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Economic Constraints On Food Production From The Sea

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That marine ecological systems are tremendously productive of plant and animal life is an established fact. In assessing the potential for food production from the sea, however, marine scientists have produced quite a range of "estimates" of the sea's productivity. In 1965 Schaefer (1) conservatively estimated that the world fishery production could be increased to 200 million tons "with no radical developments, such as fish farming or far out kinds of fishing gear." This total production was to include all fish, molluscs, and crustaceans supporting traditional fisheries.

Noting that the nutritional value of animal protein is essentially the same whether it comes from the bluefin tuna, the anchovy, or the lowly Antarctic krill, Chapman (2) surmised that any estimate of the sea's potential must assume something about man's tastes and needs. If people need and desire a traditional mix of taste, texture and fragrance, then much of the food must come from the relatively scarce populations of third and fourth-stage carnivores. If, on the other hand, man desires only a balanced mix of amino acids, minerals and vitamins, then food production may rely upon the more abundant lower-stage plants and animals. The potential annual yield of well-balanced, undifferentiated animal protein could, according to Chapman, range up to 2 billion tons. The annual sustainable yield of the more desirable predators would amount to only around 60 million tons.

These estimates refer only to the harvest of wild stocks. More intense cultivation techniques, loosely termed "aquaculture", are estimated to yield over 4 million metric tons worldwide annually (3). Much of this tonnage is derived from fresh and brackish waters. True mariculture is really an infant industry, but Bardach, Ryther and McLarney claim that yields from existing aquaculture installations could increase tenfold over the next three decades if "there were no economic constraints on the upgrading of culture" (3).

All these predictions of physical or technological potential appear somewhat academic in view of the history of world fish catches. World production of fish has leveled off since the post-war boom (see Table I). Whether this is a more-or-less permanent feature of world fisheries is not easy to determine at this early stage. But many of the known, abundant food fish stocks having the "taste, texture and fragrance" to which Western man, at least, has become accustomed, appear to be fully exploited. North Atlantic groundfish stocks have been fully, or nearly-fully exploited for several years (4). It is becoming increasingly clear that the same is true of North Pacific stocks of groundfish and of most northern hemisphere pelagic fish. Certainly, there are several stocks which are relatively lightly fished at present (jack mackerel, anchovies and squid in the Pacific come to mind), and further exploratory fishing in the South Pacific and Indian Ocean could reveal more potential fisheries. Nevertheless, the volume of untapped potential resources is dwindling. The expansion of production of food fish requires that increasingly marginal stocks be exploited or that tastes be altered to accept previously unacceptable fish. It appears that Chapman's estimate of 60 million tons for highly desirable food fish was close to the mark.

Fish caught for reduction to meal and oil accounted for a major part of the expansion in world fish production in the 1960's. Peru, South Africa, Norway and Iceland are responsible for the lion's share of the fish meal

Table I

Total World Fisheries Catches, 1950-1975

(million of metric tons)

Year	Catch	Year	Catch
1950	21..1	1963	48.2
1951	23.5	1964	52.5
1952	25.1	1965	53.3
1953	25.9	1966	56.8
1954	27.9	1967	61.1
1955	28.9	1968	64.3
1956	30.4	1969	62.9
1957	31.5	1970	70.0
1958	33.2	1971	70.9
1959	36.7	1972	66.2
1960	40.0	1973	66.8
1961	43.4	1974	70.5
1962	46.9	1975	69.7

and oil entering world trade, although the United States and Japan produce significant amounts of meat, also. As shown in table II, however, a halt to the expansion in fish caught for reduction paralleled the deceleration in food fish catch. It has been found, at least tentatively, that many of the abundant schooling pelagic fish easily exploited for reduction are either fished to the maximum yield or are only infrequently highly abundant. A few pockets of potential expansion, such as the northern anchovy off the west coast of North America, are well known. But the few hundred thousand tons of annual yield which could be afforded by addition of these under-exploited stocks to the world fisheries would not change the world situation significantly.

Table II

Disposition of World Catch, 1970-1975

Year	1970	1971	1972	1973	1974	1975
	(millions of metric tons)					
Total world catch	70.0	70.9	66.2	66.8	70.5	69.7
For human consumption	43.5	45.4	45.8	48.2	49.5	48.7
Marketed fresh	19.5	20.1	19.8	20.5	21.3	20.7
Freezing	9.7	10.7	11.2	12.5	12.9	12.7
Curing	8.1	8.0	8.0	8.0	8.1	8.1
Canning	6.2	6.6	6.8	6.8	7.2	7.2
For other purposes	26.5	25.5	20.4	18.6	21.0	21.0
Reduction[1]	25.5	19.4	19.4	17.6	20.0	20.0
Miscellaneous	1.0	1.0	1.0	1.0	1.0	1.0

[1]Includes only whole fish destined for the manufacture of oils and meals.

Source: FAO, Yearbook of Fishery Statistics, 1975. (Rome 1976).

In comparison to Schaefer's 200 million ton estimate of annual yield, or to Chapman's 2 billion ton estimate, the limited world production revealed by this casual review of fisheries is disappointing. To some extent the sea's potential may yet succumb to relatively straightforward application of technology, exploration and capital investment. Nevertheless, there are some fundamental economic conditions which must be met before any extensive fishery development efforts can pass unscathed through the crucible of economic reality.

Among the pertinent economic conditions are:

(i) Prices of seafood products must cover all costs of production while being low enough to compete with alternative sources of food; and

(ii) economic waste inherent in over-fishing and overcapitalization must be discouraged in marine fisheries.

These two conditions and likely constraints to their achievement are discussed in the following sections.

Prices and Costs

It is widely recognized that for any productive activity to be economically successful the unit cost of production must be kept below the price at which consumers will buy significant quantities of the product. Individual fishermen and aquaculturists obviously understand this principle and make daily decisions based upon cost and price considerations. The economists' task is to extend and generalize this idea and to apply it to overall supply and demand situations.

Demand analysis begins with the notion that the needs and desires of consumers can be satisfied by a variety of products, and that actual purchases are determined, in part, by the array of prices confronting consumers and by the amount of income available to the consuming public. Thus, given a desire for both an adequate nutritional balance and for special tastes and textures, the typical consumer will allocate his available income over the available foods in a way that is most beneficial to him. Prices have a crucial part to play in the consumer's choices. Obviously, if seafoods, for instance, are more expensive per unit of nutrition and "taste", and if the supplies of alternative foods are expanding at lower prices, then demand for sea food cannot be expected to grow rapidly. The demand for sea food in the United States should be sensitive to price because there are so many red meat and poultry products available in great quantities and at reasonably low prices.

Given this very general conclusion, the retail price indices listed in table III are revealing. During the period 1955-1976, per capita consumption of red meat rose from 128 pounds to 213 pounds; per capita consumption of poultry rose from 27 pounds to 53 pounds; while per capita consumption of fish increased from 10 to 13 pounds. During the same period meat prices have risen at about the same rate as food prices in general; poultry prices have fallen relative to meat and food prices. As a class, fish has become relatively more expensive than the principal alternative high-protein foods. It is probably only the rising trend in per capita income that has helped to maintain the increasing consumption of fish in

Table III

Price Indices for Fish and Competitive Agricultural Products in the United States. (1956-1958 = 100)

	Retail price indices for:				Wholesale price indices for:	
Year	Meat	Poultry	Fish	All food	Soybean meal	U.S. fish meal
1955	87.7	121.5	93.9	94.0	1.11	1.00
1956	84.8	106.5	93.8	94.7	1.00	0.99
1957	94.2	103.8	95.0	97.8	0.92	0.99
1958	104.9	102.6	101.6	101.9	1.09	1.02
1959	101.0	93.5	103.4	100.3	1.10	0.99
1960	99.2	95.0	103.5	101.4	1.03	0.70
1961	100.5	85.8	105.8	102.6	1.29	0.85
1962	102.5	90.7	110.2	103.6	1.29	0.91
1963	100.9	89.3	110.0	105.1	1.41	0.89
1964	99.4	87.3	107.4	106.4	1.35	0.95
1965	106.9	90.0	110.6	108.8	1.39	1.17
1966	116.8	94.9	117.8	114.2	1.63	1.13
1967	113.8	88.9	121.8	115.2	1.49	0.94
1968	116.5	91.7	123.8	119.4	1.51	0.95
1969	126.8	96.9	130.6	125.5	1.45	1.17
1970	133.9	96.4	143.7	132.4	1.54	1.38
1971	132.9	96.9	158.6	136.4	1.51	1.18
1972	147.1	98.2	172.9	142.3	2.04	1.30
1973	183.4	137.7	198.3	162.9	4.63	3.41
1974	186.8	130.7	228.7	186.3	1.74	2.09
1975	202.7	144.4	247.7	202.1	2.41	1.79
1976	202.7	136.9	276.9	208.3	3.16	2.49

the United States. Assuming that the price trend revealed by the retail price index for fish is the result of increasing costs of production relative to those of the other foods, these figures may reflect a relatively poor performance of the U.S. fisheries relative to U.S. agriculture. Another interpretation of the retail price trend is that the fisheries have operated at least cost but have been unable to expand production to meet the increasing demand due to constraints on the available fish stocks. With increasing demand and steady or sluggish supply, prices will rise. With either interpretation, it is clear that the domestic sea food industry is not demonstrating a capability for expanding production in tandem with land-based food industries. Furthermore, because much of the sea food consumed domestically is imported, it may be inferred that our foreign trading partners are subject to the same limitations. Yet the biological potential of the oceans, if we are to believe Chapman (5) and Schaefer (1), has hardly been exhausted. The increasing cost and sluggish supply is probably due to the full or over-exploitation of traditionally important fish stocks, accompanied by the inability of the industry to supplement traditional fisheries with new species or product forms from the unused or under-developed fish stocks. From an economic viewpoint the ocean's potential is well developed.

Available biological productivity does not imply economic productivity unless the biological products are both desired by consumers and cheaply produced. The most stringent economic constraint upon further expansion of food fish harvests appears to be the meager demand for most of the unused species at prices covering the unit production costs and providing a reasonable expectation of profit to the producers.

The market for industrial fishery products is quite similar to that for food fish, but with a twist. Because fish meal and oil enter the production processes for other goods as relatively undifferentiated inputs (i.e. not species-specific nor required to have subtle qualities to be acceptable), the market potential is not so severely constrained by tradition, culture or the biological productivity of popular fish stocks. In the case of fish meal the need for high protein supplements in poultry and livestock feed can be met by vegetable protein meals such as soybean meal. In table III it is indicated that soybean meal prices have risen relative to fish meal prices during the last two decades. Fish meal producers should, therefore, be in a good position to expand production and increasingly encroach upon the markets for high protein meals.

Contrary to this expectation the production of fish meal has shown the same sluggish tendency as has become expected of food fish production. Apparently, the concentrations of pelagic schooling fish (clupeoids, in particular) which can be caught inexpensively (i.e. at a cost of 25-50 dollars per ton) are an increasing rarity. Thus with fishery reduction products, as with food fish, the biological potential of the sea is barely exploited while the economically useful portion of that potential is largely developed. To expand the fisheries for reduction fish into, for example,"trash" bottomfish would cause an increase in the cost of fish meal due to the harvest costs. Higher raw fish costs must be covered by higher final product prices, but prices cannot be much higher if competitiveness is to be maintained. Any technological advances which increase the availability of fish for reduction at current prices would be useful. This applies equally to food fish production. However, technical innovations in our domestic fisheries are as likely to increase the rate of exploitation on existing fully exploited stocks as they are to help broaden the resource base.

Aquaculture may be a solution to this dilemma. By placing the entire process of production (or, at least, more of the process than is encompassed by the traditional fisheries) within the control of men, aquaculture presents us with the opportunity of applying more scientific methods to the food production process. Instead of hunting wild stocks, we establish specific stocks of favored species selected for genetic characteristics which optimize growth, appearance or whatever else promotes economic value. Under controlled conditions mortality is low and growth is fast. The productivity of the feed lot is applied to marine organisms.

There are isolated instances of reasonable success with aquaculture. Paradoxically, very few of the real successes have been developed through the application of Western technological knowhow in recent years. Oyster and mussel culture, salmon and trout rearing, and pond culture of carps and "milkfish" have all been developed over a much longer period than is spanned by the recent science of aquaculture. Infusions of modern scientific methods have undoubtedly helped to overcome problems of disease control and nutrition. This makes possible more physically productive and economically profitable aquaculture projects, but the amount of food fish produced by aquacultural techniques remains relatively meager.

Current developments in aquaculture seem to focus almost entirely upon high-priced products such as the salmonids, shrimp (6), freshwater prawns (7), and delicacies like lobster and abalone. The major reason for this emphasis is clear—the cost constraint on the production of delicacies is much less severe than on the production of staples. Given the high production costs characteristic of developing technologies, it is not surprising that intensive aquaculture techniques should be applied to high-priced species. High prices, however, dictate low volume.

Furthermore, in assessing the potential for food from the sea, it is not clear that the intensive aquacultural techniques will ever be economic enough to compete with agriculture or even to challenge the primitive hunting of fish with vessels. Ultimately, the cost and availability of requisite inputs such as water, coastal land, labor and technical expertise will determine the extent to which aquaculture will become competitive. Unless it is competitive in price, aquaculture will never contribute significantly to the world food supply. Recent studies (8) seem to be pessimistic about the possibility of great strides in the direction of lower cost aquaculture.

Management of Fish Stocks

Although biological productivity, demand for sea food, and harvest costs encompass the main constraints to food from the sea, a different type of impediment to food production is the institutional convention called "common property" or "free access". So long as oceanic fishery resources are open to exploitation by all without restriction, no fisherman competing vigorously to improve his own lot in life has much incentive to control his take of fish. It has long been recognized that the limited biological productivity of any animal population can be severely reduced through over-fishing by competitive fishermen. The power of government has been invoked in many instances to prevent over-fishing, but existing fishery regulations are often economically irrational and are also too limited in scope to deal with international fishery problems. As more of the world's fishery resource comes under the jurisdiction of coastal States, and as more of the oceanic fish stocks of real importance are brought under international management conventions, prospects for conservation of biological productivity will improve. Even if overfishing in the biological sense is prevented, however, the economic costs associated with sea food harvests may be unnecessarily high due to excessive competition for the limited harvests allowed under biologically oriented fishery management.

The importance of economic issues in fishery management was first analysed rigorously by Gordon (9). His conclusions are still appropriate today. Under fishery regulations which do not restrain the number of men and the capital equipment in the fishery, normal economic incentives of competitive fishermen will drive them to apply more and more economic inputs to the fishery until no net economic return can be earned. Thus over-capitalization (that is, investment of excessive amounts of capital equipment) occurs even when over-fishing is prevented. Strictly speaking, over-capitalization does not specifically result in a reduction in harvest of any managed fish stock. The use of enormous amounts of fishing vessels over short fishing seasons can result, however, in a shortage of capital for use in other fishing ventures which would otherwise attract investment funds. Thus the overall impact of free access may be to lessen the world harvest of sea foods.

This economic view of fisheries exploitation has some important ramifications. For one thing, application of advanced technology to ocean fish stocks will not necessarily result in greater harvests but may instead simply lead to more sophisticated and costly over-capitalization. I would certainly hesitate to argue that technological innovation is unimportant to the further development of world fisheries, but I would emphasize that progress would be more rapid if there were institutional safeguards to prevent over-capitalization and to assure at least moderate operating profits in existing fisheries.

Progress toward greater food production would be much facilitated by a re-direction of innovative expertise and capital investment. Rather than emphasizing cost reduction in already heavily-exploited fisheries, investment activities could be devoted to developing new products and new fisheries. Institutions are needed which restrain over-capitalization and encourage the use of the resulting economic profits for fishery development elsewhere. Currently, no such institutions exist. Thus there are as many problems with over-development as there are with under-development in fisheries. The north Atlantic and north Pacific fisheries are coming under increasingly strong harvesting restraints, while potentially profitable fisheries in the Indian Ocean remain underdeveloped largely for lack of investment capital (10). Any field of resource development must reconcile limited availability of capital and innovative expertise with seemingly unlimited opportunities. Under current institutions, the world fisheries must operate under the further constraint that much of the available capital and technology is wasted on duplicate efforts in over-capitalized fisheries. In the long run, the inability of international fishing conventions to deal effectively with the inherent economic inefficiency of common property fisheries may be the most effective constraint to full development of the sea's potential for food production.

That there are economic constraints to the production of food from the sea should come as no surprise. The required relationship of cost to price retards the economic development of many biologically productive fish and shellfish populations due to excessive harvest costs or to lack of consumer demand for reasonable rates of harvest. The same considerations of cost and price limit the current potential for aquacultural developments. And the irrational over-capitalization of many of the world's fisheries squanders an important source of funds for investment and technological development in new fisheries and products. These are real constraints which can prove troublesome to any plans for further rapid development of food from the sea. At the same time, economic constraints should not be accepted with great pessimism, for cautious and deliberate effort to remove or relax the constraints should prove both feasible and beneficial.

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