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World fisheries—utilisation of catches

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Abstract

After considering the early history of fish as food the paper places fish and fisheries within the context of the second millenium, with particular reference to the impact on European and N. American development. In the 20th century in nutritional terms, fish is seen more as an important source of micro-nutrients, minerals and essential fatty acids than protein. Per capita consumption of fish has risen on a global basis to 15 kg/head/year but projected population growth and mismanaged resources will make this difficult to sustain. Fish consumption, even in limited quantities, has been shown to protect against coronary heart disease and also tends to reduce low birth-weight.

After decades of production, growth capture fisheries are levelling off, with future increases likely to come from aquaculture. However, up to 25% of marine catches are discarded and almost 30% is used for the production of fish meal and oil. International trade in fish has risen to US $50 000 million/year, representing 37% of fish for human consumption and tending to stimulate distribution of fresh and value-added products. Sustainable fish supplies for the future will be expected to be safer and traceable to their source.

1. Early history of fish as food

The links between fish as food and human development are profound. Crawford et al. [1] have speculated that man's particular metabolic requirements for a number of essential fatty acids, preferentially available from the aquatic food chain, stem from the origins of mankind. Terrestrial life evolved from the proto-oceans and seas, where the principal food source, phyto-plankton, produce large quantities of these essential fatty acids, which remained essential for terrestrial life forms. They are required, particularly, for the development and maintenance of the vascular and

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nervous systems. Man differentiated himself from the apes, with a massive expansion of brain capacity, about 50 000 yr ago. According to Crawford et al. [1], the quantity of essential fatty acids required to form and maintain this large brain can only have come from the aquatic environment, leading to the assumption the human life originated at the margin of the sea. It, therefore, comes as no surprise that shellfish refuse and bones of fish have been uncovered from refuse heaps of the most ancient sites of human habitations [2]. Subsequently, the hunter–gatherers wandering around in small groups must have seen fish in all coastal waters, rivers and lakes and added them to their diet of vegetables, grains, fruits, insects and small animals.

The emergence of agriculture around 6000 BC and the transition from food collection to food production caused highly significant changes in the human diet. Grain became more easily available and the shift from a nomadic existence to living in permenent settlements called for the processing and storage of food. The first use of processed fish, described by Kreuzer [3] in a review of the place of fish in culture, was in Mesopotamia around 3500 BC. There saltfish and quern-ground barley porridge were the main foods while in Sumeria the staple foods were vegetables with dried, salted and smoked fish. In ancient Egypt, salted and dried fish were important commodities and there are written accounts of fish processing in China as early as 1500 BC. In ancient Rome, there are accounts of fish being sold as luxury items, live fish was imported from Greece and other Mediterranean countries and such delicacies as oysters, mussels and the eggs of sea urchins were commonly consumed. In Roman dishes vinegar-marinated tuna and fermented fish intestines were used for spicing other foods.

2. Fish and fisheries in a millenial context

Based on this broad historical background the more recent developments in fisheries, from a subsistence hunting activity to a significant food-producing industry, fit quite neatly within the second millennium. Prior to this the only significant fish-processing industry was the drying of cod in Norway and Iceland, which started in the 9th century. Since 1000, we have passed from a resource lightly exploited at the land–water interface to a situation where aquatic resources all over the world have progressively, and at an accelerating rate, been brought under exploitation, often at or above their maximum sustainable capacity [4]. This growth has been driven both by population increase and the availability of technology. It is interesting that from being the first wild creature to be hunted for food by man, today fish is the last wild beast that makes a significant contribution to the human diet.

Throughout the millennium, fish and fisheries have had a very profound effect on food supplies as well as on both social and political developments. Local records from the Basque country show that as early as 1000 Basque fishermen from the Iberian Peninsula were fishing the Atlantic Grand Banks for cod and preserving their catch by salting. Profitable markets in southern Europe, previously supplied from Norway and Iceland, encouraged this trans-Atlantic trade in which many countries

participated after the discovery of Newfoundland by Cabot in 1497. The Basque fishermen had previously made no claims of discovery or given publicity as to where they obtained their fish, behaviour that has been copied by many fishermen down through the ages. Having a land-based "platform" on the western side of the Atlantic, close to the resource, enabled the salted cod to be dried for longer conservation. Thus, 5 years after Colombus' discovery of the New World salted dried cod, (*bacalao,bacalhau,baccala or morue*) was on the way to becoming a dietary staple and an extremely important item of trade. It continues today to be well appreciated in Mediterranean countries.

The early economic and political development of the east coast of North America, particularly New England, was heavily dependent on the cod trade. Likewise the plantation economies of the West Indies relied for their sustenance on dried cod. The historic importance of cod is well described by Kurlansky [5] who also details the triangular trade patterns which developed between the North American seaboard, the West Indies and Africa from the 17th to the 19th centuries. This introduced the taste for dried cod to the Caribbean and West Africa where it still endures. Portugal and Spain also spread the tradition to their colonies in southern Africa and Latin America.

In the northern part of Europe, the major fishery industry to develop for food was based on herring. Cutting [6] shows that preservation of herring by salting, smoking or drying increased greatly from the beginning of the millennium as a result of the introduction of technology. In the 14th and 15th centuries, the Dutch were pre-eminent but were subsequently challenged by the British. Catches from the summer and autumn fishery in the North Sea, taken when the fat content was high, were preserved in brine (to reduce oxidation) for use during the period of Lent (i.e. winter) in that part of Europe where food resources were limited. It was not possible to conserve sufficient feed for land animals, or to preserve their meat and fat. As a result, all but the breeding stock were slaughtered and consumed by the New Year, leaving the population dependent on salted herring and the remaining supplies of cereals until the spring.

Despite the increased demand for food by growing populations the next major change had to await the availability of technology. Although the use of ice for the preservation and transport of fish had been known in China since time immemorial its application in Europe had been restricted to the very wealthy due to cost, limited availability and the slowness of transport. The introduction of steam power for fishing and fish carrying and subsequently development of mechanical ice making, enabled fresh fish to reach even inland consumers, via the expanding railways, during the 19th century. Cod can reasonably claim to be considered among the first of the modern fast foods. The industrial revolution in Britain concentrated population through urban migration from the mid-1800s. The lowest cost food for these large concentrations of people was provided through the fried fish and chip shops, which at their maximum absorbed 25% of the fresh iced cod that landed in Britain.

Increasing production through more efficient technologies including diesel engines, synthetic twine, electronic fish finding, freezing at sea, etc. accelerated from the mid-19th century until today when the poor fish has nowhere to hide. This

has provided raw material for a large, technologically efficient, market-driven food industry.

Interest in technological development of the fish industry was greatly stimulated at the end of the 19th century, by fisheries exhibitions in Berlin in 1880 and London in 1883. However, it has been in the 20th century that fisheries, fish processing and trade have taken off on a scale never seen before in history.

3. Fish in 20th century human nutrition

The traditional view of fish in nutrition has been as a source of high-quality animal protein, supplying approximately 6% of the world's protein requirements and 16% of the total animal protein [7]. This view was supported in the widely held belief in the 1960s that there was an emerging "protein gap" that would particularly impact on the poor in developing countries. Now it is clear that the earlier estimates of protein requirements were on the high side and that, with the exception of people eating protein-deficient starchy diets based on staples such as cassava, if food intake is adequate the protein requirements are met. Nevertheless, fish does make a very significant, though not essential, contribution to the protein supplies of many fish-consuming communities in both the developed and developing worlds. In general, lean fish is not an important source of calories, which are mostly obtained from the staple carbohydrates in the diet. Fatty fish, however, are also a significant energy source. Today it is recognised that fish is probably more important as a source of micro-nutrients, minerals and particularly essential fatty acids than for its energy or protein value. The essential micro-nutrients and minerals in fish, which are deficient in staples, include vitamins A and D, phosphorus, iron, calcium, magnesium, selenium, iodine in marine fish, etc.

Determining the quantity of fish that is, or might be, available to the average consumer or to a particular individual is not easy. The total food supply available from fisheries would give an apparent availability, in live weight terms, of 15 kg for each of the world's inhabitants. This figure increased from about 7 kg in 1950 as production more than kept pace with population growth, but is now levelling off. However, such availability, or per capita consumption figures need to be viewed with some caution. Who actually eats the fish or fish products within a population is heavily skewed to those who have a cultural preference for fish, those who can afford it or alternatively those who can find it in the market. Even at the first level of disaggregation, between developed and developing countries, there is a discrepancy as availability in developed countries is 29 kg per capita, while it is only 12.5 kg per capita in the low-income food deficit countries. Projections of demand resulting from population and income growth point to an increasing gap between supply and demand. It is likely that these effects will impact particularly severely on the least developed countries. They will directly affect:

- Levels of consumption by at-risk groups and how this can be improved or sustained.

- The contribution of fish and fisheries to the realisation of national nutritional goals.

4. Fish consumption and health

The protective effect of a small amount of fish on coronary heart disease (CHD) mortality has been established throughout numerous epidemiological studies. A diet including 2–3 portions of fish per week has been recommended on this basis. These studies show a beneficial effect of consumption of lean as well as fatty fishes, in the prevention of cardiovascular diseases. Among others, Kromhout et al [8] and Menotti et al. [9] have shown a 50% reduction of CHD mortality after 20 years, with consumption of as little as 400 g of fish a week.

It has been suggested that the content of long-chain *n*-3 polyunsaturated fatty acids (PUFAs) (eicosapentaenoic 20:5 and docosahexaenoic 22:6) present in a fish offers this protection against CHD. This has inspired a number of scientists throughout the world to carry out studies on the importance of dietary intake of fish oil and to explore the effects of *n*-3 PUFAs on various important biological systems. Several recent studies have shown that a large intake of *n*-3 fatty acids is beneficial with regard to lowering blood pressure, reducing triacylglycerols and modulation of cell function and cell reactivity to external stimuli. The final conclusion whether it is possible to substitute fish consumption with fish oils or *n*-3 fatty acid supplements, and gain the same reduction in mortality from CHD, awaits more studies. However, the protective role of fish consumption is unquestioned.

Docosahexaenoic acid (DHA, 22:6, *n*-3) is the major PUFA in the adult mammalian brain. It is among the materials required for development of the foetal brain, central nervous system (CNS) and for retinal growth in late pregnancy. Brain growth utilises 70% of the foetal energy and 80–90% of cognitive function is determined before birth. However, the placenta depletes the mother of DHA [10], a situation exacerbated by multiple pregnancies [11,12]. Dietary enhancement or fortification with aquatic products before and during pregnancy, rather than after the child is born would be of great benefit to the child and mother, and is more likely to lead to sustainable good health than any other policy. Furthermore, the same food sources which are rich in DHA are also rich in zinc, iodine and vitamin A, so it may be possible to provide several dietary supplements at one time. Deficiencies of the latter micro-nutrients are established causes for mental retardation and blindness.

This work is being extended to the developing world to supplement deficiencies in the staple diets of poor consumers.

5. Disposition of the catch

Fig. 1 shows development of global fish production from 1950 to 1997[1]. After decades of phenomenal growth it is evident that the marine capture

[1] All data are from the FAO Fishery Statistics Data Base (FISHSTAT) unless otherwise indicated.

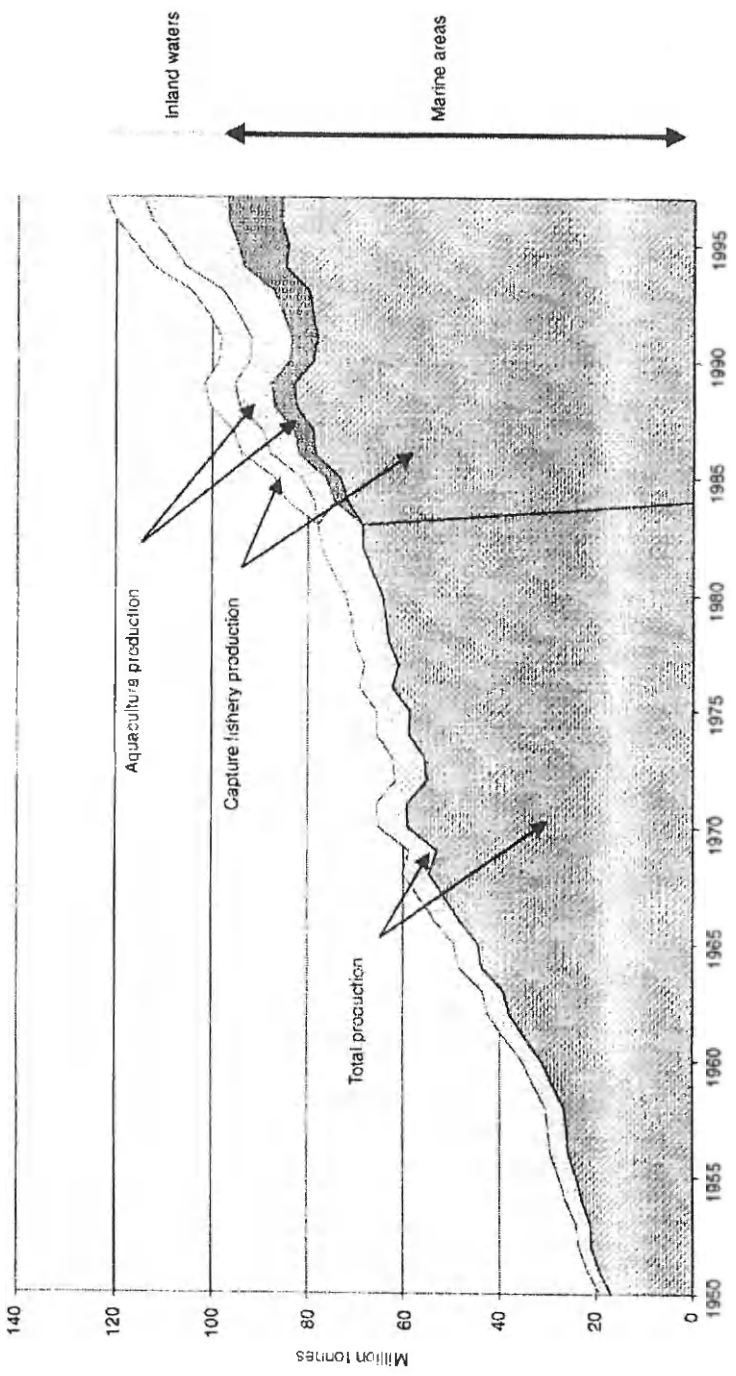


Fig. 1. World—inland and marine fishery production, total: 1950–83; capture/aquaculture: 1984–97.

fishery is levelling off and that increased production has in recent years mainly come from aquaculture. Not shown in this figure are discards which have a potential to be used for food or feed. These mostly comprise non-targeted fish that are thrown back (usually dead). It is estimated by FAO that the bycatch could be as high as 20 million metric tonnes annually or about 25% of marine capture fisheries production (a revision of the estimate of [13] by a follow up meeting of experts who reviewed the discard situation in FAO fishing areas [14].

With regard to the utilisation of landings it would seem that the processing industry or consumers are very conservative, as there seem to have been relatively little change in how the fish is prepared or processed over the last four decades. Over 70% of world fish production is used for direct human consumption and 27% currently goes to fishmeal and oil production. The highest share of the global catch for fishmeal was 38% in 1970 but it dropped sharply in 1973 due to the El Niño effects off the coast of South America and never recovered to its former share. For cured fish, once the staple product, the same trend has been observed in both developed and developing countries, with a steady decline from 20% to 10% of total production since 1960. Canning has remained constant at around 10% but developing countries have doubled their share of the catch being canned. A further significant change for developing countries is that their share of frozen products has steadily been going up from 1961 (13%) to 1996 (36%) but then for the first time in 1997 showed a downward trend. The proportion of the catch frozen showed strong growth until recently when it has levelled off at about 22%. So the share of fish being marketed fresh seems to be on the rise, now reaching 35%. This does not come as a surprise as fresh fish fetches significantly higher prices than frozen and therefore the incentive is high. Marketing fresh fish, however, is made difficult due to its perishable nature and a very short shelf life. This increses the economic risk to the producer and it is evident that the vast bulk is marketed close to where it is landed. However, progress in packaging, lowered prices of air freight, as well as generally more efficient and reliable transport systems have enabled the more expensive products to be marketed fresh in the most profitable locations.

Figs. 2–3 show developments in some of the main commoditites over the last 20 years. Figures for imports are used here to demonstrate the trends as they are generally more reliable than production figures for commodities. It should be noted that figures for commodities are in actual product weight, not live weight equivalents. Fig. 2 shows that whole frozen fish is by far the most significant product in international trade. This may change with advances in processing and marketing as more "value-added" products will be produced. Fig. 3 shows developments for two of the most traded fishery commodities: frozen tunas and shrimps. The bulk of production of both is frozen but canning of tuna has shown strong growth since 1985. While the quantity of fresh tuna in international trade has become significant that of shrimp is less so, perhaps indicating potential for the future.

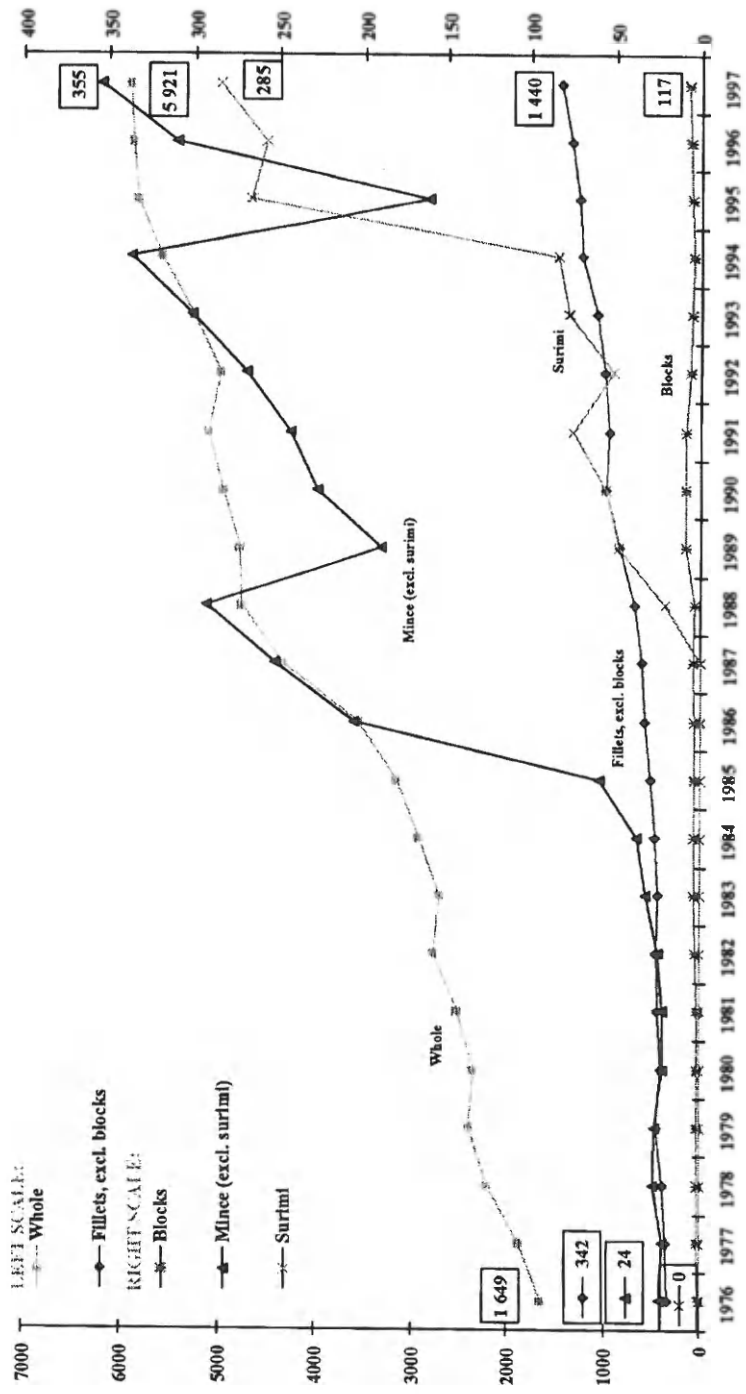


Fig. 2. World imports of frozen fish (in 1000 tonnes).

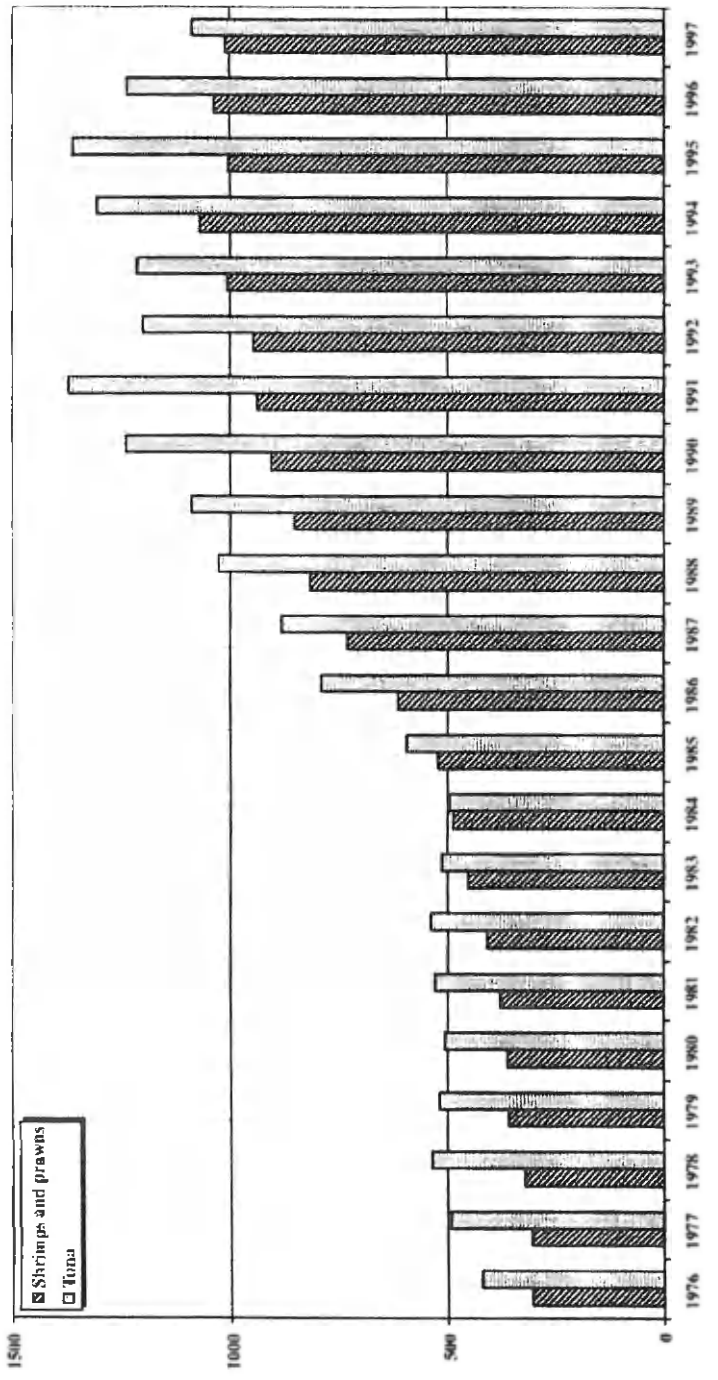


Fig. 3. World imports of frozen shrimps/prawns and tunas (in 1000 tonnes).

6. Fish trade

International trade in fish has increased dramatically in recent years as shown in Fig. 4, with exports rising from US $8000 million in 1976 to US $53 000 million in 1997. Thirty-seven per cent of fish produced for human consumption now enters international trade. Developing countries participate actively in this trade, reaching over 50% of value in 1995, a position that appears to be sustained. Net export revenues are equivalent to the total returns from the traditional tropical export industries of tea, rubber, bananas and coffee. Fig. 5 shows the major markets. Three major market areas: the EU, USA and Japan absorb as much as 76% of global fish exports. It has been suggested on many occasions that the rapid increase of exports from developing countries has impacted on the availability of fish to the poor in these countries. While it is difficult to draw a definite conclusion from the statistical data there is a clear inference that those developing countries that have become substantial exporters have also shown significant rises in domestic availability. For example, it seems that low-income food deficit countries have increased their apparent per capita availability even though they are exporting more fish than they are importing. But, it is evident that encouragement of exports must be exercised with care by governments in order to ensure that all sectors of the population share the benefit from the common resource.

There is little doubt that the increase in international trade has significantly accelerated technology transfer in the fish industry and contributed to more awareness regarding the safety and quality of products. The industry now is heavily concentrating on "value addition" or convenience foods with a healthy image. Developments in food science and technology coupled with better refrigeration chains and the use of the microwave oven are making convenience foods a fast growing industry in developed countries. Fish is very much part of this trend and indeed it seems to help in the marketing of fish because many consumers express concern that they do not know how to cook the more traditional fishery products. Consumers' demand for convenience foods has spawned much product development in food retailing. There is little doubt that the fish sticks and portions that were invented and introduced to the US and the European markets around 1950 did much to popularise fish and sell it to many people who previously did not eat or like it. A later introduction of pre-cooked frozen battered products further expanded the convenience market in fishery products [15]. In 1996, it was estimated that the European market for frozen ready meals exceeded 1 million tonnes and had increased more that 10% per year over a 5-year period. These include all frozen meals, pizzas, meat,vegetable and seafood products. Value-added seafood products are regarded as part of the overall market for convenience foods as they are governed by the same general trends in consumer tastes and buying habits. The overall European market for ready meals is dominated by the frozen sector at 65%, chilled meals 25% and ambient meals at 12.5% [16]. The price of fish as compared with other animal protein over the last decade, from unity in 1990 gives the following picture for the major commodities. Bovine meats stabilised at 0.75 in 1999, poultry showed an upward trend during the period but reached 0.90 in mid-1999, whereas

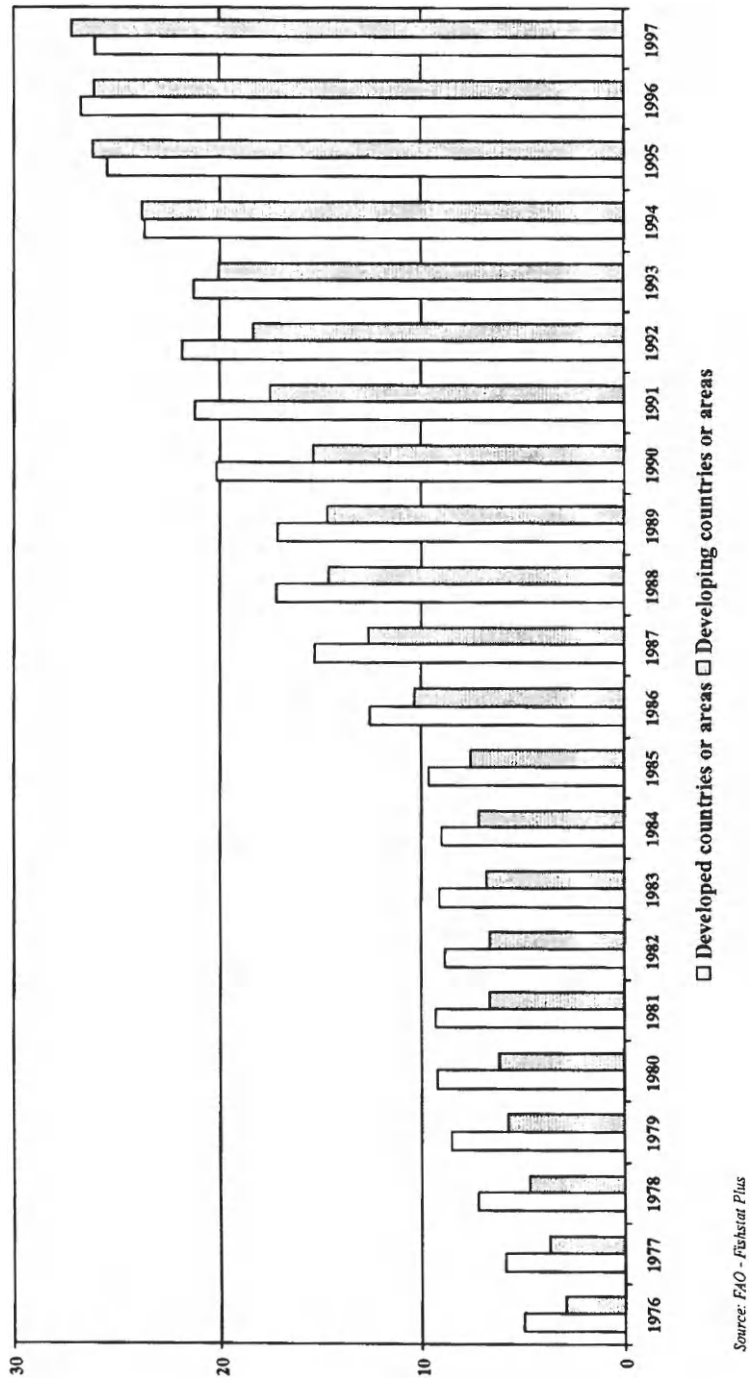
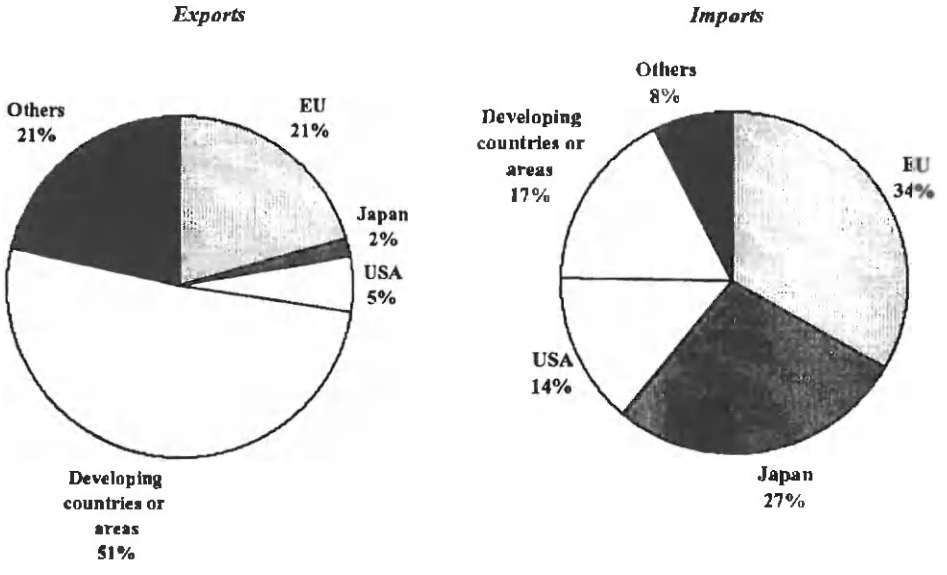


Fig. 4. World exports of fish and fishery products in US $1 billion.



Source: FAO - Fishstat Plus

Fig. 5. Share (by value) of major markets in total international trade in 1997.

prices for pigmeat have been fluctuating but are presently slightly below 1.00. Groundfish species, on the other hand, have increased in price over this period reaching an index of 1.2 in 1999 and the index for shrimp has gone up to 1.15. Thus, during the 1990s the meat price index has fallen whereas fish is more expensive now compared with meat than it was in the early 1990s.

7. Fish-processing technology

It is commonly accepted that fishery products are best accepted when prepared as fresh as possible, as is demonstrated by the increased popularity of live seafood. Most processing such as freezing, salting and smoking primarily serves the purpose of minimising the loss in quality and nutritional value, even though modern consumers are also demanding more convenience foods. The challenge in processing fish should be seen in the context of the great number of species, their seasonal availability and their extremely perishable nature. Even if the above broad analysis of utilisation does not indicate any drastic changes over the last decades, tremendous progress has been made in line with developments in other sectors of the food industry. No attempt will be made here to review all of these or their relative importance but some of the developments deserve mentioning.

With the growth of aquaculture an increasing share of fishmeal and fishoil is being used for aquafeeds. In the 1960s, fishmeal was almost entirely used in pig and poultry diets. Now, some 25% of the world production is used for aquafeeds. This has resulted in a significant change in processing technology for fishmeal, as low temperature drying must be used and much fresher raw material is required. Today, about half of all fishoils produced go into aquafeeds. Earlier fish oil for human consumption was mostly hydrogenated as margarine but fish oil is no longer used in this way. Production of acid silage from fish waste seems to be catching on for aquaculture feeds. Commercial production of such silage is now at about 120 000 tonnes/year [17].

What has been learned in the history of fish-processing development is that the potential consumers have to be kept in mind. Many developments have failed because they were driven more by a technology push rather than a market pull. A good example is the story of fish protein concentrate (FPC), which was aimed at solving protein shortages in developing countries. After successful technological development of the white highly nutritious fish powder that could be produced from almost any fish resource, it failed to find a market. However, today there is a renewed interest in hydrolysed fish protein powders due to their functional properties. Other examples of such unsuccessful products include salted dried fish cake, marine beef, grey surimi and low-cost canned fish. Improvements in fishing technology enabled new, but unfamiliar, species to be taken at greater depths. However, there was consumer resistance, leading to a promise by the marketing manager of a large fish producer that his company would not sell such "bug-eyed monsters".

The seafood industry has taken much interest in surimi since the beginning of the 1980s when surimi-based products, especially crab analogues, started to gain popularity in the USA and Europe. The analogues are made from washed fish mince to which flavour is added followed by structuring to imitate the texture of crab muscle. What made the surimi industry take off was a discovery in Japan in 1959 that surimi could be kept frozen without loosing its all-important functional properties. This was achieved by adding cryoprotectants such as sugar and polyphosphates to the washed mince. Surimi now has a firm place in the market and is used for making a range of products [18]. The annual production has been around 1.5 million tonnes made from approximately 7 million tonnes of fish, mainly Alaska pollock.

A brief glance over today's available fish-processing technology signals future developments in the utilisation of catches [19]. Mechanical fish processing equipment such as filleting machines have steadily improved over the years giving ever-increasing utilisation of the edible part of the fish. New machines, such as for quick and precise evisceration have emerged. Specialised electronic weighing systems for fish processing are in common use. These are installed into complete systems that make it possible to monitor yields at all key locations in the processing plants feeding the information into a central computer. Precision weighing systems are now in use on board processing vessels at sea. Linked to graders of various sorts, continuous weighing and "best" combination machines are now available for use on land or at

sea. Image processing is finding use in a new generation of graders. Images from a camera are analysed by computer to calculate volume, recognise shapes and to grade according to colour, at high speed. By linking the computers to cutting devices, accurately calculated cuts can be made [20]. Fully computerised tele markets for fresh fish are already in operation where information on the catch is made available to the prospective buyers before the fish is landed. Laminated plastic materials have made possible modified atmosphere packaging, which can extend refrigerated shelf life. Progress in transportation, not the least air transportation is making every corner of the world accessible to fresh fishery products from far away.

8. Future developments

Two of the most important factors shaping future demand for food fish are population increase and economic growth. Making meaningful predictions on future trends requires a complex analysis of many factors including: prices, eating habits, competing foodstuffs, etc. Fish and fishery products have become the most international of all foodstuffs as between 30% and 40% of fish is at present traded on the global market [4]. There is little indication that this will change in the near future if supplies remain stable. Aquaculture is producing a rapidly growing share of fish for human consumption and this will make the capture industry adapt to supplying fish of even quality. For the consumers, fish fits well with the concept of "natural" or "organic" food. Wild fish are not fed with formulated diets and they enjoy the freedom of space and are free from veterinary drugs. New "miracle solutions" for extending shelf life (the latter day equivalents of salting, drying or freezing) are unlikely to happen. In the world of highly processed and genetically modified foods, captured fish may become the food that links humanity to its past. But harvesting Mother Nature carries great responsibility. The fish industry will have to establish a system, which allows all products to be traceable from the fishing ground to the consumer. Such systems are already beginning to emerge. We now have a fresher, safer seafood supply than at any time in the past. The biggest challenge for the industry in the next millenium remains to sustain this image and bring the prey as fresh as possible to the market.

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