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Aquaculture and Marine Fisheries: Will Capture Fisheries Remain Competitive?

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Abstract

The importance of aquaculture as a means of supplying the predicted shortfall of fisheries and other aquatic products has been increasingly proposed. It would appear certain that increased demands from growing populations must be met from managed systems in which outputs can be increased from selected productive inputs. While aquaculture largely meets such criteria, this is far less the case for marine fisheries, whose ecological and institutional complexity constrains most options for growth. However, aquaculture itself is by no means free of constraints, and is unlikely to have unlimited potential for expansion and the sustainable delivery of benefits. This paper explores comparative features of aquaculture and marine fisheries, internationally and at the regional North Atlantic level, and considers the extent and circumstances in which marine fisheries will retain their significance, and in which, if at all, aquaculture might be expected, to supplant their former role. The conclusion drawn is that while aquaculture can offer important advantages of controllability, ownership rights and responsibilities, and market adaptation, the future may see greater integration of the aquaculture and marine fisheries sector, and greater appreciation of their comparative roles.

Keywords: aquaculture, marine fisheries, world demands

Introduction

In the 50 years since the Food and Agriculture Organisation of the United Nations (FAO) first estimated the world fishery production, the sector has developed rapidly, to the extent that an increasing number of resources are overexploited and few underexploited resources remain (FAO, 1996). During this period, the marine production of fish, crustaceans and molluscs grew from 18 to 90 million tons from a point at which only North Pacific and North Atlantic fisheries were developed, accounting for 47 and 46% of total harvest, respectively. The areas noted as possible for fisheries expansion, mainly off Central America, Peru and Chile, in the Caribbean, off West Africa and off Australia, New Zealand, the South Pacific Islands and the East Indies, have increasingly been brought into production and into the ever-growing global trade in fisheries products.

In 1995 total production of finfish, crustaceans, molluscs and aquatic plants reached 120.7 million tons (FAO, 1997), an increase of about 15.6 million tons since 1989. Much of the gain has been attributable to aquaculture, whose contribution to fish and shellfish supply rose from 11.7% to 18.5% over the same period; including aquatic plants this share increased from to 14.4% to 23.0%. Over a quarter of the total world supply of food fish was derived from aquaculture. By 1995, aquaculture production reached 27.8 million tons, valued at US$ 42.3 billion (an average US $ 1 522 per ton), about 9.6% and 5.2% over 1994 quantity and value, respectively. As in recent trends, the increase was higher for finfish and shellfish, some 13.6% and 7.4% for quantity and value, respectively. By contrast, except for an increase in 1993–94, probably due to short-term trends in small pelagics, capture fisheries showed near zero or negative growth (FAO, 1997).

Supply for direct human consumption in 1995 was estimated at 80 million tons, some 3.4 million tons over 1994, exceeding the estimated rate of population growth, availability of food fish rising to 14 kg per capita. Of the 1995 production, some 28% or 31.5 million tons were used for reduction, a ratio similar to that described in initial records. The value of international fish exports was estimated to have risen from US$ 17 to US$ 47 billion from 1985 to 1994. This was associated with greater trade in low-value commodities such as fishmeal, reducing value per volume. However, preliminary figures for 1995 suggested an increased value due to higher prices. In value terms, the developed countries accounted for about 85% of total fish imports in 1995. Japan remained the world's biggest importer, with some 30 % of the global total, and imports by the three major importers, including the European Union (EU) and USA increased. For many developing nations, sectoral trade is a significant source of foreign exchange. From 1985 to 1994, receipts increased from $5.1 to $16 billion, with a further increase expected for 1995 (FAO, 1997).

Freshwater finfish, particularly Chinese and Indian carp, accounted for the greatest share (45.6%) of aquaculture production, while aquatic plants contributed a quarter. Although higher in value, diadromous and marine finfish accounted for only 7% of output. Though only 4.1% of total tonnage, crustaceans accounted for 17.3% of value. In 1995, 65% of all reported species or groups contributed up to 10^4 tons, only 32 species (including Atlantic salmon, *Salmo salar*) contributed between 10^5-10^6 tons and only 8 species above 10^6 tons. (FAO, 1997). The highest rate of growth of reported production (> 4×10^6 tons) was for kelp, *Laminaria japonica*; three of the top ten aquatic species produced are plants. Unclassified finfishes aside, the top 10 species over the last decade represented organisms low in the food web – filter feeders, herbivores/omnivores or plants. Though subject to great interest, cultured shrimp are much less significant, the major species *Penaeus monodon* was ranked only 14th in 1995; other regionally dominant species, *P. vannamei*, (Latin America) and *P. chinensis* (China), were ranked 39th and 42nd.

The role of aquaculture in total supply is significant and increasing (Ruckes, 1994), although its significance varies nationally and regionally. In 1995, key countries were China, accounting for 60.2% of national production, nearly twice that of the next ranking countries France, India, Korean Republic and the Philippines. Lower contributions were recorded in Thailand (13.2%), Norway (9.4%) and USA (7.2%), although in most cases these ratios were far larger in value terms. Global aquaculture production continues to be dominated by Asia, in 1995 accounting for over 90% of world output, with China, India and Japan in turn contributing 63.4, 5.8 and 5.1% and Korea, Philippines, Indonesia and Thailand accounting for 3.7, 2.9, 2.6% and 1.7%, respectively. A few developed countries feature notably, but the Low Income Food Deficit Countries (LIFDCs) in 1995 contributed some 21.6 million tons or 78% of world total production – although around 98.5% of this originated from just six countries. The growth of aquaculture within LIFDCs between 1984 and 1995 was nearly six times that for non-LIFDCs, although Chinese aquaculture expanded at an average 13.6% per year, leaving an equivalent growth rate for other LIFDCs of only 5%. (FAO, 1997)

Comparative aspects of fisheries and aquaculture

The growing importance of aquaculture, and the critical role of key countries is clear, as are the implications of diminishing supply from traditional fisheries. The plight of the Northwest Atlantic seaboard fisheries, and its devastating effect on coastal communities has been widely documented. Within the European Union, traditional supply sources from capture fisheries in the North Sea, the North Atlantic and the Mediterranean, have all experienced declining yield, and throughout, trends of indigenous supply differ only in magnitude of decline, indicating the extent of excess fishing effort applied to declining biomass. In the United Kingdom for example, landings of cod in the 1990s, were less than 15% of those in the early-1970s. Within the pelagic sector, vagaries of supply have been dramatic, and may have hindered their potential for market substitution. However, while limitations in capture fisheries may be deduced, aquaculture does not inherently possess the means to increase to the point of dominating or to any extent supplanting fisheries. The characteristics of aquaculture are different from those in capture fisheries (Table 1).

TABLE 1. Key discriminants between aquaculture and fisheries supply.

Factor	Characteristics
Management	Aquaculture is primarily a managed activity, and so can be far more definable and deterministic. It is also far more clearly specifiable in terms of location, scale and system.
Recruitment	Unlike fisheries, recruitment inputs can be known or estimated directly; with definable mortalities to market size, there can be some degree of correlation with outputs.
Linkages	There are broadly definable linkages between aquaculture outputs and necessary resource inputs; there are also linkages with waste outputs and other impacts, and with financial returns.
Flexibility	In terms of timing and market size; higher average values may be obtained than for the wild caught equivalent; more notably where there is a higher degree of management control.
Ownership	Ownership and rights allocation are usually more explicit; production may be a more definable determinant of local economic potential, and broadly, of national capacity; the 'live storage' potential also means that aquaculture stocks may provide a local store of food supply or wealth.
Ecology	Aquaculture systems are far more concentrated in respect of nutrients, energy and yields; their capacity and potential is linked, and ultimately constrained by the potential for collecting and applying inputs, and by local environmental capacity.

(Developed from Muir, MS 1995).

As a more managed activity, aquaculture may have greater resemblance to agriculture, in both productive and management aspects; as outlined in Table 2. These parallels may also extend to the relationships with producing communities. However, as discussed later, the consumer and market context of supply from the aquaculture and fisheries sectors will also interact with these supply features, and will define the relative competitiveness of each sector, and their respective potentials.

However, while such features may offer advantages to aquaculture, and while rates of growth in some subsectors have been dramatic, over capacity and declining profitability have become more evident, particularly in target High Unit Value (HUV) species, as production competes within narrow market boundaries (Young and Muir, 1995). This has led to significant restructuring in the aquaculture industry, and increasing concern for the existing production base, let alone for further growth. Greater internationalisation both of investment and trade has also increased pressure from competing or analogous products, and has increased direct or indirect attempts to regulate or exclude productive sectors, at least temporarily. Production problems also remain, including system failures, feeding and nutritional inefficiencies, diseases, and issues of genetic and reproductive control, and environmental management. These continue to constrain profitability, as well as maintaining levels of risk. Though many LIFDCs show potential for expansion, constraints include low national priorities/policy development for aquaculture, unavailable, limited or inappropriate coastlines, limited and/or inadequate water supply, poor infrastructure and limited capacity of institutions and technical and financial constraints (FAO, 1997). Given this range of constraints, can aquaculture be sustainable in resource use, structural and competitive terms, and how will capture fisheries interact?

The Development Framework

To describe further the comparative status of aquaculture, and the competitive implications for the fisheries sector, it is useful to consider the driving forces for aquaculture development and growth, particularly in the last two decades. Table 3 summarises critical factors.

While many of these driving forces still remain to varying degrees, other potentially constraining factors, cross-sectoral and intra-sectoral, have emerged as aquaculture has grown, as outlined in Table 4.

As Table 5 indicates, certain subsectors appear to be capable of significant endogenous expansion. While often driven by high market value (Young and Muir, 1995), these have increasingly faced oversup-

TABLE 2. Comparative productive and management features of fisheries, aquaculture and agriculture.

Characteristic	Fisheries	Aquaculture	Agriculture
Location	Widely variable, though specific nursery, migratory, feeding grounds may be definable.	Defined by site conditions, acceptability for intended stock; usually fixed, limited variation.	Defined by site factors, acceptability for intended crops/stock; Usually fixed, limited variation.
Productive Investment	Vessels and catching gear, highly mobile, adaptable.	Fixed in structures; management systems, only some mobile.	Fixed in structures; management systems, only some mobile.
Ownership	Means of production only; though increasingly conferred through access rights, licenses.	Lease or property ownership of sites, access to water; plus means of production.	Lease or property ownership of sites, possibly access to water, plus means of production.
Infrastructure	Port, specialist product handling, transport.	Specialist product handling, transport, may be shared with fisheries. Seed, feed, fertilizers.	General and specialist product handling, transport. Seed, feed and fertilizers.
Management	External regulation of effort/ efficiency to varying degrees, limited *in situ* management of catching decisions.	Internal management of production process, some external regulation of resource access, management practices, etc.	Internal management of production process, some external regulation of resource access, management practices, etc.
Output	Highly variable within moderately definable stock/year-class boundaries.	Originally seasonal, increasingly controlled and extended, chosen species, size, quality.	Originally seasonal, partially controlled, extended, chosen species, size, quality.
Markets	Volatile, responding to wide range of supply and quality; simple transactions, pressure to sell.	More stabilized, longer term supply trends; producer may control outputs, longer-term contracts, future trades, etc.	More stabilized, longer term supply trends; producer may control outputs, longer-term contracts, future trades, etc.
Development	Identify/develop new resources better targeting, gear improvement, efficiency, selectivity, more effective management and ownership issues.	Identify/manage more species lifecycles; equipment/systems; genetic improvement, feed and husbandry efficiency; disease control; environmental management.	Genetic improvement, feed and husbandry efficiency, disease control, equipment and systems, environmental management.

(Developed from Muir, MS 1995.)

TABLE 3. Factors in the development of the aquaculture sector.

Factor	Implications
Market demand	Good demand and high prices for selected species in traditional markets offering initial, if limited, targets for producers.
Environments	Initial availability of lagoons, sheltered bays, with suitable water quality, production temperatures, nutrient supply for shellfish growth.
Infrastructure	Improving transport, power, communications, access to major markets, relatively good information system; scientific support structure.
Technical capability	Emerging and rapidly established techniques for hatchery production, husbandry, feeds, cage and offshore culture systems; improvements to traditional systems.
Investment	Local, national and regional private, commercial and institutional investment; incentives and support schemes for development, and technical research.
Human resources	Initial nucleus of primary technical skills, developed through pioneer companies and development centres; increasing level of management skills in core groups.
Institutional system	Generally positive and proactive environment, providing strategic research inputs, adapting to changing needs of industry, development of legal and regulatory systems.

TABLE 4. Current issues for the aquaculture industry.

Issue	Features/implications
Cross-sectoral	
Policy and planning	Opportunities for aquaculture to access resources, operate effectively and securely in conjunction with other sectors; plan and develop strategically.
Internationalisation	Increased competition from imports/substitutes, reduced local identity for production, possibly reduced/altered quality standards.
Disease management	Identification, control and transmission management; substantial loss potential in most species, costly control measures.
Environmental quality	Maintenance of suitable environments as production increases and/or in conjunction with other resource users; cost of environmental management.
Wildlife/conservation	Increasing value placed on natural habitats/key species and their preservation; reduced access to sites and/or restriction on operations.
Intra-sectoral	
Market prices	Profitability, security, investment potential.
Seed supply	Potential for expansion, production scheduling, diversification, quality improvement, cost reduction.
Feed supply	Production costs; problems of ingredient quality/costs, availability.
Technical capacity	Reliability and cost of production systems; efficient operation, access to new resources.
Local environments	Critical interactions with other uses; impacts of overloading.
Land availability	Increased pressure on traditional inland and coastal areas..
Public health issues	Accumulation of toxic materials, algal/bacterial toxins, pathogenic bacteria.
Traditional livelihoods	Difficulty of maintaining simple, low profitability practices.

(Developed from Muir and Young, 1995)

ply and the need to expand market towards lower priced products. Growth rate improvements, food conversion, maturation management, disease control can all reduce production cost, and in the case of Atlantic salmon, the pioneer for the more intensive sector, costs for efficient operators have dropped from around US $ 5.00 per kg in the late-1980s towards US $ 2.50 per kg in 1996. In the Mediterranean, seabream production costs are dropping from around US $ 9.00 per kg to US $ 6.00 per kg over the same time (Stirling Aquaculture, 1997), while in the US, average 1996 farm gate price of channel catfish was about US $ 1.70 per kg (Fish Farmer, 1997), and tilapia production costs as low as US $ 1.00 per kg have been quoted for new large-scale projects in tropical locations (D. C. Little, Asian Institute of Technology, Thailand).

Though the aquaculture sector has been diverse in its features and production methods, both commercial and artisanal production, there have also been increasing signs of aggregation, and a more clear-cut division between two main subsectors:

- larger scale corporate producers using intensive methods, primarily based on intensive fish production, moving towards increasing integration and internationalisation of markets.
- smaller-scale family or co-operative producers based mainly on traditional forms of production of fish, shellfish and aquatic plants, supplying specialised niche local or national markets through traditional agents.

Many of these characteristics echo features of coastal fisheries, and the role of artisanal producers in small coastal communities, and many of the constraints, competing forces and policy issues are similar. Table 6 summarises some of the factors involved in the process of change towards larger scale production.

TABLE 5. High development growth rate fish species.

Species	% growth*	Notes
S. auratus	61.9	Intensive cage culture in the Mediterranean; likely to consolidate as market prices decline; moderate scale.
P. olivaceus	33.0	Intensive marine pond and tank culture in Asia/Pacific; signs of leveling; possible in Latin America.
L. calcarifer	29.4	Highly priced in Australasia; intensive cage culture, more growth but moderate overall scale.
O. kisutch	29.2	Significant increase in North America cage culture, now leveling or declining as *S. salar* becomes more dominant.
S. salar	26.2	Major marine cage culture species; further growth expected but may slow down unless radical market or technology development.
M. cephalus	19.6	Widely produced in coastal ponds, Asia, moderate potential, but low food chain feeder, moderate scale.
C. idella	19.1	Very important species for polyculture/water body management, but poor markets. Very significant scale.
C. mrigal	18.6	Major Indian carp, good markets, significant potential expected in polycultures.
C. carassius	18.4	Chinese carp polyculture species, good potential for further development.
O. niloticus	18.2	Very versatile and increasingly popular and widespread, major potential in mono/polyculture.
O. mossambcus	17.8	As niloticus, better in saline waters, though less popular; hybrids highly marketable; major potential.
Pagrus major	12.0	High value intensive marine cage culture species in Australasia; moderate potential for increase.
C. catla	11.7	Major Indian carp, very good markets, significant potential for polycultures.
L. rohita	11.2	As above, also good market and high degree of potential.
P. gonionotus	11.0	Excellent potential in pond polycultures and increasing popularity in Asia.
Salmo sp.	10.0	Mixture of rainbow trout, sea trout and salmon; good general potential for intensive culture.

(From Muir, MS 1995, based on 1992 FAO production data, * growth % per year, 1986–92).

TABLE 6. Scale economy/aggregation factors in aquaculture.

Factor	Implications/effects
Site locations	Impose a natural constraint on unit scale, but technical change may act to increase outputs – e.g. better growth, survival, environmental control, productivity.
Direct/indirect cost structures	Demonstrate significant efficiency gains towards the upper scale limits of individual sites and management structures.
Fiscal/financial	Taxation and reinvestment incentives tend to stimulate increased capacity and productivity; regional development support promotes expansion.
Integration	Efficiency gains through, e.g. linking hatcheries, ongrowing, joint marketing initiatives.
Markets	Demands for uniform supply and product quality in larger-scale markets drive suppliers to increase management control, scale and/or co-ordination.
Acquisition	Different management, finance and site conditions leading to varied commercial performance, and hence opportunities for take over and capital write-down.
Management systems	Development of effective management systems and staff teams increasing investor confidence in good performers, increasing opportunities for growth/acquisition.

(Developed from Muir *et al*., 1996.)

In many parts of the world, particularly in relatively free market conditions, it is increasingly common for individual sites to move from annual production ranges of 10–50 tons, towards 100–500 tons, and for enterprises to move from several hundred to several thousand tons annually. Unless regulation increases, either for company size or structure (e.g. through competition policy) or through site limitations (through environment/local development policy), mainstream sectors of the industry are likely to become more aggregated, and become more uniform in their management approach, and in technical and market development characteristics. Competition is likely to increase, and prices and margins may decline further. This may also drive industry policy, in further pursuit of size and competitive advantage, and hence the case for greater deregulation within trading regions.

Although resource requirements for the sector – particularly in terms of land, water, feeds, and overall environmental capacity, can be significant, recent reviews (e.g. EC, 1995; Muir, MS 1995) would suggest that most sub-sectors are not notably resource limited. However, increasing competition for these resources may place additional demands on efficiency and productivity, and comparative resource access between global regions may become key determinants of growth and opportunity. The next section considers alternative development routes, based on two major strategies, diversification or product development, before returning to the issue of competitiveness with capture fisheries.

Future development routes

A widely advocated approach for expanding production beyond the endogenous rates is to diversify - which in coastal areas would normally include indigenous or established species, though other species could be produced given physical (e.g. land-based systems) or ecological (temperature, salinity or location-separated) barriers. Species such as halibut (*Hippoglossus hippoglossus*), cod (*Gadus morhua*), wolffish (*Anarhichas lupus*), Arctic char (*Salvelinus alpinus*) and various flounder species (e.g. *Paralichthys* sp.) in cooler waters, and various bass, bream (*Puntazzo puntazzo*), jack (*Seriola* sp.), grouper (*Epinephelus* sp.), dolphin-fish (*Coryphaena hippurus*) and other species in warmer waters have been proposed and researched for commercial production. However, these often occupy similar market niches to those already produced, adding further to market congestion. The time and cost needed to bring new species into production (Table 7) may be difficult to recoup through the gains of a 'honeymoon period' (Young and Muir, 1995). Though development times may reduce, as knowledge and skills can be transferred, and as generalised understanding emerges in genetics, reproductive, behavioural and energetic physiology, feed formulation and system design and operation, a significant time may still be required to develop a distinctive and sustainable production sector. Many marine species still require at least 5–10 years of focused and sustained development.

Extending this and taking a sectoral perspective, as outlined in Table 8, a simple NPV (Net Present Value) can be applied to suggest the appropriate scale of development cost, at institutional or corporate level, which might be justified by the revenue curve generated. In the case shown, the rational incentive to develop might be limited, unless costs could be subsumed within routine corporate operations or existing national research budgets, or other non-sectoral objectives (e.g. local economic support, research prestige) were involved. Within the industry current levels of competition may leave most enterprises with little surplus for development, even if previous phases had been profitable. In practice therefore, the uncertainty of market potential, the ineffective co-ordination of research and development, and proprietary confidentiality, have tended to result in a slow rate of development. Finally there is concern for biodiversity (Beveridge *et al.*, 1994), and the potential problems of introducing yet more species and strains in concentrations typical of aquaculture. This may become a particular issue in coastal areas using potentially loss-prone systems, with increasing threats of supplanting wild stocks with releases from aquaculture.

According to FAO (1997), the trend of diversifying the number of cultured species, while also increasing the production of mainstream species, continued in 1995, although the reported production of several species and groups has declined[1]. In many cases however, particularly for simpler, extensive or

[1] The actual number of species may in fact be considerably higher, but reported to FAO as unclassified.

TABLE 7. Typical time periods for technical and production development in aquaculture.

Development stage	Time required	Comments/implications
Experimental rearing of wild stocks;	1–3 years	Mixed origins and stock quality, variable results, but may indicate basic production risks, operating parameters.
Defining life-cycle features	1–10 years	Many species known at basic level; time required depends on habitat and behavioural complexity.
Developing a basic compound feed	1–2 years	At least one production cycle; adapt other feeds to 'best guess' levels of energy, protein, etc; may be inefficient with poor results.
Holding and spawning broodstock	1–7 years	May be done at basic level; handling and keeping conditions are critical – replicate natural conditions, may use hormones.
Successful early rearing	1–5 years	Depends on sensitivity, feeding needs of stocks; low survival only.
Acceptable survival levels	1–5 years	From previous stage; feeds, environment and handling are critical, also disease diagnosis/management.
Basic pilot stage ongrowing	1–3 years	Based on hatchery supplies and simple compound feeds; variable performance, growth, survival.
Acceptable ongrowing performance	3–5 years+	Needs to meet target levels of feed efficiency, disease loss, growth, production timing using standard procedures.
Sufficient quantities for initial production	1–5 years	Depends on species; may be unreliable and expensive, with wide variation in stock performance.
Basic stock improvements	1–7 years	Depends on lifecycle, viable broodstocks and whether controlled reproduction is feasible.
Routine seed supply	3–10 years	Needs investment, broodstock supplies, skills and reliable production systems.
Significant genetic gains	5–20 years	Needs facilities, broodstocks, planned program.

(Source: Muir *et al*., 1996.)

TABLE 8. Growth and profitability scenario for new species development.

Year	Output tons	Profit/ton (US $'000)	Surplus to sector (US $ million)	Notes and comments
0	5	1 800	0.009	Early pioneer phase; good prices but production losses.
1	20	2 000	0.040	Prices stay good and losses decrease; investment increases.
2	50	1 800	0.090	Quantities still small and prices good but resources expensive.
3	200	1 600	0.320	Prices decrease slightly but production costs also decline.
4	500	1 500	0.750	Prices decrease further but cost also decline, more investment.
5	1 000	1 400	1.400	Prices continue to fall, as do production costs; further investment.
6	2 000	1 400	2.800	Supply changes become significant but costs still fall; investment.
7	5 000	1 200	6.000	Further supply change, prices decrease more than costs.
8	8 000	800	6.400	Greater supply change, cost gains limited, investment slows.
9	12 000	300	3.600	Further production still in train, little gain in costs, typical stage of industry rationalization, as poorer producers become unprofitable.
Total	28 775	495	21.409	

(Developed from Muir *et al*., 1996 – note, discount rate unapplied.)

partially fed systems, wider diversity occurs as a result of introducing of non-target stock materials. With respect to longer-term targets, Table 9 outlines comparisons between average values of aquaculture products and those of key fisheries commodities. Although sources and market forms are not strictly compatible, key issues include the relatively low value of production in Asia – influenced by lower-value carps, raised in turn by higher-value crustacea, and the surprisingly low value in North America, influenced by lower-value fish and most particularly by the significant mollusc production. Values in South America (dominated by shrimp) and in Europe (with higher-value fish weighting the average) are more typical of the more intensive market-oriented aquaculture sector. Product prices, which include distribution and wholesaling margins cover a broadly similar value range, but the low prices of the major fisheries pelagic groups (mackerel, herring and skipjack tuna) and the demersal hake and pollock, which provide substantial raw material for global supply, are to be noted.

Product development represents the second route to expansion of the aquaculture, in which its outputs could be converted into a wider range of product forms, and in particular could enter the broader value-added markets being developed widely in wealthier sectors of the global market. Muir *et al.* (1996) provided a comparative outline of the relative potential of three major European production groups, Atlantic salmon (*Salmo salar*), seabream (*Sparus aurata*) and mussels (*Mytilus* sp.). This is developed further in Table 10 to include three other major categories of block white fish, American (channel) catfish (*Ictalurus punctatus*) and tilapia (*Oreochromis* sp.). It could be summarized that while seabream and similar species may be developed more widely, there will be basic constraints, while catfish and tilapia, and possibly salmon may have considerably greater potential. The prospects for species would appear to be rather more distant. Thus, though the Asian carps have the potential to be produced relatively cheaply, their disadvantages of texture and bone structures make their widespread incorporation in major traded commodity flows unlikely. It is salutary to note the increasing vertical integration of larger companies in the fishery product sector, the increasing power of major multiple retailers, and the growing importance of developing effective and innovative product forms. Thus the United Kingdom chain Marks and Spencer, which is pioneering a range of value-added fish products now uses about 50 000 tons fish and seafood annually distributed in 628 locations, and is actively developing and spearheading these products in external markets (Seafood International, 1997). Clearly, aquaculture products hold distinct advantages in their potential regularity of supply and ability to deliver just when the retailer orders. Moreover with the wider adoption of HACCP (Hazard Analysis Critical Control Point) systems, the farmed product is again more favourably placed. Such advantages may be important as penetration of wider markets is sought. The result will be an increasing targeting of reliable, uniform quality, adaptable aquaculture product, in which species origin and primary characteristics may become far less significant. Not surprisingly, processors have identified opportunities to broaden their raw material base and spread their fixed costs of process plant over a wider product range, just as farmers have recognised the need to compete within the current offerings of captured fish and food products. Further incentives to promote this co-operation should result from the basic characteristics of the farmed product, especially when compared to the traditional captured alternative.

As the quantity of aquaculture products increases in relative terms, expanding opportunities for substitute farmed products can be expected. This may partly arise from the wider introduction of species currently caught, such as turbot (*Scophthalmus maximus*), halibut (*Hippoglossus hippoglossus*), cod (*Gadus morhua*), and wolffish (*Anarhichas lupus*), especially where they are positioned to skim under-supplied quality markets. As suggested earlier, there is growing evidence of alternative positioning becoming viable, in which targeted species provide raw material, positioning in traditional capture fishery roles, rather than become new wholefish products in themselves. The rapid acceptance of Channel catfish (*Ictalurus punctatus*) within the German market is a good example; this might be capable of repetition with African catfish (*Clarias gariepinus*), tilapia (*Oreochromis niloticus*) and other species (Young and Muir, 1995). Further diversity may also be anticipated as various sectors of the food fish industry become more integrated. The result may be that product diversity, based around a core of well-established and reliable aquaculture species may become the major source of sectoral growth and competition, though once established, this would in turn create a more positive framework for the use of new aquaculture species should they become available. However, the drive to bring more species into culture may become less important in consequence.

TABLE 9. Typical aquaculture and marine product value.

Aquaculture Species group	Avg. value (US $ per kg)	Region	Avg. value (US $ per kg)	Product	Wholesale price, (US $ per kg)
Fish	1.8	Asia	1.8	Cod blocks	3.5–4.0
Crustacea	6.7	Europe	2.8	Hake and pollock	1.5–2.0
Molluscs	1.0	North America	1.9	Salmon, farmed Atlantic	4.5–6.0
Aquatic plants	0.9	South America	4.1	Salmon, troll Silver	3.0–5.5
Other	1.8	Former USSR	2.4	Tuna, albacore	2.0–3.5
		Africa, Oceania	2.3	Tuna, skipjack	1.0–1.5
				Mackerel	0.8–1.6
				Herring	0.5
				Cephalopods	5.0–9.0
				Shrimp – *Penaeus monodon*	12–16

(Source (1) FAO, 1994 ex-farm values (2) Seafood International 12/96.)

TABLE 10. Comparative development features of salmon, seabream and mussels.

Product features	Block white Salmon	Channel Seabream	Block white fish	Channel catfish	Tilapia	Mussels
External appearance	Medium-large, powerful, long, deep, silvery, clean	Small, short stubby, flat, silvery bright, clean – 'marine'	N/a – sourced from range of species	Small, slender, blue/grey, unprepossessing	Short, stubby silvery or red, bright	Black/green shells clean to crusted – 'marine'
Internal appearance	Pale-deep pink/ orange, distinct flakes varying fat levels	Pale/creamy, close-textured lean	White (fish), close-textured, flakes, lean	White(ish), quite close-textured, neutral	White(ish), close-textured, quite lean	Light-deep orange, single nugget
Flavour/ Texture	Distinct, firm, soft to well-textured, can be coarse	Mild, succulent, fine textured low-medium fat	Neutral, well-textured	Mild, soft-well textured, can be muddy	Mild, well textured, can be muddy	Distinct, soft to well textured can be gritty
Connotations	Good quality, associations with clean, cold waters	Very good quality, linked with coastal/city restaurants	Widely accepted though not always recognized	Poor-neutral, but improving widely due to marketing	Neutral but improving strongly	Popular; occasional public health concerns
Availability	Increasingly available year-round, in range of sizes and product forms	Seasonal availability gradually extending, limited sizes and product forms	Generally ubiquitous in wide range of quality and form	Seasonal, but widening access; mainly whole and fillets	Wide sourcing for year-round supply; whole and fillets	Seasonal availability supplemented by imports very very limited size/product form
Production costs	Moderate costs, reducing but above 'bulk' fish prices	High costs, reducing; may have constraints	Baseline product costs; target for other supplies	Low-moderate costs, margins being reduced	Low-moderate costs, potential to reduce	Low cost, increasing due to environmental limits
Distinctiveness	Medium-high in most forms, but can be varied	High if fresh/ whole; otherwise limited	Low-medium, depending on sources	Medium, but can be varied e.g. with husbandry	Medium, can be varied either way	High in most forms; also ingredient
Adaptability	Very adaptable-whole, steaked, portioned, fresh, cured smoked, in value-added foods	Currently limited – whole, split, filleted fresh/frozen	Adaptable; portions, nuggets, fillets, in value-added food	Moderate, improving; fillets, nuggets, value added products	Moderate but potentially improving; fillets, value-added products	Moderate – whole, shelled, fresh, pickled, smoked, in value added foods

Finally, a range of technical development routes needs to be considered. The competitive cost base of current aquaculture production has already been noted, a number of commercial industry sectors are anticipating significant expansion based on lower production costs and fully international competitiveness (e.g. Hempel, 1997; Torrisen, 1996), and trade disputes are increasingly common. The viability of new species has already been questioned, and the use of aquaculture for target marine species such as cod and halibut is still some way distant (e.g. Whitmarsh and Pickering, 1996), and is unlikely to become important barring major change in genetic characteristics. The potential for combining aquaculture with capture fisheries, by releasing young stocks, has been widely raised, and indeed practised over a considerable time, with generally poor results. Current financial projections based on present hatchery costs and known stock survivals are still unpromising, with the possible exception of sedentary and relatively robust species such as lobster (*Homarus* sp.). Developments such as offshore cages (Polke, 1996) and water recycle systems may offer a range of technical advantages, but are ultimately constrained by costs production efficiency, which are still in most cases some 10–20% away from acceptable targets (Stirling Aquaculture, 1997)

The Challenge of Sustainability and the Green Consumer

The previous sections have outlined areas of potentials and constraints for the aquaculture sector, and have compared diversification and product development routes for expansion. However, the comparative position of the marine fisheries sector remains to be considered. Fundamental issues of supply availability and the costs of supply will determine much of the potential of the capture sector, just as the issues of resource availability, productive efficiency and cost of supply will determine that of aquaculture. However a further major influence can now be determined, at least in developed country markets, in that consumption of fishery products, as with others, is increasingly being overlain with ethical concerns, particularly those involving issues of the environment and sustainable development. The 'green consumer' phenomenon has grown rapidly from its origins in North America and in North Europe – notably Germany, Netherlands and Denmark, and it is generally accepted that the fishery sector will come under closer scrutiny, as has been witnessed in a number of markets. The past decade has seen campaigns against the purchase of frozen fish products from Canada, Faroes and Norway in response to their sealing and whaling activities. For tuna, capture with 'dolphin-friendly' gear now seems to be an almost standard product attribute, essential to ensure that the product is not de-listed from supermarket shelves. The campaign for using turtle-exclusion devices (TEDS) has affected not only capture shrimp suppliers, but also aquaculture producers, who may be unable to separate their products on the international markets. Further concerns about the social impacts of shrimp farming (Bundell and Maybin, 1996) have added to consumer unease.

The recent partnership of WWFN (Worldwide Fund for Nature) and Unilever to form the Marine Stewardship Council (MSC), broadly following the principles of the FAO Code of Conduct for Responsible Fishing, but developing its own consultative procedures and criteria to define and 'eco-label' products, bears witness to the higher profile of sustainable fishing activities and by implication, the potential economic penalties of exclusion from the cartel for those who are unable or refuse to participate. Arguably, the notion that individual fish products can be traced back through the myriad of marketing channels and intermediaries to an unendangered fish stock prosecuted in a responsible manner, may be at least unrealistic, and could well be open to malpractice. However, the increasing uptake of HACCP systems and similar approaches has demonstrated the inexorable movement in this direction, and their growing power as a result of increased buyer concentration. Notwithstanding national differentials, supermarkets have emerged as dominant players across all fish product sectors. Given their concerns to protect and enhance their image and reputation across their typical 25 000 product line range, fish products will be subject to the same hues of green as are applied elsewhere in their range. Moreover intense competition within the small numbers of the major chains in each country tends to 'ratchet upwards' green and other positive credentials, which are raised ever-higher to promote customer appeal. The traditional capture-based fish marketing environment has to contend with market-based problems in addition to those rooted within raw material supply.

The rise of these consumer trends is of more than passing concern, throughout the market chain, and has resulted in a range of responses. While a realistic approach to environmental and social concern, and good practice, is welcomed by responsible industry participants, considerable dangers are perceived from potentially ill-informed and unsubstantiated green propaganda. Thus to present the industry more positively, the Global Aquaculture Alliance was formed in 1997; more than 50 founding members are anticipated, primarily tropical shrimp producers but open to others. More widely, considerable debate has developed concerning sustainable practice and acceptable product, embracing both the capture fishery and aquaculture sector, ranging from fundamental ethics (e.g. Hallerman, 1997) through to practical aspects of establishing product source and practice assurance. Table 11 summarises some of the key issues involved.

Not all of these are specifically within the management scope of the sectors themselves; the issues of product contamination for example are dependent on a range of external factors as well as those controllable through culture or processing. While differences can be identified between capture fisheries and aquaculture, there are many similarities, and apart from specific issue-based campaigns (e.g. turtle exclusion, coastal fishery workers in India), the aggregate view of the sectors may be rather similar, and where they occur the general unease, or associative negatives being applied to fishery products of whatever origin. Arguably, however, the aquaculture sector may have more scope to effect management change, act to establish more confidence, and – it must be admitted – to 'score points' against the potentially more

TABLE 11. 'Green'issues for capture fisheries and aquaculture.

Capture fisheries	Aquaculture
Existential concerns for the preservation of major ecosystems and their unique characteristics.	Existential concerns for biodiversity and protection of 'natural' undeveloped environments.
Ethical issues of humane capture and slaughtering methods.	Ethical issues of humane husbandry and slaughtering methods.
Overexploitation of major stocks and possible sive destruction of vulnerable species.	Acquisition of key land and water resources for inten- monoculture practices.
Damage to sensitive habitats, particularly spawning ment, grounds, coral reefs and mangroves.	Discharges of organic wastes, husbandry/disease treat- chemicals, and other contaminants.
	Introduction and potential escape of non-indigenous species; and possible use and release of genetically modified organisms.
	Damage to sensitive habitats, particularly mangroves, coral reefs, coastal water tables, other high quality environments.
Excessive capture and waste of by-catch materials; by-catch of sensitive species.	Reservoirs, possible 'amplifiers' of aquatic diseases; impacts of wild populations and their food chains.
Accumulation of contaminant chemicals and bioactive agents.	Accumulation of contaminant chemicals and bioactive agents.
Adverse competition from industrial sectors affecting livelihoods of artisanal producers, and viability of coastal communities.	Industrial sectors affecting livelihoods of artisanal producers, and viability of coastal communities; salinisation of coastal areas affecting agriculture.
Reduced food supply base for other species, notably birds and mammals.	Dependence on high quality feed materials, notably fish meals and oils, increasing capture fisheries demand and potentially depriving dependent communitties and other species consumers of food supply.
Exploitation of resources in poor countries to meet developed country market demands.	Exploitation of resources in poor countries to meet devoped country market demands.

disorganised and unmanageable capture fisheries sector. However, while this may be tempting in some cases, the need to maintain a positive image for the sector as a whole will probably constrain more responsible industry representatives, unless the capture fishery sector simply cannot be trusted to contribute consistently to reassuring uncertain customers.

Whether or not aquaculture production succeeds in establishing the lines of responsibility and quality control with respect to 'green consumption', the practical issues of sustainability will continue to cause concern, particularly if the sector grows to the extent predicted. As a result, increasing constraints may reduce the potential for aquaculture to emerge as the saviour of the fishery sector. Some of the more widely raised issues, many of which inter-relate, are discussed below.

Land and water. Aquaculture is dependent on good quality water resources, and although external impacts may be insignificant, slightly degraded outlet waters can be costly to restore relative to the value of production involved. Such changes might be tolerated in larger hydrological systems with ample dilution and biological transformation capacity, but might in some cases lead to unacceptable impact. Land requirements may also be significant, though intensive aquaculture may demonstrate high areal yields compared with other food production systems. Two features are noteworthy; the use of specifically sensitive land areas, particularly wetlands and mangroves, and the need for 'ghost land', i.e. area required to provide the total inputs allocated to the system, which for intensive systems may be orders of magnitude greater than area occupied by the production unit. The implications for supporting increased production will depend significantly on the forms of aquaculture being developed; intensive flow-through systems may be increasingly constrained by water availability, or the cost of maintaining its quality, while more extensive, low-output systems will also be affected by land-use constraints.

Feeds. Many forms of aquaculture, particularly those producing HUV species, require good quality feeds, usually incorporating higher quality materials such as fishmeal and oil. Tacon (1994), noted that some 14% of 1990 fishmeal output was used in aquaculture, though the bulk of which relied on omnivorous/ herbivorous species, which merited greater emphasis in the face of declining fishery supply. Where necessary, other feed sources could be encouraged in substitution of fish-based materials. However, fishmeal production can also be considered a rational way to retain value, particularly for by-catch, providing stable and versatile inputs to a range of production systems, including aquaculture. The aim might then be to recognise the value of fishmeal and oil stocks, ensuring they are used to best effect. According to Barlow and Pike (1997) 17% of fishmeal and 25% of fishoil output was used for aquaculture in 1994, of which salmon and trout diets took 50% and 70%, respectively. Using projected aquaculture outputs for the year 2010, they proposed a demand of 1.5 million tons fishmeal – some 25% of current production, and 1.1 million tons of fishoil, approximately 100% of current supply. However, assuming price equilibration with other oil stocks (e.g. plant sources), substitution with other materials should be feasible, and hence, given further efficiency gains, future feed demands should be attainable.

Disease management. It is in the direct interest of the aquaculture sector to maximise efficiency, and hence to control disease, as far as possible targeting causes rather than symptoms. Aquatic disease may often be multifactorial in aetiology; a complication for effective understanding and response, but an important reminder of the subtleties involved, and the fact that aquaculture organisms can act as 'integrators' to pick up longer term environmental degradation. The dilemma of effective control and the limited availability of environmentally friendly therapeutants has been widely noted, and in many cases intensive producers are forced to use materials of known toxic effects to external environments, even though these are carefully regulated. Certain materials may also have a long residence time in aquaculture product, further complicating treatment decisions and increasing the imperative for defining and enforcing proper withdrawal times. The continuing evolution of disease agents means that although pathogenic and immune processes are better understood, disease remains a potentially significant threat for any sector of the industry. Good and well tested techniques, and sensible, observable regulation are critical in maintaining consumer and investor confidence.

Biodiversity. This characteristic is closely related to sustainability, a qualitative feature of ecosystems and hence natural resources. Beveridge *et al.* (1994) have reviewed the case of aquaculture, and note three areas of potential effect; consumption of resources, the transformation process, and output of wastes. The use of land, water, feeds and wild seed resources, and the effects of concentrated waste nutrients and treatment chemicals may all reduce biodiversity, either directly, in terms of habitat destruction or removal of feed supply, or indirectly, in more subtle shifts in local ecosystems. However, the most direct concerns are for maintaining the genetic diversity of aquaculture stocks themselves. While aquaculture could pose risks to biodiversity, there is a need to establish rational criteria, and effective management guidelines; there may be positive challenges in using aquaculture to meet biodiversity objectives, as a component in biodiversity enhancement.

Socio-economic effects. It is important in any context to consider relationships between natural resource use, economic output and societal benefit. At the simplest level, this can be in terms of food supply and its distribution, but in many other cases, employment, and access and ownership rights to factors of production could be important. While aquaculture has had a positive role in some areas, most notably where alternative employment opportunities have been limited, access to resources, as in other sectors, does not necessarily favour poorer small-scale producers. Muir (MS 1995) reviewed employment opportunities associated with a range of aquaculture systems, commenting on the diversity of effect, and in many cases, the rather limited direct employment impact. In many regions, socio-economic gains associated with aquaculture are available only to those who are already privileged, either through ownership of resources, or by being able to afford the produce. There is clearly a challenge in making aquaculture provide for poorer sectors of society, and indirectly, in satisfying consumers and policy makers that social objectives can be met. Recent evidence (J. N. Brown, Institute of Aquaculture, Scotland, pers. comm.) suggests that while major retailers are conscious of the need for social equity, they may be reluctant to accept the complications and uncertainty of multiple sourcing from a myriad of small suppliers.

Coastal area management. The issues involved in managing the world's coastal zones are subject to increasing attention (Chua, 1993; Clark, 1992) ; partly as a result of an increasingly thematic approach to policy and management in natural resources, but also as a consequence of directly perceived conflict over development, resource use and environmental quality. A significant part of aquaculture already involves coastal resources, coastal aquaculture is likely to be the major element of future sectoral growth, and so its demands and effects need to be incorporated within coastal area management. As such its role will interplay specifically with that of coastal fisheries, hence returning to the primary theme of this paper. As Table 12 indicates, the impact of aquaculture within coastal zones varies widely, as does the potential capacity for further development. In review, Muir and Beveridge (1994) and Muir (MS 1995) concluded that although there were some issues of significance, there was on over-riding need to place aquaculture within a realistic context, recognizing where impacts could be important (GESAMP, 1991), avoiding over-regulation otherwise.

Ecosystem loading. A number of more generalized indicators can be applied to measure the impacts of particular production processes on ecosystems. One such, is the total input industrial energy required per output ton of product (Table 13), which in effect accounts all the contributory resource acquisition and/or manufacturing and distribution energy required to make inputs available for the production process concerned. This form of energy accounting is of interest in comparing hidden fuel, fertilizer and other subsidies in food production, and is of direct interest as the costs or availability of global fuel energy change. More technically, it indicates the relative proportion of non-renewed to renewable energy used in production, and hence the generalized external resource dependence. A further and more complete approach is to consider the embodied energy or 'emergy' involved in production, as outlined in Table 14 (Folke and Kautsky, 1992) This sums the energy incorporated in photosynthetically driven processes (including that used in the growth of various inputs, such as feed materials) with the applied external (industrial) energy. Both examples demonstrate the rapid rise in energy input with more intensive systems, the increased level of resource focusing implied, and the implications of high resources dependence for many of the currently promoted aquaculture practices.

TABLE 12. Comparative aquaculture loadings on selected coastal zones.

Region/country[1]	Production load (ton/km)	Nitrates (kg/km)	Phosphates (kg/km)	Notes
France	65.2	44.1	10.3	Primarily molluscs
Norway	20.8	1396.0	325.6	Atlantic salmon cage culture
UK (Scotland)	3.4	219.5	51.2	Atlantic salmon cage culture
Greece	0.8	25.2	5.9	Seabream and seabass culture
Iceland	0.6	37.8	8.8	Atlantic salmon cage culture

Region/country[2]	Production load (ton/km)	Fish	Crustacea	Molluscs	Notes
Taiwan	52.8	22.0	11.8	39	Range of coastal aquaculture
Japan	52.3	19.3		33	Intensive fish and mollusc production
China	129.6	4.1	15.5	110	Mollusc production
Thailand	76.9		55.9	21	Intensive shrimp production

(Sources: (1) Muir, MS 1995; (2) Csavas, 1995.)

TABLE 13. Industrial energy costs for aquaculture.

Type of system	GJ per ton of protein	GJ per ton of whole fish
Mussels, intensive, longlines	116	–
Carp ponds, feeding and fertilizer (Germany)	250	11
Trout ponds, feeding (UK)	389	2
Catfish, ponds, feeding only (USA)	891	25
Salmon, intensive, cages	688	56
Grouper/seabass, intensive, cages	1 311	95
Carp, intensive recycle, feed only	3 090	56

(Source: developed from Muir, MS 1995.)

TABLE 14. Total embodied energy relationships.

	Seaweed culture	Mussel culture	Cage salmonid culture
Energy inputs (kcal $\times 10^5$)			
Solar/renewable (%)	0.30 (4.5%)	0.75–2.05 (71.4–85.4%)	470–830 (81.0–87.4%)
Fossil/non-renewable (%)	6.35(95.5%)	0.30–0.35 (28.6–14.6%)	110–120 (19.0–12.6%)
Total energy	6.65	1.05–2.40	580–950
Protein output (kcal)	6 605	255–440	22 420
Input/output ratio	100	410–545	2 585–4 235

(Source: developed from Muir, MS 1995.)

Techniques are also being developed to cost more comprehensively the impacts of developments on the environment. In the case of fisheries and aquaculture, assessments may involve not only the technical, economic and social feasibility, but also environmental efficiency. A related measure – ecological footprint analysis (EFA) – uses land/sea area as the primary denominator, calculating the total area required to support a process – including supplementary food supply, the processing capacity to absorb, metabolise and/or recycle the nutrients involved, and in the most developed form, area required to compensate for fossil fuel energy expended and for carbon sequestration. Based solely on nutrient input and waste absorption it has been estimated that every hectare of intensive salmon production, requires some 40 000 to 50 000 hectare of sea area. Though such indices may be rather crude, they illustrate more clearly the overall resource implications of production systems, the effects of concentrated fish-meal dependent systems dispersing nutrients across a wide area, and the nature and extent of possible ecologically-based interactions with other sectors.

In summary therefore, while aquaculture carries with it many benefits of concentrated and broadly controllable management, and has the potential to offer significant benefits to modern markets and consumers alike, it does so – particularly in its more intensive forms – at the expense of considerable resource use inefficiency. To the extent that these inefficiencies remain uncosted, opportunities will continue for the specialised HUV sector to develop, and for the relatively resource-efficient capture processes such as gill, seine, trap and line fisheries to be disadvantaged. However, more stringent development criteria, and more explicit resource costing may see the balance between aquaculture and fisheries reassessed, and aquaculture move towards semi-intensive systems using lower-food chain species, simpler (e.g. plant based) foods, and possibly (noting earlier consumer issues) genetically modified stocks capable of using less ecologically expensive feeds. Finally, to respect fully the principles of sustainability, and the need to define output efficiency in social and human development terms as much as by traditional financial measures, 'social accounting' might support the continuance of smaller-scale enterprises involving smaller communities and local ownership.

Conclusions

An attempt has been made here to take a broad overview of current trends in production and marketing for the fisheries sector, to which both capture fisheries and aquaculture contribute, and for which substantial additional demand is expected. While only part of this lies at the level of the modern industrialised country consumer, there are broad similarities in underlying trends of supply and access, and in the increasing constraints for the traditional capture fisheries sector. As a result, aquaculture is likely to gain further ground in supply, the extent of which depending on whether and how capture fisheries can maintain output, and can contribute effectively to more sophisticated and more closely controlled market and distribution systems.

Aquaculture has been notable for its development in the last decades; there have also been significant changes in many of the productive ecosystems involved. In coastal areas these have been primarily based around intensive culture of higher value fish and crustacea – particularly in cage and pond culture, but also involves a range of artisanal sectors, producing fish, molluscs, seaweeds and crustacea. The relatively narrow production base in many areas and markets, and the limited system/site configurations involved, may cause concern for longer term sustainability, particularly in market and economic terms, but also in terms of production security (continuing disease problems) and for increasingly competitive resource use. While resources *per se* are not immediately limiting, costs of access are rising – either through direct competition or through the need to invest more heavily in new production options such as offshore cages or intensive recycle systems.

Though capture fisheries are almost universally under threat of over-exploitation, and serious declines have been recorded in a number of key stocks, both in the North Atlantic and elsewhere, and increasing concern for the consequences, and a greater preparedness to take decisive corrective action may see a return to more stable conditions, though under greatly changed management terms, and with potential implications for the social fabric of many dependent areas. While the growing role of aquaculture, and its likely focus in coastal areas may offer some additional opportunities, structural changes in the aquaculture sector itself may limit these, unless radically different approaches to ownership and social distribution are contemplated.

In practical terms, aquaculture output is likely to remain based on key species, and market changes stimulated to expand demand of these core species rather than to replicate existing species ranges and quantities. This suggests the emergence of versatile raw material aquaculture products, whose choice will depend primarily on production efficiency, whether in conventional raw material terms, or more long-term, in terms of ecological efficiency. Internationalisation, industry scale and consumer perceptions will increasingly dominate viability in all parts of the fishery sector, and in the case of aquaculture will move production towards larger units and towards global lowest-cost sources, whether of cage culture salmon or tilapia, or of pond raised catfish or shrimp. Though significant efficiency and cost gains might be achieved, the extent to which genetic modification is adopted will depend substantially on trends of consumer acceptance, which will apply across the wider food supply spectrum

Though species diversification may continue as a route for many aquaculture sectors, this is unlikely to develop to the point where the diversity of capture fisheries are challenged. At present, most candidates compete with existing aquaculture species, and may only expand markets marginally. Development costs and the potentially rapid rate of market saturation may limit the attraction of pioneering investment. However, to the extent that development costs can be absorbed within existing operations, and provided no other significant marginal costs are incurred (e.g. through capacity underutilization, higher labour costs, unreliable hatchery supplies, or additional disease risks), these sectors are like to develop as a useful adjunct to mainstream production.

Apart from genetic modifications, a range of consumer issues may affect the markets and comparative preference for sources, products and production methods. While many of these are well-founded, and at least some are within the management scope of producers, particularly in aquaculture, a certain area of irrational concern may attach to fisheries or aquaculture products, and will need particular care and commitment in response. In addition to more elemental concerns of food safety and environmentally sound production, social and ethical issues may become more notable. However, much of this is brokered by the major multiple retailers, whose attitudes to more complex issues may be difficult to map out.

For developed country markets, this may suggest greater segmentation of product areas in the future, with a more explicit separation between specialised niche market products, supplied by both capture fisheries and by specialist aquaculture producers – possibly at artisanal levels, and mainstream products whose key attributes, in addition to basic organoleptic satisfaction, are simplicity, availability and reliability, and whose natural sources would be major larger-scale producers. Opportunities for mass food supply of lower cost materials in other countries are likely to focus around the range of low-input systems, both in fisheries and aquaculture, and resource costs are likely to be a primary constraint. While production and quality standards are always desired, these may be rather lower than those demanded by developed country markets, and producers are unlikely to be able to demand access to highest quality input resources.

Coastal areas represent the major resource context for future expansion of aquaculture, and as suggested above, key species will be defined by simplicity of culture and effectiveness of culture systems. However, aquaculture opportunities may be subject to a range of development constraints, not all of which may be justifiable. For smaller scale producers in particular, producer associations, possibly linked with those in capture fisheries, may be pivotal in many areas, and aquaculture supply may become critical in supporting infrastructure, value addition, and local employment. The integration between fisheries, aquaculture and the complete supply chain should be a target of planners and industry stakeholders; strategies for sectoral development need to account for interlinkages at local, national and international levels. Finally, the challenges remain for defining and promoting sustainable development, in which both aquaculture and capture fisheries may play a part, in which more fundamental criteria of ecosystem health, resource use efficiencies, environmental and social accounting might be applied. Using the newly emerging criteria of human development (UNDP,1997) we might foresee a context in which consumer markets can be satisfied while limiting undesirable externalities of ecosystem degradation and community disintegration.

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