The Potential of Aquaculture Development

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THE POTENTIAL OF AQUACULTURE DEVELOPMENT

The task of this paper is to provide insight into the potential of having widespread aquaculture development in the Pacific community and to explore the role Hawaii might play in its realization. Actually, to be specific, we are going to be speaking of expanding and diversifying the existing activity; for many island groups have experimented and are experimenting with various species and systems.

The subject is complex so we will highlight only a few important aspects of the field of aquaculture and its potential for the Pacific. Perhaps, it will suffice at this point to say that successful aquaculture development for the region will have biological and technological needs, economic and marketing considerations, sometimes very subtle sociological overtones and no doubt, a few political concerns to address.

Much of what is characterized and described in this rather broad brush treatment may not be new information and may seem obvious. However, by looking at the region through the eyes of an aquaculturist, we hope that we are helping frame your existing factual knowledge and impressions in a new light and through relating our experiences and insights as aquaculture planners and developers, we will begin to foster a collective understanding of the realistic development potential of the Pacific.

AQUACULTURE AND HAWAII

What is aquaculture? Simply, aquaculture is culturing animals and plants in water. In essence, farming water. The water can be freshwater or saltwater or a combination of the two, brackish water. The choice depends on the species grown. Brackish and seawater aquaculture are generally termed mariculture.

The word "culturing" implies some sort of beneficial control or management of the aquatic animals and plants. Through this application of control, such as breeding or feeding or protection from natural predators, greater amounts of aquatic life can be harvested per unit area of water than what we might normally see from the natural ecological processes in lakes, rivers and the ocean.

When one thinks about aquaculture, one probably conjures up images of shrimp cocktails or fried catfish or perhaps, lobster with a little drawn butter. In short, aquaculture produces for direct human consumption. But this image is only part of the story.

There is, of course, a great deal of aquaculture around the world being carried out to simply feed people and no doubt expansion of this activity is the number one priority for the future. However, aquaculture techniques are also used for other ends (Table 1). Some examples are discussed below.

Culture of aquatic stock for enhancing commercial and recreation fisheries is carried out in numerous places around the world. For example, here in Hawaii rainbow trout cultured from eggs brought from California are grown to fry-size at the Anuenue Fisheries Research Center on Sand Island for stocking in the recreational fishing streams of Kokee, Kauai. And the State of Maine has been growing baby lobsters for stocking in the ocean for a number of years to supplement natural replacement processes.

TABLE 1. PRODUCTS DERIVED FROM AQUACULTURE

1. Food for Human Consumption
2. Stock for Enhancement of Commercial and Recreational Fisheries
3. Baitfish for Commercial or Recreational Fishing
4. Aquarium Species
5. Animal Feeds
6. Plant Fertilizer
7. Jewelry and Decorative Items
8. Biomass for Fuel Energy
9. Treatments for Agriculture, Industrial and Domestic Wastes and Waste Waters
10. Industrial Chemicals and Pharmaceuticals

Another product is bait used by our recreational and commercial fishermen. You say be aware that one of the chief constraints to expanded development of the tuna industry in Hawaii and the rest of the Pacific is the availability of suitable baitfish. Aquaculture of topminnows and mullet and milkfresh-fry are possible solutions. It is of interest to note that the recreational baitfush industry on the mainland has an estimated retail value of $60 to $80 million.

There is also the production of ornamental or aquarium fish, such as goldfish or koi, so that we can appreciate their beauty. It is estimated that the aquarium industry, with the inclusion of all its related products (aquariums, pumps, filters, etc.) has a retail value in the U.S. of well over a billion dollars annually.

Some more exotic products that may become widely produced in the future are industrial chemicals or pharmaceuticals. For example, certain gels made from cultured seaweed are used as thickeners in ice cream, milk, paint, cosmetics and numerous other widely used household items.

The final product I would like to mention is the application of aquaculture systems for treating industrial, agricultural and domestic waste and waste water. Some of these prototype systems can also produce potentially saleable by-products. Currently, a few small alternative technology development companies are capable of building small-scale treatment systems. For example, the city of Hercules, California which is just outside Berkeley, has recently inaugurated such a system for treatment of its domestic wastes. The implication of Hawaii and other Pacific Islands which are limited in available land and water are obvious.

The remaining products listed in Table 1 are self explanatory. It suffices to say that today, technologies and species exist to produce each of these products. And as aquaculture technologies become more efficient and the products become cost-competitive with the conventional products, we are likely to see more and more aquaculture production schemes come into being around the world.

WORLDWIDE AQUACULTURE SYSTEMS

I would like to briefly discuss the four major types of aquaculture systems seen around the world; these are: 1) release and recapture; 2) pond culture; 3) cage, raft and suspended net-pen culture and 4) raceway culture. These growout systems begin with young fish or shellfish that are generally produced in hatcheries or are caught in surrounding coastal waters. These fish and shellfish are then raised to market size under one of the systems mentioned above. The systems differ from each other in the amount of control that can be exercised over the cultured animal or plant.

Culture of salmon in the Northwest is a good example of the release and recapture system, also known as ocean ranching. Young salmon are produced in hatcheries and then released into streams. After three months, they travel to the ocean and feed on natural foods. They remain in the ocean for several years, then return to their home stream where they are harvested. Virtually no control can be exercised over the growing conditions in the ocean.

The pond culture system with its many types, shapes and sizes is the most widely-used system in Hawaii and in the world. Animals or plants are raised in dirt, concrete, or other specially-constructed ponds. Feeding and pond water quality may be controlled to a large extent, but temperature is difficult -- if not impossible -- to regulate. Pond culture in its many forms is the most common aquaculture system today -- accounting for perhaps 90% of the world's aquaculture production.

Cage, raft or suspended net-pen culture systems are used in many countries around the world. In this system the farmer must control feeding and the amount of fish stocked. The fish are also protected from being eaten by their natural enemies. A good example of this form of system is sea bream and yellow tail culture in Japan.

In raceway culture, more animals can be placed in a small area because the quickly flowing water maintains high oxygen levels and removes waste products. The crop is usually confined to a narrow concrete canal-like structure through which the water is passed. Although this system is costly, a high degree of control can be exercised over nutrition, water quality and the physical temperature of the environment. Two local operations, the Kahuku Seafood Plantation, which raises oysters and the Coca-Cola operation, which will raise marine shrimp, use this form of culture.

SYSTEMS FEASIBLE FOR HAWAII AND THE PACIFIC

All of these management systems, with the possible exception of release and recapture, appear to be feasible in Hawaii and could be adapted to many Pacific Islands. However, from a business perspective the initial capital investment, as well as, the annual operating costs, generally increase with the increasing degree of control. But at the same time, I should mention that more, and in some cases better, higher priced products can be produced with increased control over the growing environment.

I'd like to make two additional points about these production systems. The first is that the sophistication of technology and hence, the amount of energy, cost of materials, and know-how necessary to successfully operate a system, generally increases as one goes down the list from one, release recapture to four, raceway culture. The second point is that today, there is a large array of technologies available to raise fish, shellfish and seaweeds and these technologies can vary greatly in materials used and scale of operation; that is, from backyard, family subsistence kinds of operations, to hundreds of acres of ponds harvested by tractor pulled nets, to industrial, automated factory operations where the seafood is raised at extremely high densities in plastic raceway tanks and is never touched by human hands until it's eaten by the consumer.

The applicability and workability of these management systems clearly will depend on a complex mix of biotechnical, economic, social, environmental and political characteristics of a particular location, nation or region. In other words, there are at least three important considerations for being successful in aquaculture. Site, site, and site. By this I mean that the location must be conducive to successful management of the aquaculture technology being used and appropriate for its environmental and logistic requirements. This is particularly important for island situations.

AQUACULTURE -- ANCIENT ART WITH A FUTURE

As you have probably heard said, Aquaculture is an ancient art that dates back thousands of years. And actually it has come to light recently, that the very first aquaculture consultant hung out his shingle in China in the fourth century B.C. It is said that he laid out a business plan for fish ponds for a local emperor and projected a net return of 1,250,000 yi in the first year and a second year return of well over five million yi. The emperor, of course, took his advice and began quickly building ponds. History records that the emperor grossed 300,000 yi the first year or less than a quarter of the consultant's projection, and without reporting on the second year, the emperor died - at the early age of 33.

Now, the dollar equivalent of the yi is lost in the mists of time, and history does not record whether the emperor went into a decline in health from having his overhead overtake the 76% underrun in his projected yield. But, the point in this story is that in some respects, things haven't changed much in 2.3 millennia. In the recent past, uncounted thousands of people have gone into aquaculture, either to feed the world or to make a quick buck, and neither materialized to any great extent.

The idea here is that in many respects and in many parts of the world, aquaculture is still considered more of an art than a science and as such, it is a high risk activity for investment. However, it can be said that some species and systems are more risky than others. For example, aquaculture of freshwater species has been going on for a long time and procedures for many species are routine. Trout culture in the United States is well over a hundred years old and culture of carps and tilapias may be several thousand years old. Culture of marine finfish on the other hand, is still in the experimental stage and many brackish water shellfish are technologically feasible at laboratory scale but have only recently proven economically feasible at commercial scales. To put these statements in perspective, it has been said that the field of aquaculture in the U.S. is basically at a point where the field of agriculture was 100 years ago prior to large R&D expenditures by the Federal Government via the land Grant College System. But there is good reason to believe that aquaculturists are learning much from the years of advances in agriculture and other related industries and hence, will increase their level of know-how, that is, come up the learning curve, at a much more rapid rate. Key to this progress will be the availability of adequate research and development funds and the timely communications of results.

CURRENT RENEWED INTEREST

Today, aquaculture is enjoying a re-emphasis in research attention around the world and the data base from which private companies, as well as, governments and world development agencies, can make investment decisions, is rapidly expanding. In particular, I would anticipate a breakthrough in the next five years in the commercial feasibility of various marine finfish and shrimp. Also I might add that today, virtually all major world development agencies are considering aquaculture as one viable economic development and food production alternative to carry out their goals and this can be taken as a very good sign that the field has matured.

Let me emphasize then, that aquaculture is probably not the panacea for feeding the world when the green revolution fails to meet expectations or the world's capture fisheries collapse from over fishing. However, I do believe it is a flexible, multi-purpose, variable scale technology, which can make a significant contribution to many world needs. For developing countries in particular, aquaculture can be a non-energy intensive method for increasing the availability and affordability of food thus reducing chronic shortages. For developed, industrialized, food-surplus countries, though increasing the supplies of affordable food is an important motivation, ample consideration is also given to anticipated benefits such as improved balance of trade, increased private business investment and profit, new employment opportunities, encouragement of environmentally clean industries and increased tax revenues. Some experts predict that aquaculture production is expected to climb from producing 10% of the world's aquatic protein today to producing approximately half by the year 2000.

THE HAWAII PERSPECTIVE

Hawaii has recognized that aquaculture development can play a significant role in its future and indeed, progress to-date is quite promising. Currently, the commercial production sector of the industry is valued at over $2 million annually. In the next two years over $20 million of new capital will be invested in aquaculture which would boost the annual value of the industry to over $20 million. There are many reasons why we are enjoying such success; not least of which are our warm tropical climate, unpolluted waters and the tremendous support from the Governor, the Legislature and the people of Hawaii.

I would, however, like to briefly highlight two actions which we believe have also played major roles in expanding our rate of development and which should be considered by a government wishing to explore aquaculture as an economic development alternative. These are: the formulation of the State Aquaculture Plan and the creation of the State Aquaculture Development Program.

In November, 1978, Hawaii became the first state in the nation to have an Aquaculture Development Plan. This plan, which took two years to research and write, identified opportunities for and constraints to aquaculture developments in Hawaii.

I am reminded that while writing the plan, we were often told by skeptics that such plans have a tendency to resemble the horns on a steer, that is, a point here, a point there and a lot of bull in between.

However, I am pleased to report that our plan has proved an excellent working document for guiding developments in the State. Basically, our approach to planning aquaculture addressed three questions: What are the talents and resources that we have? What level of development can we hope to attain? What do we need to do and spend to attain this level of development?

Answering these questions required detailed assessments and analyses of eight general areas: 1) History of ancient and modern aquaculture, 2) Natural resources, principally land and water suitability and availability, 3) Technical resources including facilities, programs and expertise, 4) Legal and regulatory constraints which may restrict certain kinds of development, 5) Species selection and evaluation particularly what is culturable, what is native and what must be imported, 6) Market characteristics, both local and export, 7) Funding and financing opportunities and 8) Formulation of economic projections or cost benefit ratios.

There is not sufficient time to discuss the plan in any detail; however

I would like to present the six basic development objectives we formulated. They are:

1) Achieving a unified approach to development
2) Creating a better business climate
3) Developing new economic opportunities
4) Achieving excellence in research and development, training and technology transfer
5) Developing vocational training and formal education
6) Becoming an aquaculture information center

Each of these objectives had appropriate policies and specific recommendations for implementation. These objectives will foster development of both sectors of our State industry, the commercial production sector and the research, training and technology transfer sector.

Of perhaps equal significance to a plan is the existence of an implementation mechanism. The State recognized the necessity of a lead agency in which responsibility and accountability for follow-through could be placed. The Aquaculture Development Program was created to provide this follow-through and again Hawaii became the first state in the nation to have such a program.

Briefly, the Aquaculture Development Program functions in three broad areas: 1) statewide planning and coordination, 2) provision of support services to industry such as: general information,species and site counseling, permit assistance, marketing assistance, and disease diagnosis and prevention and 3) funding of research, development and demonstration projects. We have found these functions in concert with a hatchery/extension/advisory program and a special state low interest loan program, extremely valuable in developing a commercial industry, as well as, establishing Hawaii as a center of research and development expertise.

I will conclude with a quote from a marvelous new book called Seafarm: The Story of Aquaculture by Elizabeth Mann Borgese. She writes about aquaculture thus "In the East it is culture, it is life: culture to improve life by providing food and employment. It is embedded in the social and economic infrastructure. All that science can and must do is make this culture more effective. In this respect the East has much to learn from the West. In the West, aquaculture is science and technology, embodied in industry and providing profits: Money. It has no social infrastructure. The economic infrastructure has yet to be created. In this, the West has much to learn from the East. It is on this meeting, this merger, that food for the world and peace for the world largely depends."

While there is much food for thought in these words, I would like to extract one morsel and leave it with you. Hawaii's role in Pacific aquaculture development is being the place where the meeting or merger of Eastern practicability and Western technology occurs for the benefit of both. In short, our role can be one of education, training, and technology transfer between East and West.

The Potential of Aquaculture Development: Part II

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AQUACULTURE INDUSTRY DEVELOPMENT -- HAWAII AND BEYOND

Aquaculture is an economic development activity of increasing significance throughout Asia and the Pacific Basin. It is clear, that Hawaii has played a key part and will continue to adopt an increasingly important role as a center for aquaculture excellence in research, planning, training and technology transfer. In the past 18 months the Aquaculture Development Program has hosted representatives from the independent nations of: Western Samoa, Kiribati, Tonga, Fiji, Solomon Islands, Vanuatu (formerly the New Hebrides), the United States Flag Islands of Guam, Commonwealth of the Northern Mariana Islands, Federated States of Micronesia, the Marshall Islands Government, the Repbulic of Belau, and, lastly, French Polynesia.

I might also add that Hawaii's impact on this new technology reaches well beyond the Pacific area, as evidenced by a constant stream of visitors to our offices by foreign government agents and businessmen from over 30 nations outside the Asian-Pacific region. Our most recent group of extra-Pacific visitors was a delegation of bankers, private entrepreneurs and government officials from the Commonwealth of the Bahamas.

Typically, the common need expressed by our Pacific Island neighbors who come to seek counsel is for aquaculture technical assistance to affect the planning, feasibility assessment and technology transfer process. Recent acceleration of these contacts has caused us to re-evaluate and affirm our increasing responsibility in providing sound, technical guidance and planning assistance not only to Hawaii, but also to virtually all of the Pacific. It became apparent that our visitors were earnestly and often desperately shopping for clear, concise and relevant guidelines for planning towards the development of this exciting, expanding new industry.

In response to this awakening need for expert counseling in the highly technical area of aquaculture development, which so delicately interweaves the scientific and socio-economic processes, the Aquaculture Development Program of Hawaii produced in 1980, a major resource document entitled, "Considering Aquaculture for the Pacific Islands." The work provides a Pacific basin-wide inventory of aquaculture activity — including a status report on those island areas with programs already underway, and an assessment of the existing potential of as yet undeveloped or underdeveloped areas in terms of location parameters, economic opportunities, natural resources, manpower requirements and associated constraints, characteristic of this new form of economic diversification.

REGIONAL OVERVIEW

The island groups considered here are those that are encompassed by Melanesia, Micronesia and Polynesia. This vast area totals approximately 40 million square miles (104 million square kilometers) of ocean in which there are approximately 7,500 islands making up less than 40 thousand square miles(104,000 square kilometers) in land area(Figure 1). Within these 7,500 or so islands there are 8 independent nations, 2 unincorporated U.S. Territories, one U.S. Commonwealth, 1 U.S. State, 3 "Free Association" U.S. Flag Island Territories, and 7 Trusteeship or Quasi-Territorial Governments under France, New Zealand and Australia (Table 1). Only one group, the Coral Sea Islands Territory, is uninhabited. At least 8 of these island groups have undergone major changes in political status since 1978 and additional political status changes are forecasted in the next few years.

ENVIRONMENTAL CHARACTERIZATIONS

These 22 island groups, or 21, if we exclude the uninhabited Coral Sea Islands Territory, are located in the climatic regions known as the Tropics and Subtropics (Table 2). Coastal air temperatures in the region are exceedingly constant throughout the year ranging from 70-90 degrees F. (21-33 degrees C.) for equatorial islands and slightly lower in the subtropical latitudes. Sea surface temperatures are extremely uniform and generally in the range of 70-86 degrees F. (21-30 degrees C.). Except for torrential rainfall associated with tropical storms, monsoons and major tropical cyclonic disturbances, rainfall patterns are generally uniform throughout the year. Coastal rainfall extremes reported for the region range between 10-275 inches (25-700 CM) per year with an estimated regional average of 98 inches (250 CM) per year. All of these conditions are ideal for aquafarming.

TABLE 1
PACIFIC ISLAND GROUPS UNDER STUDY

INDEPENDENT
Western Samoa
Republic of Kiribati
Tuvalu
Tonga
Fiji
Solomon Islands
Nauru
Vanuatu (New Hebrides)
UNITED STATES AFFILIATION
American Samoa
Guam
Commonwealth of the Northern Mariana Islands
Federated States of Micronesia
Marshall Islands
Palau
Hawaii
OTHER GOVERNMENT AFFILIATION
French Polynesia (France)
Cook Islands (New Zealand)
Niue (New Zealand)
Wallis & Futuna (France)
Tokelau (New Zealand)
New Caledonia (France)
Coral Sea Islands Territory (Australia-uninhabited)

Despite the Pacific's great political and cultural diversity, all island groups are generally confronted with the same sobering economic realities and infrastructural limitations. Intra-regional trade of local agricultural or fishery commodities is limited since most of the island groups have similar products to offer, such as copra and bananas. Import-export ratios for the region show a negative balance of trade. Because of competitive uses for flat, arable lands, development costs, dispersed populations, or socio-cultural reasons, local agriculture often has not developed beyond the subsistence level.

In addition, most successful commerical fisheries are dominated by foreign-based tuna vessels manned by foreign crews and the catch is generally exported. Historically, most small-scale commercial fishing ventures have been unsuccessful because of poor planning, under-capitalization, insufficient infrastructure, absence of vertical integration from harvest to export, and failure to consider the needs and aspirations of the indigenous population. Recent hopes for fishery expansion programs have been largely dashed by the soaring cost of fuel.

For many island areas, the influx of western technology and capital following World War II, under various national stewardships for economic, moral, as well as, militaristic intentions, spawned a gradual erosion of traditional, social and economic systems and has lead to artificial cash economies dominated by government employment, grant and appropriations from the respective administering authorities. Marginally productive government employment remains as the economic backbone of most of the Pacific.

Recent movements toward political independence and the resulting necessity for greater economic self-sufficiency have required many emerging Pacific island governments to assess the economic development alternatives available to them. We in the Aquaculture Development Program feel that aquaculture activities have potential for local export food production, ability to provide revenue and jobs for island people, involve relatively benign land and water use characteristics, and, hence, may offer a distinct class of economic activities which are compatible with island needs, available resources and lifestyles.

ISLAND TYPES AND ASSOCIATED OPPORTUNITIES

With few exceptions, Pacific Islands can be classified into one of four major geologically distinct categories: Atoll, Coral Island; uplifted Coral and high Volcanic Islands. Each island type has certain physical characteristics which offer differing potentials for development of fresh, brackish or sea water aquafarming. One of the most important topographic characteristics is the amount of flat land that is available. High islands typically have between 20-40% of their surface area in this category. However, these areas are often the most heavily populated.

Soils and soil fertility are an important consideration in aquaculture production. As a function of the climatic conditions and the character of the parent rock materials, at least five major soil types are found, including limestone, volcanic, alluvial plain, swamp and coral-sand. Generally, uplifted Coral Islands such as Guam and Saipan, and High Islands, such as Ponape, have all soil types present, whereas, Atolls and Coral Islands (such as Majuro and Nauru, respectively) are limited for the most part to limestone and coral-sand soil types with occasional thin soil veneers. The soil of coastal alluvial plains and wetlands of high islands is generally of low porosity clay and clay-loam and suitable for impounding water without artificial modification, such as plastic liners or sealants. As a general rule, water in and around mangrove forests has unacceptable acidic properties.

The abundance and availability of surface and groundwaters is a striking and distinguishing characteristic of Pacific Islands. Most atolls and coral islands have extensive rainfall;however, nonexistent due to porosity of substrates, and perennial or intermittent streams are generally absent. Most atolls and coral islands have thin groundwater lands which is often reserved for human consumption during periods of extended draught.

Uplifted coral and high islands generally have intermittent or perennial streams and rivers and well developed groundwaters. However, groundwaters on uplifted coral islands can be very deep and the cost of sources-development and subsequent pumping costs very high. Both uplifted coral islands and high islands usually have extensive brackish and groundwater resources along the coastal plains.

Water quality is a major consideration for aquaculture development in all island areas. High island population centers are often concentrated on the coastal plain, frequently in close proximity to major rivers or estuaries. Unfortunately, utilization of these waters may be restricted by encroaching pollution from domestic sewage and other pollutants. Thus, a sanitary survey should be a priority item early in the feasibility assessment stage of any aquaculture venture that would involve the use of surface waters.

Given these sets of region-wide constants in temperature, land forms and water resources, certain conclusions on the aquaculture potential of the region can be drawn. Opportunities for freshwater aquaculture are limited on atolls and many coral islands because of the porosity of the substrate. The feasibility of water recycling systems for freshwater or brackish waters would have to be evaluated. The limited land available on atolls would post a serious constraint to development. However, on many atolls, airport construction, dredging and limestone quarrying have left shallow-protected pools on reef flats that show promise for pen culture of certain marine finfish and crustaceans. Similarly, some atolls offer the opportunity for cage or raft culture of fish in protected lagoons.

By way of contrast, high islands are characterized by heavy rainfall and ample fresh surface waters and groundwaters for development. High islands also offer great potential for certain brackish water species because of the availability of both fresh and sea water, and the presence of extensive, nutrient-rich estuaries. Here, a strong potential exists for raceway or pond culture of commercially valuable brackish water species such as oysters, marine shrimp, certain colloid-rich algae, and baitfish. Abundant freshwater and warm water temperature would also be conducive to freshwater species such as prawns, carp, eels and certain popular indigenous species of local subsistence value. The availability of flat coastal lands and the presence of abandoned World War II airfields offer opportunity for minimizing land development and construction costs for aquaculture ventures.

It is also clear that those responsible for land use, zoning and coastal zone development decisions should incorporate within the provisions for preservation of sites for future aquafarming. I might add that this has already been achieved in Guam and in the Commonwealth of the Northern Mariana Islands. With the exception of certain types of commercially valuable eels, freshwater prawns and food organisms of local importance, planning actions will have to address the introduction of exotic species which have been cultured elsewhere, and any environmental impact attendant with such introductions. Lastly, competition for land and water resources and resource allocation issues must be addressed early in aquaculture development planning.

SOCIO-ECONOMIC CONSIDERATIONS

For the Pacific Basin as a whole, economic and social constraints appear to post a greater impediment to aquaculture development than environmental or technological considerations.

Despite the high annual population growth rate in the range of 2.5-3.5% per annum, few island groups have the necessary population base and local demand to support large, local, commercial food production industries, though growth of the visitor industry in the region is expected to increase demand for locally grown seafoods in some areas.

The major metropolitan centers of the Pacific rim, such as Hong Kong, Sydney, Auckland, Taipei, Tokyo, and Manila offer outstanding market potential for island-grown aquaculture products such as oyster, shrimp and eels. Of these urban centers and major tourist destinations, virtually all import in excess of 50% of their seafood needs from sources as distant as Europe and the United States. Though air miles to these major markets are great, the Pacific Islands are actually in closer proximity to these markets than other major seafood exporting countries. Moreover, many Pacific Island groups can benefit from reduced back-haul rates in a similar fashion as has Hawaii. Government centers of all island groups have direct access by air and sea to most major metropolitan markets on a scale ranging from daily to infrequent.

The existing situation for other components of island infrastructure, such as electricity, potable water supplies, and public roads will not be covered here, but suffice it to say that infrastructure network to meet the needs of aquafarming is found at the major population centers and adjacent areas, and little, if any, suitable infrastructure on outer island situations. Thus, commercial aquaculture development is likely to take place in close proximity to major government centers in the Pacific, though important subsistence aqua-crops geared for local consumption can make a significant contribution to reducing the trade deficits in outer island communities.

Based upon our experience in Hawaii we in the Aquaculture Development Program propose the following recommendations which would have the effect of vastly encouraging Pacific-wide economic development and diversification in aquaculture:

1) Planning and feasibility assessments be made at a regional level to maximize the natural and human resources, infrastructure, government support services and product transportation networks to Pacific rim nations;
2) Regional approaches to aquaculture information collection and dissemination, such as centralized data banking and satellite communication via PEACESAT or other systems to be made available to the Pacific Basin as a whole;
3) Regional and national government assistance and incentive programs in land-use arrangements, preferential labor and tax treatment, and revolving loan programs be established to encourage local, as well as, foreign capital investment;
4) Strong local, national and regional government support is vital to industry development; in this area special attention should be focused upon providing a conducive, legal and regulatory permit climate for potential aquaculturists;
5) Development will necessitate vertically-integrated technology transfer in all aspects of development, from hatchery to growout to product destination markets;
6) Collectively, the University of Hawaii, the University of the South Pacific, and the University of Guam, offer a regional educational/institutional network for promoting and coordinating aquaculture technology transfer, research, advisory and extension services, and a means for identifying new or indigenous island species offering potential for development.

In conclusion, we would like to outline two proposed aquaculture development models which appear to offer opportunity for many island nations -- a small scale production model and a large scale production model.

In the small-scale production model, we realize that potential for subsistence and small-scale commercial aquaculture where seed stock, demonstration of culture methods and extension/advisory services are provided by government support or through regional assistance programs for technical assistance and/or facilities construction. Production would be consumed on-site or sold locally or perhaps intra-regionally. Pacific-wide export markets may be developed with few products if small farms run by individual families, clans or villages organized to form marketing cooperatives. Candidate species would include those with relatively simple and well-studied life cycles with feeding requirements adaptable to local agriculture products or agricultural by-products, and a culturally acceptable and nutritionally sound food source. Freshwater prawn, rabbitfish, milkfish and tilapia would be excellent candidates. Culture of baitfish for sale to expatriate fishing operations would also offer opportunities for cash revenues.

In the large-scale production system, we envision aquaculture production financed as joint-ventures or single venture projects by multinational corporations. Activities would probably involve high value, luxury species, such as shrimp or eels, for export to major metropolitan centers in Asia and the United States. Operations would be extensive to semi-intensive in character due to maintenance, labor and logistic considerations. Large-scale operations would also stand to benefit as a result of cost savings associated with economies of scale.

We suggest that implementation of either or both of the two proposed development models for Pacific Islands could occur in the near future.

In summary, I have attempted to provide a broad framework from which island governments and private investors can better identify opportunities for commercial aquaculture. I also attempted to focus on potential constraints to achieving significant levels of aquafarming in the near future. Moreover, I hope that broad, brush qualitative efforts will contribute to the formulation of a regional approach to aquaculture planning for the Pacific.