training must be provided to improve fisheries management.
- Governments should encourage fisheries to adhere to the *FAO Code of Conduct for Responsible Fisheries* (FAO, 1995) and the *Principles and Criteria for Sustainable Fishing* of the Marine Stewardship Council (MRC, 2002) and where appropriate, should aim to achieve MSC certification and accreditation.
- Government are strongly encouraged to collect and record fishmeal and fish oil production statistics.
- National fishmeal and fish oil production statistics need to be recorded and reported according to source, i.e. dedicated fishery, bycatch, trimmings, spoilt foodfish, overproduction, etc.
- Governments are strongly encouraged to record statistics of fishmeal use in the animal feed industry.
- FAO aquaculture production statistics should also be compiled according to feeding guilds (i.e. carnivorous, herbivorous, omnivorous, detritivorous and planktivorous) to better understand, interpret and predict the demand for aquafeeds in the future.
- Where appropriate, governments should be encouraged to develop policies regarding the use of water for aquaculture and aquaculture effluent.

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APPENDIX

Countries in Africa and the Near East that are aquaculture producers or that have produced, consumed, exported or imported fishmeal and fish oil between 1950 and 2004.

A.1. Aquaculture-producing countries in sub-Saharan Africa

Benin	Kenya	Rwanda
Burkina Faso	Lesotho	Senegal
Burundi	Libyan Arab Jam.	Seychelles
Cameroon	Madagascar	Sierra Leone
Central African Republic	Malawi	South Africa
Congo, Democratic Republic	Mali	Swaziland
Congo, Republic	Mauritius	Tanzania, United Republic of
Côte d'Ivoire	Mayotte	Togo
Ethiopia	Mozambique	Uganda
Gabon	Namibia	Zambia
Gambia	Niger	Zimbabwe
Ghana	Nigeria	
Guinea	Réunion	

A.2. Aquaculture-producing countries in North Africa

Algeria	Liberia	Sudan
Egypt	Morocco	Tunisia

A.3. Aquaculture-producing countries in the Near East

Bahrain	Kuwait	Saudi Arabia
Iran, Islamic Republic of	Lebanon	Syrian Arab Republic
Iraq	Oman	United Arab Emirates
Jordan	Qatar	

A.4. Countries in Africa that either produce, consume, import or export fishmeal and/or fish oil

Algeria	Gambia	Réunion
Angola	Ghana	Rwanda
Benin	Guinea	Saint Helena
Botswana	Kenya	Sao Tome and Principe
Burkina Faso	Lebanon	Senegal
Burundi	Libyan Arab Jamahiriya	Seychelles
Cameroon	Madagascar	Sierra Leone
Cape Verde	Malawi	Somalia
Comoros	Mali	South Africa
Congo, Democratic Republic of the	Mauritania	Sudan
Congo, Republic of	Mauritius	Swaziland
Côte d'Ivoire	Mayotte	Tanzania, United Republic of
Djibouti	Morocco	Togo
Egypt	Mozambique	Tunisia
Eritrea	Namibia	Uganda
Ethiopia	Niger	Zambia
Gabon	Nigeria	Zimbabwe

A.5. Countries in the Near East that either produce, consume, import or export fishmeal and/or fish oil

Bahrain	Kuwait	Syrian Arab Republic
Iran, Islamic Republic of	Lebanon	United Arab Emirates
Iraq	Oman	Yemen
Israel	Qatar	
Jordan	Saudi Arabia	

