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Post-harvest to consumer driver review of the aquatic supply chain

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Contents

1. Introduction: Key features of the aquatic value chain

This paper provides an overview of the key current features of the international markets for aquatic food and appraises how the future drivers of the post-harvest/consumption aspects of the value chain will interact. This encompasses product from both wild capture fisheries and aquaculture. Here, ‘post-harvest’ covers all those activities involved in delivering aquatic products from the water to the plate, in particular those concerned with their processing and trading. The system is highly diverse, and a wide range of aquatic species and products, changing patterns of demand and supply, in a spectrum of cultural, economic and political contexts give rise to a variety of post-harvest configurations and future directions. The only constant across the sector is product perishability, at higher rates than for most terrestrial foods, and a critical element to be managed if values are to be delivered without loss and if the potential for adding value can be realised.

Aquatic food value chains have undergone many changes over the past 50 years, as evident from the statistical outlines of trends in fish[1] supplies, trade and consumption documented in the FAO biennial publication SOFIA (FAO, 2009). Greater detail is available about supplies than end use of raw material and markets, though there is widespread evidence of change to be found in consumer spending, species and product availability in key markets, and in competitive behaviour of supply chain and retail firms. Analyses of local supply chains, assessments of income and nutritional impacts of artisanal production, changing patterns linked with international trade in more highly valued species, and rapid developments in products and retail options all contribute to current understanding of the sector.

[1] Note: ‘fish’ is used in the paper as a generic term for aquatic products, including crustacea, molluscs and aquatic plants. Distinctions are made when necessary to separate the various categories. ‘Seafood’ is used in other texts, but not employed here to avoid possible confusion about marine or freshwater origins.

Throughout its history, the market for fish has been international, with expanding exports from a wide range of countries, just under 200 in 2006. These include a wide diversity of products spanning fresh, chilled, frozen, canned, dried, salted, smoked and other forms, with varying levels of yield and value addition. The associated value chains vary substantially according to the structure and functions involved. These range from capital-intensive, technology-laden (in terms of production, processing and logistics) 'long global' chains, sourcing from multiple points in developing and developed countries and supplying primarily the 'developed' markets, through to low-technology 'short local' chains which mainly source from small-scale fisheries/aquaculture and cater for markets (subsistence, local, regional and national) primarily in less developed markets.

It is common for a wide range of value chain structures to coexist within the same countries, reflecting market diversity, emergent trends and the major impact of fish trade from lower income to wealthier countries. Net exports of fish are substantially greater (and rising faster) than all other agricultural commodities (FAO, 2009), and are a significant element in trade and income for many poorer countries. Global data also shows the importance of the artisanal fisheries' post-harvest sector, particularly in poorer economies. The effectiveness of this sector in meeting emerging demands – both in increasing and retaining income by meeting needs of wealthier markets and in supporting food security and livelihoods of the many millions of dependent people and communities – will be a critical challenge.

Patterns of fish consumption mirror the complexities of trade, ranging from local, seasonally variable and subsistence-based to those dependent upon sophisticated global logistics constructed to accommodate perishability and supply standardised products year-round. Purchases and consumption reflect changing demands within markets as shaped by the composition of fish supplies and prices, demographics, income distribution, competing foods, retail and foodservice organisational structures, governance relations, (NGO) pressure groups and many other determinants. An evolving mix of target destinations from niche to mass-markets has also arisen, based upon combinations of spatial, social, economic, technical and other driving factors.

Global demand for aquatic products has grown substantially, not least associated with positive health values, with greatly increased aquaculture production, and with widespread availability, in increasingly convenient product forms. However this demand connects with important challenges such as continued access among poorer communities, accountability for responsible fishing, and the need to deliver safe food with an acceptable environmental footprint. The shape of future post-harvest value chains must include the myriad of challenges and uncertainties of both aquatic and other food supply chains. Notwithstanding the vagaries of raw material availability, particularly for core species, future products are likely to show ever more esoteric points of differentiation and competition, with different and potentially radical technical innovations, such as those developed for the microwave and modified atmosphere packaging (MAP) in the past.

A perspective for 2050 is likely to comprise both currently recognisable features and elements which are as yet unknown. To gain some insight on the key drivers and their possible implications, this paper proceeds along the value chain from production to consumption, recognising that whatever the point under consideration, all are commonly interconnected and interdependent even where geographically distant. Developments in the aquatic sector will signal fish production and consumption decisions, farmed or captured, just as aquatic supplies will influence what non-fish foods are chosen, and interact with consumption and wider issues of global food supply.

1.1 Production and trade overview

The principal features of fisheries production and trade are shown in Table 1. Global production in 2009 is estimated at 142 million tonnes, with some 37% entering international trade. About 75% of production is used for human consumption with the balance primarily for animal feeds. Fish trade topped US$100 billion in 2008, falling slightly in 2009. Production from capture fisheries is relatively stable at around 90 million tonnes. Aquaculture has grown steadily over recent decades, reaching 51.6 Mt in 2008 and contributing 45% of human fish consumption. However, production is skewed by China, with more than one third of total fish production, and 65% of global aquaculture. Excluding China, aquaculture accounts for about 20% of total production.

Table 1: World fish production and markets

	2007	2008 est.	2009 est.
WORLD BALANCE	Million tonnes		
Production	140.4	141.6	142.0
Capture fisheries	90.1	90	90
Aquaculture	50.3	51.6	52
Trade value (exports US$ bn)	92.8	99.2	98
Trade volume (live weight)	52.9	52.6	52.0
Total utilisation			
Food	112.8	113.9	114.4
Feed	20.8	20.6	20.4
Other uses	6.8	7.1	7.2
SUPPLY AND DEMAND INDICATORS			
Per caput food consumption Food fish (kg/year)	16.9	16.9	16.8
From capture fisheries (kg/year)	9.4	9.3	9.2
From aquaculture (kg/year)	7.5	7.6	7.6

Source: FAO/Globefish (http://www.fao.org/docrep/011/i0250e/i0250e00.HTM)

Distinctions may be made between 'artisanal/small-scale' and ‘industrial’ fisheries. Although category definitions are imprecise, the 'Big Numbers Project' (BNP) (Willmann *et al.,* 2008) estimates that 70% of capture fishery production comes from the developing world, and that of this between 37 and 43 Mt derives from small-scale fisheries. However, these figures may well be gross underestimates given the prevalence of illegal, unreported and unregulated (IUU) fishing. In sum, however, around 36% of global fish production is derived from the artisanal sector, most of which is also handled by small-scale traders and processors.

Global per capita consumption remained stable at 16.9 kg in 2008, of which 8.5 kg came from capture fisheries and the remainder from aquaculture. This masks significant regional and national variations in consumption: Icelanders consume 90 kg/yr while Afghanis record no fish consumption at all. Given the very clear resource limitations in marine and inland capture fisheries, future growth in supply to meet demands associated with rising population, income and consumer preference is proposed to derive primarily from aquaculture. However, further potential gains in supply from capture fisheries might also be made through banning discards and by reducing inefficiencies related to quota imposition and other resource management measures.

1.2 Main species and sources

Humans consume products based upon many hundreds of different species derived from three of the main aquatic phyla – fishes, crustacea and molluscs. Aquatic plants also play a role with 72 species of edible seaweeds accounting for about half of total global seaweed production. Table 2 summarises the volume of production by source and species group.

Freshwater fish account for almost 9 Mt (11%) of capture fisheries production, though these figures are widely considered to be under-reported (see Welcomme *et al.*, 2010). Within marine capture fisheries and aquaculture the main categories are noted as follows:

Table 2: Production by method and main species group

Capture production		**Aquaculture production**	
Species group	**Quantity ’000t**	**Species group**	**Quantity ’000t**
Freshwater fish	8,715.2	Freshwater fish	28.056.0
Freshwater molluscs	428.7	Freshwater crustacea	1.065.8
Salmonids	1,617.9	Salmonids	2.763.1
Demersal fish	20,461.7	Marine fishes	1.793.9
Small pelagic fishes	29,927.7		
Tunas and tuna like fishes	6,65.8		
Other fishes	10,642.2		
Crab and lobsters	2,100.5	Crabs and lobsters	224.8
Shrimps	3,460.0	Shrimps	3.206.1
Krill and others	606.0		
Marine bivalve/gastropods	1.873.4	Bivalve & gastropod molluscs	12.844.7
Cephalopods	5.289.0	Cephalopods	1.255.9
Others (inc. frogs)	406.3	Others	443.0
World total	**91.994.3**	**World total**	**51.653.3**

Source: FAO Yearbook of Fishery Statistics (2008), FAO Fisheries and Aquaculture Department.

NB. Excludes seaweeds.

Small pelagic species (fast growing, swimming in the middle or upper part of the water column) mainly herring, mackerel, sardines and anchovies, accounted for about 30 Mt in 2006. The top two species caught, Peruvian anchovy and Chilean jack mackerel, are commonly used for fishmeal and present opportunities for improved utilisation despite handling and distribution challenges related to their high perishability. Demersal fish such as hake, Alaskan Pollack, cod and haddock live on or near the seabed, accounting for over 20 Mt tonnes from capture fisheries.

Fish from the tuna family are also important. Tuna catching and processing is notable for its vertical integration and concentrated investment. In 2007, two-thirds of the 6.5 Mt tuna catch was internationally traded, notably bluefin, yellowfin, skipjack and bigeye. Most is caught in the Pacific (c.70% in 2007), c.20% in the Indian Ocean and the balance from the Atlantic and Mediterranean. Most product is canned, but higher value products are also distributed frozen and fresh by air freight. There are major concerns regarding sustainability of some species, particularly bluefin, but also bigeye and yellowfin tuna**.** Cephalopods (squid, cuttlefish and octopus) represent the other main category of capture fishery production, with 5.3 Mt caught globally. Production centres on Morocco, Vietnam, Indonesia and Korea.

Salmonids (including Atlantic and Pacific salmon and trout) and shrimp are the only major global commodity groups with both capture and aquaculture supplies. Wild salmonids account for 1.6 Mt and farmed salmonids about 2.7 Mt of global output. Salmonids comprise about 8% of global fish trade, with Norway leading farmed salmon production and the USA most significant for capture output. Chile has also demonstrated its capacity to play a significant role in farmed salmon production but supplies collapsed in 2008 due to an outbreak of ISA (infectious salmonid anaemia) disease, and the industry is currently recovering slowly, although its pace is expected to accelerate.

The categories of shrimp or prawns embrace numerous species, with a major division being those of tropical and cold-water origin. Capture produced shrimp totalled about 3.5 Mt in 2006 compared to 3.2 Mt from aquaculture (plus around 1 Mt of freshwater shrimp). Shrimp is the most important fisheries commodity traded worldwide, with about 1.7 Mt (after processing) marketed in 2006, some 16% of total export value of fishery products. Developing countries are the main source of supply and aquaculture production is very important (Thailand, Indonesia, Bangladesh, Ecuador, Vietnam and China) with main markets in Japan, the EU and USA. Other crustacean (crabs, lobsters) contributes about 2.3 Mt mostly from capture fisheries, though aquaculture supplies of estuarine and mangrove crabs are becoming more important in Asia.

The other main categories of aquaculture production are freshwater fish (carps, tilapias, catfishes and others), which accounted for 28 Mt of output in 2006. These are still the main supply category for aquaculture, with China and the Indian sub-continent particularly important suppliers and consumers, notably for carps. Much of this production, at relatively low value, is consumed within these regions. However, tilapia and catfish, particularly pangasius catfish, are increasingly important globally traded aquaculture products, mainly originating from China, Vietnam, Thailand, and also, for tilapia, from Central and Southern America. Freshwater capture fisheries, in which carps and other cyprinids, catfish and tilapias are also important, together with a range of small pelagic species, primarily supply regional markets, with the particular exception of Nile perch, an important export product from Lake Victoria mainly to European markets.

Aquaculture production of bivalve molluscs (oysters, clams etc) by weight is also important, with around 12 Mt produced in 2008. Various marine fish are also farmed, accounting for a further 1.8 Mt, and with significant market value and supply growth in most instances. Culture and harvest of marine plants and algae (not shown in the above table) accounted for some 15 Mt of production in 2006. This is globally distributed, though culture is primarily in tropical and sub-tropical zones, particularly in Asia. Supplies are mainly for industrial production of gelatine and derived products, some of which are also used in foods. A small but significant proportion is also used for direct human consumption, primarily in Asia, where there is substantial regional trade.

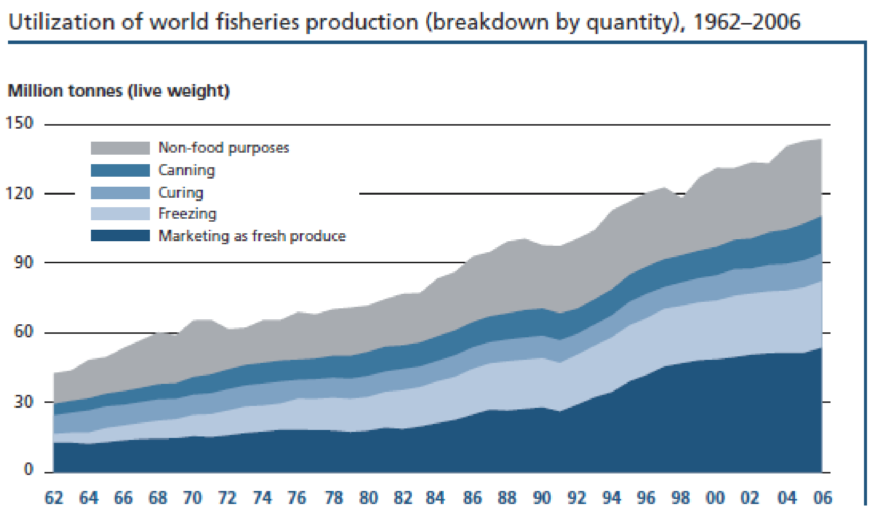
1.3 Utilisation and trade

1.3.1 Utilisation by form of product

Only 75% of all fish landed is consumed directly by humans (Table 1). Some 31 million tonnes is used for animal feeds (increasingly now for aquaculture), thus indirectly entering the human food chain, and other industrial purposes.

Small amounts of fish are used in dietary supplements (particularly fish oils) and food additives (isinglass). Some products are used for non-food purposes (pet foods, fertilisers, specialised lubricants, leathers). About half of the fish destined for human consumption is consumed in fresh form, usually close to the point of production (fish consumption in coastal areas is usually higher than inland). The rest is preserved for consumption at another time or place. Freezing, curing and canning are the most common methods of preservation. Traditionally preservation by curing, drying, salting etc., accounted for under 10% of utilisation in the 40-year period shown in Figure 1.

Figure 1: Utilisation of fish catches in different forms – 2006



Source: FAO (2009) SOFIA (Fig 28).

A notable feature in recent trends has been the growth in consumption of fresh product, and its increasing role in fish trade. This is particularly driven by demands in higher income markets, improvements in infrastructure and logistics, technical innovation in packaging and transport, and by the commitment by major retailers in developing effective chill chain systems to deliver widely sourced product reliably to consumers. However, increasing concerns for the environmental impacts associated with aspects such as air freight and refrigerated systems may mean that some forms of fresh product delivery may become less viable, whether through increased energy costs or through consumer preference for less resource demanding products.

1.3.2 Distribution and trade

Table 3 shows the volume of fishery products entering international trade, which in 2006 accounted for 37% of all production. About 27% of fish produced in less developed countries enters trade mainly as higher value exports, though in some cases (e.g. West Africa, Egypt) there are substantial import volumes, including dried and salted cod and hake, and lower value pelagic species, commonly frozen. In industrialised countries, particularly in Europe, a substantial part of trade is inter-regional, and value addition and re-export of imported raw material is also important.

Table 3: Production and trade in fishery products (2006), tonnes

	Industrialised	**Less developed**	**Totals**
Production	28,673	114,975	143,648
Trade	21,962	31,567	53,536
Trade as % of production	77%	27%	37%

Source: FAO Summary tables of fishery statistics *http://www.fao.org/fishery/statistics/en*

By 2006 the value of world fish exports reached a record of $85.9 billion FOB[2], 55% more than 2000. China dominates exports ($9 billion in 2006) with other major roles assumed by Norway ($5.5 billion), Thailand ($5.2 billion) and Denmark ($ 4 billion). Over the same period, imports were estimated at $89.6 billion (CIF).

The EU is the main aquatic products importer with $22.4 billion in 2007 (excluding intra-community trade), accounting for 60% of its fish consumption. Spain, France, Italy, Germany and the UK are the main markets. Japan accounted for about 22% of total world imports ($19 billion) and the USA 16% ($13.7 billion). China is also a major importer ($4.1 billion) with a growth rate of 15%/yr, largely driven by an expanding middle class. Rising relative

[2] Free on board, i.e. cost at departure, excluding carriage, insurance and freight (CIF)

incomes in South East Asia, India and elsewhere are expected to continue to stimulate domestic demand for fishery products, increasing competition for traditional export value chains such as the EU and US, where increasing compliance costs also lessen their appeal for some suppliers.

Imports by South East Asian countries supply growth in domestic demand, but increasingly represent development of processing and distribution platforms. The positions of China and Thailand (with imports at about 30-40% of exports) show how globalisation of fish supply chains means that a significant amount of fish and seafood is now caught in one part of the world, transported to another for processing and finally consumed in yet another country. As an example, some whitefish caught in the North Atlantic by Russian and Norwegian vessels is processed in China for European markets. These trends are likely to continue, as improved processing skills and compliance with food safety conditions (previously barriers to reaching the value-added western markets) mean that lower cost operations for global supply of fish become feasible. The same competitive pressures are also liable to impact upon the processing infrastructure and supply chains within developed countries and so further consolidate market power within retail and foodservice firms and related organisational structures.

In 2006, fishmeal represented around 3.5% of the value of exports and fish oil less than 1%, although the volumes of fish entering reduction were significant. Key markets are the large aquaculture producers, including Norway, China, Chile, Ecuador, Thailand and the EU, mainly but not exclusively for intensive aquaculture of high value salmonids, shrimp and marine species. Considerable quantities of ‘trash fish’ – by catch and process wastes – are also used, particularly in Asia for locally produced aquaculture feeds (FAO, 2009).

Developing countries accounted for 49% of all aquatic exports by value and 59% by quantity in 2006, while 80% of global imports go to industrialised countries. Net exports of fish by non-industrialised countries have shown a notably rising trend over recent decades, from $7.2 billion in 1986 to $24.6 billion in 2006. These levels are significantly higher than for other agricultural commodities, e.g. rice, coffee or tea, and place aquatic products as one of the most important elements in global food trade. Fishery products are an important source of income and foreign exchange earnings for a number of non-industrialised countries, some of which have very high dependencies on fish trade (Table 4) e.g. Maldives (98.5%) and Uganda, with 14.6% in 2006.

Table 4: Fishery trade balance and export dependence in 2006

Net exporters	**Value, US$1,000**			**Fishery exports as % of total merchandise exports**
	Exports	**Imports**	**Net balance**	
				%
Maldives	133,590	5,667	127,923	98.5
Faroe Islands	569,244	12,867	556,377	90.2
Greenland	344,278	5,226	339,052	84.3
Iceland	1,811,742	79,616	1,732,126	52.5
Turks and Caicos Islands	8,054	2,372	5,682	45.7
Seychelles	199,015	95,696	103,319	36.5
Panama	381,510	21,217	360,293	33.2
Belize	43,079	1,996	41,083	15.4
Madagascar	162,606	32,102	130,504	15.0
Uganda	140,705	187	140,518	14.6
Namibia	458,458	20,119	438,339	13.6
Bahamas	93,655	17,990	75,665	13.1
Senegal	277,555	1,072	276,483	12.1
Grenada	3,829	2,890	939	11.8

Nicaragua	89,203	4,992	84,211	11.8
Guyana	64,863	1,458	63,405	11.3
Tanzania, United Republic of	187,020	1,047	185,973	11.1
Ecuador	1,335,939	12,710	1,323,229	10.5
Mauritius	225,510	213,499	12,011	10.4
Morocco	1,224,729	59,536	1,165,193	9.8

Source: FAO Summary tables of fishery statistics http://www.fao.org/fishery/statistics/en

Distribution channels for aquatic products vary with the location, source and the social and historical context. For artisanal fisheries, product reaches consumers through various channels. Many households involved in aquatic capture or culture consume some part of their output; other product, particularly lower quality fish for relatively poor and marginalised consumers, may be sold directly, or exchanged for services or social obligations. More specific market sales may be made at local markets, or through small traders who operate via direct bargaining between parties or auctions at harvest or landing sites. Typical trading volumes are 10-50 kg per batch; small-scale value chain actors also undertake distribution via basic transport, walking, bicycle, motorbike or local public transport over various distances to sell products, either directly or into further market hierarchies.

Larger scale artisanal value chains also operate with more sophisticated systems and trading networks. Traders consolidate product through buying and selling within a network of sources and outlet channels, sometimes on commission or contract, with products passing through a number of levels such as wholesale to small-scale retailers. Processors may intervene before selling on. Although there is a certain amount of trade in live fish, especially in South East Asia, and although fresh fish reaches the final consumer in areas adjacent to production centres, most fish is ‘processed’ in one way or another. This allows fish to be transported to relatively distant markets, mitigates the perishability and helps to even out supplies.

More industrial fishing activity and larger scale aquaculture production commonly enters more organised and often shorter, vertically integrated supply channels. Traditionally, centralised economies such as those in the former Eastern bloc, China, Vietnam and North Korea operated national fishing fleets supplying state owned or parastatal processing, distribution and retail systems, but with the development of market economies these have commonly been restructured and privatised, sometimes in joint ventures with external enterprises. National fishing enterprises have also been developed in regions such as North Africa and the Middle East, though some have also moved towards the private sector. A range of organisations, from family businesses to corporate entities, operate in the commercial sector undertaking various market functions within the value chains and are increasingly dominated by larger retailers and their supply agents.

At the international level criticism has been raised that expanding fish trade linking into artisanal production damages food security, particularly for vulnerable groups in developing countries. This could occur in servicing national or regional urban markets, but potentially much more so for exports. However, traded and exported product tends to be of higher value species, providing valuable income and potentially allowing greater purchases of less expensive protein, including lower priced fish. Only in specific locations and situations does fish make a vitally important contribution to food security (e.g. sub-Saharan Africa, remote communities) and in these situations trade has not widely impacted on supplies. However, the relative market power of different actors in these chains needs to be considered carefully, and widening demands and periodically marginal viability of fishing or aquaculture may lead to trade increasing the vulnerability of some groups.

The global scope of fish trade also has implications for sustainability, especially since assuring fish are derived from sustainable sources becomes more difficult when they are caught, processed and consumed in different countries. Much IUU (illegal unregulated and unreported) fish is intentionally ‘laundered’ through third country processing operations to disguise its provenance. In response to this, market countries concerned about sustainability have introduced both voluntary and regulatory certification of provenance. Examples are, respectively, the Marine Stewardship Council scheme and the EU's IUU certification scheme for imported fishery products, due to come into play from 2010. At the time of writing such schemes are scheduled to become an integral part of procurement policy and seem set to continue for the foreseeable future, or until some exogenous pressure dictates alternative criteria be set.

1.4 Implications of production system for utilisation

Capture fisheries are the last major hunted food resource, characterised by the highly variable quantity of supplies (from year to year, as well as seasonality) and variations in quality. Marketing chains need to be flexible to adapt to supply side changes, making the supply chains for international fish trade highly dynamic. Traders need multiple sources to satisfy a less variable demand (e.g. one tuna supplier to a UK supermarket is weekly purchasing yellowfin tuna from over 20 different countries). Aquaculture production, although seasonally affected by the temperatures and growth rates, has a more predictable, stable and even programmable supply, creating the confidence for producers in some sectors to invest in the downstream supply chain (processing, distribution, value added activities and generic promotion). Major successes of sea bass and bream, salmon, shrimp and pangasius catfish are instructive. Here the problems are of matching supply with demand to avoid oversupply to market, and dealing with the problems of intensive animal production (environmental impacts and veterinary medicines etc), but which are not exclusive to fisheries.

Providing that these limitations can be managed, increasing stability of supply should allow increased investment in value added processing, leading to greater industrial concentration of production and distribution. Combined with the trend to rights-based fisheries and the transferable access arrangements (e.g. in Iceland, Faroe Islands and New Zealand), which also tend to reduce and concentrate producer numbers, this would be expected to create additional pressure for sectoral aggregation. This may demand a regulatory response to protect small producers, processors and traders, to ensure that they can retain access to resources and markets.

Furthermore, fish is one of the most perishable of foods, with the different production systems presenting many production and distribution challenges. Given this diversity of species and production conditions and a wide range of processing and distribution technologies, fishery products present a range of different quality characteristics and food safety hazards. This makes ensuring quality, including ensuring food safety conditions, a technically complex task, presenting substantial compliance challenges.

1.5 Economic and social aspects of aquatic supply chains

1.5.1 Sector and component values

A recent study estimated that in 2006 the global fishery sector was worth some $400 billion annually, approximately 0.6% of gross world product (Valdimarsson, 2007). Capture fisheries are estimated to contribute value added of $80 billion, aquaculture $60 billion, primary processing $60 billion, secondary processing $120 billion, and distribution $80 billion. Value added processing and distribution therefore accounts for some 65% of the value added (Davidson, 2007; Valdimarsson, 2007).

Studies by the FAO and Glitnir Bank (Table 5) suggest that most benefits are obtained by the retail/wholesale/secondary processing sector, whether for products originating from developing or developed countries fisheries. However, it is not clear whether these studies included fishers' incomes in the value added calculations. The retention of economic value varies widely with production conditions.

Table 5: Estimated distribution of value added in the fishery supply chain

	Icelandic cod	Tanzania Nile	Denmark herring	Morocco anchovy	Glitnir Bank

		perch			**study**
Retail/wholesale and secondary processing	54	61	75	75	50
Processing	27	18	17	21	15
Capture	18	16	8	4	20
Aquaculture					15

Source: Fish in the global food supply chain, Grímur Valdimarsson, Director, Fish Products and Industry Division, Food and Agriculture Organization of the United Nations, presented at World Seafood Congress, Dublin, Ireland, 25-27 September 2007.

A primary issue, particularly for capture fisheries, is the cost of supply and economic loss related to inefficiencies concerning overcapacity and overfishing. Estimates by the World Bank/FAO suggest that as much as $50 billion (Willmann *et al.,* 2009) is lost through subsidising capacity and fishing (particularly fuel) costs. Otherwise, losses in the supply chain can be significant, and less developed countries continue to suffer from high rates of physical post-harvest losses due to bacterial and insect spoilage, and economic losses due to reduction in quality. The FAO estimates (FAO, 2009) that post-harvest losses account for some 10% of global fish production, a significant rate of underutilisation.

1.5.2 Structural trends

At the more commercialised end of the spectrum, industrialisation of fishing, expansion of aquaculture and globalisation of fish trade has encouraged the emergence of major corporate entities. Table 6 lists some the main publicly quoted companies by market capitalisation. Out of the top five, four are Norwegian. Two of these have market power largely established on vertically integrated salmon farming interests. There is a strong trend to vertical integration of the supply chain, industrial concentration and consolidation. All of these companies combine production (fishing and/or aquaculture) with fishmeal and feed production, fish processing and distribution systems.

Table 6: Main global fisheries companies by market capitalisation (2007)

Company	**Country**	**Main activity/Area of operations**	Market capitalisation**US$ (m)**
1. Marine Harvest	Norway	Aquaculture (salmon: Norway and Chile)	3.423
2. Austevoll Seafood Asa	Norway	Pelagic fishing and processing Chile, Norway and Peru	1.506
3. Cermaq Asa	Norway	Aquaculture (salmon: Norway and Chile)	1.427
4. Nippon Suisan Kaisha Ltd	Japan	Fishing, processing, brokerage and distribution (global interests)	1.357
5. Leroy Seafood Asa (64% owned by Austevoll)	Norway	Salmon farming and processing/seafood trading (Norway)	1.138
6. China Fishery Group Ltd	China	Marine fishing and processing (including fishmeal) Pacific rim	1.049
7. Maruha Group Inc	Japan	Tuna fishing, shrimp and salmon aquaculture, feedstuffs, processing, brokerage (Japan/China/USA)	789
8. Pescanova S.A.	Spain	Shrimp fishing and aquaculture, processing, brokerage (Spain, Ecuador, Argentina, S. Africa)	675
9. Thai Union Frozen Products	Thailand	Tuna fishing, processing, shrimp aquaculture and processing	653
10. Alfesca	Iceland	Processing, sourcing and trading of speciality seafoods	603

Source: Glitnir Bank, Seafood Stockwatch http://www.islandsbanki.is/

Vertical integration provides the level of control and traceability necessary to ensure quality and food safety systems and to meet the technical and cost requirements of the major multiple retail buyers. All of the companies concerned use their size and spatial distribution to gain strategic efficiencies in the sourcing of raw materials and in distribution to market. All have pursued growth through international acquisitions in selected sectors to meet global strategies. They are all significant suppliers to multiple retail chains. However, in relation to the buying power of the multiple retailers, fishery concerns remain relatively small. Thus, for example, Walmart had a market capitalisation of $200 billion in 2009, some 60 times as great as that of Marine Harvest. However, in terms of sectoral share, larger entities now show similar if not greater levels of concentration than their retail counterparts.

It is interesting to note that six of the top ten seafood companies are European, and four Asian, but none are from the Americas. However, the table excludes non-publicly quoted companies. The expectation is that some of the emergent Vietnamese and Chinese enterprises, based on integrated aquaculture production with high capacity processing establishments, would feature in this list, were they publicly quoted.

1.5.3 Employment implications

The FAO estimates that global employment in fisheries and aquaculture in 2006 was about 43.5 million people directly engaged in primary production of fish, either in capture fishery or in aquaculture. The FAO estimates that about 95% of these are from Africa, Asia and Latin America and that 65% of the total are employed in small-scale fisheries (FAO, 2005). Traditionally, employment multipliers quoted have been as high as ten (i.e. ten jobs in the supply chain for each job in production), though a value of three is used here. In developed countries the employment multipliers are lower. Thus an EU study showed that for every job at sea, there are a further 1.1 jobs on land in direct fisheries related employment[1] and many other jobs will be indirectly linked through shared functions such as distribution and retailing etc.

Notwithstanding this indirect employment, this suggests a global total of 119 million jobs directly dependent on fisheries (see Table 7).

Table 7: Estimated global employment in fisheries

	Jobs in fishing (m)	**%**	**Multipliers**	**Total jobs (m)**
Small-scale fisheries	30.45	70	3.0	91.3
Industrial scale fisheries	13.05	30	2.1	27.4
Total	**43.50**	**100**		**118.7**

Source: FAO and consultants' estimates.

While industrialised value chains are increasingly typified by increased concentration of ownership and substitution of capital for labour, other parts of the sector are more diverse. For artisanal fisheries it is estimated by the FAO that globally around 43.5 million people are directly engaged in fishing with another four million in part-time fishing. Including those in upstream and downstream activities, around 170 million people are involved, with around 520 million dependent on the fisheries sector, some 8% of the world's population.[3] The FAO/World Bank 'Big Numbers Project' (Willmann *et al.,* 2008) estimates that overall around 90 million people are involved in the artisanal fisheries sector and of these between 73 and 76 million are involved in the post-harvest sector in the developing world.[4] Many of these combine their involvement in the fishing sector with other activities, notably agriculture, petty trading and labouring. One striking feature is the importance of the inland fisheries and aquaculture, which may account for as much as 50% of all employment in fishing.

Although coastal and inland fisheries may also serve as a recreational resource and be significant in terms of income and employment multipliers in some regions, this is beyond the scope of the present study. For the majority

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3 FAO (2009)

4 Willmann *et al.* (2008). See also Béné *et al.* (2007) who estimate that around 100m are involved.

of fishery sector communities the most important economic impact is in relation to sources of income and employment associated with the supply of food products in the wider supply chain. However, linkages between commercial and recreational fishing activities can be important in some locations, particularly for livelihood diversification.

1.5.4 Social and gender issues

There is frequently a strong gender division of labour in artisanal fishing, aquaculture, trading and processing. Although by no means universal, there is a tendency for women to be particularly active in post-harvest aspects of the supply chain. This is particularly the case in artisanal fisheries, in both marine and inland areas. Women frequently sell fish caught by their husbands or other family members, either formally purchasing it, as is the case in parts of West Africa, or marketing the fish as part of their household duties. In some cases, women have a much more independent and financially significant role, becoming significant local entrepreneurs, supplying credit and in some cases owning fishing vessels. However, moving up the marketing chain, women become less important (although again West Africa is a partial exception) and men tend to control larger scale aspects of trade.

In processing, women are also heavily involved, especially in those aspects which require little capital, for instance fish drying. This is particularly important for very poor women who use waste or spoiled fish for drying. Indeed, the low capital requirements have meant that these functions, together with related activities such as fuel collection, carrying fish and assisting with pond harvests, provide a safety-net of sorts for the poorest of the poor in coastal and inland fisheries contexts. Thus throughout South Asia, poor women are active in buying up waste or spoilt fish, processing it and taking it inland to consumer markets.[5] In Africa, Béné *et al.* (2007) report that women experiencing crop failure have moved into fish trading as a survival strategy. There are also cases where the ease of entry into small-scale

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5 For examples, DFID (2001)

trading provides a safety-net for unemployed men, for example Bangladeshi cultivators who have lost their land.

Credit of one sort or another is crucial to the working of the artisanal post-harvest sector. Traders and fish processors frequently make advances or loans to the producers in order to ensure supplies of fish. In return they either function as commission agents taking a percentage of the price obtained in wholesale markets, or they buy at a price which guarantees them a profit, or in some cases a price is only agreed on a monthly basis or at the end of the fishing season. For producers, the credit advanced by traders serves as a source of capital but also ensures that traders are available to take the produce. This is especially important in seasonal and migratory fisheries where there is often no local market for the produce. Examples of such traders are the Dadandars of Bangladesh or the fish mudalalis in Sri Lanka.

Other social interactions associated with supply chains are also very critical and are important in mediating food access and security, poverty and vulnerability. There are also important issues of social policy, including control of HIV/Aids, as very high incidences among fishworkers in some regions, particularly sub-Saharan Africa, are commonly associated with trading favours for access to product or credit. In some circumstances, the post-harvest sector can also be controlled by specific social groups. Thus the dried fish trade in North East Bangladesh is controlled by a small community of Buddhists, probably because the main market for dried fish in this area is across the border in Buddhist Burma. In India certain castes associated with fishing were traditionally dominant in the fish trade. More generally in fish processing the nature of the tasks involved are routine, repetitive and poorly paid – activities that tend to attract a lower calibre of workers with low skills; even in those activities which are more skill-specific, such as filleting, labour recruitment and retention is commonly problematic. This has tended to encourage mechanisation and thus some reduction in employment opportunities.

Fish is also important in terms of its contribution to the wellbeing and health of the population. Human dependency on fish as food takes two forms.

Communities may depend on fish for subsistence as an important part of the diet. This is characterised by high fish consumption in less developed countries and regions, for example coastal and island regions, and in parts of sub-Saharan Africa. The FAO (2009) estimated that fish provides about 20% of the animal protein intake in developing countries in 2005. This figure, however, represents an average at a global level and does not reflect the very large heterogeneity at the national or, even more importantly, at the local level. It should also be considered that fish contributes important micronutrients to the human diet (iodine, essential fatty acids, fat soluble vitamins) and nutritional dependency may often be greater than calorific or protein intake indicators might suggest.

Critics argue that the marketing systems frequently encountered in this sector lead to traders and middlemen being in a position to appropriate the resource rents involved in fishing, and for high value products in particular, to deprive producers of practical options for food security. However, those few detailed studies which have been made of marketing chains indicate the margins are not unreasonable given the costs and risks involved. Thus a study of the post-harvest sector in Bangladesh concluded that marketing margins were reasonable and that loan arrangements reflected the high opportunity cost of capital in the Bangladeshi economy as a whole (Kleih *et al.*, 2003). Other work (Young, 1994) has suggested that by improving availability and access to market information, small-scale producers and other channel intermediaries can effect more efficient marketing transactions. It may be contended that further moves in ICT will facilitate this tendency towards more efficient market operations. ICT in supply chain development is likely to gain much more attention with its influence in shaping power balances in value chains in developing countries, enabling geographically remote buying and enhancing logistics efficiency.

2. Developments in aquatic food processing

2.1 Background to processing technologies

2.1.1 Overview

Compared to other protein foods, fish is a highly perishable commodity and traditional methods of processing were aimed at preserving the catch for consumption in other places or, since catches are seasonal and unpredictable, at other times. Traditional methods include salting, drying, smoking, pickling and fermentation. The industrial revolution brought mechanical refrigeration and canning processes, which led to the industrialisation of distant water fisheries and processing and the development of mass markets. Traditional methods of preservation are still used, but increasingly in western markets, they are used to impart desirable characteristics rather than for their preservative effect. Since the advent of canning and mechanical refrigeration, there have been few major innovations in fish processing, but there has been continuous evolutionary development.

As aquaculture production expanded, products commonly entered traditional supply systems, but as a primary market advantage has been freshness and regularity of supply, traditional processing forms have been less common, though smoked products as luxury foods have been an important development. The drive for product diversification and value addition has also meant that process options common for capture fisheries are increasingly being considered for aquaculture products.

Within the artisanal post-harvest fisheries sector there is undoubtedly scope to improve considerably upon the efficiency of raw material transformation. There is evidence that losses can be very high. Thus Béné *et al.* (2007) claim that in some sub-Saharan African contexts post-harvest losses average around 20-25% of the catch and may reach 80% in remote areas at certain seasons. Another estimate, again for Africa, claims that losses can be over 50%. These figures do, however, appear to be extreme and elsewhere loss levels are probably much lower, especially given the increasing pressure on aquatic resources. Where losses are high this is often associated with glut conditions where shortages of ice, salt or labour, coupled with transport difficulties make it impossible to handle short-term over-supply. In South and South East Asia loss levels appear to be much lower, almost all aquatic products being utilised in one way or another. Even so, pest infestation such as blow-fly can be a problem in preserving dried fish, and this like other losses may be reflected in some loss of product unit values. Nonetheless it should be noted that in contrast to the industrial fisheries sector, almost all the fish handled by the artisanal sector is directed to human consumption.

As with the wider food sector, the adoption of new processing technology is widespread, although newer investments in lesser developed countries are commonly more focused upon more basic systems designed to comply with export standards for raw or part-processed materials. However, as markets for key products expand – e.g. for shrimp, pangasius or tilapia – processing technology tends to become more sophisticated, with higher degrees of transformation within the exporting country. While there is some evidence of rising levels of processing sophistication spilling over into adjacent domestic markets, as in the case of Vietnam with pangasius, lower level technologies for local markets commonly coexist with more developed investments. However as regional markets, particularly in Asia, respond to rising prosperity, international standards and technologies are more likely to apply locally.

2.1.2 Traditional processing options

The primary actions in retaining and adding value for aquatic products require basic cleaning and hygienic handling, and the control of bacterial and other spoilage by reducing temperature, using ice, chilled water or by freezing. Other basic actions include gutting, filleting or portioning and descaling or skinning. A key issue throughout is the yield of product from the initial raw material, where prices attained for the marketed output should compensate for the loss of weight from the whole unprocessed form. The use of ice has become widely adopted in most artisanal fisheries and aquaculture operations although the quality of ice and consistency of practice varies greatly. Depending on amounts used and containers employed, the use of ice allows fish to be transported for 5-6 days before final consumption. In small-scale fisheries, unless entering commercial market chains, freezing is not common and standards of implementation do not always conform to recommended practice.

Throughout the developing world, fish is dried, often after salting. Drying is also frequently employed to deal with spoilt or damaged fish but in some cases high-value fish is dried. The process is advantageous because it can use naturally available resources of sun and wind, it reduces bulk, making transport cheaper, and it allows fish to be stored for long periods at ambient temperature. However, where weather is variable and/or drying is assisted with external heat sources (e.g. wood fires), product quality can vary, and costs and environmental impacts of fuel use can be important.

An alternative to drying is smoking, to which certain species of fish are particularly suited, and in some markets it adds significant value to the product. In Cambodia, freshwater fish is smoked while in West Africa marine fish is more popular, but smoking, whether cold or hot, is common in all fishing areas. As with drying it increases the shelf life of fish but as it involves special equipment (e.g. smoking rooms in Cambodia and South Asia; special stoves such as the Chorkor stove in West Africa) it is more expensive. While capable of promoting more efficient use of raw material, smoking also has potential environmental implications because as with assisted drying, the need for firewood can reduce scarce available resources in certain areas. This has been a particular issue in some parts of sub-Saharan Africa, where in some locations, community tree planting activities or micro-enterprises of commercial woodlots are being promoted.

Fermenting and pickling are quite complex processes and with certain notable exceptions (e.g. Maldie fish in Sri Lanka) are relatively uncommon as smaller scale activities. Pickling, particularly of pelagic fish such as herring and mackerel, has been a traditional process in Europe, continuing for specialist markets, and fermenting fish became a source of great wealth and trading importance in Roman times. As a very similar product, the production of commodities such as fish sauce consumes around 150,000 tonnes of fish per annum in Thailand and is an important input to a wide variety of foods.

Frying and the boiling of fish as processing options are relatively rare but are used in parts of Africa.

2.1.3 Development of traditional approaches

In industrialised countries, and increasingly in the developing world, all of these primary techniques are utilised to varying degrees. These have commonly been extended in a number of ways to enable additional values to be incorporated. Value adding spans a broad range of product attributes which may relate to those of the core product or extend to the augmented dimensions of the product such as convenience in preparation and storage. Values may also be added through the incorporation of non-fish food ingredients to create ready meals, or perhaps simply by communicating information about the sustainability and ethics of its provenance.

2.2 Fish has also been regarded as a good experimental test-bed for other food processing technologies due to its demanding characteristics of perishability, colour, taste and texture. A number of innovations have emerged and can be expected to diffuse throughout the global industry as market demands determine. An increasingly important emerging issue is the energy and resource costs within the supply and value chain, where energy-demanding processing and distribution options are likely to become less favoured, and where potentially rising fuel costs, together with consumer preferences, will require changes in process choices and transport options. Current developments are outlined in the following section.New and emerging processing technologies

2.2.1 Modified packaging systems

Traditional models of fish distribution changed little during the early part of the 20th century. In western countries the rise of the supermarkets initially had little effect, due to the difficulties of handling fresh fish. Only with the search for new markets due to increased concentration in multiple retailers, and improvements in distribution technology, did fish catch up with the retail revolution of the second half of the century. Together with improved infrastructure for distribution of chilled foods, and innovations in demand information and logistics, historical milestones included the development of modified atmosphere packaging (MAP) technology and its application to fishery products. This allowed fresh product to be handled more safely and at a higher quality level, with a sufficiently long shelf life to meet nationwide distribution demands. This has provided new opportunities at retail and foodservice levels to deliver higher quality seafood products.

The packaging technology of MAP and concurrent improvements in distribution logistics have allowed supermarkets to sell fish packed off premises. However, this has not made any widespread impact on wholesale distribution (i.e. of bulk quantities of product) and limited trials have not yielded significant commercial benefits. However, as carbon efficient but slower systems of airfreight are implemented, there may be opportunities for extending the shelf life of bulk fresh fish transport using this technology.

2.2.2 Additives and processing aids

In the 1970s treatments such as antibiotic ice were considered, providing significant increases in shelf life due to the arrest of bacterial decomposition. However, with concerns regarding residues and antibiotic resistance, such approaches would now be illegal in most countries. Generally the use of additives is not permitted in aquatic products (for example, in the EU only a very limited use of additives is permitted, e.g. sulphites for crustacea and cephalopod molluscs and cryoprotectants (polyphosphate glazes)). However glazes have generated controversy since their use can be abused to increase water content of the product.

One new processing aid is the possibility of using bacteriophage treatments for rendering products with longer shelf life and to sterilise products from specific pathogens. One company is marketing a phage treatment as an anti-Listeria measure in processed foods, including for example smoked salmon. Other potential applications might include application to tuna and mackerel-like fish, to prevent growth of the bacteria which produce histamine. Classification of the these treatments as processing aids in the EU and their general high specificity means they could replace many applications where chemical preservation is used at present. In the USA, phages are approved under 21 CFR § 172.785 for surface treatment of meat and poultry products.

One product is already on the market in the EU – EBI Food Safety's LISTEX P100 (EBI Food Safety, 2010).

2.2.3 Freezing technology

Freezing technologies for fish have advanced steadily from brine immersion freezing, through the development of the plate freezer (food frozen between metal plates through which the refrigerant is passed) and the modern standard blast freezer (cold air blown by fans over the product). Modern blast freezers employ conveyors passing the food through tunnels or spirals to conserve energy and space and ensure controlled exposure to cooling. For high value products freezing by nitrogen or even CO_2 can be employed (cryogenic freezing) with a view to obtaining phase conversion from liquid water to ice as quickly as possible. The latest technology, termed 'cells alive freezing' employs electromagnetic radiation (radio or microwave frequencies) to maintain water in the aqueous phase while the temperature is reduced by conventional means, with virtually instantaneous freezing when the radiation is switched off.

Quality of frozen foods has therefore shown continuous improvement over the decades, towards the objective of retaining the fully fresh characteristics (especially texture, which can be easily damaged by ice crystals and osmotic pressures during the freezing process). Advances have also been made in micro- and radio-wave thawing technology to ensure even thawing rates and reduce structural damage and liquid loss. Together with improved efficiency in distribution, allowing lower temperatures to be maintained throughout the food chain (-25ºC is typically specified in the fishery sector compared to -18ºC in previous decades), and lower distribution costs for sea and road freight, frozen aquatic foods are likely to enjoy a resurgence.

2.2.4 Improvements in processing yields and utilisation

Advances in fish processing technology have made significant gains in overall product utilisation, reducing wastes and improving financial yields from raw materials. The development of mechanised deboning technology in the 1960s allowed the recovery of flesh from fillet frames and from small fish species not otherwise marketable. Recovered materials can be used for a range of pates, soups and other composite foods. The technology has also given rise to new analogue products based on surimi technology, i.e. formed, structured, coloured and flavoured products used for crab sticks, shrimp substitutes etc. Originally developed in Japan, this has now been widely adopted to create a range of higher value fish-based products.

Microprocessor based weighing and image analysis has also led to improved accuracy of grading, reducing 'give-away' and improving commercial yields. Combined with robotic controls systems for cutting fish (for example using laser guided water jets) such technologies have provided effective and increasingly popular tools for improved portion control.

Yields and productivity in other labour intensive processes, such as shelling shrimp and shucking shellfish, have been vastly improved by the use of High Pressure Processing (HPP) technology, which subjects the product to pressures up to 6,000 atmospheres. This allows easy shucking and increased yields. Although HPP technology also inactivates microbes and thus extends microbiological shelf life, this application has not so far been extensively applied in fish processing.

2.2.5 Addressing environmental impacts of fish processing

In post-harvest sectors the management of environmental impacts has largely focused on the use of water in processing and on treatment of processing discharges. The need for only clean water to be used in fish processing (due to the risks of transmission of waterborne diseases), and its convenience as a means of washing and transporting products, means that fish processing operations use large volumes of water, up to 40 times the weight of product (Table 8).

Table 8: Water consumption in fish processing activities

Type of business	**Number audited in detail**	**Water used to produce 1 tonne of product (m^3)**

White fish filleting	3	5.0 – 7.4
White fish thawing and filleting	3	9.5 – 24.0
White fish thawing, filleting, enrobing and freezing	1	23.4
Pelagic fish primary processing[1]	2	3.2 – 6.6
Nephrops primary and secondary processing	1	38.7

[1]Not including fish landing operations

Source: Seafish (1999)

Driven by water scarcity and effluent charges based on volume and biochemical oxygen demand (BOD), there is an increasingly compelling incentive to improve water use efficiency and the quality of effluents. In the EU the Urban Waste Water Treatment Directive will require operators to find ways to use less water in fish processing and consider investment in their own pre-treatment plants, as well as finding ways to improve utilisation of solid process waste (guts, fillet frames, trimmings etc). The Danish fish processing sector has led in terms of cleaner production with potential for transfer of the technologies in future (Thrane *et al.,* 2009).

Fish processing and distribution relies extensively on refrigeration systems. The use of certain chlorofluorocarbon (CFC) based refrigerants has largely been phased out due to their ozone depleting properties and their potential contribution to climate change. They are being replaced with refrigerants with lower ozone depleting potential. Non-CFC refrigerants are also being considered. Ammonia is one possibility, despite its toxicity, and research into CO_2 based refrigeration systems is also moving ahead. One of the first modern CO_2 fish freezing plants was installed in Finland in 2005. More food industry applications are likely to follow.

3. Potential technical barriers to trade

3.1 Introduction

Trade in aquatic products is a highly important feature of sectoral value development, and in particular offers significant economic opportunities for poorer countries to supply high value product to wealthier markets. While basic requirements of sourcing, cleanliness, grading, weighing and packing are prerequisites for accessing such markets, a range of additional criteria may be applied, and if ill-considered or inappropriately exercised, may act as barriers to otherwise viable and desirable trade. This could involve complete denial of access, or more commonly, the imposition of significant additional costs to exporters.

Consumers, especially in the developed world, are increasingly concerned with the social and environmental aspects of food production and trade. The result has been a growth in the number of certification schemes supposedly guaranteeing certain standards and providing a means of traceability and verification. How far these will benefit small-scale producers, traders and processors is open to doubt (Gardinier and Viswanathan, 2004; Young *et al.,* 2007) but in so far as such schemes imply costs and a degree of technical and market sophistication it might be expected that they favour larger scale operators. Though a number of initiatives have arisen to improve options for small producers and less well resourced national agencies to address these demands, there remain concerns that some sectors are disadvantaged and that specific interests will continue to pursue standard setting as a means of gaining additional market power.

A number of systems of standards are described, ranging from more basic sanitary and hygiene standards to more complex determinants of ethical and sustainable supply, together with their trends, implications and potential directions.

3.2 Food safety, hygiene and traceability standards

3.2.1 Approaches to food safety management

Regulations on food safety have impacted significantly on fisheries trade. In recent years there have been substantive changes to the concept and nature of sanitary controls, moving away from end product (compositional) standards to process based controls such as GMP (good management practice) and GHP (good hygiene practice) and then to requirements for control systems applied throughout the supply chain, such as HACCP (hazard analysis critical control point). In some cases, such as the EU, regulations associated with sanitary measures apply not just to products, or to processes (e.g. HACCP) but also to systems of official controls in the exporting country.

Food safety conditions linked to origin mean that increasingly in the case of more developed markets, fish can only be sourced from approved sources, where conditions for catching, handling and processing are known to comply. Traceability requirements (without which such an approach is meaningless) have therefore become important as well.

The EC approach to ensuring imported food products of animal origin are safe for consumption, requires that official controls in third countries are 'at least equivalent'. This principle was expressed in the original EC fish hygiene Directive 91/493/EEC (European Commission, 1991), and extended in the 2004 food hygiene package and official control regulations. Many less developed countries with weak governance have struggled to meet the requirements, although there is no evidence that supplies have been disrupted. The imposition of standards has also highlighted the coexistence of dual standards in certain markets. In many developing countries attention to export standards has resulted in the quality of export products often surpassing requirements while simultaneously allowing sub-standard food safety levels on products for domestic consumption.

There are also concerns that smaller scale producers are unable to meet such requirements (due to lack of infrastructure, services, skills and poor sanitary conditions) and will therefore be unable to draw benefits from globalisation.

Non-compliant producers who cannot overcome the technical barriers will increasingly look to other emerging markets, such as China, and India, together with various regional markets without the same sanitary and technical barriers such as those of western markets.

While only a few importing states have placed the higher level requirements such as those for the EC, many have introduced process based controls (USA, Canada, Australia, Saudi Arabia). There is also a notable tendency for the highest requirements to be adopted from other countries (e.g. Seychelles policy is to allow imports only from those sources that are EC approved establishments). Although China is a major market with known weaknesses in its food safety controls, this situation is changing rapidly and will lead to stricter regulation for its imports.

In global terms this process is likely to be replicated, and in future there will be increased regulation of food safety conditions. The dynamics of the production and marketing system for fishery products presents considerable challenges for those seeking to comply with regulatory requirements. For example development of increased supplies from aquaculture poses new and different hazards (contamination with food chain contaminants via feed e.g. dioxins, veterinary medicine residues and transmission of fish diseases) which are not present in capture fishery products. Many major aquaculture producers have struggled to meet importing countries' requirements in these respects, and in some cases (e.g. Bangladesh and Indonesia) this has restricted opportunities for trade.

3.2.2 Sanitary and Phytosanitary Agreement

The Agreement on the Application of Sanitary and Phytosanitary Measures (the 'SPS Agreement') entered into force with the establishment of the World Trade Organization on 1 January, 1995. It concerns the application of food safety and animal and plant health regulations to international trade. The SPS Agreement (and its associated Technical Barriers to Trade – TBT Agreement) allow states who have acceded to the WTO to apply measures limiting trade based on food safety, animal health and welfare, plant health and environmental measures. The measures must be risk based (that is related to specific hazards and risks) and they must be proportionate to the risk, although a precautionary approach is also permitted under certain circumstances.

These agreements have had a major impact on trade in fishery products since they provide a formal framework for the application of protective measures. Consumer pressure for food which complies with standards has led to policies applied by governments to strengthen domestic food safety controls, and where foods are imported from other countries (as in the case of many fishery products), to apply these controls equally to imports. This has led to the globalisation of food safety standards (e.g. through the FAO/WHO Codex Alimentarius).

Within developing countries, agreements on sanitary and phytosanitary standards have had a much wider impact, especially on the trade in shrimp and shrimp products. This has led to EU bans on shrimp imports from Bangladesh in 1997 and on imports of Nile perch from Uganda in 1999. The short-run impacts of these measures on small-scale producers, processors and traders can be extremely serious and in the longer term it has led to changes in the structure of the post-harvest sector. In many cases it also leads to external investment and/or effective ownership of larger scale processing facilities. Thus small-scale shrimp peeling and pre-processing plants in South India have tended to disappear, their functions being taken over by larger scale industrial concerns, and in general the impact of these regulations appears to have encouraged the growth of larger vertically integrated enterprises.

However, in at least some national contexts the adoption of HACCAP systems and greater stress on sanitary and phytosanitary standards has increased the quality of fish available to local consumers. Furthermore, as Kurien has pointed out, it has also improved the working conditions of those involved in the export sector (Kurien, 2005).

3.2.3 Traceability requirements

Traceability systems that function across national borders are therefore vital in applying SPS and related standards and ensuring access to export markets. The development of efficient, effective and equitable traceability approaches is hence a major issue. Traceability requirements come from the need for consumers and those responsible for their safety to have assurance regarding food safety conditions throughout the production chain. In the EC traceability of foodstuffs is demanded by Article 18 Council Regulation 178/2002 of 18 January 2002 'laying down the general principles and requirements of food law….' which requires that traceability of 'food, feed, food-producing animals, and any other substance intended to be, or expected to be, incorporated into a food or feed shall be established at all stages of production, processing and distribution'. In addition, certification to voluntary standards (BRC, HACCP, MSC, organic) all require traceability or 'chain of custody' to establish the link between the product, the certified production system and ultimately the purchaser and consumer.

In response to this, producers and distributors have invested extensively in data and verification systems to provide the required level of traceability. Numerous proprietary systems have also been developed and marketed (usually comprising elements of software, data capture and physical attachments e.g. barcodes). Establishing traceability in a global business where producer, processor and markets are often in different territories, is often a challenge, especially since unscrupulous traders may seek to conceal product origins due to the circulation of products from IUU fishing, passing off lower value species, overcoming constraints regarding sanitary controls such as the EU system of authorised countries and more recent catch certificates, or the use of fish trade as a cover for smuggling operations.

There is considerably more potential for the introduction of RFID (radio frequency identification) tags and scanners, automated data capture and internet transmission of data than has been implemented so far. New traceability tools may include use of DNA markers to verify origins of fishery products. A Norwegian company, GenoMar has developed a genetic verification tool, 'Genopass', based on recognition of DNA markers, marketed with software and a database. Variations in micro-components (e.g. rare metal profiles) may also provide unique identifiers which are usable for traceability purposes. Advances in portability and speed of testing methods bring such tools within the reach of field operatives.

The development of new traceability tools can be expected to marginalise the non-authentic trade in fishery products (e.g. from IUU fisheries), provide opportunities for better marketing (the consumer can know the specific fisherman and catch location of what is purchased e.g. http://www.pacificfishtrax.org) and ensure that food safety incidents are addressed quickly and with more limited impacts; and thus establish more sustainable markets. It will, however, require greater investment in traceability systems and an environment in which they can be applied. For example, traceability requires greater batch separation in vessels, processing, storage and distribution, which has implications for physical dimensions of facilities and productivity. However, the efficiency benefits, in terms of improved stock control, reduced post-harvest losses, more limited recalls and withdrawals, better matching of supply and demand (for example different quality grades for different markets) are expected to more than compensate for the efficiency costs.3.3 Environmental, ethical and social responsibility

3.3.1 Introduction

A range of features and attributes is now being promoted for aquatic products, particularly in more developed and wealthier retail markets. Similar attributes are also increasingly being demanded in the food service sector. These cover more specific technical requirements for sourcing and supply chain activities such as those ensuring animal welfare and good environmental practice, to less tangible, less measurable and more contestable areas of sustainability and social responsibility.

3.3.2 Corporate social responsibility

The promotion of sustainability information schemes for aquatic products comes from a wide variety of organisations internationally, with diverse and sometimes contradictory requirements and consumer advice (Parkes *et al.*, 2010). NGOs have been to the fore in their promulgation among retailers, notably supermarket chains who have in turn been eager to demonstrate their own corporate social responsibility. There is some expectation that emphasis on a sector such as fish, where concerns over sustainability issues may be more readily appreciated, can also be used to infer green values to other food and non-food sectors and thereby help protect and advance brand equity. Such roles seem liable to continue to evolve, although some doubt remains as to the point when their message becomes too complex and confusing for audiences to consume.

The perceived importance of certification schemes, and consumers' willingness to pay for them, remains contentious (Roheim, 2009). While some have argued that longer term preferences for environmental, quality and safety attributes tend to be self-reinforcing, it seems equally likely that these will be maintained only so long as the price charged is considered to be affordable and worthwhile. Consumers signal this implicit set of values each day, yet only make more direct votes for strategic aspects of policy through political changes every few years. Given the rapidity of change in the issue of certification and trade there is arguably a need for policy to be more responsive to changes evident within the market; but also to be capable of setting any such change in the longer term context of wider policy goals.

3.3.3 Animal welfare standards

Animal welfare concerns in the production and slaughter of aquaculture products are increasingly on the agenda. The European Food Safety Authority (EFSA) has recently reported on the animal welfare aspect of the slaughter of the main European farmed species (salmonids, turbot, carp, eels, seabass and seabream). There are no specific proposals for legislation at this stage, but clear differences in welfare aspects of husbandry and slaughter practices have been identified. A series of recent risk assessment studies by the European Food Safety Authority (European Food Safety Authority, 2009) on the welfare of eight species of farmed fish have found that some killing practices cause extreme distress (e.g. use of salt and ice to kill eels). Policy-makers could decide that a regulatory approach is necessary, and if so, it is likely that this will be applied to imported products to ensure a level playing field (the 'at least equivalent' principle).

A fish welfare requirement as a condition of international trade is therefore a distinct and foreseeable possibility for the future and is currently being considered by the European Commission (European Food Safety Authority, 2009a). Welfare issues in commercial capture fisheries have not been raised so far in that context, but many common practices – long hauls in trawl cod-ends, rapid hauling from depth, poor deck handling and slaughter practices – could be regarded as being sub-optimal in welfare terms. More specific aspects such as cutting fins off live sharks, tangling seabirds and tailing live crustaceans are also under question. Welfare is already a major theme in anti-whaling arguments and the principles could equally be applied to fish species in future. The welfare campaign group PETA (http://www.peta.org.uk) has already started to raise issues of cruelty in fisheries and aquaculture and wider impacts are to be expected.

3.3.4 Environmental standards

As well as concerns regarding sanitary, animal health and plant health, trade measures are being extended to environmental conservation and social measures. A notable example is the EC catch certification scheme in force from the start of 2010, requiring fishery products traded with the EC to be accompanied by a certificate, validated by a national competent authority, declaring that they have been caught lawfully. The measure is intended to prevent the entry into the EC market of fishery products which are derived from illegal, unregulated and unrecorded (IUU) fishing and applies to fish from all sources except aquaculture and freshwater capture fisheries.

As well as requiring national authorities to strengthen their fisheries' monitoring and controls, the measure will need the establishment of officially verifiable systems of traceability. A similar approach is being considered by other markets such as the USA. The IUU requirements may have impacts as buyers migrate to suppliers who are able to provide the necessary guarantees. There are concerns that the measure will also further marginalise small-scale fisheries who in many countries operate without regulation, and without catches being recorded, and may therefore be regarded as IUU operators.

In many cases environmental standards clearly underpin the intentions of certification schemes and related eco-labels. Overlaps to varying extents occur and there is a tendency for a ratchet effect whereby incremental levels are successively demanded on the market. Attempts to create more accurate measures of environmental impact and identify implications for sustainability employ more sophisticated metrics such as carbon footprints and life cycle analysis. Increasingly these use methodologies which aim to be consistent and compatible across system and product categories to enable more accurate comparisons. Significant challenges undoubtedly await in the task of ensuring accurate communication and understanding of these criteria among diverse market segments.

3.3.5 Social and human welfare standards

There are no specific social standards applied for aquatic products in main markets at present but they could be in future – e.g. labour standards including those for child labour, safety and related requirements. If applied in the markets of destination their application to trade is possible. Interest has arisen concerning the development of Fair Trade aquatic products, for example in tropical shrimp, but social issues are otherwise linked mainly to more general corporate social responsibility initiatives described earlier.

3.4 Future impacts of regulatory measures on fish trade

The current approach to food regulation for international trade has given rise to concerns regarding the moral issue of dual standards of food safety for export and domestic markets. While there is no such thing as safe food, there is a balance of costs and benefits to be sustained in the investments in export and domestic food safety controls, which has given rise to the *de facto* existence of dual standards in many less developed countries. However, domestic and export control systems are increasingly impossible to separate.

Since a single production system often supplies products to both markets (often based on quality grades) then export controls have to apply throughout. An example is in relation to veterinary drug controls for aquaculture. In a given country there is either a drug control regime in place (registration, positive-negative lists, controlled distribution and use under veterinary supervision) or there is not. It is not possible to operate dual systems. There is therefore a trend towards convergence of export and domestic control systems. The development of one without the other makes less and less sense. The farm to fork approach applied to international trade will have an increasing impact on domestic control systems.

There have been major benefits of strengthened regulatory compliance on the fish exporting countries. Compliance in fishery product requirements has often resulted in the insertion of modern quality and food safety control concepts for the first time, and has lead to impacts on other sectors. Fishery product exporters are often the first food businesses in Less Developed Countries (LDCs) to implement HACCP (Hazard Analysis Critical Control Point) systems and operate modern hygienic establishments. Many establishments in LDCs are of a very high standard (e.g. the Nile perch industry around Lake Victoria). The pangasius sector in Vietnam now operates some of the most modern and well-capitalised production and processing systems anywhere in the world.

However, until now food safety controls have not been successfully applied lower down the supply chain, largely due to dysfunctional structural features of the sector at the level of the fishery. This means for example that export revenues are not channelled to support development of fish landing infrastructure for small-scale fisheries. The need to adjust fishery sector structures to employ the benefits of international trade to improve conditions throughout the supply chain is perhaps one of the biggest challenges facing fisheries development.

The SPS Agreement has provided a formalised rationale for the application of sanitary barriers in international trade, providing a requirement that measures be risk based and proportionate. Food safety risk assessment as a science is in its relative infancy, and until now the domain of a few specialists, and few countries engaged in international trade in fishery products (as importers or exporters) have the capacity to assess risks and apply the information gained in their risk management approach. There is a need for the development of such capacity to ensure the defence of the rights granted by the SPS

Agreement, and suppliers who fail to achieve these skills will become hostages to the decisions of the receiving countries' technical and sanitary barriers. The development of SPS capacity in supplying countries is another challenge for which less developed countries are expected to require support in coming years. There is also a role for the development of empirical models that can be applied in a wide range of situations. However, as in all cases, lack of valid and reliable data will continue to be the limiting factor in the predictive validity of risk assessment models.

4. Emerging structural and policy drivers

4.1 Overview

The future of the post-harvest supply chain elements of the aquatic food sector will be subject to a range of internal and external drivers, applying both directly and to related or competing food systems and products. Here these factors are grouped into those associated with the supply of materials and products, those which may drive markets and the more cross-cutting impacts of climate change.

4.2 Supply side factors

4.2.1 Introduction

A number of supply side factors are liable to become increasingly important in shaping the future post-harvest supply chain for fish. A primary assumption is that greater quantities of product will be delivered to meet expanded demands; these may be sourced in greater quantities from existing locations or systems, or be derived from much wider geographic and production ranges. A key theme will be the further shift expected in the proportions of marine/inland capture fisheries and aquaculture supplies. Given the origin of global supplies as discussed earlier, these shifts will be especially notable in the developing world. An essential element across these will be the extent to which expanded demand and structural features will generate prices and profitability to drive investment both in output and in diversifying and improving supply chain performance, efficiency and wider impact.

4.2.2 Marine capture fisheries

Marine capture fisheries will continue to provide an important component of supplies but at around the current volume in absolute terms (see Garcia and Rosenberg, 2010). Species ranges and stock sizes may also vary, imposing changes on processing and market options. Within this share of global supply the trend of more capital-intensive fishing is liable to continue with greater concentration within supply chains, whether at sea or onshore and through vertical integration. While well-regulated and managed fisheries may permit the participation of small-scale operations, in many situations their more restricted capacity will curtail their role in more value added fish supplies. However, in less developed countries, particularly with limited infrastructure, small-scale sectors are likely to maintain an important role supplying local markets and providing inputs to aggregators for exports.

These processes are likely to encourage greater concentration of the supply chain especially in terms of port-based infrastructures. This will also link with the regulatory drive for ‘port state measures’ (PSM) – where only designated landing sites can be used, in which catches (and often bycatch) are properly recorded. Smaller landing sites are likely to continue their decline in importance with greater emphasis upon fewer but larger harbours. This process has been intensified by improved ICT, allowing fishermen to land their catch where prices are best or conducting auctions at sea. The move towards landing of bycatch is also likely to diversify market functions at or around ports, with greater pressure (and opportunity) to add value from raw materials which have otherwise been underutilised.

More intensive and commercialised post-harvest systems also tend to impact upon the artisanal sector, favouring activities of relatively large post-harvest enterprises while marginalising small operators based in small landing sites. While overall there may be improvements in the quality of fish reaching the final consumer, the changes favour relatively wealthy urban-based groups of consumers rather than poor rural producers and their linked consumers. More efficient and intensive value chains also tend to afford fewer opportunities for marginal operators to utilise spoilt or sub-standard fish, with the consequent reduction in affordable supply to poorer consumers.

An interesting side effect of the concentration of landing and marketing in some artisanal fisheries has been that an increasing number of sales are made on a cash basis, and older forms of credit and advances which created long-term social bonds between producers and traders are being abandoned. This has led to what one observer describes as a more 'opportunistic' ethos governing trading relationships (Salagrama, 2002). Elsewhere more formal commercial links and guarantees demanded by large-scale post-harvest and marketing organisations present more onerous barriers to prospective new entrants, which tends to accelerate the process of concentration.

4.2.3 Inland capture fisheries

The FAO estimates that output from inland capture fisheries rose from 2.3 million tones in 1961 to 8.1 million tonnes in 2001, and this is almost certainly an underestimate (see also Welcomme *et al.*, 2010). Yet with only a few exceptions, inland fisheries do not appear to have been subject to the same degree of technological change as marine fisheries, even though they have grown rapidly in importance. Even in situations such as the Cambodian Tonle Sap fishery, one of the world’s largest systems subjected to great political and economic change, and recent policy changes in management, there have been few major changes in features and outputs. However, as pressure on marine fisheries has grown, and export values for aquatic products have risen, so has interest increased in the more organised value addition and trade from inland fisheries. Thus in Cambodia considerable amounts of freshwater fish are exported to Thailand, Thai entrepreneurs taking over from smaller scale Cambodian traders and diverting fish which would otherwise be locally consumed either fresh or smoked. This has had a negative impact on small-scale female traders and processors, but has expanded trade volumes and value.

In the African case of Lake Victoria the initial commercial success of small-scale fisheries supplying Nile perch soon led to environmental pressures on the lake, overfishing and problems of quality and access to the EU market.

Repositioning the fishery through improved stock management, certification and improved logistics is being attempted and stocks have stabilised, albeit at much lower levels. However, the overall prognosis for economic stabilisation and development is by no means clear given the stronger emergence of pangasius and other competing products.

4.2.4 Aquaculture

Aquaculture has grown rapidly over the last few decades, and having already matched capture fishery supply (FAO, 2009) is likely to provide the dominant share of future supplies of fish for human consumption. Much of this will originate from the Asia-Pacific region though potential in Africa and Latin America is also substantial. The character of the post-harvest sector in aquaculture varies enormously. At one extreme are large-scale industrial units catering for global markets while at the other are much more traditional small-scale domestic activities focused on consumption within the producing household. Small-scale processors and traders are active in the context of aquaculture, especially in Asia, and as with capture fisheries are engaged in supplying credit and inputs (e.g. fish seed) to producers. As demand has grown, especially from richer urban markets, small-scale post-harvest operators have come under increased pressure to meet the demand for higher quality and guaranteed products.

The increase of supplies from aquaculture is likely to continue especially with greater emphasis upon production of lower cost species which are less dependent on marine fisheries as a feed source. Technology changes are also likely to see composite feeds for higher value aquaculture species which are much less dependent on marine substrates. Aquaculture also has significant advantages of being more predictable and manageable than is the case with capture supplies. These characteristics should afford the opportunity for more stable conditions and so encourage longer term, more stable business relationships. Economies of scale are likely to continue to drive increased concentration and will drive investment through global multinationals, but with an increasing focus on major producers (and markets) in South East Asia such as China and Vietnam.

The range of species produced is liable to expand as technical barriers to production are surmounted. However despite this, cost competition is likely to place emphasis on a much more limited range of species which might be regarded as closer substitutes for one another. This would suggest broad groupings with shrimps, salmonids and white fish probably dominated by pangasius and tilapia, with carp also playing a key role in a narrower range of markets. Aquaculture of species which also continue to be available from traditional capture sources might provide for niche markets, particularly if certainty of supply of specific product attributes is required. But otherwise these are likely to remain too vulnerable to price competition from wild stocks to develop into dominant category leaders.

Genetically modified (GM) fish production has possible supply benefits, as experimental transgenic fish have shown the potential to grow much faster and larger than natural equivalents, with improved feed conversion ratios. In one study transgenic trout had a 17.3-fold difference in weight by 14 months, compared to non-transgenics (Devlin *et al.*, 2001). Transgenic salmon, tilapia, channel catfish and others are being actively investigated in laboratory studies, leading to better understanding of genetic improvement, even if transgenic fish do not reach the market at any foreseeable stage. While no regulatory agency has yet approved any transgenic food animal for release, subject to various conditions, approval for commercialisation of GM salmon by the US FDA appears at least possible by the end of 2010. In this case there would be expectations of technology transfer to other species.

Consumer resistance to GM foods remains strong, but fish could be one of the food animals with most immediate potential should the market environment change. The food industry could also learn from errors in introduction of GM plant products, by focusing initial approaches on consumer benefits rather than production benefits. Thus the introduction of GM fish might address quality, taste, and nutrition rather than size, productivity, or product yields. Concerns over the impact of potential escaped stocks remain to be overcome, though technical means (enclosed systems with no water routes to outside environments, sterility of production stocks) may be considered. In overall terms, potential cost and price advantages, simpler and less demanding resource and environmental impacts and possibly improved potential for supplying affordable high quality food may all change public attitudes and policy directions.

4.3 Market factors

4.3.1 Overview

Recent decades have been characterised by dramatic structural, location and product-based changes in market for aquatic products. With emerging technologies, expanding and new production centres, and further evolution in consumer expectations, market factors are likely to be key determinants of change, not only driving wealthier market sectors, but also influencing choice and demand in less developed economies. The overall scale of aquatic markets is likely to grow substantially in the next 40 years, as will the range of products, technical delivery, and quality requirements. Though aquaculture production will increasingly shape and drive markets, capture fisheries' output and its consumption choice will also remain a substantial feature of the sector. Some of the key issues are outlined below.

4.3.2 Demographic growth

Over the last few decades, the global population has grown steadily, from three billion in 1960 to 6.5 billion in 2005 with an estimate of nine billion by 2050. Much of this growth has been concentrated in the developing world, expanding from two billion in 1960 to reach 5.3 billion by 2005. This steadily growing market has presented a major challenge to the post-harvest sector and what is perhaps surprising is that growth in aquatic products has kept step with and actually exceeded the growth in the global population, mainly due to the major increases in aquaculture production. It is further likely that any future growth – projected to expand by 70-100% above current markets – will be met by aquaculture product.

4.3.3 Urbanisation

The global population has not only grown, it has become increasingly urbanised, and it is estimated that today over 50% of the world's population live outside rural areas. Between 1960 and 2005 the proportion of the population of less developed regions living in urban areas increased from 22% to 43%. This has a number of effects as far as the post-harvest sector is concerned. First, it increases the proportion of the population who have no direct access to aquatic resources and thus makes them more dependent on traded fish. Second, urbanisation appears to be associated with a widening of tastes, with the result that urban populations demand a greater range of aquatic products with consequent implications for the post-harvest sector.

The more urban environment has also proven amenable to the growth of more concentrated retail chains, notably supermarkets, whose business model has been built upon the coexistence of a large catchment of adjacent consumers able to access their stores. At one level these afford opportunities to provide a greater diversity of products to consumers although the relative attractions of different locations can result in the provision of a diminished service to certain population groups as more traditional retail outlets become marginalised. In addition to concerns over the accessibility, especially those without private transport, and possibly affordability of supermarkets for consumers, questions must also be resolved over the ability of producers to meet the supplier requirements. Compliance with supermarkets' procurement specifications, not least in terms of volume, is often problematic for medium and smaller scale producers, let alone concerns about the profitability of so doing.

4.3.4 Rising income levels

Not only has the world's population grown and become increasingly urbanised, it has also become richer, even in less developed countries. In newly industrialising and the large and economically expanding BRIC (Brazil, Russia, India and China) countries, the emergence of new middle classes is having a particular impact on higher value foods. This has involved new forms of consumer preference including a shift towards higher quality fish, better preserved fish (usually involving the use of ice) and greater popularity of packaged and partially processed fish (e.g. filleted fish). It has also involved some shifts in purchasing sites away from open markets and street vendors towards supermarkets and 'modern' retail facilities.

The overall impacts of these processes on the post-harvest sector are mixed. On the one hand it has presented potential new openings for small-scale traders and processors. Thus a larger market, especially larger urban markets, has created more possibilities for all levels of the supply chain. At the same time, the stress on improved quality and presentation has worked against the smaller operators in the post-harvest sector who are less able to meet these new demands, while the increased demand for wet fish, either fresh or iced, has decreased the supply of fish for drying or smoking. There are also indications that fish is ceasing to become a poor person's food. This is likely to heighten as more sophisticated logistics can distribute to centres paying the highest prices with greater ease.

4.4 Climate change impacts

4.4.1 Overview

The fisheries sector interacts with climate change in different ways. In the first place, through emissions from vessels and transport vehicles it is one of the drivers of climate change, although not substantially compared with food sectors such as red meat production. Secondly, climate change impacts on marine, coastal and inland environments and therefore potentially affects the supplies and costs of fishery and aquaculture products. More broadly there may be interactions with respect to climate change mitigation potential, and in terms of wider impacts on rural economies, livelihoods choices, resource competition, incomes and markets.

4.4.2 Emissions from vessels and aircraft

Fish production and distribution is an energy intensive process. Seas at Risk estimates that global fisheries consumed almost 42.4 million tonnes of fuel in 2000 (Seas at Risk, 2007). This represents about 1.2% of the global oil consumption. In 2000, fishing boats emitted an estimated 130 million tonnes of CO_2 into the atmosphere, comparable to the annual amount emitted by road transport in the UK. On average, for every tonne of fish landed 1.7

tonnes of CO_2 is released into the atmosphere (*Ibid*). Historically subsidisation of fishing fleets and the fuel they use combined with the innate tendency towards overcapacity of fishing effort has exacerbated the impact.

The need for reduced emissions is leading to greater fuel efficiency in fishing. It exerts pressure to switch to less energy intensive production e.g. passive gears. For example, the fuel needed to catch and land a kilo of Norway lobster can be reduced from nine to 2.2 litres by switching from trawl fisheries to pots. However, such gear substitutions may not always be feasible and could result in reduced and more variable volume of supply.

In addition to fish being traded across long distances, distribution of fish also consumes significant amounts of energy due to temperature controls, and provides opportunities for reduced emissions. In terms of distribution, air freight emits about ten times as much CO_2 as sea freight (Table 9). Furthermore high altitude release of CO_2 increases the greenhouse effect such that the effect of emissions of aircraft are two to three times as high as those derived from ground level. Even though energy is expended in freezing and thawing, transport of frozen fish often provides a more environmentally sustainable means of distribution, although alternative system configurations might also prove more viable. While slower transport (e.g. airships) might be a future option for non-perishables, for fresh fishery products it is out of the question.

Table 9: Carbon dioxide emissions from different distribution methods

Transportation method	**CO_2 emission/tonne/km**
Air plane (air cargo), average Cargo B747	500 g
Modern lorry or truck	60 to 150 g
Modern train	30 to 100 g
Modern ship (sea freight)	10 to 40 g
Airship (Zeppelin, Cargolifter) as planned	55 g

Source: http://timeforchange.org/co2-emissions-shipping-goods

4.4.3 Impacts of climate change on supply patterns

A recent study by the WorldFish Center (Allison *et al.*, 2009) examined the fisheries of 132 nations to determine which were the most vulnerable to the impacts of climate change, based on economic and dietary dependency on fisheries, and the capacity of the country to adapt. They identified 33 countries as 'highly vulnerable' to the effects of global warming on fisheries, 22 of which are classified by the UN as 'least developed'. Two-thirds of the most vulnerable nations identified are in tropical Africa. Guinea, Malawi, Senegal and Uganda were among the most vulnerable to impacts of climate change and were identified as being a priority for climate change adaptation efforts. Impacts may also be experienced by fisheries clusters located in low-lying coastal areas. The Ganges/Brahmaputra and Mekong deltas (in Bangladesh and Vietnam respectively) with high concentrations of small-scale shrimp producers, are also highly vulnerable to changes in sea level and frequency of tidal surges. Industrial shrimp production in Thailand and Ecuador may be similarly affected.

On the other hand, increased temperatures will, *prima facie,* provide increased supplies through improved biological productivity, although other factors (environmental, feed supply, demand) will limit growth in production, and it is recognised that climate change may bring benefits to some fisheries. For example experience to date suggests that climate change impacts are being experienced now at the margins (polar regions) where small temperature differences appear to be making substantial differences to reproduction and migration. This has already altered supply patterns from the North Atlantic with increased abundance of cod and haddock, which is considered to have a potential positive impact on the Greenland economy (Arnason, 2007). However, in these regions lower biodiversity at each trophic level means that large changes in abundance and species' composition could result, presenting challenges for the rapid implementation of the ecosystem approach to fisheries management, as well as to the adaptability of the supply chain.

5. Conclusions

International trade in fishery products is well established as a global industry. Future trade flows will trend towards meeting rapid growth of demand in emerging markets, especially China. Consumer demand in developed markets will continue to drive policies for strengthened trade barriers based on food safety, animal welfare and sustainability conditions. Voluntary and regulatory measures are likely to continue to be refined and applied more strictly. One consequence of this is that trade flows may be increasingly diverted to emerging markets, at least in the short term, since compliance costs to producers are lower. However, in the longer term, disparities in SPS and technical trade barriers between the major global markets are likely to be eliminated. It is in the interests of all parties to support the development of effective SPS measures in emerging markets such as China and other South East Asian countries.

Less developed countries will continue to benefit from production and trade in fisheries products, as population growth and recovery of the global economy sustains demand. Here, the need for a more equitable distribution of the benefits of trade to the level of artisanal producers should drive policies to restrict open access and introduce rights-based fisheries. This is required as a precondition to ensuring the re-investment of export revenues in upgrading infrastructure, thus correcting a major failure of fisheries policy, and providing the means to achieve better utilisation and reduced post-harvest losses. However, this requires a degree of policy awareness which is presently lacking in many less developed countries and donor programmes.

Changes in climatic conditions have already impacted on fish production in some regions. The overall future impact is not predictable, but there is a risk of greater fluctuations in quantity and quality of production, especially in capture fisheries. Certain tropical low-lying areas dependent on aquaculture are also vulnerable to inundation, which could impact on supplies for some products such as shrimp. Here policies need to be flexible, to ensure that investment reflects the additional risks (for example favouring projects with higher rates of return in early years).

Carbon emission reduction measures are not expected to impact greatly on fisheries production, but may drive changes in distribution by limiting the air freight of fresh fish. New processing technologies offer niche advantages to certain products and market combinations, or levels of the distribution chain, but are unlikely to revolutionise production and trade. Freezing of fish is therefore likely to remain the mainstay of the international trade in fishery products. The main technological potential for the future, that of genetic modification of fish for aquaculture production, is currently prohibited in most countries. Further research on the possible human and animal health implications of GM fish is therefore desirable, with a view to developing a science-based approach to policy decision making in this important area. It might also be foreseen that once market entry is gained, it is likely that rapid expansion will follow soon after.

Notwithstanding the emergent scenarios in non-fish food sectors which will also impinge upon the more precise pattern of aquatic supply chains, the prognosis for those endogenous factors identified themselves point to more dynamic and more complex interactions. However, the post-harvest sector has demonstrated quite remarkable resilience in the past and it is arguable that, on balance, it is better equipped to meet such challenges now and will be all the more so in the future.

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