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Caton,Douglas; Moss,D.D.; Urano,J.A.

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9. ABSTRACT

Aquaculture, the production of freshwater and marine organisms through husbandry, now contributes less than 10% of the water-derived proteins in the world. However, if the best existing methods were applied more widely, aquaculture could produce ten times as much protein annually by the year 2000. The total area presently used for fishculture is estimated to be four million hectares. This area could be expanded to about 30 million hectares. With improved methods, this would increase production from the present five million metric tons to 50 million tons by the end of the century. Ongoing research needs to be reinforced by coordinated planning and financial assistance. This paper describes selected aquacultures, including those of the Chinese carp, common carp, Indian carp, tilapia, trout and salmon, catfish, pangasius, walking catfish, milkfish, molluscs, shrimp, and eels, and discusses the most effective way to reinforce present research efforts. Research relating to LDC's should concentrate on important scientific problems concerning a small number of species: carps, catfish, tilapia, milkfish, mullets, and shrimps. The highest priority research is also needed on diseases and the broad spectrum of water quality problems related to the cultured animal and its aquatic environment. One or more regional research centers should be established to conduct the long-term research required, offer short-term training for scientific personnel of national institutions, and disseminate research findings. A network of national centers should also be established to investigate local problems and conduct pilot studies.

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Improving Food and Nutrition Through Aquaculture in the Developing Countries

by

Douglas D. Caton, Donovan D. Moss and James A. Urano

I. A. Problem: **Economic development of food supplies needs to be sharply accelerated because:**

1. Per capita food supplies are not keeping pace with income and population growth, and the need for stocks
2. The world protein gap is between 60 and 80 percent and increasing
3. The economical land base is decreasing under urbanization, cost and population pressures requiring:
   a. intensification of output yields per land unit
   b. diversification of crop and animal production
   c. multiple cropping using same soil and water resources

B. Hypotheses

1. Aquaculture is an economical source of protein and vitamins
2. Aquaculture meets the criterion of bio-physical resource intensification
3. Aquaculture provides value added products to multiple land and water uses
4. Aquaculture helps utilize all the food niches in the water environment

II. Role of Aquaculture

Presently Aquaculture, the production of freshwater and marine organisms through husbandry, contributes less than 10 percent of the world's water-derived proteins, with a production of 5-6 million metric tons (MMT) valued at more than 2,500 million U.S. dollars annually. However, this is double the production of fice years ago, and an equally high rate of aquacultural growth could be sustained for a long period if the best existing production methods were applied more widely, and if necessary improvements were effected. By the year 2000, aquaculture could produce at least 50 MMT (millions metric TONS) of animal protein, representing an annual return of 25,000 million dollars at present proces.

Its importance in the nutrition of certain countries, expecially land-locked ones, is greater than the magnitude of production suggests. Furthermore, aquaculture represents an ecologically sound practice and a use of solar energy that would otherwise be wasted. The increasing impact of the industry in developing countries and the recent results of development programs clearly shows its role in integrated rural development.

The supply of one third of the world's animal protein (exclusive of milk) is dependent upon fisheries. Ninety percent or more of fish are captured from wild stocks, for which no yield increase comparable to that of aquaculture is regarded as possible within the same time span. Many of the most valuable stocks are already fully exploited or overfished, and relatively few new stocks are open to exploitation.

Capture fisheries did increase by 25 percent in the last five years, but this increase was largely through industrial fish landings, and levelled off to less than two percent during the last two years despite large injections of capital and of new technologies.

III. The Present Status of Aquaculture

A. Background

The present contribution to world protein supplies by aquaculture is estimated between 5-6 million metric tons (MMT) of fish, equivalent to 10 percent of the total annual world fish catch utilized directly for human consumption[(1)]. The potential for increased production of protein by aquaculture is large, with a ten-fold increase judged to be realistic in the immediate future through application of present technology.

The total area presently utilized for fishculture is estimated to range between 3-4 million hectares, and this area could be expanded to approximately 30 million hectares which could, with improved aquaculture methodology, increase present level of production of about 5 MMT to 50 MMT by the end of this century. The major expansion would be into presently unused resources and not encroach onto lands now in production.

(1) Report of the Technical Advisory Committee on Aquaculture, Consultative Group on International Agricultural reasearch, FAO, Rome. 1973

B. Definition

Aquaculture may be defined as the culture of food crops in water. Different culture systems have been developed for freshwater, brackish water and sea water where crops produced are proncipally fish, shrimp, bivalves (mussels and oysters) and certain edible aquatic plants.

The significance of aquaculture in the nutrition of many countries is considerably more important than is indicated by the volume of production. Production through aquaculture constitutes 40 percent of total fish harvest in China, 38, 22 and 20 percent of the total annual fish production in India, Indonesia and the Philippines respectively(2). Another example of the importance of aquaculture to a country bordering the Mediterranean Sea is Israel where fish culture harvest amounts to 50 percent of the total fisheries annual catch.(3)

C. Importance

Aquaculture makes a significantly large contribution to the food supplies of developing countries. It now contributes four percent of the world's animal protein supply (milk excluded), and its importance in the nutrition of certain countries, especially landlocked ones, is greater than the magnitude of production suggests. Its considerable importance in integrated rural development is indicated by the increasing impact of the industry in developing countries and by recent results of development programs.

(2) FAO Aquaculture Bulletin, Volume 5, April-July, 1973.
(3) BAMIDGEH Bulletin of Fish Culture in Israel, Vol. 25, No. 2, June, 1973.

The future potential for an increased production of protein food by aquaculture is very large. While capture fisheries for food fish are not expected to double their present tonnage (45 MMT), means can already be identified to prompt a ten-fold increase in aquaculture production. Even greater increases are possible if certain unproved and imaginative techniques (e.g. artificial upwelling of deep water) can be developed.

Unlike capture fisheries production, which is to a large extent dependent on uncontrollable natural variables, the limitations on production in aquaculture are directly related to inputs.

The total area presently under fish culture is not accurately known but is believed to be in the order of 3-4 million ha. It is estimated that this area could be increased up to about 30 million ha.

A significant proportion of these large potential increases in aquaculture production will depend upon the solution of certain problems through research. On-going research does not now solve the problems at a pace which is desirable, and which would be possible if the effort were reinforced strongly by coordinated planning and financial assistance. Other constraints (e.g. lack of development policies and programs in aquaculture, pollution, site competition) also restrict expansion of aquaculture, but with only their partial resolution significant advances could be made through research. are summarized in the next section.

IV. Purposes and Types of Aquaculture

A. Characteristics of Aquaculture

Although aquaculture, especially the culture of fish in ponds, originated many centuries ago, it is practiced on a large scale only in relatively few countries. Food production from this source has been significant in Asia and the Far East, but the overall importance of aquaculture in human nutrition came to be recognized only in recent years. Studies on quantity and quality of world food supplies in relation to increasing demand and popualtion growth have shown that a much greater proportion of our future animal protein requirements can be met by aquatic farming.

Many of the national and international fish stocks, especially those of high value, are fully or over-exploited, and are in need of strict management measures, even to maintain the present level of production. There are still some areas and stocks from which increased production of valuable wild fish is possible, but most new development is expected to yield catches of low-value species. The political and practical problems of managing international fisheries, which are currently under international discussion, have also served to focus the need to develop fishery resources within national boundaries where effective control can be easier. The trend toward exercising greater control over the sources of food production and the adoption of 'husbandry' to replace or supplement 'hunting' has therefore become increasingly evident in recent years.

Aquacultural practices range from propagation of aquatic organisms under complete human control with considerable sophistication, to the manipulation of at least one stage of an aquatic organism's life before harvest for the purpose of increasing its production and yield. Seven types of culture, each with its own goal can be recognized, viz:

(a) culture for food production

(b) culture to improve natural stocks through artificial recruitment and transplantation

(c) culture for the production of sport fish

(d) culture of bait for commercial fishing

(e) culture of ornamental fish

(f) culture for the recycling of organic wastes

(g) culture for industrial or other similar purposes (fish for reduction to meal or fertilizer; production of culture pearls, etc.)

B. Socio-Economic Aspects of Aquaculture

Although aquaculture is of importance in one way or the other in most countries, it is of special significance in the developing world. As a means of producing food and particularly animal proteins, it has several advantages. In particular, unlike in commercial fishing where production depends to a significant degree on uncontrollable natural variables, the limitations of production in aquaculture are directly related to the inputs. This is regardless of the nature of the medium: fresh, brackish or salt water.

The type of culture adopted in any country is greatly influenced by the local socio-economic conditions and needs. High-priced species like eel, shrimp and certain oysters are cultured mainly for the luxury or tourist market, or for export to earn foreign exchange. However, the bulk of world production is clearly for human consumption, and at least 75 percent of the current production serves directly as food of the common man in the countries of production. The tilapias, common carp, Chinese and Indian carps, milkfish and mussels constitute a good proportion of these.

Fish farming has been an integral part of rural development in some countries. By combining fish culture with pig, cattle or duck raising, and in some cases with rice cultivation, small scale farming practices have been evolved which contribute substantially to rural economy and nutritional standards. It is of special significance in developing countries that aquaculture can be carried out at different levels of organization and sophistication. While large-scale commercial operations should be promoted under certain conditions, aquaculture can also be very successfully undertaken by the small farmer with limited capital investment. In fact, much of the development so far has been along these lines.

Due to the lack of adequate and reliable statistics, it is difficult to make an accurate assessment of the present production and economic role of aquaculture. Based on available information from 43 countries (including China), the world production through aquaculture (excluding sport, bait and ornamental fish and pearls) is estimated as follows:

		Production in thousands of tons
1.	Finfish	3 680
2.	Shrimps and prawns	14
3.	Oysters	711
4.	Mussels	180
5.	Clams	56
6.	Other molluscs	20
7.	Seaweeds	373
		5 034

A breakdown of these data on a regional basis indicates the current relative importance of the industry in different regions. Clearly it is of the greatest magnitude in Asia and the Far East. In many of the countries of this region, such as China, India, Indonesia and the Philippines, aquaculture contributes a significant proportion of the fish and shellfish consumed. Being a labor-intensive operation at present, it provides full and part-time employment to large segments of the rural populations. For example, milkfish culture in Indonesia provides employment to about half a million people; in the Philippines over 170 000 people are employed in this industry. In Korea, aquaculture employs about 130,000 full-time and some 300 000 part-time workers.

Aquaculture production in different regions
(in thousands of metric tons)

	Finfish	Shrimps & Prawns	Molluscs	Seaweeds	Total
Asia and the Far East	3 287	14	366	373	4 041
Europe (including U.S.S.R. and Israel)	329		202		531
North America	40		355		395
Latin America	20		43		63
Africa	4				4
TOTAL	3 680	14	966	373	5 034

Profitability depends on a number of variables, few of which have been adequately assessed; as in most industrial and agricultural enterprises, there are profitable and non-profitable operations. Some examples of the ratio of profit on operating costs would illustrate the magnitude of variation. (Capital costs were omitted because of the wide variation in site and fixed input-related costs at current rates. They are listed in Pillay, 1973[1/].)

1/ Pillay, T.V.R. The role of aquaculture in fishery development and management.
Technical Conference on Fishery Management and Development, Vancouver, Canada, 1973 (Mimeo)

		Ratio of profit to operating costs	Ratio of profit to gross income
		%	%
(i)	Rainbow trout pond culture in Ireland (1970)	107.9	51.9
(ii)	Rainbow trout culture in floating enclosure in Norway (1969)	95.2	48.7
(iii)	Common carp culture in a State Farm in Poland (1969)	29.8	23.0
(iv)	Pond culture of Indian carps in West Bengal, India (1971)	28.8	22.3
(v)	Polyculture of grey mullet and Chinese carps in ponds in Hong Kong (1972)	60.1	37.5
(vi)	Milkfish culture in ponds in the Philippines	125.7	55.6
(vii)	Yellowtail culture in net cages in Japan (1971)	26.6	-
(viii)	Channel catfish farming in ponds in Mississippi, U.S.A. (1967)	71.4	41.6
(ix)	'Extensive' type Penaeid shrimp culture in ponds in Thailand (1970)	78.0	49.0
(x)	Intensive shrimp culture in ponds in Japan (1970)	40.7	28.9
(xi)	Oyster culture in Japan	15.8	13.6

C. Status of Certain Aquacultures (by H. S. Swingle, Auburn Univ.)

Following is a short description of the salient features and present-day status of selected aquacultures.

1. Carp Cultures

Carp cultures are the oldest of the aquacultures, with its origin in China a thousand or more years B.C. The carp cultures of today may be grouped under culture of Chinese carps, common carp, and Indian carps. None of the carps spawn in ponds at the densities normally used in cultures.

2. Chinese Carp Culture

This is a polyculture, combining fishes of different feeding habits. It includes the plankton feeding silver carp, Hypophthalmichthys molitrix; grass carp Ctenopharyngodon idella; bighead carp Aristichthys nobilis, a feeder on larger sized plankton; black carp Mylopharyngodon piceus, a benthic feeder; common carp, Cyprinis carpio, an insect eater; and miscellaneous other fishes. An excellent discussion of their interrelationship is given by Tang (1970).

This is a very efficient combination and contains two outstanding species. The silver carp is perhaps the most efficient plankton feeder used in any culture, screening out the small particles through a sieve-like plate on the gill arches. The White Amur or grass carp is very effective in utilizing higher aquatic plants. The culture of these species began in prehistoric times and continues today in China, Taiwan, and with immigrants from China into various parts of Southeast Asia. This is a freshwater culture, and is also used in waters with salinities up to 9 ppt.

3. Common Carp Culture

This species is probably the most widely cultured of all fishes. It was introduced from Asia to Europe in the middle ages, where its culture was highly developed. From there it spread to all other continents. Its culture in ponds was developed to high intensity in Israel, where production of 3,000 kg/ha/yr is obtained by feeding. In Japan, it is raised in a pond-raceway-type culture, with production up to 960,000 kg/ha/yr.[1/] (76 to 243 kg/m^2 of raceway), (Chiba, 1970). Chiba calculates the relationship between X (liters of water per second per m^2 of raceway surface) and Y (kg fish/m^2 yield) as $Y = 12.32 X + 25.7$.

In the U.S., its introduction has been widely deployed, but few studies have been made to determine its desirable contribution to fish populations. Experiments at Auburn, where it was used for control of Pithophora indicated that its presence probably increased production of sport fish (bluegill-redear-bass).

4. Indian Carp Culture

This also is a polyculture that came into use in India in the distant past, and consists of 3 to 5 carps native to rivers in India. The principal species are: Catla catla, Labeo rohita, L. mrigala, and L. calbasu.

In recent tests at the Cuttack Station, the silver carp of China proved more efficient than catla. This polyculture is used today only in India, East Pakistan and neighboring

[1/] Preliminary--depending on finalization of research.

countries, and is confined to freshwaters.

5. Tilapia Culture

The tilapias are probably next to the carps in universality of culture, being used to greater or less extent on all continents where water temperatures permit. They grow in waters with salinities up to 34 ppt and tolerate up to 60 ppt The cultural methods used include the following:

a) Raising males and females together, with feeding and continuous harvest of the larger fish.

This is a primitive method that cannot be expected to yield large harvest of fish, and requires excessive amounts of labor for harvest.

b) Monosex culture

1) All male-hybrids

All-male progeny are produced by crossing *T. hornorum* males with either *T. mossambica* females, or with *T. nilotica* females.

2) All-male culture by selection

Progeny of a single species with 50-50 sex ratio are grown to 10 to 20 gram size, when males only are separated out for culture and females discarded.

A variation of this is crossing two species of tilapias that give approximately 70 per cent males, growing them to 10 to 20 gram size and separating the males for culture. This procedure is used in Israel for monosex culture of T. aurea x T. gallilea or other tilapias.

c) Culture of tilapia too young to spawn

Small tilapia fingerlings are stocked into production ponds at 20,000 to 30,000 per ha and grown rapidly by feeding to size of 45 to 60-gram at which time spawning begins. The stocked fish are harvested after light spawning has occurred and these fish used for restocking. This culture can produce only small-sized harvestable fish by the time first spawning occurs. A similar cultural method was used for culture of the catfish Ictalurus nebulosus (Swingle, 1957).

d) Polyculture of tilapia with piscivorous species

This type of culture is used in Thailand, using the sea bass (Lates calcarifer) or pla chon (Ophicephalus striatus) as the piscivorous species. In the U.S., largemouth bass (Micropterus salmoides) was used for a similar purpose (Swingle, 1960). For the cultures, no attempt is made to establish balanced populations, and sufficient piscivorous fishes are stocked to eliminate most of the small tilapias. In culture including the sea bass, tilapias are used primarily as food for the bass, with production of harvestable tilapia of incidental importance.

6. Trout and Salmon Cultures

These fishes are grown in fresh, brackish or sea-strength water. They are traditionally cultured in raceways using flowing water from springs, wells, or streams. They do not spawn in ponds or raceways during culture. Their culture has spread to all continents in areas where water temperatures range from 12 to 25 C for a sufficiently long period annually to allow rapid growth.

Most of the early information dealing with fish feed formulation was developed for trout culture by the Cortland Station of the U.S. Fish and Wildlife Service. The problems relating to pollution in flowing cultures has been discussed previously. Production from raceway culture varies from 5,000 to over 400,000 kg/ha of raceway, depending on the rate of water exchange, stocking and feeding.

The most recent development in this field has been the rearing of trout in sea waters, first developed in Denmark (Bardach, 1968). In the U.S. annual production from trout cultures ranges from 8 to 10 million pounds annually.

7. Catfish Culture

Three species of catfishes have been used in important cultures. These are the channel catfish, Pangasius and the walking catfish.

a) Channel catfish culture

This is a recent development in the U.S. The culture is principally in freshwater ponds, with some in raceways and in cages. This spedies does not spawn except to a small extent in either ponds or raceways at the population densities used in cultures.

Feeds used are supplemental or complete pelleted formulation, largely based on the requirements for trout. Production ½er ja pf ½pmd ½er uear ramges frp, 1,500 tp 3,000 kg, in cages from 90 to 200 kg/m^2 of cage in 4 to 5 months. Culture in raceways has not been adequately evaluated, but would approach that of trout. Production per year in the U.S. reached 15.9 million kg. in 1971, and is rapidly rising.

Limiting factors in need of solution are development of year-round harvest for market, disease problems, problems with off-flavors in the flesh, prevention of fish kills, and disposal of wastes from cultures. Similar problems are encountered in all cultures.

8. Pangasius culture

Pangasius sutchi has been cultured for over 70 years in cages floating in rivers of Thailand and Cambodia. This culture was developed by local river-dwellers, without benefit of research. This catfish does not spawn during culture. Young are obtained from rivers or swamps. Feed used is chopped weed Ipomea plus cooked broken rice, rice bran, kitchen wastes, and trash fish (Thiemmedh 1957).

Culture requires 2 years at end of which the fish average 2 kg. Production ranges from 10 to 20 kg/m^2 of cage.

9. Walking Catfish Culture

Clarias batrachus culture was developed in Central Thailand by farmers without benefit of research. This species is an air-breather and does not spawn in ponds under conditions of culture.

The young are collected from nearby canals and stocked into ponds at the rate of 50/m^2. Feeding is with a ground mixture of trash fish and rice bran. Since the fish is an air-breather, heavily polluted waters have little effect and they were found living and doing well at zero dissolved oxygen and 200 ppm free CO_2. However, heavier pollution throws them "off feed", at which time the grower replaces part of the polluted water with fresh water from a well or roadside canal. Production is of the order of that normally expected in flowing water culture. Pond production in 6 months of culture ranged from 13,000 to 30,000 kg/ha. Two crops yearly are expected.

The fish remain in the ponds until harvest and have not been noted to pose any danger to passing pedestrians or cars. Also, they are a minor part of the natural fish populations in rivers and reservoirs in Thailand, as predatory fishes keep them well in check. They are considered a desirable fish in Southeast Asia and sell for a premium price on most markets (Sidthimunka et al, 1968).

The culture of this fish is interesting because its air-breathing ability makes inoperative many of the principles of fish production that apply to underwater gill-breathers.

10. Milkfish culture

Chanos chanos is a marine fish, spawning offshore in warm waters from Formosa southward. The young migrate to the shallow shores and into estuaries where they are captured for culture principally in Formosa, Philippines, China, Viet Nam and Indonesia. The largest area of chanos ponds is in the Philippines, where over 100,000 ha of brackish water and sea water ponds are used for their culture. The most intensive culture is that practiced in Taiwan where production up to 3,000 kg/ha was obtained by fertilization plus light supplemental feeding (Lin, 1968). These fish feed on benthic periphyton and upon both living and decaying filamentous algae. The Taiwan system consists of 3 stockings of small Chanos, with 3 harvests before final draining of the pond in the fall. In most Taiwan ponds, the milkfish is cultured in sea-strength water that may rise to 70 ppt salinity in dry weather. The fish is also used as part of a polyculture in freshwater ponds. They can be raised from fingerlings to harvestable size 300 g or larger in 4 to 5 months. This is one of the most important cultures in Southeast Asia and neighboring islands.

11. Culture of Molluscs

The most important of the mollusc cultures are those for oysters (Ostrea sp. and Crassostrea sp.) and those for mussels (Mytilis smaragdinus, M. edulis). These cultures are in brackish water or seawater with salinities from 16 to 34 ppt.

These cultures are different in that the seed molluscs are caught on various types of collectors and then placed out in suitable locations either on the bottom of bays, as with oysters in the U.S., or suspended in the top waters on lines of evenly-spaced collectors, attached to rafts, horizontal poles or long-line ropes.

In Taiwan and the Philippines oysters set on clean bamboo or wood stakes driven into the bottom muds, where they grow to harvestable size. A similar method is used for the mussel Mytilis smaragdinus in the Gulf of Thailand.

These cultures at present involve neither fertilization nor feeding. The cultured animals remain in fixed positions and feed upon whatever food particles of suitable size are brought to them by water currents. In most countries the bays where oysters and mussels are cultured receive large amounts of sewage which is in itself a relatively effective fertilizer.

A low level of culture exists for the Arch shell clam (*Arca* spp.) in the Gulf of Thailand, where the grower gathers the young animals in areas where they are too abundant and plants them at lesser concentrations in his fenced-in farm in the Gulf. This is similar to the "culture" of oyster practiced in parts of the U.S. in the estuaries, but without fencing.

12. *Shrimp Culture*

Shrimp cultures generally belong in two groups--that for *Macrobrachium* species and that for *Penaeid* species. The principal difference is that the final stage in production to marketable size occurs in freshwaters for the former and in brackish water or sea water for the latter.

The Macrobrachium shrimp are often called freshwater shrimp. However, all species of the group studied so far apparently must migrate to brackish water of 15-20 ppt salinity for spawning because their planktonic stages will die if salinity drops below 10 ppt. Procedures for rearing *Macrobrachian rosenbergii* from egg to juvenile stage have been developed in Malasia, Taiwan, Thailand and Hawaii, but no successful commercial method for intensive monoculture to harvestable size has yet been devised. (Fujinura and Okanota, 1970;

Swingle and Smitherman, 1969; Swingle and Allison, 1971). Their use as a supplemental species in commercial fish culture shows some promise.

In the U.S., similar success in raising M. carcinus has been achieved (Costello, 1971). No successful commercial methods for their culture has yet resulted.

The success of Dr. M. Fujinaga of Japan in production of juvenile Penaeus japonica is now well-known and various modifications of the method are used in the U.S. for other species. In Japan a small commercial culture of shrimps for market sale alive resulted. This consists of 14 farms, the largest of which utilized 20 ha of ponds. The feeds used for shrimp in production ponds were primarily clam, shrimp, fish, squid, and other meats. Conversions were 10 to 15, with maximum production approaching 2,500 kg/ha/year. Cost of production and marketing were estimated at approximately $7 per kg and they can be sold alive on the market at $7.50 to $30 per kg in Japan. However this cost of production is too high for profit elsewhere. Problems adding to the cost are high price of feeds, low survival, low production, and high labor cost. Shigeno (1970) gives an excellent discussion and suggestions for improvement in production of juvenile shrimp, but reports no advances in in production of market-sized shrimp.

Research to develop shrimp farming as a profitable operation is continuing in most coastal countries in Asia, principally in Japan, Taiwan, Philippines, Thailand and India. Well-financed efforts are being made in the United States and in Latin America. While some progress has been made in production of juvenile shrimps the principal problems of commercial culture remain unsolved. These include development of suitable feeds and feeding rates that can produce 1 kg shrimp with not over 2 kg of feed, methods of culture that give consistently high survival and production of over 1,000 kg/ha, low cost methods of harvest, economical and reliable methods for maintaining high oxygen and high water quality in the culturing area, and effective controls for disease.

D. Specific Examples of Important Aquacultural Operations

1. Culture of Eel in Taiwan[1/]

Total water surface devoted to eel culture increased from about 600 ha. in late 1971 to 1,058 ha in 1972. Total value of eel exported to Japan in 1971 exceeded US $10 million. (5 return = $10,000/ha).

Elvers are stocked in March and begin to reach market size in June at which time they are harvested almost on a daily

[1/] Eel farming in Taiwan by T.P. Chen: Presented at Joint National Science Foundation (US) - Chinese National Science Council (CNSC) Workshop, La Jolla, Calif., April 10-14, 1973.

basis by placing net of particular size under the feeding platform prior to feeding the eels. During feeding operation net is raised to surface and smaller eels simply drop through the net while larger ones are retained for marketing locally or for export.

A. Production Expected & Obtained - Mono & Polyculture

(a) pond with continuously running water = 35,000 kg/ha/year

(b) pond with nightly addition of freshwater (2-5 am) plus aeration ----- = 20,000 kg/ha/yr

(c) pond with aeration plus stocking Chinese carps ________ = 15,000 kg/ha/yr Eels; 1,000 kg/ha/yr Carps

(d) large ponds without aeration or water exchange ________________ = 6,000 kg/ha/yr Eels; 4,000 kg/ha/yr Carps & mullet

B. Economic Data

Presently eel farmers receive \$5/kg for eels while production costs are averaging \$4/kg. Greatest cost component is trash fish used as food and for young elvers for stocking.

2. Fish and Duck Culture (Thailand, Philippines, Taiwan)

A. Ponds are usually fenced to prevent ducks from wandering. About 600 ducks/ha are utilized plus polyculture with fish.

B. Approximately 3000 fish fingerlings are stocked:

Bighead carp	600/ha	
Common carp	600/ha	3000 fingerlings/ha.
Grass carp	600/ha	
Silver carp	1200/ha	

Ducks are fed rice bran and soybean meal daily.

C. Production: (in addition to duck eggs or duck meat)

3000 kg/ha fish annually or

6000 kg/ha if fish also are fed.

White duck used for meat

Native duck used for egg production

ducks sell at 50 to 60¢/kg live weight

eggs sell at a higher price

Fish sell at $0.50/kg (average for all species)

3. Example From "Coastal Aquaculture in the Indo-Pacific Region (T.V.R. Pillay, Fishing News, Landon, p. 497)

Area under aquaculture and manpower employed in selected countries of the Indo-Pacific Region.

Country	Area (ha) Already Developed	Area (ha) Additional for Development	Manpower Full-Time	Manpower Part-Time
Taiwan	27,611	10,000	5,000	10,000
Indonesia	165,000	400,000		
Korea	27,549	168,858	129,600	299,550
Philippines	166,000	500,000	160,000	10,000
Thailand	20,000+	500,000+	-	-
Vietnam	2,600	150,000		

V. Development Potential of Aquaculture

A. Introduction

Several projections of global increases in production have been made. In a report on the world food problem, the President's

Science Advisory Committee (1967)[1] predicted an increase in yield of 15 million tons through pond culture alone by the year 2000, if research could provide the management inputs. FAO's indicative World Plan for Agricultural Development (1969)[2] considered an expansion factor of five by the year 1985 as feasible. Bardach and Ryther (1968)[3] estimated an increase of ten times by the year 2000, which would result in a world production of 40-50 million tons annually. The latter estimate seems justified. In fact, this may be conservative because it omits various presently unassessable items, the most prominent of which are increases through application of new techniques.

B. Expansion of Areas under Culture

Swamps and low-lying areas with assured sources of water are usually selected for pond construction. Data available from FAO show that over 2½ million hectares are now under pond culture of finfish. Since the area of ponds in three of the major aquaculture producing countries is not included in this estimate, it is obviously an underestimate. The area is probably in the order of 3-4 million ha.

Preliminary and incomplete surveys have indicated that in addition some 11.3 million ha of freshwater swamps and 9.7 million ha of brackish and saltwater swamps and other tidal lands are suitable

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1/ President's Science Advisory Committee, The World Food Problem - A report 1967 of the President's Science Advisory Committee. Vol. II. Report of the Panel on the World Food Supply. The White House, Washington, D. C.: 772 p.

2/ FAO. Provisional Indicative World Plan for Agricultural Development 1969 Vols. 1 and 2, 672 p.

3/ Bardach, J.E. and J.H. Ryther, The Status and Potential of Aquaculture. 1968 Vol. II, U.S. Dept. of Commerce: 225 p.

for pond culture of finfish in eleven countries of the Indo-Pacific
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region. A worldwide country by country survey is certain to identify many times more new area. The total may be as much as 30 million ha.

The estimates above do not in all cases represent areas identified as suitable for aquaculture after ecological studies and cite investigations. Detailed surveys are therefore required to evaluate the expansion potential accurately.

In spite of the deficiency of data and the various expansion constraints that exist, it can be assumed that at least a ten-fold increase in the area presently identified as pond culture is feasible by the end of the century.

It is difficult to make reliable estimates of the area available for other forms of culture, such as those in cages and enclosures. But nearly a million hectares of small reservoirs are presently used for fish production through stocking in seven countries (Pillay, 1973[1/]) and this is undoubtedly a very small percentage of such waters now used or available for use.

There are large potentials for expanding fish farming integrated with rice cultivation and animal production. There are some 61,000 ha of rice fields now used for fish culture in Indonesia, and large areas in India, China and elsewhere support such activity. But rice field fish culture has received a set-back in some countries due to the widespread use of pesticides.

The area used can be considerably expanded in the use of persistent pesticides can be controlled. For example, rice field prawn

1/ Pillay, T.V.R., The role of aquaculture in fishery development and
1973 management. Presented at the Technical Conference on Fishery Management and Development. Vancouver, Canada, 1973 (Mimeo)

farming in India and carp and tilapia farming in rice fields in Madagascar, are capable of further expansion. According to an estimate made in 1967, if fish culture were conducted in only 30 percent of the existing 35.6 million ha of rice fields, even at a very low rate of production a yield of 2.2 million tons of fish can be obtained. The possibilities of expanding duck- or pig-fish raising appear very considerable, especially as part of integrated rural development.

The global yield of oysters and mussels at present is just below one million tons. Sheltered and relatively shallow areas of lakes, reservoirs, lagoons, estuaries and fore-short areas of the sea suitable for open water systems of oyster and mussel farming and other systems may be at least a hundred million hectares.

IV. A Comparison of the Economic Potential of Aquaculture (Taiwan)[1/]

A. Introduction

The need for a substantial increase in the world supply of animal protein has stimulated interest in aquaculture in recent years. There are essentially two schools of thought on the question of the contribution of aqua-farming to alleviate the problem of protein shortage in the coming decades. The pessimists (Ehrlich and Ehrlich, 1970) state that sea farming offers no hope at all for the immediate future. However, the optimists (Bardach and Ryther, 1968) suggest that aquatic animal husbandry is one of the valuable weapons to be deployed in the attack on protein deficiency. The latter speculate that it may be cheaper to grow some aquatic rather than land animals for food because of faster growth rate. They also surmise that the rate of return on investment may be higher in certain aquacultural

1/ Yunge C. Shang, University of Hawaii (undated) ventures than in ocean fishing because the latter deals with common property resources.

Most of the current studies have focused on the technical and biological aspects of aquaculture. Whether it will realize its economic potential is not known with certainty, as little information is available on the economics of aquaculture. This paper examines a few of the more frequently mentioned questions concerning the economic potential of aquaculture such as cost of production of cultured fish as compared with those of animal meats, the rate of return on investment in aquaculture as compared with those in ocean fisheries, and demand for cultured fish.

The information presented here for Taiwan is significant because, of different types of aquaculture, ocean fishing and animal husbandry in one country. Taiwan's aquaculture, ocean fishing and hog industry, are very advanced and there is a rapidly growing demand for animal protein due to the increase in population and real income.

B. Aquaculture vs. Animal Husbandry

The nutritive value of food products was for a long time judged predominantly in terms of calories. Research of the last few decades has indicated that an adequate amount of high-quality protein is a vital condition of full nutrition. Fish products are rich in protein; in many cases protein content is even greater than that of land-based livestock. Nutritionally, fish products can replace meat from land animals. The two differ in tast, of course, but in terms of comparisons of the efficiency of production, this factor is unimportant.

Comparisons are available on yield per acre or on productivity of labor between some aquatic and land animals in different countries

(Bardach, Ryther, and McLarney, in press). These comparisons are interesting but incomplete, since labor (or land) is not the only input. Comparisons of the production functions of aquaculture and agriculture would be more significant. Unfortunately, data to derive these functions are not readily available. In this paper, the cost o production per unit of output and per unit of protein are estimated and compared.

Fish culture in Taiwan is classified into three types: the brackish water culture, mainly milkfish; the fresh water culture, carps and tilapia; and the shallow sea culture, mainly oysters. Fish fry, feed and fertilizer[1] are the major cost items of brackish and freshwater fish farming, representing about 62 and 53 percent of the total production cost respectively. In the case of shallow sea farming, bamboo stakes and fish fry are the major cost items, accounting for about 43 percent of the total production cost. Brackish water farming has the lowest productivity per man-year, but highest yield per hectare and highest cost of production per unit of output (Table 1). The low labor productivity of brackish water fish farming reflects a relatively labor intensive operation while the high cost of production is mainly due to the high cost of fish fry, which is about twice as much as that of fresh water fish farming and about five times as much as that of shallow sea fish farming per unit of output. All milkfish fry are collected

1 The purpose of the fertilizer is to increase the natural algae which the species prefers as food.

from coastal waters. Yearly fluctations in the supply of fry have been a serious problem confronting the milkfish farmer.

Hog raising is the most important and well established animal industry in Taiwan. The average productivity per man-year is higher than brackish and fresh water fish farming under average management conditions, while the cost of production (per pound) of hog is much higher than those of all three types of fish farming. The difference in cost of production between fish farming and hog raising is mainly due to feeding costs. The conversion ratio of dry feed to hog is 3.83:1, while the ratio of dry feed and fertilizer to fish (milkfish) is 3:1 (Liang and Huang, 1970). It costs about $0.39 of feed to produce one pound of hog, while it costs only about $0.09 and $0.07 of feed and fertilizer to produce one pound of fish for brackish and fresh water fish farms respectively. No feed and fertilizer are necessary for shallow sea fish culture.

TABLE 1

PRODUCTIVITY AND PRODUCTION COST PER HECTARE FOR DIFFERENT TYPES OF WATER AND LAND ANIMAL HUSBANDRY

Type of Husbandry	Kg/man-year		Kg/hectare		Cost/kg	
	Ave.[c/]	High[d/]	Ave.[c/]	High[d/]	Ave.[c/]	Low[d/]
					(U.S. $)	
Brackish water[a/]	5,098	11,022	2,112	2,687	0.37	0.29
Fresh water[a/]	10,453	70,607	1,537	2,413	0.31	0.20
Shallow sea[a/]	45,575	-	1,292	2,096	0.16	0.10
Hog[a/]	12,000	-	-	-	0.43	-

a/ Derived from Report on the Sampling Survey of Production Cost of Private Private Fisheries in Taiwan, Taiwan Fisheries Bureau, 1966.
b/ Derived from Annual Report of Livestock Operation, Taiwan Sugar Co., 1968.
c/ Under average management.
d/ Under superior management.

The protein content of pork and selected fishes is presented in Table 2. With this basic information, the productivity of labor and the cost of production of per unit of protein are calculated and shown in Table 3. All the cost figures in the above table are in favor of aquaculture. In terms of protein, fish is less costly to produce than pork.

It is expected that the cost of production will decrease in the future, with advances in technology and management practices. In contrast, the hog industry is well established and the cost of production is not likely to decrease as much as that of fish farming.

Fish is also the cheapest source of protein in Taiwan. The nutritional value of one dollar's (New Taiwan $) worth of selected foods is listed in Table 4. The amount of protein contained in one dollar's worth of fish is the highest among all of the selected foods. It is 45%, 58%, 47% and 32% higher than that of meat, poultry, eggs and vegetables respectively.

Neither the low cost of production nor the low price of fish is sufficient to ensure that a huge potential exists for aquaculture. Such a potential depends mainly on the effective demand for fish which is a function of price, tast, preferences, competition with other foods, and income levels, and how much of this fish market cultured fish can share.

Fish satisfies an important dietary requirement of the people in Taiwan. The 1965 Food Balance Sheet shows that fish accounted for 63 percent of the animal protein intake of the population. The per capita consumption of fish in Taiwan was 70.4 pounds in 1968, compared with 52.8 pounds of pork and 11.0 pounds of poultry respectively. Per capita fish consumption increased about 90 percent during 1953-1968, while per capita pork consumption increased about 60 percent. The estimated income elasticity of demand is .50 for fish (Chu, 1970) and .60 for pork (Chang, 1970). The faster rate of increase in per capita fish consumption in the past was probably due to the relatively favorable price. The price of fish in constant dollars has been decreasing while the price of pork has been increasing.

Real per capita income increased about 7.3 percent annually during 1960-69 and population increased about 3.3 percent. If the present situation continues, other things remaining equal, the demand for fish will still be strong in the future and experience an estimated 7 percent increase annually. How much cultured fish shares in this growing fish demand depends on the relative cost, price and preference of pond-raised and wile fishes, which will be discussed in the next section.

TABLE 2

NUTRIENTS IN THE EDIBLE PORTION OF ONE POUND OF PORK AND SELECTED FISHES

	Protein	Fat
	(percent)	
Medium Fat Pork (carcasses)[a/]	8	41
Milkfish[b/]	20	2
Oyster[b/]	10	4
Carp[b/]	22	9

a/ Composition of Foods, U.S. Dept. of Agriculture, 1963.

b/ From Joint Commission on Rural Reconstruction, Taiwan.

TABLE 3

ESTIMATED COST OF PRODUCTION OF PROTEIN

	Protein/man-year		Cost/1000 grams	
	Ave.	High	Ave.	Low
	(1000 grams)			
Brackish Water	519	1,123	$3.63	$2.84
Fresh Water	1,148	7,759	2.80	1.81
Shallow Sea	4,552	-	1.60	-
Hog	757	-	6.81	-

TABLE 4

NUTRITIONAL VALUE OF ONE DOLLAR'S WORTH OF SELECTED FOODS

	Calories	Protein	Fat
		(g)	(g)
Fish	67	10.1	2.6
Meat	110	5.5	9.8
Poultry	25	4.2	1.3
Eggs	63	5.3	4.6
Vegetables	123	6.8	0.6

Source: Consumer Survey of Fishery Products, Taiwan Fisheries Bureau, 1964.

C. Aquaculture vs. Ocean Fisheries

The cost structures of aquaculture and ocean fishing - labor not considered - are different. The capital cost in ocean fisheries is the boat and gear while in aquaculture it is the construction of ponds and equipment. Fuel and oil and bait are the major operating expenses in ocean fisheries. In aquaculture, fish fries, feed and fertilizer are the major operating expenses as mentioned earlier.

The ocean fisheries of Taiwan are also classified into three types: deep-sea, inshore and coastal fisheries. The catches of the deep-sea fishery are mainly tuna and tuna-like fishes for export. There is little in the domestic fresh fish markets.

The cost of production per unit of output is much lower in ocean fisheries than those of brackish and fresh water fish farms:

	Ocean Fisheries	
	Inshore	Coastal
Cost of production per kg.	$0.17	$0.15

However, the profit margin of fish farming is higher than those of ocean fishing due to higher prices which, in turn, are due to better product quality and consumer preference. The internal rates of return on investment in aquaculture are almost double that in ocean fisheries under the present conditions (Table 5). This may encourage efforts to expand production.

The price elasticity of medium-priced fish is estimated about -.86 (Chu, 1970). If this figure is reasonably representative of cultured fish,[2] it suggests that, other things being equal, the faster rate of

[2] Milkfish and carps are all included in medium-priced fish. However, price elasticity of demand for individual types of fish might differ from

increase in the production of cultured fish than that for demand, would decrease total revenue for the industry. However, other things are not likely to be equal. The cost of production in aquaculture is expected to decrease over time due to the advance of technology and management practices. In contrast, ocean fishery resources are not only relatively fixed but common property in nature. The rapid growth of demand for fish will eventually lead to over-fishing thus reducing the stock and increasing the cost of production per unit of fishing effort. The catches of coastal fisheries in Taiwan are already declining as a result of over-fishing and pollution. Of course, over-fishing would not present a problem to the aquaculturist who would own or lease rearing sites. With proper management and intelligent site selection, water pollution can be kept to a minimum. This is especially true for fresh water aquaculture.

TABLE 5

ESTIMATED INTERNAL RATES OF RETURN ON
INVESTMENT IN AQUACULTURE AND OCEAN FISHERIES

	Internal Rate of Return
Brackish water culture	35%
Fresh water culture	34%
Shallow sea culture	32%
Deep-sea fisheries	20%
Inshore fisheries	11%
Coastal fisheries	16%

At present, pond-raised fish contributes much to family nutrition in Taiwan; Aquaculture accounted for about 22 percent[3] of the total fishery production in 1970, excluding the deep-sea (export) fishery. Milkfish, with a production of 27,857 metric tons, led all species, followed by carps, 15,664 metric tons, oysters, 13,072 metric tons, and tilapia, 11,358 metric tons. In terms of quantity milkfish accounted for moje than one-third of the total production from aquaculture. Based on a consumer survey (Taiwan Fisheries Bureau, 1964) of 1,000 families, 592 families indicated that milkfish is the most frequently purchased fish. It is preferred by both urban and rural families. Carps and tilapia are also among the well-liked fish produced from fresh water ponds, the former being purchased mostly by urban families while the latter is rural fare. Though oysters are not purchased as often as the other species, it is a very low-priced shellfish rich in protein. Though oyster production may be enhanced by marketing promotion the status of oyster culture begins to be precarious because of estuarine pollution (Bardach, pers. communication).

It should be less costly to create a demand for fish produced in aquaculture facilities than for wild fish. Quality control is easier. Fish farmers would be able to guarantee delivery of a certain amount and quality of fish which is sometimes not possible for ocean fisheries. Another advantage of aquaculture is that fish farmers could control production and could market their stock at times when natural supplies are seasonally low or unavailable for other reasons. Aside from being a valuable supplement to ocean harvesting, aquaculture also offers the possibility for species improvement by

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[3]Most of aquacultural productions are consumed locally, except a portion of eel and shrimp production is exported.

selective breeding to meet consumers' tastes and marketing requirements (Table 6).

TABLE 6

PER CAPITA INCOME AND PER CAPITA DAILY SUPPLY OF PROTEIN IN SELECTED ASIAN COUNTRIES, 1968

	Grams of Animal Protein Per Day	Grams of Total Protein Per Day	National Income Per Capita ($)
Japan	28.2	74.7	928
Taiwan	23.9	68.2	221
Indonesia	4.5	38.2	95
Thailand	9.9	46.0	127

Source: Pedro Belli, "The Economic Implication of Malnutrition: The Dismal Science Revisited", Economic Development and Cultural Change, University of Chicago, October 1971.

VIII. Deficiencies and Apparent Needs of LDC's in Aquaculture

A. Research

(1) Research Priorities

The most effective way to reinforce present research efforts appears to be to concentrate strongly on limited scientific problems of importance and urgency for developing countries applied to a small number of species: These are carps, catfish, tilapia, milkfish, mullets and shrimps.

The highest priority for the most fruitful new research effort lies in the fields of reproductive physiology and selective breeding. A high priority exists in the realm of food and feeding, but that this research is not conducive to centralization. High priority research is also required on diseases and the broad spectrum of water quality problems related to the cultured animal and its aquatic environment.

On Economics and Marketing, while preliminary indications are available that favor the integration of aquaculture into the food chain, no thorough economic analysis has yet been made. An economic assessment of the economic role and potential should proceed, or coincide with movements forward on production research and adaptative practices.

(2) Research organization

In considering the framework necessary for the rapid achievement of research objectives as identified above, this paper recognizes the following realities:

(a) the intensive inter-disciplinary nature of the required research effort,

(b) the financial and technical inadequacy of existing national centers in developing countries for this purpose without infusion of outside assistance, and

(c) the differences that exist in various regions of the world in respect to ecological conditions, species available for culture, and socio-economic situations.

A need exists to develop one or more regional centers, with multi-disciplinary expertise and facilities to undertake the long-term and intensive research required. These centers should serve as lead institutions to a network of selected national laboratories which should be strengthened to enhance their ability to do research on problems of a local nature.

Such a network of research institutions should be established by a high-level international coordinating group associated with an international agency. The coordinating group should have broad experience in aquaculture development and have the main purpose of providing effective guidance and harmonization of such a global effort.

To have the most concentrated impact on aquaculture development, it would be desirable to undertake the research on the priorities previously stated in all the regions simultaneously. Lesser but still noticeable benefits could be achieved by carrying out high priority research in the regions where they would yield the best results when undertaken singly, or in groups. A task force would be necessary to determine suitable arrangements and sites.

The proposed research could be carried out in new centers or in existing centers strengthened for this purpose. The establishment of a network of existing national research as national cooperating outposts of the regional centers to investigate problems of a local nature within the regions is essential.[1/]

A supplementary approach worthy of consideration, and in no way in conflict with the global recommendations is the infusion of funds into important on-going aquaculture research projects in developing countries. This has a high likelihood of demonstrating quickly to funding agencies the high pay-off potential of aquacultural research, and provides the basis for wider and more complete support. Some examples of such projects are given below. They are by no means exhaustive, or in any order of priority.

(i) attaching a tilapia breeding and management unit to the African Live Stock Development Center;

(ii) seed and feed production aspects of on-going Indian carp research;

1/ Consultative Group on International Agricultural Research, Feb. 4-8, 1974 FAO, Rome.

(iii) seed survival research in an area where mullet is of great importance, such as North Africa and the Near East;

(iv) controlled breeding and seed production of milkfish in Asia.

C. Training and extension programs

Regional centers should offer short-term training in highly specialized technical subjects related to aquaculture for scientific personnel (research and technical staff) of national institutions. Training of field personnel, particularly extension workers, as well as short-term courses for farmers should be organized in selected national centers. Long-term degree education in aquaculture should initially be in universities or other institutes in developed countries, especially those that have active exchange or cooperative programs with developing countries. Later the advanced training should be transferred to appropriate national universities.

D. Information dissemination

The highly sophisticated and complex function of information collection, storage and retrieval, as well as the preparation of text books, manuals and extension material, should be undertaken in a central unit associated with an international organization which is active in both this field and in aquaculture development.1/

E. Improvement of Techniques

In developing countries most in need of animal protein supplies, the yield from finnish culture rarely exceeds 500 kg per hectare. Thus,

1/ Ibid

for example, expansion to potential new areas in the Indo-Pacific region (20 million ha) with even only the present low yields would result in a total annual production of 10 MMT.

Some indications of the potential for increased production through the application of improved techniques can be gleaned from results already obtained. The average production from commercial milkfish ponds in the Philippines was increased from 300-400 kg/ha to 1000-1200 kg/ha in a period of about five years through the improvement of culture techniques. In pilot areas in India, the average production of Indian carps was raised from 600 kg to 4000-5000 kg/ha over a period of only two years, through the adoption of moderately intensive polyculture techniques. Under favourable conditions, raft culture of mussels in Spain produces 4000 kg of meat per hectare of water surface. Although such yields will not be possible in the whole area of potential molluse production, the enormous potential for increased production through the expansion of such types of culture is evident.

It would therefore appear that application of improved techniques to existing and new areas would result in massive increases in total production. In the example used above, assuming even modest returns (a three instead of six-fold increase in yield) from transfer of existing technologies and their application to the expanded area (estimated at 20 MMT in the Indo-Pacific region), an annual production of 30 MMT of finfish might be expected.

Application of improved techniques, however, will be possible only to a limited extent at this time, due to a number of constraints. Technical constraints include assured availability of seed, development of suitable feeds, and efficient management methods, including disease control. For instance, application of the improved milkfish culture techniques will be restricted very soon by the inadequacy of natural seed supplies.

F. Development of New Systems and Techniques

Possible increases as a result of the development of new techniques are more uncertain. Innovations in cage and raceway culture are being developed, and efficient methods of culture in recirculating water systems are also being developed. Additional species suitable for culture are being sought. Such imaginative schemes as the artificial upwelling of deep nutrient-rich sea water, and the production of industrial fish (for fish meal) through sewage-based aquaculture are also being considered or investigated. Proteins from new sources such as agricultural wastes and yeast grown on petroleum products or wood pulp may eventually replace fish meal in feed formulations and reduce the cost of feeding fish. If the engineering and economic problems associated with new systems are solved, and the techniques become widely utilized, major increases in production will occur - perhaps greatly exceeding estimates so far put forward.

G. Trained Personnel

Nowhere, either nationally, regionally or internationally, is there sufficient personnel trained in aquaculture to implement the development of the industry on the scale recommended and which its potential warrants. This lack applies to scientists, technicians and extension workers.

The facilities for education and training in this subject are extremely limited. The majority of aquaculturists today are those who developed their expertise mostly through on-the-job training.

H. Information

The inadequacy of existing facilities for collection, storage and dissemination of information is a major constraint to all the activities concerning aquaculture. This is true not only in the less advanced countries; inadequate professional communications and inadequate availability of aquaculture data are major deficiencies throughout the world.

I. Policy, Development and Planning

A basic constraint to the development of aquaculture in most countries is the lack of a policy in respect of aquaculture, incorporated in the national development plans. This leads inevitably to inadequate or virtually no planning in this field of activity.

Constraints to the production aspects of aquaculture are interwoven with socio-economic policy-related problems such as competition for areas, water pollution and the like. The solution to the whole problem cannot be achieved unless its various constituent parts are solved.

J. Financing

Sources of financing for aquaculture development programs have been severely restricted. In most developing countries aquaculture is practised by small operators who have major problems in obtaining credit. In the present state of technology, many systems of aquaculture are frequently classed as high risk activity and this acts as a further deterrent to financing. The main capital investment in aquaculture consists of the cost of installations, and this varies with the type of culture and the nature of the sites.

IX. Technical Assistance Inputs Required to Expand and Intensify Aquaculture

A. Research to Improve Existing Techniques

Although aquaculture includes many diverse practices, it is possible to list research areas which are common to most if not all of them.

(a). Seed production

(b). Genetic improvement

(c). Natural food and artificial feed supply

(d). Water quality control

(e). Stock composition and space relationships, including polyculture

(f). Disease control

(g). Predator and competitor control

Priorities among these depend upon circumstances at the point of production. These priorities and the nature of research needed to increase the yield through existing aquacultural practices are set forth below for each of a small number of species groups judged to be of the greatest commercial importance and potential.

The species groups should be selected on the basis of the following considerations:

(a). The extent to which the species are presently cultivated in the developing world.

(b) The potential for expansion or intensification of their culture

(c) The probable response in terms of protein output to technical inputs

(d) The global pattern of protein shortage.

High potential species groups and their classification according to principal habitats are the following:

Species	Aquacultural habitat
Carps, catfish	Fresh water
Tilapia	Fresh and brackish water
Milkfish, mullets, shrimps	Fresh water, brackish water or marine

Common carp, Indian and Chinese carps and tilapia can be reproduced in captivity. In the remaining groups controlled reproduction and hence reliable seed production still presents a serious problem.

Two noteworthy characteristics of all these species, with the partial exception of shrimp and catfish, is that they are herbivores and omnivores and are generally consumed within the country of production. The shrimp, though feeding at later developmental stages at a higher and therefore more expensive tropic level, could nevertheless be an excellent revenue-earner. It may be noted that oysters, mussels and trout are not on the list. This is because their very great potential for increased production could be fulfilled largely by wider application of present techniques.

B. Socio-Economics Research on the Direct and Indirect Effects

The research on agriculture should be guided by the social and economics goals of the LDCs. The need is for appropriate technology reflecting concern with small farmers and overall rural developement. The issues of how output is increased are critical to the economic and social consequences of new technology.

In the short run, economic research can help establish policies that enhance favorable effects and diminish less favorable effects of technological change. In the longer run, economic research can help to guide the process of generating new technology.

The development of aquaculture must take into account the following socio-economic considerations:

1. Social aspects of aquaculture

   (a) Social status of the fish farmer in his community

   (b) Ability to individuals to respond to changes in technology

   (c) Social displacement that may result from large-scale aquaculture development

   (d) Acceptance of aquaculture products (traditional food preferences and religious taboos)

2. Levels of aquaculture

   (a) Family subsistance

   (b) Family farming, basically for sale

   (c) Cooperative systems

   (d) Company or corporation type organization

   (e) Vertically integrated enterprises

In many developing countries, the first two lower levels are prevalent.

3. Marketing and distribution

A hindrance to expansion of aquaculture in most developing countries could be an unsatisfactory development of marketing and distribution sysbems as listed below:

(a) Inadequacies of existing marketing systems (lack of marketing information, market organization, product identification, market flexibility, and processing)

(b) Quality control

(c) Improvements of transportation

4. Auxilliary socio-economic factors

   (a) Leadership in the public and private sectors

   (b) Cost-benefit accounting and evaluation of the various economic aspects of aquaculture operations

   (c) Credit facilities

   (d) Crop insurance

   (e) Legal problems of land and water rights

5. Supporting services

Among the supporting services needed for efficient aquaculture operations, high priority needs to be given to the production and distribution of high quality seed, suitable feeds, fertilizers and technical assistance (particularly for disease control). Assistance for site selection, construction of aquaculture installations and their maintenance are also of importance.

Different levels of aquaculture ranging from subsistence level operations to verticially integrated enterprises; have to be developed. A reliable supply of seed is vital to all of them to overcome many of the problems inherent in breeding and raising of fry. In farms meant for the production of marketable fish, it is necessary to establish special seed farms; this is specially important in relation to the culture of genetically improved strains and of mono-sex and sterile fish.

When artificial feeding has to be adopted: appropriate arrangements for the manufacture of suitable feeds, preferably based on locally available ingredients, and their distribution to farms have to be organized.

Intensive aquaculture is generally accompanied by increased hazards of diseases and further international exchange of cultivable organisms can lead to the spread of communicable diseases, if proper precautions are not taken. Besides centralized diagnostic and treatment facilities, a system of regular health inspection in aquaculture installations will therefore be required for effective control of diseases.

Suitable training and extension services are basic requirements for the wider application of existing practices as well as new and improved technology. Parallel development of these services is therefore of special importance.

B. Education and Training

The limited training facilities available now in a few centers are not able to meet even the existing needs, let alone the much greater needs that will emerge when large-scale development is undertaken. This applies equally to developing as well as developed countries, and the different types of personnel, from scientists to extension workers.

Education and training require advanced planning as integral parts of aquaculture development. They must be closely linked with man-power needs and career development so as to utilize trained personnel to best advantage and avoid waste of expertise.

C. High-Level technical expertise

High-level technical education is required to provide the basic expertise for research and development activities. A small number of existing universities in developed and developing countries should be encouraged, and where necessary assisted, to institute regular degree-level courses in aquaculture, probably at the post-graduate level for those holding a first degree in basic science. Full use should be made of exchange programs and international aid for this purpose.

D. Training of field personnel for adaptive research

The field personnel required for aquaculture development programs and the technicians or farmers undertaking actual culture operations need a very different kind of specialized training, with emphasis on practical aspects, and oriented to the aquaculture systems practised in the countries concerned.

E. Extension Workers

Special attention has to be paid to the training of extension service personnel. This is of prime importance for the success of aquaculture development in any country. Technical advice and assistance, method and results, demonstrations and training of farmers have to be carried out by extension workers who are not only properly trained, but who are technically and temperamentally suited for the job. As they form key personnel for field activities, their training should receive special emphasis in national programs.

F. Instructional materials

Early preparation of suitable text books and o-her educational material is basic to the implementation of all training programs. Special projects for the preparation of this material should be envisaged.

Curricula for field personnel training with their supporting materials are best developed at regional or national centers. Preparation of instructional materials for extension workers and farmers should be developed at the national level.

X. ORGANIZATION OF INTERNATION PROGRAM

A. Regional Organization of Research

The interdisciplinary nature of research effort required for achieving a rapid increase in aquaculture production has been recognized. A survey of the existing research programs shows that no institution in developing countries and few in developed countries have the necessary financial andother support required for such an effort. Because of the many differences that exist among the areas in ecological conditions, species available for culture, suitability of culture systems, and socio-economic political situations, it would be extremely difficult to investigate all the major problems of aquaculture in all parts of the world at a single international institute, even though this might permit the maximum concentration of financial and manpower resources to ensure a high level of effort.

Two alternatives for the organization research are: (a) strengthening of a selected number of national institutions for undertaking research on regional problems, and (b) the establishment of one or more regional centers, both linked closely with a net work of national countries. Taking into account the advantages and disadvantages of these alternatives, it was generally agreed that it will be useful and efficient to develop one or more regional centers in each of the aquaculture regions of the world, e.g. (a) Asia and Oceania; (b) Africa and the middle East and (c) Central and South America. These could be new centers or the existing centers strengthened for this purpose.

The main constraints to aquaculture development and the nature of research and other inputs required to solve the immediate problems have been discussed earlier.

The research and other activities required are highly complex and extensive, and since insufficient ideas of the magnitude of financial support necessary or likely to be available, the possibility of phasing the activities should be considered.

To have the maximum impact on aquacultural development, research should be undertaken on all the priority problems related to each culture system simultaneously. Lesser but still noticeable benefits can be achieved by carrying out research on selected single problems.

The task force proposed earlier would be required to determine the site or sites where: (a) a maximum number of species in need of studies on seed priduction occur: (b) food and feed research can be most fruitfully undertaken with reference to regional priorities and the intensity of the culture of the species in question; (a) genetic upgrading can be initiated; and (b) research into diseases and milieu factors appear urgently necessary to removeimmediate constraints, especially those of species composition, stocking densities and hygiene. A detailed study of facilities and governmental support will have to be made before recommending the sites for the location of regional centers and working out specific costed proposals.

Although the suggested regional centers should have a continuous long-term program of research linked by the disciplinal priorities

during the initial phase they should concentrate on problems considered to be the major constraints to rapid expansion and intensification of existing practices and on the development of culture systems likely to have an immediate impact on food production. They must have sufficiently flexible and dynamic work programs and staffing to meet the changing needs of the countries.

Besides undertaking research on problems of a regional and long-term nature, the regional centers should offer training facilities for the scientific personnel (research and technical staff) of national institutions. Formal training courses should be of a specialized nature, be related to specific aspects of aquaculture, and be for short periods (say three to six months). On-the-job training for young research workers for longer periods should also be arranged as necessary.

B. Network of National Centers

While the regional centers should work on problems of a regional and long-term nature, it is necessary to have a network of national centers to investigate problems of a local nature within the region, and to undertake pilot-scale studies. These centers should also provide training facilities for field personnel, particularly extension workers. Short-term courses for farmers should also be organized in such centers.

Some of the existing national research centers should be recognized as 'centers of excellence' for participation in a network, and be provided with the necessary assistance to improve their research and training activities. Only those centers that have the potential capability to take an active role in the program and to cooperate with the regional centers should be selected for assistance. They should have the necessary support of the government or other financing agency to continue operations at an expanded level. The task force proposed to select the site for regional centers should be given the responsibility of selecting the national centers also. An alternative would be to entrust this task to the Regional Centers.

C. Information Retrieval and Dissemination

Since considerable effort and expenditure are involved in the collection, storage and retrieval of aquaculture information, and since this activity is a highly sophisticated and complex one, it will be more economical and more effective to utilize an existing data center for this purpose. The FAO Department of Fisheries, through its Aquaculture Team, assisted by the Fisheries Data Centers and the Research Information Section, is already carrying out these functions on a small scale. The information services required and the preparation of text books, manuals and extension material may therefore be undertaken in a central unit such as the FAO Department of Fisheries.

XI. Suggested Immediate Action

It is suggested that a small task force of competent economic and technical experts be appointed to study the matter of aquaculture in greater detail. They should study available data, design a field study procedure, and they should visit the major governmental and academic institutions concerned in the regions, hold discussions with the authorities, and review the existing facilities and future requirements of institutions to participate in the program. Consultations should be initiated with interested universities to ascertain the possibilities of establishing the proposed educational program.

The second major assignment of the task force would be to recommend priority assignments, mechanisms, staffing and financing for the network and national activities to be supported by international agencies and the LDC's.

Recommendations:

1. Task force to be assembled by July 1, 1974.
2. Task force to prepare a set of recommendations on immediate Technical Assistance needs by October 1, 1974.
3. Task force to prepare recommendations on research, regional and national centers by June 30, 1975.