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CONSULTATIVE GROUP ON INTERNATIONAL AGRICULTURAL RESEARCH

TECHNICAL ADVISORY COMMITTEE

Second Meeting, Rome

19-22 October 1971

AQUACULTURE

(Agenda Item 13(e))

TAC SECRETARIAT

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

ROME 1971

WM/C2106

cc Mr. A.A. Neylan, World Bank, Washington D.C.

13 October 1971

Dear Professor Bardach,

Thank you very much for your letter of 6 October and the accompanying material. I very much appreciated the promptness of your action and will endeavour to have the matter discussed in Rome next week.

As I think I mentioned, it will be initially necessary for me to ensure that aquaculture can be regarded as within the terms of the reference of TAC.

I will keep you informed,

Good wishes,

Yours sincerely,

(J.G. Crawford)

Professor J.E. Bardach,
Director,
Hawaii Institute of Marine Biology,
University of Hawaii,
Coconut Island,
PO Box 1067
Kaneohe,
HAWAII

UNIVERSITY OF HAWAII

Hawaii Institute of Marine Biology

October 6, 1971

Sir John Crawford
Vice Chancellor
Australian National University
Canberra, Australia

Dear Sir John:

This note accompanies the promised memorandum on agenda and participants of a possible aquaculture workshop sometime in the spring. It also is to tell you about the other enclosure, namely, the memorandum by the Oceanic Institute to the Agency for International Development. As you may recall, your visit in Hawaii coincided with Mr. Pryor's absence on a fact-finding trip to southeast Asia. There he contacted a number of people involved in and interested in aquaculture. With Dr. Colin Nash, formerly of the British Whitefish Authority and now with the Oceanic Institute, he put together the memorandum I enclose here. I was not aware of their activities in this regard and only learned about it when they came back a few days ago. I find in it a most remarkable correspondence of ideas with the one I prepared for you.

You will remark that the experts Mr. Pryor and associates deem of importance in such an endeavor are practically to a man the same that I have proposed to you entirely on my own. Mr. Pryor now would further his plan by getting together some of the experts mentioned in Bangkok and to do some ground work on the various questions both his proposal and my earlier memorandum to you raised independently. You should note that presently he addresses himself here to southeast Asia. We had, I think, talked of a somewhat wider geographic area, certainly to include the Pacific. It is further to be noted that Mr. Pryor's approach is that of a foregone conclusion, namely, that aquaculture can, and, in fact, will be one of the important solutions to the problem he postulates in the beginning of his proposal.

His request will be directed to the United States Agency for International Development; it may or may not be acted upon. For reasons we have discussed, I would find this not the best of all possible solutions but would much rather see the matter approached through a World Bank effort in which a number of other institutions or agencies can join forces. I have suggested to Mr. Pryor to await the outcome of your endeavors but he believes he should not lose momentum at this point. Now the peculiar problem is that Mr. Pryor and I have identified essentially the same people as potential resource persons. Yet it is well possible that the assessment effort which Mr. Pryor and his

associates and/or recent contacts now might mount - if it succeeds - can be preparatory for a larger and more basic fact-finding session after you have ascertained the World Bank's interest in December. I therefore think it extremely timely to raise the question of aquaculture assessment at your committee meeting in Rome, and further that you do endeavor to attain World Bank sponsorship for such a fact-finding meeting as I here propose to you on your request. I would think, though, that one should try and bring matters forward as speedily as possible. So as not to lose momentum, one should perhaps think of March as the target date for the meeting which is the subject of my memorandum. I would be interested to hear your reactions to my comments and I wish you a good trip and much success at the meeting in Rome.

Yours very sincerely,

John E. Bardach
Director

JEB:li

Enclosures

P.S. Please do avail yourself of the good offices and advice of Dr. T. V. R. Pillay of the Fisheries Resources Division of the FAO in Rome. He's one of the more knowledgeable people about world aquaculture.

To Sir John Crawford
(Chairman, World Bank Agricultural Research Group)
Vice Chancellor
Australian National University
Canberra, Australia

From J. Bardach
Director, etc.

Concerns role of Aquaculture in Development

Aquaculture, especially in brackish water and marine areas may have a role to play in increasing available animal proteins and diversifying diets in Asia and the Pacific region. If one were intent on examining this potential with a target date of the year 2000, a suitable procedure may be to convene a workshop of experts with the following agenda:

(1) The present status of fish and invertebrate protein supply from aquacultural operations in the above mentioned region (aquaculture here is understood as defined by Bardach and Ryther in their 1968 U. S. Dept. Commerce monograph). A substantial portion of these data might be supplied from FAO data - T.V.R. Pillay, Fisheries Resources Division, FAO, Rome. It would be useful here to assess present and probable future demands of fish in nutrition in the area, to make a market analysis of mullet, mussles, shrimp and the most prevalent piscine carnivores under aquaculture production.

(2) The present status of aquacultural research in the region with attention to a) fresh, brackish and salt water sectors and b) types of aquacultural organisms, i.e. herbivores, filter feeders (bottom and plankton), and carnivores.

(3) Assessment of deficiencies in the aquaculture research base in the region (and in the world); here would be considered deficiencies in basic information for mission oriented development in the following categories

and with attention to species, species complexes and feeding types, as per (2) above.

A) Reproductive physiology, the mastery of which would permit a steady and secure supply of offspring

B) Genetic information, if any

C) Knowledge to ensure larval survival

D) Nutrition (larval, juvenile and adult)

E) Diseases

(4) Assessment of non research oriented factors and deficiencies that may enhance or preclude approaching, at the earliest opportunity, patterns of aquacultural developments, to be comparable, in a loose sense, to development opportunities realized with strong and concerted research inputs in rice and wheat. To be considered here are:

A) Potential conflicts in land and water uses

B) Regional diversities such as mainland and island total ecologies (e.g. India or Thailand vs. Indonesia and the Philippines), and, therefore, distribution of potential aquacultural organisms and sites.

C) Combinations of land-based with water based animal husbandries, recycling of wastes, pollution.

At this point the workshop panel would address itself to the crucial question whether or not massive inputs of coordinated research and financial support could indeed make aquaculture yield a substantial contribution to protein nutrition (say 20 - 30 million metric tons wet weight) by, or close to, the year 2000. If it were the consensus that it could, the panel would proceed to:

(5) Propose possible ways to structure the necessary inputs for realization of the above implied potential. Topics to be considered, among others, are:

A) What might be the usefulness of strategically placed new laboratories?

B) Could present laboratories be strengthened to achieve the goal?

C) Would a task force, or task forces to existing laboratories be useful as an interim measure should the building of new laboratories be recommended?

D) What would be the best "mix" of measures A, B and C?

E) What is the present scientific manpower situation? If it is deficient how can it be improved? Training missions, sites, an aquaculture technical school or college?

Suggested Workshop Participants (please talk this over also with Dr. T.R.V. Pillay at the FAO)

The rationale for suggesting the names below is that there should be a mix of younger and more senior scientists and that participants should have a wide national distribution.

Dr. S. W. Ling, FAO/UNDP Fish Culturist for Asia & the Far East, FAO Regional Office, Maliwan Mansion, Phra Atit Road, Bangkok, Thailand

Dean D. K. Villaluz, College of Fisheries, Mindanao State University, Marawi City, Philippines

Dr. Arporna Sribhibhadh, Marine Fishery Laboratory, Department of Fisheries, 89/1 Soi Sapan Pla., Yanawa, Bangkok, Thailand

Dr. Takashi Ino, Deputy Secretary-General, SEAFDEG, c/o R. S. Motel, Larn Luang Road, Bangkok, Thailand

Dr. I. C. Liao, Tungkang Shrimp Culture Center, Tungkang, Pingtung, Taiwan, Republic of China

Prof. R. Doumenge, Director, South Pacific Islands Fisheries Development Agencies, South Pacific Commission, P. O. Box No. 9, Noumea, New Caledonia

Dr. Yun - An - Tang, FAO/UNDP Fishery Biologist, Philippine Fisheries Commission, Manila, Philippines

Dr. Y. Yashouv, Central Fisheries Research Station, DOR, Israel

Dr. Z. Shehadeh, Oceanic Institute, Makapuu Point, Waimanalo, Hawaii

Dr. T. V. R. Pillay, Fisheries Resources Section, FAO, Rome

Dr. C. F. Hickling, London, England

95, Greenway
LONDON, N. 20

A PROGRAM FOR AQUACULTURE IN SOUTHEAST ASIA

A memorandum for the United States Agency for International Development prepared by the Oceanic Institute of Hawaii.

September, 1971

1. WHY AQUACULTURE ?

Fish is the most vital source of animal protein in the diet of the peoples of Southeast Asia. For the predicted population of 1360 million in the year 2000, the calculated need is 17.7 million metric tons per annum. Yields from offshore fisheries can be significantly increased but can not meet the demand. The yields from Aquaculture are therefore increasingly more important to the region.

Aquaculture is a tempting alternative compared with (say) the production of poultry or aquatic plants as there is a long tradition of brackishwater fish farming which offers an invaluable foundation for rapid development. No other area of the world has such a good basis on which to build.

The advantages of Aquaculture in the region are that :-

1. existing freshwater ponds and undeveloped ricelands are used,
2. little (if any) additional agricultural land is required,
3. large areas of waste coastal mangrove are available for use,
4. extensive and protected marine sites are available,
5. labour intensive nature of the practice provides additional opportunities for skilled and unskilled labor,
6. finfish and shellfish can be reared intensively.

2. WHICH SPECIES TO FARM ?

Herbivorous finfish and shellfish offer the most immediate prospects of providing high yields of animal protein. They can be sustained successfully in low density by natural fertilization of ponds or lagoons but it has been demonstrated that intensive management, supplementary feeding with vegetable wastes (rice bran, soybean cake, etc..) and by careful use of both organic and inorganic fertilizers. the production from the same areas can be dramatically increased.

Carnivorous aquatic animals, when cultured, have high feed costs and require elaborate facilities. They are therefore more expensive to produce and can only be purchased by the oppulant minority. Added to these disadvantages is the need to introduce the farmers to highly sophisticated technology. The advantage of producing desirable carnivorous finfish or crustaceans is their value in foreign exchange as an export crop. This however would defeat the purpose of the program.

The herbivorous fish for consideration must be :-

- grey mullets (Mugil sps.)
- milkfish (C.chanos)
- Chinese and/or Indian carps (Cyprinid sps.)
- mussel (Mytilus sps.)

The husbandry of all these finfish has been worked regionally but modern techniques for the intensive production of mussels can be introduced and adapted for the area.

3. WHAT ARE THE PROBLEMS ?

The problems associated with Aquaculture are the shortage of qualified technical personnel and skilled laborers; a predictable supply of fingerlings or seed; a conflict with coastal (or communal) fisheries; pollution. The shortage of capital and reasonable credit terms have contributed to the problems by precluding well organized large scale developments.

4. HOW IS THE PROGRAM APPROACHED ?

A team of applied biologists experienced in all aspects of Aquaculture must be convened to consider the problems, formulate a plan and produce an agenda. They would consider the most crucial decisions necessary for the proper planning and successful execution of such an ambitious program.

Preferably the team should meet at a place where the most recent published and unpublished information is available, for example, the FAO Headquarters in Rome.

Some crucial questions of policy to be resolved are :-

1. regional site(s) selection for research and/or development and/or production,
2. scale of operation at each,
3. selection of species,
4. projected economics,
5. requisit funding scale,
6. time scale and intermediate targets,
7. relationship to and co-operation with established organizations and/or existing regional development programs (FAO, UNDP, AID, SEAFDEC, etc.),
8. technical staff problems.

Some additional problems relating to implementation are :-

9. training and subsequent extension services,
10. intensification of research in reproductive physiology.
11. pond production and nutrition,
12. mass propagation and distribution of juveniles,
13. pest and predator control,
14. pond or facility design and construction,
15. distribution and marketing of the produce.

5. CONCLUDING REMARKS

Whilst the importance of developing the capture fisheries has been fully recognized and been supported, for example by UNDP Special Funds or by the creation of SEAFDEC, the vastly greater resource potential of Aquaculture in Southeast Asia has not been realized. It is a major source of immediately available animal protein and as such should be compared equally to an intensive research and development program in agriculture.

Fortunately in Southeast Asia the problem is the improvement of existing practices in the light of increasing knowledge, but this can only be achieved by a well funded long term international program based on defined research and organized technical development.

The team invited to convene the program is likely to include the following :-

Ling, Dr. S.W.	FAO/UNDP , Bangkok, Thailand.
Ino, Dr. T.	SEAFDEC, Bangkok, Thailand.
Hickling, Dr. C.F.	London. Ex- Director, Malacca, Malaysia.
Prowse, Dr. G.A.	Univ. Hawaii. Ex-Director, Malacca, Malaysia.
Blanco, Dr. G.J.	Philippine Fisheries Commission, Manila, Philippines.
Tang, Dr. Y.A.	FAO/UNDP, Manila, Philippines.
Villaluz, Dean D.K.	College of Fisheries, Mindanao, Manila, Philippines.
Bardach, Dr. J.E.	Univ. Hawaii. U.S.A.
Demangeon, Prof.A.	SPIFDA, Noumea, New Caledonia.
Arporna, Dr.S.	Dept. of Fisheries, Bangkok, Thailand.
Liao, Dr. I.C.	Tungkang Culture Center, Taiwan, Rep. of China.
Andreu, Dr.B.	Instit. Invest. Pesqu. Barcelona, Spain.
Pillay, Dr. T.V.R.	FAO, Rome, Italy.
Tal, Dr. S.	Dept. of Fisheries, Tel Aviv, Israel.
Pillai, Dr.T.G.	FAO/FUNDWI, Djakarta, Indonesia.
Shehadeh, Dr. Z.	Oceanic Institute, Hawaii, U.S.A.
Nash, Dr. C.E.	Oceanic Institute, Hawaii, U.S.A.
	ex- White Fish Authority Fish Cultivation Unit, London.
Gould, Dr. J.	Senior Economic Advisor, UNDP, New York.

Make file

THE BLUE REVOLUTION

Referred by TAP. From Oceanic Institute Honolulu.

I. AQUACULTURE: Changing Fast.

II. HAWAII'S RUNNING START IN SEA FARMING.

III. STARTING WORLD-WIDE AQUACULTURE: A Game Plan for Hawaii.

IV. AQUACULTURAL FUTURES FOR PACIFIC NATIONS.

V. THE FUTURE OF AQUACULTURE.

THE BLUE REVOLUTION

I. AQUACULTURE: Changing Fast

The peculiar thing about aquaculture is the lack of any organized effort to make it productive and economic on a large and useful scale.

In recent years, "farming the sea" has become a popular concept suggesting that the very large potential return from manipulating sea life in a relatively few acres of sea water is no secret. Neither is the threat of widespread famine in this century unknown. And anyone who has paid $3.50 for 6 shrimp on ice will be aware of the marketability of some oceanic products.

Less known is the fact that last year, for the first time, the world fisheries catch declined, while more vessels were at sea with a greater cost than ever before for being there. Surely the handwriting is big on that wall.

The situation isn't entirely black however. The beginnings of rational, planned, and ultimately well funded efforts can be seen in Japan and Hawaii. Recently in an address to the first workshop of the newly formed World Mariculture Society, Paul Bente Jr. gave this report on the Japanese situation:

"Two Japanese colleges specialize entirely in the study of marine products. Twelve more Japanese Universities have 2,000 students studying marine biology in an effort to apply more scientific methods to production of

foods from the sea. In addition, there are 82 Fishery Experiment Stations located all over the country similar to the Agricultural Experimental Stations in the United States. Eight research stations, one for each fishery district, experiment with new techniques for fish farming and ways to improve the age-old art of fishing that is still practiced in much the same way it was when it first began. All this goes on in a densely populated area about the size of California."

Until recently this effort was unmatched elsewhere. Now there is a build up of talent and facilities in Hawaii which could well surpass Japan's, not in volume of effort but in vigor, diversity, and capacity for innovation.

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Hawaii has a proud tradition in marine farming. For at least 800 years, ponds have been operated throughout the islands. Largely used to attract, raise and harvest mullet and milkfish, they also doubled as live storage for the excess catch of reef fish. At one time there were over 80 ponds on Molokai alone providing a major protein source and an important basis for barter when the dried and salted product was packed and canoed to other islands. The more we learn of the ancient Hawaiian techniques the more skilled they appear.

The practice of maintaining stocks of freshwater fish in ponds can be traced in Chinese history for over 3,000 years. References to systematic working

in coastal waters are rare but confirm an age-long interest to practice subsistence farming in water as well as on land. The Asians progressed with many species, particularly carp and milkfish, but little information percolated through to Caucasian cultures until Medieval times when records show that "stewponds" existed in the grounds of several monasteries and later on large estates.

According to C.P. Idyll, "the most extensive culture of a marine fish is that of the milkfish or 'bango' it is farmed in shallow-water areas in many parts of the world, especially in the Philippines and Indonesia. In 1962, it was estimated that there were over 200,000 acres of milkfish ponds in the Philippines and over 300,000 acres along the shores of Indonesia. An additional 100,000 acres are farmed in Pakistan, Formosa, India and Hong Kong."

Here it's important to differentiate between farming and culturing. The pond farming described above developed and still survives through the collection of fry or baby fish from the sea, and confinement of them until they are ready for marketing. For example, in Japan the yellowtail, and elsewhere in Asia the mullet, are both caught in shallow waters as very young fish, and fattened in protected enclosures. This catching and rearing of juveniles has proved an effective method of producing marketable fish and shellfish but is only a modest improvement over hunting adult fish at sea. These practices can damage the wild stock. Furthermore, the wild fry are becoming more and more scarce as pollution takes its effect on all populated coastal zones. The difference between harvesting of this kind and culturing is the difference between collecting baby birds from nests in the woods and running a modern poultry factory.

Between 1880 and 1950 several attempts were made to culture and rear marine species from captive parent stock but without success. It was not until after mid-century that positive progress in incubation and large scale hatchery rearing both in Japan by Dr. Fuginaga working with shrimp, and in Great Britain by the Whitefish Authority working with a flatfish, the plaice.

Since these successes the intensive cultivation of aquatic organisms has been the object of a great deal of laboratory research and effort throughout the world. Of all this effort, one of the most successful has been quietly accomplished with Malaysian prawn culture by Takuji Fujimura and Henry Okamoto of the Fish and Game Division of the State of Hawaii, where they have expanded and improved the methods initially developed by Dr. S.W. Ling.

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II. HAWAII'S RUNNING START IN SEA FARMING

The long legged giant Malaysian prawn of fresh and brackish water has for centuries been a prized food in tropical countries. In the modern era of aquaculture it was logical that the species should be cultured in hatcheries. With State and Federal funds and facilities on Sand Island, Fujimura and Okamoto have developed culture and farm techniques to the point where large-scale commercial production is a near hand possibility. The advantages of this particular species over many other crustaceans are its wide distribution and its adaptation to fresh and brackish waters allowing future hatcheries and farms a wide range of localities and water quality. The prawn also has a short larval life and best of all it is a fast growing omnivore, feeding on both plant and animal material.

The juvenile shrimp are stocked 86,000 per acre in drainable dirt ponds and furnished with a source of well aerated fresh water. They are fed commercially available chicken pellets, converting this at a rate of five pounds of broiler mash to more than one pound of prawn. About half survive until harvest which begins six months later giving a yield of 2,000 lbs per acre each year, or $6,000 from one acre at today's market price. A Fujimura-designed hatchery can presently produce stock for the ponds at about 2 cents each and future improvements are expected to reduce this cost.

Other substantial culture progress has been made under the direction of Dr. Ziad Shehadeh of the Oceanic Institute at Makapuu Point. Beginning in 1964 with funds provided by The Rockefeller Foundation and local charities, the Oceanic Institute has attempted to hatch mullet larvae from captive brood stock. Some success was achieved in 1970 and in January and February of 1971 was repeated in several different ways with a much higher survival rate. One beauty of Shehadeh's work is his high precision capacity to determine exactly when an individual fish is ready to spawn followed by the ability to encourage the spawning without harming the brood stock adults. By so inducing natural spawning he is able to cause fertilization of over 95% of the female's 1,000,000 eggs. The importance of the work is that the methods developed will be applicable soon to many other commercially interesting finfish including the flying fish, the pompano and the mahimahi.

Shehadeh must satisfy two other steps in the months ahead before mullet can go into full commercial production. First, it's necessary to achieve commercially acceptable larval survival. In the meantime he is working on breeding and producing any time of the year rather than in just the short winter season of nature. Light and temperature control laboratories built to

readjust the natural cycles appear to be forcing this change. After that, cheap ways to grow out the mullet have to be devised to keep the final market cost as low as possible. Here one innovative approach devised by Dr. Ken Norris seems to hold great promise, the use of plastic sheets cut in strips floated in ponds to provide vast areas of surface for scum-like diatoms to grow as mullet pasture.

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The Coconut Island Marine Laboratory, which began with the vision of Ed Pauley and Dr. Robert Hiatt, was keeping tuna in large holding pens in the late 1940's studying behavior and feeding habits with management of tuna as a resource ultimately in mind. As the laboratory increased in size and capability in recent years under the direction of Dr. Phil Helfrich, space and time has been increasingly devoted to aquaculture with interesting results. Larvae of ulua and other finfish have been collected from plankton tows in Kaneohe Bay and raised artificially, contributing both to knowledge of culture techniques and to an understanding and identification of the life phases in nature. Extensive and basic work with crabs and octopuses at this oasis marine lab will also probably pay off eventually in mass culture methods.

Under its new program-oriented thrust, the East-West Center on the Manoa Campus has made a vigorous start under Dr. Nicolaas Luykx to develop new food resources. In cooperation with other private and public activities the Center has begun to fund the training of technicians from the island nations. Two staff members of the Fisheries Division of the Government of the Cook Islands recently arrived for three months of practical work under this program.

After two days in Hawaii the trainees left for another Hawaiian activity in Puget Sound at the Multunna Aquacultural Laboratory where Dr. Wally Heath, Associate Director of the Oceanic Institute has been advising another traditionally sea-going people, the Lummi Indians, on the development of tidal enclosures for fish and shellfish production. Now with over 750 acres completed, the Indians there expect to harvest over 10,000 lbs of trout and salmon per acre each year by 1974. They can obtain such enormous production only because at 18 months of age they open the gates and release salmon to grow at sea. Two years later 30% will return to the pond and hatchery gates weighing thirty times more than when released. Fresh water trout also have been forced to adapt to the tidal ponds where they feed partially on marine organisms, gaining rapidly from the abundant natural foods. Presently oyster, clam and mussel rafts are being floated in the ponds to take full advantage of these plankton blooms provided by rich excretions from the crowded fish populations. Because of the ideal conditions, oysters have become sexually mature at four months of age and are marketable at nine months as compared to two or three years in nature.

The visiting Cook Islanders can't help but compare the expensively built tidal dikes in Bellingham to their naturally provided lagoons and atolls down south. It will be obvious to them that throughout the Pacific there are tens of thousands of abandoned atoll acres which could be even more productive than the Puget Sound area. The Cook Islanders already have begun construction on a promising demonstration project by Ngatangiia lagoon on Rarotonga where they are about to apply the new mullet techniques, along with a plan for tripling their akule harvest by holding the migrating adults in lagoon pens and feeding them shark meat and copra meal for several months beyond the normal catch time.

If the demonstration project proves itself, the Cook Island Government, guided by the Oceanic Institute and University of Hawaii scientists, intends to shift to another island with a larger lagoon and combine the aquaculture project with a new kind of vegetable production, nutriculture, developed by Carl Hodges of the Environmental Research Laboratory in Arizona. Together, they will form a Total Atoll Production System which could not only eliminate nutrition problems within the Cooks, but quite possibly develop into a much needed export industry.

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The Cook Island project has attracted the interest of the faculty of the University of Hawaii School of Public Health. Perceptive about applications of new technologies which can have a beneficial effect on entire communities, the Department under Dr. Edward O'Rourke is joining with Dr. Joe Williams, Director of Health in the Cook Islands, to determine the basic condition of health, educational capacity, and economic well-being now for comparison in several years after the new system is fully effective. Another member of the same university department, Dr. Manny Voulgaropoulos, has left on an assignment to Indonesia where he will survey the possibility of a similar demonstration project for Bali. Trainees again would be based in Hawaii and also be exposed to the Bellingham, Arizona, and Cook Island work.

Other aquaculture projects under construction in Maui County promise to add to that exposure. Encouraged by Mayor Cravalho, three efforts are moving concurrently there. Two shrimp farms, one funded by the Office of Economic Opportunity guided by a University student, Robert Cordova, and the other backed by Global Marine Inc. under Carter Pyle's direction. The

third is a research annex of the Oceanic Institute on Molokai where several of the ancient Hawaiian ponds are being rebuilt for a combination of research under scientific direction and commercial production by local operators.

Most intriguing of all on the Hawaiian scene is the Gulliver strength of four large agricultural companies with over four hundred years of practical production management between them. A sleeping presence in this field now, Amfac, Castle and Cook, C. Brewer and Alexander and Baldwin represent a wealth of management, technical and financial strength. They also have a research arm in the Hawaiian Sugar Planters Association which constantly seeks new ways to improve plantation management. Conversion of cane waste to food for marine life could be one of their contributions. The utilization of marginal lands and water for brackish and fresh water production might be another. The big companies have two other assets. Two, C. Brewer and Castle and Cooke have subsidiaries which for years have consulted internationally on agricultural practice and on the economics of new techniques. The other great asset they share is California and Hawaiian Sugar Company, their $300,000,000 marketing cooperative which now seeks diversification under the leadership of its new chairman, Boyd McNaughton.

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III. STARTING WORLD-WIDE AQUACULTURE: A Game Plan for Hawaii

A new and potent asset to the Hawaiian build-up of aquaculture skills is Dr. John Bardach who arrives this week from the University of Michigan to take a joint position with the University of Hawaii and the Oceanic Institute. Recruited by Dean John Craven, Bardach is unquestionably the "big gun" in

American aquaculture. A highly rated scientist, he is one of the few who has taken a serious interest in the field for years. His students, like Shehadeh, are the best performers and his publications are standard inclusions in any aquacultural reference list. Bardach's book "Harvest of the Sea" is a probing and imaginative review of marine progress and marine potential. Reviewing many of the opportunities, he states "..... when the wild animals of the sea have been exploited at the highest rate permissible if serious depletion is to be avoided, what else can be done to increase the yield? Clearly, man must do in the sea what he has done on land, and what he has now begun to do in fresh and brackish water: he must engage in marine animal husbandry." Bardach goes on to leave no doubt that now is the time to begin.

There are very few skilled aquacultural scientists in the world outside of Japan. Eight of these are presently working for Hawaiian based organizations. Others are presently considering offers to join the mid-Pacific build up. Some recent arrivals are Ching-Ming Kuo from Taiwan, a specialist in the study of fertilization and hormonal control of the reproductive angles. He has begun here with work on mullet breeding and larval rearing. Also new to Hawaii is Dr. Colin Nash, formerly a senior member of the Whitefish Authority which was responsible for outstanding progress in breeding and rearing flatfish. Nash also doubles as an expert on the utilization of thermal effluent -- the hot water discharge of power plants and refineries -- for aquacultural purposes.

Planning to split his time between Hawaii and Bellingham, Washington, between tropical and temperate conditions, Nash could be the person to resolve the dilemma that faces Hawaiian Electric Company as it seeks a windward power plant without thermal harm to the coastal zone.

A third to associate with Hawaii projects is Jerry Liang from Taiwan who is skilled in nutrition and the intensive use of raceways and cages for economic catfish production. Working here recently, he helped to devise pompano cages to be slung from floating platforms on offshore petroleum production towers. One such tower, he estimates, could provide twice the U.S. pompano catch annually.

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As these widely scattered skills become associated within a group of interlocked programs for the first time, the real potential of aquaculture in this decade begins to emerge. More and more species look promising within two, five and seven year time spans and more and more environments appear practical for demonstration projects and scaled up commercial efforts. Larger sources of funds, not previously attracted by the piece-meal approach, now become interested in supporting this new thrust in protein development. What is needed is a game plan, a coherent program to make the most efficient use of these resources in the shortest period of time and to do so with the widest impact in the areas of both commercial value and human need.

The game plan -- yet to be developed -- might go like this: first, technical requirements; second, funding sources; third, the project nations. An example of the first is the absolute requirement for a central experimental hatchery located adjacent to a relatively uncontaminated sea water source. The hatchery should initially handle several finfish species as well as oysters and perhaps crabs. It should be expandable both experimentally for more species -- even for mahimahi and tuna -- and for eventually high volume commercial production. Why commercial production from an experimental

hatchery? Because additional space requirements are still minimal, since a brood stock of 12 adult mullet, for instance, would provide 3 million fry or all of Hawaii's needs at peak production. Dove-tailing assembly line hatchery operations with scientific work will allow a concentration of technicians and a wide range of biological material for experimental use. Once such a combination is in being, it should be possible to ship fertilized eggs to aquafarms throughout the world where they could be received by Hawaii trained technicians and reared in compact portable apparatus near to the eventual growing areas.

Another technical need is for production test areas. At present it is extremely difficult to extrapolate costs of production on a commercial scale from the information provided by laboratory work. Accurate estimates can be made within a probable range of results but too often the commercial interest is faced with an upper level which would be unprofitable and a lower level which seems unrealistic. Pilot ponds and cages will resolve this.

Joint proposals by various Hawaiian groups to a number of funding sources are in preparation. Private foundations like The Rockefeller Foundation, the Ford Foundation and the Richard King Mellon Charitable Trust on the mainland, will be asked to take the lead as they so often do in projects of this kind. They are the ideal sources of support not because of the amount they provide -- they often start modestly -- but because they will take risks in new ventures while providing very excellent guidance to their grantees. Other agencies which could provide substantial and timely help are AID and the World Bank. Robert S. McNamara, President of the World Bank, has

suggested "a new and sustained effort in applied research for developing countries, especially on protein production, water management, and plant and animal disease control." Supplementing this, AID has an Institutional Grant Authority providing for the strengthening of U.S. research institutions involved in economic and social development. The administration gives primary emphasis on War on Hunger. Another possible source of assistance is the U.S. National Oceanic and Atmospheric Agency, especially the U.S. Sea Grant Program which has been an innovative funding source to aquaculture since its inception in 1966. Those agencies polled have expressed unanimous interest in encouraging a coherent aquacultural effort in the Pacific. With their guidance substantial funds could be available within a year and more thereafter if the first demonstration projects prove out.

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IV. AQUACULTURAL FUTURES FOR PACIFIC NATIONS

Along with identifying funding sources, the game plan requires site selection. Several areas are presently prime, the Pacific Island groups, Indonesia and a scattering of others. The Pacific islands are first priority because of the availability of lagoons, of a wide variety of species -- especially the plant and filter feeding types -- and of warm, sunlit conditions. Most important also is the increasing need for protein among islanders who have everywhere migrated in from outlying islands to more densely populated centers where the reefs inevitably become fished out and indeed polluted.

Along with the opportunities of the island areas there are drawbacks peculiar to the area. With the exception of Fiji and Hawaii, the island nations

are short of capital. There are also exceptional logistic, communication and transportation problems. There is a need for training of new skills and a simultaneous concern that the new technologies complement rather than alter the cultures and ecologies involved.

The problems however can be turned into assets. The lack of capital demonstrates a previous lack of interest by the major funding sources in this intriguing region, rich in viable cultures. The wide stretches of water may slow down early development but later become pathways for low cost export shipping. The lack of scientific and technical skills may be offset by the marine oriented attitude of the indigenous peoples and their abundant talents in fishing, diving and observing nature and the sea. The Cook Islanders, at least, appear well able to measure and handle the impact of a new technology on their own culture and should be able to assimilate without too much harm the westernization that comes with it. Given a choice they prefer aquaculture to tourism, health to malnutrition, and income to poverty. They welcome the possible repopulation of outlying atolls but know that some of the good things of recent times must return with the inhabitants -- movies, electrical power, health service and schooling, for example. These are all possible, especially with the advent of satellite TV, since power is needed to supply the refrigeration needs of the aquaculture and nutriculture system, and with the increased transportation that will be necessary anyway to handle the product of their work. As to the ecology of the atolls, these are the people who invented ecological engineering. For centuries they adapted in the dozens of ways available to them to very limited space and food resources, practicing advanced techniques of wild crop rotation, ritual population control, and deification of food producing trees.

Indonesia is a natural for the aquacultural thrust. Recently Dr. Shehadeh wrote: "Despite the availability of a vast brackish water area which is suitable for fish and shellfish culture, a comparable area of undeveloped rice lands with an abundant supply of fresh water, and a pronounced need for additional animal protein sources little has been done to realize the high fish-shellfish production potential of this area.

The reasons for this inaction probably relate, by and large, to the lack of capital, trained personnel, and the fact that, unlike agriculture and capture fisheries, aquaculture still receives little more than lukewarm reception in development schemes."

He went on to say that two men, Dr. S.W. Ling, the FAO Regional Representative to South-East Asia, Dr. John Bardach and the fisheries experts of the region in question could adequately survey the possible areas in not more than twelve months and develop a major project proposal which would have every chance of succeeding on a large scale, perhaps considerably larger initially that the Pacific Island program could ever be.

In a revolutionary development that has great strength and momentum in its early stages, it's all too easy to scatter energies and funds. Stepping into a vacuum everywhere one sees that each opportunity has merit and some ease of achievement. Where an obvious need and easy method of performance exists, the temptation is great. For the aquaculturist then, these are trying times. Look at the areas that beckon: Hong Kong, the Philippines, Ceylon, East Pakistan, Iraq and Iran, Lebanon, Greece, Egypt and Cyprus. A good case can be made for each. Certain values come from concurrent work in different climates. How far we should go, however, depends on how soundly we devise the game plan for this decade.

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V. THE FUTURE OF AQUACULTURE

When we put artificial surfaces like plastic "sea grass" in three foot deep ponds, we can harvest two ton of fish for each acre every year. Around Oahu, sunlight penetrates to one thousand feet. To play with a theoretical calculation, suppose the first third of that had enough sunlight to also produce one ton average for each three foot/acre annually. Then two million acres off Oahu would provide protein for twice the present world population. Two million acres is actually not that much. That's the amount of land in California that is going out of production due to urbanization over the next fifteen years. If the community on Oahu gets very smart about its sewage system when it pools all the sewage outlets into a conduit and put to sea at one place like Kaena Point, then twice the production could result by placing the open sea aquafarm in a current to catch the nutrients as they pass.

Whether all or any of the above is a possibility depends on the outcome of some experimental work presently underway. But the point is that marine farming combined with marine culture can produce astronomical results in a very limited area. The results are not all in the future either. Mussel farms in Spain produce 700,000 lbs of mussel per acre per year or the equivalent of 200,000 lbs of pure protein power -- while island cattle ranches are glad to get 300 lbs per acre per year and some Texas ranches one tenth of that.

For twenty years land farming has been undergoing a well funded, highly technical, brilliantly guided revolution, the "Green Revolution", aimed at producing where production didn't exist, at getting far more per acre where it did. It has been highly successful. Even though half the world remains underfed a great many are better off already as a result. There are drawbacks,

however. So far this intensive production has been heavily dependent on pesticides and fertilizer concentrations. Now that we know the hazards of depending on continual application, now that they head the list of pollutants, we wonder how much more of our limited terrestrial world should be cleared or altered to expand the agricultural goals. Possibly no more, certainly none if the marine world can accomplish the same goal sooner, easier and with fewer hazards.

Why fewer hazards? In the marine world, because of the intensity of the production, it's possible to confine the effects of aquaculture to a very limited area and to obtain a relatively higher control within that space. Fertilizers, for example, can be metered into an embayment at the rate they will be used by the diatoms and algae, and can be turned over by induced currents, not at "plowing time" but constantly until they are fully utilized. Often artificial applications will be unnecessary. Deep water is nutrient rich and can be brought up from offshore, and fossil water exists in the coral limestone throughout the Pacific islands loaded with organic phosphates and nitrates.

Sea water itself is fertilizer, with all of the needed elements available. Mix sea water and sunlight and you have enormous energy. Add the fantastic reproduction capability of most marine organisms and then take this rate under your control and you have the elements of a new and massively important event. Call it the "Blue Revolution", the capacity to not only feed the world but to do so with a much increased level of economic well-being.

It's been shown that where economic well-being reaches certain high levels, the population seems to level off. Malnutrition and poverty bring

lowered mental capacity and population excesses. Aquaculture in this century can cause the opposite. Isn't it time to organize this force and to cause it to happen? The next century is not far away. Will it be a century of disaster? Or will it be the first century where man came into balance with his planet.

Isn't it time "to tap the oceans", as Kennedy asked? I think so. Let us begin.