

CHAPTER 1

FISHERIES FOR FORAGE FISH, 1950 TO THE PRESENT¹

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ABSTRACT

Following a brief historical review of the emergence of fisheries for forage fish that are primarily destined for reduction, and their competition with fisheries for human consumption, an account is given of landing trends in various parts of the world, and catch maps are provided for the 1970s and 2000s which allow spatial and temporal comparisons. A brief account is also given of the changing species composition of the landings, the exploitation status of the fisheries, the trophic levels trends of species destined for reduction, the fuel consumption of the global fleet exploiting forage fish which are primarily small pelagics, the fishing gear they use, and the ex-vessel prices they fetch.

The discussion, finally, attempts to amalgamate this material, which is further discussed in the other chapters in this report.

INTRODUCTION

Historically, all fish that could be caught, including small pelagic fish, were used as a source of food for humans (see Chapter 2), and the reduction of fish to fishmeal and fish oil for indirect use is relatively recent. Seasonally abundant catches of herring and sardines, which could not be absorbed by local markets, started the fish oil industry in northern Europe and North America at the beginning of the 19th century (Huntington *et al.*, 2004). The oil was used for lubrication of machinery and leather tanning, soap production and other non-food products, and the by-products of fish oil production were used as fertilizer.

In the early 20th century the production of fishmeal for animal feed began in Northern Europe, based on Herring (*Clupea harengus*), and in North America, based on Atlantic menhaden (*Brevoortia tyrannus*) in Chesapeake Bay and South American pilchard (*Sardinops sagax*) in California. Once the benefits of fishmeal as an inexpensive feed supplement for animal production were realized and demand increased, the fisheries began to deliberately target fish for reduction to fishmeal, with fish oil more as a by-product. In the early 1950s, a huge reduction fishery for Peruvian anchoveta (*Engraulis ringens*) developed in Peru, then in Chile, which at first complemented, then replaced, the earlier indirect exploitation of this fish, in the form of guano produced by fish-eating birds (Muck and Pauly, 1987; Muck, 1989).

In California, the benefits of fishmeal in the animal feed sector were quickly realized and demand for fishmeal with corresponding demands for increased landings raised concern over food supplies and sustainability of the industry (Radovich, 1981). The California legislature responded in the early 1920s with the introduction of legislation prohibiting the processing of fish for reduction if it was fit for human consumption. The controversial issue of competition between human and industrial consumption for raw material such as the 'California sardine' (which led to similar legislation in other areas and times) became moot when, due to excess fishing and the 'changes in environmental conditions' that are always evoked in such cases (see e.g., Radovich, 1981), catches peaked in the 1930s, and collapsed in the late 1940s, and the ghost of this fishery, through the works of John Steinbeck and Ed 'Doc' Ricketts, entered the realm of legend (Tamm, 2004).

¹ Cite as: Watson, R., Alder, J., Pauly, D. 2006. Fisheries for forage fish, 1950 to the present, p. 1-20. *In*: Alder, J., Pauly, D. (eds.) On the multiple uses forage fish: from ecosystems to markets. Fisheries Centre Research Reports 14(3). Fisheries Centre, University of British Columbia [ISSN 1198-6727].

The same scenario was replayed a few decades later, off Peru, where the annual catch of Peruvian anchoveta grew to 17 million tonnes (t) in 1970 (Castillo and Mendo, 1987), about 6 million t higher than the official catch of 12 million t—itself higher than recommended by experts at the time (Gulland, 1968; Murphy, 1967; Schaefer, 1967). The fishery collapsed in 1972/73, following an El Niño event that was subsequently seen by many as solely responsible for the collapse.

As earlier in California, the Peruvian reduction fishery was seriously contested by those who felt that Peruvian anchoveta should somehow be processed for human food, e.g., in the form of fish protein concentrate (FPC) that could be used to fortify flours, an obvious product in a country with an animal protein deficiency in its highlands. Moreover, not only juvenile South American pilchard (*Sardinops sagax*) and Horse mackerel (*Trachurus murphyi*), which frequently occur in anchoveta schools (Bakun and Cury, 1999), were caught by the anchoveta reduction fishery, but also pure schools of full-sized *S. sagax* sardine and *T. murphyi*, adding to the controversy. Landing *S. sagax* for reduction has long been prohibited in Peru, and recently, regulations were announced which also limit the catch of *T. murphyi* to vessels fishing the stocks for human consumption, and not fishmeal (Fishing Information and Service, 2004).

This, however, is not the main research area for scientists working on the small pelagic fishes which support the most important reduction fisheries. Rather, it is their extraordinary responsiveness to environmental fluctuations, and their apparent resilience to fishing, notwithstanding collapses in South America, California, Southern Africa, and Europe. This research has yielded some powerful generalizations (Bakun, 1996), but still does not allow for prescription on how to ensure 'sustainable' catch levels in the face of environmental variability, growing industry demand and climate change.

In the following, we briefly review various aspects of the fisheries for 'forage' fish, based on geo-referenced catches, from 1950 to the present, and analyze some features of these catches and of the fleets that made them.

FORAGE FISH

Forage fish is a term used to describe schooling fish that are often the prey for larger fish, seabirds and marine mammals. These larger animals often 'forage' on smaller fish because they are found in large schools and are easy to capture. Small pelagic fish (< 30 cm in length) such as Peruvian anchoveta make up the bulk of forage fish, but some medium-sized fish (30-90 cm in length) such as mackerels are also considered forage fish. Many populations of forage fish, especially small pelagics, fluctuate in response to changing oceanographic conditions, which affect their planktonic food (Cury *et al.*, 2000). Other factors such as predation levels, current patterns for larval retention, food availability and water conditions such as temperature affect the annual abundance of these fish (Fréon *et al.*, 2005).

The schooling behaviour of forage fish allows them to be easily caught so that the fishing fleets do not require as much fuel as, for example, trawlers (Tyedmyers *et al.*, 2005; see also Chapter 2). This translates to lower operating costs and hence cheaper fish. Forage fish that are not consumed directly by humans are extremely inexpensive compared to other fish to the extent that they can be reduced to fishmeal and fish oil and still be price-competitive with soymeal. Some of these small and medium pelagic fish are also consumed by humans (Chapter 2), and caught using the same gear, often on the same fishing grounds.

GEO-REFERENCED CATCHES

Reported catch data from FAO, ICES, NAFO and other regional/national sources were allocated to a global system of 30-minute spatial cells using a rule-based approach that utilized databases of fish distributions and fishing access agreements as filters (Watson *et al.*, 2004b; see also www.seaaroundus.org). Emphasis was given to small pelagic fishes, and other species used in reduction fisheries, i.e., forage fish as defined in this report (Table 1). Also, the fuel consumed by the various gears used to catch forage fishes was estimated, based on the approach and data in Tyedmers *et al.* (2005).

RESULTS

Landing trends

Although forage fish have been used for industrial purposes for the last two centuries, it was not until after World War II that these fisheries became highly industrialized with landings of fish destined for reduction being a significant proportion of the fish landed globally (Figure 1). In 1948 only 7.7% of total landings was reduced to fishmeal and fish oil (Macer, 1974). In 2002, 29.2 million t or 36% of all marine fish landings were used for non-food purposes. Ninety percent of these landings (non-food), much of it consisting of forage fish, is reduced, with the remaining 10% used directly for feed in aquaculture and fur animals (FAO, 2005; Figure 1). The by-products of processing fish for human consumption are also destined for fishmeal and fish oil, but make up a small, albeit increasing, proportion of catches and are not included in this analysis (Kelleher, 2005).

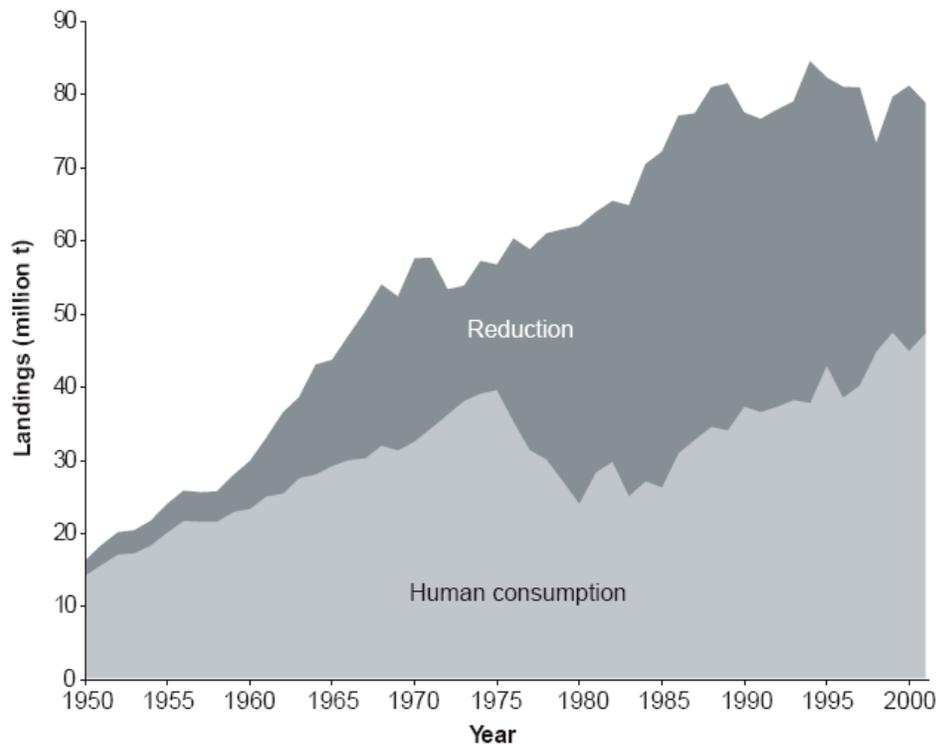


Figure 1. Trend in landings destined for reduction as proportion of total global landings 1950 to 2001. Data from 1950 to 1970 based on Macer (1974); 1971 to 1975 based on Grainger and Garcia (1996); data after 1975: *Sea Around Us Project (2006)*.

Landings destined for reduction increased very slowly until 1958, when large industrial-scale fishing for Peruvian anchoveta (*Engraulis ringens*) began (Figure 2). This fishery is now the world's largest with recent landings of 2.5 million t in 2001, all of it destined for reduction. As indicated above, landings of fish destined for reduction are highly variable, as seen in total global landings of fish destined for reduction (Figure 2) and landings of forage fish by region (Figure 3). Declines in landings in the 1970s, 1980s and 1990s are due to the impact of the El Niño in those years.

The global pattern of fish catches destined for reduction has remained roughly similar since the 1970s (Figure 4). If anything, the role of the forage fish fisheries for economic well being and food security along the coasts of Chile and Peru has increased since the 1970s.

The bulk of the fish caught for reduction are caught in South America (Peru and Chile), Northern Europe (Denmark, Iceland and Norway) and on the east coast of the United States. In the early 1960s and 1970s, Japan and the USSR had sizeable fleets including factory ships fishing for fish for reduction. However, with the establishment of EEZs and consequent closing of fishing areas to these nations, they have scaled back their fishing operations, including processing plants.

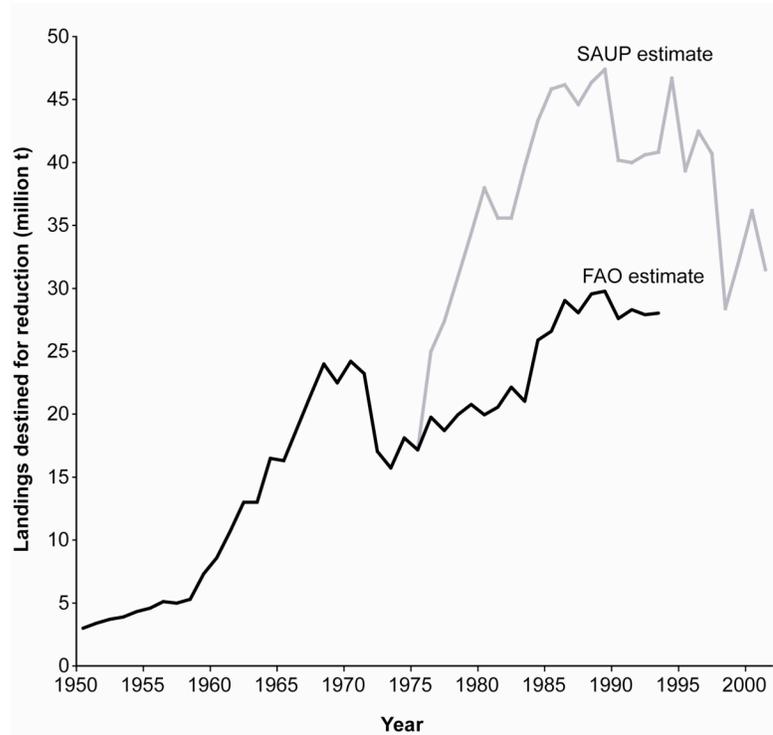


Figure 2. Trend in global landings for fish destined for reduction 1950 to 2001. Data prior to 1976 based on FAO total estimates (see Grainger and Garcia 1996), data from 1976 onwards based on *Sea Around Us Project* (2006) taxon- and country-based associations with fishmeal types reported in FAO production figures.

South America, in particular Peru and Chile, experienced considerable growth in landings from the late 1950s and peaked in the early 1990s; although catches are highly variable, they now fluctuate at around 20 million t annually (Figure 3). The fisheries in Northern Europe and on the east coast of the United States were established much earlier than those in South America. The landings in these two areas are less variable with much lower landings (Figure 3).

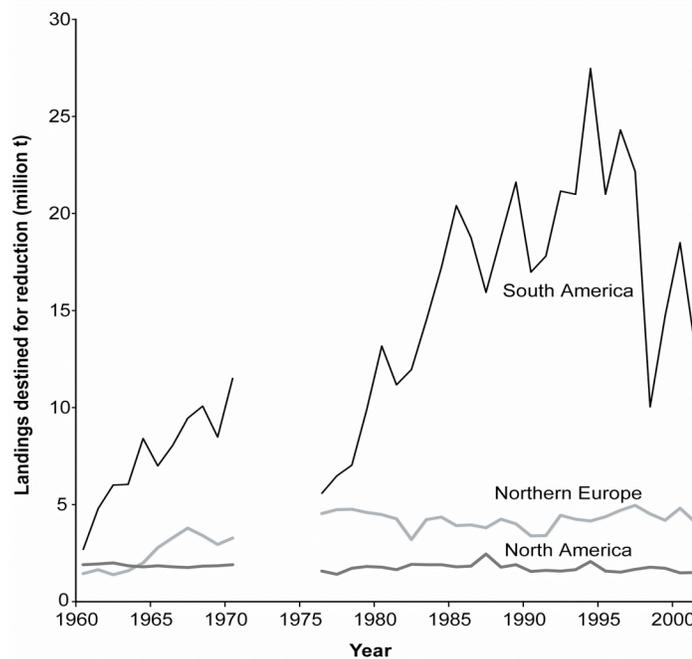


Figure 3. Trends in landings for fish destined for reduction 1960 to 2001, by major region. Region-specific information not available between 1970 and 1976 (Grainger and Garcia, 1996; *Sea Around Us Project*, 2006)

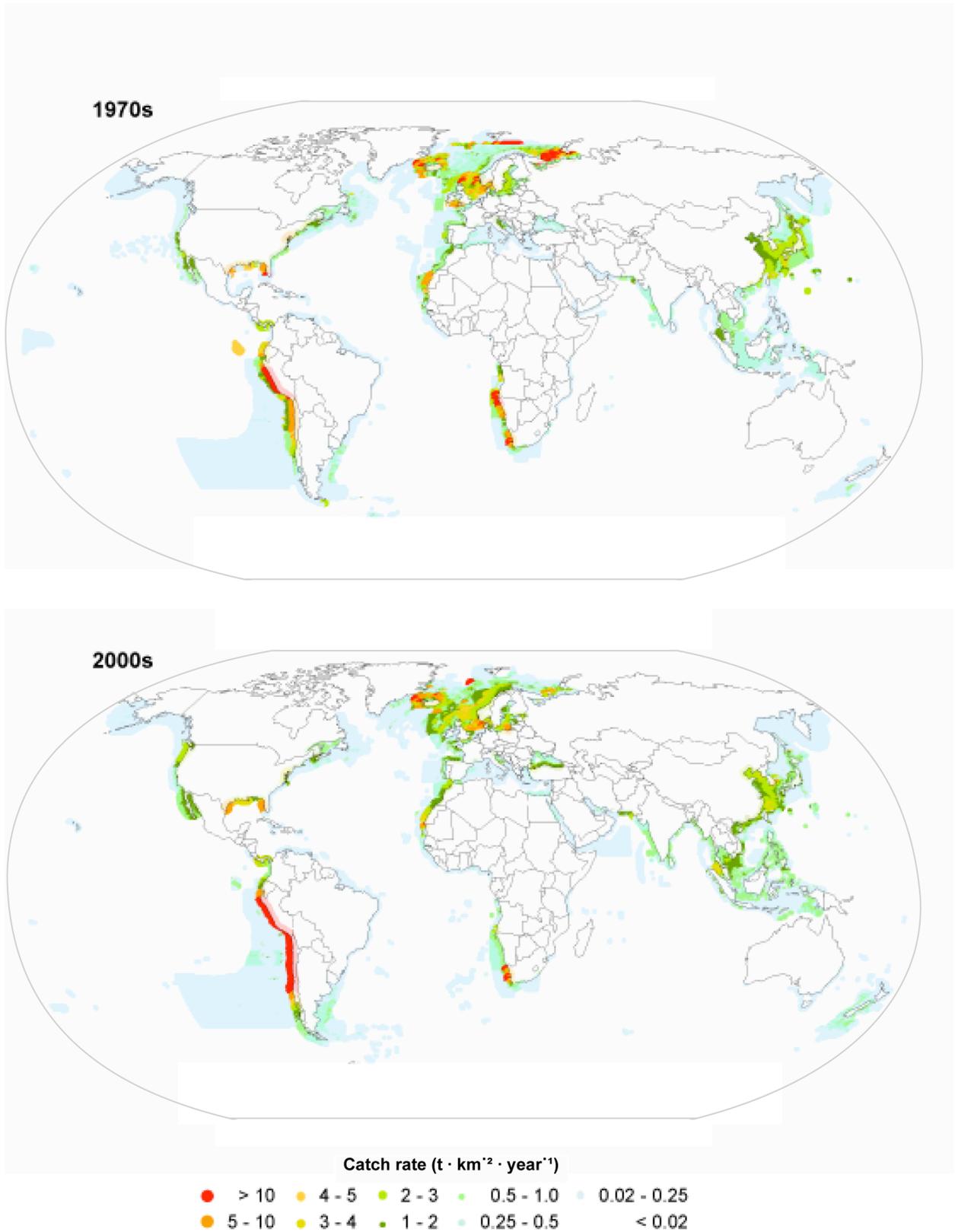


Figure 4. Catch rates for species associated with reported species destined for reduction for the 1970s and 2000s based on spatial cell-based global fisheries data (Watson *et al.*, 2004b) and a taxon- and country-based association with fishmeal types reported in FAO statistics.

Composition of landings

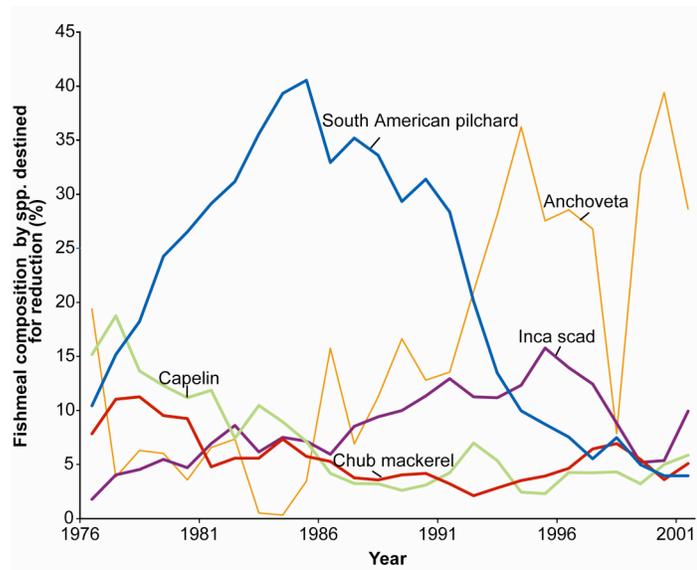
While herring, sardines and menhaden were the main species targeted early in the 20th century, the range of species targeted has expanded since then (Table 1). In the 1950s, the bulk of fishmeal produced originated from landings of fish from Northern Europe (e.g., herring), Japan (e.g., Pacific herring), Southwest Africa (e.g., Pilchard) and the United States (e.g., Menhaden). The development of the anchoveta fisheries off Peru and Chile soon overshadowed these countries with volumes of landings far exceeding that of the other countries.

Table 1: Species that made up 75% of the fishmeal produced globally in 1950, 1976 and 2001, starred species were present in only that year. Data from 1950 based on Grainger and Garcia (1996); other data: *Sea Around Us* database (2006).

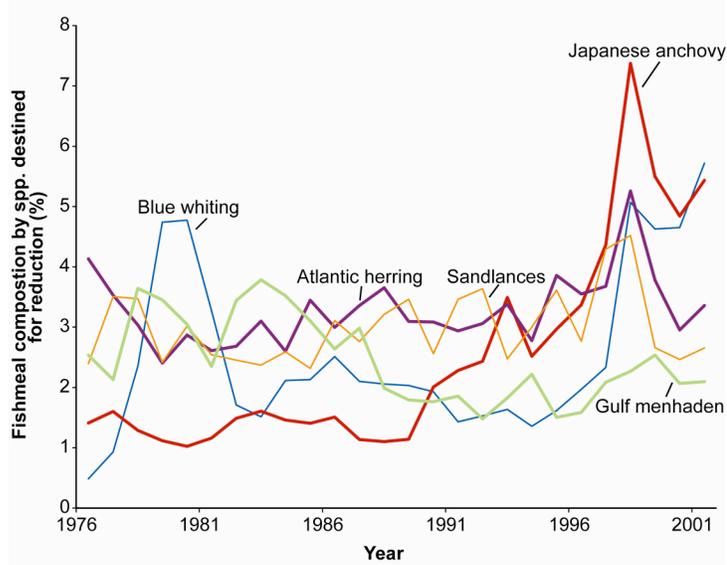
1950	1976	2001
Atlantic herring	Peruvian anchoveta	Peruvian anchoveta
Atlantic menhaden*	Capelin	Inca scad*
Japanese pilchard*	South American pilchard	Capelin
Gulf menhaden	Chub mackerel	Blue whiting
Chub mackerel	Atlantic herring	Japanese anchovy*
European sprat	European pilchard*	Chub mackerel
Capelin	European sprat	South American pilchard
Blue whiting	Norway pout*	Atlantic herring
Pacific menhaden*	Atlantic mackerel	Threadfin breams*
Peruvian anchoveta	Gulf menhaden	Sandlances
Chilean jack mackerel	Sandlances	Gulf menhaden

The expansion of the reduction industry in South America from the late 1950s saw a dramatic change in the species composition of fishmeal globally (Table 1). In 1950 landings of anchoveta made up a very small proportion of the global production of fishmeal. However, by the late 1960s, it was the major species for fishmeal (Figure 5). It was estimated that, in 2003, Peruvian anchoveta landings made up 57% of global landings used for fishmeal production (IFFO, 2004). While Peruvian anchoveta was the major species used in Peru, Chile uses additional species such as Hake (*Merluccius gayi*) and Horse mackerel (*Trachurus murphyi*). In the past, Pilchard (*Sardinops sagax*) was also used. The estimated use of pilchards increased steadily until the early 1980s and then declined (Figure 6) while the estimated use of hake has fluctuated markedly throughout the 1990s (Figure 7).

a)



b)



c)

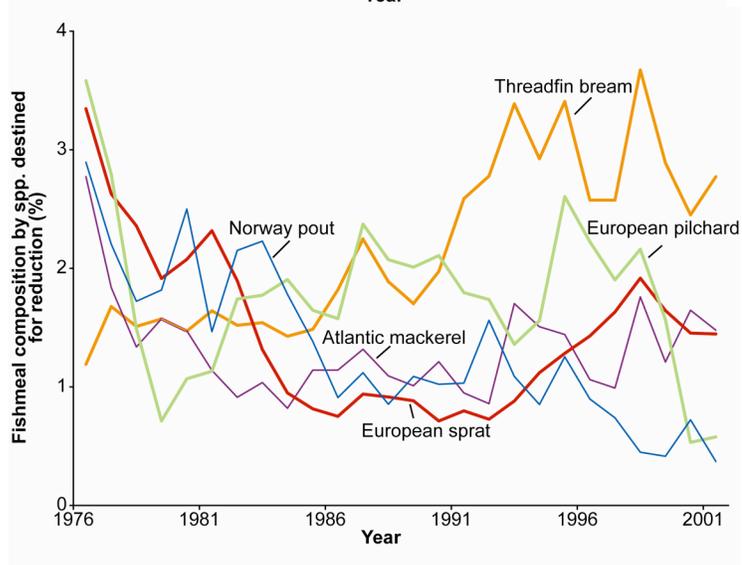


Figure 5a, b and c. Trends in the composition of fishmeal based on the top species destined for reduction that made up at least 75% of the fish used by volume for reduction in 1976 and 2001; 5a is top 5, 5b is middle five, 5c is bottom 5 (Sea Around Us Project, 2006).

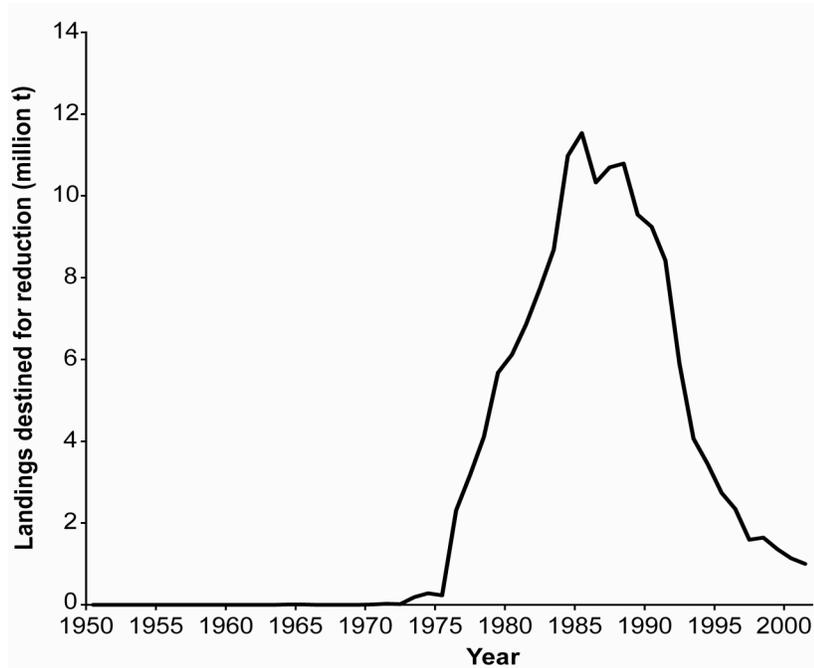


Figure 6. Landings of South American Pilchard destined for reduction 1950 to 2001. (*Sea Around Us Project, 2006*).

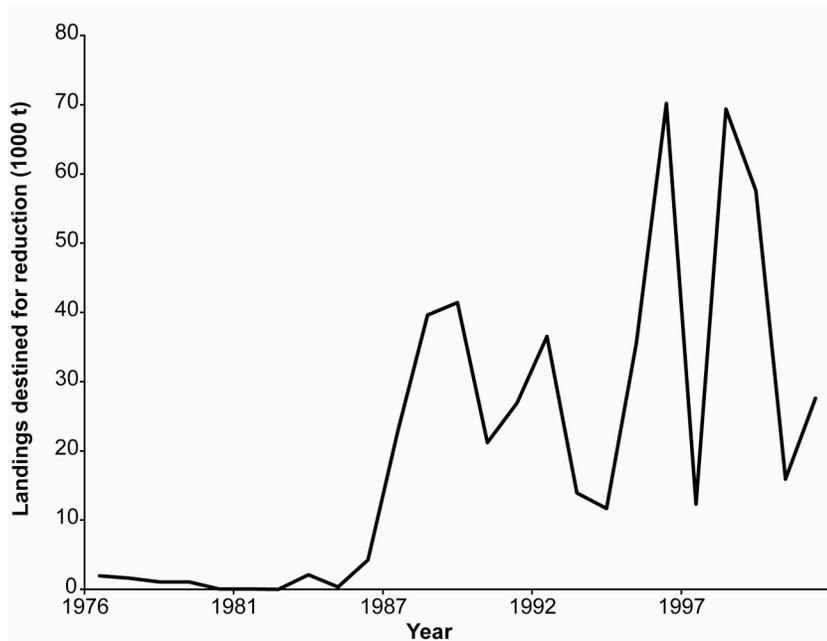


Figure 7. Chilean landings of Hake destined for reduction between 1976 and 2001. (*Sea Around Us Project, 2006*).

In Northern Europe, landings of Atlantic herring and Capelin have historically been used for fishmeal, and Capelin continues to be a major reduction fishery, making up 10% of fish landings used for fishmeal globally. Northern Europe has used a variety of species for fishmeal including the European sprat, Norway pout and Haddock (Macer, 1974). European sprat declined as a major component of fishmeal from the 1960s with current landings accounting for a small proportion of total fishmeal production (Figure 8). Norway pout followed a similar pattern. It was not used in fishmeal production until the early 1960s; landings peaked in the mid-1970s and then declined steadily, with current catches of this species estimated to be less than 100,000 t (Figure 9). Initially, Blue whiting was caught as bycatch from industrial fishing and used as fishmeal but as species of fish traditionally used for fishmeal were reduced a fishery targeting this species developed as early as the late 1960s (Macer, 1974). This species is now a

major component of fishmeal globally and is especially important in Northern Europe where it makes up 2% (in 1975) to 35% (in 2001) of fish destined for reduction (Figure 9). While declines in the abundance of some target species can account for the change in composition of fishmeal in Europe historically the composition of herring in fishmeal has changed due to European policy. A recent EU directive prohibits the use of Atlantic herring being used for fishmeal and therefore may account for some of the decline in the use of these species (Huss *et al.*, 2003). However, the restriction does not apply to Norway and Iceland, two of the largest producers of fishmeal in Northern Europe.

In the United States, Menhaden has been used since the early 1900s for reduction and continues to be the major fishery for reduction in the United States; its catches are relatively constant (Figure 10). Japan has an even longer history of fishmeal production based on Pacific saury, Pacific herring and sardines. When the stocks of these fishes declined, Japan extended its fishing efforts further offshore using a distant water fleet and factory ships, especially for processing the by-products of the Alaska pollock fishery (Macer, 1974). Japan's landings of fish destined for reduction declined as did the volume of fishmeal and fish oil as countries established their EEZs and restricted access to their fish resources including fish used for reduction. In Southwest Africa, landings used for reduction have declined since the 1960s after peaking in the 1960s, with catches now fluctuating around 850,000 t annually (Figure 11).

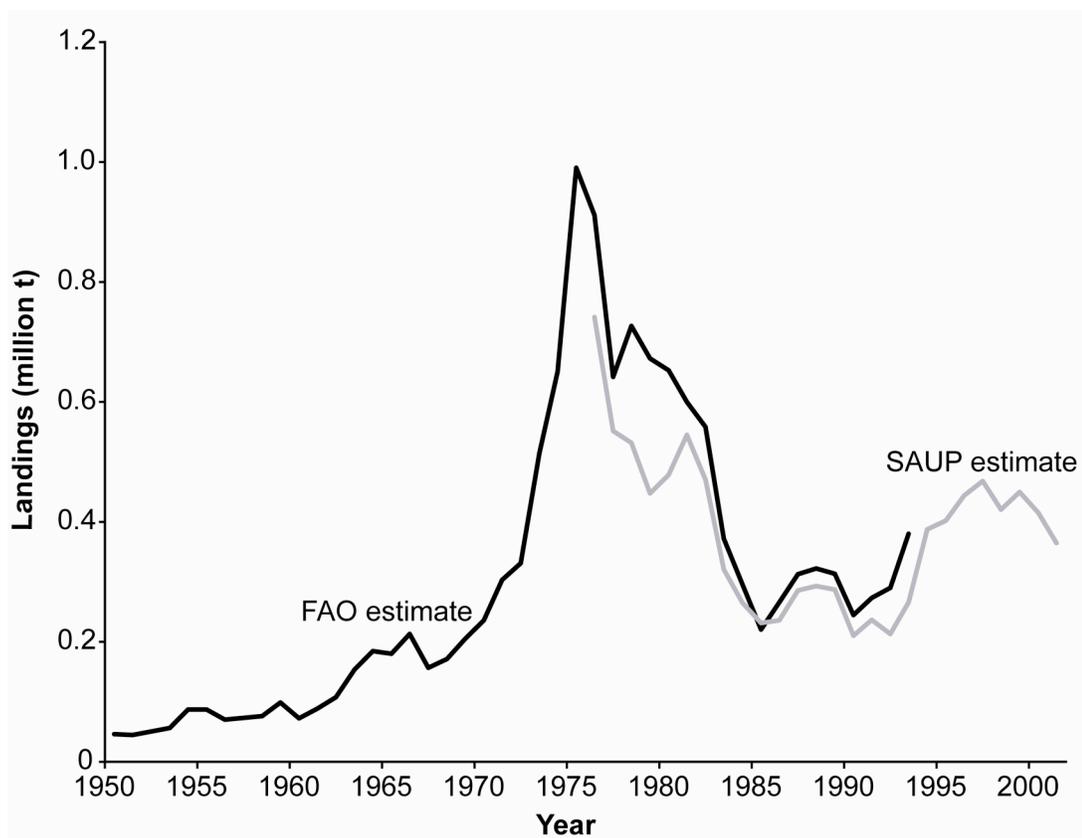


Figure 8. Northern European landings of European sprat from 1950 to 2001. Data from 1950 to 1992 from Grainger and Garcia (1996); after 1975, data are from the *Sea Around Us* Project (2006). The FAO estimates were derived from expert opinion, i.e., from the International Fishmeal and Fishoil Organisation (R.J.R. Grainger, FAO, *pers. comm.*). *Sea Around Us* Project data were derived as described in methods section.

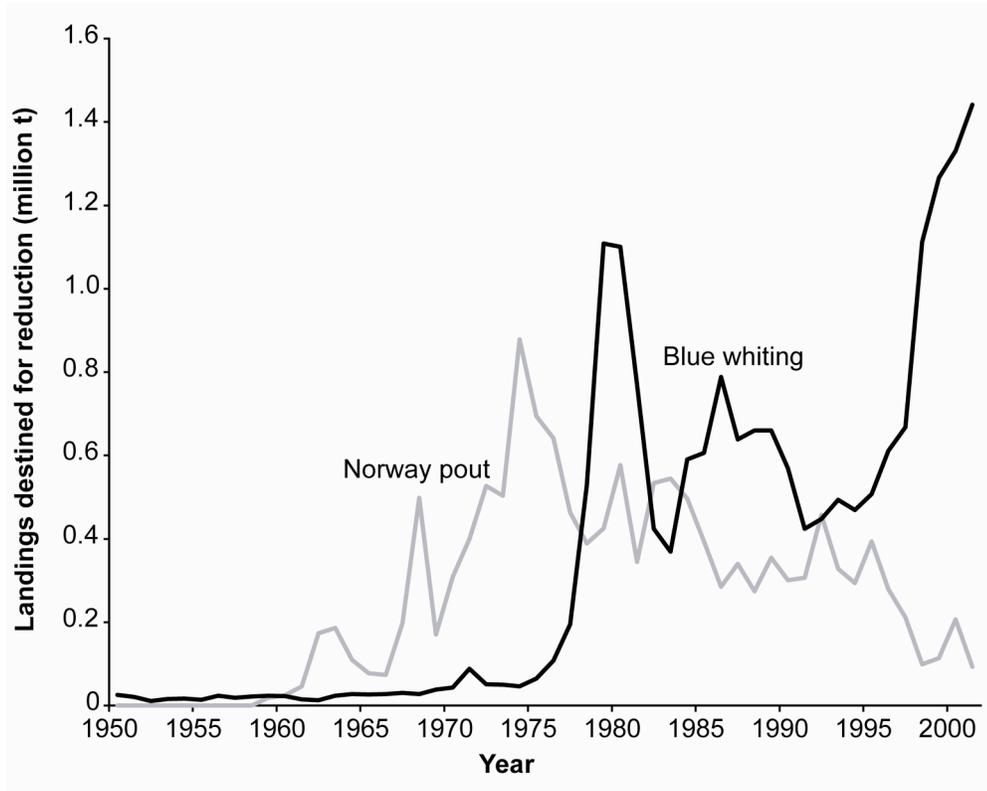


Figure 9. Northern European landings of Norway pout and Blue whiting destined for reduction from 1950 to 2001. Data from 1950 to 1975 are from Grainger and Garcia (1996); after 1975, data are from the *Sea Around Us* Project (2006).

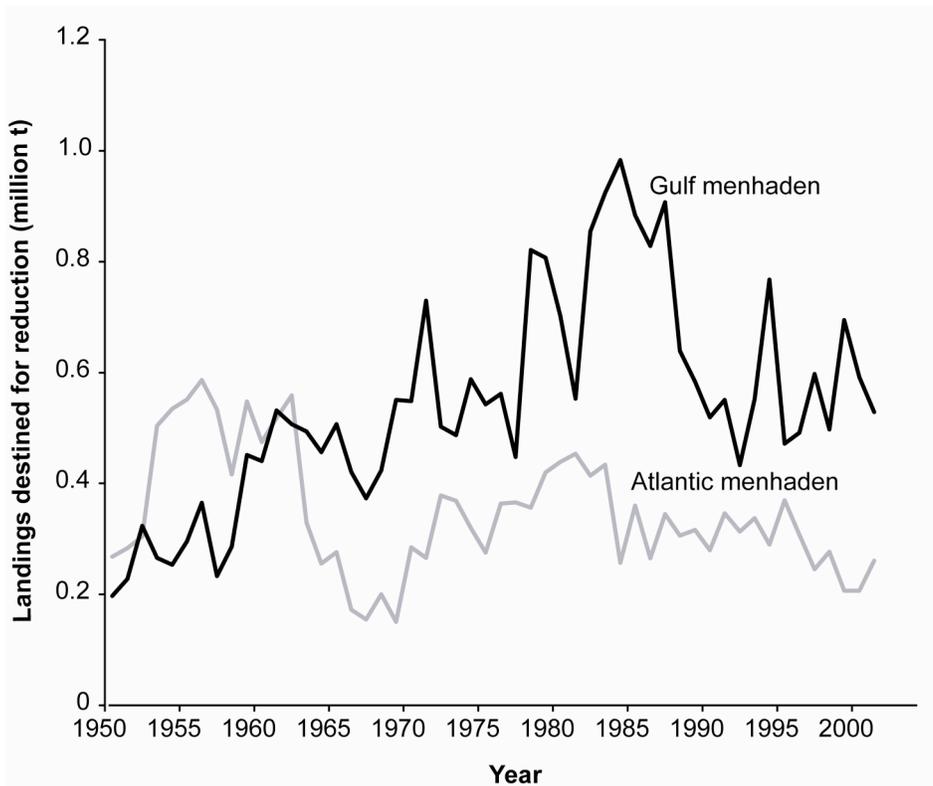


Figure 10. United States landings of menhaden from 1950 to 2001. Data from 1950 to 1975 are from Grainger and Grainger (1996); after 1975, data are from the *Sea Around Us* Project (2006).

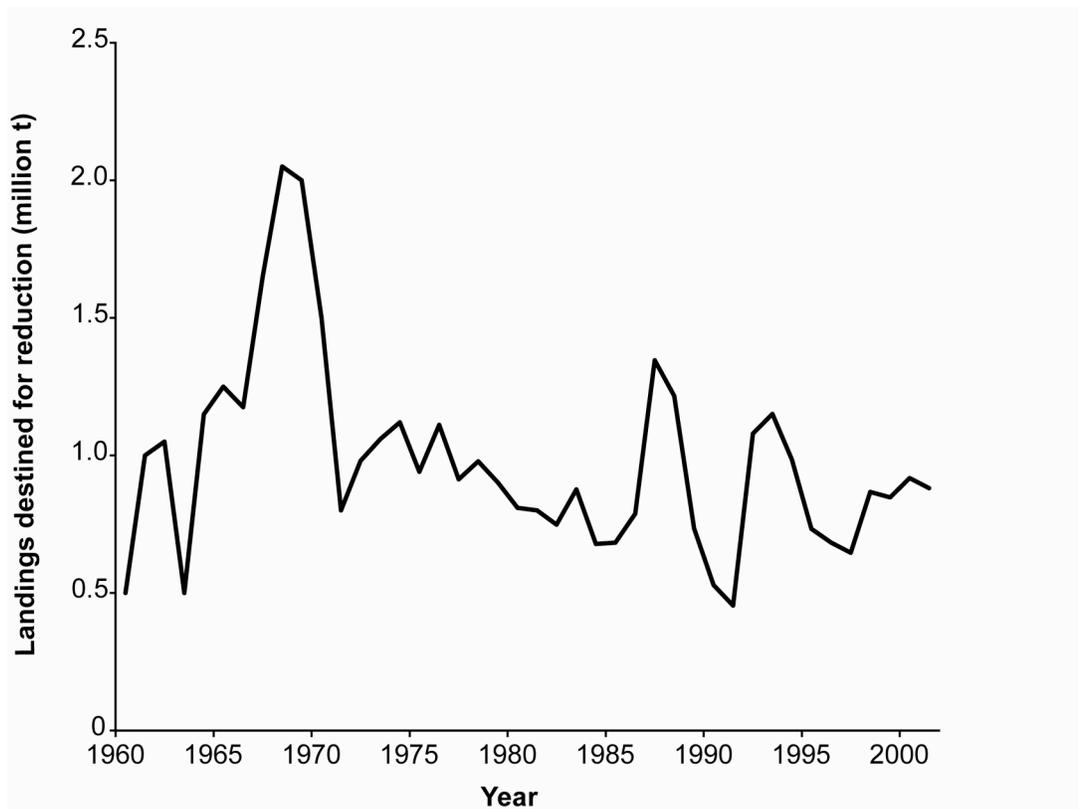


Figure 11. Trends in landings of fish destined for reduction in Southern Africa (Macer, 1974; Payne and Crawford, 1989 and *Sea Around Us* Project, 2006).

Globally, the species composition of fishmeal and fish oil is highly variable from year to year because the fisheries that are used as inputs into this sector are highly sensitive to oceanographic changes (Figure 4). For example, in strong El Niño years anchovy abundance declines, while sardine abundance increases (Bakun and Broad, 2003); this is also reflected in the catch and ultimately in fishmeal composition from Chile and Peru. The variability in the composition also affects the quality; fishmeal and fish oil high in Peruvian anchoveta are considered superior to fishmeal and fish oil with significant sardinella inputs since the fat content is different. Figure 4 illustrates the variability of landings of the majority of species that are used in the production of fishmeal. In 1976 the top five species (Peruvian anchoveta, Capelin, South American pilchard, Chub mackerel and Atlantic herring) accounted for 57% of the fish used for reduction, the same suite of species accounted for 47% of fish used in 2001.

The status of most species used for reduction is fully exploited or over-exploited, and in a few cases declining, indicating that overall there is little scope to increase landings of these species (Table 2). Technological advances have reduced the conversion ratio of live fish to fishmeal from 5 to 4, enabling production of fishmeal to increase slightly. However, fisheries based on other species will need to be developed if total fishmeal production is to increase from its current level.

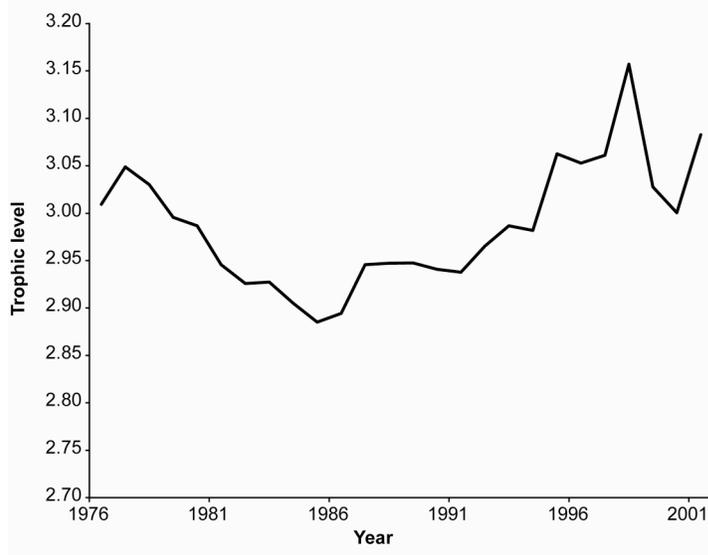
Table 2. Stock status for fish destined for reduction in 2002 (based on FAO, 2005). Multiple values of exploitation are due to multiple stocks with the FAO area being in different states of exploitation.

Target Stock	FAO Area	State of exploitation in 2002 (FAO 2005)*
Atlantic menhaden	NW Atlantic (21)	F
	WC Atlantic (31)	F
Gulf menhaden	WC Atlantic (31)	F
Atlantic mackerel	NE Atlantic (27)	F
Blue whiting	NE Atlantic (27)	O
Norway pout	NE Atlantic (27)	F
Sandeels/Sandlances	NE Atlantic (27)	F
Atlantic herring	NW Atlantic (21)	U-F-R
	NE Atlantic (27)	F
European sprat	NE Atlantic (27)	F
	Mediterranean & Black Sea (37)	D
Capelin	NE Atlantic (27)	F
Chub mackerel	EC Atlantic (34)	F
South African anchovy	SE Atlantic (47)	F
Horse mackerel	SE Atlantic (47)	M/F
Pilchard	SE Atlantic (47)	F
Pacific herring	NW Pacific (61)	?
Pacific saury	NW Pacific (61)	F
Japanese sardine (anchovy)	NW Pacific (61)	F
Peruvian anchoveta	SE Pacific (87)	R-O
South American pilchard	SE Pacific (87)	F-O
Chilean jack mackerel	SE Pacific (87)	F-O
Hake	SE Pacific (87)	F-O-D

*F=fully exploited; O=overexploited; U=underexploited; R=recovering; M= moderately exploited (FAO, 2005)

Trophic level trends

The mean trophic level was calculated as described in Pauly and Watson (2005) for fish used for reduction from 1976 to 2001. Globally, the trophic level of fish destined for reduction has increased since the mid



1980s (Figure 12). Increasing average trophic levels has occurred in most areas of the world, the exception being Africa, where the average trophic level has remained relatively stable (Figure 13). The biggest increases have been in Europe where the trophic level increased from 3.17 to 3.4, and in Asia where the trophic level increased from 3.11 to 3.77. In North America and South America, the average trophic level has increased by 0.26 between 1986 and 2001.

Figure 12. Trend in weighted mean trophic level of fish destined for reduction from 1976 to 2001 (*Sea Around Us Project*, 2006).

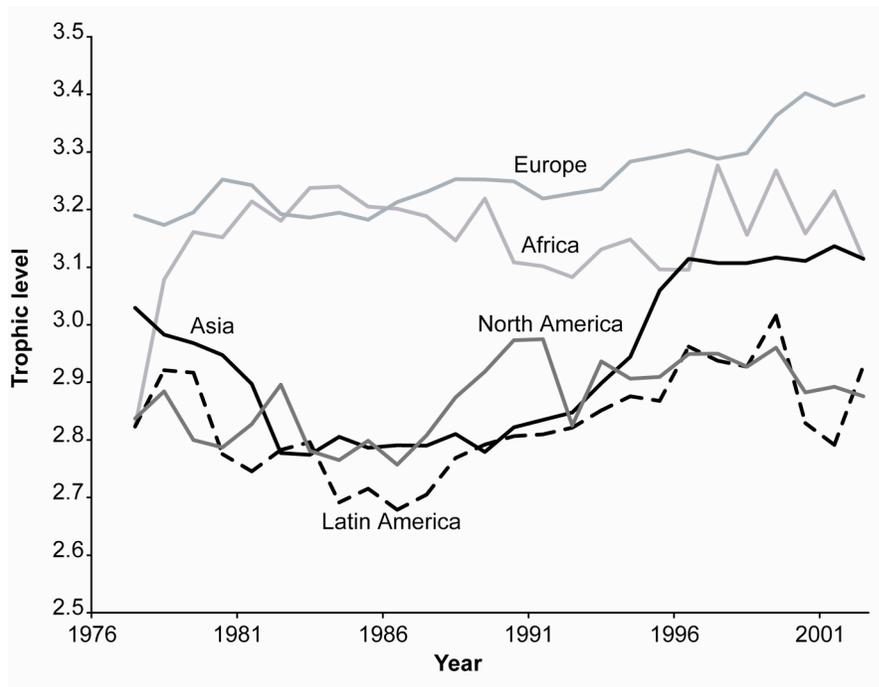
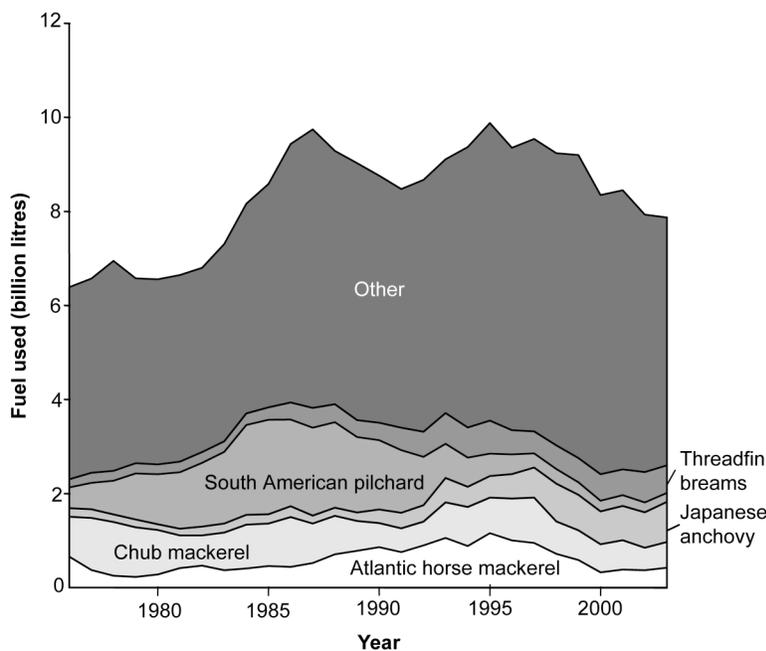


Figure 13. Trend in weighted mean trophic level of fish destined for reduction in the major continents from 1976 to 2001 (*Sea Around Us Project, 2006*).

Fuel consumption

Using global fuel intensities available for all reported catch (Tyedmers *et al.*, 2005) it was possible to associate the landings of all forage fish with the fuel used to catch them. In Figure 14, we can see that a maximum of 10 billion litres of fuel was used in some years for the reported forage fish catch, which was



nearly a fifth of all fuel expended in global fisheries. Forage fisheries use approximately 40% less fuel than the average fishery. Of all species used for reduction, more was expended on Atlantic horse mackerel than any other. This was followed closely by Chub mackerel, Japanese anchovy, South American pilchard, and Threadfin breams (*Nemipterus* spp.). There were many other species ('other') which, combined, accounted for more than two-thirds of fuel expended in forage fisheries. Because the value of fish used primarily for reduction is low compared to other species used as seafood, it is necessary to catch large quantities for the same amount of fuel as expended in other fisheries.

Figure 14. Fuel used to catch reported reduction fishery landings (*Sea Around Us Project, 2006*).

Fishing gear used

A database associating all global catch and the gear used to take it (Watson *et al.*, 2004a, Watson *et al.*, 2006) based on the gear descriptions of von Brandt (1984) was used to break down the landings of forage fish (Figure 15). This revealed that most were taken by seine net; however, this has declined as there is an increasing use of trawls to catch forage fishes. Other types of gears are not globally important (Figure 15).

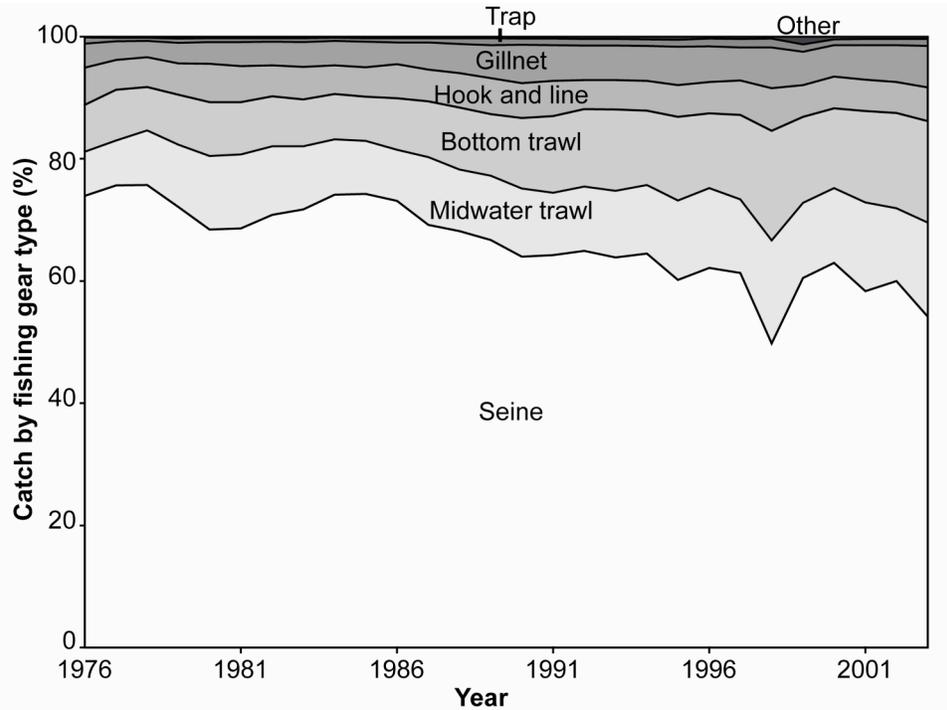


Figure 15. Gears used globally to catch forage fish. The dominance of seine nets is evident (*Sea Around Us Project*, 2006).

Prices

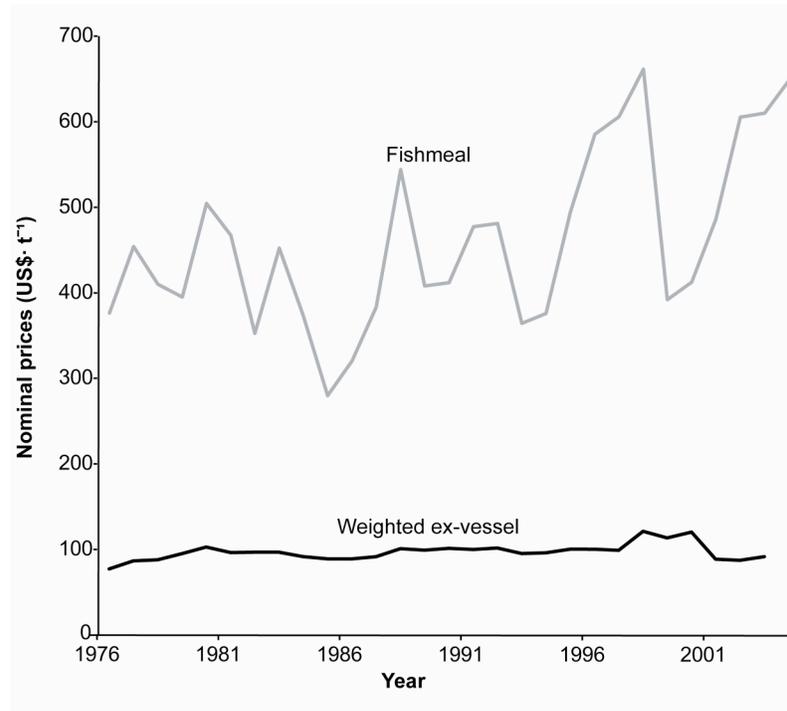
The *Sea Around Us Project* prices database (Sumaila *et al.* [*in press*], and www.seararoundus.org) was used to estimate the average ex-vessel price of fish destined for reduction. Similarly, the UN Conference on Trade and Development (UN, 2006) database was used for fishmeal. Only prices that were observed or derived directly from observed ex-vessel prices were used (Table 3). A weighted average price was used since anchoveta dominates the species composition of fishmeal and has one of the lowest ex-vessel prices. The weighted prices are based on nine taxa that make up at least 60% of the landings used in fishmeal for the period 1976 to 2003. Both weighted nominal and real prices (adjusted to 2000) were calculated, and the nominal ex-vessel price compared to the nominal price of fishmeal (Figure 16 a and b).

Table 3. Countries and taxa used to estimate weighted ex-vessel prices for fish used for reduction.

Taxon	Countries				
Atlantic herring	Denmark	Germany	Iceland	Ireland	USA
Blue whiting	Denmark	Iceland	Ireland	Norway	UK
Capelin	Canada	Denmark	Iceland	Norway	□
European sprat	Denmark	Germany	Norway	UK	□
Sandlances	Denmark	Norway	UK	□	□
South American pilchard	Chile	Mexico	USA	□	□
Chub mackerel	Chile	USA	□	□	□
Peruvian anchoveta	Chile	□	□	□	□
Gulf menhaden	USA	□	□	□	□

Since 1976, the nominal price of fishmeal has increased while the average nominal ex-vessel price has remained relatively constant (Figure 12). However, when real prices (adjusted to 2000) are used, the real price of fishmeal actually declines and the real ex-vessel price declines, albeit very slowly. The combined uncertainties associated with ex-vessel prices, of tonnage used and the Hamburg market prices (see Figure 16b) make the global value of fishmeal and the ex-vessel value of fish difficult to estimate reliably, and we abstain from presenting such a figure here.

a)



b)

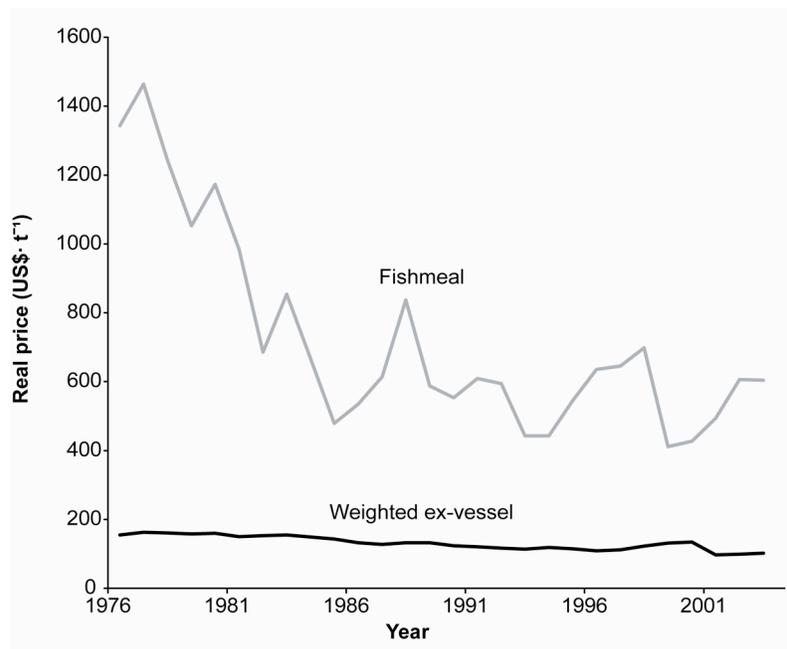


Figure 16a and b. Trends in weighted ex-vessel prices (nominal and real 2000) for fish used in reduction and prices for fishmeal sold at the Hamburg market (United Nations, 2006)

DISCUSSION

Landings of fish destined for reduction have increased since the 1950s and appear to have stabilized around 25 million t live weight. However, the species targeted for reduction have changed and, in most areas of the world, fish at higher trophic levels are being used. While some argue that most fish landed for reduction are not consumed by humans, the evidence is otherwise (Chapter 2).

The fluctuation in global landings and landings of particular species for reduction often raises the question of the impact of these catches on stocks and the ecosystem. Bakun and Broad (2003) noted that small pelagic fish, which make up much of the bulk of forage fish, are extremely important to the transfer of production 'upward' in the food webs of the ecosystems they are found in. They operate at the crucial 'wasp-waist' trophic level where one or more small plankton-consuming nektonic species tend to dominate the trophic transfers, whereas there are relatively more species involved in transfers at lower and higher trophic levels (Bakun and Broad, 2003).

For fisheries where assessments are available, the status of many of these fish stocks have been assessed as 'sustainable' and fished 'within safe biological limits' by various organizations (IFFO, 2004; Seafeeds, 2003). However, an analysis of the exploitation status of the major species used for reduction indicates that not all stocks are within safe limits (Table 2). Some stocks such as North Sea herring were used for reduction until 1997, when the stock collapsed and the EU banned the use of herring for reduction. Some herring that is caught as bycatch can be used for reduction (EU, 2004). The status of forage fish stocks are often reported on large geographic areas and are usually amalgamations of more than one stock within an FAO area, so the status of individual stocks in an FAO area can be masked if one or two stocks overwhelm the overall assessment.

Most fisheries are under some form of management and, given the variable nature of these fisheries and their sensitivity to changing oceanographic conditions, a precautionary approach to management including setting of quotas and effort limits is needed. In Europe, the quota for capelin was recently reduced from 700,000 t in 2005 to 200,000 t in 2006 (Carvajal, 2006). A notable exception is Blue whiting, one of the major inputs to fishmeal and fish oil in Europe. The stocks in the North Atlantic are exploited by a number of countries within and outside of the EU, which cannot agree on quotas for the fishery. In 2004 landings totalled over 2 million t, despite a recommended quota of less than a million t by ICES (EU, 2004). There is considerable concern over the long-term viability of this fishery, as there is for other forage fish fisheries such as Horse mackerel, European sprat, North Sea herring and other species throughout the world.

The impact of landing 40% to 60% of the Sandeel biomass consumed by many demersal fish in the North Sea and of landing 15% to 20% of the total biomass is poorly understood for this and other species (ICES, 2003). A study of the impact of reduction fisheries on EU marine systems was completed in 2003. The general conclusion was that "*the impact of industrial fisheries we were able to identify is relatively limited compared to the effects of fisheries for species destined for human consumption*" (Anon., 2004). ICES also looked at the particular questions of the impact of the fisheries on predators and bycatch. Information on predator interactions was limited to the North Sea and they concluded that the overall impact of industrial fisheries was relatively limited; however, interactions can be locally significant with certain populations of predators. Again, data were available from the North Sea to investigate only the impact of incidental bycatch and the conclusions were that most incidental catches are also species used for fishmeal (e.g., Blue whiting is a bycatch of the Norway pout fishery). Also, where edible species are caught incidentally, they generally make up a low proportion of the catch, which is considered acceptable by the EU (EU, 2004).

Forage fish are important prey for marine mammals and seabirds as seen in El Niño years in South America, where there are significant mortalities of these animals due to a reduction in prey abundance (Hays, 1986). Changes in the Benguela upwelling system also result in substantial mortalities of marine mammals and seabirds (Crawford *et al.*, 1992). The additional impact of commercial fishing of prey species on marine mammals and seabirds in El Niño years has yet to be assessed. In the US, there is growing concern over the landings of Menhaden impacting the catch of Striped bass in Chesapeake Bay (Uphoff, 2003). Similarly, concern in the UK over the interaction of Sandeels and seabirds resulted in the European Union Council of Fisheries Ministers banning catches of Sandeel in the North Sea, in an area of 20,000 km² bordering the east coast of Scotland and Northumberland (EU, 2004).

The weighted average nominal price of fish destined for reduction has increased from an estimated US\$ 77 /t to \$US 92 /t, an increase of 19% between 1976 and 2003, while the average Hamburg price for fishmeal has increased from \$US 376 /t to \$US 611 /t, an increase of 63% over the same time period. The weighted price of fish destined for fishmeal and fish oil has declined from \$US 155 /t to \$US 91 /t, a decline of 42% between 1976 and 2003, while the real Hamburg price of fishmeal declined from \$US 1343 /t to \$US 604 /t, a change of 55% over the same period. The price of fishmeal and in turn the ex-vessel price of fish destined for reduction is driven by:

- Supply of fish: when catches increase in South America, prices decline;
- Demand from Asia, which accounts for 60% of fishmeal consumption, much of it in China; and
- The price of soymeals, which can be used as a substitute for fishmeal in animal production (Asche and Bjorndal, 1999).

In the meal market, fishmeal accounts for 5% of total supply while plant meals, especially soy, account for almost 95% of supply. This high percentage of plant meal therefore influences the price of fishmeal and in turn, the ex-vessel price of fish destined for reduction. Although fishmeal is nutritionally superior to soy and other plant meals in intensive animal production systems, if fishmeal prices increase, consumers will substitute plant meals if quality is not compromised (Asche and Bjorndal, 1999), limiting the scope of fishmeal producers to increase price and in turn allowing fishers to increase ex-vessel prices. In Europe, it was noted that ex-vessel prices for fish used for reduction were generally 10% of the cost of fish used for human consumption (Nielsen, 2000).

The upward trends in the average trophic level of landings destined for reduction are in contrast to the downward trend in the average trophic level of fish for human consumption (Pauly and Watson, 2005). This indicates that fish potentially suitable for human consumption are being diverted to fishmeal (a topic discussed further in Chapter 3). This trend is not unexpected since the species composition of fishmeal has changed, including the growing use of Dorab wolf-herring in Asia, King mackerel in the United States, Japanese and Spanish mackerel in China and Japan, Southern hake in Chile and Blue whiting in Europe. Some of these species are also used for human consumption, or through processing technology directly consumed by humans, as is the case for Blue whiting (Chapter 2).

The fisheries for forage fish have changed significantly since 1950, especially with the development of the anchoveta fishery in Chile and Peru. Initially, the demand for fishmeal and fish oil was driven by intensive animal production systems seeking inexpensive, yet effective components to animal feeds. Although the growth of aquaculture over the last 20 years has changed the landscape of use of fishmeals and oils, it has not dramatically changed the nature of the fisheries in South America and the USA. However, the increasing demand for these products has expanded the species of fish targeted for reduction, which now include higher trophic level species. This expansion has also at times resulted in a competition with human needs.

In Europe there have been major shifts in the species exploited and in the sustainability status of some of those species. While the intensive animal production sector can substitute fish for soy, the aquaculture sector is currently limited and thus the pressure to exploit forage fisheries at their maximum will continue as new species become exploited with unknown impacts on marine mammals and seabirds.

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