Prospects for Fisheries Development Assistance

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Authors' Note

Our purpose is to spell out the justifications, if any, for extending substantial assistance to developing countries in support of fisheries development projects. For this reason, our assessments are more global than national in character.

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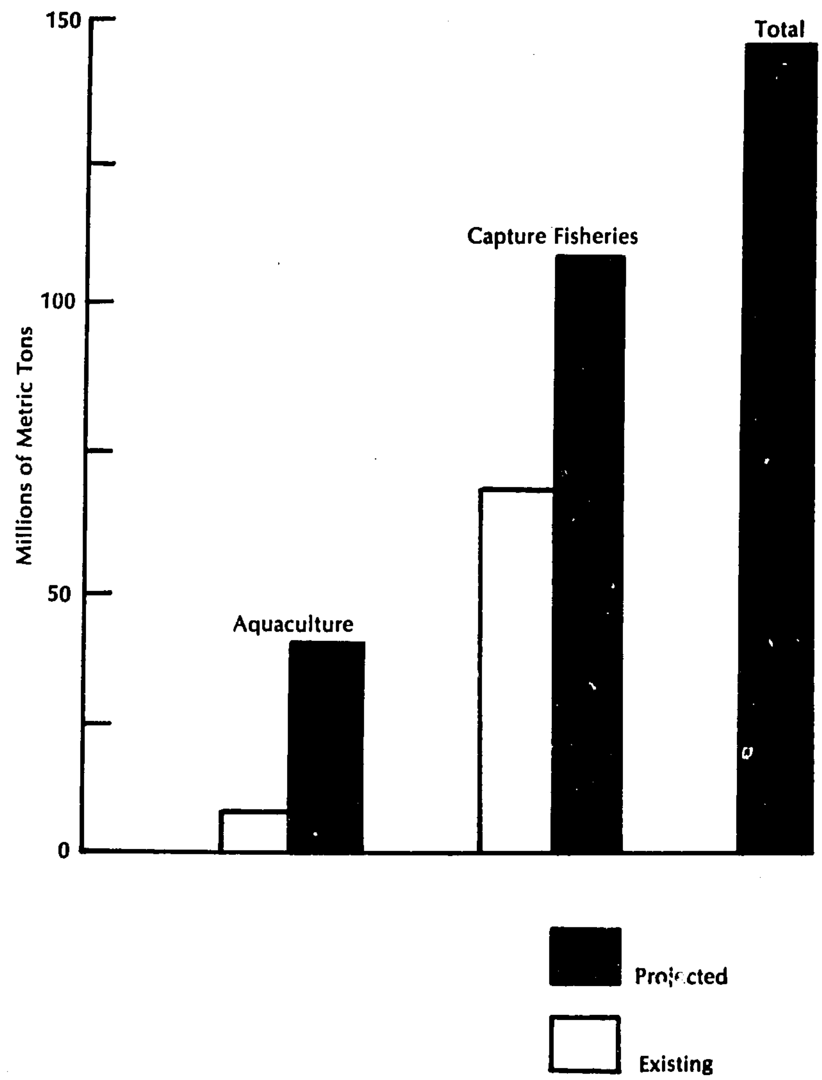

Figure 1. The world's fishery potential; approximate and generally conservative, it excludes whales. White bars indicate existing while the black bars indicate projected potential.

A Summary Statement

There is need to double the world protein supply before 1990, and this need is most acute in the developing countries, or LDC's. For a solution to the world's food problems, one must, look not only to the more efficient use of all the known sources of food and protein, but to the development of new nutritional sources along with an assessment of the technical and economic feasibility of doing so. Stressing that the development and use of the world's fishery resources form part of the problem of assessment, we note the following:

1. With respect to capture fisheries, the present yield is about 65 million metric tons, while the potential is for a harvest almost double that amount. Geographically this potential exists largely in the waters of, or adjacent to, the developing countries.

2. With respect to aquaculture, the present yield is 5 to 10 percent of the yield of the capture fisheries, but it has a greater potential for increase—in the order of a fivefold growth or, perhaps, substantially more. With supporting research and planning, the growth of aquaculture is often particularly well suited to developing countries.

3. Much of the development of capture fisheries and aquaculture in the LDC's can be handled best as labor intensive, relatively low-capital undertakings. Such an approach will increase employment and upgrade the living standards of large numbers of people, with fishermen progressing from subsistence or minimal artisan levels to economically more successful artisan fishery practices. This point dovetails well with the realization that upgrading the economy and the nutrition of a nation or region must be treated as complementary goals since increased and improved supplies of foodstuffs and other goods require enhanced demand for them through increased income levels.

4. To the extent that these developing countries also move into more offshore ventures requiring more capital, they may run into competition, even conflict, with more developed nations that are continually expanding into new resource areas distant from their shores. Present Law of the Sea deliberations suggest that the developing countries will gain significant control over such fisheries off their coasts. Experience with such interactions indicates that unrestricted competitive pursuits in these fisheries can lead to over-fishing, but that well conceived agreements between the investment interests of *developed* countries and the controlling interests of *developing* countries can be mutually beneficial.

5. Economically, the propects for developing the fisheries are favorable in that (where subject to comparison) the cost per pound of producing fish

protein, both in the capture fisheries and aquaculture, is often less than the cost for other protein sources of equivalent quality. While the prospects are good for producing fish protein more cheaply than other animal protein, development plans dependent on such prospects must be considered on a case-by-case basis. It should also be noted that some relatively costly fishery products are in demand as exports; yet from the derived income, other protein may become more available to people involved in production.

6. To realize the foregoing benefits it will often be necessary to provide for expansion of present facilities and for new ones in the economic infrastructure. This need can usually be met through economic assistance programs once specific situations are analyzed.

We cannot neglect potential high quality protein resources of such magnitude, particularly inasmuch as the fisheries sector, having received relatively little attention, often lags behind other sectors of the economy in development and thus can respond more rapidly. As with any general resource that may be responsive to development, attention to a specific component of the fishery requires a detailed prior analysis of that component and the country or region under consideration. Furthermore, each component must be considered in the broader context of the fisheries, agriculture, and economy of which it is a part.

Assistance extended in behalf of fisheries development must be accompanied by the growth of in-country capability to foster and manage such resource development if benefits are to be maintained.

Fish and the World Need for Protein

The World Need

The President's Science Advisory Committee reported in 1967 on the world food situation and outlook in the following terms:

> There is an increasingly serious nutritional problem, world-wide in scope, stemming not only from discrepancies between food supplies and per capita needs but also from the uneven distribution of the food supply among countries, within countries and among families with different levels of income. In the LDC's, which accommodate about two-thirds of the world's population, there is overwhelming clinical evidence of under-nutrition (too few calories) and malnutrition (particularly lack of protein) among the people. Clearly millions of individuals are not receiving the amounts of food suggested by average figures.

Were the world population to increase at the rates prevailing in 1965, the total caloric needs to meet nutritional requirements in 1985, as stated by the Advisory Committee, would increase by 52 percent. Under the assumption of a progressive decrease in fertility rates due to effective population control measures, the caloric requirements would still be 43 percent higher in 1985 than in 1965. As illustrated in table 1, the situation is far worse in the LDC's.

Table 1. Total estimated needs for calories and proteins in 1985, expressed as percent increase over needs estimated for 1965.

Needs	Population Estimate	World	India	Pakistan	Brazil
Calories	high	52	108	146	104
	low	43	88	118	92
Protein	high	52	110	145	109
	low	45	93	121	98

Source: President's Science Advisory Committee (1967), Vol. II.

In general the Advisory Committee's report predicts that food output of the underdeveloped world would have to double by the mid-1980s, or grow at a rate between 4 and 5 percent annually, in order to deal with population growth and the caloric deficit. This required rate of growth is 50-80 percent higher than the actual rate of annual increase in food production during the early 1960s.

We note in the Food and Agriculture Organization (FAO, 1967) agricultural commodities projections for 1975 and 1985 (using 1962 as a base year), its comment on the food increase and production situation for the developing countries:

> The recent food production performance in developing countries gives no ground for optimism. Production per head after increasing by nearly 1% per annum between 1950 and 1958, has since remained almost stagnant.

The FAO projections also indicate that protein deficiencies in developing countries are likely to present even more serious problems. The rate of growth in demand for animal proteins is appreciably higher than demand for other food items, while prospects are meager for increasing animal production in developing countries to meet this demand growth which varies between 3 and 5 percent annually, depending on assumptions made about the growth of gross domestic production and populations. It is likely, therefore, that the proportions of animal proteins in the total supply of calories will remain at their present unsatisfactory levels.

Fish as Protein

The deficiency in protein in the LDC's and the projected increases in need call for an appraisal of fish as one of several sources of protein in the overall effort to improve the nutritional standards of the peoples of the world.

Our basic viewpoint is that the extent to which fish and fish products will, in fact, contribute toward increasing the consumption of protein in the LDC's will depend on two things: (1) the demand for fish and fish products in the LDC's as determined by income, the cost of alternate foods and a combination of taste preferences and dietary habits, and (2) the ability to produce relatively low cost fish and fish protein products, which depends on the availability of fishery resources, the ability to harvest and culture these resources, and the cost of processing and marketing the products.

We recognize further that fisheries development promises not only to increase the world's supply of animal protein but to increase employment, particularly at the artisan level, as we will point out. Moreover, in some cases it can create a favorable increase in foreign exchange levels, which will raise incomes and, thus, indirectly improve dietary conditions.

Protein Properties of Fish

Protein from fishery products and other animal sources is of high quality, being composed of relatively large amounts of the essential amino acids. Fish is rich in protein whether expressed as a percentage of total energy content or in relation to its edible portion compared to other important dietary staples. Table 2 shows the amount of protein in fish compared to that in red meats and rice.

Table 2. Protein in fish, red meats and rice.

Item	Percent of Moisture-free Flesh
Shrimp	88
Flounder	80
Channel catfish	79
Red meats	40-50
Rice	7

Source: Lovell (1973).

The nutritional "score," or net protein utilization (NPU), of fish approximates that of red meat and both are well above the score for plant protein, as shown in table 3.

Table 3. Net protein utilization (NPU) values of selected food proteins.

Food	NPU (Egg = 100)	Limiting Amino Acids
Fish muscle	83	Tryptophan
Beef muscle	80	Methionine + cystine
Rice	57	Lysine
Corn meal	55	Lysine + tryptophan
Soy flour	56	Methionine + cystine
Navy beans	47	Methionine + cystine

Source: World Health Organization (1965).

For comparison, the essential amino acid profiles for fish, red meat and rice are shown in table 4. Of all animal foods, fish is the best source of lysine which is the amino acid most limiting in cereal proteins.

Fat in fish, compared to fat in red meats, is shown in table 5. The fact that fat in fish is more unsaturated than that in the flesh of red meat animals may be a significant health advantage. The omega-6, or linoleic, fatty acids, which are higher in fish fat than in hard animal fats, are essential in the diet of man. Incidentally, the greater fat content of red meat results in a higher caloric value per unit weight of flesh than is the case for fish.

Table 4. Amino acid composition of channel catfish, beef and rice.

Amino Acid	Percent of Protein		
	Catfish	Beef	Rice
Arginine	6.3	6.1	8.8
Histidine	2.8	3.6	2.3
Isoleucine	4.3	5.0	4.4
Leucine	9.5	7.8	8.6
Lysine	10.5	8.7	2.8
Methionine	1.4	2.7	1.4
Phenylalanine	4.8	3.8	4.8
Threonine	4.8	4.5	3.6
Valine	4.7	5.2	6.4
Tryptophan	0.8	1.0	0.1
Total essential	49.9	48.4	43.2
Nonessential	50.1	51.6	56.8

Source: Lovell (1973).

Table 5. Fat in fish and red meats.

Item	Percent Fat	Percent Saturated	Percent Unsaturated
Shrimp	0.5	27	73
Flounder	2.0	28	72
Channel catfish	4.2	30	70
Red meats	15-30	48	52

Source: Lovell (1973).

Potential of the Capture Fisheries

It is clear that one step in determining the future significance of fish as a source of protein is an assessment of the potential yields of the resources of the oceans and coastal and inland waters and their relation to recent catch levels, estimated at about 60 million metric tons in 1971 (FAO, 1973).*

Estimates of potential yields from the ocean usually embody two important assumptions: (1) that we can improve on present harvest production by capturing species lower on the food chain, i.e. herbivores or low-level carnivores rather than high-level carnivores, and (2) that we can develop the capability of harvesting and can use species now underexploited or not exploited at all.

The lack of adequate data, an inadequate understanding of biological processes in the oceans and the use of differing estimation procedures cause the estimates of total sustainable catches to vary. Graham and Edwards (1962) have based their estimate of 60 million tons for bony fishes by assuming a potential productivity of 20 pounds per acre for continental shelf expanses and adding a small figure for non-shelf areas. Schaefer (1965) has estimated annual potential production at various trophic levels, assuming alternative ecological efficiencies. He believes that 200 million tons is a reasonable minimum estimate of the potential yield. Many other estimates are available (see reviews in Rounsefell, 1971); of these, we rely most on ones which rest primarily on extrapolation of the harvest experience. In fact we rely heavily on Gulland's (1971) comprehensive analyses and projections in which he has estimated the potential annual sustainable yield of the traditional major fish groupings (large pelagic, demersal, and shoaling pelagic) to be close to 100 million tons (table 6). He suggests that harvests of these better known stocks beyond 100 million tons probably cannot be realized on a sustained basis and that well conceived fishery management, clearly requiring more information than we have to date, will be needed to avoid depletion.

To arrive at an estimate of the gross potential yields from all harvest resources, additional categories mentioned by Gulland (1971) and shown in table 6 must be considered.† Some of these groups, such as the squid, the krill in the Antarctic, and lantern fish are already yielding substantial catches. Finally, an overall estimate should include an allowance for inland fisheries harvests which are so intertwined with aquaculture that we tend to consider their future more under aquaculture than under capture fishery expectations.

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* *The term "tons" in this paper always refers to metric tons.*

† *Whales and sea grasses are not included in the yields and projections presented herein.*

Table 6. Estimated potential yields of various groupings of marine animals and recent catches.

	Estimated Potential Yield (Million Metric Tons)	1968 Catch	
		Million Metric Tons	Percent of Potential Yield
A. Large pelagic	4.3	2.0	46.5
B. Demersal	43.8	22.4	51.1
C. Shoaling pelagic	56.7	26.4	46.6
D. Cephalopods (squid, etc.)	10-100		
E. Myctophids (lantern fish, etc.)	100		
F. Euphausids (krill)	?		
G. Crustaceans	2.3	1.4	60.9
H. Shellfish (mollusks other than Cephalopods)	?	2.2	
Total A., B. and C.:	105	50.8	48.4

Source: Gulland (1971).

Regional Considerations

Clearly, some coastal and adjacent ocean areas are potentially capable of significant increases in sustainable yields while others are not (table 7).* Considering the needs of developing countries, it is important to note that table 7 shows the highest potential for an increase in sustainable yields in areas in the southern temperate and tropical zones. These are the zones where we generally find the countries referred to as less developed with large sections of the populations malnourished or undernourished (see table 1, last 3 columns). Thus we are facing a situation in which the prospects for increased exploitation of capture fishery resources are brightest in those areas of the world where the nutritional need and potential demand for fish are the greatest.

While these prospects are encouraging, increased production from such resources and increased participation in particular fisheries by the LDC's can only be realized with investments by these countries and improved indigenous technologies. Close to the coast, that is, within territorial sea boundaries usually 12 miles offshore or less, the LDC's do not face competi-

* *All estimates of recent catches and resource potentials which follow in this section on capture fisheries are from Gulland (1971).*

Table 7. Potential fish resources (categories A, B, C of table 6).

	Recent Catches (Million Metric Tons)	Estimated Potential Yield	
		Million Metric Tons	As Percentage of Recent Catches
Northern Temperate Zone			
Northwest Atlantic	4.2 (1969)	6.4	152
Northeast Atlantic	9.1 (1969)	13.3	146
Mediterranean and Black Sea	0.9 (1969)	1.2	133
Northwest Pacific	5.0 (1964)	5.2	104
Northeast Pacific	2.1 (1967)*	4.6	219
Tropical Zone			
Eastern Central Atlantic	2.0 (1969)	3.4	170
Western Central Atlantic	1.5 (1969)	5.5	367
Indian Ocean	2.7 (1969)	14.1	522
Western Central Pacific	3.3 (1968)	16.0	485
Eastern Central Pacific	1.0-1.4 (1967)	6.0	1000
Southern Temperate Zone			
Southwest Pacific	0.2 (1969)	2.0	1000
Southeast Pacific	10.2 (1969)	12.5	122
Southwest Atlantic	0.7 (1969)	7.3	1043
Southeast Atlantic	2.3 (1967)	4.3	187

Source: Gulland (1971).

* *Includes demersal fish, salmon, herring.*

tion in this effort. Farther offshore they do face competition, even when they unilaterally declare an extended national boundary. The day is imminent, however, when, through pending Law of the Sea Conference deliberations plus increasing unilateral expectations, coastal countries will probably have substantial controlling rights offshore.* With such rights they can pursue development on their own and can work out fishery agreements with other countries, all the while protecting their interests and realizing a gain from offshore resources.

* *This point, except for miscellaneous cases, wherein the unilateral posture has been publicly proclaimed, cannot be fully documented. The expectation stems largely from conversations with informed observers of the trend.*

In our review of the coastal and ocean harvest potential by regions and by some of the resource groupings, we will only note for the northern temperate zone that: (1) in the Northwest Atlantic potential increases in yields for the better known fish resources are negligible, although when stocks are added for which knowledge is limited or lacking (squids, myctophids, macrurids, ammodytes), the possibility exists that the potential yield may almost double; (2) in the Northeast Atlantic major species for which potential increases in sustainable yields might be realized include small demersal fish, capelin, herring group and squid; (3) in the Northwest Pacific, the pelagic species (in contrast to the demersal fishes which dominate the catches) can probably support a slightly increased sustainable catch, and (4) in the Northeast Pacific the potential yield from known demersal species is only slightly higher than recent catches and the major proportion of the estimated unexploited potential of 2.5 million metric tons consists of shoaling pelagic fish (herring, capelin, saury, etc.).

Added attention to potentials is given in the following under subdivisions of the tropical zone. Brief mention of the freshwater capture fisheries' potential is incorporated in the section on aquaculture.

Tropical Zone

Eastern Central Atlantic. This includes the continental shelf of northern and central West Africa. A potential yield of 3.4 million metric tons is about one and one-half times the catch in 1969. Demersal stocks in the northern part are already intensively fished, and the greatest potential is among large pelagic fish like mackerels, horse mackerels, blue fin, etc. Increased fishing for both sardine and *Sardinella* seems feasible.

Western Central Atlantic. This includes the Gulf of Mexico, the Caribbean Sea, the Atlantic coast of South America to the Brazilian border, the southern part of the United States east coast. Given favorable technological and economic circumstances, catches from this area could be greatly increased. Among the highly exploited resources with substantial potential are the demersal fish off the Atlantic coast of South America and also possibly local stocks of snappers and groupers in the Caribbean.

Indian Ocean. This includes the coastal waters of the Indian Ocean and adjacent seas from South Africa to the Thailand-Malaysia border, southern coast of Indonesia, and the west coast of Australia. Although some individual stocks of large tuna, some shrimp and some local stocks of demersal fish are fully exploited, it is fairly certain that present total catches can be greatly increased. Potential yield of demersal and shoaling pelagic fish in the western Indian Ocean are estimated at 8.5 million tons, leaving an estimated 5 million tons for the eastern section.

Western Central Pacific. This includes mainland Asia coasts from Korea south to Malaysia, Sumatra, Java, the west coast of Australia, and the coast of New Guinea. An estimate of potential yield, around 16 million tons, compared to recent catches of 3.3 million tons, suggests great opportunities for the expansion of production. Estimates given also suggest that, by virtue of the extent of the shelf area, the region is one of the most promising, particularly for demersal fish. However, the fact that distant water fleets, particularly from Japan, have not been making major inroads here casts some doubt on these expectations. Apparently the stocks are not favorably concentrated and consistent.

Within the region, the hoped-for increased yields from the demersal resources are greatest in the Yellow Sea, the East China Sea and the Gulf of Carpentaria.

Eastern Central Pacific. This includes the coastal waters of California to northern Peru. The potential yield from the fish resources of the region is estimated to be 6 million tons (4.6 million tons pelagic and 1.4 million tons demersal). By including myctophids, deep sea smelts, etc., the estimate might rise to 9 million tons.

Southern Temperate Zone

Southwest Pacific. This includes Australia eastward to 115°W, the shelf areas around New Zealand and off the east and south coasts of Australia. Recent catches of about 0.25 million tons are extremely low compared to estimated potential sustainable yields of 2 million tons per year.

Southeast Pacific. This includes the coasts of Peru and Chile. The estimated potential yield of pelagic and demersal fish resources totals 12.5 million tons (11 million tons from Peru and 1.5 million tons from Chile). Adding squids, myctophids and other fish presently relatively unexploited, the figure might rise to 14 million tons. In terms of volume, the anchovetta fishery of Peru is by far the biggest single species fishery in the world. Catches in the area increased tenfold in the period 1958-69 but recently dropped to about half the peak catches and have not returned. Recuperation and even some increases in the sustainable yield might occur if trade winds are favorable, spawning is good, etc.

Southwest Atlantic. This includes the coasts of Brazil, Uruguay and Argentina. The most important species in terms of abundance are anchovy, herring, mackerel, sardines, croaker (corvina) and merluza, poutasson and squid. The potential yield of sardines is not estimated to be much in excess of the present level. The anchovy is regarded as the biggest resource of the region, and the total of demersal and pelagic resources are estimated to have a potential yield of 7.3 million tons. Unexploited stocks like squid and myctophids are in abundance. This is in marked contrast to recent catches of marine animals from the southwest Atlantic, which in 1969 was less than 0.70 million tons.

Southeast Atlantic. This includes the coast of Africa from the mouth of the Congo River around the Cape of Good Hope to 30°E. Demersal fish (mainly hake) resources are estimated to have a total potential yield of over 1 million tons as compared to the 1967 catch of 0.5 million tons. Coastal pelagic fish (of which the pilchard is the main species) are believed to have a potential yield at least twice that of the 1967 catch of 1.7 million tons.

Antarctic

Now that the limits of the potential yield of many of the intensively exploited fish stocks of the world are being approached, increasing attention is being paid to Antarctic resources. Prior to 1970, there was virtually no commercial fishing in the Antarctic Ocean except for whales, the stocks of which are heavily depleted and may require decades to recover. Some 60 species of pelagic fish have been recorded there. The biggest resource of the region is the krill, which is estimated on a speculative basis as being capable of sustaining a potential yield of tens of millions of tons. Squid resources also may be large.

*World-Wide Considerations Bearing on Certain Groupings**

Open Ocean Resources. The world catch of tuna and tuna-like fishes from oceanic areas has increased steadily from 1 million metric tons in 1958 to 1.6 million tons in 1970. The potential catch of tuna has been estimated at 3 to 4 million tons (see recent review of world tuna resources by Saila and Norton, 1973).

The oceanic squid potential has been estimated to be 10 to 100 million tons. Also, by including the myctophids, the oceanic resource potential may rise in the order of 100 million tons.

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* *The oceanic populations are included in the estimates of table 7; the crustaceans and shellfish are not.*

Crustaceans. The present production is estimated to be 1.3 million tons (prawns, 0.8; crabs, 0.4; and lobsters, 0.1 million tons). The production potential for prawns is estimated to be almost twice that of present catch levels with prospects greatest in the Western Central Pacific and the Western Indian Ocean, but also significant in the North Pacific and Eastern Central Atlantic. The prospects for increased lobster harvests are more limited on a global basis, but substantial increases could be sustained in the Northeast Atlantic and moderate increases, in the Western Central Atlantic. The potential yield of crab resources on a global basis is 72 percent higher than present production, and prospects for potential increases are particularly promising in the Western Central, South and Southeast Pacific.

Notwithstanding the value of these crustacean resources to the LDC's as a source of local food supplies, these highly valued marine species tend to flow from the LDC's to the luxury markets of the developed countries. Consequently, the increased participation of the LDC's in the fishing, processing and marketing of these resources is to be viewed primarily as a valuable means of strengthening their holdings of foreign currency and of using accessible marine resources for monetary impact on their economies. Of course, monetary gain does increase the capability for purchasing other foods.

Shellfish. Mussels and oysters: the world production of mussels was 0.33 million tons in 1969; oysters, almost 0.8 million tons. Scallops: present production of 0.2 million can increase to less than 0.5 million tons if all stocks of larger species are used. If smaller species are harvested a further quarter of a million tons may be forthcoming. Clams, cockles and arc shells: the present production of 0.5 million tons could probably reach a minimum of 4 million tons by fuller use of existing stocks.

Summary Observations on the Potential Yield

1. Though the estimates of potential yields are rather crude, it is apparent that the known fish resources, on an aggregate basis, are capable of yielding substantially higher catches. Improved management practices are needed if these increased yields are to be maintained.

2. Coastal and ocean areas capable of the largest increases in sustainable catches of familiar demersal and pelagic species lie along the shoreline and offshore of the LDC's. Improved knowledge of these resources, and enhanced gear and boat efficiency, both inshore as well as in areas further out on the shelves and beyond, can help to realize greater use of this potential. Such participation offshore is likely to involve not only new efforts by the

LDC's, but new efforts by developed countries to extend their fisheries into these regions. Highly competitive multi-national fishery endeavors in a given area often lead to depletion; however, if bordering nations gain controlling rights, as expected, fishery compacts in the interest of conservation and, of course, favorable to adjacent developing countries would be possible.

3. Further, the projection of the world's marine resources indicates that an unquantified and virtually untapped reserve exists of lesser known fishery stocks which, pending the development of efficient and economical harvesting methods (note the comments on myctophids earlier), may prove to be a significant addition to the world sources of fish and protein. To a large extent such stocks are located off the shores of the LDC's and the development of such resources is subject to the conditions noted under 2.

4. All production increases suggested under 2. and 3. would require an accompanying development of the infrastructure, including a greatly expanded marketing system, to effect the desired use.

5. With some possible exceptions increases in freshwater yields will probably be tied more to the development of aquaculture than to capture fisheries.

The Potential of Aquaculture

Aquaculture, although a novelty to many people, has been practiced throughout much of man's history.* Oyster culture thrived in ancient Rome, and there are earlier, less certain reports of the artificial propagation of fish. In spite of the antiquity of aquaculture, the contribution of fisheries to man's diet still depends largely on the hunting and gathering of untended stocks. As the foregoing chapter on capture fisheries suggests, there has been a substantial increase in these and we can expect even further expansion; however, reasoning based on ecological considerations dictates that we must eventually reach a ceiling in the take of wild aquatic organisms. On recognizing this, as well as appreciating some of the advances we might expect from improved aquaculture techniques, our interest in such culture has grown rapidly in the past 20 years and will certainly continue to rise. Unfortunately this interest has been in terms of technological promise without due regard, in all cases, to the socio-economic factors and adjustments that must be considered if we are to realize desired goals.

The growing, or culture, of aquatic organisms under controlled conditions can make a special contribution to nutrition in many parts of the world, not only in terms of gross food yield but in terms of the high protein value of fishery products. Moreover, in high-production aquaculture we take advantage of the fact that certain aquatic organisms are very effective converters of primary foods not readily used by man; many are more efficient than the first-level food converters, such as cows and pigs, which we raise on land, and this is the case whether they are supported on natural food sources or on supplied food. For example, carp outproduce cattle almost twofold when given equivalent units of fodder (Shpet, 1972). In aquaculture we can often use areas that otherwise remain wasted and we can even use waste products—in some instances sewage effluents are successfully used with the water being partially upgraded in the process. Finally the resulting crops, i.e., fish and shellfish, are available in small units and multiples thereof quite in contrast to the meat product of the farm where one must always sacrifice a whole large animal to get any yield at all.

In quantifying the potential for aquaculture, we should look first at the status of aquaculture today. Ryther and Bardach (1968) estimate that the total yield from aquaculture may be between 5 percent and 10 percent of the total world catch; Pillay's (1973) figure of 5 million metric tons as the present world total is in keeping with this. There is widespread expectation

* *The term "mariculture" is also used, particularly when the focus is on the culture of marine or brackish-water organisms.*

that the aquaculture yield can be increased five to tenfold, even greater; this is based on potential advances in technology and the likelihood that areas under cultivation will be increased. For example, Pillay (1973) projects a tenfold increase in area use and Ling (1972) estimates that over 1.5 million hectares, about one-half of the present world total, are still available for culture in Southeast Asia alone.

In broad groupings, Pillay (1973) estimates that about 3.7 million tons of overall aquaculture production is finfish, I million tons mollusks and 0.3 million tons seaweed. He also offers the following impressive example of countries in which aquaculture, developed over several years, constitutes a major percentage of the total fishery production: China 40, India 38, Indonesia 22 and the Philippines 20. In Israel pond culture has accounted for approximately 50 percent of fisheries production since 1969, and has doubled the country's supply (Sarig, 1973).

Bardach, Ryther and McLarney (1972) categorize culture techniques in order of increasing complexity as shown in table 8. The positive correlation between yield and intensity or complexity of the methods employed is impressive.

To be ideally suited for aquaculture an organism should: (1) respond to measures to induce reproduction in captivity; (2) have eggs and larvae hardy enough to withstand hatchery conditions; (3) have feeding requirements and habits easily and cheaply satisfied, and (4) respond with rapid gains in growth and weight.

Of the organisms with life histories presently known, only a few combine all these attributes. An added important aspect of the suitability of a species for aquaculture is that a culture organism must fit or be adaptable to the tastes and preferences of the people for whom it is intended and must lend itself to practical handling, processing (where applicable) and marketing.

Before reporting some of the aquaculture practices in developing countries, primarily in the tropics and subtropics, it is useful to generalize briefly with respect to inland fisheries as a whole. An FAO report (1972) has recorded an annual catch of about 8.8 million metric tons from the estimated 500 million hectares of inland waters of the world. This figure does not include sport catches and some of the subsistence harvests. In a number of countries, especially those with limited or no coastline, inland fisheries have supplied most or all of the fishery commodities. These are generally used entirely as food rather than being reduced to meal or oil as is the case with large quantities of the marine catches. While the inland fisheries are often highly vulnerable to man-induced stresses, particularly pollution; are relatively confined, and thus easily depleted by overfishing, declines in such harvests may be more than offset by increases in aquaculture. This may involve practicing aquaculture on the same acreage used for agriculture, or carrying out transient aquacultural practices where land is being reclaimed from swampy areas. The combination commonly seen, as in Southeast Asia, is the secondary use of rice paddies where fish culture provides not only a cheap, acceptable, and nutritious protein food, but also may increase the rice crop as much as 15 percent (Hora and Pillay, 1962).

Although in many developing economies, aquaculture is at the subsistence level, it has great potential for improving the economy by providing employment as well as food. For example, milkfish culture provides jobs to about 520,000 people in Indonesia and to 170,000 people in the Philippines (Pillay, 1973). Shrimp farming can provide not only food and jobs but also has the added potential of generating exchange from export to the world markets demanding shrimp as a "luxury" food.

The following examples of aquaculture as carried on throughout the world are cases which attracted our attention, but we have obviously overlooked some cases others might elect to mention. We begin with Southeast Asia where fish rearing has been an important source of food since the third century B.C., perhaps earlier.

Some Specific Successes

Southeast Asia

In an early report, Schuster (1952) described ponds constructed along the northern coast of Java that made skillful use of the tidal movements in the area. With proper management, an acre of mangrove tambak swamp yielded several hundred pounds of fish, chiefly *Chanos*, and shrimp per year. This area now has even more advanced aquacultural methods; fish are being reared in floating cages and cycling the raw sewage produced by millions of people, thereby greatly increasing the production of fish flesh per unit area. The advantages and disadvantages of the use of cages-versus-ponds as a culturing technique are discussed in more depth by Hempel (1970). Briefly, cages are constructed easily and use flowing water as a natural source of food replenishment, but are easily fouled and may prove too weak to sustain damage from solids floating in the waters.

In Malaysia a common pond-culture practice involves rearing fish as a secondary "crop" to pigs. The pigs feed on water hyacinth and other aquatics grown in the ponds, while manure and washings from the pigsties fur-

Table 8. Selected examples of aquacultural yields arranged by ascending intensity

Culture Method	Species	Yield [Kg/(Ha) (Year)] or Economic Gain
Transplantation	Plaice (Denmark, 1919-1957)	Cost:benefit of transplantation, 1:1 or 1:1-1.3 in best years (other social benefits)
	Pacific salmon (U.S.)	Cost:benefit, based on return of hatchery fish in commercial catch, 1:2.3-5.1
Release of reared young into natural environment	Pacific salmon (Japan)	Cost:benefit 1:14-20, on above basis
	Shrimp, abalone, puffer fish (Japan)	Not assessed; reputed to increase income of fishermen
	Brown trout (Denmark, 1961-1963)	Maximum net profit/100 planted fish: 163%
Retention in enclosures of young or juveniles from wild populations with no fertilization, no feeding	Mullet	150-300
	Eel, miscellaneous fish (Italy)	
	Shrimp (Singapore)	1,250

nish the ponds' fertilizers. Research, such as that reported by the Tropical Fish Culture Research Institute (1961) at Malacca, shows that greater yields might be realized with artificial fertilizers; however, most of the material used by the farmers in the carp ponds is waste material and of minimal cost. Furthermore, at the end of the season when the ponds are drained, the manure remaining on the bottom is used on the land crops. This is not only a fairly economical system, but is also one the farmers know and have successfully used for years. The Fisheries Division of Malaysia (1972) has also provided information on coastal aquaculture which includes the culture of cockles, prawns or shrimps, pearl oysters and milkfish.

For Thailand, Swingle and Smitherman (1967), Sprague (1970), Ling (1967), Teinsongrusmee (1970), and Sribhibhadh (1972) note that the Thais are working on the culture of carp, milkfish, *Tilapia*, walking catfish and shrimp in ponds, and cockles, mussels, and oysters on rafts in the Gulf.

or complexity of culture methods.

Culture Method	Species	Yield [Kg/(Ha) (Year)] or Economic Gain
Stocking and rearing in fertilized enclosures with no feeding	Milkfish (Taiwan)	1,000
	Carp and related spp. (Israel, S.E. Asia)	125-700
	Tilapia (Africa)	400-1,200
	Carp (Java, sewage streams) (¼-½ of water area used)	62,500-125,000
Stocking and rearing with fertilization and feeding	Channel catfish (U.S.)	3,000
	Carp, mullet (Israel)	2,100
	Tilapia (Cambodia)	8,000-12,000
	Carp and related spp. in polyculture (China, Hong Kong, Malaysia)	3,000-5,000
	Clarias (Thailand)	97,000
Intensive cultivation in running water with feeding	Rainbow trout (U.S.)	2,000,000 [170 kg/(liter) (sec)]
	Carp (Japan)	1,000,000-4,000,000 [about 100 kg/(liter) (sec)]
	Shrimp (Japan)	6,000
Intensive cultivation of sessile organisms, mollusks and algae	Oysters (Japan, Inland Sea)*	20,000
	Oysters (U.S.)	5,000 (best yields)
	Mussels (Spain)*	300,000
	Porphyra, Nori (Japan)*	7,500
	Undaria, Wakame (Japan)	47,500

Source: Bardach, Ryther and McLarney (1972).

* *Raft culture calculations based on an area one-fourth covered by rafts.*

They are using unprocessed fish as well as ground and dried whole fish as supplemental feeds in the ponds and in floating cages. The coastal area of Thailand under cultivation includes nearly 10,000 hectares, most of which is in shrimp farms. Tables 9 and 10 give the costs and earnings from shrimp culture farm holdings of three different sizes along the coast. In the inner regions of the Gulf of Thailand the average yield of shrimp per hectare varies with the growing season and the species. Teinsongrusmee reported that the average from December to May was 204 kilograms per hectare and during the second season, June to November, was 135 kilograms per hectare. This production was based on a farm of 25 to 50 rai, classified as small to medium in tables 9 and 10. Sprague indicates that, because of the large-scale reclamation projects linked with such aquaculture ventures and in view of

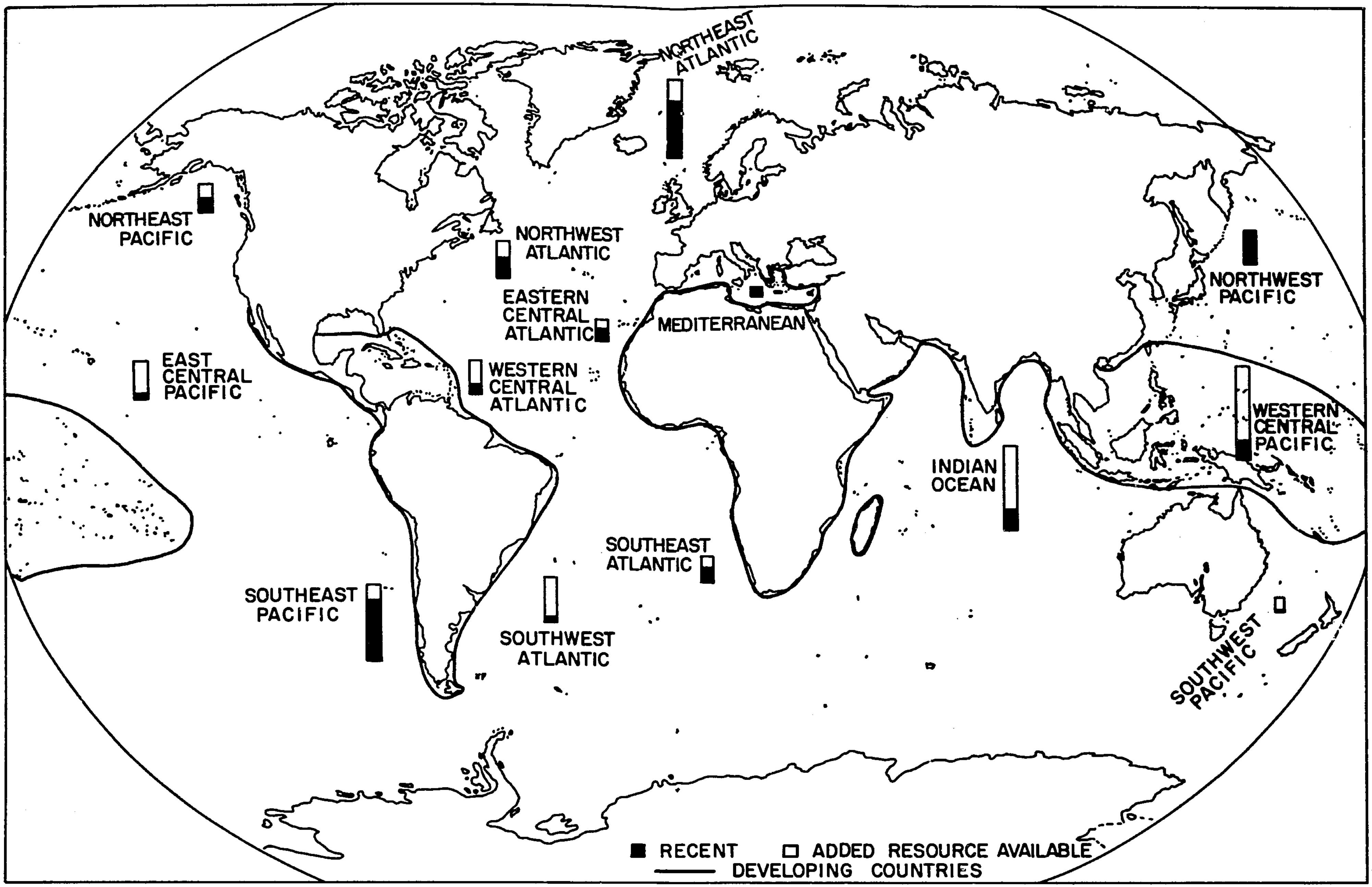

Figure 2. Recent catches and potential, by regions (see table 7).

the capital required, these development projects can only be handled efficiently by governments, corporations or large cooperatives.

Table 9. Average costs and earnings of shrimp culture in three provinces of Thailand, in United States dollars.

	Small Holdings	Medium Holdings	Large Holdings	Weighted Average of Holdings
Average area in hectares (1)	2.8	8.15	18.4	
Quantity of shrimp kg/ha (2)	173.1	162.5	118.8	136.3
Gross income/ha				
Shrimp (4)	120.63	116.69	96.32	104.13
Fish (5)	9.88	9.32	7.50	8.38
Total (3)	130.50	126.00	103.82	112.50
Production cost/ha				
A. primary (6)	141.94	88.19	63.94	77.69
B. secondary (7)	173.75	117.32	90.88	105.63
Net return/ha				
A. primary (8)	−11.44	37.82	39.88	34.82
B. secondary (9)	−43.25	8.69	12.88	6.25
Family Labor cost/ha (10)	36.63	21.63	10.19	15.88
Gross receipt/ha (11)	25.19	59.38	50.13	50.69
Production cost less income from fish/ha				
A. primary (12)	132.06	78.87	56.44	69.32
B. secondary (13)	163.82	108.00	83.38	97.19
Production cost/kg of shrimp (14)	0.95	0.66	0.70	0.72
Price of shrimp/kg (15)	0.70	0.72	0.84	0.77
Capital investment/ha (16)	706.50	666.00	662.69	667.82
Net return/capital investment X100 (17)	−1.61	5.68	6.02	5.21

Notes: (7) = (6) + land rent (= 80 Baht each holding) + capital interest
(8) = (3) − (6)　(12) = (6) − (5)　(15) = (4) ÷ (2)
(9) = (3) − (7)　(13) = (7) − (5)　(17) = (8) ÷ (16) × 100.
(11) = (8) + (10)　(14) = (13) ÷ (2)

Source: Department of Fisheries (Thailand) (1971); conversions of Baht and rai are 4.8¢ per Baht and 6.25 rai per hectare.

The pond culture of the walking catfish, *Clarias*, in Southeast Asia deserves special comment since, as an air breather, it can be produced at extremely high concentrations. Over 15 metric tons per hectare have been

Table 10. Average costs per farmer of shrimp culture in three provinces of Thailand, in United States dollars (holdings as in table 9).[1]

	Small Holdings	Medium Holdings	Large Holdings	Average of 3 Holdings
Maintenance and repair:				
Pond	57.60	116.83	314.74	163.06
Machinery and equipment	27.36	58.90	80.40	55.58
Total (1)	84.96	175.73	395.14	218.64
Implements (1)	46.03	64.80	103.01	71.28
Materials (1)	69.74	111.41	171.70	117.60
Charges and fees (1)	25.01	37.49	41.14	34.51
Labor costs:				
Family	103.15	173.28	186.34	154.22
Temporary employees	13.20	31.10	55.77	33.36
Permanent employees	—	22.08	38.55	20.21
Total (1)	116.35	226.47	280.66	207.88
Depreciation (1)	56.12	105.12	174.96	112.08
Primary costs (2)[2]	398.21	721.01	1167.07	761.85
Land rent (2)	67.59	196.08	441.60	235.10
Capital interest (2)	22.08	40.32	55.97	39.46
Secondary costs[3]	487.87	957.41	1664.64	1036.41
Quantity of shrimp and fish, yield per farmer				
Total kg of shrimp	488	1327	2182	1332
Total kg of fish	147	765	957	623
Value of yield/farmer[4]				
Total for shrimp	339.88	953.14	1770.58	1021.20
Total for fish	28.18	75.70	140.50	81.46

Source: Department of Fisheries (Thailand) (1971).
[1] *Converted to United States dollars at rate of 4.8¢ per Baht.*
[2] *Calculated as the sum of all (1)'s.*
[3] *Calculated as the sum of all (2)'s.*
[4] *Calculated as price/kg. × quantity in kg.*

harvested (Ling, 1967) and even greater production has been cited. With intensive feeding a conversion rate of 6:1 has been claimed. The catfish are fed primarily on trashfish and animal offal in the Thai culture ponds, while rice-bran is apparently preferred as a feed in Taiwan.

Aquaculture, particularly milkfish farming in ponds, with yields up to 2500 kilograms per hectare per year (Ling, 1969) has been a noteworthy success in Taiwan. After a glance at the profit possible in this farming, given in table 11, we might assume this is indeed a most remunerative business but, as Lin (1968) notes, when the salary of the farm manager or owner is added to the cost of production there remains very little margin for profit, especially for small farm operations which are merely subsistence at less than 10 hectares. Lin concludes that, unless the pond construction system can be consolidated and mechanization of fish farming encouraged (as Delmendo et al., 1970, propose and encourage), raising the living standards of this lot of fish farmers will be difficult. In terms of protein availability for the least cost and the best return on investment, Shang (1973) reports that aquaculture is a considerably better choice than hog production (see table 17).

Table 11. Finances per hectare of milkfish farming in Taiwan.

	U.S. $
Total income from fish sale	832.50
Harvest of overwintered stock 1200 kg. @ 0.48	
Harvest of new stock 700 kg. @ 0.38	
Costs of production	
Milkfish fingerlings	
4500 overwintered fingerlings	225.00
6500 new fry	65.00
Feeds and fertilizers	
Rice bran 1800 kg.	135.00
Peanut or soybean cake 300 kg.	45.00
Other (night soil, chicken manure, pesticide)	37.50
Labor and equipment	100.00
Rentals and miscellaneous	75.00
Total costs	682.50
Profit (income—costs)	150.00

Source: Lin (1968).
Conversions at rate of 40 Taiwanese dollars = 1 United States dollar.

Turning to India, the present outlook for fish and shrimp culture is summarized by Jhingran and Gopalakrishnan (1973). Using natural sources of fish fry and shrimp larvae, as is commonly done in the rest of Asia, production averages 200 kilograms per hectare per year. They see a great potential for increase and suggest a return of 15 percent per annum under average conditions. Sreenivasan (1967) has reported milkfish yields of over 1000 kilograms per hectare per year from ponds, moats and quarries with permanent blue-green algae blooms. Combined *Tilapia* and *Chanos* culture showed decreasing yields but *Tilapia*, cultured alone and cropped at a size of 50 grams, yielded over 2000 kilograms per hectare per year. Sreenivasan also has reported that intermittent fertilization with superphosphate virtually tripled the yield.

In concluding this subsection we have neglected to mention the Philippines where the interest and undertakings in aquaculture are pursued very much as indicated for the rest of the region. We might mention seaweed culture there for products used as food and food additives, such as gelling compounds. In one such development, Marine Colloids, a United States corporation, has been encouraging extensive seaweed farming in the Philippines and is considering the potential elsewhere in the region.

The Caribbean and Latin America

Bardach (1958) has reviewed fish culture as a means of improving the protein supply to the island peoples. He reported that fish culture had developed to some extent in Haiti, Jamaica and Trinidad, and, at that time, much of the culturing was in government-operated facilities. In the government hatcheries of Haiti, carp ponds have yielded 2240 kilograms per hectare and more, and comparable yields have been realized from the *Tilapia* ponds in Jamaica. But there has been little success culturing the local relatives of these two species. Bardach suggested that the optimum advances could be made in fish culture in the Caribbean by scattering many small ponds over the islands, thereby minimizing problems of marketing and distributing.

Lovell and Moss (1971), on an Agency for International Development (AID) survey in Haiti, reported that the fish culture program established in 1950 on the island should be "revitalized." Over 4,000 ponds have already been built and stocked and personnel have been trained in fish culturing techniques. Other information from the International Center for Aquaculture of Auburn (Alabama) University demonstrates, on a cost-profit basis, the feasibility of culturing *Tilapia* and Guapote Tigre in El Salvador. There is also a new and growing interest in Panama in such *Tilapia* culture.

Dibbs (1969) claims most of the inland harvest fisheries in the Caribbean are at the subsistence level. But he does note the presence of large, fresh- and brackish-water swamp areas on some islands and the possibility of establishing molluskan or shrimp culture. The latter, he suggests, could make an important contribution to the foreign exchange balance by providing an export product of high demand in the markets of the developed countries. Webber (1970) and Broom (1972) also have explored the potential of shrimp culture and recommend it for countries bordering the Caribbean, and, as of this writing, there are a number of companies, many directed by personnel from the developed countries, venturing into freshwater *(Machobrachium)* shrimp culture in the region. A paper from the FAO (1969) predicts high promise for clam and oyster culture in the Caribbean, using techniques established in other areas.

Mention also should be made of two new ventures. On St. Croix in the Virgin Islands experiments are being conducted, under the direction of O. E. Roels (see Othmer and Roels, 1973), on the potential for accelerating aquaculture by pumping nutrient-rich water from the ocean depths that are close to shore in that region. On Grand Cayman Island, Mariculture Ltd. has a large, rather sophisticated green turtle rearing facility. The very high production (in the order of 1000 kilograms per day and increasing) is based on imported pellet food, but we have no data on costs. Egg stock for the hatchery is obtained from nesting beaches elsewhere, and this involves a commitment to release a certain percentage of hatchlings to the natural environment. But there is no assurance, in terms of existing knowledge, that this is a satisfactory conservation measure. Simpler versions of such sea turtle culture are carried on in several places in the South Pacific.

In a survey of the brackish- and fresh-water fisheries of Guyana, Shell (1969) reports thousands of acres of potential fish producing areas and suggests that, with proper management, enough fish could be produced to meet local demands and yield a surplus for export. Presently the brackish-water fisheries of Guyana are poorly developed, but their potential appears great due to the existence of favorable tidal fluctuations and a year-round growing season. Shell suggests that promise for the immediate future lies with the culture of mullet and shrimp in brackish-water ponds. One of the problems in Guyana, especially for the development of inland fisheries, is a plantation and colonization policy which limits the availability of land for pond construction.

Swingle and Pagan (1969), reporting on fish culture in Ecuador, see a substantial potential, but note the need for basic research on species suitable for cultivation. In view of the market prices for a number of inland and marine fish, they state that "the present prices of fish appear too low to encourage rapid development of commercial culture of fish in inland pond areas. . . ." Smitherman and Moss (1970) report much the same general needs and potential for Peru.

The above accounts are admittedly lacking with respect to recent developments in northeast Brazil, an area of great need, which apparently is quite amenable to finfish aquaculture and is currently receiving considerable attention. Supporting research is being conducted at the well-known Pentecoste Station.

Africa

The prospects for aquaculture, mainly as fish culture, in Africa seem bright; however, such efforts are pursued mostly on a subsistence level or as a spare-time occupation of farmers providing for their home food needs only and using mixed methods (Meschkat, 1967). The shortage of capital is apparently the main reason for the lack of development beyond such "home-pond culture," or subsistence practices. Thus, while fish production as a secondary crop in rice field culture increased from 40 tons in 1962 to 4,600 tons in 1968 in Malagasi, the production of fish from fish ponds only doubled during that time from a 1962 level of 2,000 tons (FAO, 1970).

Mortimer (1967) reports on three types of fish culture facilities that have been developed in the rural areas of land-locked Zambia. These are family ponds, irrigated small holdings and conservation dams. After stocking, the dammed areas also support a subsistence rod-and-line fishery. The costs of staffing and operating these three cultivation areas are given in table 12, with the additional information that the minimum cost for a one-tenth acre contour pond is $84.80. Mortimer found that "in terms of benefit in cash and food to rural communities making best use of available skilled manpower and financial resources, conservation dams show a better return than do small family ponds." These are among the most comprehensive data we have seen on aquaculture costs in Africa, but an assessment of the direct effect upon the economy is difficult without knowledge of species supplied, the demand and the costs in any given country.

Table 12. The comparative cost of fish culture development and extension work, Zambia, in United States dollars.

	Family Ponds	Small Holdings	Conservation Dams
Capital costs			
Demonstration-stock unit	2,100[1]	2,100	7,700
Staff housing	25,900	7,560	14,700
Total	28,700	9,660	22,400
Annual costs			
Technical assistant	840	840	840
Unit staff	840	840	840
Extension staff	4,200	840	2,100
Sub-total of salaries	5,880	2,520	3,780
Unit running costs	420	420	420
Vehicles	2,800	1,400	2,800
Fish stocking	700	700	1,400
Capital depreciation (20 years)	1,400	490	1,120
Central services (20%)	2,240	1,240	1,960
Sub-total	7,560	4,060	7,790
Total annual costs	13,440	6,580	11,480
Pond owners (number)	200	50	240
Dam areas in hectares	8.1	10.5	1,092
Average annual production (kg./ha.)	896.6	1,121	112
Annual total production (kg.)	7,258	11,340	122,472
Annual expenditure per unit weight of fish produced (per kg.)	19.80	6.30	0.99

Source: Mortimer (1967).

[1] *Conversion at the rate of $1.40, United States dollars, per Z.L. and 75¢ per Zambian schilling.*

Other cases

Workers at the University of Hawaii and the Oceanic Institute in Hawaii are currently directing considerable attention to the potential of aquaculture for the islands of the mid- and South Pacific. Some general notes on this are found in Murphy (1973).

Being interested primarily in the developing countries, we have not discussed aquaculture in Japan where it is a very ancient, and yet in techniques, a very modern enterprise, ranging widely and successfully over a spectrum of seaweeds, shellfish (even pearl oysters), crustaceans and finfish. We have not mentioned the United States where efforts are relatively new, but highly successful in inland farms. We note particularly that trout and pond catfish production in the United States are both highly profitable enterprises.

Speaking of activities on the part of developed countries, it is important to note their recognition of the potential in the tropics. To some extent this has taken the form of assistance programs by countries and by the United Nations. To some extent, this is unfolding through commercial ventures in the tropics, such as those involving the green turtle, freshwater shrimp and seaweed culture that we have mentioned.

Some Socio-Economic Considerations to Be Surmounted

FAO (1969) and Ryther and Bardach (1968) have projected up to a five-fold production increase through advances in aquaculture. These estimates may be conservative; yet to be realistic we should take note not only of technological, but of socio-economic factors, that may tend to retard, and in some cases even obstruct, the attainment of greater expectations.

1. Successful aquaculture depends on control by the investor, whether private or governmental, of the area and the contained stocks he is developing. Thus the fact that vast water and submerged bottom areas, well-suited for aquaculture, are part of the public heritage and are not readily controlled in a manner conducive to culture practices, is a substantial constraint on development. On the other hand, effective aquaculture often can be practiced in extensive swampy and lowland tracts, more readily controlled than open water areas and often grossly underused. In the main, pond culture is on sites where control is not a major problem.

2. Since there is such a high correlation between yield and the complexity of a given aquaculture practice (see table 8), the practices with the greater yields may be too complicated to be adopted by relatively untrained peoples. Accompanying the greater complexity is the obvious payoff of scale and capital investment in many aquaculture pursuits; all of these pose obstacles to the people of developing countries.

3. The cost of production often limits commercial enterprises to species intended for the luxury market, whereas the potential of aquaculture for

meeting the world's protein needs depends on culture practices which operate or can be operated at lower costs. This and 2. are, of course, interrelated.

4. Demand, whether based on income, cultural preferences or combinations thereof, may not respond to aquaculture output or may not sustain such output.

Maximum Expectations

Other researchers express optimism about possible increases in aquacultural production. Hickling (1962) has stated that fish species can produce three to five tons per acre per year (about 7½ to over 12 tons per hectare). And numerous specific illustrations of highly successful culture show a great deal more than the suggested fivefold average increase in production. This suggests that, by selected concentration of effort and improved planning for development, the increase on a worldwide basis might be greatly augmented. Furthermore, advances in techniques, beyond those now foreseen, may increase expected gains. But, we note again that sophisticated technological advances may not be mastered readily within the developing nations where the food need is most acute.

To put all such expectations in perspective we return to the earlier estimate that at present aquaculture probably amounts to only 5-10 percent of the world's fisheries production. Thus the increases anticipated certainly do not place aquaculture out in front of harvest fisheries, especially because those harvests will be increasing as well. However, as we think about assistance to LDC's and the propects for a response thereto, the potential is impressive for effective assistance through aquaculture.

Some Socio-Economic Considerations Affecting the Fisheries Potential

Potential Demand and the Development of Fishery Products

Obviously the expansion in fisheries production over the past 25 years has been supported by available and growing markets for fish, and during this period fish have competed successfully with other foods in the marketplace. Part of this demand has been for fish as a preferred product and not as just another protein source.

Although the world produces about 65 million metric tons of fish (1972 data, FAO, 1973), perhaps no more than 25 million tons of this total is used directly for human food. There are obvious reasons: (1) about 25 million tons (using Robinson's 1973 percentage estimates) are used for fish meal and other industrial purposes—most of which, we should note, later finds its way into human food products—and (2) perhaps 20 million tons are lost in viscera and bones, etc., which are not consumed by humans.*

Some of the diversion to fish meal might be countered if methods were developed that could offer key species, e.g., anchovetta, menhaden, certain sardines, to consumers in a form for which they will pay. Other losses of currently edible fish, e.g., herring and some hakes, to fish meal occur because of existing market conditions. Irrespective of these losses, almost a kilogram of fish protein per capita per year is used directly as food. If this were uniformly distributed it would be enough, based on an average protein requirement of 35 grams per capita per day, to allow every person to satisfy his minimum protein requirements for one month each year.

Starting with a world average per capita consumption of 11.8 kilograms (live-weight) in 1970, Robinson (1973) has projected an increase in demand (at constant relative prices) to 13.3 kilograms in 1980 and to 16.2 kilograms in the year 2000. As shown in table 13, consumption is unequally distributed. The large, well-developed countries consume more than three times the fish protein per capita than do the LDC's, even though this amount often constitutes a very small part of the total protein intake of the populations in these developed areas. Uneven fish consumption across geographical sectors is largely due to differences in dietary habits, incomes and prices.

For present purposes it is important to observe that the percentage increase in additional supplies of fish for direct human consumption required to maintain 1970 per capita consumption in 1980 is greater in the developing countries (31 percent) than in the developed countries (11 percent).

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* *Authors' estimates.*

Table 13. Estimated demand for fish in 1980 and 2000 due to income and

	Per Capita Consumption Kg/Year			Actual Con-sumption
	Actual	Projected		
	1970	1980	2000	1970
WORLD	*11.8*	*13.3*	*16.2*	*43,933*
Developed countries	*23.5*	*26.5*	*28.7*	*17,064*
North America	15.4	16.7	17.7	3,492
Western Europe	20.3	24.0	26.6	7,235
Oceania	12.4	13.6	15.2	191
Others	47.5	51.4	54.7	6,147
Developing countries	*7.4*	*8.7*	*11.7*	*12,950*
Africa	7.1	8.7	9.3	2,015
Latin America	6.5	7.6	9.2	1,842
Near East	2.4	3.0	3.5	409
Asia	8.5	10.0	14.8	8,654
Centrally-planned countries	*11.3*	*13.3*	*18.7*	*13,919*
Asian	8.1	9.5	14.8	7,190
U.S.S.R.	23.9	29.7	37.9	5,808
Eastern Europe	8.7	10.6	13.1	922

Source: Robinson (1973).

The point also must be made that, because of the interdependence of food needs, food demand, overall income, agricultural and fisheries output, and total output (GNP), we cannot consider a nation's demand and supply of foodstuffs without reference to its overall economic growth. Accordingly, as we discuss and evaluate the need to increase the production of food and protein to meet nutritional requirements, we must be fully aware that, to achieve an effective demand in relation to this need, the economic growth rate and the capital investments in the LDC's will have to be significantly increased. Fortunately financial and technical aid to the fisheries will help to generate both additional food and additional employment and income. Needless to say, international aid in other sectors of the economy of an LDC will also be essential for expanding markets for all such food resources if nutritional requirements are to be met.

population increase.

Increase Required[1, 2] If Population Growth Is					
Low	Medium	Constant Fertility	Low	Medium	Constant Fertility
	1980			2000	
7,316	*8,228*	*9,412*	*23,069*	*27,252*	*38,210*
1,938	*1,952*	*1,952*	*5,916*	*6,073*	*6,208*
416	416	416	1,507	1,507	1,507
551	551	551	1,692	1,692	1,692
41	41	41	133	133	133
930	943	943	2,583	2,740	2,875
3,554	*4,015*	*4,354*	*12,004*	*14,670*	*20,714*
570	623	621	2,199	2,711	2,958
560	604	666	2,071	2,386	3,027
113	125	133	438	516	701
2,302	2,654	2,923	7,264	9,022	13,983
1,824	*2,261*	*3,106*	*5,149*	*6,509*	*11,288*
1,116	1,553	2,398	2,908	4,268	9,047
627	627	627	2,027	2,027	2,027
80	80	80	213	213	213

[1] *1000 tons live-weight.*

[2] *Additional supplies of fish required for direct human consumption, excluding fish meal, to maintain 1970 per capita consumption in 1980 and 2000.*

In concluding this section, we note that the impact of this potential expansion of production on artisan fishermen, the present producers of much of the fishery products in LDC's, can be great. In fact, systems designed without reference to the wants of, the participation by, and the cultural impact on such traditional suppliers could disrupt their welfare and that of large populations to which fishing is important. Thinking positively we note—especially inasmuch as many of the development possibilities are relatively low-capital, labor-intensive ventures—that these fishermen can be integrated into and can support these development systems.

Production and the Price of Fish

To meet the projected increase in demand shown in table 13 and the even greater demand if fisheries products are to help more substantially in offsetting the growing world protein deficit, improvements must be made in both the production and marketing sectors of the developing countries' fishing industries.

First, it should be noted, much of the present yield from the sea is being obtained at more than minimum cost. There are several reasons for this including: (1) the common property nature of the resource has often led to overinvestment in the exploitation effort in some waters; (2) national interests have sometimes dictated the pursuit of fisheries for other than economic reasons, and (3) a variety of constraints, for example certain gear restrictions not conducive to efficient operations, are to be found; also some inefficiencies exist due to lack of enterprise within the industry.

We do recognize that an increase in consumption in fishery products can only be achieved if these products can be produced at prices readily recognized as "reasonable" to the consumer. But the issues involved with this price problem become rather complex. It is difficult to determine (see next section) the relation between prices for different sources of protein, and it is even more complicated to make projections concerning relative prices in the future. Nevertheless, we think it necessary to attempt to discuss some aspects of the influence of fisheries development on prices and/or costs. While the discussion will deal with traditional capture fisheries, the simplest to consider in a situation already very complex, many of the same considerations prevail as new sources and aquaculture are considered.

We have already pointed out that most of the fish stocks that remain lightly or underexploited are in areas associated with the LDC's. It would seem that such stocks could be exploited advantageously by them, but the question of costs in accomplishing this must be considered. It could be argued that, were it economically feasible to exploit these stocks, the great fishing nations would already be fishing more vigorously close to the shores of the LDC's, that is, unless the costs were greater than in other areas of the world. Certainly distance alone would increase these costs. On the other hand, it could be countered that the stocks of fish in the LDC areas are not sufficiently well known as yet to permit distant investments in fishing or even vigorous exploration.

But what if the nearby LDC is provided with detailed information on stocks and is prepared to exploit them, increasing both its artisan and more heavily capitalized efforts? Given conventional technology, it is not clear that costs to the LDC would be much lower than costs experienced by a fleet from a well developed country operating in these waters, especially inasmuch as time spent by a large integrated fleet travelling to the grounds is often small relative to time spent fishing. For some of these fishery enterprises, the costs to the LDC of boats and gear needed, and their operation and maintenance may, well be higher; and, although cheaper labor may more than compensate for these, we cannot assume that the net cost of producing fish will be dramatically reduced.

An essential adjunct to an effective production increase is an expanded system for marketing as well as associated provisions for handling and processing. In most underdeveloped countries the supply elasticity of fish appears to be very low. This apparent inelasticity may be largely a limitation of the distribution system coupled with the perishability of fresh fishery products in high and moderate temperatures. Where populations are large and the marketing system reasonably diffuse, the apparent inelasticity is mitigated; yet, where markets are not sufficiently developed, large supplies of fish could often and do result in disastrously low prices.

The marketing of fresh, unprocessed (usually eviscerated) fish in local areas has not characteristically been capital-intensive and, given cheap labor, the system functions relatively cheaply at the local level. Marketing outside limited areas is more difficult, however, due to high transport costs and to a disorganization of broader markets with myriad inefficiencies.

As noted above, the large amounts of fish used for industrial purposes cannot but attract the attention of those concerned with human nutrition. Were it possible to transfer any significant part of our current production of fish for meal into edible fish, market prices would be reduced. However, as we have discovered with fish protein concentrate, the production of an edible protein product can be expensive. Almost any shift in the use of these resources for human food will require the development of supporting technology, which will certainly increase costs, yet may still produce a relatively cheap protein food. Other shifts may be realized simply through changes in eating habits, which may be achieved often through education.

In summary, the potential fishery resources available to LDC's can only be exploited if there is an expectation of reasonable prices coupled with a capacity to pay such prices, as noted in the previous section. Without expansion of the distribution, handling and marketing systems, increased supplies would very likely reduce prices below acceptable levels to producers. Market and distribution development, the key to the desired exploitation, would also reduce gross existing inefficiencies and unsatisfactory marketing margins.

The Relative Cost/Price of Fish Protein

It has been established that fish is an excellent, if not superior, source of the essential amino acids derived from animal protein generally. It is tempting to suggest that fish protein is also the cheapest among the animal proteins that provide the necessary amino acid balance; however, it is obviously perilous to generalize about products subject to so many local and

Table 14. Average producer prices of selected animal protein foodstuffs and their respective protein contents, 1961-63.

	Average Producer Price U.S. Cents/Kg.[1]	Protein Content %[2]	Estimated Producer Price/Kg. of Protein, U.S. $
Latin America			
Wheat (flour)	10.3	11.7	0.88
Beef and veal (carcass)	30.9	14.7	2.10
Mutton and lamb (carcass)	24.7	11.9	2.07
Pork (carcass)	30.9	9.8	3.15
Poultry (carcass)	46.3	12.0	3.85
Eggs	41.2	11.0	3.74
Fish (round-weight)	28.8	9.0	3.20
Milk (whole)	6.2	3.5	1.77
Far East			
Wheat (flour)	13.9	11.7	1.19
Beef and veal	55.6	14.7	3.78
Mutton and lamb	41.7	11.9	3.50
Pork	55.6	9.8	5.67
Poultry	62.5	12.0	5.20
Eggs	64.6	11.0	5.86
Fish	34.7	9.0	3.85
Milk	13.2	3.5	3.77
Africa			
Wheat	11.9	11.7	1.02
Beef and veal	41.6	14.7	2.83
Mutton and lamb	53.5	11.9	4.49
Pork	35.7	9.8	3.64
Poultry	59.5	12.0	4.95
Eggs	55.9	11.0	5.08
Fish	23.8	9.0	2.64
Milk	8.3	3.5	2.37

Sources: [1] FAO (1967); [2] USDA (1963).

Table 15. Comparative prices of fish, meat and poultry in various countries.

	Price Per Kg., U.S. $
Thailand	
Clarias, walking catfish	.50
Freshwater prawn	1.50-2.00
Marine prawn	.50-1.00
Pork	1.25
Beef	1.00
Poultry	.75
Philippines	
Milkfish	.67
Clarias, walking catfish	.50
Marine prawn	1.00-3.00
Pork	1.00
Beef	1.10
Poultry	.75
Dominican Republic	
Grouper	.45-.50
Snapper	.65
Spanish mackerel	.60-.65
Fish heads	.10
Conch (meat)	1.00
Chuck roast	.42
Ground beef	.80
T-bone steak	1.00
Pork chops	1.00
Costa Rica	
Corvina	.37
Dorado	.30
Marine prawn	.45
Pork	.68
Beef	.75
Poultry	.42
Nepal	
Common carp	.80
Poultry	.50

Source: Lovell (1973); Dominican Republic data supplied by Lampe.

temporal influences. And as we do generalize we must recognize that we produce some fish for which the cost of protein is high and others for which it is low, because a demand exists for both kinds.

Table 14 shows the relative price of fish protein compared with several other commodities for three different regions. Table 15 offers added comparison data for five countries. In each region fish is highly competitive with animal protein, even with milk in the Far East and Africa. While the data are not current, they do place fish in perspective. Without other information, it is difficult to determine how much the picture may have changed.

For the United States we have in table 16 more recent data (July 1969), and, although obviously different today because of recent inflation, it is clear that the American consumer gets relatively inexpensive protein in fish.*

Table 17 considers another issue, the cost of protein from various fisheries, using data obtained in Taiwan and compared to the cost of protein

Table 16. Relative protein costs at retail for selected commodities, July 1969, in United States dollars.

Commodity	Grams Protein/Kg.	Price/Kg.	Cost/Kg. Protein
Ocean perch fillets 1 lb. pack, frozen	179.9	1.22	6.79
Tuna in water 6½ oz. cans	280.0	1.92	6.86
Haddock fillets 1 lb. pack, frozen	183.0	1.63	9.00
Catfish frozen, skinned	176.0	3.15	17.95
Hamburger regular	179.0	1.44	8.03
Round steak with bone	195.1	2.98	15.28
Bacon	84.0	1.98	23.55

Sources: meat prices from USDA (1972); fish prices from USDI (1970a); catfish from USDI (1970b); and protein from USDA (1963).

** A very rough assumption, difficult to confirm because of rapid recent changes, is that cost increases for meat and fish products have been about the same.*

from hog production which is very advanced technologically in that country. The table shows that assumptions made concerning meat or protein yields can clearly influence a comparison. Shang (1973), who provided the data in the first column, observed that, although the production costs of the harvest fisheries are lowest, profit margins are sometimes better in aquaculture ventures.

Table 17. Cost per kilogram of protein for Taiwanese fisheries and pork production under selected assumptions.

	Production Cost/Kg., U.S. $	**Cost/Kg. of Protein**
Capture fisheries product		
Inshore	.17	1.89[1]-3.15[2]
Coastal	.15	1.67 -2.75
Aquaculture product		
Brackish water	.37	4.11 -6.85
Fresh water	.31	3.44 -5.74
Shallow seas	.16	1.78 -2.96
Hogs	.43	4.94[3]-8.70[4]

Source: for production costs, Shang (1973).

[1] *This figure assumes the level of protein/kg. of total live-weight to be 9%—a high figure equivalent to levels in haddock and halibut.*

[2] *This figure assumes the level of protein/kg. of total live-weight to be 5.4%—a moderate figure equivalent to levels in carp.*

[3] *This figure assumes 75% carcass yield and 64% lean on the carcass.*

[4] *This figure assumes 75% carcass yield and 36% lean on the carcass.*

The rather sketchy evidence in table 18 suggests that United States protein costs are higher than elsewhere. Red snapper, used for this illustration because it is produced in warm waters so characteristic of developing countries, is, however, a highly valued species in the United States, which perhaps distorts the picture.

With extensive research it would doubtless be possible to develop a more complete view of relative fish protein costs. However, this is hardly necessary for present purposes, and it seems clear that fish protein is in general competitive with animal protein. Finally, it must be stressed that in any development situation, comparisons must be adduced case by case.

Table 18. Cost of red snapper protein at the producer level for selected countries, 1971.

Country	Cost/Kg. (U.S. $) (round wt.)	Cost/Kg. Protein
Venezuela	0.63	6.20
Malaysia	0.91	8.80
Philippines	0.60	5.78
United States	1.52	15.24

Source: FAO (1972).

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